Connected Vehicle Pilot Deployment Program Phase 2

Operational Readiness Plan (ORP) – Tampa (THEA)

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Notice

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16. Abstract

The Tampa Hillsborough Expressway Authority (THEA) Connected Vehicle (CV) Pilot Deployment Program is intended to develop a suite of applications that utilize vehicle-to-infrastructure (V2I) and vehicle-to-vehicle (V2V) communication technology to reduce traffic congestion, improve safety, and decrease emissions. These CV applications support a flexible range of services from advisories, roadside alerts, transit mobility enhancements, and pedestrian safety. The pilot is conducted in three phases. Phase 1 includes the planning for the CV pilot, including the concept of operations development. Phase 2 is the design, development, and testing phase. Phase 3 includes a real-world demonstration of the applications developed as part of this pilot.

This document represents the Operational Plan (ORP)

This ORP ensures the operational readiness of the system (the execution of these plans occurs under task 2-H). The objectives of these activities are to demonstrate the deployed system operates as designed in a safe and secure manner. Operational readiness conceptually applies to the system itself as well as the implemented institutional and financial framework that supports, finances, and governs the deployed system.

This ORP consists of multiple sections:

- Overview, including description of pilot site study area and description of ORP document organization
- Operational Readiness Demonstration Plan (ORDP)
- Operational Readiness Test Plan (ORTP), consisting of:
  - Test Plan
  - Test Cases
  - Test Procedures populated with Test Data that serves as the Test Report

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Version History

#	Date	Author (s)	Summary of Changes
Final v4	6/15/2018	THEA	Added One Bus Away test results
			Repeated ERDW without HamWAN interference
			Added ERDW queue radar detector test results
			Updated per comment disposition
Final v3	5/21/18	THEA	Added VTRFTV and FCW Test Results
			Added XM WWE Anomaly Report
Final v2	5/15/18	THEA	Added Test Results, minus VTRFTV and FCW
Final v1	4/12/18	THEA	Merged all sections after individual review
Draft v2	3/26/18	THEA	Update after USDOT review and comment
Draft v1	3/02/18	THEA	Initial draft release for USDOT review and comment
Final	4/4/19	THEA	Address USDOT comments and added System Reliability Report

1. Operational Readiness Overview

1.1 Operational Readiness Plan Objectives

The Operational Readiness Plan (ORP) describes a series of a coordinated Operational Readiness Test Plans (ORTP) and an Operational Readiness Demonstration Plan (ORDP), including study participants, used to ensure the operational readiness of the system. The objectives of these activities are to demonstrate that:

- The deployed system operates as designed in the System Design Document (SDD).
- The deployed system operates in a safe and secure manner.
- All aspects of the technology work correctly, but not necessarily to scale.
- The deployed system can be maintained.
- The deployed system demonstrates privacy based on the operational privacy concept.
- Performance measures and evaluation can be supported.
- Institutional coordination is successfully executed with a governance framework.
- The deployed system is scalable to the extent described in the project documents.

Operational readiness conceptually applies to the system itself as well as the implemented institutional and financial framework that supports, finances, and governs the deployed system. Operational readiness is established with a comprehensive set of tests and supporting demonstrations designed and conducted by the Tampa Hillsborough Expressway Authority (THEA) team. The THEA test team conducts a set of relevant tests to verify that the system performs according to the documented System Requirements, but not necessarily to scale. Test results are documented and reported to the United States Department of Transportation (USDOT). Demonstrations are at a higher level and show that the system performs as expected in key use cases and scenarios. Operational Readiness Testing is conducted before conducting the Operational Readiness Demonstration. Demonstrations are differentiated from tests by the following general features:

- Demonstrations exhibit a set of selected integrated, end-to-end system capabilities central to the deployment Concept of Operations key use cases.
- Demonstrations are conducted as live, real-time activities for the Agreement Officer Representative (AOR), and federal team wherein success and failure of the demonstrated uses are directly observable.

The high-level objective of the ORDP is not to demonstrate the effectiveness of each Connected Vehicles (CV) application, but rather to demonstrate the system's ability to support the evaluation of CV application by the researchers during Phase 3 of the project. For example, a successful ORDP could note ineffective CV applications in need of further evaluation and improvement during Phase 3. The performance gap is evaluated by the Change Control Board (CCB). If the performance gap represents a safety issue, the issue is documented, and the application is not deployed to the field. If the performance gap does not represent a safety issue, the performance issue is documented for further study and improvement.

Operational Readiness also includes operation and maintenance training for the stakeholder staff identified in the Operations Roles and Responsibilities section of the Comprehensive Maintenance and Operations Plan (CMOP). For example, the Transit, Traffic, and Research staff demonstrates access to and operation of respective portions of the overall system.

1.2 Relationship of ORP to the Systems Engineering Process

The ORP relationship to the Systems Engineering Process (SEP) is shown in Figure 1, which appeared in the Comprehensive Deployment Plan (CDP) and was presented during the April 20, 2017, Operational Readiness Concept Briefing (ORCB) webinar.

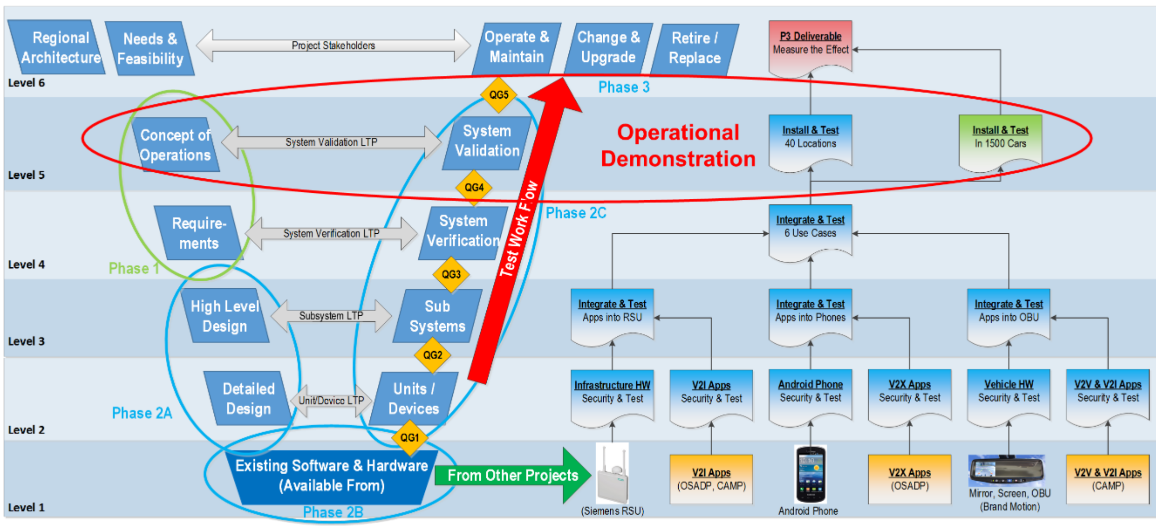


Figure 1: SEP Level 5: Operational Concept Briefing
Source: Siemens

Within the THEA project workflow, the ORDP relates to System Validation that traces to the Concept of Operations at Level 5 of the V-model. At SEP Level 5, all aspects of the technology have been deployed in the field and work correctly for stakeholders and participants, but not necessarily to scale. For example, the technology is demonstrated using Friends of the Pilot equipped vehicles, while the system is being scaled to equip the remaining participant vehicles of Phase 3. Friends of the Pilot are participants owning private vehicles that are employees of the THEA project team residing in Tampa that received early operational and safety training.

ORDP at SEP Level 5 follows the successful execution of ORTP of Level 4, as shown in Figure 2.

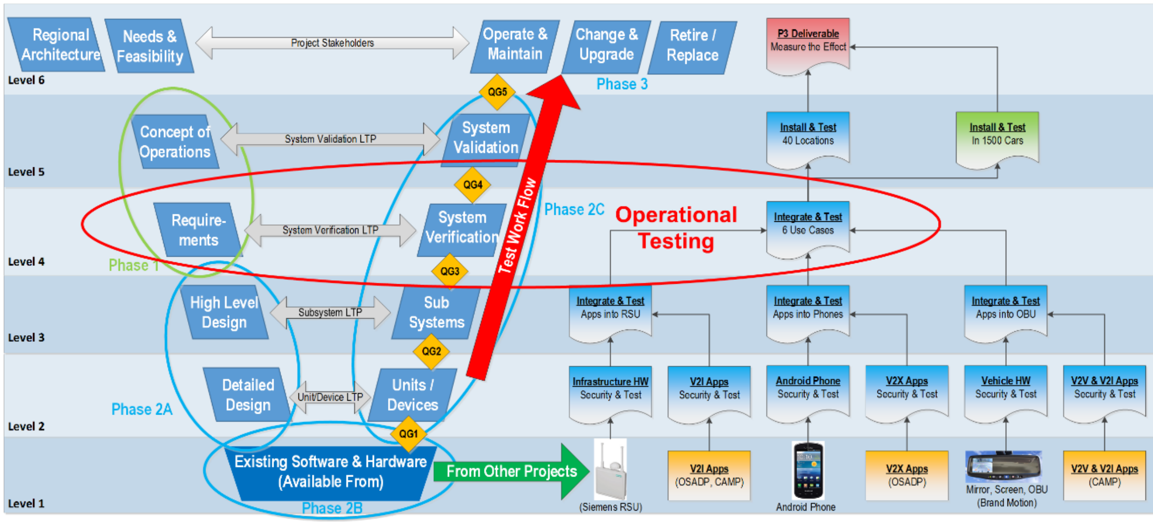


Figure 2: SEP Level 4: Operational Test Plan
Source: Siemens

At SEP Level 4, the operation of all subsystems of software objects that were integrated into hardware devices at SEP Level 3 is verified through six working use cases. ORTP relates to verification that each use case fulfills the System Requirements.

1.3 ORP Document Organization

In addition to the Overview (Section 1 of this document), the ORP document consists of two major sections, as shown in Figure 3.

- Operational Readiness Test Plan (ORTP)
- Operational Readiness Demonstration Plan (ORDP)

For logistics, sections are authored and reviewed initially as separate documents, which are shown in Table 1, and then merged into one ORP after a final review of each section.

Table 1: ORP Document Sections

Section	Document Title
1	Operational Readiness Plan (ORP)
2.1	Operational Readiness Test Plan (ORTP) – Test Plan
2.2	Operational Readiness Test Plan (ORTP) – Test Cases
2.3	Operational Readiness Test Plan (ORTP) – Test Procedure
3	Operational Readiness Demonstration Plan (ORDP)

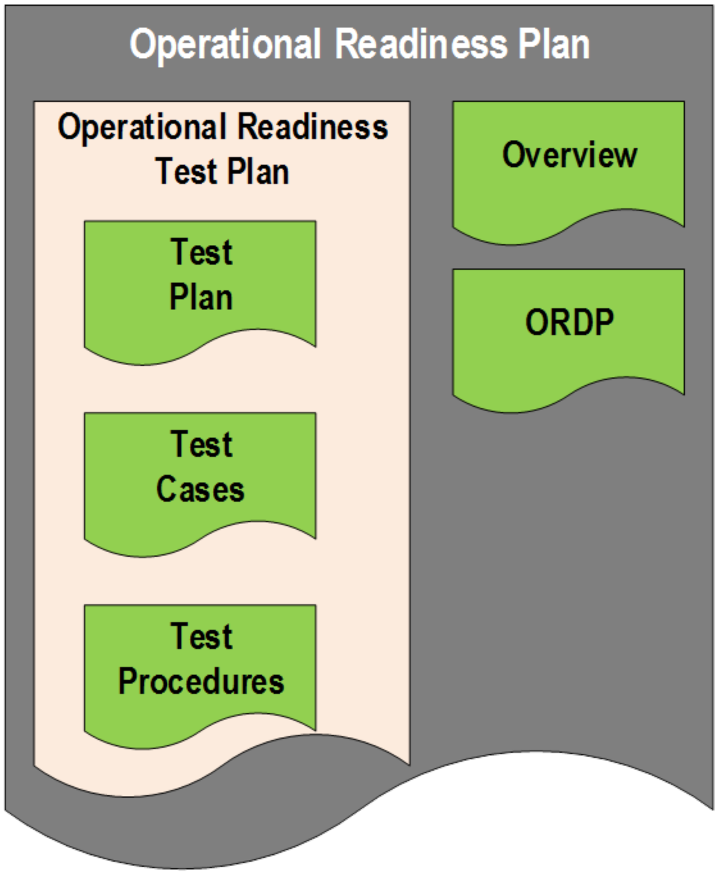


Figure 3: Operational Readiness Plan Document Organization
Source: Siemens

The sequence of document creation, walkthrough, and review is shown in the workflow diagram of Figure 5. The horizontal swim lanes identify the role of each organization in Operational Readiness.

1.3.1 Operational Readiness Test Plan

The ORTP consists of three sections developed and reviewed separately by the USDOT AOR and reviewers. Upon review and reconciliation of reviewer comments, the three sections are consolidated into the ORTP section of the ORP.

1.3.1.1 Test Plan

The Test Plan is a shortened version of the Institute of Electronic and Electrical Engineers (IEEE)-829 Master Test Plan (MTP) including the Test Descriptions. The MTP is not published but is an internal project document describing the relationship of the Level Test Plans (LTP) for all five levels of the V-model. As presented in the ORCB, the Test Plan includes written descriptions of the individual verification and validation processes that occur at Level 4 of the V-model. The Test Plan describes activities that occur as part of the effort to ensure that the system was built correctly and that the correct system was built. The Test Plan is linked back to documented System Requirements. The document includes a requirements-to-test procedure matrix that shows that each test has at least one test case associated with it, and each test case has at least one requirement associated with it.

1.3.1.2 Test Cases

Each test case includes a set of test inputs, execution conditions, and expected results developed for a particular objective. Examples of such an objective would be to exercise a particular path within a system or a software application or to verify compliance with a specific requirement or set of requirements.

1.3.1.3 Test Procedures

Test Procedures includes multiple sections as follows:

1.3.1.3.1 Test Procedure Objectives

Test procedures spell out exactly how one verifies and validates that the component of the system examined actually functions as intended and as desired. When test data are used as part of the verification and validation process in this step, the test procedures spell out how to determine that the system actually performed the correct transformations on the data entered. Verification can involve the use of inspection, test, demonstration, and analysis, with the respective use identified in each test.

1.3.1.3.2 Test Data

Test data could include scripts used to execute software operations, data that must be entered by someone as part of the process of verification and validation of the system, and its component integration. Additionally, test data could include a description of what system-generated data will flow through different components of the system to accomplish a system function. Test data fields are supplied to record the test data by the test operator.

1.3.1.3.3 Test Results

This section describes the results of each test conducted. The Test Procedure document is populated with test data by the test operator as an updated revision of the Test Procedure document. The ORTP also describes how test results are summarized and documented across all tests and delivered to USDOT in Task H.

1.3.1.3.4 Test Failure Remediation

This section describes the actions to be taken in the event of unexpected test results resolved in the investigation of the Anomaly Report and included in the final Test Procedure document.

1.3.2 Operational Readiness Demonstration Plan

The ORDP is a storyboard of scenes depicting live operational demonstrations for USDOT staff. Each scene demonstrates fulfillment of System Requirements previously verified during ORTP, including:

- UC: Use Case
- SAF: Safety
- SEC: Security
- PFM: Performance
- INM: Information Management
- SGD: System Generated Data

- MNT: Maintenance
- SRL: System Reliability
- PAR: Policy and Regulation

Actors in each scene are trained stakeholder staff operating that aspect of the system during Phase 3 of the project. Staffing and training readiness is not documented as a deliverable of the ORP. Rather, ongoing staff training is conducted as the system elements enter service ahead of the Operational Readiness Demonstration (ORD). Training is demonstrated by the trained staff operating the system as actors in the ORD. For example, the Master Server's ability to collect data from the Roadside Units (RSUs) is demonstrated by the research staff using the Master Server during Phase 3. Traffic Operations staff demonstrates the system's ability to switch signal plans from pre-timed to Intelligent Signal software application (I-SIG).

1.4 ORP Workflow

The ORP Workflow is depicted in Figure 5, beginning with the ORCB conducted on February 20, 2017. Each horizontal swim lane identifies the organization owning the work packages within the lane. The effort of each work package is identified by the graphic icons shown in Figure 4.

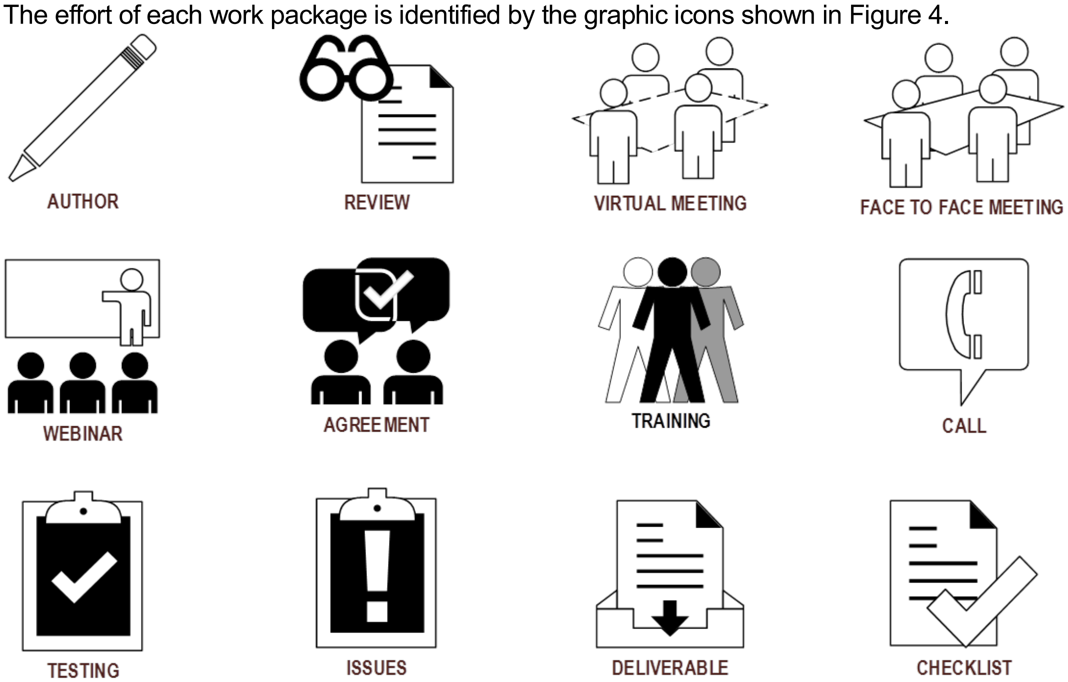


Figure 4: Workflow Icons
Source: Siemens

Five workflow trails of Figure 5 are listed in Table 2. The five workflow trails verify each requirement designated by "D," "T," or "I," which culminates in the Operational Readiness Report (ORR).

Table 2: Workflow Trails

Trail	Icon #	Description	Workflow Result
1	01-32,39,40	Testing workflow	Verifies “T” requirements
2	33 to 38	I-SIG workflow	Selectable I-SIG and Actuated plans
3	41 to 54	Demonstration workflow	Verifies “D” and “I” requirements
4	55 to 61	Operation and maintenance plan	Stakeholder staff set for Phase 3
5	62	Operational Readiness Report (ORR)	Transition to project Phase 3

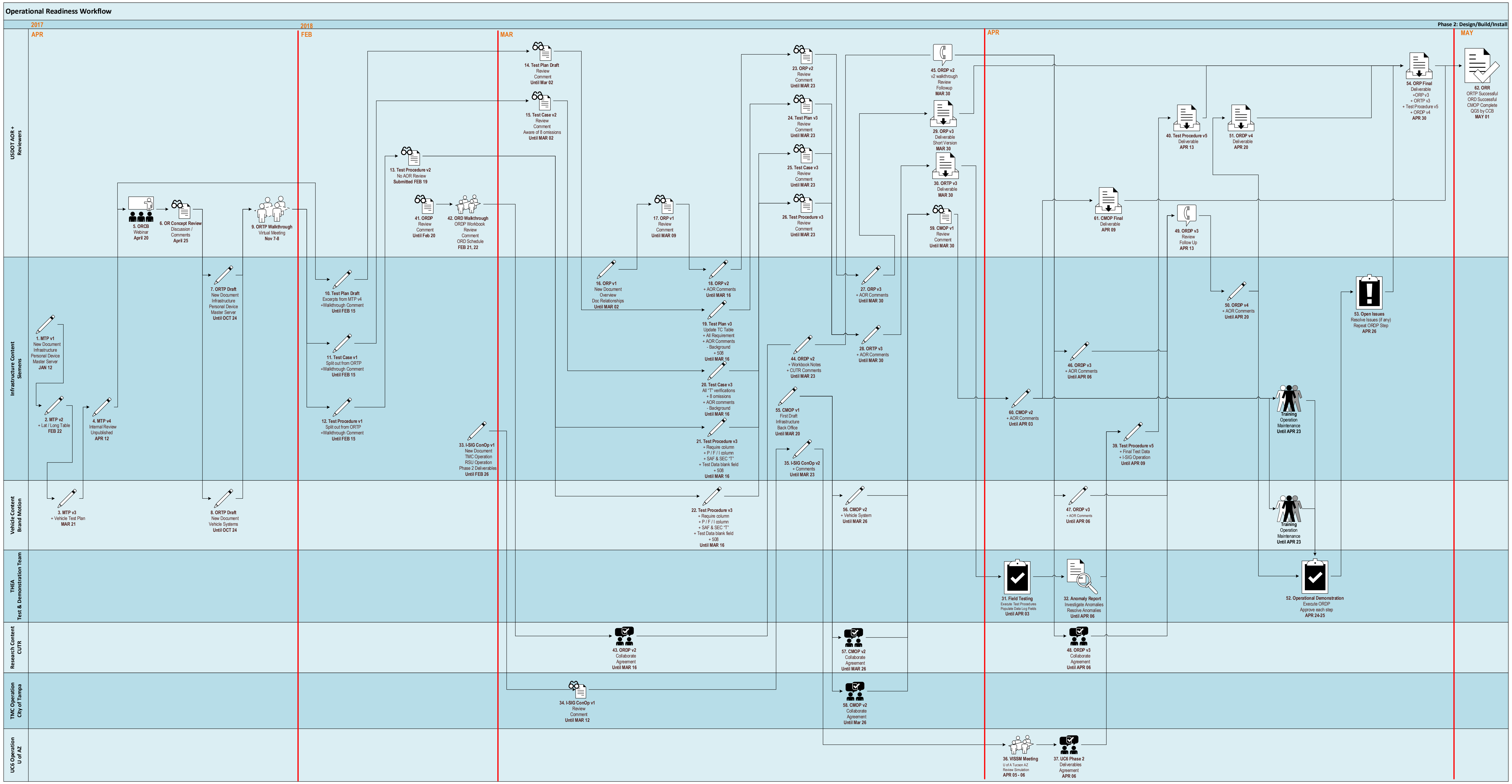


Figure 5: ORP Workflow Diagram
Source: Siemens

Figure 5 resulted from the Operational Deployment Plan walkthrough of February 21-22, 2018. The responsible organization for each workflow step is identified at the left of each workflow swim lane. Each icon includes:

- Workflow step identification number
- Workflow step name
- Work product for that step
- Latest date for completion

1.5 ORP Deliverables

The ORP deliverables at the end of project Phase 2 are:

- Consolidated ORP document including all sections shown in Figure 3
- Test Procedure section populated with data recorded according to the ORTP
- ORDP section describing the ORD conducted at the end of project Phase 2

1.6 Operational Readiness Review

The final Operational Readiness Review (ORR) affirms that the system is ready to enter Phase 3 Operations and Maintenance. The ORR consists of a checklist of completed key activities including:

- ORTP successful completion
- CMOP ensuring that all operators and maintainers are trained and knowledgeable
- ORD completed successfully
- Quality Gate 5(GC) approval by the THEA Change Control Board (CCB)

1.7 Project Overview

1.7.1 General Location

Figure 6 is an area map of the pilot location in Tampa, Florida, specifically the Selmon Expressway that is owned and operated by the Tampa Hillsborough Expressway Authority (THEA). THEA also owns and operates the traffic signals on Meridian Avenue. The routine traffic flow is TO and FROM the residential community of Brandon to the east, ending at MacDill Air Force Base (AFB) to the west. The focused study area for this pilot is within the red box at the center.

Figure 6: Pilot Site General Location
Source: THEA

1.7.2 Focused Study Area

The red box of Figure 6 is expanded to the one-mile-by one-mile focused study area shown in Figure 7. This study area was selected as having existing and measurable safety and mobility issues that might be mitigated by the application of CV technology at the following locations shown on the map:

- Use Case 1 (UC1): Rush Hour Collision Avoidance on the inbound Reversible Express Lanes
- Use Case 2 (UC2): Wrong-Way Entry (WWE) at the entrance of the outbound REL
- Use Case 3 (UC3): Pedestrian Safety on Twiggs Street
- Use Case 4 (UC4): Bus Priority on Marion Street, Kennedy Boulevard and Jackson Street
- Use Case 5 (UC5): Streetcar Safety on Channelside Avenue
- Use Case 6 (UC6): Traffic Flow Optimization on Channelside Drive
- Use Case 6 (UC6): Traffic Flow Optimization on Meridian Avenue
- Use Case 6 (UC6): Traffic Flow Optimization on Florida Avenue
- Use Case 6 (UC6): Traffic Flow Optimization on Nebraska Avenue
- Traffic Management Center at Twiggs Street and Meridian Avenue is shown in dark gray

Note that the focused study area includes several applications operating simultaneously on one RSU, as well as interdependent applications, where the output of one CV application serves as an input to another CV application running on another RSU.

Figure 7: Focused Study Area
Source: Global-5

ORDP includes a live demonstration of six use cases made up of 13 Safety, Mobility, and Agency Data applications. Where a use case is deployed at multiple locations, one location will be used for the ORDP. Note that Vehicle-to-Vehicle (V2V) applications operate anywhere within or outside of the study locations shown in Figure 7, wherever equipped vehicles encounter one another. The effectiveness of the V2V applications is limited to data collected within the study area shown. Over-the-air software updates are sent from the Master Server to RSUs and then to participant vehicles via dedicated short-range communications (DSRC). Additional RSUs shown in orange provide additional coverage area for updates. This process is described in the System Design document.

1.7.3 Participants and Deployed Equipment

Figure 8 lists the equipment deployed and the number of participants during Phase 3 of the Pilot.

Figure 8: Equipment Deployed and Participants
Source: HNTB and Siemens

2. Operational Readiness Test Plan

2.1 Test Plan

2.1.1 Objectives and Purpose

2.1.1.1 Test Approach

2.1.1.1.1 Project Workflow

The Project Workflow relates to Development as shown in **Figure 9**, that is carried forward from the Work Breakdown Structure (WBS) section of the *"THEA Connected Vehicle Pilot Deployment Comprehensive Deployment Plan"* document created during Phase 1 of the project. The horizontal arrows represent the testing processes at each of the six levels of development.

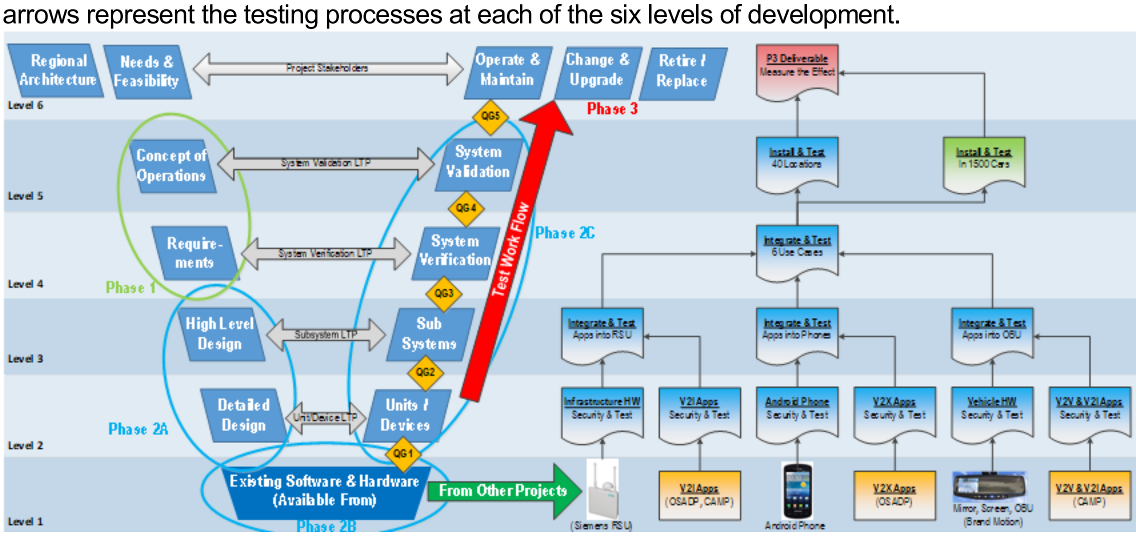


Figure 9: Project Workflow
Source: Siemens

Level 1 Scope: Existing Hardware/Software Investigation

The ultimate project deliverable is not the development or improvement of CV hardware and software, but rather to measure the effectiveness of existing Connected Vehicle (CV) hardware and software. Therefore, the traditional Development Phase 2B is replaced with an Investigation Phase 2B shown at the bottom of the V-model in **Figure 9**. Level 1 Test Plans of Phase 2B assess the availability and suitability of each existing hardware and software object needed to fulfill the project requirements. Existing technologies that best fit the project requirements are selected for procurement and gaps to fulfill requirements are identified if any. Project development is limited to filling the gaps (if any). The findings of the investigation and project cost to fulfill the gaps are presented to the Change Control Board (CCB) to pass Quality Gate (QG) 1.

Level 2 Scope: Unit/Device Test

After successfully passing Quality Gate 1 (QG1), each hardware and software object is tested independently at Level 2 for functionality, such as the first article test of procured hardware device and software apps. At Level 2, expected test results indicate a PASS, while unexpected test results do not result in FAIL, but rather result in an Anomaly Report for further investigation, such as test equipment malfunction, operator error, or failure of the Device Under Test (DUT). Anomalies are resolved before the meeting of the CCB to pass Quality Gate 2 (QG2).

Level 3 Scope: Subsystem Integration Test

After passing QG2, software objects are integrated into hardware objects to form subassemblies; in this case, On-Board Unit (OBU), RSU, Personal Information Device (PID), and Master Server subsystems. At Level 3, each subassembly is tested to performance requirements. Expected performance results indicate a PASS, while unexpected performance does not result in FAIL, but rather results in an Anomaly Report for further investigation. Anomalies are resolved before the meeting of the CCB to pass Quality Gate 3 (QG3).

Level 4 Scope: System Verification

After successfully passing QG3, subsystems are integrated into systems fulfilling the use cases. At Level 4, each use case is tested for conformance to requirements. Expected conformance results indicate a PASS, while unexpected conformance does not result in FAIL, but rather results in an Anomaly Report for further investigation. Anomalies are resolved before the meeting of the CCB to pass Quality Gate 4 (QG4).

Level 5 Scope: System Validation

After successfully passing QG4, the system is deployed in the roadside infrastructure and test vehicles. At Level 5, each deployment is tested for end-to-end conformance to requirements. Expected conformance results indicate a PASS, while unexpected conformance does not result in FAIL, but rather results in an Anomaly Report for further investigation. Anomalies are resolved before the meeting of the CCB to pass Quality Gate 5 (QG5).

Level 6 Scope: Project Stakeholders

After successfully passing QG5, the complete system is commissioned and turned over to the system project stakeholder owner/operators and the researchers for operation and maintenance during Phase 3 of the project that measures the effectiveness of the CV applications on existing safety and mobility issues.

2.1.1.1.2 Relationship of Test Processes to Project Management

HNTB is responsible for the overall project management, while Siemens Intelligent Transportation System (ITS) is responsible for project management for summary tasks relating to infrastructure, back office, and personal safety devices, such as smartphones. Brand Motion is responsible for project management and summary tasks related to vehicle systems. Refer to Section 2.1.7 for testing milestones.

Test processes are included in the Master Schedule corresponding to the workflow described above. The Master Test Plan (MTP) and Level Test Plans (LTP) are completed and approved by the stakeholders during Phase 2B ahead of QG1. At each Quality Gate (QG), test results are evaluated for that prior level before proceeding to the next level. Requirements management at each QG can result in updates to level tests.

2.1.1.1.3 Relationship of Test Processes to Quality Assurance

Relationship of Test Processes to Quality Assurance falls into three categories:

- Infrastructure, Personal Information Device (PID), and Master Server Test Processes are governed by Siemens Project Evolution Process (PEP)
- Test organization and workflow of vehicle systems assigned to Brand Motion follow the Ford Motor Company Design Verification Plan (DVP)
- Quality of the process follows the Quality Management (QM) process of Siemens PEP

The work products of combined PEP and DVP are documented in the Work Breakdown Structure section of the Comprehensive Deployment Plan reviewed during Phase 1 of the project.

2.1.1.1.4 Relationship of Test Processes to Configuration Management

Configuration Management (CM) begins for all accepted hardware and software objects at QG2 and is updated at each remaining QG. Before moving to the next level, the hardware and software that completed successful testing require CM management, including at a minimum:

- Archive for each hardware and software object consisting of:
  - LTP
  - Test Cases
  - Test Procedures
  - Test Report
- Source code, with the revision number
- Binary code, with the revision number
- Board Support Packages (BSP) containing development tools, with the revision number
- Step-by-step instructions to compile the source code to obtain the object code, with the revision number

2.1.1.2 Project Items Tested

As described in the April 22, 2017, Operational Readiness Briefing and Figure 10, this ORTP is limited to verification of the system requirements at Level 4, described in the Concept of Operations, which are required to support Operational Demonstration of the system at Level 5:

- UC1: Morning Backups
- UC2: Wrong-Way Entry
- UC3: Pedestrians at Courthouse
- UC4: Bus Rapid Transit Optimization
- UC5: Streetcar/Auto/Pedestrian/Bicycle Conflicts
- UC6: Traffic Progression

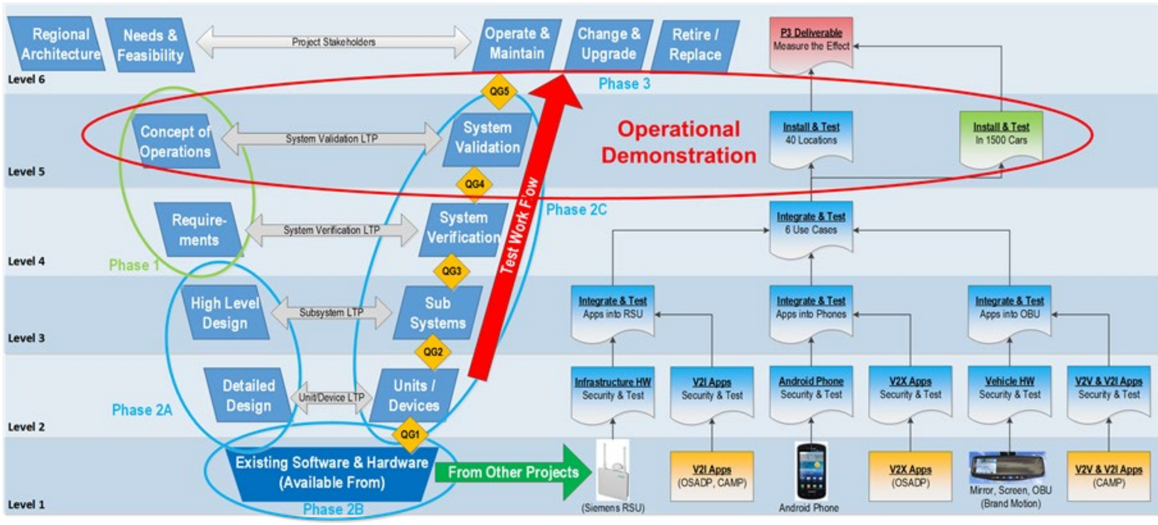


Figure 10: Operational Demonstration
Source: Siemens

2.1.1.3 Hardware, Software, Tools, Resources, Environment Support

Each test case lists the test hardware, software, tools, resources, and test environment. In general:

- Commercial-Off-the-Shelf (COTS) DSRC Analyzer manufactured by 3M corporation is used to verify over-the-air data
- “Golden” subsystem examples verified at Level 3 under CM are used as test equipment
  - Siemens Roadside Unit (RSU) with integrated software objects for Vehicle-to-Infrastructure (V2I) applications
  - Savari On-Board Unit (OBU) with integrated software objects for V2I and V2V applications
  - Siemens PID with integrated software objects for Virtual-to-Physical (V2P) applications
  - Siemens Master Server with integrated software objects for data collection
- Test environment consists of a roadway closed to public traffic

The “golden” subsystem is an RSU or OBU with integrated software that implements the interface protocols. Each protocol is verified, and then the software is archived. Devices from other manufacturers are then tested with the golden device, as would be the case with commercial test equipment.

2.1.1.4 Types of Tests Performed

Testing verifies that the four subsystems of 2.1.1.3 above operate correctly when connected as systems:

- Vehicle subsystem connected to infrastructure subsystem
- Personal subsystem connected to infrastructure subsystem
- Infrastructure subsystem connected to Master Server subsystem

Once connected and basic operation is verified, the systems are tested as six use cases.

2.1.1.5 Resources and Constraints

2.1.1.5.1 Resources

The following organizations supply the testing resources:

- Brand Motion: Vehicle system test
  - OBUs with integrated software
  - OBU antennas and power cords
  - Installation on test vehicles
  - Test Operator personnel
- Siemens: Infrastructure, Master Server and PID system tests
  - COTS DSRC test equipment
  - RSU kits with antennas and mounting bracket
  - Application software for RSUs
  - Power over Ethernet Injectors
  - Back office server with integrated software
  - Test Operator personnel

2.1.1.5.2 Constraints

Testing is constrained in at least one instance of each UC installed in the field with operational test data. Testing covers all of the use case requirements that are marked as verified by "T" in the System Requirements document, but not to scale. For example, not all 1,600 vehicles are tested per this plan, and not all signalized intersections are tested per this plan.

2.1.1.6 Roles and Responsibilities

- Siemens ITS in Austin, Texas, is responsible for procurement, integration, installation, and testing of all infrastructure, back office, and smartphone equipment and software.
- Brand Motion is responsible for procurement, integration, and installation of vehicle equipment, software, and collaboration with Siemens ITS for Vehicle-to-Infrastructure (V2I) communications.
- Siemens Corp Technologies in Princeton, New Jersey, is responsible for cybersecurity scans, hardening recommendations, security breach response plans, and stakeholder training.

2.1.1.7 Management of Test Activities

2.1.1.7.1 Change Control Process

The project change control process is managed by a Change Control Board (CCB), as shown in Figure 11:

- Chair: Presides over the CCB and serves as a reviewer representing THEA
- Reviewers: Voting members representing their organizational needs
- Advisors: Non-voting members representing their organization's project responsibility
- Coordinator: Configuration Management (CM) to ensure conformance to process

Organization	Name	Title	Role
THEA	Bob Frey	THEA Planning Director / CV Program Director	Chair
	David May	Director of Expressway Operations	Reviewer
	Anna Quinones	Engineering Specialist I	CM Coordinator
City of Tampa	Vik Bhide	Traffic Engineer / TMC Manager	Reviewer
HART	Shannon Haney	Intelligent Traffic Systems Coordinator	Reviewer
FDOT District 7	Ronald Chin	District Traffic Engineer	Reviewer
USF	Steve Reich	Research Lead, Center for Urban Transportation Research	Reviewer
HNTB	Steve Johnson	CV Pilot Program Manager	Advisor
	Steve Novosad	CV Pilot System Engineering Lead	Advisor
	Terry Opdyke	CEI Manager	Advisor
Brand Motion	David McNamara	Vehicle Systems Lead	Advisor
Siemens	Dave Miller	Infrastructure, Back Office and Personal Systems Lead	Advisor

Figure 11: Change Control Board
Source: Siemens

The CCB activities occur primarily at the Quality Gate (QG) symbols in **Figure 9**:

- QG1: Any gaps between the Requirements and the Level 1 inherited hardware and software are identified and documented for consideration by the Change Control Board (CCB) for agreed adjustments to project requirements and schedule.
- QG2: The CCB reviews the results of the Unit/Device Anomaly Report for agreed alignment of project requirements and schedule to available hardware and software.
- QG3: The CCB reviews the results of the Subsystem Anomaly Report for agreed alignment of project requirements and schedule to available hardware and software. Here, the CCB can authorize underperforming subsystems that do not present a safety issue for further study to improve performance. Underperforming subsystems that present a safety issue are not deployed.
- QG4: The CCB reviews the results of the System Anomaly Report for agreed alignment of project requirements and schedule to use case availability for deployment. Here, the CCB can authorize non-conformant use cases that do not present a safety issue for further study to improve conformance. Non-conformant use cases that present a safety issue are not deployed.
- QG5: The CCB reviews the results of the Deployed System Anomaly Report for agreed alignment of project requirements and schedule to infrastructure and vehicle availability for deployment. At QG5, the CCB can authorize non-conformant deployments that do not present a safety issue for further study to improve conformance. Non-conformant deployments that present a safety issue are not enabled.

Note that at each QG, the CCB can add, delete, or change requirements provided that the user needs of the system owner/operators are fulfilled. With a CCB majority vote of reviewers, the following are updated at each QG:

- Requirements Document
- Requirements Traceability to Needs
- Project Schedule
- Project Cost Allocations

Note also that the CCB is the ultimate arbitrator of test anomalies and performance issues relating to safety. Unexpected test results that still fulfill user needs of the system owner/operators can be accepted by the CCB, along with corresponding updates to the test documentation. Improvements are developed as Phase 3 Application Maintenance or as separate projects, such as Multi-Modal Intelligent Traffic Signal System (MMITSS).

2.1.1.7.2 Communication Coordination for Key Activities

Key activities of the development and testing organization are shown in Figure 12:

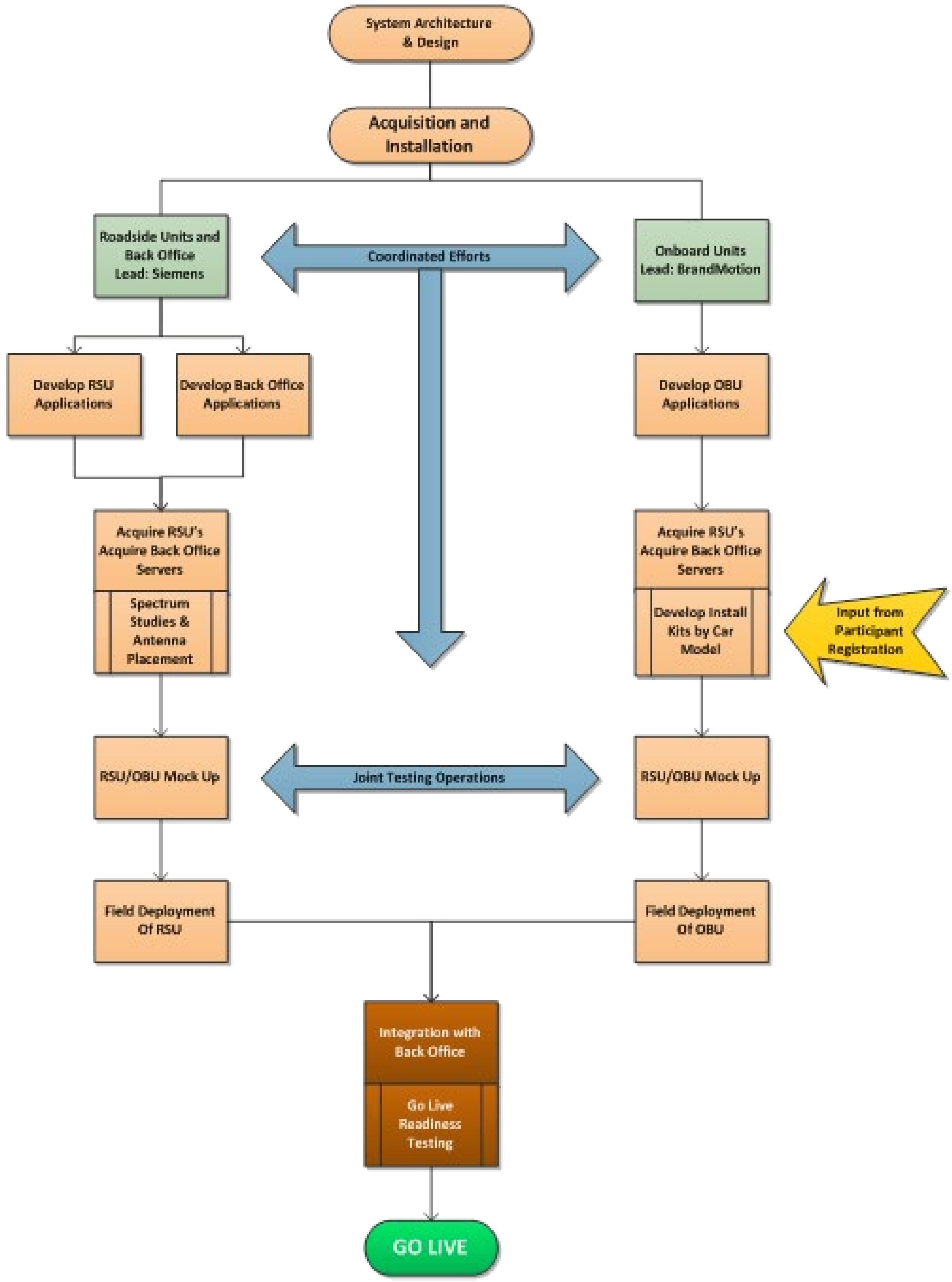


Figure 12: Development and Testing Organization
Source: Siemens

The left side of the workflow indicates the development and test of infrastructure, Master Server, Transit Server, and PID applications assigned to Siemens ITS.

The right side of the workflow indicates the development and test of the vehicle systems and applications assigned to Brand Motion.

The crosscutting horizontal arrows represent the testing collaboration between Siemens and Brand Motion for the Vehicle-to-Infrastructure over-the-air messages in the Vehicle-to-Infrastructure applications.

2.1.1.8 System Architecture

The system architecture is shown in Figure 13. The colored areas represent the existing Traffic Operations and are out of scope for testing:

- Centracs™ ATMS communicating via NTCIP 1202 to ASC3 controllers
- Peek MTCS communicating via Protocol 90 to ASC2 and PEEK 3000 controllers
- Mixture of fiber and copper FSK communications from Centracs to controllers
- Peek MTCS, Protocol 90, ASC2 and Peek 3000 controllers are being phased out

Remaining software, equipment, and communications shown are within scope for testing.

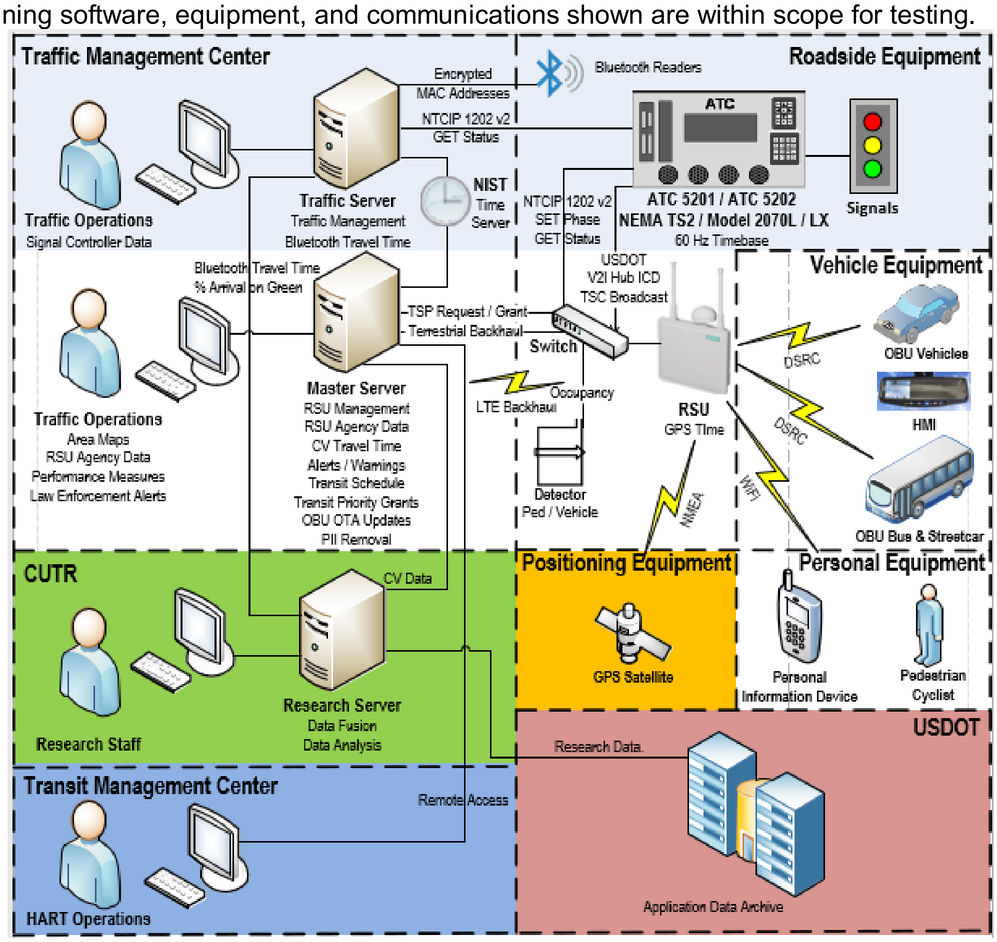


Figure 13: System Architecture
Source: Siemens

2.1.1.9 Equipment and Software to Be Tested

The equipment, communications, and the software are installed and tested in a one-mile-by-one-mile study area of downtown Tampa, Florida. Figure 14 is a map of the study area that locates each hardware object installed and the software objects installed within each hardware object as shown in the legend.

Figure 14: Study Area
Source: Global-5

2.1.2 Approach

2.1.2.1 Overall Test Strategy

The ORTP Test Workflow is depicted in Figure 15.

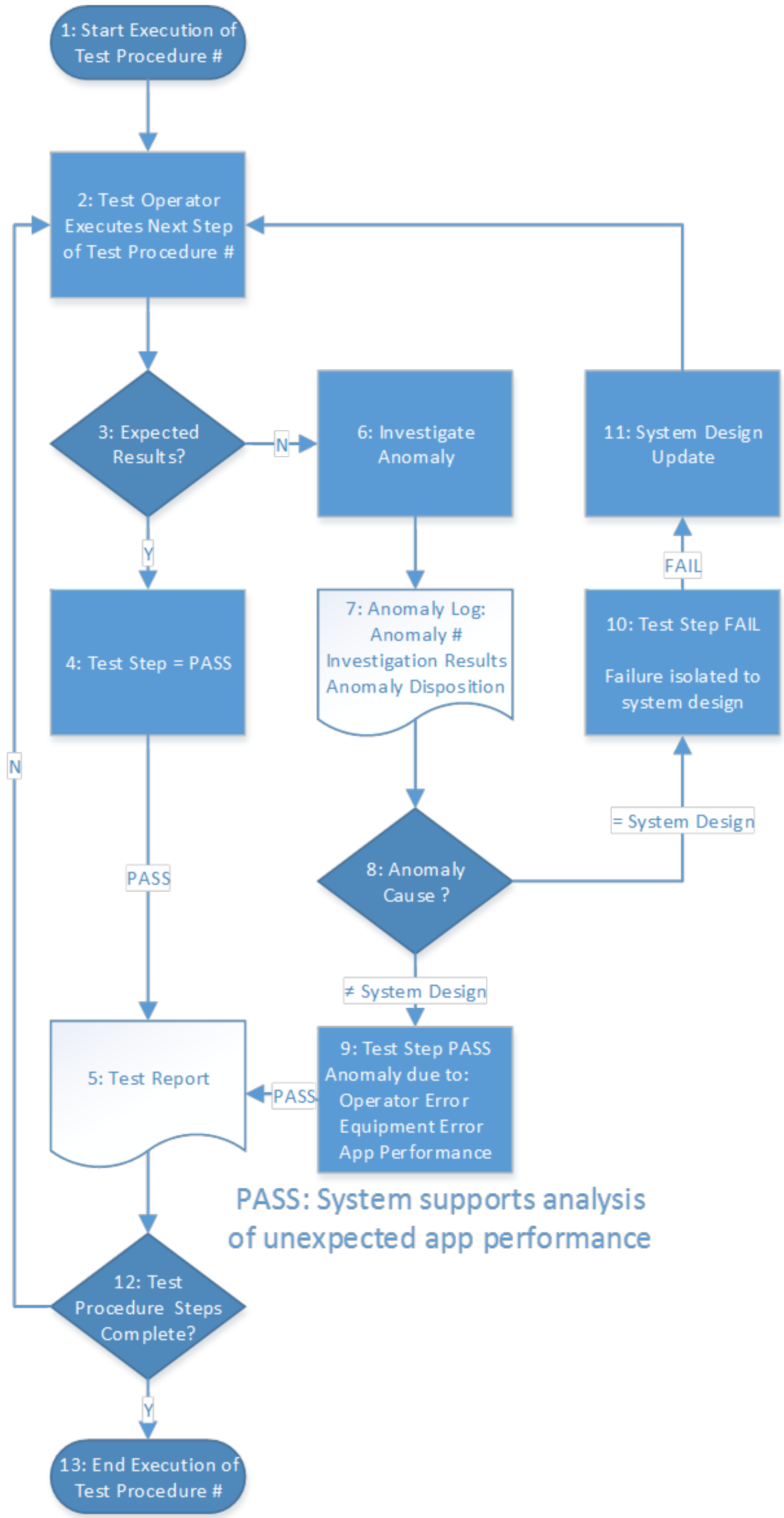


Figure 15: ORTP Test Workflow
Source: Siemens

Description of the flowchart numbered steps of Figure 15 follows:

1. Start with Step #1 of the Test Procedure.
2. Test operator executes the Test Procedure step.
3. Test operator compares the measured test result to the expected test result.
4. If the measured test result matches the expected test result, the test step PASSES.
5. The expected test result is logged in the Test Report as PASS.
6. If the test operator determines that the measured test result is unexpected, the test is not a FAIL but is further investigated as an Anomaly.
7. The results of the anomaly investigation are entered into the Anomaly Log.
8. The system contribution to the anomaly is determined.
9. If the anomaly is not determined to be caused by the system and resolved with documented changes to operator action or test equipment adjustment, the test procedure step PASSES and is entered as such in the Test Report. For example, the test step PASSES if the anomaly is determined to be caused by:
    a. Operator error.
    b. Test equipment malfunction.
    c. Poor application performance, meaning that the correctly-operating system correctly identified poor application performance.
10. If the anomaly investigation isolates the unexpected test result to the system, the test step FAILS.
11. The system design is updated to correct the anomaly.
12. The test operator completes the test step and proceeds on to the next step.
13. The Test Procedure is complete when all steps have been completed and logged.

2.1.2.2 Individual Tests

2.1.2.2.1 Conventions Used

2.1.2.2.1.1 Application Naming Convention

APP<n>: Application software object, where:

- APP: Application Acronym
- n = V: Software object for APP installed in OBU
- n = I: Software object for APP installed in RSU
- n = P: Software object of APP installed in PID

For example, the Vehicle-to-Infrastructure (V2I) End-of-Ramp Deceleration Warning (ERDW) app includes ERDW I software object in the RSU, plus ERDW Vehicle (V) software object in the OBU.

2.1.2.2.1.2 Level Test Naming Convention

Each Level Test is named with Numeric (N), Alpha (An), underscore, alpha (a)

- N: Use case number with a range of 1 through 6
- An: Test Case Name
- A: Suffix for Test Procedure

For example, UC2 WWE_F is Use Case 2, Test Case Wrong-Way Entry for Test Procedure F

2.1.2.2.2 Requirements to Test Case Traceability

Table 3 through Table 11 is the Requirements to Test Case Traceability Matrix (RTCTM)

- Requirement ID: Requirement identifier from the System Requirements Document dated February 2018
  - Active Requirements are shown in Table 3
  - Removed Requirements are not shown in Table 3, but are shown in the Requirements Document as strikethrough, with a comment describing the reason for removal
- Verification Method (VM): Verification Method of the Systems Requirements Document
  - T: Requirement is verified by Test traceable to the Test Case ID
  - I: Requirement is verified by Inspection traceable to an Inspection Procedure
  - D: Requirement is verified by Demonstration within the Operational Demonstration
- UC: Use Case identifier of the Test Case document
- Test Case (TC) ID: Test Case Identifier of the Test Case document
- Configuration: Abbreviated test configuration. Please refer to the Test Case document for detailed test configuration information
- Metric: Refers to observations recorded in response to test input stimuli
- Pass: Abbreviated criteria to pass the test. Please refer to the Test Case document for detailed criteria

Table 3: Use Case RTCTM

SyS REQ Document			Test Case Document			
Requirement	VM	UC	TC ID	Configuration	Metric	Pass
THEA-UC1-001	T	1	I-SIG_A	RSU receiving BSM	Queue Length	Accurate queue length log
THEA-UC1-012	T					
THEA-UC1-013	T					
THEA-UC1-014	T					
THEA-UC1-015	T					
THEA-UC1-017	T					
THEA-UC1-018	T					
THEA-UC1-028	T					
THEA-UC1-029	T					
THEA-UC1-030	T					
THEA-UC1-019	T		I-SIG_B	RSU receiving Basic Safety Message (BSM)	CALLS, OMITS, HOLDS	Signal phase modification
THEA-UC1-022	T		ERDW_A	Manual queues	Speed advice Traveler Information Message (TIM)	Speed advice is proper
THEA-UC1-024	T					
THEA-UC1-026a	T					
THEA-UC1-002	T		ERDW_B	Manual queues	Speed advice location 1	Speed advice for location
THEA-UC1-023	T					
THEA-UC1-025	T					
THEA-UC1-004	T		EEBL_A	Forward hard brake	> Hard braking threshold	Hard braking warning
THEA-UC1-005	T					
THEA-UC1-006	T					
THEA-UC1-007	T					
THEA-UC1-008	T					
THEA-UC1-011	T					
THEA-UC1-004	T		EEBL_B	Forward soft brake	≤ Hard braking threshold	No hard braking warning
THEA-UC1-005	T					

THEA-UC1-006	T					
THEA-UC1-007	T					
THEA-UC1-008	T					
THEA-UC1-011	T					
THEA-UC1-008	T		FCW_A	Same lane	≤ Time and distance	Forward crash warning
THEA-UC1-009	T					
THEA-UC1-010	T					
THEA-UC1-011	T					
THEA-UC1-008	T		FCW_B	Adjacent passing	≤ Time and distance	No forward crash warning
THEA-UC1-009	T					
THEA-UC1-010	T					
THEA-UC1-011	T					
THEA-UC2-010	T	2	WWE_A	Left to oncoming	Inbound Map message conformant to Society of Automotive Engineers (SAE) standard J2735-2016 (MAP)	Do Not Enter → Wrong Way
THEA-UC2-011	T					
THEA-UC2-012	T					
THEA-UC2-016	T					
THEA-UC2-018a	T					
THEA-UC2-018b	T					
THEA-UC2-010	T		WWE_B	Left to closed	Closed MAP	Do Not Enter → Transportation Management Center (TMC)
THEA-UC2-011	T					
THEA-UC2-012	T					
THEA-UC2-016	T					
THEA-UC2-018a	T					
THEA-UC2-018b	T					
THEA-UC2-001	T					
THEA-UC2-010	T		WWE_C	Inbound to closed	Closed MAP	Do Not Enter → No Travel
THEA-UC2-011	T					
THEA-UC2-012	T					
THEA-UC2-016	T					
THEA-UC2-018a	T					
THEA-UC2-018b	T					
THEA-UC2-010	T		WWE_D	Head-on	Inbound MAP	Head-on crash warning

THEA-UC2-011	T					
THEA-UC2-012	T					
THEA-UC2-015b	T					
THEA-UC2-015c	T					
THEA-UC2-015d	T					
THEA-UC2-016	T					
THEA-UC2-018a	T					
THEA-UC2-018b	T					
THEA-UC2-010	T		WWE_E	U-turn morning	Inbound MAP	No head-on crash warning
THEA-UC2-011	T					
THEA-UC2-012	T					
THEA-UC2-016	T					
THEA-UC2-018a	T					
THEA-UC2-018b	T					
THEA-UC2-010	T		WWE_F	U-turn evening	Closed MAP	No head-on crash warning
THEA-UC2-011	T					
THEA-UC2-012	T					
THEA-UC2-016	T					
THEA-UC2-018a	T					
THEA-UC2-018b	T					
THEA-UC2-001	T		IMA_A	T-Bone	Crash trajectory	Intersection Movement Assist (IMA) crash trajectory
THEA-UC2-002	T					
THEA-UC2-003	T					
THEA-UC2-003a	T					IMA crash warning
THEA-UC2-007	T		Signal Phase and Timing (SPaT) MAP	COTS test equip.	Broadcast MAP, SPaT	Enabled Lane ID correct
THEA-UC2-008	T					
THEA-UC2-008b	T					
THEA-UC2-008c	T					
THEA-UC2-008d	T					
THEA-UC3-001	T	3	Pedestrian in a Signalized	Vehicle BSM → PID	PID Crash Warning	Crash alert → Master Server
THEA-UC3-002	T					
THEA-UC3-003	T					

THEA-UC3-008	T		Crosswalk (PED-X)			
THEA-UC3-009	T					
THEA-UC3-011	T					
THEA-UC3-012	T					
THEA-UC3-015	T					
THEA-UC3-016	T					
THEA-UC3-016a	T					
THEA-UC3-016b	T					
THEA-UC3-001	T		PCW_A	Pedestrian (PED) near crosswalk	No crash trajectory	No crash warning
THEA-UC3-002	T					
THEA-UC3-003	T					
THEA-UC3-008	T					
THEA-UC3-009	T					
THEA-UC3-011	T					
THEA-UC3-012	T					
THEA-UC3-015	T					
THEA-UC3-016	T					
THEA-UC3-016a	T					
THEA-UC3-016b	T					
THEA-UC3-001	T		PCW_B	PED in crosswalk	Crash trajectory	Crash warning
THEA-UC3-002	T					
THEA-UC3-003	T					
THEA-UC3-008	T					
THEA-UC3-009	T					
THEA-UC3-011	T					
THEA-UC3-012	T					
THEA-UC3-015	T					
THEA-UC3-001	T		PCW_C	PED near crosswalk	Crash trajectory	Crash warning
THEA-UC3-002	T					
THEA-UC3-003	T					
THEA-UC3-008	T					
THEA-UC3-009	T					

THEA-UC3-011	T					
THEA-UC3-012	T					
THEA-UC3-015	T					
THEA-UC3-016	T					
THEA-UC3-016a	T					
THEA-UC3-016b	T					
THEA-UC3-001	T		PCW_D	PED in crosswalk	No crash trajectory	No crash warning
THEA-UC3-002	T					
THEA-UC3-003	T					
THEA-UC3-008	T					
THEA-UC3-009	T					
THEA-UC3-011	T					
THEA-UC3-012	T					
THEA-UC3-015	T					
THEA-UC3-016	T					
THEA-UC3-016a	T					
THEA-UC3-016b	T					
THEA-UC4-001	T	4	TSP_A	Green Extension	Phase CALL / HOLD	DARK bus Human Machine Interface (HMI)
THEA-UC4-002	T					
THEA-UC4-004	T					
THEA-UC4-005	T					
THEA-UC4-007	T					
THEA-UC4-008	T					
THEA-UC4-009	T					
THEA-UC4-013	T					
THEA-UC4-001	T		TSP_B	No Green Extension	Phase CALL / HOLD	DARK bus HMI
THEA-UC4-002	T					
THEA-UC4-004	T					
THEA-UC4-005	T					
THEA-UC4-007	T					
THEA-UC4-008	T					
THEA-UC4-009	T					

THEA-UC4-013	T					
THEA-UC4-001	T					
THEA-UC4-003	T		TSP_C	Schedule Deviation	Hillsborough Area Regional Transit (HART) Schedule	Next Connect = update
THEA-UC5-011	T		Pedestrian Transit Movement Warning (PTMW)	Approach, departure	BSMs and geo-fence	PID warnings per test cases
THEA-UC5-012	T					
THEA-UC5-007	T	5	VTRFTV_A	Moving streetcar	Vehicle / Streetcar BSM	Streetcar, on track warnings
THEA-UC5-007a	T					
THEA-UC5-008	T					
THEA-UC5-008a	T					
THEA-UC5-007	T		VTRFTV_B	Stopped streetcar	Vehicle / Streetcar BSM	No warnings
THEA-UC5-007a	T					
THEA-UC5-008	T					
THEA-UC5-008a	T					
THEA-UC5-005	T		PTMW	Streetcar, pedestrian	Vehicle / Streetcar BSM	Warning within geo-fence
THEA-UC5-006	T					
THEA-UC5-008b	T					
THEA-UC5-009	T					
THEA-UC5-009a	T					
THEA-UC5-009c	T					
THEA-UC6-006	T	6	I-SIG	BSM, ISM → RSU	Queue length	Queue length log correct
THEA-UC6-008a	T					
THEA-UC6-018	T		PED-SIG_A	North-South	PED Phase CALL	Correct WALK phase runs
THEA-UC6-018b	T					
THEA-UC6-018c	T					
THEA-UC6-018d	T					
THEA-UC6-018e	T					
THEA-UC6-018f	T					
THEA-UC6-018g	T					
THEA-UC6-018	T		PED-SIG_B	East-West	PED Phase CALL	Correct WALK phase runs

THEA-UC6-018b	T					
THEA-UC6-018c	T					
THEA-UC6-018d	T					
THEA-UC6-018e	T					
THEA-UC6-018f	T					
THEA-UC6-018g	T					

2.1.2.2.2.1 Safety Requirements to Test Case Traceability Matrix

Table 4: Safety RTCTM

SyS REQ Document		Test Case Document			
Requirement	VM	TC	Configuration	Metric	Pass
THEA-SAF-001	I		As installed	Relevant standards	Statement of Compliance
THEA-SAF-004	D		Installed RSUs	Maintenance	Maintenance Demonstration
THEA-SAF-005	T	SAF_A	OBU Failure	Vehicle operation	Safe Vehicle operation
THEA-SAF-006	T	SAF_B	RSU Failure	Controller Unit (CU) operation	Safe CU operation
THEA-SAF-007	I		PID Failure	PID operation	Documented app failure
THEA-SAF-011	D		Crashed car	Vehicle operation	OBU demonstration
THEA-SAF-014	I		Vehicle with HMI	HMI operation	Stakeholder inspection, approval
THEA-SAF-020	I		Vehicle installers	Certification, resume	Integrator inspection, approval
THEA-SAF-020a	D		Participants	Training	Participant demonstration
THEA-SAF-021	I		Infrastructure. installers	Certification, resume	Integrator inspection approval

2.1.2.2.2.2 Security Requirements to Test Case Traceability Matrix

Table 5: Security RTCTM

SyS REQ Document		Test Case Document			
Requirement	**VM**	**TC**	**Configuration**	**Metric**	**Pass**
THEA-SEC-001	I		OBUs as installed	OBU IEEE 1609.2	Inspect Statement of Compliance
THEA-SEC-001a	I		RSUs as installed	RSU IEEE 1609.2	Inspect Statement of Compliance
THEA-SEC-002	I		RSU non-DSRC IP com.	Encrypted messages	Inspect decrypted message file

SyS REQ Document		Test Case Document			
Requirement	**VM**	**TC**	**Configuration**	**Metric**	**Pass**
THEA-SEC-003	I	[redacted]	Security Credential Management System (SCMS) POC EE, 11/1/17	SCMS operation	Inspect SCMS certificates
THEA-SEC-004	I	[redacted]	Master Server as installed	Personally-Identifiable Information (PII) removal	Inspect data logs after removal
THEA-SEC-005	I	[redacted]	Master Server as installed	Intrusion detection	Inspect per DPP
THEA-SEC-006	I	[redacted]	RSUs as installed	RSU firewall operation	Inspect RSU service console
THEA-SEC-006a	I	[redacted]	OBUs as installed	OBU firewall operation	Inspect OBU service console
THEA-SEC-014	I	[redacted]	Master Server as installed	Participant data access	Inspect Master Server access method
THEA-SEC-019	I	[redacted]	Master Server as installed	PII data removal	Inspect Master Server data PII removal
THEA-SEC-023	I	[redacted]	RSUs as installed	RSU bootstrap access	Inspect RSU physical access
THEA-SEC-023a	I	[redacted]	OBUs as installed	OBU bootstrap access	Inspect OBU physical access
THEA-SEC-072	I	[redacted]	RSUs, OBUs as installed	Unused media access	Inspect tamper-evident seal

2.1.2.2.2.3 Performance Requirements to Test Case Traceability Matrix

Table 6: Performance RTCTM

SyS REQ Document		Test Case Document			
Requirement	VM	TC	Configuration	Metric	Pass
THEA-PFM-001	I	[redacted]	CUTR Server as installed	Collect "Before" data	Inspect collected "Before" data
THEA-PFM-002	I	[redacted]	CUTR Server as installed	Store "Before" data	Inspect stored "Before" data
THEA-PFM-003	I	[redacted]	CUTR Server as installed	Collect PFM data	Inspect collected performance data
THEA-PFM-004	I	[redacted]	CUTR Server as installed	Store PFM data	Inspect stored performance data
THEA-PFM-005	I	[redacted]	CUTR Server as installed	Before- After compare	Inspect analysis report
THEA-PFM-006	D	[redacted]	CUTR Server as installed	Automate reports	Demonstration by CUTR staff
THEA-PFM-007	D	[redacted]	CUTR Server as installed	On-demand reports	Demonstration by CUTR staff
THEA-PFM-012	I	[redacted]	Concert Server as installed	Data collected	Inspect collected data
THEA-PFM-012a	I	[redacted]	Concert Server as installed	Data computed	Inspect computed data
THEA-PFM-012b	I	[redacted]	Centracs Server as installed	Data collected	Inspect collected data
THEA-PFM-012c	I	[redacted]	HART Server as installed	Data collected	Inspect collected data

SyS REQ Document		Test Case Document			
THEA-PFM-012d	I	[redacted]	CUTR Server as installed	Data collected	Inspect collected data
THEA-PFM-013	I	[redacted]	CUTR Server as installed	Data stored	Inspect stored data

2.1.2.2.2.4 Information Management Requirements to Test Case Traceability Matrix

Table 7: Personal Data Management RTCTM

SyS REQ Document		Test Case Document			
Requirement	VM	TC	Configuration	Metric	Pass
THEA-INM-001	I	[redacted]	Master Server as installed	Review participant PII	Inspect collected PII to requirement
THEA-INM-002	I	[redacted]	Master Server as installed	Separate PII storage	Inspect stored PII data
THEA-INM-003	I	[redacted]	Master Server as installed	PII login	Inspect login for PII data
THEA-INM-004	I	[redacted]	Master Server as installed	PII removal	Inspect data destined for Research Data Exchange (RDE)

2.1.2.2.2.5 System Generated Data Requirements to Test Case Traceability Matrix

Table 8: System Generated Data RTCTM

SyS REQ Document		Test Case Document			
Requirement	VM	TC	Configuration	Metric	Pass
THEA-SGD-001	D	[redacted]	OBU as installed	Vehicle Data Storage	Demonstrate vehicle data storage
THEA-SGD-002	D	[redacted]	RSUs as installed	RSU message storage	Demonstrate RSU message storage
THEA-SGD-003	I	[redacted]	Master Server as installed	PII login	Inspect login for PII data
THEA-SGD-004	I	[redacted]	Master Server as installed	PII removal	Inspect data destined for RDE
THEA-SGD-007	I	[redacted]	Master Server as installed	Archived data security	Inspect data archives, redundancy

SyS REQ Document		Test Case Document			
THEA-SGD-008	I	[redacted]	Master Server as installed	Password Access	Inspect login hierarchy documents
THEA-SGD-009	I	[redacted]	Master Server as installed	Authorized per SMOC	Hierarchy documents to SMOC

2.1.2.2.2.6 Maintainability Requirements to Test Case Traceability Matrix

Table 9: Maintainability RTCTM

SyS REQ Document		Test Case Document			
Requirement	**VM**	**TC**	**Configuration**	**Metric**	**Pass**
THEA-MNT-001	I	[redacted]	RSUs as installed	Failure response time	Inspect RSU service response policy
THEA-MNT-002	I	[redacted]	RSUs as installed	Restoration time	Inspect RSU service restoration policy
THEA-MNT-003	I	[redacted]	RSUs as installed	RSU hardware service policy	Inspect RSU service contract
THEA-MNT-004	I	[redacted]	RSUs as installed	RSU software app issues	Inspect RSU software app maintenance
THEA-MNT-005	I	[redacted]	RSUs as installed	RSU planned maintenance	Inspect RSU planned maintenance process
THEA-MNT-006	I	[redacted]	RSUs as installed	RSU off-peak maintenance	Inspect RSU planned maintenance process
THEA-MNT-007	I	[redacted]	OBUs as installed	OBU failure log entries	Inspect OBU failure log examples by TOD
THEA-MNT-008	D	[redacted]	OBUs as installed	OBU failure participant alert	Demonstrate OBU failure alert method
THEA-MNT-009	D	[redacted]	OBUs as installed	OBU service appointments	Demonstrate service appointment process
THEA-MNT-010	D	[redacted]	OBUs as installed	OBU replacement	Demonstrate OBU replacement
THEA-MNT-012	D	[redacted]	RSU, OBU, PID as installed	Support staff training	Demonstrations by support staff
THEA-MNT-013	D	[redacted]	RSU, OBU, PID as installed	Diagnostic procedures	Demonstrate a diagnostic procedure

2.1.2.2.2.7 Reliability Requirements to Test Case Traceability Matrix

Table 10: Reliability RTCTM

SyS REQ Document		Test Case Document			
Requirement	VM	TC	Configuration	Metric	Pass
THEA-SLR-002	I	[redacted]	RSUs as installed	Data deletion	Inspect RSU data deletion documentation
THEA-SLR-003	I	[redacted]	OBUs as installed	Data deletion	Inspect OBU data deletion documentation

2.1.2.2.2.8 Policy and Regulation Requirements to Test Case Traceability Matrix

Table 11: Policy and Regulation RTCTM

SyS REQ Document		Test Case Document			
ID	VM	TC	Configuration	Metric	Pass
THEA-PAR-001	I		RSUs as installed	FCC registration	Inspect FCC website for all RSU locations

2.1.3 Operational Readiness Test Deliverables

The ORTP is split into the following deliverables:

- Operational Readiness Test Plan (this document)
- Operational Readiness Test Cases
- Operational Readiness Test Procedures
- Operational Readiness Test Report, including
  - Test/Demonstration Data
  - Test/Demonstration Results
  - Test Anomaly Logs
  - Anomaly Remediation
  - Summary Report
  - Sign-off by Stakeholders
- Test Summary

2.1.4 Remaining Operational Readiness Testing Tasks

2.1.4.1 Master Test Plan

The following testing conducted under the project Master Test Plan (MTP) was conducted before the Level 4 ORTP, including Level Test Plans, Level Test Procedures, and Level Test Reports for:

- Level 1: Existing Hardware/Software Investigation
- Level 2: Acceptance Test for Hardware Devices and Software Units
- Level 3: Subsystem Test of Software Units Integrated into Hardware Devices

Outcomes of Level Tests 1 through 3 are inputs to Level 4 ORT.

2.1.4.2 Application Performance

Evaluation of CV application operation and effectiveness is part of project Phase 3. It is out of scope and is not part of the system acceptance testing, as explained in 2.1.1.7.1.

2.1.5 Responsibilities

Table 12 lists the roles and responsibilities for the operational readiness Test Leads.

Table 12: Testing Responsibilities

Name	Organization	Responsibility
Rafal Ignatowicz	BrandMotion	Vehicle System Test Lead
		V2V Application Test Lead
Dave McNamara	BrandMotion	Vehicle Configuration Management
Iouri Nemirovski	Siemens ITS	Infrastructure System Test Lead
		V2I Application Test Lead
		Master Server Test Lead
Wolfgang Buckle	Siemens ITS	Infrastructure Configuration Management
		Master Server Configuration Management
Change Control Board	Owner/Operators	Test Acceptance at QG 4

2.1.6 Staffing and Training Needs

No additional staffing or unique training needs to be required.

2.1.7 Schedule

Table 13 lists the expected start date and expected end date for conducting the operational readiness testing. Slippage in the schedule is mitigated by early application field testing in Tampa during March, ahead of number 31 Field Testing.

Table 13: Operational Readiness Testing

No	Activity	Start	Stop	Dependency
1	MPT v1 first draft	11/1/16	1/12/17	Phase 1
2	MTP v2 update	1/12/17	2/22/17	1
3	MTP v3 update	2/22/17	3/21/17	2
4	MTP v4 update	3/21/17	4/12/17	3
5	ORCB webinar	4/20/17	4/20/17	4
6	OR Concept review	4/20/17	4/25/17	5
7	ORTP Draft (I) update	4/25/17	10/24/17	6
8	ORTP Draft (V) update	4/25/17	10/24/17	6
9	ORTP walkthrough	11/7/17	11/8/17	7, 8
10	Test Plan draft	4/12/17	2/15/18	4
11	Test Case v1 from ORTP	11/8/17	2/15/18	9
12	Test Procedure v1 from ORTP	11/8/17	2/15/18	9
13	Test Procedure v1 review	2/15/18	2/19/18	12
14	Test Plan review	2/15/18	3/2/18	10
15	Test Case v2 review	2/15/18	3/2/18	11
16	ORP v1 first draft		3/2/18	
17	ORP v1 review	3/2/18	3/9/18	16
18	ORP v2 update	3/9/18	3/16/18	17
19	Test Plan v3 update	3/2/18	3/16/18	14
20	Test Case v3 update	3/2/18	3/16/18	15
21	Test Procedure v3 (I) update	2/19/18	3/16/18	13
22	Test Procedure v3 (V) update	2/19/18	3/16/18	13
23	ORP v2 review	3/16/18	3/23/18	18
24	Test Plan v3 review	3/16/18	3/23/18	19
25	Test Case v3 review	3/16/18	3/23/18	20, 21, 22
26	Test Procedure v3 review	3/16/18	3/23/18	20, 21, 22
27	ORP v3 update	3/23/18	3/30/18	23
28	ORTP v3 update	3/23/18	3/30/18	24, 28, 26
29	ORP v3 deliverable	3/30/18	3/30/18	27
30	ORTP v3 deliverable	3/30/18	3/30/18	28
31	Field Testing	3/30/18	4/3/18	30
32	Anomaly Report	4/3/18	4/618	31
33	I-SIG ConOps v1 draft		2/26/18	
34	I-SIG ConOps v1 review	2/26/18	3/12/18	33
35	I-SIG ConOps v2 update	3/12/18	3/23/18	34
36	VISSM Meeting	4/5/18	4/6/18	35
37	UC6 Phase 2 Agreement	4/6/18	4/6/18	36
38	Task 38 Deleted			
39	Test Procedure v5 update	4/6/18	4/9/18	37
40	Test Procedure v5 deliver	4/19/18	4/13/18	39
41	ORDP v1 first draft		2/20/18	
42	ORDP Walkthrough	2/20/18	2/21/18	41
43	ORDP v2 Center for Urban Transportation Research (CUTR) collaborate	2/21/18	3/16/18	42

No	Activity	Start	Stop	Dependency
44	ORDP v2 update	3/16/18	3/23/18	43
45	ORDP v2 call	3/30/18	3/30/18	44
46	ORDP v3 (I) update	3/30/18	4/6/18	45
47	ORDP v3 (V) update	3/30/18	4/6/18	45
48	ORDP v3 CUTR collaborate	3/30/18	4/6/18	45
49	ORDP v3 call	4/6/18	4/13/18	46, 47, 48
50	ORDP v4 update	4/13/18	4/20/18	49
51	ORDP v4 deliverable	4/20/18	4/20/18	50
52	ORD live demonstration	4/24/18	4/25/18	50
53	ORD resolve issues	4/25/18	4/26/18	51
54	ORP deliverable	4/26/18	4/30/18	53
55	CMOP v1 (I) first draft		3/30/18	
56	CMOP v2 (V) update	3/30/18	3/26/18	55
57	CMOP collaborate, Tampa	3/30/18	3/26/18	55
58	CMOP collaborate CUTR	3/30/18	3/26/18	55
59	CMOP v1 review	3/26/18	3/30/18	56, 57, 58
60	CMOP v2 update	3/30/18	4/3/18	59
	Maintenance Training (V)	4/3/18	4/23/18	60
	Maintenance Training (I)	4/3/18	4/23/18	60
61	CMOP deliverable	4/3/18	4/9/18	60
62	ORR checklist	4/9/18	5/1/18	54, 61

2.1.8 Risks and Contingencies

Table 14 lists the risks and contingencies with emphasis on the operational readiness testing. **Figure 16** depicts the Risk Matrix. For each major risk, one of the mitigation approaches shown is taken.

Table 14: Risk and Contingencies

RISK #	TASK	RISK OWNER	RISK IDENTIFICATION	PROBABILITY (1-5)	IMPACT (1-5)	SEVERITY (P*I)	RISK RESPONSE	RISK MITIGATION STRATEGY	CLOSING RISK DATE
	Title or description of the task.	Owner of the risk.	Brief description of risk.	1 - Low 5 - High	1 - Low 5 - High	Formula calculated risk (Probability * Impact)	Avoid, Mitigate, Accept, Contingency, Transfer the risk.	The overall approach to reducing risk impact severity and or probability of occurrence.	Title or description of the task.
P1-1	ConOps/Schedule/ Requirements	THEA	Unknown system/device compatibility issues	2	2	4	Mitigate	Early engagement with FDOT-TERL and Float in deployment schedule	
P1-2	Program Management	THEA	Loss of Key Staff	2	1	2	Contingency	Succession Plan	
P1-3	Stakeholder Education	THEA	Public Opposition/Privacy or safety concerns	2	2	4	Mitigate	Effective Outreach Plan	
P2/3-1	Deployment Plan	THEA	Extended road closures - Planned private development	4	2	8	Mitigate	Close Coordination with CoT/Developer	
P2/3-2	Deployment Plan	THEA/FDOT-D7	Conflicting Construction projects - Managed Lanes 2018	3	3	9	Mitigate	Close coordination with FDOT-D7 - Opportunity for shared cost.	
P2/3-3	Deployment Plan	THEA/Partner CoT	Conflicting construction projects - CoT planned signal upgrades in the pilot area	4	4	16	Mitigate	Close coordination with CoT (Pilot Partner) - Opportunity for shared cost.	
P2/3-4	Safety Plan/ Outreach Plan	THEA/USDOT Pilots	Accident in the pilot area with litigation.	1	5	5	Mitigate/Transfer	Mitigate risk through safety plan and outreach plan. Transfer financial risk via insurance	

Risk level Determination - 5 x 5 Matrix

Impact					
5	5	10	15	20	25
4	4	8	12	16	20
3	3	6	9	12	15
2	2	4	6	8	10
1	1	2	3	4	5
	1	2	3	4	5
	Probability				

Action Table

Color	Score	Risks
Red	15 - 25	High
Yellow	5, 8 - 12	Medium
Green	1 -4, 6	Low

- **Avoid** – Eliminate the threat or condition or to protect the project objectives from its impact by eliminating the cause
- **Mitigate** – Identify ways to reduce the probability or the impact of the risk
- **Accept** – Nothing will be done
- **Contingency** –Define actions to be taken in response to risks
- **Transfer** – Shift the consequence of a risk to a third party together with ownership of the response

Figure 16: Risk Level Determination Matrix
Source: HNTB

2.1.9 Approvals

Provide a listing of the individuals who can sign off and say the project is complete and can process to the next stage. This plan is effective as of the most recent date from the signatures provided below. All signatures indicate acceptance of the test plan.

Manager	Date	Comment
Tester	Date	Comment
CCB Director	Date	Comment

2.2 Test Cases

2.2.1 Introduction

2.2.1.1 Requirements to Test Case Traceability

The Test Cases verify the Requirements identified by "T" (test) in the "VM" column of the Requirements to Test Case Traceability Matrix (RTCTM) of 2.1.2.2.2. The Test Cases do not include verification of Requirements identified by "D" (demonstrate), or "I" (inspect).

2.2.1.2 Conformance to Safety Management Plan

2.2.1.2.1 Safety Risk Classification

Each Test Case considers the safety-related needs identified in the Safety Management Plan.

- Four safety ratings are identified as A, B, C, and D.
- Safety risks D have the highest safety risk and need the highest level of mitigation.
- Safety risks A have the lowest safety risk.
- Safety Risks identified by QM (Quality Management) do not require specific mitigation measures but are controlled by processes of the quality management system.
- None of the potential safety scenarios are classified as A, B, C, or D.
- Quality Management practices are applied to each Test Case, with no specific safety risk mitigation measures included in the Test Cases.

2.2.1.2.2 Quality Management

Safety Risks along with Safety Risk Response plan are listed in the “Summary of Risk Assessment” table of the Safety Management Plan.

- Risks include weather events, traffic control equipment malfunctions, and others that are mitigated by organizational processes and training. Level 4 Test Cases do not reiterate these existing organization risk mitigation measures in place.
- Other risks listed relate to participant training. Level 4 Test Cases do not reiterate these participant risk measures in place. Training and operation documentation relating to the CV elements of the system are described in Comprehensive Operations and the Maintenance Plan.
- Risks specific to Level 4 Test Cases beyond QM measures are listed in the “Initial Conditions” of each Test Case.

2.2.2 Use Case 1 (UC1) Morning Backup

2.2.2.1 UC1 Morning Backup Test Plan

UC1 test plan approach includes the following four Connected Vehicle applications

- I-SIG
- ERDW
- Emergency Electronic Brake Light (EEBL)
- FCW

The purpose of the test is to ensure that the implementation of the four applications fulfills the requirement of UC1.

2.2.2.2 UC1 Morning Backup Test Cases

2.2.2.2.1 I-SIG Test Cases

Test Case UC1 I-SIG_A

Table 15: Test Case UC1 I-SIG_A

Initial Conditions	**Safety Management Test Conduct:** • **Closed roadway with law enforcement present** • **Use of stakeholder vehicles** • **Conducted by stakeholder participants** • **Applications tuned to match Phase 3 study configuration**
Objectives	Test the interfaces between three overlapping applications: • Infrastructure Sensor Gateway (ISG) application running in RSU located on the REL creates Infrastructure Sensor Messages (ISM) for all vehicles based on a radar detector. • I-SIG application running in RSU located at Twiggs and Meridian computes southbound queue length to control traffic. • ERDW application running in RSU located on the REL computes speed advice per zone based on the queue length on the REL as computed by I-SIG. System Operation:

Initial Conditions	**Safety Management Test Conduct:** • **Closed roadway with law enforcement present** • **Use of stakeholder vehicles** • **Conducted by stakeholder participants** • **Applications tuned to match Phase 3 study configuration**
	• The detector on REL sends vehicle presence and speed to ISG. • RSU sends an ISM to I-SIG for each vehicle using the known latitude, longitude, and elevation of the detection zone. • I-SIG receives BSMs from equipped vehicles. • I-SIG receives ISMs from ISG for all vehicles. • I-SIG running in RSU computes queue length for all lanes. • I-SIG controls traffic at Twiggs and Meridian, based on BSMs and ISMs. • Southbound queue length is an I-SIG output to ERDW. Verify that: • I-SIG receives BSMs. • Master Server logs contain queue length estimates for all approaches. • ISG receives detection events. • ISG converts detection events to ISMs. • ERDW receives queue lengths for southbound lanes on REL. • ERDW uses the longest queue as input to TIM selection.
Test Inputs	The varying queue of vehicles on the approaches to two intersections: Twiggs/ Meridian and Twiggs/Nebraska
Resources Needed	RSU installed and communicating at Twiggs/Meridian RSU installed and communicating at Twiggs/Nebraska OBU equipped cars communicating
Execution Conditions	1. Morning Peak with an expected high penetration rate of equipped vehicles (20% or higher) 2. Mid-day low with an expected low penetration rate of equipped vehicles (< 5%) 3. Evening Peak with an expected high penetration rate of equipped vehicles (20% or higher)
Requirements Verified	THEA-UC1-001: Transmit SB Twiggs/Meridian queue to ERDW THEA-UC1-012: I-SIG (all) receives BSMs from equipped vehicles THEA-UC1-013: Twiggs/Meridian I-SIG processes BSMs for SB queue THEA-UC1-014: Twiggs/Nebraska I-SIG processes BSMs for queue THEA-UC1-015: Twiggs/Meridian I-SIG queue to Master Server THEA-UC1-017: Master Server receive queues from I-SIG (all) THEA-UC1-018: Master Server store queues from I-SIG (all) THEA-UC1-028: Vehicle detector issues CALL to RSU when occupying a zone THEA-UC1-029: RSU issues ISM when receiving CALL

Initial Conditions	**Safety Management Test Conduct:** • **Closed roadway with law enforcement present** • **Use of stakeholder vehicles** • **Conducted by stakeholder participants** • **Applications tuned to match Phase 3 study configuration**
	THEA-UC1-030: Equipped vehicles broadcast BSMs

Test Case UC1 I-SIG_B

Table 16: Test Case UC1 I-SIG_B

Initial Conditions	**Safety Management Test Conduct:** • **Closed roadway with law enforcement present** • **Use of stakeholder vehicles** • **Conducted by stakeholder participants** • **Applications tuned to match Phase 3 study configuration**
Objectives	Test the interface between: • RSU and I-SIG • I-SIG and the Controller Unit (CU) System Operation: • I-SIG receives BSMs as inputs under varying traffic conditions • I-SIG sends NTCIP 1202 dialogs of: o SET CU signal phases to control traffic o GET signal phase from CU to insure expected operation • Based on the dialog, the CU applies: o Phase CALLs to demand service by approaching vehicles o Phase OMITs to skip phases, such as train blocking lane o Phase HOLDs, such as allowing time for pedestrian crossing Verify that: • CU status screen shows CALLs, OMITs, and HOLDs are applied • Phase green times vary with estimated queue length for the corresponding approach • CU serves the minimum GREEN time as a minimum response

Initial Conditions	**Safety Management Test Conduct:** • **Closed roadway with law enforcement present** • **Use of stakeholder vehicles** • **Conducted by stakeholder participants** • **Applications tuned to match Phase 3 study configuration**
Test Inputs	The varying queue of vehicles
Resources Needed	RSU installed and communicating at Twiggs/Meridian RSU installed and communicating at Twiggs/Nebraska OBU equipped cars communicating
Execution Conditions	1. I-SIG_A verifies collection of BSMs before this test is executed 2. Morning Peak with an expected high penetration rate of equipped vehicles (20% or higher) 3. Mid-day low with an expected low penetration rate of equipped vehicles (< 5%) 4. Evening Peak with an expected high penetration rate of equipped vehicles (20% or higher) 5. MMITSS is enabled and active 6. Estimated queue lengths are significant (> 10 vehicles) on at least one intersection approach
Requirements Verified	THEA-UC1-019: Combination of CU and RSU app modifies signal phasing

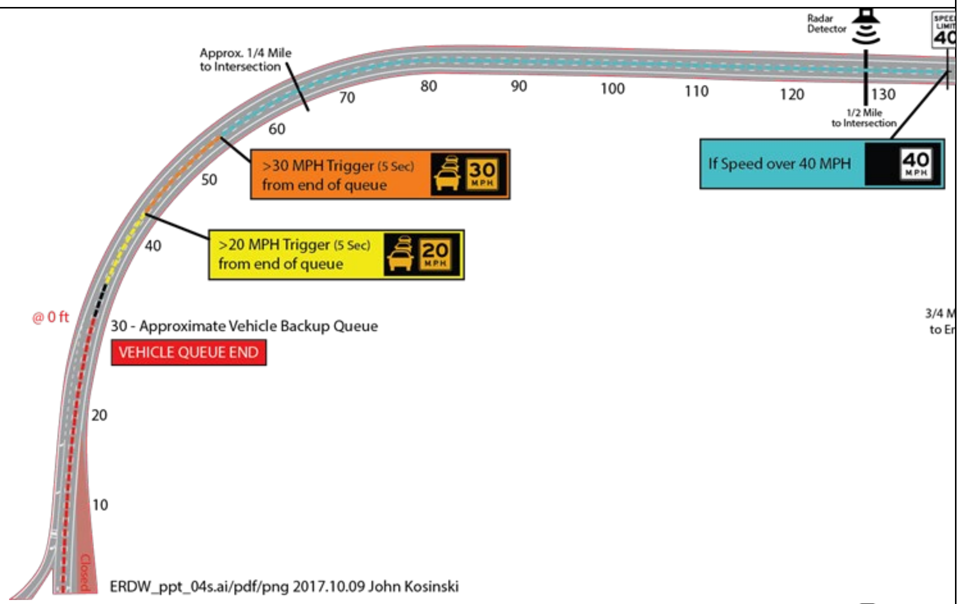
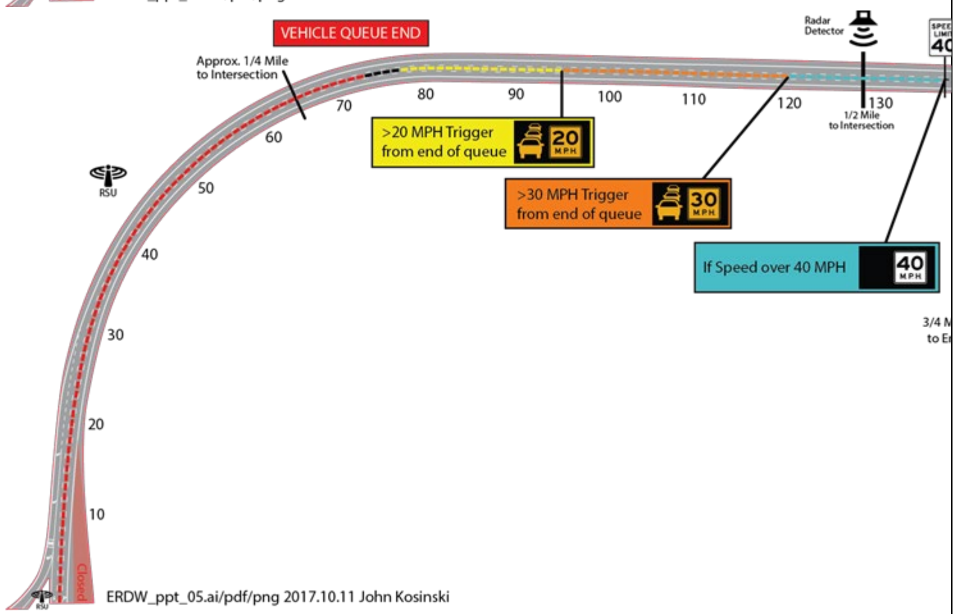
2.2.2.2.2 ERDW Test Cases

Test Case UC1 ERDW_A

Table 17: Test Case UC1 ERDW_A

Initial Conditions	**Safety Management Test Conduct:** • **Closed roadway with law enforcement present** • **Use of stakeholder vehicles** • **Conducted by stakeholder participants** • **Applications tuned to match Phase 3 study configuration**
Objectives	Test the following interfaces: • Queue length input to ERDW • TIM output from ERDW System Operation: • I-SIG is disabled • Differing queue lengths are manually entered as inputs to ERDW using the RSU service console • ERDW creates TIMs with the recommended speed per zone for light-duty vehicle

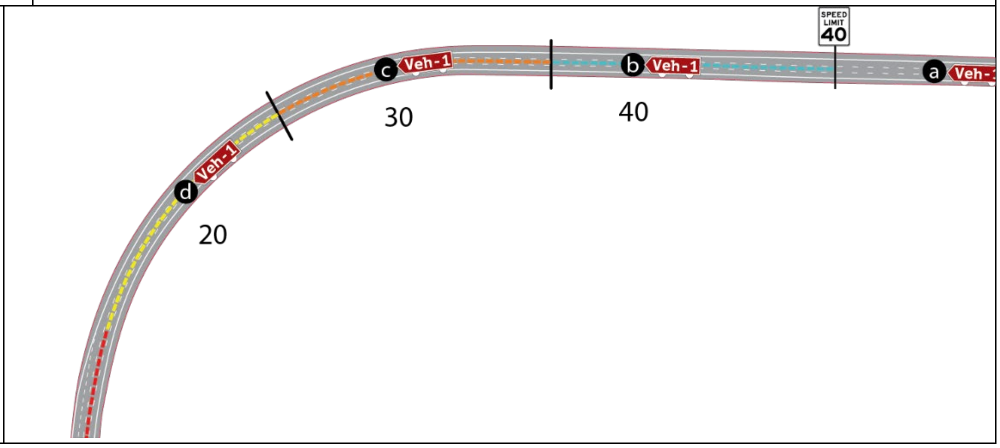
Initial Conditions	**Safety Management Test Conduct:** • **Closed roadway with law enforcement present** • **Use of stakeholder vehicles** • **Conducted by stakeholder participants** • **Applications tuned to match Phase 3 study configuration**
	Verify that: • ERDW is accepted • ERDW displays entered queue length • ERDW uses the displayed queue length to select TIM associated with that queue length based on ERDW configuration. Mathematical relation of TIM output to queue length input is configurable. Test Case verifies that the output TIM is issued as a configurable relationship to the input queue. • COTS test equipment receives and logs broadcast TIM • TIM content (speed zones) equals the TIM configured for the queue length • ERDW picks a different TIM which is associated with the second queue length based on ERDW configuration • TIM content (speed zones) equals the TIM configured for the second queue length
Test Inputs	Varying Input: 2 different queue lengths of vehicles Configurations: Location of zones, speed advice per zone configured per illustration for each of the two queue lengths
Resources Needed	RSU installed and communicating at Twiggs/Meridian OBU equipped cars with drivers communicating
Execution Conditions	1. MMITSS is disabled 2. Queue length is entered manually via RSU browser UI
Requirements Verified	THEA-UC1-022: The RSU ERDW application shall broadcast a recommended standard speed THEA-UC1-024: The RSU ERDW application shall adjust the configurable speed recommendation zone(s) based on the southbound queue length from I-SIG application on Twiggs and Meridian THEA-UC1-026a: The RSU ERDW application shall transmit the configurable speed recommendation zones to the THEA Master Server

Initial Conditions	**Safety Management Test Conduct:** • **Closed roadway with law enforcement present** • **Use of stakeholder vehicles** • **Conducted by stakeholder participants** • **Applications tuned to match Phase 3 study configuration**
Illustration	 

Test Case UC1 ERDW_B

Table 18: Test Case UC1 ERDW_B

Initial Conditions	**Safety Management Test Conduct:** • **Closed roadway with law enforcement present** • **Use of stakeholder vehicles** • **Conducted by stakeholder participants** • **Applications tuned to match Phase 3 study configuration**
Objectives	Test the following interfaces: • TIM from RSU to OBU • Warning from OBU to HMI • Warning from HMI to Driver System Operation: • I-SIG is disabled • Differing queue lengths are manually entered as inputs to ERDW • ERDW creates TIMs with the recommended speed per zone for a light-duty vehicle • ERDW application displays a message to the driver Verify that: • ERDW displays entered queue length • ERDW uses the displayed queue length to select TIM associated with that queue length based on ERDW configuration • COTS test equipment receives and logs broadcast TIM • TIM content (speed zones) equals the TIM configured for the queue length • ERDW application picks the most recent TIM being broadcast and uses that to display a message to the driver • TIM content (speed zones) equals the TIM configured for the second queue length • Queue length matches ground true, such as mile marker or GPS
Test Inputs	Varying Input: Queue lengths of vehicles Configurations: Location of zones, speed advice per zone, ERDW app
Resources Needed	RSU installed and communicating at Twiggs/Meridian OBU equipped cars with drivers communicating
Execution Conditions	Closed REL, RSU broadcasting speed zones
Requirements Verified	THEA-UC1-002: The drivers shall receive ERDW from ERDW application on the vehicles THEA-UC1-023: The vehicle ERDW application shall receive the recommended standard speed THEA-UC1-025: The vehicle ERDW application shall convert the recommended standard speed to an appropriate speed based on the vehicle type

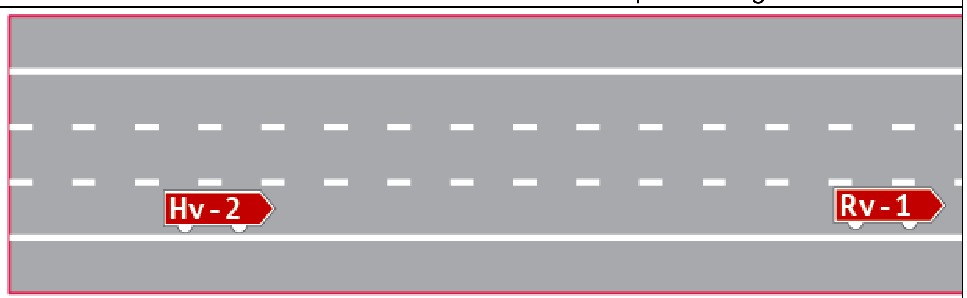
Initial Conditions	**Safety Management Test Conduct:** • **Closed roadway with law enforcement present** • **Use of stakeholder vehicles** • **Conducted by stakeholder participants** • **Applications tuned to match Phase 3 study configuration**
Illustration	

2.2.2.2.3 EEBL Test Cases

Test Case UC1 EEBL_A

Table 19: Test Case UC1 EEBL_A

Initial Conditions	**Safety Management Test Conduct:** • **Closed roadway with law enforcement present** • **Use of stakeholder vehicles** • **Conducted by stakeholder participants** • **Applications tuned to match Phase 3 study configuration**
Objectives	Test the following interfaces: • BSM from remote vehicle OBU to host vehicle OBU • Warning from host vehicle OBU to HMI • Warning from HMI to Driver System Operation: • Remote and host vehicles both have functioning OBUs • Remote vehicle varies the level of brakes above and below the hard-braking threshold (0.3g) • Remote vehicle sends out BSMs • EEBL app is installed on OBUs • OBU of the host vehicle: ○ Receives BSM from remote vehicle OBU

Initial Conditions	**Safety Management Test Conduct:** • **Closed roadway with law enforcement present** • **Use of stakeholder vehicles** • **Conducted by stakeholder participants** • **Applications tuned to match Phase 3 study configuration**
	○ Identifies the hard braking of the remote vehicle ○ Determines if host vehicle on a collision course ○ Warns driver of the hard braking vehicle ahead Verify that: • Vehicles experiencing heavy braking send out a hard-braking event through BSM • Vehicles sending, receiving and processing BSMs • EEBL application displaying a message to the driver no more than once
Test Inputs	Varying: Level of braking of the remote vehicle, the distance of the remote vehicle from the host vehicle
Resources Needed	OBU equipped host and remote vehicles, two drivers, communicating
Execution Conditions	Closed road section, host and remote vehicle driving in the same lane per the MAP file
Requirements Verified	THEA-UC1-004: EEBL V broadcasts EEBL warning for hard deceleration THEA-UC1-005: EEBL V receives EEBL warning from the braking vehicle THEA-UC1-006: EEBL V processes warning THEA-UC1-007: EEBL V warns the driver THEA-UC1-008: Vehicles receive BSMs from other vehicles THEA-UC1-011: HMI warns no more than once for multiple warnings
Illustration	

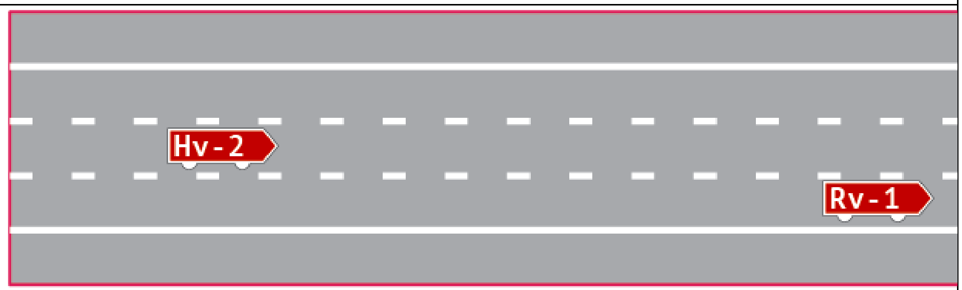
Test Case UC1 EEBL_B

Table 20: Test Case UC1 EEBL_B

Initial Conditions	**Safety Management Test Conduct:** • **Closed roadway with law enforcement present** • **Use of stakeholder vehicles** • **Conducted by stakeholder participants** • **Applications tuned to match Phase 3 study configuration**

Objectives	Test the following interfaces:
	• BSM from remote vehicle OBU to host vehicle OBU
	• Warning from host vehicle OBU to HMI
	• Warning from HMI to Driver
	System Operation:
	• Remote and host vehicles both have functioning OBUs
	• Remote vehicle varies the level of brakes above and below the hard-braking threshold (0.3g)
	• Remote vehicle sends out BSMs
	• EEBL app is installed on OBUs
	• OBU of the host vehicle:
	  o Receives BSM from remote vehicle OBU
	  o Identifies the hard braking of the remote vehicle
	  o Determines if host vehicle on a collision course
	  o Warns driver of the hard-braking vehicle ahead
	Verify that:
	• Vehicles experiencing heavy braking send out a hard-braking event through BSM
	• Vehicles sending, receiving, and processing BSMs
	• EEBL application displaying a message to the driver no more than once

Test Inputs	Varying: Level of braking of the remote vehicle, the distance of the remote vehicle from the host vehicle
Resources Needed	OBU equipped host and remote vehicles, two drivers, communicating
Execution Conditions	Closed road section, host and remote vehicle are driving in adjacent lanes per the MAP file.
Requirements Verified	THEA-UC1-004: EEBL V broadcasts EEBL warning when hard deceleration THEA-UC1-005: EEBL V receives EEBL warning from the braking vehicle THEA-UC1-006: EEBL V processes warning THEA-UC1-007: EEBL V warns the driver THEA-UC1-008: Vehicles receive BSMs from other vehicles THEA-UC1-11: HMI warns no more than once for multiple warnings

Initial Conditions	**Safety Management Test Conduct:** • **Closed roadway with law enforcement present** • **Use of stakeholder vehicles** • **Conducted by stakeholder participants** • **Applications tuned to match Phase 3 study configuration**
Illustration	

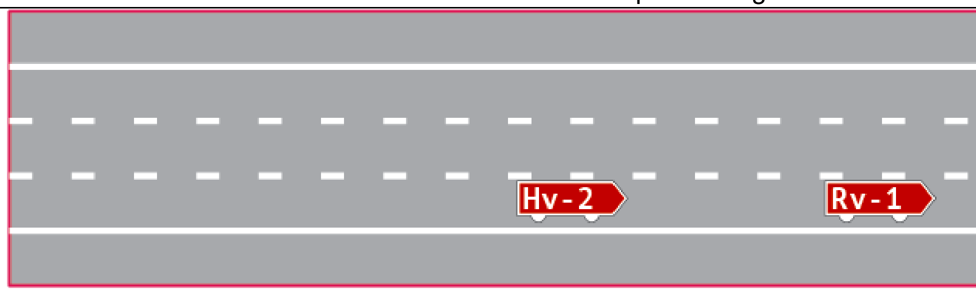
2.2.2.2.4 FCW Test Cases

Test Case UC1 FCW_A

Table 21: Test Case UC1 FCW_A

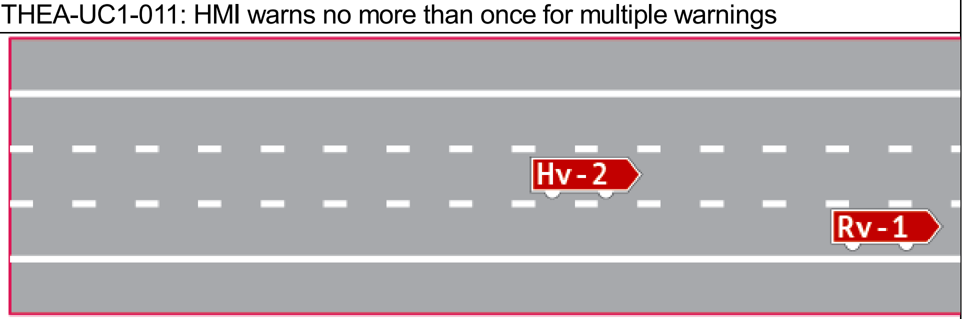
Initial Conditions	**Safety Management Test Conduct:** • **Closed roadway with law enforcement present** • **Use of stakeholder vehicles** • **Conducted by stakeholder participants** • **Applications tuned to match Phase 3 study configuration**

Objectives	Test the following interfaces:
	• BSM from remote vehicle OBU to host vehicle OBU
	• Warning from host vehicle OBU to HMI
	• Warning from HMI to Driver
	System Operation:
	• Remote and host vehicles both have functioning OBUs
	• FCW app is installed on OBUs
	• Remote vehicle sends out BSMs
	• OBU of the host vehicle:
	  ○ Receives BSM from remote vehicle OBU
	  ○ Identifies the trajectory of the host vehicle compared to remote vehicle
	  ○ Determines if host vehicle is on a collision course
	  ○ Warns driver of impending forward collision
	Verify that:
	• Vehicles sending, receiving, and processing BSMs

Initial Conditions	**Safety Management Test Conduct:** • **Closed roadway with law enforcement present** • **Use of stakeholder vehicles** • **Conducted by stakeholder participants** • **Applications tuned to match Phase 3 study configuration**
	• FCW application displaying a message to the driver no more than once
Test Inputs	Varying: Distance of remote vehicle from the host vehicle
Resources Needed	OBU equipped host and remote vehicles, two drivers, communicating
Execution Conditions	Closed road section, host and remote vehicle sending and receiving BSMs while positioned in the same lane
Requirements Verified	THEA-UC1-008: Vehicles receive BSMs from other vehicles THEA-UC1-009: FCW V calculates crash trajectories THEA-UC1-010: FCW V warns the driver of crash trajectories THEA-UC1-011: HMI warns no more than once for multiple warnings
Illustration	

Test Case UC1 FCW_B

Table 22: Test Case UC1 FCW_B

Objectives	**Test the following interfaces:** • **BSM from remote vehicle OBU to host vehicle OBU** • **Warning from host vehicle OBU to HMI** • **Warning from HMI to Driver** **System Operation:** • **Remote and host vehicles both have functioning OBUs** • **FCW app is installed on OBUs** • **Remote vehicle sends out BSMs** • **OBU of the host vehicle:** ○ **Receives BSM from remote vehicle OBU** ○ **Identifies the trajectory of the host vehicle compared to remote vehicle** ○ **Determines if the host vehicle is on a collision course** ○ **Warns driver of the impending forward collision** **Verify that:** • **Vehicles sending, receiving, and processing BSMs** • **FCW application displaying a message to the driver no more than once**
Test Inputs	Varying: Distance of remote vehicle from the host vehicle
Resources Needed	OBU equipped host and remote vehicles, two drivers, communicating
Execution Conditions	Closed road section, host and remote vehicle sending and receiving BSMs while positioned in adjacent lanes
Requirements Verified	THEA-UC1-008: Vehicles receive BSMs from other vehicles THEA-UC1-009: FCW V calculates crash trajectories THEA-UC1-010: FCW V warns the driver of crash trajectories THEA-UC1-011: HMI warns no more than once for multiple warnings
Illustration	

2.2.3 UC2 Wrong-Way Entry

2.2.3.1 UC2 Wrong-Way Entry Test Plan

The UC2 test plan approach includes the following three Connected Vehicle applications

- WWE
- IMA
- SPaT-MAP

The purpose of the test is to ensure that the implementation of the three applications fulfills the requirement of UC2.

2.2.3.2 UC2 Wrong-Way Entry (WWE) Test Cases

2.2.3.2.1 WWE Test Cases

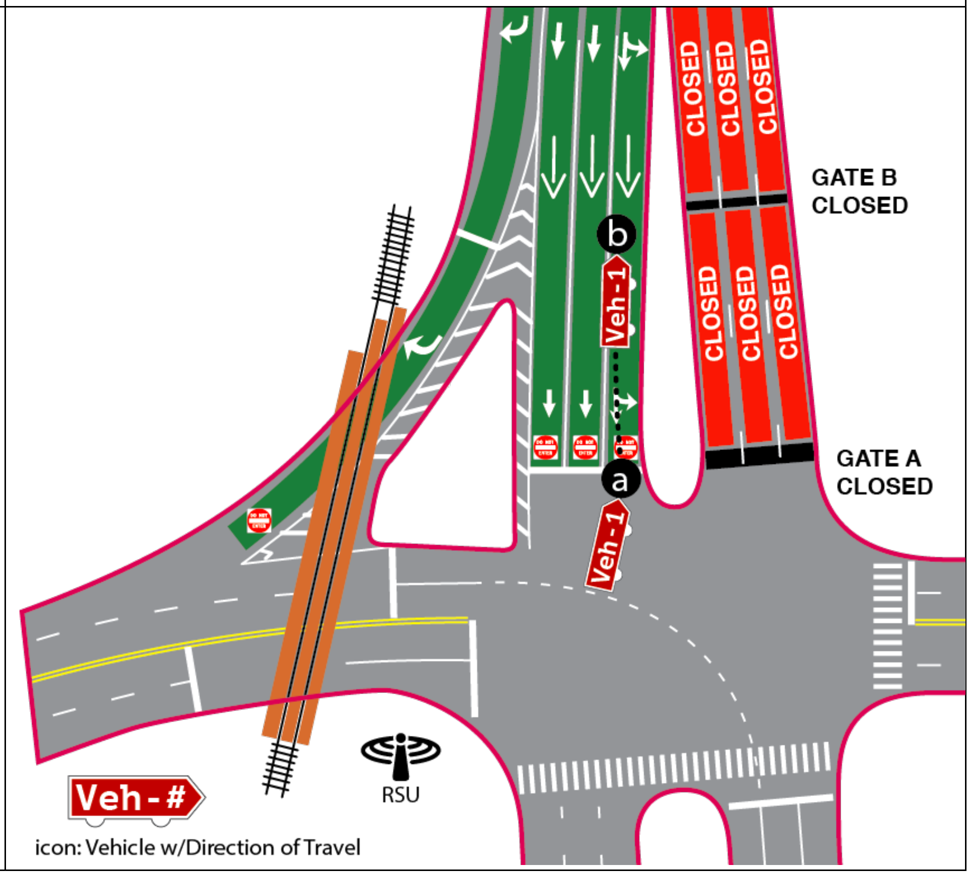
Test Case UC2 WWE_A (Left turn into oncoming traffic)

Table 23: Test Case UC2 WWE_A

Initial Conditions	**Safety Management Test Conduct:** • **Closed roadway with law enforcement present** • **Use of stakeholder vehicles** • **Conducted by stakeholder participants** • **Applications tuned to match Phase 3 study configuration**

Objectives	Test the following interface operation with inbound lanes:
	• MAP from RSU to OBU
	• SPaT from RSU to OBU
	• Warning from OBU to HMI
	• Warning from HMI to Driver
	System Operation:
	• RSU at Twiggs and Meridian broadcasts MAP message that includes EnabledLaneList
	• RSU at Twiggs and Meridian broadcasts SPaT message
	• OBU of vehicle eastbound towards Twiggs and Meridian:
	  ○ Receives MAP from RSU
	  ○ Identifies the lane locations
	  ○ Identifies the legal direction for each lane
	  ○ Identifies revocable lanes
	  ○ Receives SPaT from RSU
	  ○ Identifies the timing plan for revocable lanes
	  ○ Determines whether revocable lanes are open or closed
	  ○ Constantly determines vehicle location, direction, and speed
	  ○ Predicts wrong-way entry
	  ○ Warns wrong-way entry occurred
	Verify that:
	• EnabledLaneList matches the operational flow

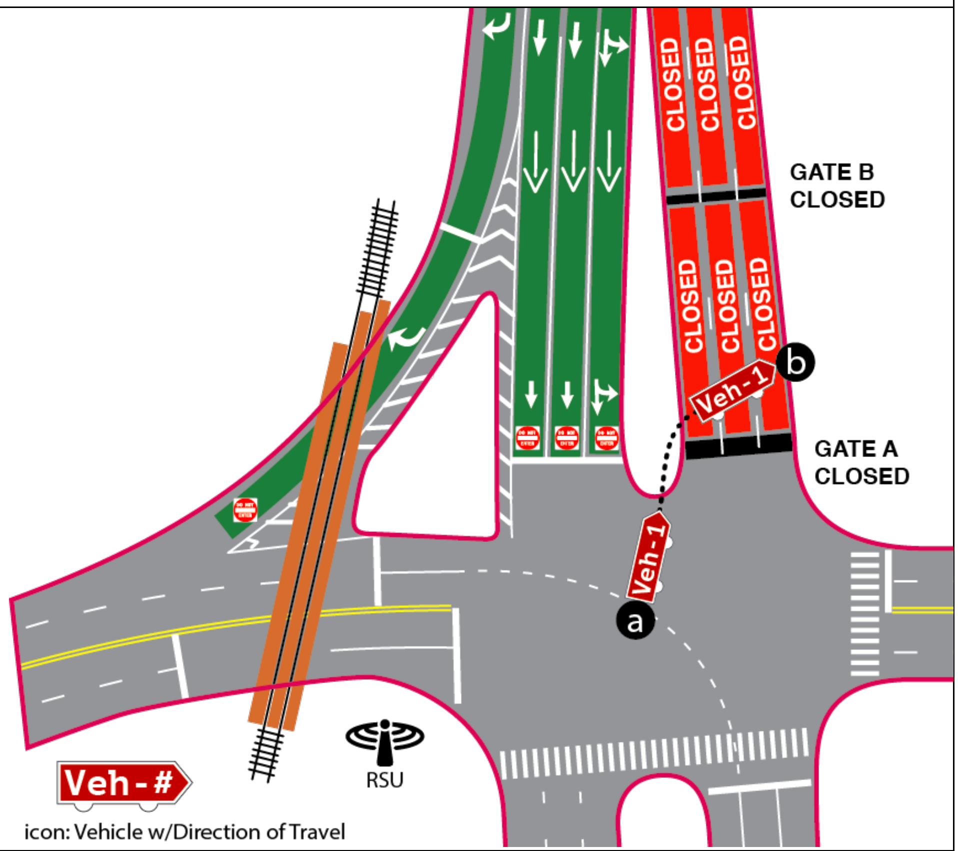
Initial Conditions	**Safety Management Test Conduct:** • **Closed roadway with law enforcement present** • **Use of stakeholder vehicles** • **Conducted by stakeholder participants** • **Applications tuned to match Phase 3 study configuration**
	• No warning is shown to the driver traveling eastbound on Twiggs • WWE issues "DO NOT ENTER" warning when an eastbound vehicle turns left towards inbound lanes, opposite of the legal direction • WWE issues "WRONG WAY" warning when a vehicle enters inbound lanes, opposite of the legal direction • Master Server stores the warnings • Warnings are available to the TMC operator
Test Inputs	RSU Broadcasts SPaT/MAP with SPaT's EnabledLaneList set to "inbound" mode
Resources Needed	RSU communicating, OBU equipped vehicle communicating
Execution Conditions	Closed REL
Requirements Verified	THEA-UC2-010: Vehicle OBU receives SPaT THEA-UC2-011: Vehicle OBU receives MAP THEA-UC2-012: Warn driver entering closed or ingress the wrong way THEA-UC2-016: Warn driver driving the wrong way on REL THEA-UC2-018a: Master Server receives wrong-way alert THEA-UC2-018b: Master Server stores wrong-way alert

Initial Conditions	**Safety Management Test Conduct:** • **Closed roadway with law enforcement present** • **Use of stakeholder vehicles** • **Conducted by stakeholder participants** • **Applications tuned to match Phase 3 study configuration**
Illustration	

Test Case UC2 WWE_B (Left turn into the closed lane)

Table 24: Test Case UC2 WWE_B

Initial Conditions	**Safety Management Test Conduct:** • **Closed roadway with law enforcement present** • **Use of stakeholder vehicles** • **Conducted by stakeholder participants** • **Applications tuned to match Phase 3 study configuration**
Test Inputs	RSU Broadcasts SPaT/MAP with SPaT's EnabledLaneList set to "inbound" mode
Resources Needed	RSU communicating, OBU-Equipped vehicle communicating
Execution Conditions	Closed REL

Initial Conditions	**Safety Management Test Conduct:** • **Closed roadway with law enforcement present** • **Use of stakeholder vehicles** • **Conducted by stakeholder participants** • **Applications tuned to match Phase 3 study configuration**
Requirements Verified	THEA-UC2-001: Vehicles receive BSMs from other vehicles THEA-UC2-010: Vehicle OBU receives SPaT THEA-UC2-011: Vehicle OBU receives MAP THEA-UC2-012: Warn driver entering closed or ingress the wrong way THEA-UC2-016: Warn driver driving no travel on REL THEA-UC2-018a: Master Server receives no travel alert THEA-UC2-018b: Master Server stores no travel alert
Illustration	

Test Case UC2 WWE_C (Inbound into the closed lane)

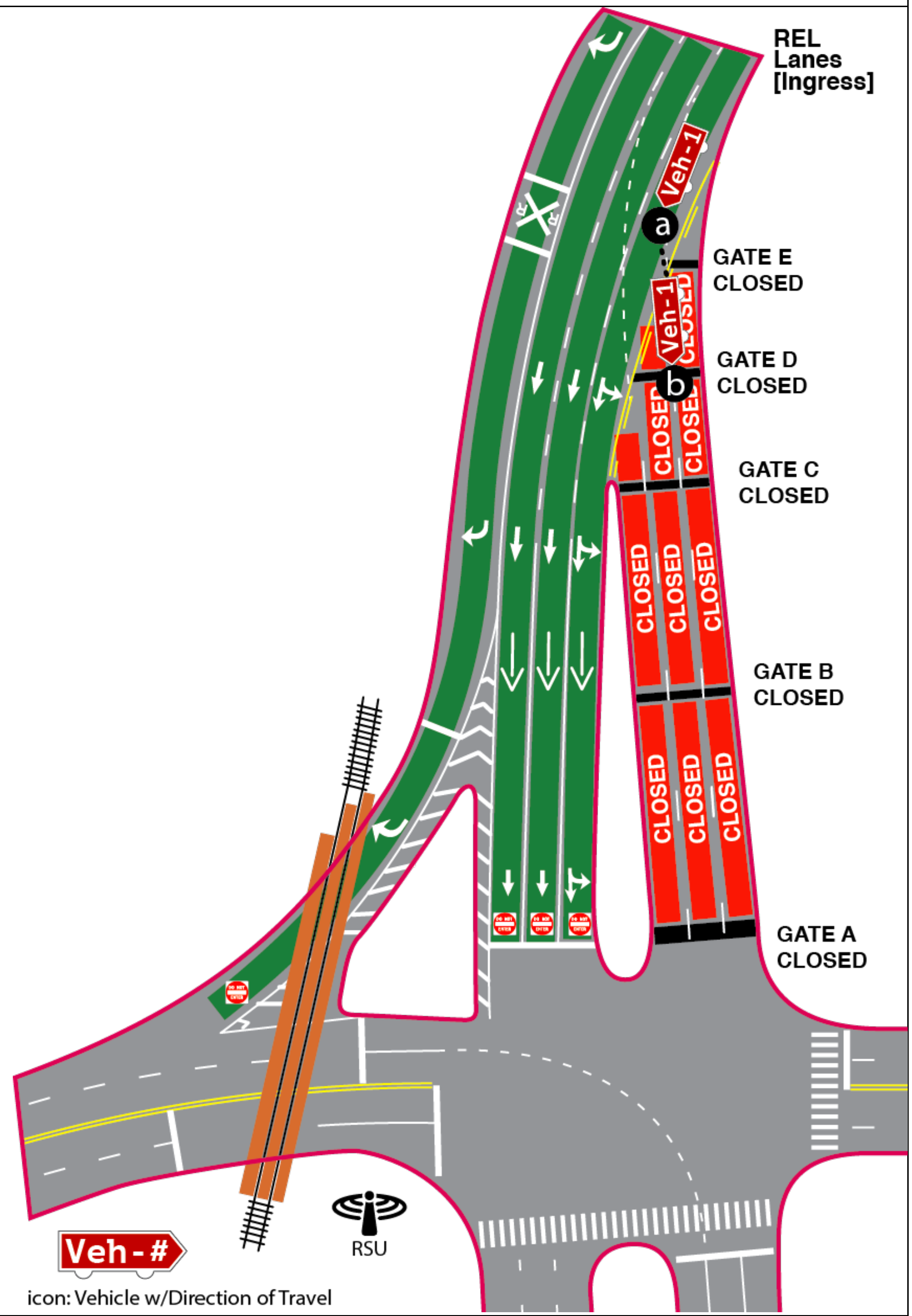
Table 25: Test Case UC2 WWE_C

Initial Conditions	**Safety Management Test Conduct:** • **Closed roadway with law enforcement present** • **Use of stakeholder vehicles** • **Conducted by stakeholder participants** • **Applications tuned to match Phase 3 study configuration**

Objectives	Test the following interfaces with inbound lanes:
	• MAP from RSU to OBU
	• SPaT from RSU to OBU
	• Warning from OBU to HMI
	• Warning from HMI to Driver
	System Operation:
	• RSU at Twiggs and Meridian broadcasts MAP message that includes EnabledLaneList
	• RSU at Twiggs and Meridian broadcasts SPaT message
	• OBU of vehicle eastbound towards Twiggs and Meridian:
	  o Receives MAP from RSU
	  o Identifies the lane locations
	  o Identifies the legal direction for each lane
	  o Identifies revocable lanes
	  o Receives SPaT from RSU
	  o Identifies the timing plan for revocable lanes
	  o Determines whether revocable lanes are open or closed
	  o Constantly determines vehicle location, direction, and speed
	  o Predicts entry into closed lanes
	  o Warns closed entry occurred
	Verify that:
	• EnabledLaneList matches the operational flow
	• No warning is shown to the driver traveling southbound REL towards inbound lanes
	• WWE issues a “DO NOT ENTER” warning when a southbound vehicle turns left towards outbound lanes, opposite of the legal direction
	• WWE issues a “NO TRAVEL” warning when the vehicle enters outbound lanes, opposite of the legal direction. The Master Server stores the warnings
	• Warnings are available to TMC operator

Test Inputs	RSU Broadcasts SPaT/MAP with SPaT’s EnabledLaneList set to “inbound” mode

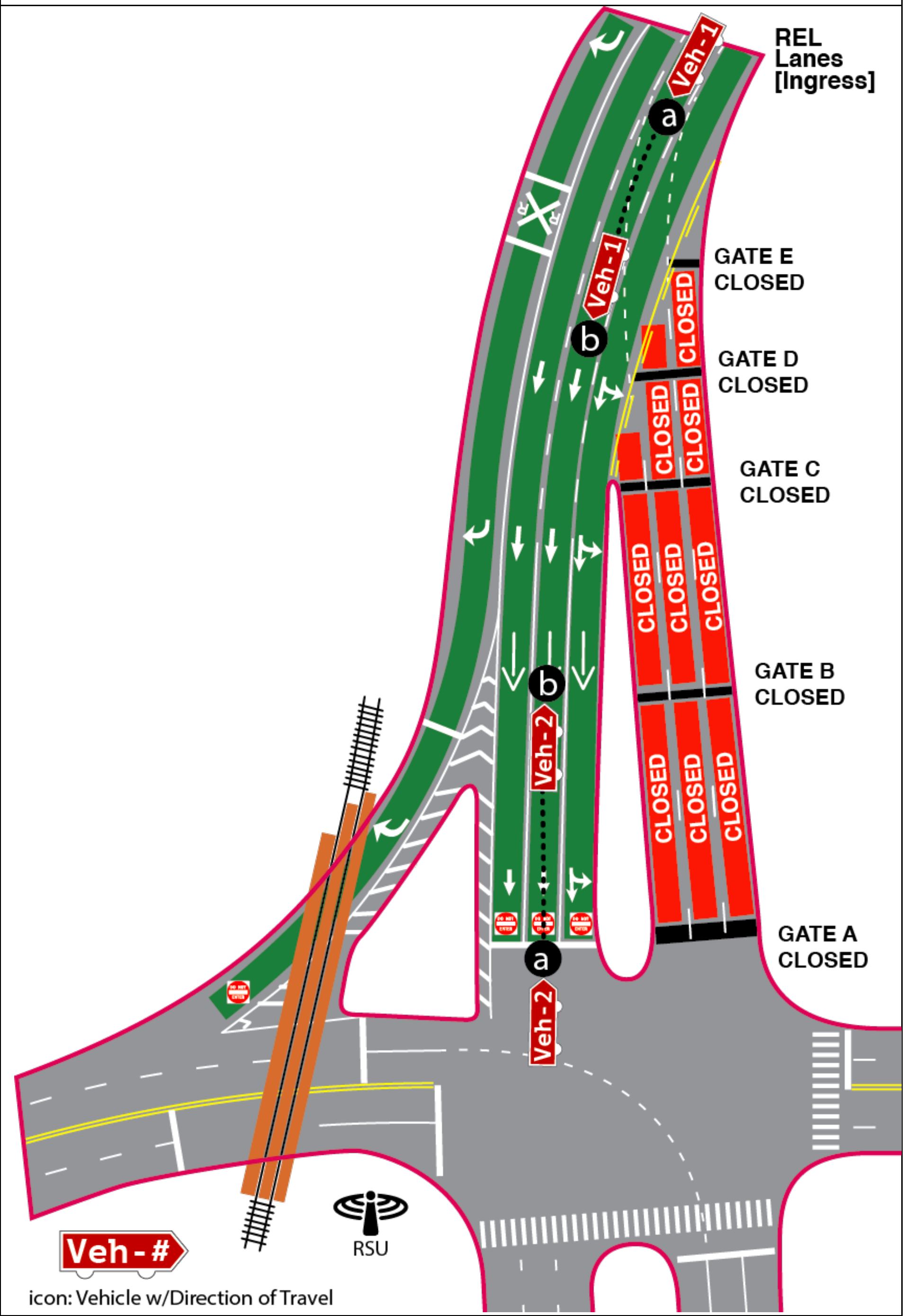
Initial Conditions	**Safety Management Test Conduct:** • **Closed roadway with law enforcement present** • **Use of stakeholder vehicles** • **Conducted by stakeholder participants** • **Applications tuned to match Phase 3 study configuration**
Resources Needed	RSU communicating, OBU-Equipped vehicle communicating
Execution Conditions	Closed REL
Requirement s Verified	THEA-UC2-001: Vehicles receive BSMs from other vehicles THEA-UC2-010: Vehicle OBU receives SPaT THEA-UC2-011: Vehicle OBU receives MAP THEA-UC2-012: Warn driver entering closed or ingress the wrong way THEA-UC2-016: Warn driver driving no travel on REL THEA-UC2-018a: Master Server receives no travel alert THEA-UC2-018b: Master Server stores no travel alert

Initial Conditions	**Safety Management Test Conduct:** • **Closed roadway with law enforcement present** • **Use of stakeholder vehicles** • **Conducted by stakeholder participants** • **Applications tuned to match Phase 3 study configuration**
Illustration	

Test Case UC2 WWE_D (Head-on)

Table 26: Test Case UC2 WWE_D

Initial Conditions	Safety Management Test Conduct: • Closed roadway with law enforcement present • Use of stakeholder vehicles • Conducted by stakeholder participants • Applications tuned to match Phase 3 study configuration
Test Inputs	RSU Broadcasts SPaT/MAP with SPaT's EnabledLaneList set to "inbound" mode RSU broadcasts a WWE TIM
Resources Needed	RSU communicating, two OBU-equipped vehicles communicating
Execution Conditions	Closed REL
Requirements Verified	THEA-UC2-001: Vehicles receive BSMs from other vehicles THEA-UC2-010: Vehicle OBU receives SPaT THEA-UC2-011: Vehicle OBU receives MAP THEA-UC2-012: Warn driver entering closed or ingress the wrong way THEA-UC2-015b: Determine if a wrong-way driver on OBU road segment THEA-UC2-015c: OBU receives TIM about the oncoming driver on OBU road segment THEA-UC2-015d: OBU warns oncoming driver on OBU road segment THEA-UC2-016: Warn driver driving the wrong way on REL THEA-UC2-018a: Master Server receives wrong-way alert THEA-UC2-018b: Master Server stores wrong-way alert

Initial Conditions	Safety Management Test Conduct: • Closed roadway with law enforcement present • Use of stakeholder vehicles • Conducted by stakeholder participants • Applications tuned to match Phase 3 study configuration
Illustration	

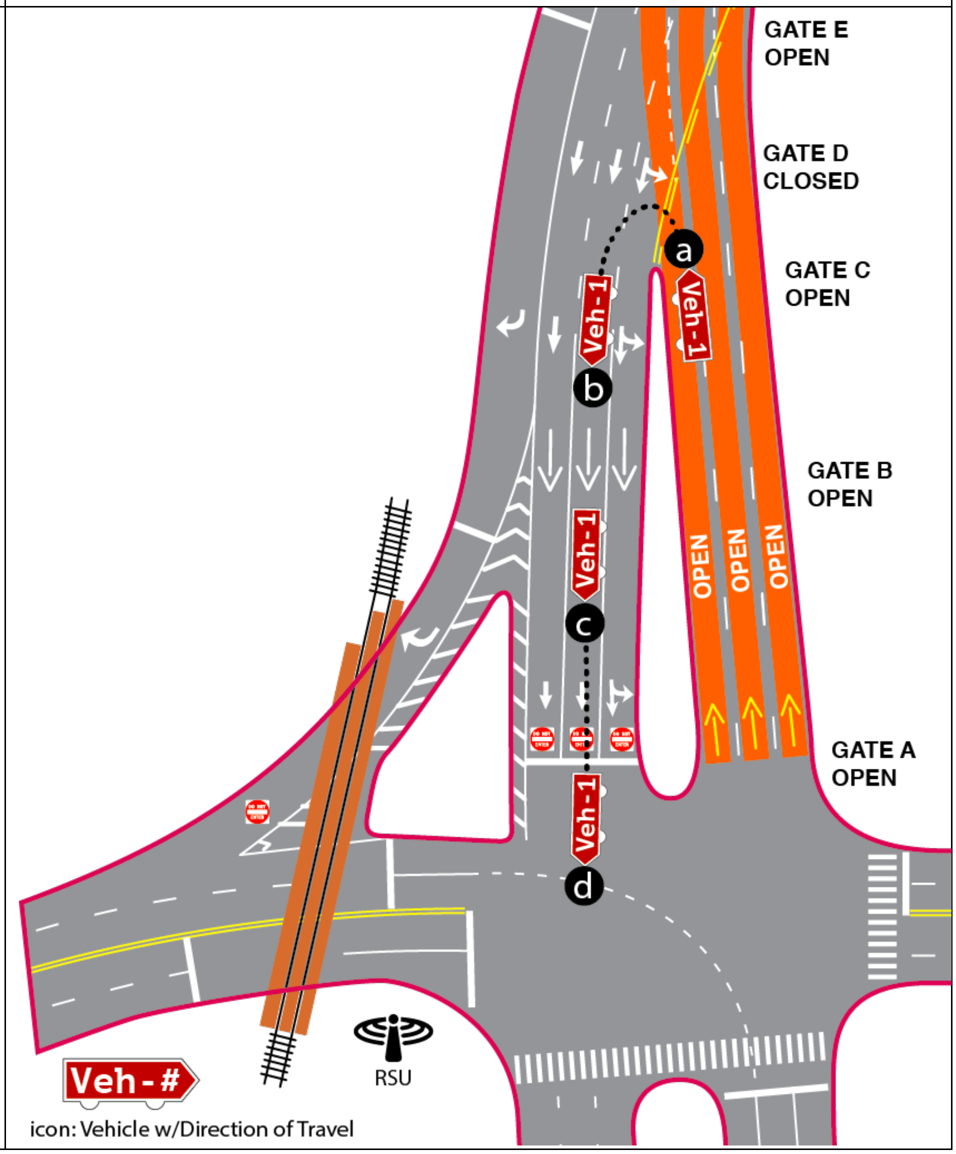
Test Case UC2 WWE_E (U-turn in the morning)

Table 27: Test Case UC2 WWE_E

Initial Conditions	Safety Management Test Conduct: • Closed roadway with law enforcement present • Use of stakeholder vehicles • Conducted by stakeholder participants • Applications tuned to match Phase 3 study configuration

Objectives	Test the following interfaces with inbound lanes:
	• MAP from RSU to OBU
	• SPaT from RSU to OBU
	• Warning from OBU to HMI
	• Warning from HMI to Driver
	System Operation:
	• RSU at Twiggs and Meridian broadcasts MAP message that includes EnabledLaneList
	• RSU at Twiggs and Meridian broadcasts SPaT message
	• OBU of vehicle eastbound towards Twiggs and Meridian:
	  o Receives MAP from RSU
	  o Identifies the lane locations
	  o Identifies the legal direction for each lane
	  o Identifies revocable lanes
	  o Receives SPaT from RSU
	  o Identifies the timing plan for revocable lanes
	  o Determines whether revocable lanes are open or closed
	  o Constantly determines vehicle location, direction, and speed
	  o Predicts entry into closed lanes
	  o Warns closed entry occurred
	Verify that:
	• EnabledLaneList matches the operational flow
	• No warning is shown to the northbound driver entering the inbound lane

Initial Conditions	Safety Management Test Conduct: • Closed roadway with law enforcement present • Use of stakeholder vehicles • Conducted by stakeholder participants • Applications tuned to match Phase 3 study configuration
	• WWE safety application issues a "No Travel Lane" warning to the driver making a U-Turn into the inbound lane • WWE safety application issues a "No Travel Lane" warning to the southbound driver on the inbound lane. • No warning is shown to the southbound driver after exiting the REL and continuing southbound on Meridian Avenue.
Test Inputs	RSU broadcasts SPaT/MAP with SPaT's EnabledLaneList set to "outbound mode."
Resources Needed	RSU, Equipped vehicle
Execution Conditions	Closed REL
Requirements Verified	THEA-UC2-001: Vehicles receive BSMs from other vehicles THEA-UC2-010: Vehicle OBU receives SPaT THEA-UC2-011: Vehicle OBU receives MAP THEA-UC2-012: Warn driver entering closed or ingress the wrong way THEA-UC2-016: Warn driver driving no travel on REL THEA-UC2-018a: Master Server receives no travel alert THEA-UC2-018b: Master Server stores no travel alert

Initial Conditions	Safety Management Test Conduct: • Closed roadway with law enforcement present • Use of stakeholder vehicles • Conducted by stakeholder participants • Applications tuned to match Phase 3 study configuration
Illustration	

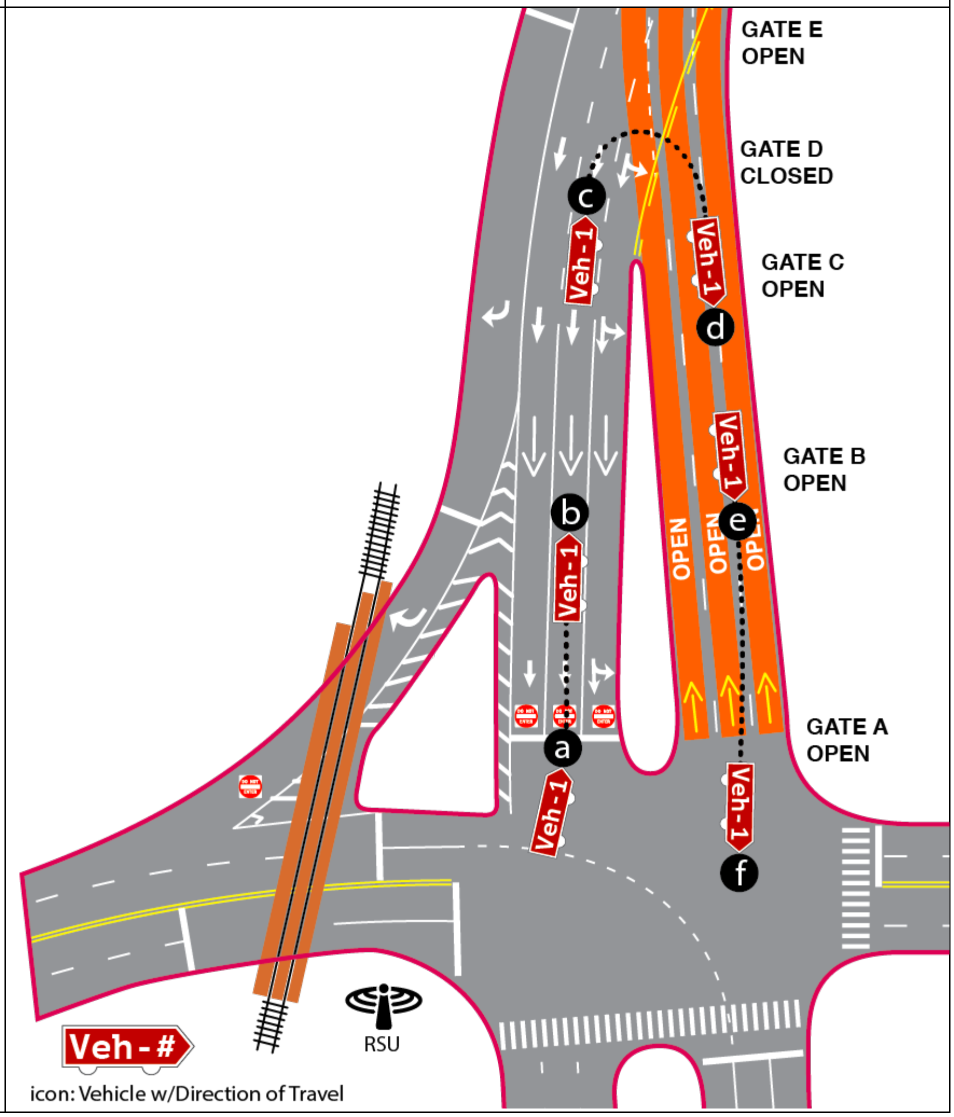
Test Case UC2 WWE_F (U-turn in the evening)

Table 28: Test Case UC2 WWE_F

Initial Conditions	Safety Management Test Conduct: • Closed roadway with law enforcement present • Use of stakeholder vehicles • Conducted by stakeholder participants • Applications tuned to match Phase 3 study configuration

Objectives	Test the following interfaces with inbound lanes:
	• MAP from RSU to OBU
	• SPaT from RSU to OBU
	• Warning from OBU to HMI
	• Warning from HMI to Driver
	System Operation:
	• RSU at Twiggs and Meridian broadcasts MAP message
	• RSU at Twiggs and Meridian broadcasts SPaT message
	• OBU of vehicle eastbound towards Twiggs and Meridian:
	    o Receives MAP from RSU
	    o Identifies the lane locations
	    o Identifies the legal direction for each lane
	    o Identifies revocable lanes
	    o Receives SPaT from RSU
	    o Identifies the timing plan for revocable lanes
	    o Determines whether revocable lanes are open or closed
	    o Constantly determines vehicle location, direction, and speed
	    o Predicts entry into closed lanes
	    o Warns closed entry occurred
	Verify that:
	• EnabledLaneList matches the operational flow
	• No warning is shown to the driver traveling eastbound on Twiggs
	• WWE safety application issues a “Do Not Enter” warning to the eastbound driver turning left towards the inbound lanes
	• WWE safety application issues a “No Travel Lane” warning to the driver continuing north on the inbound lanes

Test Inputs	RSU broadcasts SPaT/MAP with SPaT’s EnabledLaneList set to “outbound mode.”
Resources Needed	RSU, Equipped vehicle
Execution Conditions	Closed REL

Initial Conditions	Safety Management Test Conduct: • Closed roadway with law enforcement present • Use of stakeholder vehicles • Conducted by stakeholder participants • Applications tuned to match Phase 3 study configuration
Requirements Verified	THEA-UC2-001: Vehicles receive BSMs from other vehicles THEA-UC2-010: Vehicle OBU receives SPaT THEA-UC2-011: Vehicle OBU receives MAP THEA-UC2-012: Warn driver entering closed or ingress the wrong way THEA-UC2-016: Warn driver driving no travel on REL THEA-UC2-018a: Master Server receives no travel alert THEA-UC2-018b: Master Server stores no travel alert
Illustration	

2.2.3.2.2 IMA Test Cases

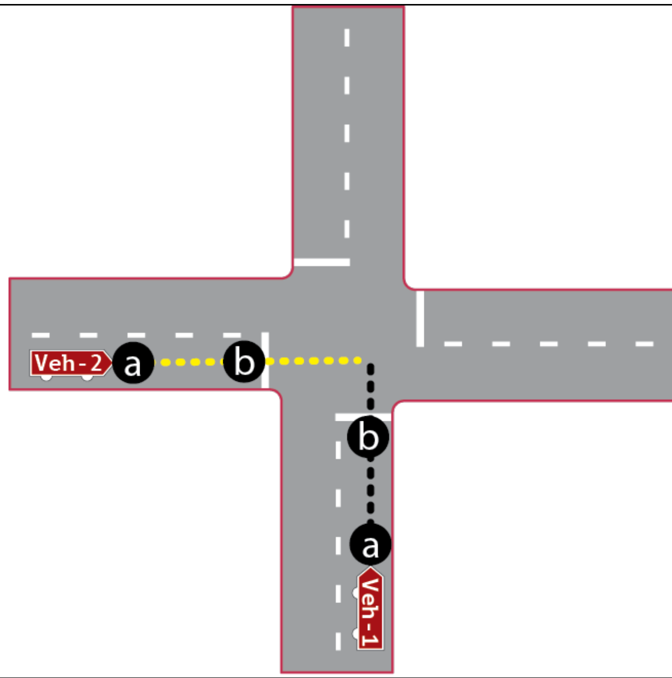
Test Case UC2 IMA_A

Table 29: Test Case UC2 IMA_A

Initial Conditions	Safety Management Test Conduct: • Closed roadway in private parking lot • Safety cones and safety vests for test facilitators • Use of stakeholder vehicles • Conducted by stakeholder participants • Applications tuned to match Phase 3 study configuration

Objectives	Test the following interfaces with inbound lanes:
	• BSM from both vehicles' OBUs
	• Warning from the host and remote vehicle OBUs to HMI
	• Warning from HMI to Drivers
	System Operation:
	• Remote and host vehicles both have functioning OBUs
	• IMA app is installed on OBUs
	• Remote and Host vehicle sends out BSMs
	• OBU of both vehicles:
	  ○ Receives BSM from another vehicle's OBU
	  ○ Identifies trajectory
	  ○ Determines if on a collision course
	  ○ Warns drivers of an imminent collision
	Verify that:
	• Vehicles sending, receiving and processing BSMs
	• IMA safety application issues a warning to the driver

Test Inputs	Varying: Distance of remote vehicle from the host vehicle
Resources Needed	OBU equipped host and remote vehicles, two drivers, communicating
Execution Conditions	Closed road section, host and remote vehicle sending and receiving BSMs while driving from perpendicular directions towards an intersection
Requirements Verified	THEA-UC2-001: Vehicles receive BSMs from other vehicles THEA-UC2-003: IMA identifies crash trajectories THEA-UC2-003a: IMA issues driver warnings

Initial Conditions	Safety Management Test Conduct: • Closed roadway in private parking lot • Safety cones and safety vests for test facilitators • Use of stakeholder vehicles • Conducted by stakeholder participants • Applications tuned to match Phase 3 study configuration
Illustration	

2.2.3.2.3 SPaT-MAP Test Cases

Test Case UC2 SPaT-MAP

Table 30: Test Case UC2 SPaT-MAP

Initial Conditions	Safety Management Test Conduct: • Public roadway in live traffic at a signalized intersection • QM including Malfunction Management Unit (MMU) and responses • Use of stakeholder vehicles • Conducted by stakeholder participants • Applications tuned to match Phase 3 study configuration
Objectives	Test the following interfaces: • SPaT from RSU to OBU • MAP from RSU to OBU

Initial Conditions	Safety Management Test Conduct: • Public roadway in live traffic at a signalized intersection • QM including Malfunction Management Unit (MMU) and responses • Use of stakeholder vehicles • Conducted by stakeholder participants • Applications tuned to match Phase 3 study configuration
	• REL Gate status from gate controller to CU System Operation: • CU sends V2I Hub “Traffic Controller Broadcast Message” to RSU • TMC operator controls the REL entrance ramp gate • REL entrance ramp gate status is mapped to CU detector input • RSU receives CU detector input status representing gate status • RSU adds gate status and “Traffic Controller Broadcast Message” information to SPaT data • RSU broadcasts SPaT message to OBUs • RSU broadcasts MAP message to OBUs showing reversible lanes as revocable • OBU determines lane direction and closures using MAP and SPaT Verify that: • SPaT message is successfully decoded by COTS test equipment • SPaT message is successfully converted to XML • MAP message is successfully decoded by COTS test equipment • MAP message is successfully converted to XML • Lanes on the REL are flagged as revocable per MAP • Lane status in WWE application is correct • Enabled LaneIDs correspond to inbound traffic pattern lanes when gates are closed; Enabled lanes are: 8 – 14 • Enabled LaneIDs correspond to outbound traffic pattern lanes when gates are open; Enabled lanes are: 15 – 21
Test Inputs	1. Traffic controller sends SPaT data to RSU 2. RSU has intersection MAP configured 3. Traffic controller provides gate status as detector status via NTCIP 1202v2
Resources Needed	1. RSU installed at Twiggs/Meridian communicating 2. 3M Tester
Execution Conditions	1. Normal operation of the intersection 2. Execute test case once for gate closed and open gate status

Initial Conditions	Safety Management Test Conduct: • Public roadway in live traffic at a signalized intersection • QM including Malfunction Management Unit (MMU) and responses • Use of stakeholder vehicles • Conducted by stakeholder participants • Applications tuned to match Phase 3 study configuration
Requirements Verified	THEA-UC2-007: RSU transmits SPaT per the current version THEA-UC2-008: RSU transmits REL entrance lane geometry THEA-UC2-008b: MAP message identifies revocable lanes THEA-UC2-008c: SPaT contains the status of revocable lanes matching gates THEA-UC2-008d: WWE app receives gate status

2.2.3.2.4 WWE Operational Test Cases

Test Case UC2 WWE_Warning

Table 31: Test Case UC2 WWE_Warning

Initial Conditions	Safety Management Test Conduct: • Closed roadway with law enforcement present • Use of stakeholder vehicles • Conducted by stakeholder participants • Applications tuned to match Phase 3 study configuration
Objectives	Test the following interfaces: System Operation: • Vehicle detector senses all vehicles traveling the wrong way towards the REL • Vehicle detector sends wrong way detection to CU • CU asserts a detector when the wrong way is received • RSU gets wrong way detector status from CU • RSU sends wrong way TIM to OBUs Verify that: • Detector CALL is correctly associated with a wrong-way vehicle • WWE app status on RSU browser user interface (UI) shows an active wrong-way entry warning • WWE TIM content matches WWE TIM Configuration • WWE TIM is logged by COTS test equipment • TIM is no longer received COTS test equipment after configurable time elapses
Test Inputs	1. Wrong-way vehicle detection at Twiggs/Meridian intersection

Initial Conditions	Safety Management Test Conduct: • Closed roadway with law enforcement present • Use of stakeholder vehicles • Conducted by stakeholder participants • Applications tuned to match Phase 3 study configuration
	2. WWE RSU app configured to broadcast TIM defined
Resources Needed	1. RSU at Twiggs/Meridian, communicating 2. 3M Tester
Execution Conditions	REL Closed Trigger emulated detector input for wrong-way detection on traffic controller from the front panel
Requirements Verified	THEA-UC2-014: Vehicle detector CALL THEA-UC2-015: WWE creates driver warning for vehicle detector CALL THEA-UC2-018a: WWE alert received by Master Server THEA-UC2-018b: WWE alert stored by Master Server THEA-UC2-020: WWE alert from Master Server displayed in Concert

2.2.4 UC3 Pedestrian Conflicts/Safety

2.2.4.1 UC3 Pedestrian Conflicts/Safety Test Plan

The UC3 test plan approach includes the following two Connected Vehicle applications.

- PED-X
- Pedestrian Collision Warning (PCW)

The purpose of the test is to ensure that the implementation of the two applications fulfill the requirement of UC3.

2.2.4.2 UC3 Pedestrian Conflicts/Safety Test Cases

2.2.4.2.1 PED-X Test Cases

PED-X Description: Calculates the path trajectory of the pedestrian and approaching vehicles and logs an event if a potential conflict is identified

Test Case UC3 PED-X

Table 32: Test Case UC3 PED-X

Initial Conditions	Safety Management Test Conduct:
	• Public roadway in live traffic
	• QM including
	  o Unsignalized midblock pedestrian crosswalk
	  o R1-5 unsignalized pedestrian crosswalk sign
	  o Flashing yellow caution
	• Conducted by stakeholder participant drivers
	• Conducted using mock pedestrians
	• Applications tuned to match Phase 3 study configuration

Objectives	Test the following interfaces: • PID to RSU • OBU to RSU • RSU to Master Server System Operation: • Vehicle OBU continually sends BSMs to RSU via DSRC • RSU forwards vehicle BSMs to PID via Wi-Fi • PID predicts crashes based on PID location service • PID sends crash alerts to Master Server Verify that: • Master Server logs PSMs from PID1 carried by pedestrian 1 • PID1 crash alert is logged by the Master Server • Master Server logs PSMs from PID2 carried by pedestrian 2 • PID2 crash alert is logged by the Master Server
Test Inputs	1. Vehicle locations and movements per Figure 17 2. Mock pedestrians equipped with PIDs located per Figure 17
Resources Needed	1. Vehicle equipped with OBU communicating 2. Driver for vehicle 3. PCW V app installed in OBU 4. RSU installed at roadside communicating 5. LiDAR installed at each end of the crosswalk 6. PCW I app installed in RSU 7. Mock pedestrian holder for PID 8. PID 9. PCW P app installed in PID

<table>
<tr><td>Initial Conditions</td><td>Safety Management Test Conduct:
Public roadway in live traffic
QM including
Unsignalized midblock pedestrian crosswalk
R1-5 unsignalized pedestrian crosswalk sign
Flashing yellow caution
Conducted by stakeholder participant drivers
Conducted using mock pedestrians
Applications tuned to match Phase 3 study configuration</td></tr>
<tr><td>Execution Conditions</td><td>Closed section of Twiggs in front of the courthouse
LiDAR sending PSMs to RSU via Ethernet
PID sending PSMs to RSU via Wi-Fi
RSU sending LiDAR PSMs to vehicle OBU via DSRC
RSU sending LiDAR and PID BSMs to Master Server via backhaul
PID calculating crash trajectories with vehicle
PID sending crash alerts to Master Server via RSU backhaul</td></tr>
<tr><td>Requirements Verified</td><td>THEA-UC3-001: OBU receives PSMs
THEA-UC3-002: OBU determines potential conflict with pedestrian
THEA-UC3-003: OBU warns the driver of potential conflict
THEA-UC3-008: PID transmits PSM to RSU
THEA-UC3-009: RSU stores PID PSMs
THEA-UC3-011: RSU sends PSMs to Master Server
THEA-UC3-012: RSU receives vehicle BSMs
THEA-UC3-015: RSU sends vehicle BSMs over Wi-Fi to PID
THEA-UC3-016: PID receives BSMs
THEA-UC3-016a: PID calculates crash warning using PID location
THEA-UC3-016b: Crash warnings are sent to RSU via Wi-Fi</td></tr>
</table>

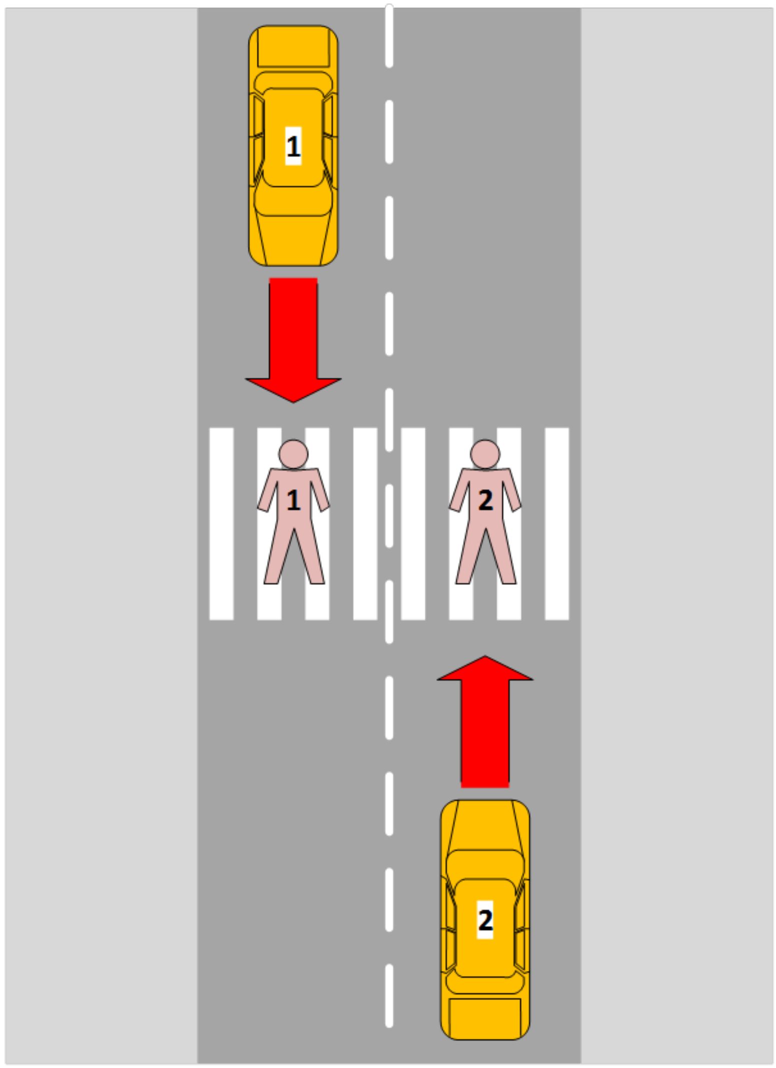


Figure 17: PED-X Test Inputs
Source: Siemens

2.2.4.2.2 PCW Test Cases

PCW Description: Alerts vehicle to the presence of a pedestrian in a crosswalk

Test Case UC3 PCW_A

Table 33: Test Case UC3 PCW_A

Initial Conditions	Safety Management Test Conduct:
	• Public roadway in live traffic
	• QM including
	  ○ Unsignalized midblock pedestrian crosswalk
	  ○ R1-5 unsignalized pedestrian crosswalk sign
	  ○ Flashing yellow caution
	• Conducted by stakeholder participant drivers
	• Conducted using mock pedestrians
	• Applications tuned to match Phase 3 study configuration

Objectives	Test the following interfaces when a pedestrian is on the curb: • PID to RSU • OBU to RSU • RSU to Master Server System Operation: • LiDAR continuously sends PSM representing PED 3 to RSU via Ethernet • LiDAR continuously sends PSM representing PED 4 to RSU via Ethernet • RSU sends PSM representing PED 3 to OBU via DSRC • RSU sends PSMs representing PED 4 to OBU via DSRC • OBU predicts crash alerts with PEDs • OBU warns the driver of potential PED crashes via HMI Verify that: • No PCW driver alert from OBU when PED 3 is on the curb • No PCW driver alert from OBU when PED 4 is on the curb
Test Inputs	1. Vehicle locations and movements per Figure 18 2. Mock pedestrians equipped with PIDs located per Figure 18
Resources Needed	1. Vehicle equipped with OBU, communicating 2. Driver for vehicle 3. PCW V app installed in OBU 4. RSU installed at roadside communicating 5. LiDAR installed at each end of the crosswalk 6. PCW I app installed in RSU 7. Mock pedestrian holder for PID 8. PID 9. PCW P app installed in PID
Execution Conditions	1. Closed section of Twiggs in front of the courthouse 2. LiDAR sending PSMs to RSU via Ethernet 3. PID sending PSMs to RSU via Wi-Fi 4. RSU sending LiDAR PSMs to vehicle OBU via DSRC 5. RSU sending LiDAR and PID BSMs to Master Server via backhaul

<table>
<tr><td>Initial Conditions</td><td>Safety Management Test Conduct:
Public roadway in live traffic
QM including
Unsignalized midblock pedestrian crosswalk
R1-5 unsignalized pedestrian crosswalk sign
Flashing yellow caution
Conducted by stakeholder participant drivers
Conducted using mock pedestrians
Applications tuned to match Phase 3 study configuration</td></tr>
<tr><td></td><td>6. PID calculating crash trajectories with vehicle
7. PID sending crash alerts to Master Server via backhaul</td></tr>
<tr><td>Requirements Verified</td><td>THEA-UC3-001: OBU receives PSMs
THEA-UC3-002: OBU determines potential conflict with pedestrian
THEA-UC3-003: OBU warns the driver of potential conflict
THEA-UC3-008: PID transmits PSM to RSU
THEA-UC3-009: RSU stores PID PSMs
THEA-UC3-011: RSU sends PSMs to Master Server
THEA-UC3-012: RSU receives vehicle BSMs
THEA-UC3-015: RSU sends vehicle BSMs over Wi-Fi to PID
THEA-UC3-016: PID receives BSMs
THEA-UC3-016a: PID calculates crash warning using PID location
THEA-UC3-016b: Crash warnings are sent to RSU for study</td></tr>
</table>

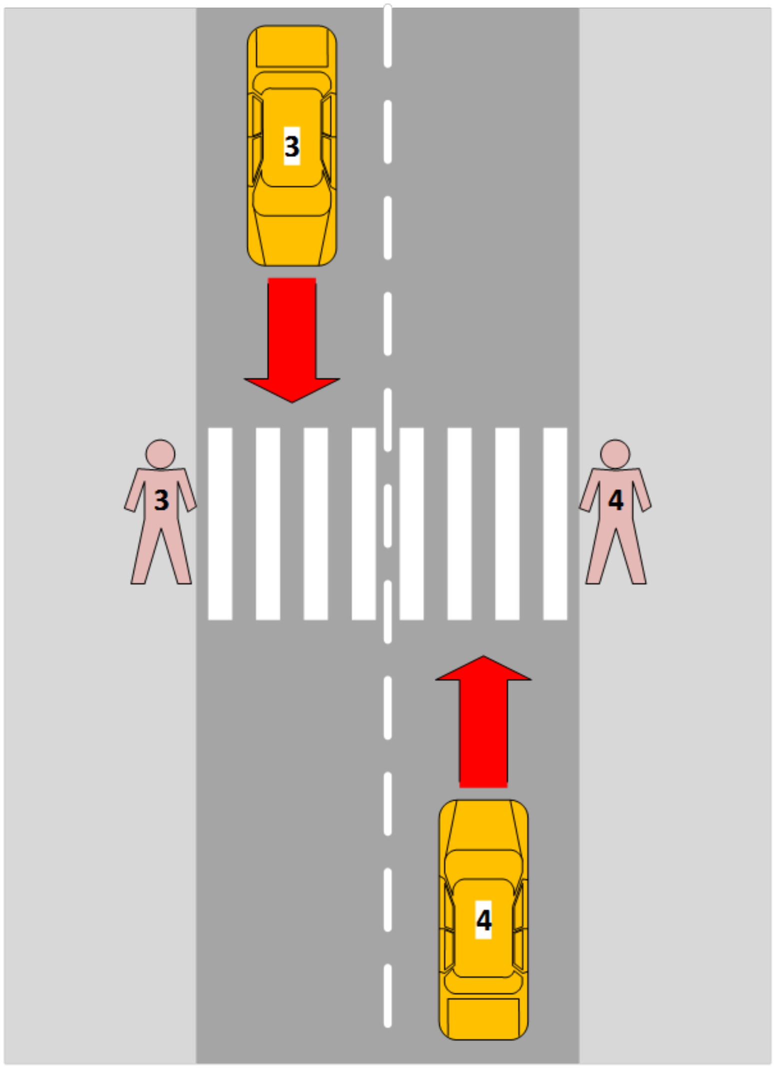


Figure 18: Boundary Condition 1, PED Near Crosswalk
Source: Siemens

Test Case UC3 PCW_B

Table 34: Test Case UC3 PCW_B

Initial Conditions	Safety Management Test Conduct:
	• Public roadway in live traffic
	• QM including
	  o Unsignalized midblock pedestrian crosswalk
	  o R1-5 unsignalized pedestrian crosswalk sign
	  o Flashing yellow caution
	• Conducted by stakeholder participant drivers
	• Conducted using mock pedestrians
	• Applications tuned to match Phase 3 study configuration

Objectives	Test the following interfaces when the pedestrian in the crosswalk near curb: • PID to RSU • OBU to RSU • RSU to Master Server System Operation: • LiDAR continuously sends PSM representing PED 3 to RSU via Ethernet • LiDAR continuously sends PSM representing PED 4 to RSU via Ethernet • RSU sends PSM representing PED 3 to OBU via DSRC • RSU sends PSMs representing PED 4 to OBU via DSRC • OBU predicts crash alerts with PEDs • OBU warns the driver of potential PED crashes via HMI Verify that: • PCW driver alert from OBU when PED 5 is on the curb • PCW driver alert from OBU when PED 6 is on the curb
Test Inputs	1. Vehicle locations and movements per Figure 19 2. Mock pedestrians equipped with PIDs located per Figure 19
Resources Needed	1. Vehicle equipped with OBU communicating 2. Driver for vehicle 3. PCW V app installed in OBU 4. RSU installed at roadside communicating 5. LiDAR installed at each end of the crosswalk 6. PCW I app installed in RSU 7. Mock pedestrian holder for PID 8. PID 9. PCW P app installed in PID
Execution Conditions	1. Closed section of Twiggs in front of the courthouse 2. LiDAR sending PSMs to RSU via Ethernet 3. PID sending PSMs to RSU via Wi-Fi 4. RSU sending LiDAR PSMs to vehicle OBU via DSRC 5. RSU sending LiDAR and PID BSMs to Master Server via backhaul 6. PID calculating crash trajectories with vehicle 7. PID sending crash alerts to Master Server via backhaul

Initial Conditions	Safety Management Test Conduct:
	• Public roadway in live traffic
	• QM including
	    o Unsignalized midblock pedestrian crosswalk
	    o R1-5 unsignalized pedestrian crosswalk sign
	    o Flashing yellow caution
	• Conducted by stakeholder participant drivers
	• Conducted using mock pedestrians
	• Applications tuned to match Phase 3 study configuration

Requirements Verified	THEA-UC3-001: OBU receives PSMs THEA-UC3-002: OBU determines potential conflict with pedestrian THEA-UC3-003: OBU warns the driver of potential conflict THEA-UC3-008: PID transmits PSM to RSU THEA-UC3-009: RSU stores PID PSMs THEA-UC3-011: RSU sends PSMs to Master Server THEA-UC3-012: RSU receives vehicle BSMs THEA-UC3-015: RSU sends vehicle BSMs over Wi-Fi to PID THEA-UC3-016: PID receives BSMs THEA-UC3-016a: PID calculates crash warning using PID location THEA-UC3-016b: Crash warnings are sent to RSU

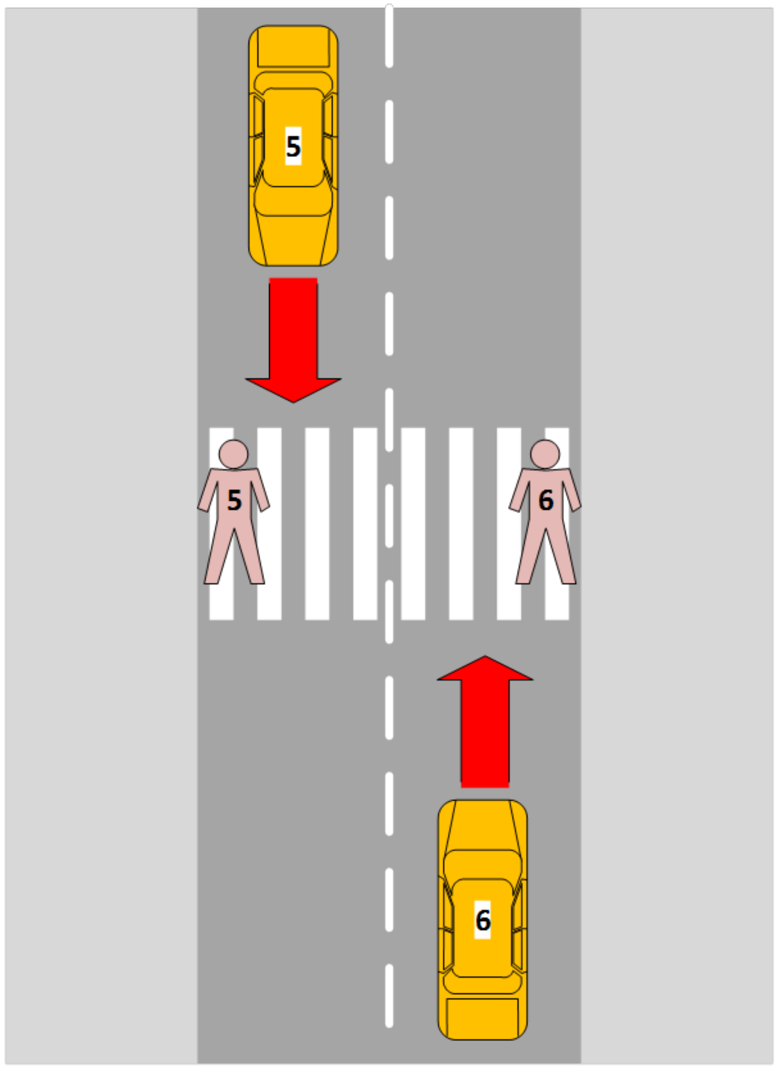


Figure 19: Boundary Condition 2, PED in Crosswalk Near Curb
Source: Siemens

Test Case UC3 PCW_C

Table 35: Test Case UC3 PCW_C

Initial Conditions	Safety Management Test Conduct:
	• Public roadway in live traffic
	• QM including
	  o Unsignalized midblock pedestrian crosswalk
	  o R1-5 unsignalized pedestrian crosswalk sign
	  o Flashing yellow caution
	• Conducted by stakeholder participant drivers
	• Conducted using mock pedestrians
	• Applications tuned to match Phase 3 study configuration

Objectives	Test the following interfaces when the pedestrian is walking towards the crosswalk before entering the crosswalk. • PID to RSU • OBU to RSU • RSU to Master Server System Operation: • LiDAR continuously sends PSM representing PED 3 to RSU via Ethernet • LiDAR continuously sends PSM representing PED 4 to RSU via Ethernet • RSU sends PSM representing PED 3 to OBU via DSRC • RSU sends PSMs representing PED 4 to OBU via DSRC • OBU predicts crash alerts with PEDs • OBU warns the driver of potential PED crashes via HMI Verify that: • PCW driver alert from OBU when PED 7 and vehicle are predicted to crash. • No PCW driver alert is sent from OBU when PED 7 and vehicle are not predicted to crash.
Test Inputs	1. Vehicle locations and movements per Figure 20, Figure 19 2. Mock pedestrians equipped with PIDs located per Figure 20
Resources Needed	1. A vehicle equipped with OBU communicating 2. Driver for vehicle 3. PCW V app installed in OBU 4. RSU installed at roadside communicating 5. LiDAR installed at each end of the crosswalk 6. PCW I app installed in RSU 7. Mock pedestrian holder for PID 8. PID 9. PCW P app installed in PID

Initial Conditions	Safety Management Test Conduct:
	• Public roadway in live traffic
	• QM including
	    o Unsignalized midblock pedestrian crosswalk
	    o R1-5 unsignalized pedestrian crosswalk sign
	    o Flashing yellow caution
	• Conducted by stakeholder participant drivers
	• Conducted using mock pedestrians
	• Applications tuned to match Phase 3 study configuration

Execution Conditions	1. Closed section of Twiggs in front of the courthouse 2. LiDAR sending PSMs to RSU via Ethernet 3. PID sending PSMs to RSU via Wi-Fi 4. RSU sending LiDAR PSMs to vehicle OBU via DSRC 5. RSU sending LiDAR and PID BSMs to Master Server via backhaul 6. PID calculating crash trajectories with vehicle 7. PID sending crash alerts to Master Server via backhaul
Requirements Verified	THEA-UC3-001: OBU receives PSMs THEA-UC3-002: OBU determines potential conflict with pedestrian THEA-UC3-003: OBU warns the driver of potential conflict THEA-UC3-008: PID transmits PSM to RSU THEA-UC3-009: RSU stores PID PSMs THEA-UC3-011: RSU sends PSMs to Master Server THEA-UC3-012: RSU receives vehicle BSMs THEA-UC3-015: RSU sends vehicle BSMs over Wi-Fi to PID THEA-UC3-016: PID receives BSMs THEA-UC3-016a: PID calculates crash warning using PID location THEA-UC3-016b: Crash warnings are sent to RSU

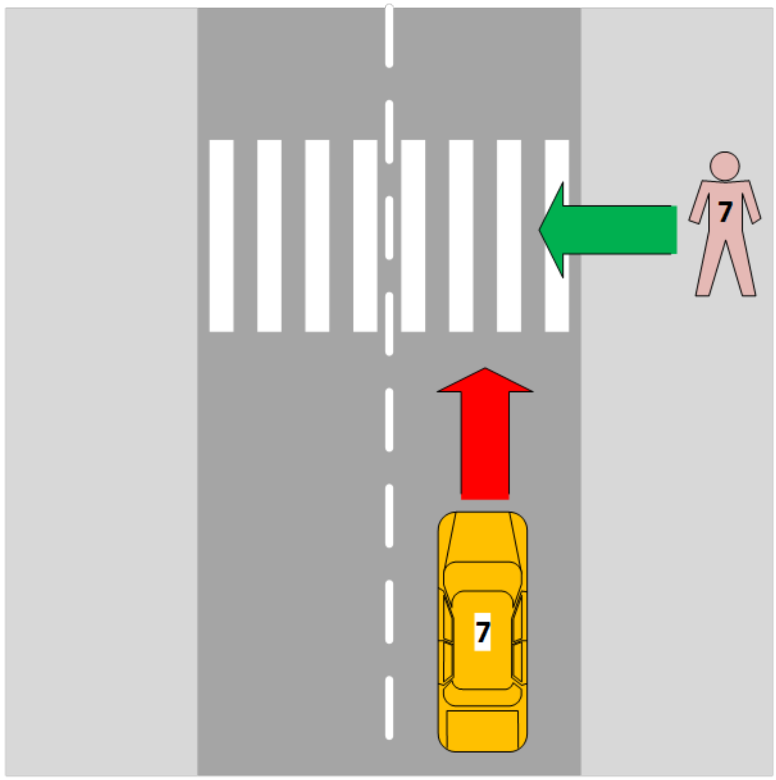


Figure 20: Ped in Crosswalk on Collision Course
Source: Siemens

Test Case UC3 PCW_D

Table 36: Test Case UC3 PCW_D

Initial Conditions	Safety Management Test Conduct:
	• Public roadway in live traffic
	• QM including
	  o Unsignalized midblock pedestrian crosswalk
	  o R1-5 unsignalized pedestrian crosswalk sign
	  o Flashing yellow caution
	• Conducted by stakeholder participant drivers
	• Conducted using mock pedestrians
	• Applications tuned to match Phase 3 study configuration

Objectives:	Test the following interfaces when the pedestrian is walking in the crosswalk • PID to RSU • OBU to RSU • RSU to Master Server System Operation: • LiDAR continuously sends PSM representing PED 3 to RSU via Ethernet • LiDAR continuously sends PSM representing PED 4 to RSU via Ethernet • RSU sends PSM representing PED 3 to OBU via DSRC • RSU sends PSMs representing PED 4 to OBU via DSRC • OBU predicts crash alerts with PEDs • OBU warns the driver of potential PED crashes via HMI Verify that: • PCW driver alert from OBU when PED 8 and vehicle are predicted to crash. • No PCW driver alert from OBU when PED 8 is predicted to clear the crosswalk before the vehicle arrives.
Test Inputs	1. Vehicle locations and movements per Figure 21 2. Mock pedestrians equipped with PIDs located per Figure 21
Resources Needed	1. A vehicle equipped with OBU communicating 2. Driver for vehicle 3. PCW V app installed in OBU 4. RSU installed at roadside communicating 5. LiDAR installed at each end of the crosswalk 6. PCW I app installed in RSU 7. Mock pedestrian holder for PID 8. PID 9. PCW P app installed in PID

<table>
<tr><td>Initial Conditions</td><td>Safety Management Test Conduct:
Public roadway in live traffic
QM including
Unsignalized midblock pedestrian crosswalk
R1-5 unsignalized pedestrian crosswalk sign
Flashing yellow caution
Conducted by stakeholder participant drivers
Conducted using mock pedestrians
Applications tuned to match Phase 3 study configuration</td></tr>
<tr><td>Execution Conditions</td><td>Closed section of Twiggs in front of the courthouse
LiDAR sending PSMs to RSU via Ethernet
PID sending PSMs to RSU via Wi-Fi
RSU sending LiDAR PSMs to vehicle OBU via DSRC
RSU sending LiDAR and PID BSMs to Master Server via backhaul
PID calculating crash trajectories with vehicle
PID sending crash alerts to Master Server via backhaul</td></tr>
<tr><td>Requirements Verified</td><td>THEA-UC3-001: OBU receives PSMs
THEA-UC3-002: OBU determines potential conflict with pedestrian
THEA-UC3-003: OBU warns the driver of potential conflict
THEA-UC3-008: PID transmits PSM to RSU
THEA-UC3-009: RSU stores PID PSMs
THEA-UC3-011: RSU sends PSMs to Master Server
THEA-UC3-012: RSU receives vehicle BSMs
THEA-UC3-015: RSU sends vehicle BSMs over Wi-Fi to PID
THEA-UC3-016: PID receives BSMs
THEA-UC3-016a: PID calculates crash warning using PID location
THEA-UC3-016b: Crash warnings are sent to RSU</td></tr>
</table>

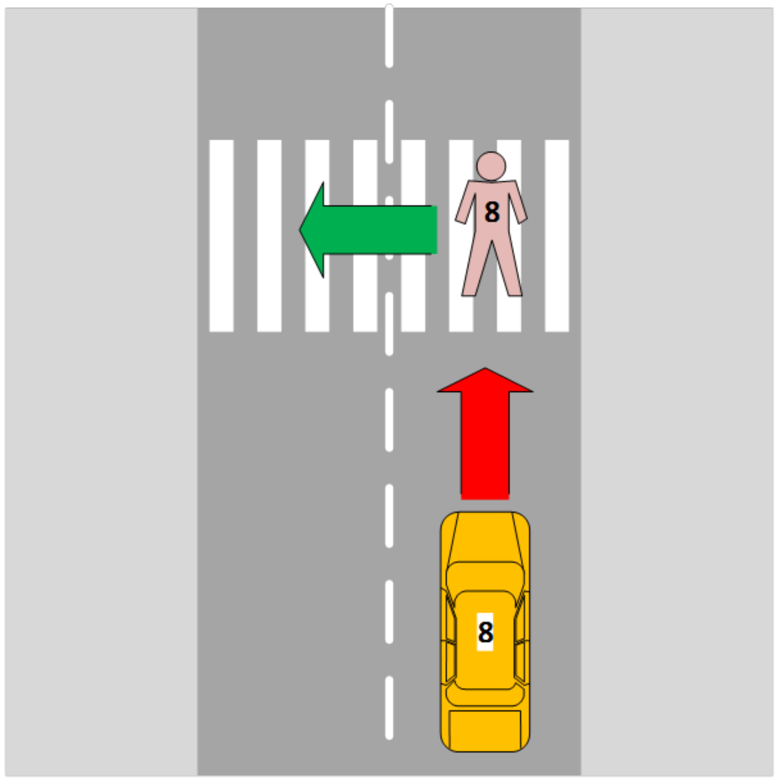


Figure 21: Ped in Crosswalk But Clearing It
Source: Siemens

2.2.5 UC4 Transit Signal Priority

2.2.5.1 UC4 Transit Signal Priority Test Plan

The UC4 test plan approach includes the following Connected Vehicle applications:

- Transit Signal Priority (TSP)
- PTMW

The purpose of the test is to ensure that the implementation of the applications fulfills the requirement of UC4.

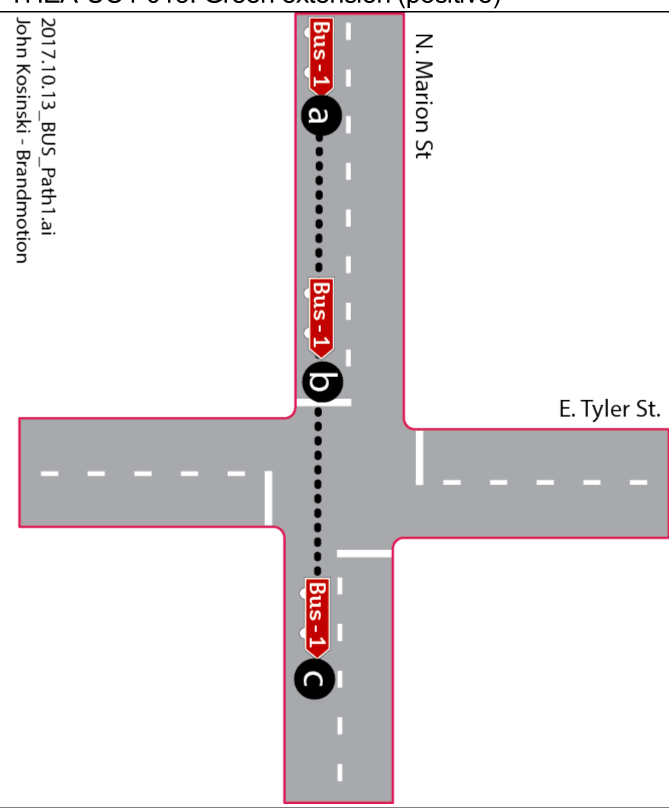
2.2.5.2 UC4 Transit Signal Priority Test Cases

2.2.5.2.1 TSP Test Cases

Test Case UC4 TSP_A

Table 37: Test Case UC4 TSP_A

Initial Conditions	Safety Management Test Conduct: • Public roadway in live traffic at a signalized intersection • QM including Malfunction Management Unit (MMU) and responses • Use of stakeholder vehicles • Conducted by stakeholder participants • Applications tuned to match Phase 3 study configuration
Objectives	Test the following interfaces with bus approach early in the GREEN phase: • SRM from OBU to RSU • SRM from RSU to Transit Central • SRM from Transit Central to RSU • NTCIP SET from RSU to CU • NTCIP GET from CU to RSU • SSM from RSU to OBU • Priority status from OBU to HMI • Priority status from HMI to Driver System Operation: • Bus OBU transmits SRM when approaching TSP intersection • RSU forwards SRM to transit central • Transit central returns SRM to RSU if a bus is behind schedule • RSU responds to SRM by NTCIP SET for priority to CU • RSU GETs signal phase from CU • RSU sends SSM to bus OBU based on signal phase • OBU sends priority status to HMI based on SSM Verify that: • Bus positioned ahead of a signal at the beginning of GREEN phase: o DARK bus HMI with nothing displayed o OBU broadcasts SRM verified by COTS test instrumentation indicates no priority granted • Bus remains positioned ahead of signal in GREEN phase: o HMI displays PRIORITY o SSM from RSU indicates PRIORITY for that approach phase, verified by COTS test instrumentation • Bus approaches the stop bar: o Controller input screen shows phase call and/or hold applied to Phase 2 o GREEN is extended beyond the programmed time

	• The bus travels south beyond intersection: ○ DARK bus HMI with nothing displayed
Test Inputs	Transit vehicle approaching the intersection late in the green phase for the approach
Resources Needed	1. Vehicle equipped with bus OBU and driver HMI are communicating 2. RSU installed at Marion/Tyler communicating
Execution Conditions	1. The Master Server is configured to grant all priority service requests 2. Traffic controller minimum green time is configured to 10 seconds for the southbound phase on Marion Street (Phase 2), and controller applies Minimum Recalls to Phase 2 3. Added green time reduces schedule delay and flushes the queue ahead
Requirements Verified	THEA-UC4-001: Send SRM from OBU to RSU when bus matches approach THEA-UC4-002: RSU sends SRM to the transit center THEA-UC4-004: Grant permission to originating RSU if behind THEA-UC4-005: MMITSS receives priority from central THEA-UC4-007: TSP broadcasts SSM decision to grant THEA-UC4-008: Bus Receives SSM THEA-UC4-009: SSM is displayed as a bus driver notification THEA-UC4-013: Green extension (positive)
Illustration	

Test Case UC4 TSP_B

Table 38: Test Case UC4 TSP_B

<table>
<tr><td>Initial Conditions</td><td>Safety Management Test Conduct:

Public roadway in live traffic at a signalized intersection
QM including Malfunction Management Unit (MMU) and responses
Use of stakeholder vehicles
Conducted by stakeholder participants
Applications tuned to match Phase 3 study configuration
</td></tr>
<tr><td>Objectives</td><td>Test the following interfaces with bus approach late in the GREEN phase:

SRM from OBU to RSU
SRM from RSU to Transit Central
SRM from Transit Central to RSU
NTCIP SET from RSU to CU
NTCIP GET from CU to RSU
SSM from RSU to OBU
Priority status from OBU to HMI
Priority status from HMI to Driver

System Operation:

Bus OBU transmits SRM when approaching TSP intersection
RSU forwards SRM to transit central
Transit central returns SRM to RSU if the bus is behind schedule
RSU responds to SRM by NTCIP SET for priority to CU
RSU GETs signal phase from CU
RSU sends SSM to bus OBU based on signal phase
OBU sends priority status to HMI based on SSM

Verify that:

Bus positioned ahead of the signal at the beginning of GREEN phase:

DARK bus HMI with nothing displayed
OBU broadcasts SRM verified by COTS test instrumentation indicates no priority requested

Bus remains positioned ahead of signal in GREEN phase:

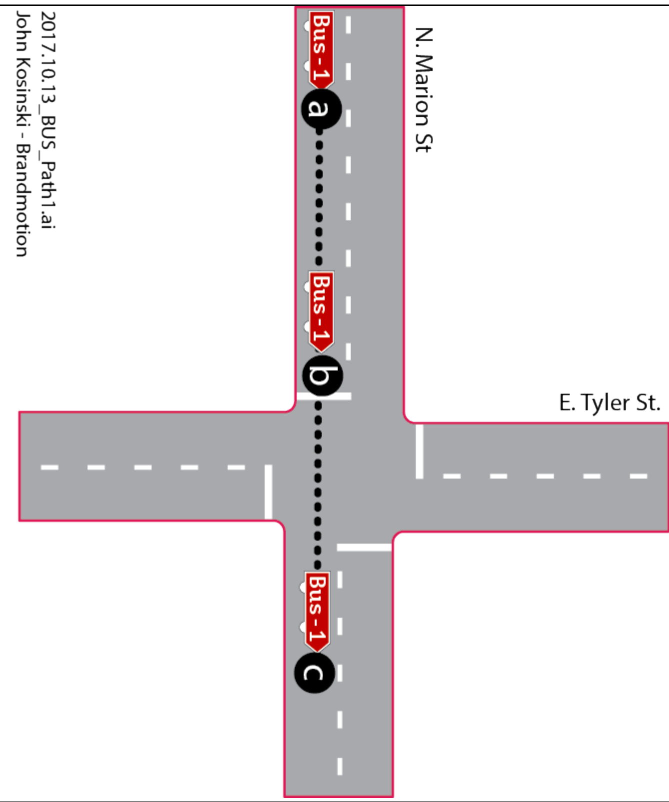
DARK HMI with nothing displayed
SSM from RSU indicates NO PRIORITY for that approach phase, verified by COTS test instrumentation

Bus approaching stop bar:

Controller input screen shows no phase call or holds applied to Phase 2.

</td></tr>
</table>

Initial Conditions	Safety Management Test Conduct: • Public roadway in live traffic at a signalized intersection • QM including Malfunction Management Unit (MMU) and responses • Use of stakeholder vehicles • Conducted by stakeholder participants • Applications tuned to match Phase 3 study configuration
	o CU front panel verifies termination of Phase 2 green after the minimum green time elapsed. • Bus stops at a red light: o Southbound signal turns yellow after 10 seconds of total green time o The southbound signal then turns red
Test Inputs	Transit vehicle approaching the intersection late in the green phase for the approach
Resources Needed	1. Vehicle equipped with bus OBU and driver HMI are communicating 2. RSU installed at Marion/Tyler communicating
Execution Conditions	1. The Master Server is configured to deny all priority service requests 2. Traffic controller minimum green time is configured to 10 seconds for the southbound phase on Marion Street (Phase 2), and controller applies Minimum Recalls to Phase 2
Requirements Verified	THEA-UC4-001: Send SRM to RSU when bus matches approach THEA-UC4-002: RSU sends SRM to the transit center THEA-UC4-004: Grant permission to originating RSU if behind THEA-UC4-005: MMITSS receives priority from central THEA-UC4-007: TSP broadcasts SSM decision to grant THEA-UC4-008: Bus Receives SSM THEA-UC4-009: SSM is displayed as a bus driver notification THEA-UC4-013: Green extension (negative test case)

Initial Conditions	Safety Management Test Conduct: • Public roadway in live traffic at a signalized intersection • QM including Malfunction Management Unit (MMU) and responses • Use of stakeholder vehicles • Conducted by stakeholder participants • Applications tuned to match Phase 3 study configuration
Illustration	

Test Case UC4 TSP_C

Table 39: Test Case UC4 TSP_C

Initial Conditions	Safety Management Test Conduct: • Public roadway in live traffic at a signalized intersection • QM including Malfunction Management Unit (MMU) and responses • Use of stakeholder vehicles • Conducted by stakeholder participants • Applications tuned to match Phase 3 study configuration
Objectives	Test the overall adherence of the bus to the bus schedule System Operation: • Bus OBU transmits SRM when approaching TSP intersection

Initial Conditions	Safety Management Test Conduct: • Public roadway in live traffic at a signalized intersection • QM including Malfunction Management Unit (MMU) and responses • Use of stakeholder vehicles • Conducted by stakeholder participants • Applications tuned to match Phase 3 study configuration
	• RSU forwards SRM to transit central • Transit central returns SRM to RSU if the bus is behind schedule • RSU responds to SRM by NTCIP SET for priority to CU • RSU GETs signal phase from CU • RSU sends SSM to bus OBU based on signal phase • OBU sends priority status to HMI based on SSM Verify that: • The schedule deviation value for each bus compared with NextConnect internal data displayed in NextConnect Explorer is recorded as a performance measurement. • Displayed schedule adherence status and content of schedule deviation match. • Internal data in NextConnect matches the updated values.
Test Inputs	Check current bus schedule adherence during the morning peak and during noontime
Resources Needed	NextConnect Explorer UI tool for inspection of NextConnect internal data
Execution Conditions	NextConnect TSP is running at the master server and properly configured to connect to the OneBusAway server
Requirements Verified	THEA-UC4-003: Central compares Vehicle Identification Number (VIN), route, run, loc, time to schedule

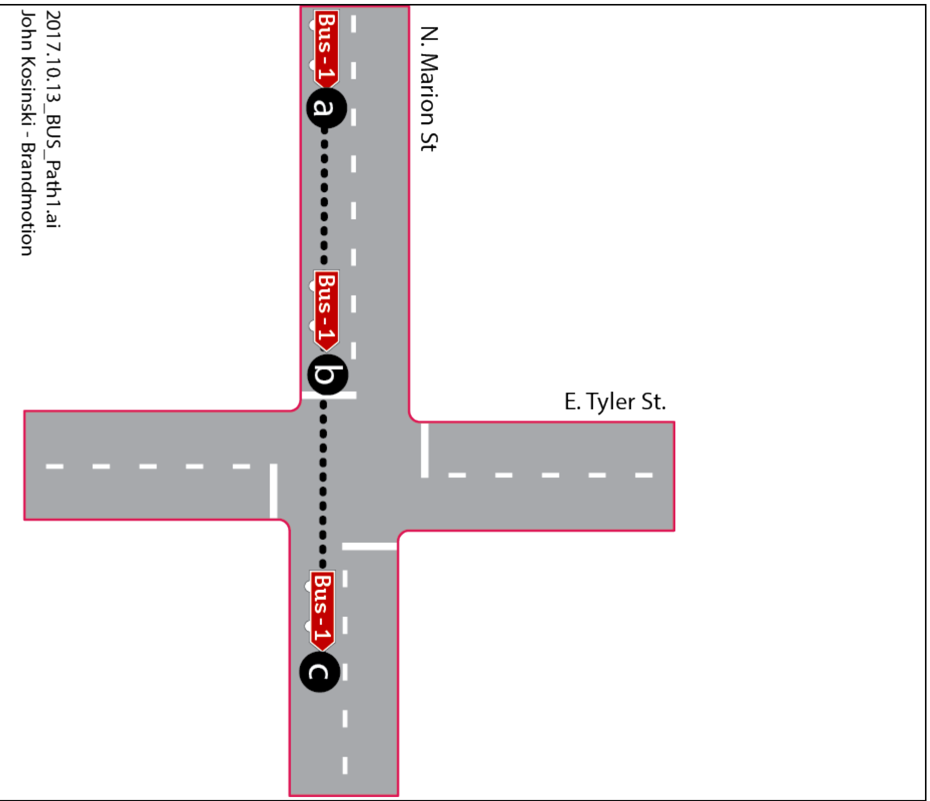
2.2.5.2.2 PTMW Test Cases

Test Case UC4 PTMW

Table 40: Test Case UC4 PTMW

Initial Conditions	Safety Management Test Conduct: • Public roadway in live traffic at bus stops • Use of stakeholder vehicles • Use of stakeholder PIDs • Conducted by stakeholder participants • Applications tuned to match Phase 3 study configuration

Objectives	Test the PID warning issued when the bus approaches and when the bus is starting up, but not when the bus is stopped in the bus stop System Operation: • Bus constantly issues BSMs via DSRC indicating bus location direction and speed • RSU translates the bus BSMs from DSRC to Wi-Fi • PID receives bus BSMs via Wi-Fi • PID determines whether the pedestrian is located within the configurable geo-fenced area ahead of the bus • If within the geofenced area, the PID further determines whether the bus is moving, based on successive bus BSMs • If within the geofenced area, and the bus is moving, the PID issues a warning to the pedestrian • If not within the area, or if the bus is stopped, the PID does not issue a warning Verify that: • PID issues a warning to pedestrians in a configurable area ahead of the approaching bus • PID does not issue warnings when the bus occupies the bus stop • PID issues a warning to pedestrians in a configurable area ahead of the departing bus
Test Inputs	Vehicle movement as shown in the illustration
Resources Needed	1. A bus equipped with OBU communicating 2. Bus driver
Execution Conditions	Bus approach, stopped and departed
Requirements Verified	THEA-UC5-011: Pedestrian app on PID alerts pedestrian of stopping bus THEA-UC5-012: Pedestrian app on PID alerts pedestrian of starting bus

Illustration	

2.2.6 UC5 Street Conflicts

2.2.6.1 UC5 Street Conflicts Test Plan

The UC5 test plan approach includes the following two Connected Vehicle applications:

- Vehicle Turning Right in Front of a Transit Vehicle (VTRFTV)
- PTMW

The purpose of the test is to ensure that the implementation of the two applications fulfills the requirement of UC5.

2.2.6.2 UC5 Street Conflicts Test Cases

2.2.6.2.1 VTRFTV Test Cases

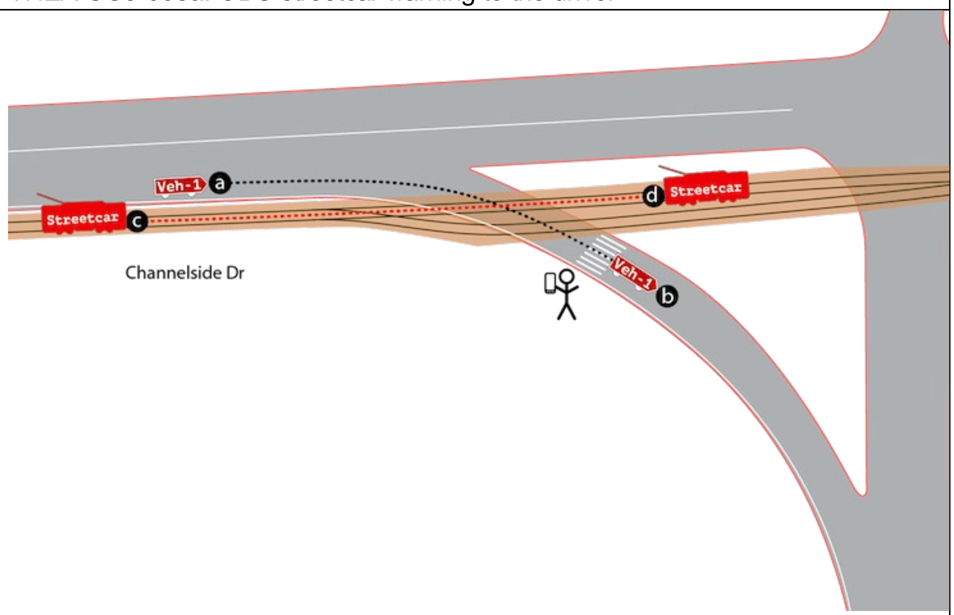
Test Case UC5 VTRFTV_A

Table 41: Test Case UC5 VTRFTV_A

Initial Conditions	Safety Management Test Conduct: • Public streetcar grade crossing • Safety cones and safety vests for test facilitators • Use of stakeholder streetcars • Use of stakeholder vehicles • Conducted by stakeholder participants • Applications tuned to match Phase 3 study configuration

Objectives	Test the following interfaces with inbound lanes:
	• BSM from vehicle OBU to Streetcar OBU
	• BSM from streetcar OBU to vehicle OBU
	• Warning from OBU to HMI
	• Warning from HMI to Driver
	System Operation:
	• Streetcar and vehicle both have functioning OBUs
	• VTRFTV app is installed on OBUs
	• Vehicle driver using a turn signal
	• Streetcar and vehicle send out BSMs
	• OBU of Streetcar:
	    o Receives BSM from vehicle OBU
	    o Identifies trajectory
	    o Determines if on a collision course
	    o Warns streetcar operator of an imminent collision
	• OBU of vehicle:
	    o Receives BSM from streetcar OBU
	    o Identifies trajectory
	    o Determines if on a collision course
	    o Warns driver of an imminent collision
	Verify that:
	• Streetcar and vehicle sending, receiving, and processing BSMs
	• VTRFTV safety application issues a warning to driver and streetcar operator

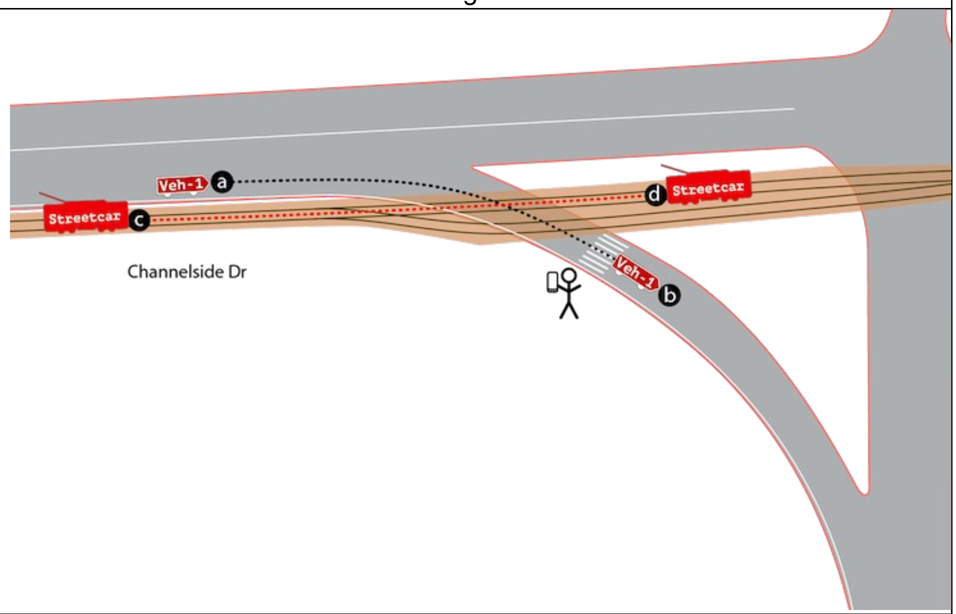
Test Inputs	Streetcar movement as shown in the illustration Vehicle movement as shown in the illustration
Resources Needed	1. Streetcar equipped with OBU communicating 2. Streetcar driver 3. A vehicle equipped with OBU communicating

Initial Conditions	Safety Management Test Conduct: • Public streetcar grade crossing • Safety cones and safety vests for test facilitators • Use of stakeholder streetcars • Use of stakeholder vehicles • Conducted by stakeholder participants • Applications tuned to match Phase 3 study configuration
	4. Vehicle driver
Execution Conditions	Closed streetcar grade crossing Streetcar approached, stopped, and departed Vehicle movement beside and turn in front of the streetcar
Requirements Verified	THEA-UC5-007: Streetcar OBUs determine potential conflict THEA-UC5-007a: Vehicle OBUs determine potential conflict THEA-UC5-008: OBU warning to streetcar operator THEA-UC5-008a: OBU streetcar warning to the driver
Illustration	

Test Case UC5 VTRFTV_B

Table 42: Test Case UC5 VTRFTV_B

Initial Conditions	Safety Management Test Conduct: • Public streetcar grade crossing • Safety cones and safety vests for test facilitators • Use of stakeholder streetcars • Use of stakeholder vehicles • Conducted by stakeholder participants • Applications tuned to match Phase 3 study configuration
Objectives	Test the following interfaces with inbound lanes: • BSM from vehicle OBU to Streetcar OBU • BSM from streetcar OBU to vehicle OBU System Operation: • Streetcar and vehicle both have functioning OBUs communicating • VTRFTV app is installed on OBUs • Streetcar and vehicle send out BSMs • OBU of Streetcar: o Receives BSM from vehicle OBU o Identifies trajectory o Determines if on a collision course • OBU of vehicle: o Receives BSM from streetcar OBU o Identifies trajectory o Determines if on a collision course Verify that: • Streetcar and vehicle sending, receiving and processing BSMs • VTRFTV safety application does not issue a warning to the driver or streetcar operator
Test Inputs	Streetcar movement as shown in the illustration Vehicle movement as shown in the illustration
Resources Needed	1. Streetcar 2. Streetcar driver 3. Vehicle 4. Vehicle driver
Execution Conditions	Closed streetcar grade crossing Streetcar approached, stopped, and departed Vehicle movement beside and turn in front of the streetcar
Requirements Verified	THEA-UC5-007: Streetcar OBUs determine potential conflict THEA-UC5-007a: Vehicle OBUs determine potential conflict

Initial Conditions	Safety Management Test Conduct: • Public streetcar grade crossing • Safety cones and safety vests for test facilitators • Use of stakeholder streetcars • Use of stakeholder vehicles • Conducted by stakeholder participants • Applications tuned to match Phase 3 study configuration
	THEA-UC5-008: OBU warning to streetcar operator THEA-UC5-008a: OBU streetcar warning to the driver
Illustration	

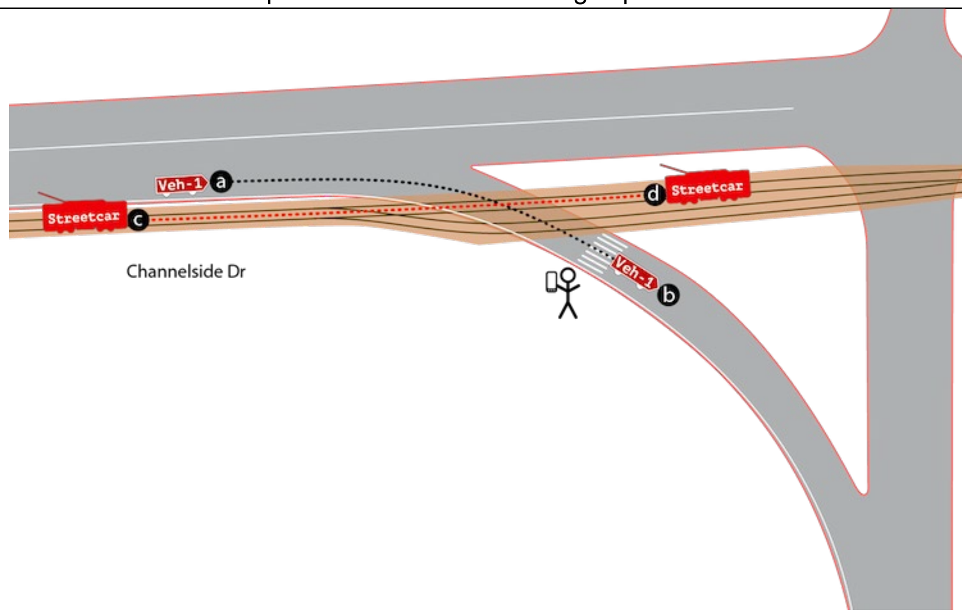
2.2.6.2.2 PTMW Test Cases

Test Case UC5 PTMW

Table 43: Test Case UC5 PTMW

Initial Conditions	Safety Management Test Conduct: • Public roadway in live traffic at streetcar stops • Use of stakeholder vehicles • Use of stakeholder PIDs • Conducted by stakeholder participants • Applications tuned to match Phase 3 study configuration
Objectives	Test the PID warning issued when the streetcar approaches and when the streetcar is starting up, but not when the streetcar is stopped with the door open. Also, test the pedestrian warning that a car is turning right in front of the streetcar. • Streetcar constantly issues BSMs via DSRC indicating streetcar location direction and speed

Initial Conditions	Safety Management Test Conduct: • Public roadway in live traffic at streetcar stops • Use of stakeholder vehicles • Use of stakeholder PIDs • Conducted by stakeholder participants • Applications tuned to match Phase 3 study configuration
	• RSU translates the streetcar BSMs from DSRC to Wi-Fi • PID receives streetcar BSMs via Wi-Fi • PID determines whether the pedestrian is located within the configurable geofenced area ahead of the streetcar • PID determines whether the pedestrian is located within the configurable geofenced area of the crosswalk ahead of the streetcar • If within the geofenced area, the PID further determines whether the streetcar is moving, based on successive streetcar BSMs • If within the geofenced area, and the streetcar is moving, the PID issues a warning to the pedestrian • If within the geofenced area, and the streetcar is stopped, and the door is closed, the PID issues a warning to the pedestrian • If not within the geofenced area, or if the streetcar is stopped with the door open, the PID does not issue a warning • If within the geofenced area near the crosswalk and a vehicle is turning right in front of the streetcar, the PID issues a warning to the pedestrian Verify that: • PID issues a warning to pedestrians in a configurable area ahead of the approaching streetcar • PID does not issue warnings when the streetcar occupies the streetcar stop • PID issues a warning to pedestrians in a configurable area ahead of the departing streetcar • PID issues a warning to pedestrians in a configurable area near the crosswalk when a car is turning right in front of the streetcar
Test Inputs	Streetcar movement as shown in the illustration Vehicle movement as shown in the illustration
Resources Needed	1. Streetcar equipped with OBU communicating 2. Streetcar driver 3. A vehicle equipped with OBU communicating 4. Vehicle driver
Execution Conditions	Closed streetcar grade crossing Streetcar approached, stopped, and departed Vehicle movement beside and turn in front of a streetcar
Requirements Verified	THEA-UC5-005: Pedestrian app on PID alerts pedestrian of stopping the streetcar THEA-UC5-006: Pedestrian app on PID alerts pedestrian of starting a streetcar

Initial Conditions	Safety Management Test Conduct: • Public roadway in live traffic at streetcar stops • Use of stakeholder vehicles • Use of stakeholder PIDs • Conducted by stakeholder participants • Applications tuned to match Phase 3 study configuration
	THEA-UC5-008b: VTRIFTV warning to RSU THEA-UC5-009: VTRIFTV warning to Master Server THEA-UC5-009a: VTRIFTV warning RSU to PIDs THEA-UC5-009c: PID provides a VTRFTV warning to pedestrian
Illustration	

2.2.7 UC6 Traffic Progression

2.2.7.1 UC6 Traffic Progression Test Plan

UC6 test plan approach includes the following three Connected Vehicle applications

- I-SIG
- PDETM (Master Server)
- Mobile Accessible Pedestrian Signals System (PED-SIG)

The purpose of the test is to ensure that the implementation of the three applications fulfills the requirement of UC6.

2.2.7.2 UC6 Traffic Progression Test Cases

2.2.7.2.1 I-SIG Test Cases

Test Case UC6 I-SIG

Table 44: Test Case UC6 I-SIG

Initial Conditions	Safety Management Test Conduct: • Closed roadway with law enforcement present • Use of stakeholder vehicles • Conducted by stakeholder participants • Applications tuned to match Phase 3 study configuration
Objectives	Test the reception of BSMs by I-SIG. The actual operation of I-SIG is tested independently under other USDOT contracts. System Operation: • Equipped vehicles continually broadcast BSMs • RSUs continually receive BSMs from equipped vehicles • BSMs are supplied as input to I-SIG running on the RSUs • I-SIG runs a control algorithm that was developed and tested previously • I-SIG issues NTCIP 1202 SETs to CU to select signal phases • I-SIG issues NTICP 1202 GETs to verify signal phase selection Verify that: • BSMs are being received by RSU • MMITTS status is “Enabled,” and MMITSS services are “Active.” • Queue length estimates and delays for all approaches for both intersections are contained in data logs
Test Inputs	BSMs of equipped vehicles approaching the intersections
Resources Needed	RSU installed at Twiggs/Meridian communicating RSU installed at Twiggs/Nebraska communicating
Execution Conditions	1. Morning peak with an expected high penetration rate of equipped vehicles (20% or higher) 2. Mid-day low with an expected low penetration rate of equipped vehicles (< 5%) 3. Evening peak with an expected high penetration rate of equipped vehicles (20% or higher)
Requirements Verified	THEA-UC6-006: I-SIG receives BSMs THEA-UC6-008a: I-SIG estimates queue lengths on studied approaches

2.2.7.2.2 PED-SIG Test Cases

Test Case UC6 PED-SIG_A

Table 45: Test Case UC6 PED-SIG_A

Initial Conditions	Safety Management Test Conduct: • Public roadway in live traffic at a signalized intersection • QM including Malfunction Management Unit (MMU) and responses • Use of stakeholder vehicles • Conducted by stakeholder participants • Applications tuned to match Phase 3 study configuration
Objectives	On North/South lanes, test the interfaces between the PED-SIG application running on the PID and the MMITSS application running on the RSU. The actual operation of PED-SIG is tested independently under other USDOT contracts. System Operation: • Pedestrian aligns the PID with the selected crosswalk • Pedestrian presses PID screen to place PED CALL • PED CALL is sent via Wi-Fi to MMITSS running on RSU • MMITSS sends NTCIP 1202 SET to place PED CALL in CU • MMITSS sends NTCIP 1202 GET to sense active WALK phase • Active WALK phase is sent to PID via Wi-Fi • Active WALK phase is displayed on PID along with haptic and audible indications • PID indicates countdown remaining in the WALK phase Verify that: • Pedestrian presence does not affect CU control when standing on the curb before using PED-SIG • Pedestrian presence does not affect CU control when aligning PID to crosswalk • Pressing PID screen: CU Active Screen displays WALK CALL service request for that crosswalk • PID WALK screen: o WALK phase for that crosswalk is displayed on PID screen, WALK signal, and CU Active Status screen o PID emits a haptic indication of WALK phase • PID DON'T WALK screen: o DON'T WALK phase for that crosswalk is displayed on PID screen, pedestrians signal and CU Active Status screen o PID emits a haptic indication of DON'T WALK phase • PID WALK phase countdown: o Pedestrian service is extended if supported by the CU

Initial Conditions	Safety Management Test Conduct: • Public roadway in live traffic at a signalized intersection • QM including Malfunction Management Unit (MMU) and responses • Use of stakeholder vehicles • Conducted by stakeholder participants • Applications tuned to match Phase 3 study configuration
	o In this particular installation, the CU does not support extended service
Test Inputs	1. Pedestrian located at varying locations shown in Figure 17 2. The varying direction of PID 3. Actuation of PED-SIG P buttons on PID screen
Resources Needed	1. Pedestrian 2. PID communicating 3. PED-X P installed and running on PID 4. RSU with Wi-Fi installed at signalized intersection communicating 5. CU controlling pedestrian signals 6. PED-X I installed in RSU 7. RSU communicating to CU
Execution Conditions	1. MMITSS controlling traffic 2. CU configured to accept and service PED CALLS 3. CU active status screen displayed to view PED CALL service
Requirements Verified	THEA-UC6-018: Pedestrian CALL to RSU from PID THEA-UC6-018b: Audibly inform the pedestrian THEA-UC6-018c: PED-SIG I receives PID CALL THEA-UC6-018d: Pedestrian CALL from RSU to CU THEA-UC6-018e: Extend walk time, if available on CU THEA-UC6-018f: PED-SIG I receives CU countdown THEA-UC6-018g: PED-SIG I sends proceeds to cross to PED-SIG

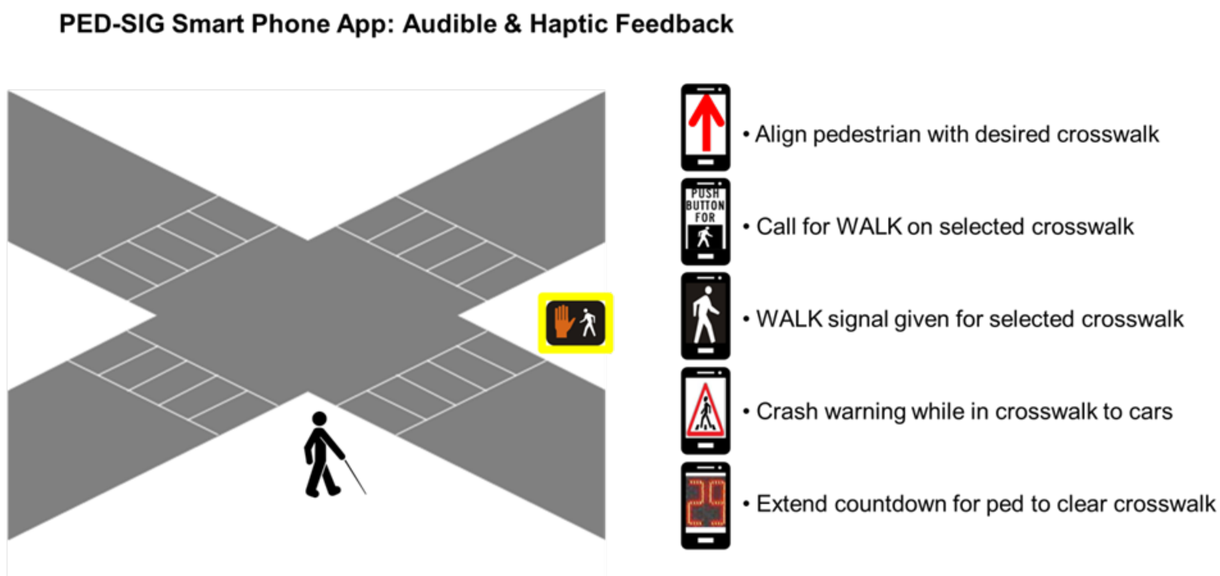


Figure 22: PED-SIG Execution Conditions
Source: Siemens

Test Case UC6 PED-SIG_B

Table 46: Test Case UC6 PED-SIG_B

Initial Conditions	Safety Management Test Conduct: • Public roadway in live traffic at a signalized intersection • QM including Malfunction Management Unit (MMU) and responses • Use of stakeholder vehicles • Conducted by stakeholder participants • Applications tuned to match Phase 3 study configuration
Objectives	Repeat the Test Case UC6 PED-SIG_A for East-West lanes
Test Inputs	1. Pedestrian located at varying locations shown in Figure 17 2. The varying direction of PID 3. Actuation of PED-SIG P buttons on PID screen
Resources Needed	1. Pedestrian 2. PID communicating 3. PED-X P installed and running on PID

Initial Conditions	Safety Management Test Conduct: • Public roadway in live traffic at a signalized intersection • QM including Malfunction Management Unit (MMU) and responses • Use of stakeholder vehicles • Conducted by stakeholder participants • Applications tuned to match Phase 3 study configuration
	4. RSU with Wi-Fi installed at signalized intersection communicating 5. CU controlling pedestrian signals 6. PED-X I installed in RSU 7. RSU communicating to CU
Execution Conditions	1. MMITSS controlling traffic 2. CU configured to accept and service PED CALLS 3. CU active status screen displayed to view PED CALL service
Requirements Verified	THEA-UC6-018: Pedestrian CALL to RSU from PID THEA-UC6-018b: Audibly inform the pedestrian THEA-UC6-018c: PED-SIG I receives PID CALL THEA-UC6-018d: Pedestrian CALL from RSU to CU THEA-UC6-018e: Extend walk time, if available on CU THEA-UC6-018f: PED-SIG I receives CU countdown THEA-UC6-018g: PED-SIG I sends proceeds to cross to PED-SIG

2.2.8 Safety

2.2.8.1 Safety Test Plan

The safety test plan approach includes the OBU and RSU device operation during:

- OBU Failure
- RSU Failure

The purpose of the test is to verify the “SAF” ID Requirements marked as “T” in the “VM” column of the RTCTM.

2.2.8.1.1 OBU Safety Test Cases

Test Case: SAF_A

Table 47: Test Case OBU Failure

Initial Conditions	Safety Management Test Conduct: • Public roadway in live traffic at a signalized intersection • QM including Malfunction Management Unit (MMU) and responses • Use of stakeholder vehicles • Conducted by stakeholder participants • Applications tuned to match Phase 3 study configuration
Objectives	Test the vehicle operation during failure: • Vehicle DSRC transmission • HMI display to the driver • HMI audible alerts to the driver System Operation: • OBU transmitting J2725 messages to COTS test equipment • OBU disabled as failed Verify that: • OBU transmits valid J2735 messages when enabled • When OBU is disabled as failed: o Vehicle operation is not affected o HMI is dark with nothing displayed o HMI emits no audible sounds
Test Inputs	OBU broadcasting J2735 messages
Resources Needed	OBU equipped vehicle communicating
Execution Conditions	Closed lot
Requirements Verified	THEA-SAF-005: OBU Failure

2.2.8.1.2 RSU Safety Test Cases

Test Case: SAF_B

Table 48: Test Case RSU Failure

Initial Conditions	Safety Management Test Conduct: • Public roadway in live traffic at a signalized intersection • QM including Malfunction Management Unit (MMU) and responses • Use of stakeholder vehicles • Conducted by stakeholder participants • Applications tuned to match Phase 3 study configuration
Objectives	Test the signal controller operation during failure:

Initial Conditions	Safety Management Test Conduct: • Public roadway in live traffic at a signalized intersection • QM including Malfunction Management Unit (MMU) and responses • Use of stakeholder vehicles • Conducted by stakeholder participants • Applications tuned to match Phase 3 study configuration

	• RSU DSRC transmission
	• Data communication interface between RSU and signal controller
	• HMI audible alerts to the driver
	System Operation:
	• RSU transmitting J2725 messages to COTS test equipment
	• RSU disabled as failed
	Verify that:
	• RSU transmits valid J2735 messages when enabled
	• When RSU is disabled as failed:
	  o Signal controller operation is not affected
	  o Communications from the controller to back office is not affected
	  o Other roadside equipment on the same network is not affected
	  o RSU failure is identified by the Master Server area map

Test Inputs	RSU broadcasting J2735 messages
Resources Needed	RSU communicating
Execution Conditions	RSU-Equipped operational signalized intersection
Requirements Verified	THEA-SAF-006: RSU Failure

2.3 Test Procedures

2.3.1 Test Procedure Scope

The scope of the test procedures described in this document describes Level 4 individual system verification tests of the six use cases identified in the Concept of Operations, as shown in Figure 23. This verification testing leads up to Level 5, System Validation, with end-to-end testing of the six use cases deployed at multiple locations using operational data and settings. The test procedures for Levels 1-3 and associated test documentation are out of scope for this document.

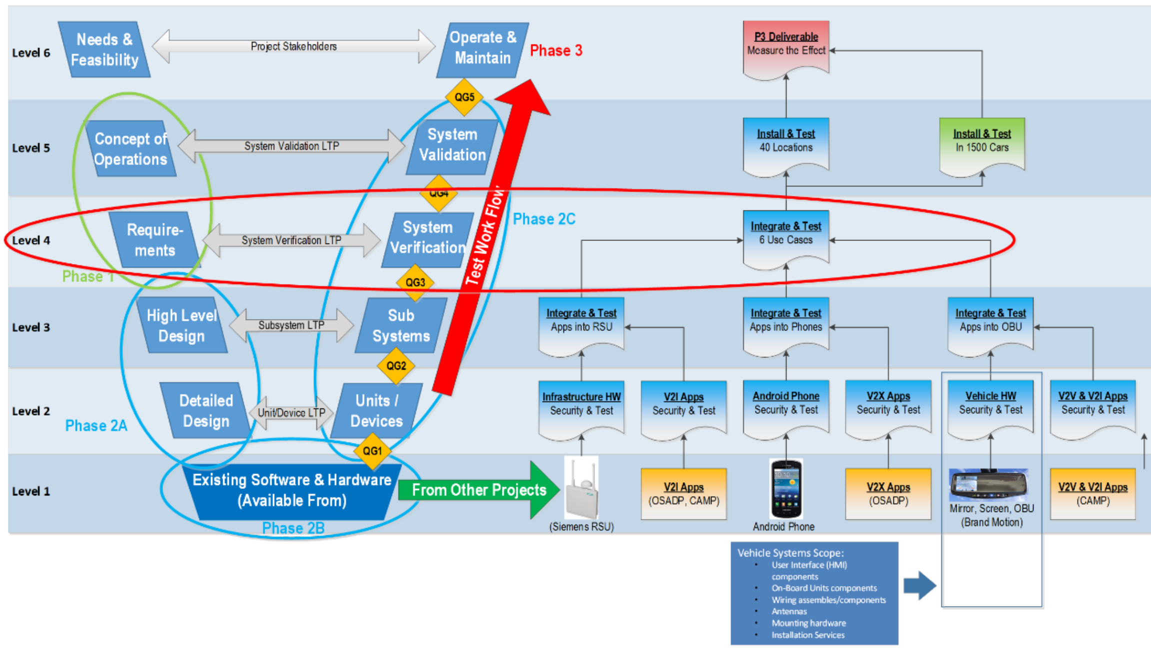


Figure 23: Operational Readiness Test Scope
Source: Siemens

2.3.2 Initial Conditions for Test Procedures at Level 4

At Level 4, the following test workflow is already completed:

- Level 1: Each hardware device and software app unit is investigated and procured
- Level 2: Each hardware device and software app unit is tested to fulfill requirements
- Level 3: Software app units are integrated into hardware devices and tested as subsystems
  - RSU Subsystem
  - OBU Subsystem
  - PSD Subsystem
  - Master Server Subsystem
- Systems tested at Level 4 are deployed on a closed course

2.3.3 Test Procedure Workflow

The Test Procedure Workflow is depicted in Figure 15. As previously noted in the scope:

- Within Scope: Validate the system's ability to support the safe and secure evaluation of CV application operation and effectiveness during Phase 3 of the project
- Out of Scope: Evaluate CV application operation and effectiveness

2.3.4 Conventions Used in this Section

2.3.4.1 Application Identifier

APP<n>: Application software object, where:

APP: Application Acronym
n = V: Software object for APP installed in OBU
n = I: Software object for APP installed in RSU
n = P: Software object of APP installed in PSD

2.3.4.2 OBU Manufacturer

OBU manufacturer ID:

- C: Comsignia
- S: Savari
- X: Sirius XM

2.3.4.3 V2V OBU Action

- → Indicates overtaking
- For example, C→X indicates vehicle equipped with Comsignia OBU is overtaking vehicle equipped with Sirius XM OBU

2.3.5 UC1 Morning Backup

2.3.5.1 UC1 Morning Backup Tests

The UC1 test procedure approach includes the following four Connected Vehicle applications:

- I-SIG
- ERDW
- EEBL
- FCW

The purpose of the test is to ensure that the implementation of the four applications fulfills the requirement of UC1.

2.3.5.2 Morning Backup Test Procedure

2.3.5.2.1 I-SIG Test Procedure

Table 49: I-SIG Test Procedure UC1

STEP	ACTION	REQ	EXPECTED RESULT	P/F/I
Test Case UC1 I-SIG_A				
1	Check RSU monitor for received BSMs.	THEA-UC1-012 THEA-UC1-030	BSMs are being received by RSU.	P
2	Check MMITSS Controller for status.	THEA-UC1-013 THEA-UC1-014	MMITTS status is “Enabled,” and MMITSS services are “Active.”	P
3	At the master server, view the stored queue length estimates from MMITSS.	THEA-UC1-017 THEA-UC1-018	Queue length estimates for all approaches for both intersections are contained in data logs.	P

STEP	ACTION	REQ	EXPECTED RESULT	P/F/I
4	Check ISG RSU app for status.	THEA-UC1-028 THEA-UC1-029	ISG is connected to the radar detector and receiving detection events which it converts to ISMs.	P
5	Check the queue length received by ERDW for REL lanes.	THEA-UC1-001 THEA-UC1-015	ERDW receives queue lengths for southbound lanes on REL and uses the longest queue as input to TIM selection.	P
Test Case UC1 I-SIG_B				
1	Monitor the traffic controller front-panel status screens and make a note of actual phase green times, phase calls, omits, and holds.	THEA-UC1-019	Status screens show phase calls, omits, and holds applied. Phase green times vary with estimated queue length for the corresponding approach (the controller will at least serve the minimum green time).	P

Test Report I-SIG

Table 50: Test Report I-SIG

Test Case	Date	Anomaly Report	P/I
UC1 I-SIG_A	4/17/18	MMITSS services suspended during the test. Discovered array out of bounds errors in MMITSS, would access memory addresses that were not allocated to MMITSS. Corrected in the software.	I
		Radar detector is installed but not implemented for end-to-end testing; queues not received.	I
	4/23/18	Update to vendor software. MMITSS operated correctly; no memory allocation errors observed.	P
		Instead of a demonstration in live traffic, the REL was closed. Varying queue lengths were forced by overwriting the queue length in the data structure for either long or short queues that were not part of normal operation in live traffic. Worked correctly, but Sirius XM OBU did not operate correctly. Decided to repeat the demo on 4/23/2018.	I
	4/24/18	The REL was closed and demo was repeated. The RSU reported as having “crashed,” but with the intersection operating safely per requirement THEA-SAF-006: “RSU/Application failure shall not affect the safe operation of the signal controller.”	I
	5/11/18	Investigation revealed the RSU had not “crashed.” High loads of unexpected traffic on DSRC channel 180 caused the RSUs network stack to restart safely with an RSU log entry recording	I

Test Case	Date	Anomaly Report	P/I
		the event. The originator of the unexpected traffic incompatible with DSRC channel 180 was traced to Tampa HamWAN.	
	5/14/18	Anomaly report *"Effects of HamWAN on Tampa CV Pilot Deployment*" by Siemens Industry Inc., included as 2.3.5.2.1.1. Example PCAP file showing data received on RSU42 5.9 GHz band not compatible with DSRC, included as 2.3.5.2.1.2.	I
		After resolution of Tampa HamWAN issue, tests for Steps 4 and 5 scheduled to be completed by 6-30-2018.	
	6/12/18	Meetings with HamWAN operator resulted in the schedule for a retest with HamWAN transmitter OFF. Successfully tested.	P
UC1 I-SIG_B	4/17/18	No anomalies observed.	P

2.3.5.2.1.1 Effects of HamWAN on Tampa CV Pilot Deployment

The DSRC channel usage for THEA, Wyoming, and New York City, is established by the Systems Engineering Roundtable such that vehicles from each pilot will operate in each of the deployment areas. During ORD, the WWE app safely suspended operation due to interference by a HamWAN operating on a DSRC channel. FCC allows HamWAN as secondary use, meaning that HamWAN ceases operation DSRC channels. Since then, the THEA team analyzes each area using a third-party DSRC test receiver for potential conflicts, including future 5G and C-V2X specifications for the use of 4G/LTE.

Effects of HamWAN on Tampa CV Pilot Deployment

Siemens Industry Inc. 5/14/2018, Rev 1.0

Summary

Findings

- HamWAN uses many of the same frequencies allocated to DSRC. Namely channel 176, 180, and 184 (with 10 MHz channels), or even 172, 178, 182 (with 20 MHz channels)
- HamWAN uses radio access points with a range of over 50 km. HamWAN networks are deployed in multiple regions throughout the US (e.g. Seattle / Puget Sound Area)
- HamWAN uses a radio mode incompatible with IEEE802.11 making coexistence of both on the same frequency impossible.
- In the Tampa CV Pilot Deployment channel 180 is unusable due to HamWAN interference from access points installed in Downtown Tampa and St. Petersburg. Channel 176 is also affected on some RSUs. CV Pilot doesn't currently use channel 184.

Conclusion

- Channel 180 is unusable for the Tampa CV pilot. Further channel sniffing needs to be done throughout deployment area in order to determine level of interference on all DSRC channels, specifically channel 176 and 184.
- HamWAN networks exist nationwide which makes this a much broader issue with implications for the successful CV deployment in the US as a whole
- USDOT should work with HamWAN and FCC to find a solution that protects the interest of CV technology to be able to use all channels assigned to DSRC on a primary basis by FCC (see FCC 99-305[1]).
- This report shows that HamWAN frequencies and wireless protocols do interfere with and disrupt DSRC channels. Amateur radio has a secondary allocation to the spectrum used by DSRC.

HamWAN Overview

HamWAN Frequencies

HamWAN uses frequencies in the following ranges[2]:

Name	Low	Center	High	True Bearing
s1-10	5.915*	5.920	5.925	0
s2-10	5.895	5.900	5.905	120

[1] https://transition.fcc.gov/Bureaus/Engineering_Technology/Orders/1999/fcc99305.txt
[2] https://hamwan.org/Standards/Radio%20Frequency%20Engineering/Spectrum%20Allocation.html

Figure 24: Effects of HamWAN, Page 1
Source: Siemens

s3-10	5.875	5.880	5.885	240
s1-5	5.9175	5.920	5.9225	0
s2-5	5.8975	5.900	5.9025	120
s3-5	5.8775	5.880	5.8825	240
o1-5	5.8625	5.865	5.8675	n/a
o2-5	5.8525	5.855	5.8575	n/a
o3-5	5.8425	5.845	5.8475	n/a

*All frequencies measured in GHz
This band plan overlaps with DSRC channels 176 (s3-10), 180 (s2-10), and 184 (s1-10).

A HamWAN radio station is built of a 3 sector antenna which uses one of the above frequencies s1-10 through s3-10 for each sector, corresponding to the sector's bearing.

Some further discussions even explore the possibility using the following 20 MHz bands[3]:

Name	Low	Center	High	True Bearing
s1-20	5.905	5.915	5.925	0
s2-20	5.875	5.885	5.895	120
s3-20	5.845	5.855	5.865	240

This band plan overlaps with DSRC channels 172, 176, 178, 182, and 184.

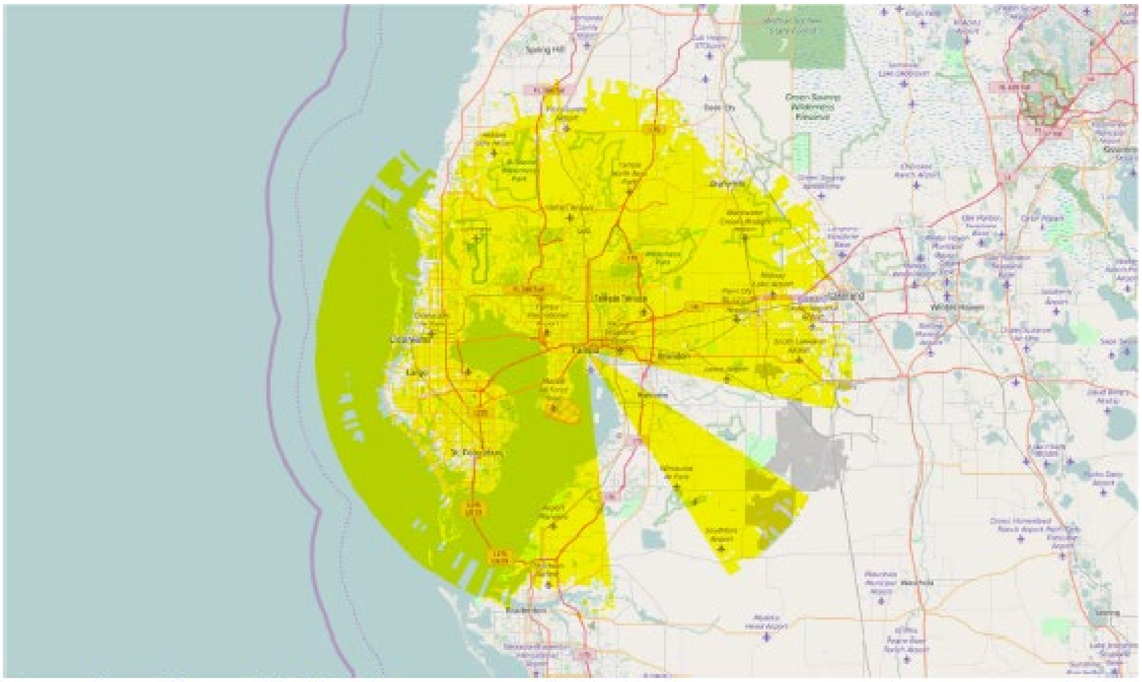
HamWAN Radio Range

HamWAN radio range covers very large areas (50+ kilometers). In the Tampa area these are the coverage maps.

Tampa HamWAN

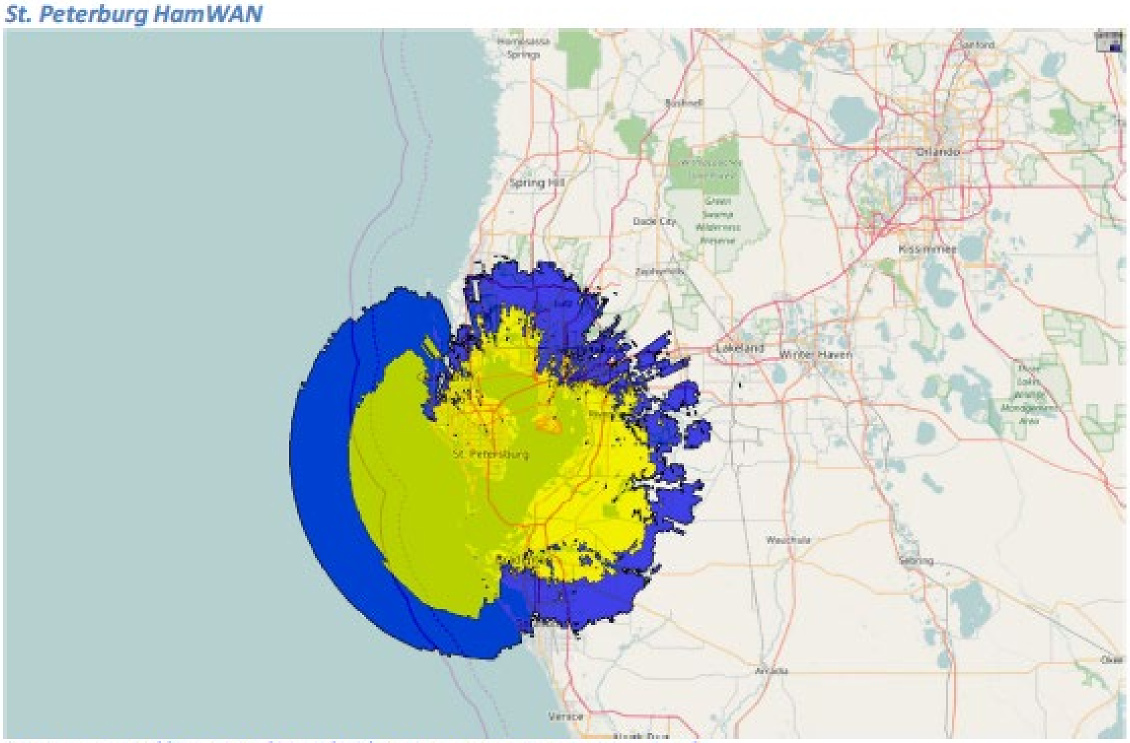
[3] https://hamwan.org/Standards/Radio%20Frequency%20Engineering/Spectrum%20Allocation.html

Figure 25: Effects of HamWAN, Page 2
Source: Siemens



(Source: http://flscg.org/2016/07/hamwan-tampa-bay-is-live/)

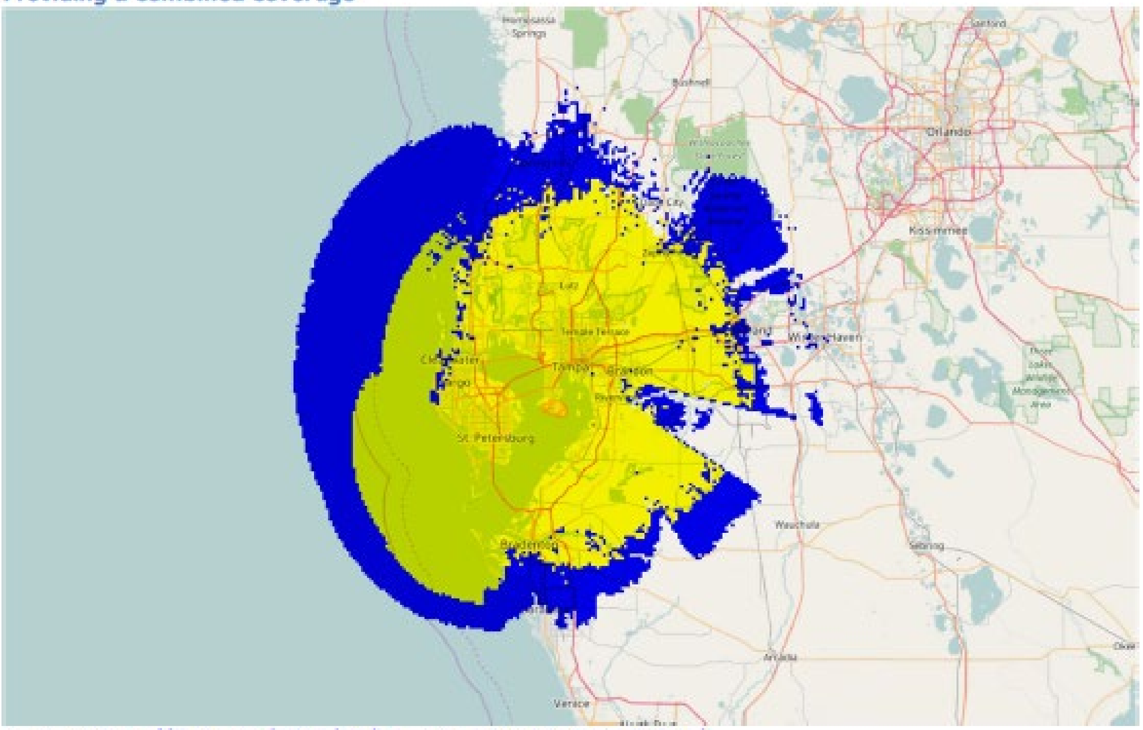
St. Peterburg HamWAN



(Source: http://flscg.org/2016/12/hamwan-st-petersburg-is-live/)

Figure 26: Effects of HamWAN, Page 3
Source: Siemens

Providing a Combined Coverage



(Source: http://flscg.org/2016/12/hamwan-st-petersburg-is-live/)

Several HamWAN networks have been already deployed throughout the US in addition to the Tampa network. For example the Puget Sound Data Ring covers the Cities of Seattle, Redmond, Tacoma, Olympia, and Victoria (Canada)[4]. Other deployments exist in Memphis (TN), Albuquerque (NM), and Valdosta (GA)[5].

HamWAN Radio Mode

HamWAN uses the proprietary Nv2 protocol developed by MikroTik[6]. "Nv2 is based on TDMA (Time Division Multiple Access) media access technology instead of CSMA (Carrier Sense Multiple Access) media access technology used in regular 802.11 devices."[7]

"**As Nv2 does not use CSMA technology it may disturb any other network in the same channel.** *In the same way other networks may disturb Nv2 network, because every other signal is considered noise. The key points regarding compatibility and coexistence:*

- *only RouterOS devices will be able to participate in Nv2 network*
- *only RouterOS devices will see Nv2 AP when scanning*
- **Nv2 network will disturb other networks in the same channel**
- *Nv2 network may be affected by any (Nv2 or not) other networks in the same channel*
- *Nv2 enabled device will not connect to any other TDMA based network*

"[8]

[4] https://hamwan.org/index.html
[5] http://hamwan.org/Standards/Certification.html#certified-networks
[6] http://hamwan.org/Standards/Certification.html
[7] https://wiki.mikrotik.com/wiki/Manual:Nv2

Figure 27: Effects of HamWAN, Page 4
Source: Siemens

An IEEE802.11 compliant DSRC radio will do LBT ("listen before talk") since that is part of CSMA to make sure the channel is free to send on. A HamWAN radio sending on that channel will just send irrespective of 802.11 radios sending already. This will turn the transmitted WAVE message unreadable to other 802.11 radios or will cause the sending 802.11 radio driver to simply drop the message as the channel isn't clear.

Additionally the HamWAN radio won't even receive DSRC radio messages due to the far lesser range of DSRC. The DSRC radio will receive the HamWAN radio messages, though, which will cause it to consider the channel "busy" and not "clear to send".

Therefore no "peaceful" coexistence is possible between HamWAN and DSRC radios on the same frequencies.

HamWAN Interference in Tampa CV Pilot

Based on SiriumXM and Siemens sniffer data the HamWAN radio is sending roughly 250 frames / messages per second continuously on channel 180. This renders channel 180 unusable for DSRC radio transmissions. This is for areas of the pilot deployment which are located in the area of the 120^0 sector antenna (HamWAN frequency s2-10).

RSUs along Florida Ave are in line of sight of the 0^0 sector antenna which broadcasts on channel 184 (HamWAN frequency s1-10). This renders channel 184 unusable for DSRC radio in that area.

RSUs along Florida Ave also see lots of radio traffic on channel 176 but drop all the received pakets at the driver level already. It is possible that those pakets also originate from a HamWAN, e.g. the one in St. Petersburg. Further sniffing in that area should be done.

Finally, even though currently not used sniffer data should be collected for channel 184 throughout the deployment area as well. The expectation is that similar amounts of wireless traffic as on channel 180 will be seen.

[8] https://wiki.mikrotik.com/wiki/Manual:Nv2#Compatibility_and_coexistence_with_other_wireless_protocols

Figure 28: Effects of HamWAN, Page 5
Source: Siemens

2.3.5.2.1.2 Example PCAP Data, RSU 42

04_RSU42.pcap 2022 total packets, 10 shown

```
1 0.000000 Routerbo_89:70:a6 Broadcast LLC 100 S, func=RR, N(R)=57; DSAP 0x6a Group, SSAP 0x6c
Command
Frame 1: 100 bytes on wire (800 bits), 100 bytes captured (800 bits)
Radiotap Header v0, Length 52
802.11 radio information
IEEE 802.11 Data, Flags: o..P....
Logical-Link Control
Data (20 bytes)
0000 57 01 00 00 00 00 00 08 00 00 18 79 00 03 08 68 W.........y...h
0010 65 82 bb 2c e..,
2 0.004269 Routerbo_89:70:a6 Broadcast LLC 100 S, func=RR, N(R)=57; DSAP Remote Program Load
Group, SSAP
0x7c Command
Frame 2: 100 bytes on wire (800 bits), 100 bytes captured (800 bits)
Radiotap Header v0, Length 52
802.11 radio information
IEEE 802.11 Data, Flags: o..P....
Logical-Link Control
Data (20 bytes)
0000 57 01 00 00 00 00 00 08 00 00 19 46 00 03 07 69 W.........F...i
0010 18 1f 5f 28 .._(
3 0.008512 Routerbo_89:70:a6 Broadcast LLC 100 S, func=RR, N(R)=57; DSAP 0x60 Individual, SSAP
0x8c
Response
Frame 3: 100 bytes on wire (800 bits), 100 bytes captured (800 bits)
Radiotap Header v0, Length 52
802.11 radio information
IEEE 802.11 Data, Flags: o..P....
Logical-Link Control
Data (20 bytes)
0000 57 01 00 00 00 00 00 08 00 00 18 a0 00 03 06 c5 W..............
0010 da 34 b7 8a .4..
4 0.012663 Routerbo_89:70:a6 Broadcast LLC 100 S, func=RR, N(R)=57; DSAP 0xc0 Individual, SSAP
0x9c
Response
Frame 4: 100 bytes on wire (800 bits), 100 bytes captured (800 bits)
Radiotap Header v0, Length 52
802.11 radio information
IEEE 802.11 Data, Flags: o..P....
Logical-Link Control
Data (20 bytes)
0000 57 01 00 00 00 00 00 08 00 00 17 bb 00 03 07 28 W.............(
0010 35 a4 3e c9 5.>.
5 0.016502 Routerbo_89:70:a6 Broadcast LLC 108 S, func=RR, N(R)=57; DSAP 0xd8 Group, SSAP 0xac
Command
Frame 5: 108 bytes on wire (864 bits), 108 bytes captured (864 bits)
Radiotap Header v0, Length 52
802.11 radio information
IEEE 802.11 Data, Flags: o..P....
Logical-Link Control
Data (28 bytes)
0000 57 01 00 00 00 00 00 08 00 00 17 5c 00 03 08 2d W.........\...-
0010 40 30 00 03 20 61 00 00 74 4f c5 1d @0.. a..tO..
6 0.020555 Routerbo_89:70:a6 Broadcast LLC 100 S, func=RR, N(R)=57; DSAP 0xb6 Group, SSAP Banyan
Vines
Command
Frame 6: 100 bytes on wire (800 bits), 100 bytes captured (800 bits)
Radiotap Header v0, Length 52
802.11 radio information
IEEE 802.11 Data, Flags: o..P....
Logical-Link Control
Data (20 bytes)
```

```
0000 57 01 00 00 00 00 00 08 00 00 18 b8 00 03 07 7f W..............
0010 80 a3 27 55 ..'U
7 0.024716 Routerbo_89:70:a6 Broadcast LLC 100 S, func=RR, N(R)=57; DSAP 0x76 Individual, SSAP
0xcc
Command
Frame 7: 100 bytes on wire (800 bits), 100 bytes captured (800 bits)
Radiotap Header v0, Length 52
802.11 radio information
IEEE 802.11 Data, Flags: o..P....
Logical-Link Control
Data (20 bytes)
0000 57 01 00 00 00 00 00 08 00 00 19 2a 00 03 07 23 W.........*...#
0010 c0 63 c0 14 .c..
8 0.028893 Routerbo_89:70:a6 Broadcast LLC 100 S, func=RR, N(R)=57; DSAP LLC Sub-Layer Management
Individual, SSAP 0xdc Response
Frame 8: 100 bytes on wire (800 bits), 100 bytes captured (800 bits)
Radiotap Header v0, Length 52
802.11 radio information
IEEE 802.11 Data, Flags: o..P....
Logical-Link Control
Data (20 bytes)
0000 57 01 00 00 00 00 00 08 00 00 18 7d 00 03 07 2e W.........}....
0010 30 d4 91 6e 0..n
9 0.032897 Routerbo_89:70:a6 Broadcast LLC 100 S, func=RR, N(R)=57; DSAP 0xd6 Group, SSAP 0xec
Command
Frame 9: 100 bytes on wire (800 bits), 100 bytes captured (800 bits)
Radiotap Header v0, Length 52
802.11 radio information
IEEE 802.11 Data, Flags: o..P....
Logical-Link Control
Data (20 bytes)
0000 57 01 00 00 00 00 00 08 00 00 19 0b 00 03 07 a6 W..............
0010 ae 4f 5d 47 .O]G
10 0.037010 Routerbo_89:70:a6 Broadcast LLC 100 S, func=RR, N(R)=57; DSAP 0xc0 Group, SSAP Remote
Program
Load Command
Frame 10: 100 bytes on wire (800 bits), 100 bytes captured (800 bits)
Radiotap Header v0, Length 52
802.11 radio information
```

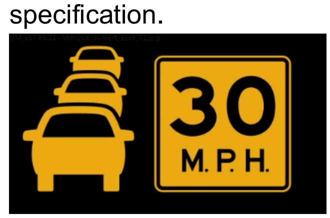
Executed By:	Witnessed By:	Date:

2.3.5.2.2 ERDW Test Procedure

ERDW Test Procedure

Table 51: ERDW Test Procedure

STEP	ACTION	REQ	EXPECTED RESULT	P/F/I
Test Case UC1 ERDW_A				
1	Set the queue length via the RSU browser UI.	THEA-UC1-024	ERDW displays entered queue length and uses it to select the TIM associated with that queue length based on ERDW configuration.	P

STEP	ACTION	REQ	EXPECTED RESULT	P/F/I
2	Verify with 3M Tester that RSU broadcasts the selected TIM, and compare to OBU.	THEA-UC1-022 THEA-UC1-026a	3M Tester receives and logs broadcast TIM. TIM content (speed zones) equals the TIM configured for the queue length.	P
3	Repeat steps 1 – 2 for the second queue length, and compare to OBU	THEA-UC1-024 THEA-UC1-022 THEA-UC1-026a	ERDW picks a different TIM that is associated with the second queue length based on ERDW configuration. TIM content (speed zones) equals the TIM configured for the second queue length.	P
		Test Case UC1 ERDW_B		
1	A vehicle approaches 40 MPH Zone but has not reached it yet (a).	THEA-UC1-002 THEA-UC1-023 THEA-UC1-025	No warning is shown to the driver.	P
2	The vehicle reaches 40 MPH zone (b).	THEA-UC1-002 THEA-UC1-023 THEA-UC1-025	ERDW safety application issues a “40 MPH” warning to the driver per the HMI specification. 	P
3	The vehicle reaches a 30 MPH zone (c).	THEA-UC1-002 THEA-UC1-023 THEA-UC1-025	ERDW safety application issues a “30 MPH” warning to the driver per the HMI specification. 	P

STEP	ACTION	REQ	EXPECTED RESULT	P/F/I
4	The vehicle reaches 20 MPH zone (d).	THEA-UC1-002 THEA-UC1-023 THEA-UC1-025	ERDW safety application issues a “20 MPH” warning to the driver per the HMI specification.  	P
5	The vehicle reaches the stop bar at the intersection with Twiggs.	THEA-UC1-002 THEA-UC1-023 THEA-UC1-025	No warning is shown to the driver.	P
6	Repeat steps 1-5 with differing queue lengths.	THEA-UC1-002 THEA-UC1-023 THEA-UC1-025	Same as steps 1-5.	P

ERDW Test Report

Table 52: ERDW Test Report

Test Case	Date	Anomaly Report (C: Comsignia, S: Savari, X: Sirius XM)	P/I
UC1 ERDW_A	3-27-18	1. C: The software version screen stays on too long	I
		2. C: Shows percentage	I
		3. C: Alerts for 20 and 30 are still speed based	I
		4. C: Alerts disappeared too quickly	I
		5. C: Alerts flash instead of showing once	I
		6. C: All alerts came up multiple times when speed fluctuates above and below the recommendation	I
		7. C: 40 comes on out of turn once at the bottom in the 20 mph zone	I
		8. S: Alerts were speed based (sounds for 30 and 20 were different based on vehicle speed)	I
		9. S: Stayed on too long	I
		10. S: Video cutting out on 40	I
		11. X: Shows Sirius icons for vehicles present in the area in the top left corner of the mirror	I
		12. X: Sound warning for going under 40 is not right	I
		13. X: 30 and 20 mph sounds are speed based, which isn't right	I
			I

Test Case	Date	Anomaly Report (C: Comsignia, S: Savari, X: Sirius XM)	P/I
		14. X: The graphic design seem slightly different than the graphics in the HMI document	
	4-24-18	Update to vendor software 1. C: All warnings were appropriate 2. S: All warnings were appropriate 3. X: All warnings were appropriate 4. After passing early morning testing, the RSU suspended the app during the demo later in the day. This is a case of overlapping apps. I-SIG sends queue length to ERDW. On the closed course, we set the queue LONG or SHORT by overwriting a data field in I-SIG. The HamWAN interference began during the demo. See 2.3.5.2.1.1	P P P
	6-11-18	Update to vendor software 1. S: Short queue- (11) runs, all proper alerts received except (7), flickered proper 40 MPH 3x (attributed to video cable problem in the vehicle), then proper 30, 20. 2. S: Long queue- (15) runs, all proper alerts received. 3. X: Long queue- (15) runs, (1-9) all proper alerts received, (10) no 30, 20, (11-12) no alerts. Restarted car, (13-15) proper alerts received, concluded app working correctly. 4. X: Short queue- (15) runs, all received proper alerts except (2) had no alerts. (6,12,14,15) also had proper FCW with a vehicle in the lane ahead. 5. C: Did not participate in testing.	P P P
UC1 ERDW_B	3-27-18	Update to vendor software 1. C: Seemed like both TIMs (shorter and longer queue) were taken into consideration and being displayed. 2. C: The car was not turned off though between the queue length changes. 3. C: Once the car was turned off, it forgot the old TIM. 4. S: The OBU forgot the old TIM as expected. 5. X: The OBU forgot the old TIM as expected.	I I P P P
	4-24-18	Update to vendor software 1. C: All warnings were appropriate 2. S: All warnings were appropriate 3. X: All warnings were appropriate 4. After passing early morning testing, the RSU suspended the app during the demo later in the day. This is a case of overlapping apps. I-SIG sends queue length to ERDW. On the closed course, we set the queue LONG	P P P

Test Case	Date	Anomaly Report (C: Comsignia, S: Savari, X: Sirius XM)	P/I
		or SHORT by overwriting a data field in I-SIG. The HamWAN interference began during the demo. See 2.3.5.2.1.1	

Executed By:	Witnessed By:	Date:

2.3.5.2.3 EEBL Test Procedure

EEBL Test Procedure

Table 53: EEBL Test Procedure

STEP	ACTION	REQ	EXPECTED RESULT	P/F/I
Test Case UC1 EEBL_A				
1	Host vehicle is driving above 20 MPH behind a remote equipped vehicle driving in the same lane ahead.	THEA-UC1-004 THEA-UC1-005 THEA-UC1-006 THEA-UC1-007 THEA-UC1-008	No warning is shown to the driver.	P
2	Remote vehicle hard brakes (above the hard-braking threshold) ahead of the host vehicle.	THEA-UC1-011	EEBL safety application issues a warning to the driver of the Host Vehicle per the HMI specification. 	P
3	Repeat steps 1-2 with the remote vehicle braking below the hard-braking threshold.	THEA-UC1-004 THEA-UC1-005 THEA-UC1-006 THEA-UC1-007 THEA-UC1-008	No warning is shown to the driver.	P
Test Case UC1 EEBL_B				
1	Host vehicle is driving above 20 MPH behind a remote equipped vehicle driving in the adjacent lane ahead.	THEA-UC1-004 THEA-UC1-005 THEA-UC1-006 THEA-UC1-007 THEA-UC1-008	No warning is shown to the driver.	P

STEP	ACTION	REQ	EXPECTED RESULT	P/F/I
2	Remote vehicle hard brakes (above the hard-braking threshold) ahead of the host vehicle.	THEA-UC1-011	No warning is shown to the driver.	P
3	Repeat steps 1-2 with the remote vehicle braking below the hard-braking threshold.	THEA-UC1-004 THEA-UC1-005 THEA-UC1-006 THEA-UC1-007 THEA-UC1-008	No warning is shown to the driver.	P

EEBL Test Report

Table 54: EEBL Test Report

Test Case	Date	Anomaly Report (→ indicates overtaking)	P/I
UC1 EEBL_A	3-28-18	1. S→C: Worked as expected with hard braking	P
		2. S→C: HMI warning disappeared too quickly	I
		3. S→C: Didn't show an alert when below the braking threshold	P
		4. C→S: Worked as expected with hard braking	P
		5. C→S: Didn't show alert below the braking threshold	P
		6. C→X: Worked as expected with hard braking	P
		7. C→X: Didn't show alert below the braking threshold	P
		8. X→S: Worked as expected with hard braking	P
		9. X→S: Didn't show an alert when below the braking threshold	P
		10. X→C: Worked as expected with hard braking	P
		11. X→C: Didn't show an alert when below the braking threshold	P
		12. S→X: Didn't show an alert when braking below the threshold	P
		13. S→X: HMI disappeared too quickly	I
		14. S→X: Didn't show an alert when below the braking threshold	P
		15. X→S: Worked as expected with hard braking	P
		16. X→S: Didn't show when braking was below the threshold	P
	4-24-18	Update to vendor software	P
		1. C: Warnings were appropriate in combination with others	P
		2. S: Warnings were appropriate in combination with others	P

Test Case	Date	Anomaly Report (→ indicates overtaking)	P/I
		3. X: Warnings were appropriate in combination with others Note: C generates lane-specific warnings, while S and X generate road-specific warnings in case cars jump lanes. Decided to leave as-is for study in Phase 3 for the effectiveness of the two methods.	
	6-13-18	Update to vendor software 1. S→X: (8) runs were appropriate except (6,8) no audio	I
	6-15-18	Update to vendor software 1. S→X: (5) runs with proper EEBL + FCW + audible	P
UC1 EEBL_B	3-28-18	Update to vendor software 1. S→C: Didn't show an alert in an adjacent lane 2. C→S: Didn't show an alert in an adjacent lane 3. C→X: Sometimes showed alert in an adjacent lane 4. X→C: Sometimes showed alert in an adjacent lane 5. S→X: Didn't show an alert in an adjacent lane 6. X→S: Sometimes showed alert in an adjacent lane	P P I I P I
	4-24-18	Update to vendor software 1. C: Warnings were appropriate in combination with others 2. S: Warnings were appropriate in combination with others 3. X: Warnings were appropriate in combination with others	P P P
		Update to vendor software 1. S→X: (9) runs were appropriate, no warnings	P

Executed By:	Witnessed By:	Date:

2.3.5.2.4 FCW Test Procedure

FCW Test Procedure

Table 55: FCW Test Procedure

STEP	ACTION	REQ	EXPECTED RESULT	P/F/I
Test Case UC1 FCW_A				
1	Host vehicle is driving above 20 MPH behind a stopped, remote equipped vehicle in the same lane ahead.	THEA-UC1-008 THEA-UC1-009 THEA-UC1-010	No warning is shown to the driver.	P

STEP	ACTION	REQ	EXPECTED RESULT	P/F/I
2	Host vehicle gets within the pre-specified time and distance behind the remote vehicle.	THEA-UC1-011	FCW safety application issues a warning to the driver of the host vehicle per the HMI specification. 	P
3	Host vehicle swerves out of the lane or brakes hard to avoid a collision.	THEA-UC1-008 THEA-UC1-009 THEA-UC1-010	No warning is shown to the driver.	P
Test Case UC1 FCW_B				
1	Host vehicle is driving above 20 MPH behind a stopped, remote equipped vehicle in the adjacent lane ahead.	THEA-UC1-008 THEA-UC1-009 THEA-UC1-010	No warning is shown to the driver.	P
2	Host vehicle passes the remote stopped vehicle in the adjacent lane.	THEA-UC1-008 THEA-UC1-009 THEA-UC1-010	No warning is shown to the driver.	P

FCW Test Report

Table 56: FCW Test Report

Test Case	Date	Anomaly Report	P/I
UC1 FCW_A	3-28-18	1. S→C: Worked as expected with the stopped vehicle	P
		2. C→S: Worked as expected with the stopped vehicle	P
		3. X→C: Worked as expected with the stopped vehicle	P
		4. C→X: Worked as a remote stopped vehicle	P
		5. C→X: X got phantom EEBL as the stopped vehicle with C turning around in front without hard braking	I
		6. C→X: Repeated (5) above twice while recording video, EEBL did not appear either time	I
		7. S→X: Did not provide warning most of the timeOccasionally provided a warning	I
		8. X→S: Worked as expected with a stopped vehicle	P
	4-16-18	Update to vendor software	I
		1. C: Inconsistent warnings	I

Test Case	Date	Anomaly Report	P/I
		2. S: Inconsistent warnings 3. X: Inconsistent warnings	I
	4-24-18	Update to vendor software Warnings displayed within the accuracy specification listed in SAE J2735-2016	P
	6-15-18	Update to vendor software S→X: (5) runs with proper EEBL + FCW + audible	P
UC1 FCW_B	3-28-18	Update to vendor software 1. S→C: Didn't show an alert when in the adjacent lane as expected. 2. C→S: Didn't show an alert when in the adjacent lane as expected 3. X→C: Showed when in adjacent lane sometimes, investigating tuning parameters 4. C→X: Didn't show an alert when in the adjacent lane as expected 5. S→X: Provided false warning sometimes, but not consistent. Speed was above 25 MPH on all runs. 6. X→S: Showed alert when in the adjacent lane	P P P I I I
	4-16-18	Update to vendor software 1. C: Inconsistent warnings 2. S: Inconsistent warnings 3. X: Inconsistent warnings	I I I
	4-24-18	Update to vendor software Warnings displayed within the accuracy specification listed in SAE J2735-2016	P

Executed By:	Witnessed By:	Date:

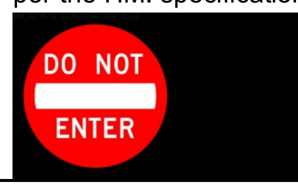
Wrong-Way Entry Test Procedures

2.3.5.3 WWE Test Procedures

Table 57: WWE Test Procedures

STEP	ACTION	REQ	EXPECTED RESULT	P/F/I
Test Case UC2 WWE_A				

STEP	ACTION	REQ	EXPECTED RESULT	P/F/I
1	A vehicle approaches intersection traveling eastbound on Twiggs.	THEA-UC2-010 THEA-UC2-011 THEA-UC2-012 THEA-UC2-016	No warning is shown to the driver.	P
2	A vehicle turns left and approaches inbound lanes (a).	THEA-UC2-012 THEA-UC2-018a THEA-UC2-018b	WWE safety application issues a “Do Not Enter” warning to the driver per the HMI specification. 	P
3	Vehicle enters inbound lanes (b).	THEA-UC2-016 THEA-UC2-018a THEA-UC2-018b	WWE safety application issues a “Wrong-Way Entry” warning to the driver per the HMI specification. 	P
Test Case UC2 WWE_B				
1	A vehicle approaches the intersection traveling eastbound on Twiggs.	THEA-UC2-001 THEA-UC2-010 THEA-UC2-011	No warning is shown to the driver.	P
2	The vehicle makes a left turn on to a closed section of the REL (a).	THEA-UC2-012 THEA-UC2-018a THEA-UC2-018b	WWE safety application issues a “Do Not Enter” warning to the driver per the HMI specification. 	P
3	The vehicle enters the closed section of the REL (b).	THEA-UC2-016 THEA-UC2-018a THEA-UC2-018b	WWE safety application issues a “No Travel Lane” warning to the driver per the HMI specification. 	P
Test Case UC2 WWE_C				

STEP	ACTION	REQ	EXPECTED RESULT	P/F/I
1	Vehicle is traveling South on inbound lane REL (a).	THEA-UC2-001 THEA-UC2-010 THEA-UC2-011	No warning is shown to the driver.	P
2	Vehicle enters the closed REL lane (b).	THEA-UC2-016 THEA-UC2-018a THEA-UC2-018b	WWE safety application issues a “No Travel Lane” warning to the driver per the HMI specification. 	P
Test Case UC2 WWE_D				
1	Vehicle 1 is approaching the Twiggs Meridian intersection coming from the REL (a). Vehicle 2 approaches inbound lanes (a).	THEA-UC2-001 THEA-UC2-010 THEA-UC2-011 THEA-UC2-012 THEA-UC2-015b THEA-UC2-015c THEA-UC2-015d THEA-UC2-016 THEA-UC2-018a THEA-UC2-018b	Vehicle 1: No warning is shown to the driver. Vehicle 2: WWE safety application issues a “Do Not Enter” warning to the driver per the HMI specification. 	P
2	Vehicle 2 travels across an inroad sensor traveling northbound.	THEA-UC2-015d THEA-UC2-016	Inroad sensor detects that a vehicle is going the wrong way and relays the information to the RSU, which broadcasts it to vehicles traveling southbound on the REL.	P

STEP	ACTION	REQ	EXPECTED RESULT	P/F/I
3	Vehicle 1 continues to approach the Twiggs Meridian intersection coming from the REL (b). Vehicle 2 enters inbound lanes going northbound on the REL (b).		Vehicle 1: WWE safety application issues a “Wrong-Way Vehicle Ahead” warning to the driver per the HMI specification.  Vehicle 2: WWE safety application issues a “Wrong-Way Entry” warning to the driver per the HMI specification. 	P
Test Case UC2 WWE_E				
1	The vehicle is traveling north using the outbound lanes (a).	THEA-UC2-001 THEA-UC2-010 THEA-UC2-011	No warning is shown to the driver.	P
2	The vehicle makes a U-turn and drives south on the inbound lane (b).	THEA-UC2-012 THEA-UC2-016 THEA-UC2-018a THEA-UC2-018b	WWE safety application issues a “No Travel Lane” warning to the driver per the HMI specification. 	P
3	The vehicle continues to travel south on the inbound lane (c).	THEA-UC2-012 THEA-UC2-016 THEA-UC2-018a THEA-UC2-018b	WWE safety application issues a “No Travel Lane” warning to the driver per the HMI specification. 	P
4	Vehicle leaves the inbound lane and proceeds South on Meridian (d).	THEA-UC2-001 THEA-UC2-010 THEA-UC2-011	No warning is shown to the driver.	P

STEP	ACTION	REQ	EXPECTED RESULT	P/F/I
Test Case UC2 WWE_F				
1	A vehicle approaches the intersection traveling eastbound on Twiggs.	THEA-UC2-001 THEA-UC2-010 THEA-UC2-011	No warning is shown to the driver.	P
2	The vehicle turns left and approaches inbound lanes (a).	THEA-UC2-012	WWE safety application issues a “Do Not Enter” warning to the driver per the HMI specification.  	P
3	The vehicle drives north on inbound lanes (b).	THEA-UC2-016 THEA-UC2-018a THEA-UC2-018b	WWE safety application issues a “No Travel Lane” warning to the driver per the HMI specification. 	P
4	The vehicle continues north on the inbound lane (c).	THEA-UC2-016 THEA-UC2-018a THEA-UC2-018b	WWE safety application issues a “No Travel Lane” warning to the driver per the HMI specification. 	P
5	The vehicle makes a U-Turn entering the outbound lane, driving South (d).	THEA-UC2-016 THEA-UC2-018a THEA-UC2-018b	WWE safety application issues a “Wrong Way Entry” warning to the driver per the HMI specification.  	P

STEP	ACTION	REQ	EXPECTED RESULT	P/F/I
6	The vehicle continues South on the outbound lane (e).	THEA-UC2-016 THEA-UC2-018a THEA-UC2-018b	WWE safety application issues a “Wrong-Way Entry” warning to the driver per the HMI specification. 	P
7	The vehicle turns left on to Eastbound Twiggs (f).	THEA-UC2-001 THEA-UC2-010 THEA-UC2-011	No warning is shown to the driver.	P

WWE Test Report

Table 58: WWE Test Report

Test Case	Date:	Anomaly Report	P/I
UC2 WWE_A	3-27-18	1. C: No warnings with security off and on 2. C: WWE TIM - shows up overriding other warnings. 3. C: Goes away after 2-minute timeout on the TIM 4. S: No warnings with security off and on 5. S: WWE TIM - shows overriding other warnings 6. S: Goes away after 2-minute timeout on the TIM 7. X: With security on, no warnings at all, no matter what approach 8. X: Blue screen on the mirror on one of the startups and never switched back to normal screen 9. X Had to restart the car 10. X Showing purple circle sometimes, which is not part of the specification 11. X With the security off on the RSU, the warnings for WWE came on 12. X: WWE TIM- shows but only for 2 seconds and then other warnings show as well (speed) 13. X: Disappears after the 2-minute timeout	I P I I P P I I I I I I P
	4-16-18	Update to vendor software C: All warnings were appropriate S: All warnings were appropriate X: All warnings were appropriate	P P P
	4-25-18	Update to vendor software During the demonstration, it was found that the WWE feature was intermittent on the Sirius XM vehicle. Sometimes it worked, sometimes it did not. THEA-SAF-005 requirement was verified	I

Test Case	Date:	Anomaly Report	P/I
		by safe operation of the vehicle during failure of the OBU function.	
	5-18-18	Update to vendor software The source of the error was found to be an issue that only manifests itself if: 1) The self-reported GPS position accuracy starts "good," becomes "bad," and becomes "good" again, AND 2) Both of the above transitions occur when the vehicle is near the intersection of interest. The issue is caused by code that clears intersection data when the GPS goes from good to bad but does not fully restore the nearby intersection data when GPS becomes good again. The issue clears itself when the vehicle travels to the next intersection, OR the vehicle returns to the intersection after being more than 300 meters away. Note: During the demo, the good → bad → good GPS transition occurred when the vehicle turned around while on the Selmon Expressway. <u>Short term fix</u>: Change the code so that when GPS accuracy goes from good to bad to good while in range of an intersection, the intersection data is restored properly. <u>Long term fix</u>: Change the code so that when GPS accuracy goes from good to bad to good while in range of an intersection, the intersection data is restored properly. Detailed Anomaly Report is included as section 2.3.5.4	P
	6-12-18	Update to vendor software S: (15) runs received DO NOT ENTER, WRONG WAY, audio	P
UC2 WWE_B	3-27-18	Update to vendor software See UC2 WWE_A	I
	4-16-18	Update to vendor software C: All warnings were appropriate S: All warnings were appropriate X: All warnings were appropriate	P P P
	6-12-18	Update to vendor software S: (15) runs received DO NOT ENTER, WRONG WAY, audio	P
UC2 WWE_C	3-27-18	Update to vendor software See UC2 WWE_A	I
	4-16-18	Update to vendor software C: All warnings were appropriate	P P

Test Case	Date:	Anomaly Report	P/I
		S: All warnings were appropriate X: All warnings were appropriate	P
	6-12-18	Update to vendor software S: (15) runs received DO NOT ENTER, WRONG WAY, audio, (6,9) received intermittent color bars unrelated to app operation	P
UC2 WWE_D	3-27-18	Update to vendor software See UC2 WWE_A	I
	4-16-18	Update to vendor software C: All warnings were appropriate S: All warnings were appropriate X: All warnings were appropriate	P P P
UC2 WWE_E	3-27-18	Update to vendor software See UC2 WWE_A	I
	4-16-18	Update to vendor software C: All warnings were appropriate S: All warnings were appropriate X: All warnings were appropriate	P P P
UC2 WWE_F	3-27-18	Update to vendor software See UC2 WWE_A	
	4-16-18	Update to vendor software C: All warnings were appropriate S: All warnings were appropriate X: All warnings were appropriate	P P P

2.3.5.4 Detailed Anomaly Report

The investigation here applies not only to the location accuracy for the correct operation of WWE but also applies to other apps that require lane-specific responses. For example, Red-Light Violation Warning (RLVW) in the New York City pilot requires the vehicle to accurately determine the location either to a lane controlled by a RED signal or to the adjacent lane controlled by a left-turn GREEN arrow. This fault extends to PID safety apps whenever lane location accuracy for safe operation is not provided by the PID. To prevent false positives, we have a GPS quality threshold that must be met for WWE alerts to be generated. This threshold is based on the self-reported GPS position accuracy estimate and is currently set to 3.0 meters (this means that the GPS position is expected to be within three meters of the reported position 95% of the time).

In Figure 29, Figure 30, and Figure 31 below:

- The orange plot is “high” when the vehicle is located in a MAP lane and “low” when the vehicle is not in a MAP lane. The orange plot was created manually by overlaying the GPS track of the vehicle with the MAP lanes and visually determining if the vehicle is located in a lane.
- The red plot is derived from the debug log taken from the vehicle and plots points in time when the software decided that the vehicle was near an intersection but was not in a

lane. When operating properly, the red plot should not be present when the orange plot is "high."

- The blue plot is derived from the debug log taken from the vehicle and plots of the self-reported GPS accuracy.
- The vertical green line indicates when the software decided that GPS accuracy was good, AND we are within 300 meters of a mapped intersection. In this case, we were already within 300 meters of the intersection, but GPS just became good.
- The vertical purple line indicates a second time when the software decided that GPS accuracy was good, AND we are within 300 meters of a mapped intersection.
  In this case, we already had good GPS accuracy, but the vehicle just became within 300 meters of the intersection.
- The red vertical line indicates when the "Do Not Enter" and "Wrong Way" alerts were correctly displayed.
- The vertical blue/gray line in the second and third plot indicate both:
  - o When the self-reported GPS accuracy got above 3.0 meters
  - o And, as a result, the debug log contained an entry "`clearing the Lane Data List in LDM IntersectionData_ as well as vehicular data`"

From this data and analysis of the code, we determined that:

- The internal lane data was cleared when the GPS accuracy became bad (vertical blue/gray).
- The lane data was not fully restored when GPS accuracy became good.
  This explains the "incorrect" areas where the red plot is present when the orange plot is "high") until the unit drove away from the intersection and back.
- The lane data was fully restored at the vertical purple line when the vehicle returned to the intersection after being more than 300 meters away from the intersection.

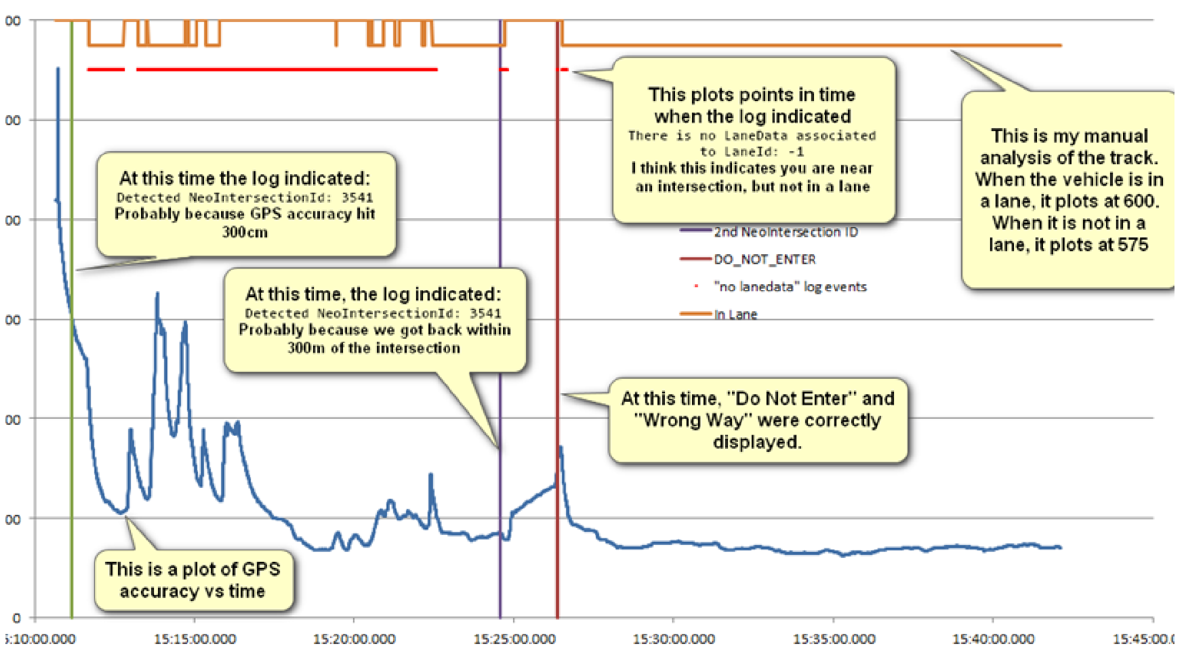


Figure 29: GPS Anomaly Graph 1
Source: Siemens

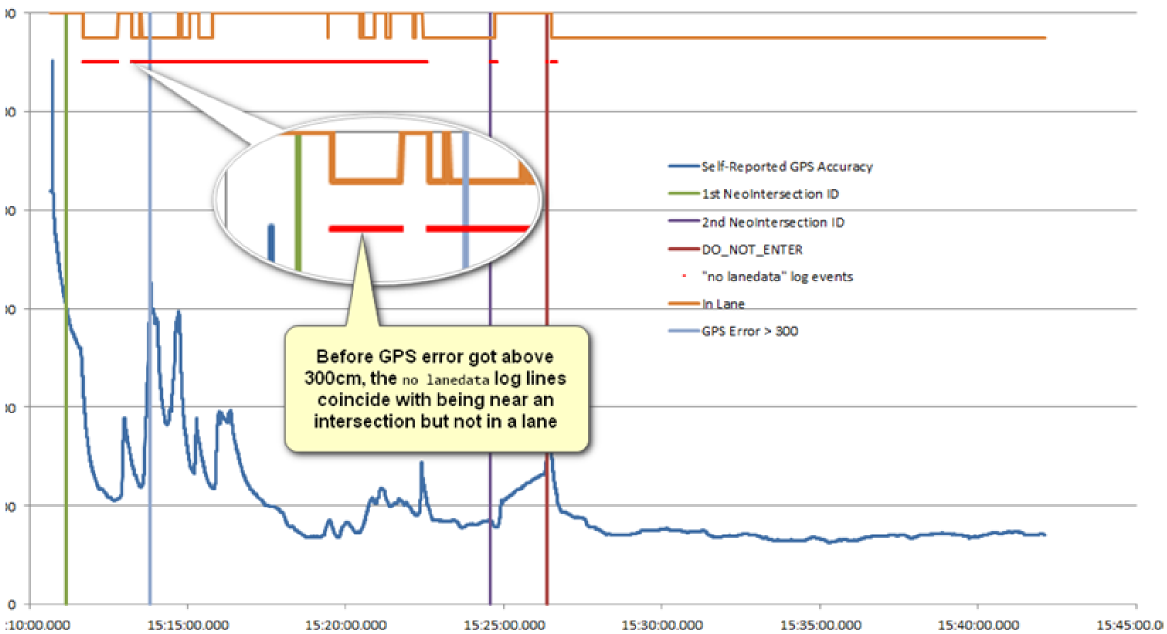


Figure 30: GPS Anomaly Graph 2
Source: Siemens

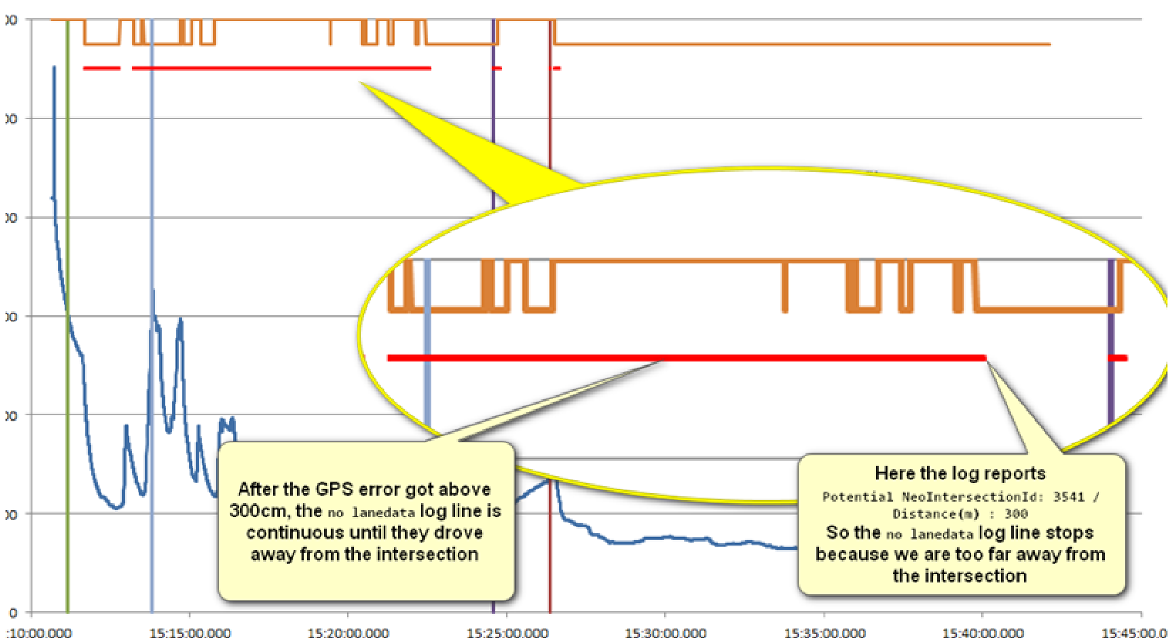
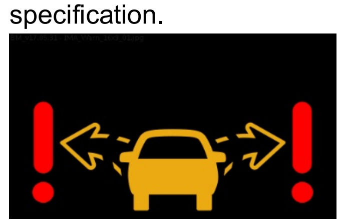


Figure 31: GPS Anomaly Graph 3
Source: Siemens

Executed By:	Witnessed By:	Date:

2.3.5.5 IMA Test Procedures

Table 59: IMA Test Procedures

STEP	ACTION	REQ	EXPECTED RESULT	P/F/I
Test Case UC2 IMA_A				
1	Vehicle 1: Vehicle is approaching intersection driving north (a). Vehicle 2: Vehicle is approaching intersection driving east (a).	THEA-UC2-001 THEA-UC2-003	No warning is shown to the drivers.	P
2	Vehicle 1: Vehicle continues to approach intersection driving north (b). Vehicle 2: Vehicle continues to approach intersection driving east (b).	THEA-UC2-003a	IMA safety application issues an “IMA” warning to both drivers per the HMI specification. 	P

IMA Test Report

Table 60: IMA Test Report

Test Case	Date	Anomaly Report	P/I
UC1 IMA_A	3-28-18	1. Initially worked for all three manufacturers	P
		2. Retested again with Commsignia and SiriusXM	P
		3. X: SiriusXM didn't get IMA on multiple attempts	I
		4. X: SiriusXM worked with Savari	P
	4-16-18	Update to vendor software	P
		1. C: Worked well with other OBUs after calibration	P
		2. S: Worked well with other OBUs after calibration	P
		3. X: Worked well with other OBUs after calibration	

Executed By:	Witnessed By:	Date:

2.3.5.6 SPaT-MAP Test Procedure

Table 61: SPaT-MAP Test Procedure

STEP	ACTION	REQ	EXPECTED RESULT	P/F/I
Test Case: SPaT-MAP				
1	Log SPaT message is broadcast by RSU with the 3M Tester.	THEA-UC2-007	SPaT message can be successfully decoded by COTS Tester.	P
2	Log MAP message broadcast by RSU with the 3M Tester.	THEA-UC2-008	MAP message can be successfully decoded by 3M Tester.	P
3	Convert MAP message to XML and identify lanes flagged as revocable.	THEA-UC2-008b	Lanes on the REL are flagged as revocable; compare with MAP.	P
4	Convert SPaT message to XML and identify enabledLanes contained in the message.	THEA-UC2-008c THEA-UC2-008d	A) Enabled LaneIDs correspond to inbound traffic pattern lanes when gates are closed; Enabled lanes are: 8 – 14 B) Enabled LaneIDs correspond to outbound traffic pattern lanes when gates are open; Enabled lanes are: 15 – 21	P

2.3.5.7 SPaT-MAP Test Report

Table 62: SPaT-MAP Test Report

Test Case	Date	Anomaly Report	P/I
UC2 SPaT-MAP	4-11-18	Opened gate, the controller, did not recognize the gate input as a detector need to set the field in the SPaT message to revoke the lanes. Corrected	I
	4-24-18	Update to vendor software Operated correctly	P

Executed By:	Witnessed By:	Date:

2.3.5.8 *WWE Operational Test Procedures*

Table 63: WWE Operational Test Procedure

STEP	ACTION	REQ	EXPECTED RESULT	P/F/I
Test Case UC2 WWE_Warning				
1	From the traffic controller, the front panel triggers the detector input associated with the wrong-way detection.	THEA-UC2-014 THEA-UC2-015	WWE app status on RSU browser UI shows an active wrong-way entry warning.	P
2	Verify broadcast TIM with the 3M Tester.	THEA-UC2-018a THEA-UC2-018b THEA-UC2-020	WWE TIM is received and logged by the 3M Tester and content matches format for intersection geometry.	P
3	Wait until the duration for TIM broadcast elapsed and verify that TIM stopped being broadcasted.	THEA-UC2-018a THEA-UC2-018b THEA-UC2-020	TIM is no longer received by the 3M Tester.	P

2.3.5.9 *WWE Operational Test Report*

Table 64: WWE Operational Test Report

Test Case	Date	Anomaly Report	P/I
UC2 WWE_Warning	4-10-18	False positives were observed. Sedco technician adjusted the configuration on the radar detector that locates the end of the queue. TIMs received and decoded correctly by OBU. No 3M tester log.	I
	4-17-18	Update to vendor software Worked corrected	P

Executed By:	Witnessed By:	Date:

2.3.6 UC3 Pedestrian Conflicts/Safety

2.3.6.1 UC3 Pedestrian Conflicts/Safety Test Procedures

The UC3 test procedure approach includes the following two Connected Vehicle applications:

- PED-X
- PCW

The purpose of the test is to ensure that the implementation of the two applications fulfills the requirement of UC3.

2.3.6.2 UC3 Pedestrian Conflicts/Safety Test Procedures

2.3.6.2.1 PED-X Test Procedures

2.3.6.3 PED-X Test Procedure

Table 65: PED-X Test Procedure

STEP	ACTION	REQ	EXPECTED RESULT	P/F/I
Test Case UC3 PED-X				
1	Vehicle 1 approaches, passes, and departs the crosswalk in the direction shown.	THEA-UC3-008 THEA-UC3-009 THEA-UC3-011	Master Server logs PSMs from PID1.	P
		THEA-UC3-001 THEA-UC3-002 THEA-UC3-003 THEA-UC3-012 THEA-UC3-015 THEA-UC3-016 THEA-UC3-016a THEA-UC3-016b	PID1 crash alert is logged by the Master Server.	P
2	Vehicle 2 approaches, passes, and departs the crosswalk in the direction shown.	THEA-UC3-008 THEA-UC3-009 THEA-UC3-011	Master Server receives PSM from PID2.	P
		THEA-UC3-001 THEA-UC3-002 THEA-UC3-003 THEA-UC3-012 THEA-UC3-015 THEA-UC3-016 THEA-UC3-016a THEA-UC3-016b	PID2 crash alert is logged by the Master Server.	P

2.3.6.4 PED-X Test Report

Table 66: PED-X Test Report

Test Case	Date	Anomaly Report	P/I
UC3 PED-X	4-12-18	No anomalies	P

Executed By:	Witnessed By:	Date:

2.3.6.4.1 PCW Test Procedures

2.3.6.5 PCW Test Procedures

Table 67: PCW Test Procedures

STEP	ACTION	REQ	EXPECTED RESULT	P/F/I
Test Case UC3 PCW_A				
1	Vehicle 3 approaches, passes, and departs the crosswalk in the direction shown.	THEA-UC3-001 THEA-UC3-002	No PCW alert from OBU.	P
2	Vehicle 4 approaches, passes, and departs the crosswalk in the direction shown.	THEA-UC3-001 THEA-UC3-002	No PCW alert from OBU.	P
Test Case UC3 PCW_B				
1	Vehicle 5 approaches, passes, and departs the crosswalk in the direction shown.	THEA-UC3-003 THEA-UC3-008 THEA-UC3-009 THEA-UC3-011 THEA-UC3-012 THEA-UC3-015 THEA-UC3-016 THEA-UC3-016a THEA-UC3-016b	PCW alert from OBU per the HMI specification. 	P
2	Vehicle 6 approaches, passes, and departs the crosswalk in the direction shown.	THEA-UC3-003 THEA-UC3-008 THEA-UC3-009 THEA-UC3-011 THEA-UC3-012 THEA-UC3-015 THEA-UC3-016 THEA-UC3-016a THEA-UC3-016b	PCW alert from OBU per the HMI specification. 	P
Test Case UC3 PCW_C PCW				
1	PED 7 and Vehicle 7 approach on a crash course.	THEA-UC3-003 THEA-UC3-008 THEA-UC3-009 THEA-UC3-011 THEA-UC3-012 THEA-UC3-015 THEA-UC3-016 THEA-UC3-016a THEA-UC3-016b	PCW alert from OBU per the HMI specification. 	P
Test Case UC3 PCW_D PCW				
1	Vehicle 8 approaches PED 8. PED8 clears the path of Vehicle 8 before arrival.	THEA-UC3-001 THEA-UC3-002	No PCW alert from OBU.	P

2.3.6.6 UC3 PCW Test Report

Table 68: UC3 PCW Test Report

Test Case	Date	Anomaly Report	P/I
UC3 PCW_A	4-13-18	1. C: Alerts not issued as expected 2. S: Alerts not issued as expected 3. X: No results recorded	P P I
	4-16-18	Update to vendor software LiDAR issuing inconsistent PSMs, no OBU results	I
	4-25-17	Update to vendor software Operated corrected at HCC campus parking lot, installation at Courthouse according to permits. Retest for same results.	P
UC3 PCW_B	4-13-18	1. C: Alerts issued when expected 2. S: Alerts not issued when expected 3. X: No results recorded	P I
	4-16-18	Update to vendor software LiDAR issuing inconsistent PSMs, no OBU results	I
	4-25-17	Update to vendor software Operated corrected at HCC campus parking lot, installation at Courthouse according to permits. Retest for same results.	P
UC3 PCW_C	4-13-18	1. C: Alerts issued when expected 2. S: Alerts not issued when expected 3. X: No results recorded	P I
	4-16-18	Update to vendor software LiDAR issuing inconsistent PSMs, no OBU results	I
	4-25-17	Update to vendor software Operated corrected at HCC campus parking lot, installation at Courthouse according to permits. Retest for same results.	P
UC3 PCW_D	4-13-18	1. C: Alerts not issued as expected 2. S: Alerts not issued as expected 3. X: No results recorded	P P
	4-16-18	Update to vendor software LiDAR issuing inconsistent PSMs, no OBU results	I
	4-25-18	Update to vendor software Operated corrected at HCC campus parking lot, installation at Courthouse according to permits. Retest for same results.	P

Executed By:	Witnessed By:	Date:

2.3.7 UC4 Transit Signal Priority

2.3.7.1 UC4 Transit Signal Priority Test Procedures

Table 69: UC4 TSP Test Procedure

STEP	ACTION	REQ	EXPECTED RESULT	P/F/I
Test Case UC4 TSP_A				
1	Stop vehicle is north of the intersection on Marion Street pointing south. Wait until signal head turns green, wait eight more seconds, and then drive slowly towards the intersection.	THEA-UC4-001 THEA-UC4-002	Vehicle OBU starts broadcasting SRM and SRM is received by RSU as verified on RSU monitor screen (and/or using 3M Tester). Driver HMI is dark. 	P
2	Monitor driver HMI for SSM status to show priority granted.	THEA-UC4-004 THEA-UC4-005 THEA-UC4-007 THEA-UC4-008 THEA-UC4-009 THEA-UC4-013	Driver HMI shows priority granted per the HMI specification. 	P
3	Drive vehicle southbound through the intersection on green.	THEA-UC4-001 THEA-UC4-002	After passing through the intersection, the driver HMI goes dark again.	P
4	As the vehicle is approaching the stop bar, monitor the controller input from the traffic controller front panel and verify that the controller holds Phase 2 green longer than the minimum green time (green extension).	THEA-UC4-008 THEA-UC4-009	Controller input screen shows phase call and/or hold applied to Phase 2.	P
Test Case UC4 TSP_B				

STEP	ACTION	REQ	EXPECTED RESULT	P/F/I
1	Stop vehicle north of the intersection on Marion Street pointing south. Wait until signal head turns green, wait eight more seconds, and then drive slowly towards the intersection.	THEA-UC4-001 THEA-UC4-002	Vehicle OBU starts broadcasting SRM and SRM is received by RSU as verified on RSU monitor screen (and/or using 3M Tester). Driver HMI is dark. 	P
2	Monitor driver HMI for SSM status to make sure that priority isn't granted.	THEA-UC4-004 THEA-UC4-005	Driver HMI stays dark. 	P
3	Stop the vehicle at the red light.	THEA-UC4-001 THEA-UC4-002	Southbound signal turns yellow after 10 seconds of total green time, then turns red.	P
4	As the vehicle is approaching the stop bar, monitor the controller input from the traffic controller front panel and verify that the controller terminates Phase 2 green after the minimum green time elapsed.	THEA-UC4-008 THEA-UC4-009	Controller input screen shows no phase call or holds applied to Phase 2.	P
Test Case UC4 TSP_C				
1	Query current bus status from OneBusAway server and open in the text editor.	THEA-UC4-004	Use the schedule deviation value for each bus to compare with NextConnect internal data displayed in NextConnect Explorer.	P
2	Open the NextConnect Explorer UI and display the bus schedule adherence-status list.	THEA-UC4-004	Compare the displayed schedule adherence status with the content of the schedule deviation field in a text editor and verify that the values match.	P

STEP	ACTION	REQ	EXPECTED RESULT	P/F/I
3	Repeat steps 1 – 2 at a later time during the day.	THEA-UC4-004	Verify that the schedule deviation values returned from the OneBusAway server changed for at least one bus. Verify that internal data in NextConnect matches the updated values.	P

2.3.7.2 UC4 TSP Test Report

Table 70: UC4 TSP Test Report

Test Case	Date	Anomaly Report	P/I
UC4 TSP_A	3-29-18	1. From the OBU, confirmed that SRM was sent and SSM received without live signal timing 2. From the OBU, confirmed that SRM was sent and SSM received with live signal timing 3. Commenced test, OBU showed exclamation point and had to be restarted 4. From the OBU, confirmed that SRM was sent and SSM received with live signal timing 5. Priority showed on the HMI 6. Priority on HMI did not show long enough 7. From RSU side, TSP did not generate a signal extension	P P I P P I I
	4-16-18	Update to vendor software 1. Confirmed that OBU is sending SRMs 2. TSP only ran on first TSP request, corrected to run on all TSP updates 3. TSP rarely sends SSMs	P P I
	4-20-18	Update to vendor software 1. Missing SSMs were resolved a. OBUs were fixed to reliably send SSMs b. MMITSS was fixed to run reliably	hP
UC4 TSP_B	3-29-18	Update to vendor software Same anomalies as UC4 TSP_A above affected UC4 TSP_B	I
	4-16-18	Update to vendor software Same anomalies as UC4 TSP_A above affected UC4 TSP_B	I
	4-20-18	Update to vendor software	P

Test Case	Date	Anomaly Report	P/I
		Same anomalies as UC4 TSP_A above affected UC4 TSP_B	
UC4 TSP_C		Update to vendor software OneBusAway interface testing scheduled to be completed by 6-30-2018	P
	6-13-18	Update to vendor software OneBusAway interface testing successful	P

Executed By:	Witnessed By:	Date:

2.3.7.3 PTMW Test Procedure

Table 71: PTMW Test Procedures

STEP	ACTION	REQ	EXPECTED RESULT	P/F/I
Test Case UC4 PTMW				
1	Bus approaches the intersection (a).	THEA-UC5-011	Pedestrian: Receives warning on PID that bus in the area is approaching.	P
2	Bus stops at an intersection (b).	THEA-UC5-011	Pedestrian: Receives no warning on PID that bus in the area has stopped driving.	P
3	Bus continues through the intersection (c).	THEA-UC5-012	Pedestrian: Receives warning on PID that bus in the area has started driving.	P

2.3.7.4 PTMWTest Report

Table 72: PTMWTest Report

Test Case	Date	Anomaly Report	P/I
UC4 PTMW	4-16-18	PTMW application tested and worked correctly. During several weeks of testing, the Wi-Fi connection was observed to be running at differing speeds, sometimes observed to suspend and resume. Agreed to add Wi-Fi anomaly to ongoing RSU stability testing, not an app anomaly.	P
	4-24-18	Update to vendor software The PTMW demonstrated at Meridian/Whiting provided the correct alerts, but that location is outside of the TSP bus route.	I

Test Case	Date	Anomaly Report	P/I
		Investigation indicates that the geofence was not active for the demo at that location. Geofence activated prevents triggers outside of the geofence.	P

Executed By:	Witnessed By:	Date:

2.3.8 UC5 Street Conflicts

2.3.8.1 UC5 Street Conflict Tests

The UC5 test procedure approach includes the following two Connected Vehicle applications:

- VTRFTV
- PTMW

The purpose of the test is to ensure that the implementation of the two applications fulfills the requirement of UC5.

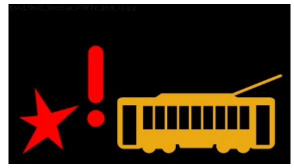
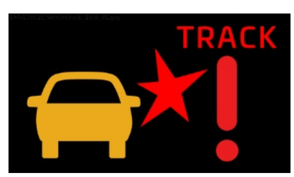
2.3.8.2 UC5 Street Conflicts Test Procedures

2.3.8.2.1 VTRFTV Test Procedures

2.3.8.3 VTRFTV Test Procedures

Table 73: VTRFTV Test Procedures

STEP	ACTION	REQ	EXPECTED RESULT	P/F/I
Test Case UC5 VTRFTV_A				
1	Vehicle 1 starts driving parallel to the streetcar. Both are going eastbound.	THEA-UC5-007 THEA-UC5-007a	Vehicle 1: No warning is shown to the driver. Streetcar: No warning is shown to the streetcar operator.	P

STEP	ACTION	REQ	EXPECTED RESULT	P/F/I
2	Vehicle 1 turns on its right-turn blinker.	THEA-UC5-008 THEA-UC5-008a	Vehicle 1: VTRFTV safety application issues a “Streetcar” pre-warning to the driver per the HMI specification.  Streetcar: VTRFTV safety application issues a “Vehicle on track” pre-warning to the streetcar operator per the HMI specification. 	P
3	Vehicle 1 begins the right turn in front of a streetcar.	THEA-UC5-008 THEA-UC5-008a	Vehicle 1: VTRFTV safety application issues a “Streetcar” warning to the driver per the HMI specification.  Streetcar: VTRFTV safety application issues a “Vehicle on track” warning to the streetcar operator per the HMI specification. 	P
Test Case UC5 VTRFTV_B				

STEP	ACTION	REQ	EXPECTED RESULT	P/F/I
1	Vehicle 1 starts driving parallel to the streetcar. Both are going eastbound.	THEA-UC5-007 THEA-UC5-007a	Vehicle 1: No warning is shown to the driver. Streetcar: No warning is shown to the streetcar operator.	P
2	Vehicle 1 continues going straight.	THEA-UC5-007 THEA-UC5-007a	Vehicle 1: No warning is shown to the driver. Streetcar: No warning is shown to the streetcar operator.	P

2.3.8.4 VTRFTV Test Report

Table 74: VTRFTV Test Report

Test Case	Date	Anomaly Report	P/I
UC5 VTRFTV_A	3-21-18	Savari implemented two levels of warnings. Worked in logs but not with mirror yet SiriusXM works most of the time but collected debug logs to figure out	I I
	4-16-18	Update to vendor software All warnings worked correctly	P
	4-25-18	All warnings worked correctly	P
UC5 VTRFTV_B	4-16-18	Comsignia had a warning come on without turn signal indicated whenever close to the streetcar.	I
	4-25-18	Update to vendor software Worked as expected	P
	6-13-18	1. S: Run (1), Not moving, turn signal – No alerts 2. S: Runs (2-4), Moving, turn signal – Appropriate alerts 3. S: Run (5), Not moving, no turn signal – No alerts 4. X: Run (1), Not moving, turn signal – No alerts 5. X: Rus (2-4) Moving, turn signal – Appropriate alerts	P P P P P

Executed By:	Witnessed By:	Date:

2.3.8.4.1 PTMW Test Procedure

2.3.8.5 PTMW Test Procedure

Table 75: PTMW Test Procedure

STEP	ACTION	REQ	EXPECTED RESULT	P/F/I
Test Case UC5 PTMW				
1	Streetcar approaches.	THEA-UC5-005	Pedestrian receives a warning of streetcar approaching in the area.	P
1	Vehicle 1 and the streetcar are stopped with streetcar doors open (a and c).	THEA-UC5-005	Pedestrian receives warning on PID of a stopped streetcar in the area.	P
2	Vehicle 1 starts driving parallel to the streetcar while streetcar closes doors and both travel eastbound.	THEA-UC5-006	Pedestrian: Receives warning on PID that streetcar in the area started driving.	P
3	Vehicle 1 turns on its right-turn blinker.	THEA-UC5-008b THEA-UC5-009 THEA-UC5-009a THEA-UC5-009c	Pedestrian: Receives a VTRFTV warning.	P
4	Vehicle 1 begins the right turn in front of the streetcar.	THEA-UC5-008b THEA-UC5-009 THEA-UC5-009a THEA-UC5-009c	Pedestrian: Receives a VTRFTV warning.	P

2.3.8.6 PTMWTest Report

Table 76: PTMWTest Report

Test Case	Date	Anomaly Report	P/I
UC5 PTMW	4-16-18	PTMW application tested and worked correctly. During several weeks of testing, the Wi-Fi connection was observed to be running at differing speeds, sometimes observed to suspend and resume. Agreed to add Wi-Fi anomaly to ongoing RSU stability testing, not an app anomaly.	P

Executed By:	Witnessed By:	Date:

2.3.9 UC6 Traffic Progression

2.3.9.1 UC6 Traffic Progression Test Procedure

2.3.9.1.1 I-SIG Test Procedure

Table 77: UC6 I-SIG Test Procedure

STEP	ACTION	REQ	EXPECTED RESULT	P/F/I
Test Case UC6 I-SIG				
1	Check RSU monitor for received BSMs.	THEA-UC6-006	BSMs are being received by RSU.	P
2	Check MMITSS Controller for status.	THEA-UC6-008a	MMITTS status is “Enabled,” and MMITSS services are “Active.”	P
3	A Master Server view stored queue length estimates and delays from MMITSS.	THEA-UC6-008a	Queue length estimates and delays for all approaches for both intersections are contained in data logs.	P

Table 78: UC6 I-SIG Test Report

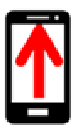
Test Case	Date	Anomaly Report	P/I
UC6 I-SIG	4/17/2018	MMITSS services suspended during the test. Discovered array out of bounds errors in MMITSSS, would access memory addresses that were not allocated to MMITSS. Corrected in MMITSS software.	I
	4/23/2018	Update to vendor software. MMITSS operated correctly.	P

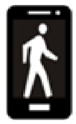
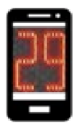
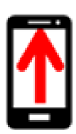
Executed By:	Witnessed By:	Date:

2.3.9.1.2 PED-SIG Test Procedures

Table 79: PED-SIG Test Procedures

STEP	ACTION	REQ	EXPECTED RESULT	P/F/I
Test Case UC6 PED-SIG_A				

STEP	ACTION	REQ	EXPECTED RESULT	P/F/I
1	Position pedestrian facing north/south lanes.	THEA-UC6-018 THEA-UC6-018b THEA-UC6-018c THEA-UC6-018d THEA-UC6-018e THEA-UC6-018f THEA-UC6-018g	Pedestrian presence has no effect on CU control.	P
2	Align PID parallel to the sidewalk, pointed towards the crosswalk. 	THEA-UC6-018	Pedestrian presence has no effect on CU control.	P
3	Press PID screen to request WALK service. 	THEA-UC6-018 THEA-UC6-018b THEA-UC6-018c THEA-UC6-018d THEA-UC6-018e	CU Active Screen displays WALK CALL service request for that crosswalk.	P
4	Observe PID screen, pedestrian signal, and CU Active Status screen. 	THEA-UC6-018 THEA-UC6-018b THEA-UC6-018c THEA-UC6-018d THEA-UC6-018e	DON'T WALK phase for that crosswalk is displayed on PID screen, pedestrians signal, and CU Active Status screen. PID emits a haptic indication of DON'T WALK phase.	P

STEP	ACTION	REQ	EXPECTED RESULT	P/F/I
5	Observe PID screen, wait to observe pedestrian signal and CU Active Status screen. 	THEA-UC6-018 THEA-UC6-018b THEA-UC6-018c THEA-UC6-018d THEA-UC6-018e	WALK phase for that crosswalk is displayed on PID screen, WALK signal, and CU Active Status screen. PID emits a haptic indication of WALK phase.	P
6	Observe PID screen, pedestrian signal, and CU Active Status screen. 	THEA-UC6-018f THEA-UC6-018g	Pedestrian service is extended if supported by the CU. In this particular installation, the CU does not support extended service.	P
Test Case UC6 PED-SIG_B				
1	Position pedestrian facing east/west lanes.	THEA-UC6-018 THEA-UC6-018b THEA-UC6-018c THEA-UC6-018d THEA-UC6-018e THEA-UC6-018f THEA-UC6-018g	Pedestrian presence has no effect on CU control.	P
2	Align PID parallel to the sidewalk, pointed towards the crosswalk. 	THEA-UC6-018	Pedestrian presence has no effect on CU control.	P
3	Press PID screen to request WALK service. 	THEA-UC6-018 THEA-UC6-018b THEA-UC6-018c THEA-UC6-018d THEA-UC6-018e	CU Active Screen displays WALK CALL service request for that crosswalk.	P

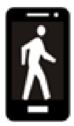
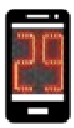
STEP	ACTION	REQ	EXPECTED RESULT	P/F/I
4	Observe PID screen, pedestrian signal, and CU Active Status screen. 	THEA-UC6-018 THEA-UC6-018b THEA-UC6-018c THEA-UC6-018d THEA-UC6-018e	DON'T WALK phase for that crosswalk is displayed on PID screen, pedestrians signal, and CU Active Status screen. PID emits a haptic indication of DON'T WALK phase.	P
5	Observe PID screen, pedestrian signal, and CU Active Status screen. 	THEA-UC6-018 THEA-UC6-018b THEA-UC6-018c THEA-UC6-018d THEA-UC6-018e	WALK phase for that crosswalk is displayed on PID screen, WALK signal, and CU Active Status screen. PID emits a haptic indication of WALK phase.	P
6	Observe PID screen, pedestrian signal, and CU Active Status screen. 	THEA-UC6-018f THEA-UC6-018g	Pedestrian service is extended if supported by the CU. In this particular installation, the CU does not support extended service.	P

Table 80: UC6 PED-SIG Test Report

Test Case	Date	Anomaly Report	P/I
UC6 PED-SIG_A	4-16-18	PED-SIG application tested and worked correctly. During several weeks of testing, the Wi-Fi connection was observed to be running at differing speeds, sometimes observed to suspend and resume. Agreed to add Wi-Fi anomaly to ongoing RSU stability testing, not an app anomaly.	P
UC6 PED-SIG_B	4-16-18	PED-SIG application tested and worked correctly. During several weeks of testing, the Wi-Fi connection was observed to be running at differing speeds, sometimes observed to suspend and resume. Agreed to add Wi-Fi anomaly to ongoing RSU stability testing, not an app anomaly.	P

Executed By:	Witnessed By:	Date:

3. Operational Readiness Demonstration Plan

3.1 Objectives

The Operational Readiness Demonstration Plan (ORDP) is the second part of the Operational Readiness Plan (ORP) with the Operational Readiness Test Plan (ORTP) being the first part of the ORP. The ORDP consists of a series of coordinated demonstrations, including participants, to ensure the operational readiness of the system. The objectives of these activities are to demonstrate the deployed system operates as designed in a safe and secure manner. The ORDP is designed and conducted by the Tampa Hillsborough Expressway Authority (THEA) team for the United States Department of Transportation (USDOT) to demonstrate that the system substantially performs according to the System Requirements. THE ORDP will be executed following the successful execution of the ORTP by the THEA team. The ORTP results will be shared with USDOT before the execution of the ORDP.

Demonstration objectives include:

- Exhibit a set of selected integrated, end-to-end system capabilities central to the deployment Concept of Operations and key use cases.
- Conduct the demonstration as a set of live, real-time activities for the Agreement Officer Representative (AOR) and federal team, wherein success and failure of the demonstration are directly observable.

Within the THEA project workflow, the ORDP occurs at Level 5 of the V-model following successful ORTP of Level 4 as shown in Figure 1, which appeared in the Comprehensive Deployment Plan and was presented during the April 20, 2017, Operational Readiness Briefing webinar.

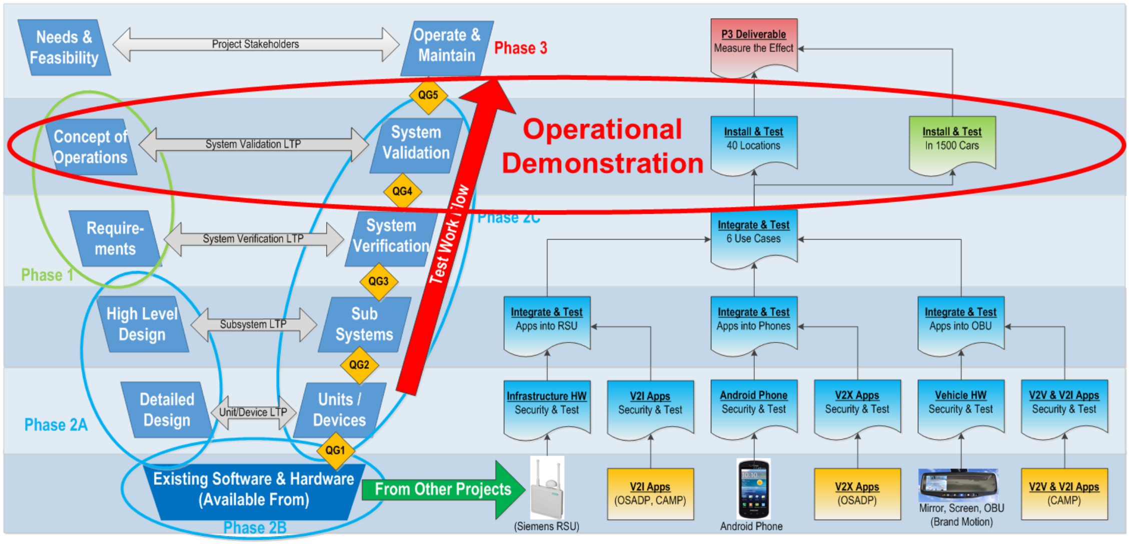


Figure 32: Level 5: Operational Demonstration
Source: Siemens

The high-level objective of the ORDP is not to demonstrate the effectiveness of each CV application, but rather to demonstrate the system's ability to support the evaluation of CV applications by the researchers during Phase 3 of the project. For example, a successful ORDP will note ineffective CV applications in need of further evaluation and improvement during Phase 3 or unsafe applications abandoned and not deployed. ORP execution serves as input to QG5 by the CCB independently.

The objectives in the tables below are organized according to and traceable from the Concept of Operations (ConOps) document and were presented during the April 20, 2017, Operational Readiness Briefing webinar.

3.1.1 Objective 1: CV Infrastructure Deployment

Table 81: Objective 1- CV Infrastructure Deployment

ConOps Goals	Readiness Demonstration
1. Develop and Deploy Connected Vehicle (CV) Infrastructure to Support the Applications Identified During Phase 1.	
Deploy Dedicated Short-Range Communications (DSRC) technologies to support Vehicle-to-Vehicle (V2V), Vehicle-to-Infrastructure (V2I), and Vehicle-to-Everything (V2X) apps.	Demonstrate deployed Roadside Units (RSUs) per Specification v4.1. Demonstrate RSU communications to Personal Information Devices (PIDs). Demonstrate Onboard Units (OBUs) per Requirements Specification. Demonstrate Pedestrian in a Signalized Crosswalk (PED-X) Wi-Fi to DSRC message translation.

ConOps Goals	Readiness Demonstration
Enhance Traffic Management Center (TMC) software to ensure compatibility with CV apps.	Demonstrate TMC current situation and capabilities. Demonstrate TMC added CV capabilities.
Recruit a fleet of transit and private vehicle owners and individuals carrying V2X-enabled mobile devices to participate in the CV Pilot by installing and using CV technology offered in the Pilot.	Demonstrate private vehicles operated by their owners. Demonstrate a transit vehicle operated by HART. Demonstrate V2X-enabled PIDs carried by individuals.

3.1.2 Objective 2: Improve Central Business District Mobility

Table 82: Objective 2- Improve CBD Mobility

ConOps Goals	Readiness Demonstration
2. Improve Mobility in the Central Business District (CBD).	
Replace existing traffic controllers and control systems at key intersections with intelligent-signal CV technology to improve traffic progression at identified problem areas.	Demonstrate controllers conforming to National Transportation Communication for ITS (Intelligent Transportation System) Protocol (NTCIP) 1202 v2. Demonstrate conformance to USDOT V2I Hub Interface Control Document (ICD). Replacement of non-conforming controllers occurred before ORD.
Provide Transit Signal Priority (TSP) applications to help Hillsborough Area Rapid Transit (HART) buses stay on a predictable schedule.	Demonstrate TSP Priority is issued if behind schedule. Demonstrate TSP Priority is not issued if on schedule.
Provide informational messages to pedestrians of a bus starting/stopping.	Demonstrate the bus approach warning. Demonstrate the bus departure warning.

3.1.3 Objective 3: Reduce Safety Incidences

Table 83: Objective 3- Reduce Safety Incidences

ConOps Goals	Readiness Demonstration
3. Reduce the Number of Safety Incidents within the Pilot Area.	
Provide detection of pedestrians and warnings to drivers of potential pedestrian conflicts.	Demonstrate driver warning: pedestrian is in the crosswalk. Demonstrate no driver warning: pedestrian is on the curb. Demonstrate driver warning: pedestrian approaches crosswalk. Demonstrate no driver warning: pedestrian clears crosswalk.
Provide detection of potential vehicle conflicts and warnings to pedestrians.	Demonstrate pedestrian warning logged for researchers. Demonstrate pedestrian warning not presented to pedestrians.
Provide early detection of wrong-way drivers and issue warnings to wrong-way drivers and upstream motorists.	Demonstrate DO NOT ENTER alert on approach. Demonstrate WRONG WAY warning on entry. Demonstrate CRASH warning to an oncoming vehicle. Demonstrate WRONG WAY incident logged at TMC. Demonstrate WRONG WAY of unequipped vehicle. Demonstrate Intersection Movement Assist (IMA) for U-Turn vehicle.
Give drivers warnings of the Reversible Express Lane (REL) exit curve and stopped vehicles ahead.	Demonstrate no warnings with a normal queue. Demonstrate lower speed warning with a long queue. Demonstrate electronic brake warning for hard braking. Demonstrate Forward Collision Warning (FCW) if overtaking.
Provide detection and warning of potential conflicts between streetcar, vehicles and autos, and pedestrians/bicycles.	Demonstrate approach warning to pedestrians. Demonstrate no warnings while streetcar is stopped. Demonstrate departure warning to pedestrians. Demonstrate no vehicle warnings while streetcar is stopped. Demonstrate no right turn warning at streetcar startup. Demonstrate vehicle turning right to streetcar operator.
Provide informational messages to pedestrians of a streetcar starting/stopping.	Demonstrate the bus approach warning. Demonstrate the bus departure warning.

3.1.4 Objective 4: Reduce Environmental Impacts

Table 84: Objective 4- Reduce Environmental Impacts

ConOps Goals	Readiness Demonstration
4. Reduce Environmental Impacts within the Pilot Area.	
Provide CV Mobility and Safety applications to improve overall mobility and reduce stops and idle time within the CBD, thus reducing emissions.	Demonstrate "before" data from Centracs, including: - Stops on GREEN. - Travel time. Demonstrate "after" data collected from Centracs. Demonstrate concert correlation to emissions savings.
Provide TSP applications to reduce idle time of HART buses.	Demonstrate TSP to reduce bus delays in traffic.

3.1.5 Objective 5: Improve Agency Efficiency

Table 85: Objective 5- Improve Agency Efficiency

ConOps Goals	Readiness Demonstration
5. Improve Agency Efficiency.	
Improve traffic data collection capability, reducing the costs of collecting data.	Demonstrate Basic Safety Messages (BSMs) vehicle counts for traffic volume. Demonstrate BSMs average speeds. Demonstrate BSMs travel time. Demonstrate BSM travel time to Bluetooth travel time.
Reduce the number of incidents and police and rescue responses to incidents.	Demonstrate logs of crash avoidance alerts and warnings.
Reduce crashes and time agencies take to gather data.	Demonstrate logs of BSMs leading up to warnings.
Improve technology for crash statistics gathering.	Demonstrate logs of crash alerts and warnings.
Improve scheduling and dispatching of HART vehicles with improved trip times and vehicle information.	Demonstrate central access to scheduling. Demonstrate automated bus authentication.
Reduce overhead of THEA responding to wrong-way entries and crashes on REL exit ramp.	Demonstrate automated collection of wrong-way alerts.

3.1.6 Objective 6: Business Environment for Sustainability

Table 86: Objective 6- Business Environment

ConOps Goals	Readiness Demonstration
6. Develop Business Environment for Sustainability.	
Work with Collision Avoidance Metrics Partnership (CAMP), Original Equipment Manufacturers (OEMs), and third-party developers to develop business cases for advancing CV-ready vehicles.	Demonstrate FCW Level 3 Test Plans shared with CAMP. Demonstrate BSMs speeds and travel time data for sale.
Work with industry sectors that will benefit from CV implementation, e.g., insurance carriers, fleet managers, safety organizations, etc., to provide education on the benefits and seek support for the advancement of the system.	Demonstrate to insurance, fleets, etc. during Florida AVCV Summit before ORD.
Work with Chambers of Commerce and other business organizations to educate members on the return on investment from increased mobility.	Demonstrate to local business organizations during Florida AVCV Summit before ORD.
Work with state and local Government to encourage positive legislation and funding in support of CV technology.	Demonstrate to state, local agencies, emergency district during Florida AVCV Summit prior to ORD.

3.2 Demonstration Action Preview

Actions to be taken within the demonstration to illustrate the successful deployment of key use cases.

Table 87: Use Case Demonstration Action Preview

#	Use Case	Demonstration Actions
1	Wrong-Way Entry	Drive test vehicle outbound on the inbound lanes. Drive the test vehicle on closed lanes. Drive a test vehicle towards violator test vehicle. Drive a test vehicle on a perpendicular path to another test vehicle.
2	Morning Backup	Drive a test vehicle towards a short queue at different speeds.

#	Use Case	Demonstration Actions
		Drive a test vehicle towards a long queue at different speeds.
3	Streetcar Conflicts	Drive a test vehicle right in front of a stopped streetcar. Drive a test vehicle right in front of a moving streetcar.
4	Transit Signal Priority	Drive a bus behind schedule towards a TSP intersection.
5	Pedestrian Safety	Drive a test vehicle towards a pedestrian who will clear the crosswalk. Drive a test vehicle towards a pedestrian who will be in the crosswalk.
6	Traffic Progression	Drive test vehicles through the equipped intersection.
7	Agency Data	Drive test vehicles through RSU range to collect counts and speeds.

3.3 Operational Readiness Demonstration Workflow

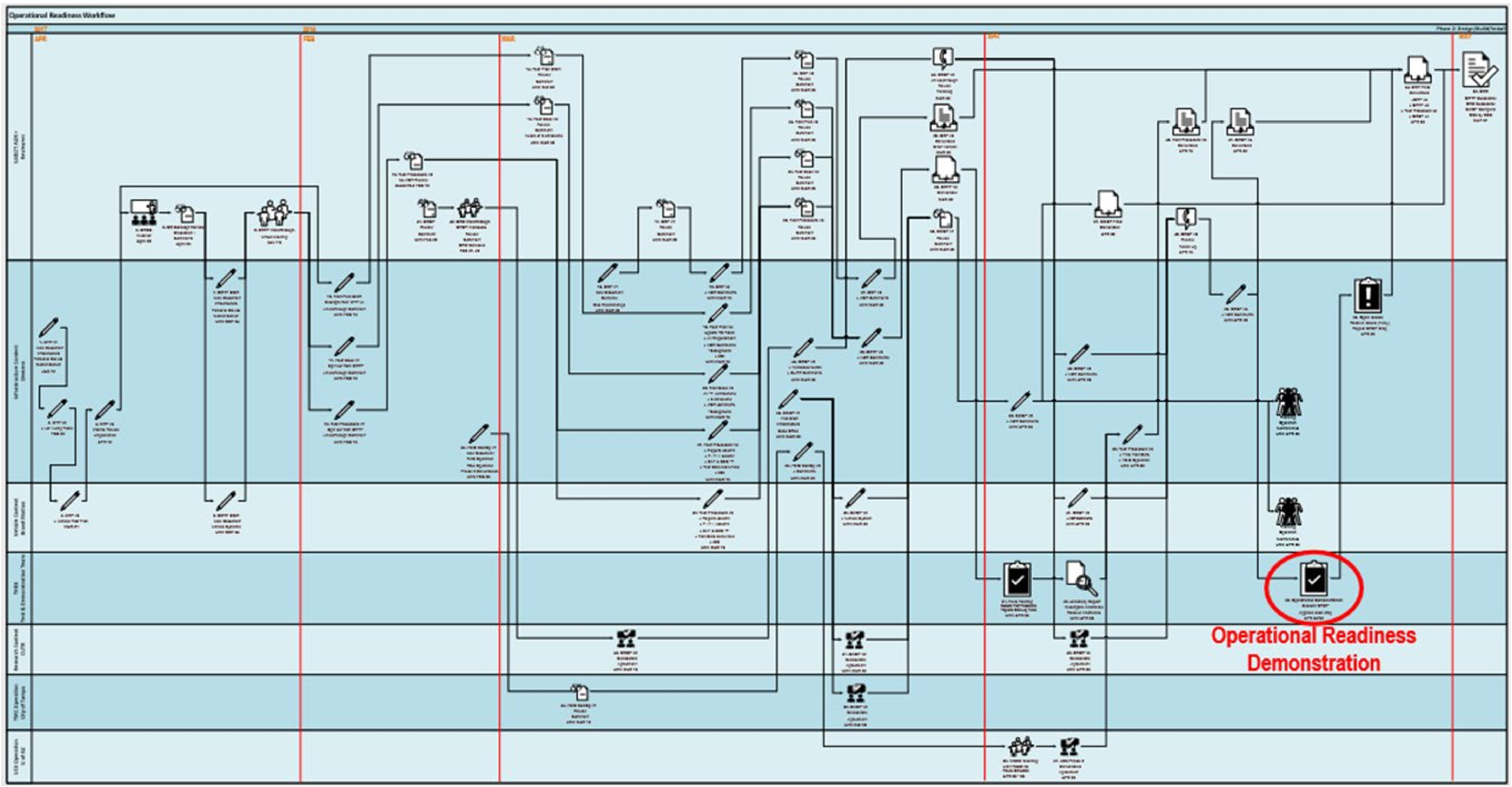


Figure 33: ORD Within the Overall Operational Readiness Workflow
Source: Siemens

3.4 Use Case Demonstration Procedures

This section is the bound hardcopy of the Operational Demonstration Procedures used by the AOR and Observer present during the Operational Readiness Demonstration conducted in Tampa, Florida, on May 24-25, 2018, with amendments agreed by AOR:

- The WWE p.m. MAP demonstration pages of the bound copies are removed here since the demonstration was conducted in the morning with the REL entrance barriers down while executing the a.m. MAP.
- The pedestrian actions of streetcar conflicts of the bound copies are removed here, as no pedestrians participated in the demonstration as a safety measure. The steps were tested at the streetcar shop without public participation.
- The table numbers of the bound copies began with Table 1 but are contiguous with the ORP here.

The Demonstration Procedure template of Table 88 describes the sequence of events demonstrated, along with the observable validation criteria associated with the overall purpose of the demonstration. In the descriptions:

- Demonstration ID is a significant alphanumeric of the use case number and the demonstration number. For example, UC1D1 identifies the first demonstration of Use Case 1.
- Purpose states the reason, subsystem, and operation of the demonstration.
- Test Cases lists the traceability from demonstration to test cases, limited to those requirements verified by “T.”
- Requirements list the traceability from demonstration to requirements for all requirements, which are verified by “T,” “D,” and “I.”
- Demonstrators identify the representative of the organization conducting the demonstration, which will be the owner/operators of the system during project Phase 3 and has received system operational training.

- Facilitator identifies a representative of the organization that designed and built the portion of the system being demonstrated. The role of the facilitator is addressing questions in the context of the System Design Document (SDD).
- Observer identifies the USDOT AOR and reviewers present during the demonstrations.
- Observer Experience describes the demonstration from the viewpoint of the observers.
- Expectation describes the system response to the demonstration actions.
- Demonstration Site View depicts the view seen by the observers.
- Demonstration Site Location depicts the location on the map of the study area as well as the location of the demonstration if different from the study area.

The Demonstration Action table follows each scene containing the Use Case number, Demonstration Step number, Demonstration Action for each step, Expected Result, and checklist for PASS/FAIL/PARTIAL plus notes by Observer.

Table 88: Demonstration Scenes

Use Case 1: ***Demonstration ID: AAnAn*** Purpose: Test Cases: Requirements: Demonstrators: Facilitators: Observer Experience: Expectation:	Demonstration Site View: Demonstration Site Location:

Table 89: UC1D1 Scene

Use Case 1: Morning Backup

Demonstration 1: End of Ramp Deceleration Warning (ERDW) application

Purpose: Demonstrate the change in location of deceleration warnings as a function of queue backing up from Twiggs/Meridian onto the REL.

Test Cases: UC1 ERDW_A, UC1 ERDW_B

Requirements: THEA-002, THEA-UC1-022, THEA-UC1-023, THEA-UC1-024, THEA-UC1-025, THEA-UC1-026a

Demonstrator: Phase 3 Participant Driver

Facilitator: Brand Motion

Observer Experience:

Observers ride in a participant vehicle equipped with a mirror HMI. A vehicle travels inbound from the Selmon Expressway via the closed REL towards the live signalized intersection of Twiggs/Meridian, representing the morning map. The observers note the MUTCD R2-1 speed limit signs installed at the roadside as well as the visible and audible operation of the HMI while traveling the complete length of the REL. A safety cone is set on the right shoulder of the closed REL, representing the last car of the intersection queue if the REL was open to live traffic. Without live traffic, the queue length is manually adjusted as either normal or longer from I-SIG running at Twiggs/Meridian. Two demonstration runs:

- Run 1: Cone is set at a short distance from the stop bar, representing the last vehicle in a normal queue for the posted speed reduction.
- Run 2 Cone is set at a longer distance from the stop bar, representing the last vehicle in a morning queue extending beyond speed reduction

Expectation:

- Run 1, short queue:
  - White speed limit sign matches the HMI speed limit (white) graphic alert location.
  - Speed advice (yellow) graphic alert is issued at a distance before the cone location.
- Run 2, long queue:
  - Speed limit sign matches the HMI speed limit (white) graphic alert location.
  - Speed advice (yellow) graphic alert issued at a distance before the new cone location.

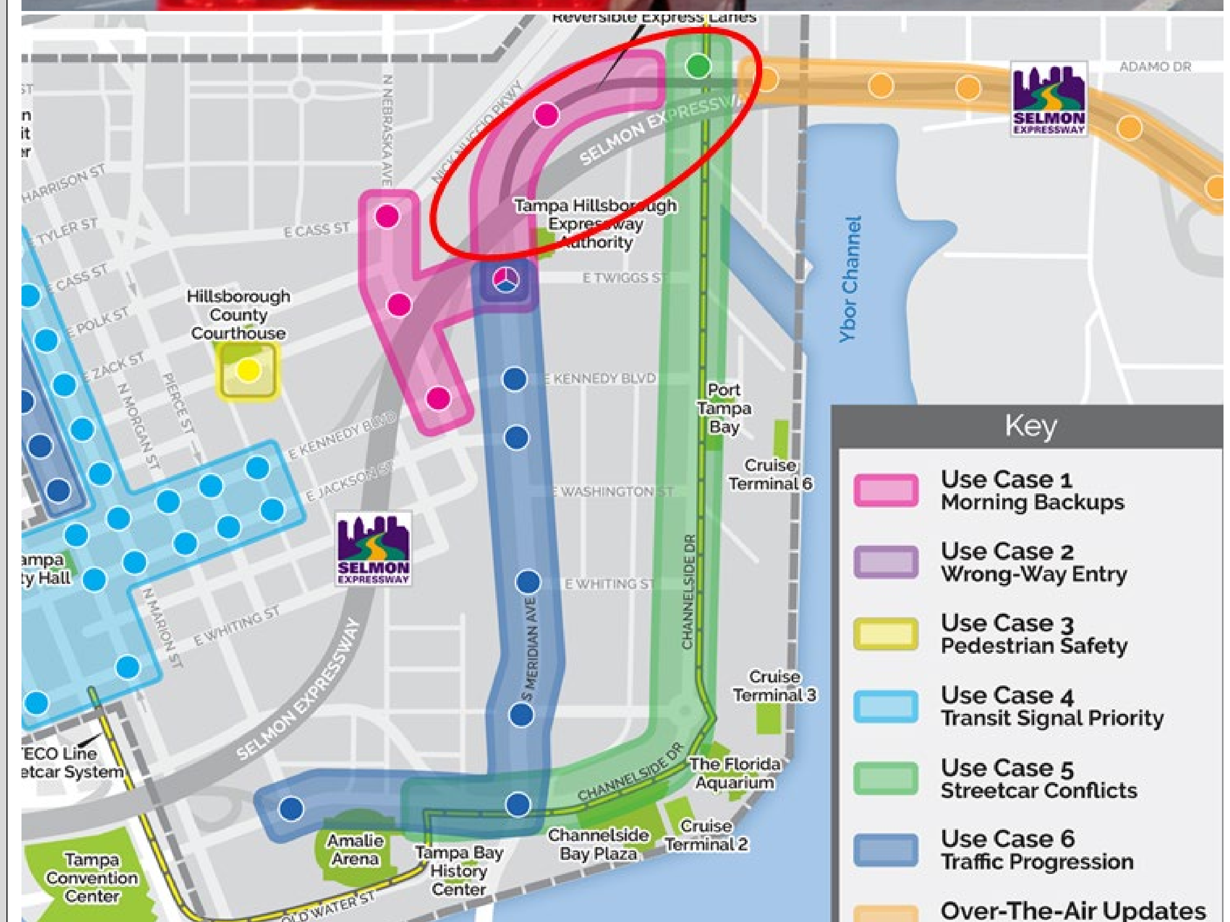
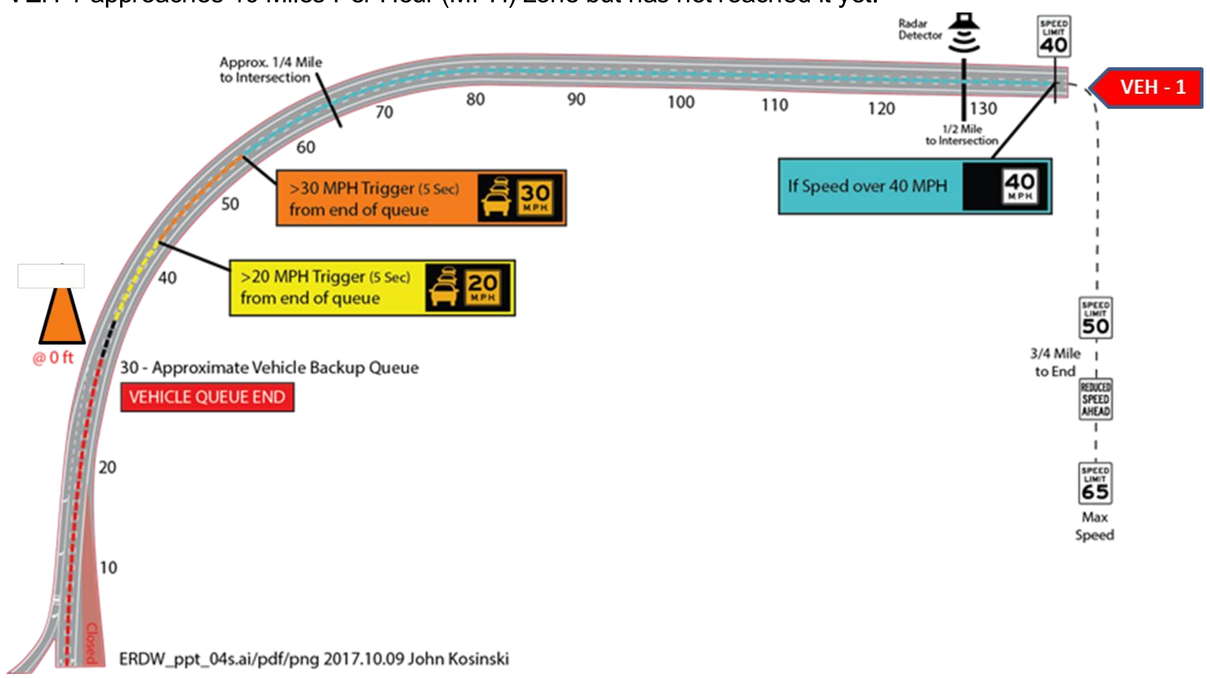
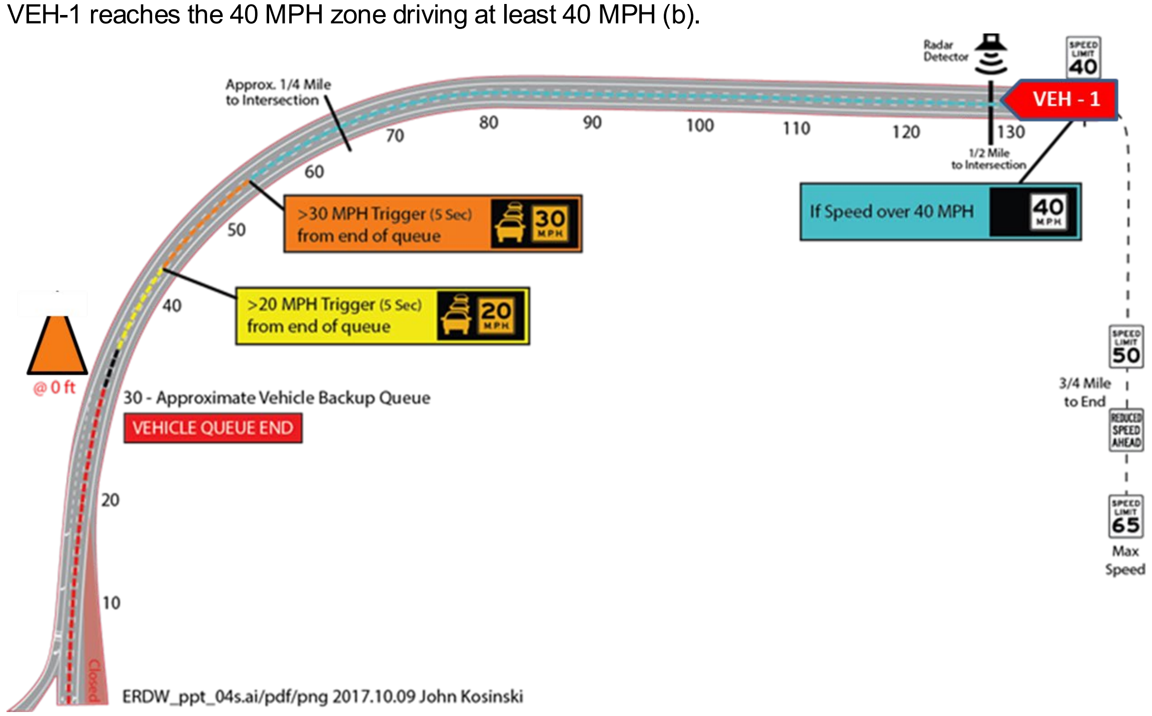
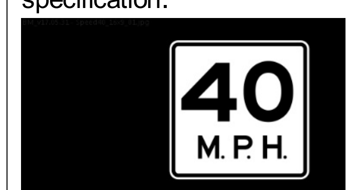
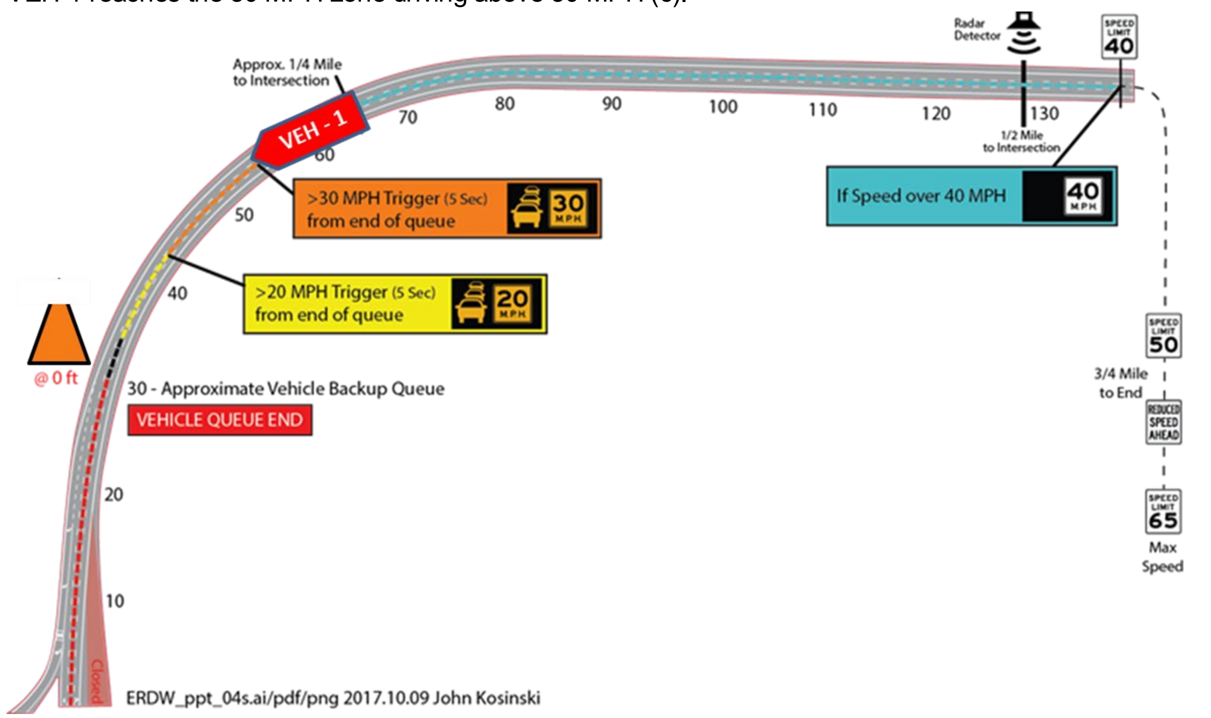
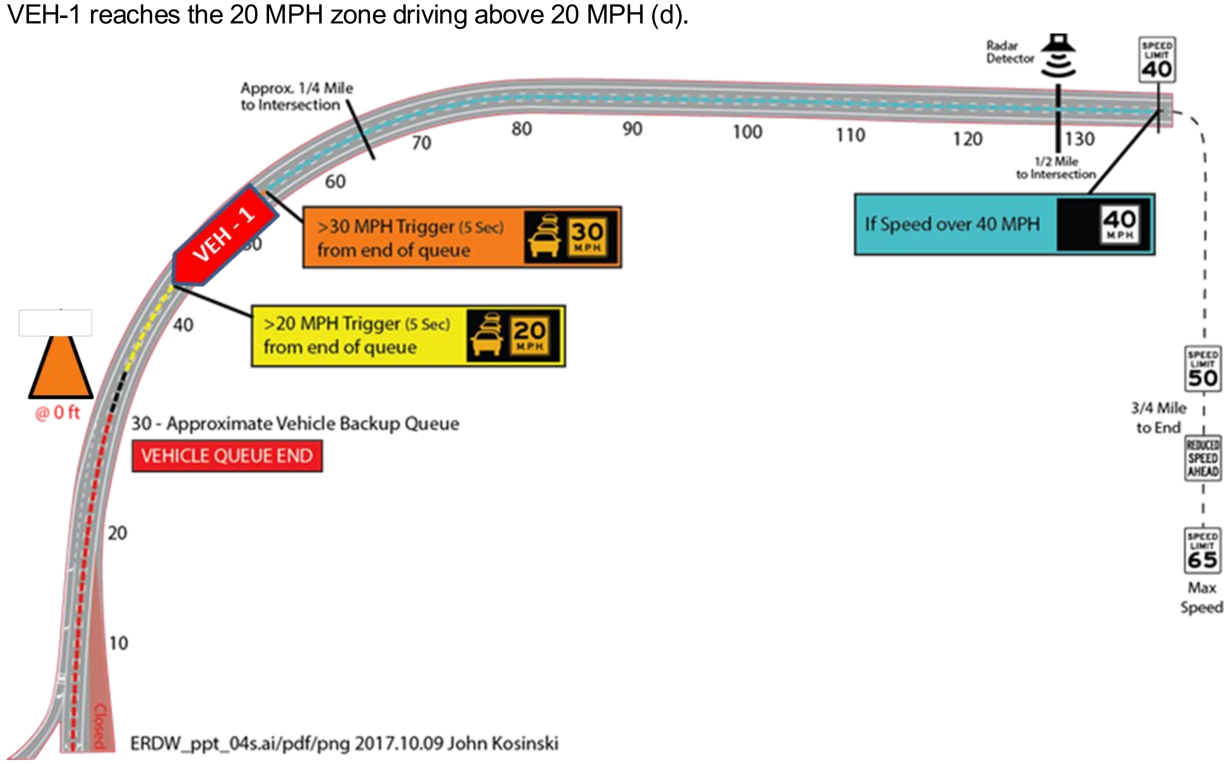


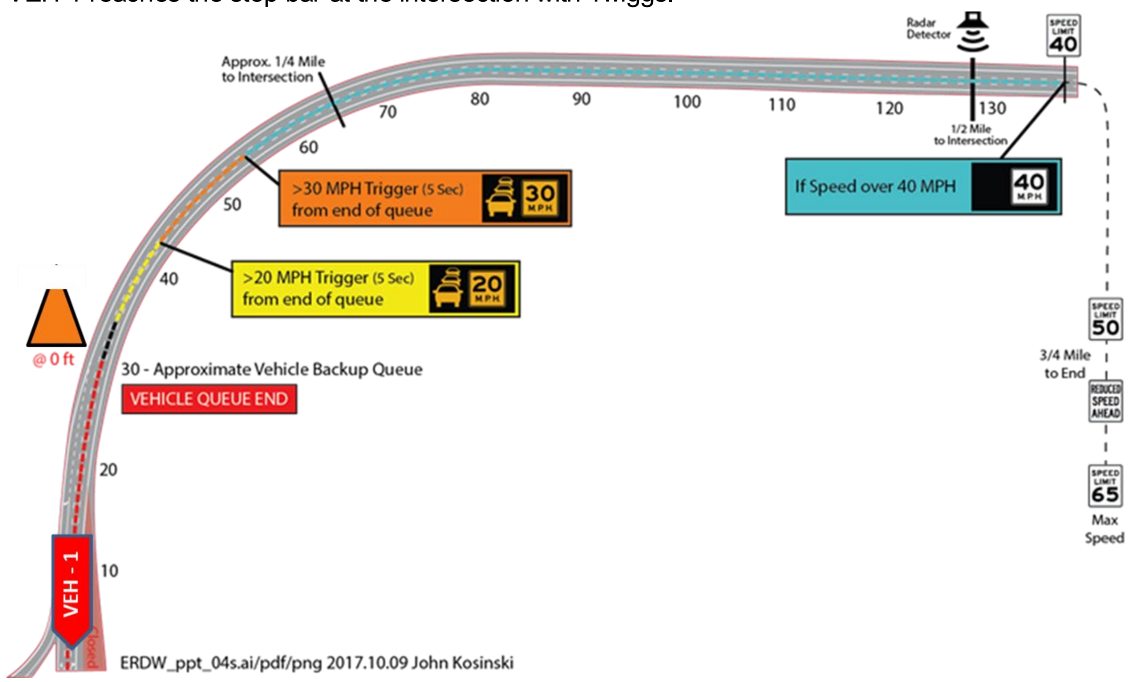
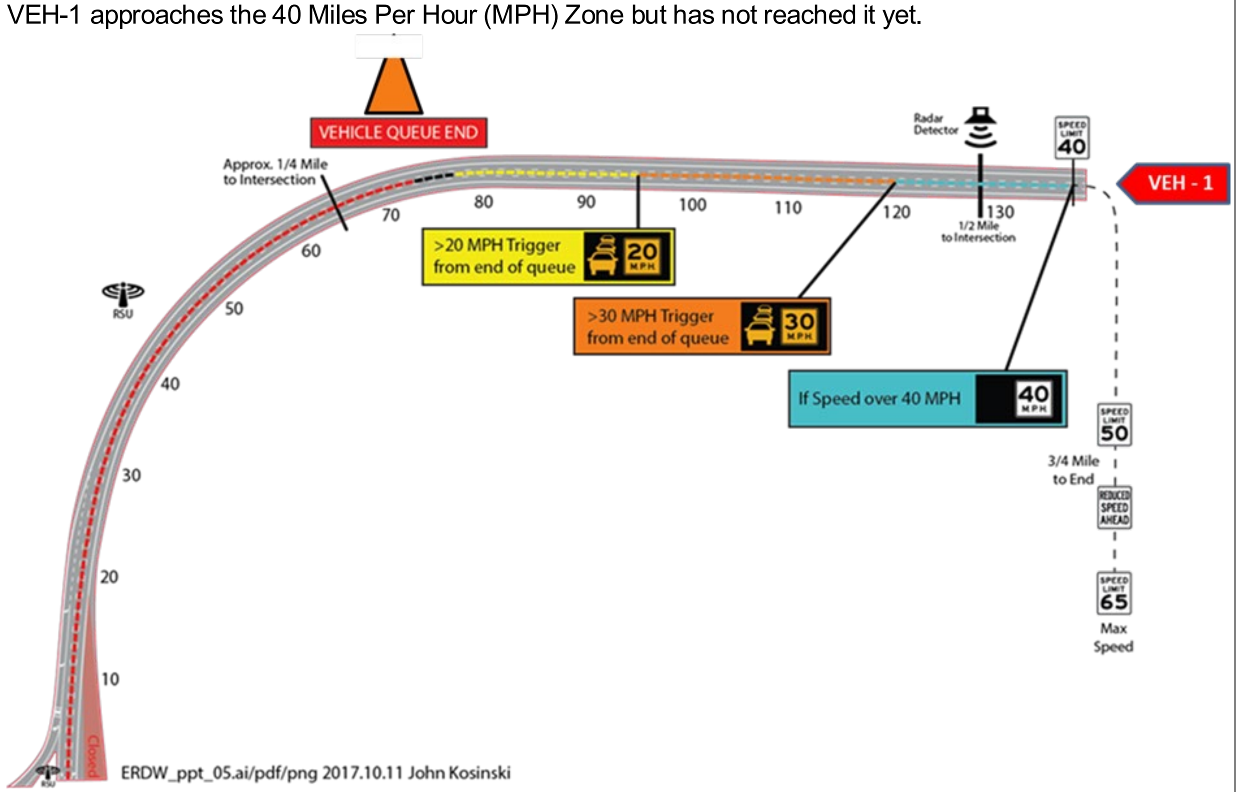
Table 90: UC1D1 Actions

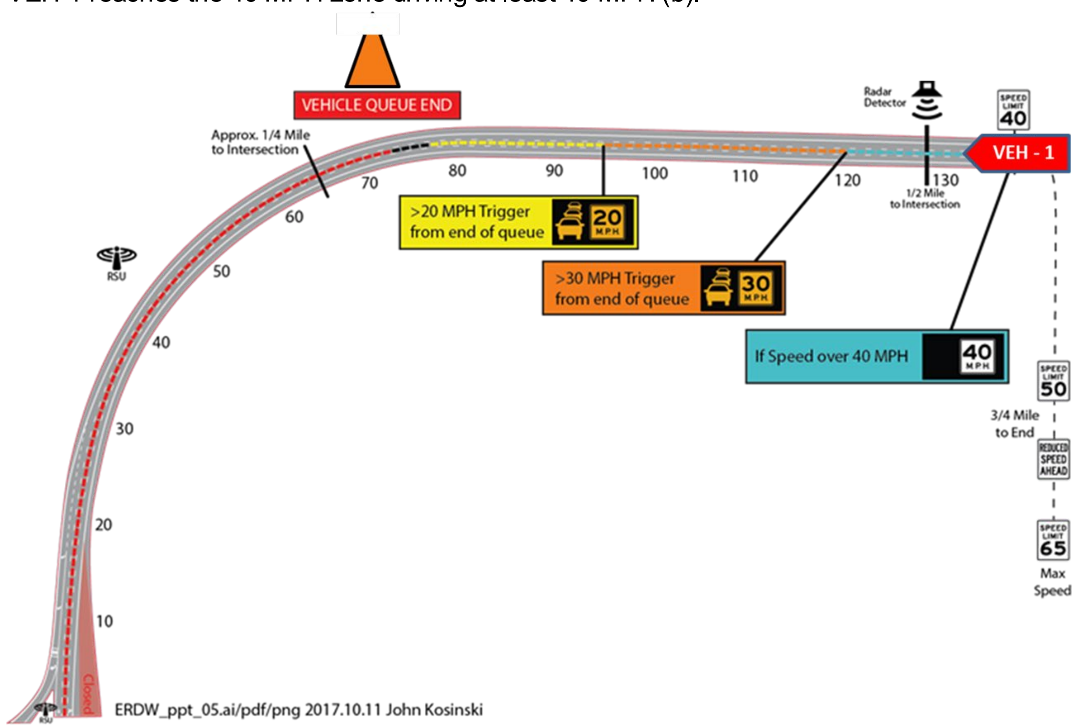
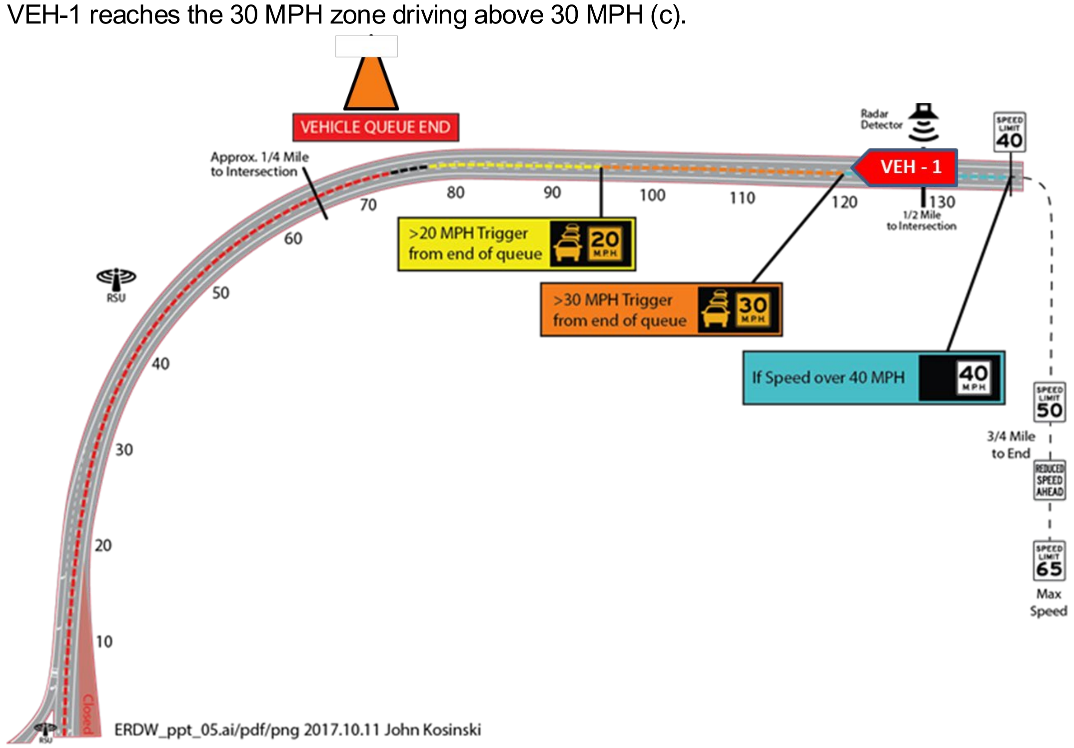
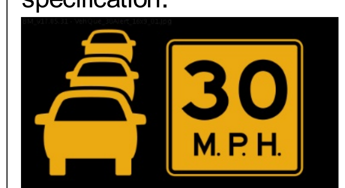
<table>
<tr><th>UC</th><th>#</th><th>Actions</th><th>Expected Result</th><th>Pass/Fail/Partial + Comments</th></tr>
<tr><td>1</td><td>1</td><td>VEH-1 approaches 40 Miles Per Hour (MPH) zone but has not reached it yet.

</td><td>No warning is shown to the driver.</td><td>Pass ___ Fail ___ Partial ___

Comments:</td></tr>
<tr><td></td><td>2</td><td>VEH-1 reaches the 40 MPH zone driving at least 40 MPH (b).

</td><td>End of Ramp Deceleration Warning (ERDW) safety application issues a “40 MPH” warning to the driver per the Human Machine Interface (HMI) specification.

</td><td>Pass ___ Fail ___ Partial ___

Comments:</td></tr>
</table>

UC	#	Actions	Expected Result	Pass/Fail/Partial + Comments
	3	VEH-1 reaches the 30 MPH zone driving above 30 MPH (c).  	ERDW safety application issues a "30 MPH" warning to the driver per the HMI specification.  	Pass ___ Fail ___ Partial ___ Comments:
	4	VEH-1 reaches the 20 MPH zone driving above 20 MPH (d).  	ERDW safety application issues a "20 MPH" warning to the driver per the HMI specification.  	Pass ___ Fail ___ Partial ___ Comments:

UC	#	Actions	Expected Result	Pass/Fail/Partial + Comments
	5	VEH-1 reaches the stop bar at the intersection with Twiggs. 	No warning is shown to the driver.	Pass ___ Fail ___ Partial ___ Comments:
	6	VEH-1 approaches the 40 Miles Per Hour (MPH) Zone but has not reached it yet. 	No warning is shown to the driver.	Pass ___ Fail ___ Partial ___ Comments:

UC	#	Actions	Expected Result	Pass/Fail/Partial + Comments
	7	VEH-1 reaches the 40 MPH zone driving at least 40 MPH (b).  	End of Ramp Deceleration Warning (ERDW) safety application issues a "40 MPH" warning to the driver per the Human Machine Interface (HMI) specification.  	Pass ___ Fail ___ Partial ___ Comments:
	8	VEH-1 reaches the 30 MPH zone driving above 30 MPH (c).  	ERDW safety application issues a "30 MPH" warning to the driver per the HMI specification.  	Pass ___ Fail ___ Partial ___ Comments:

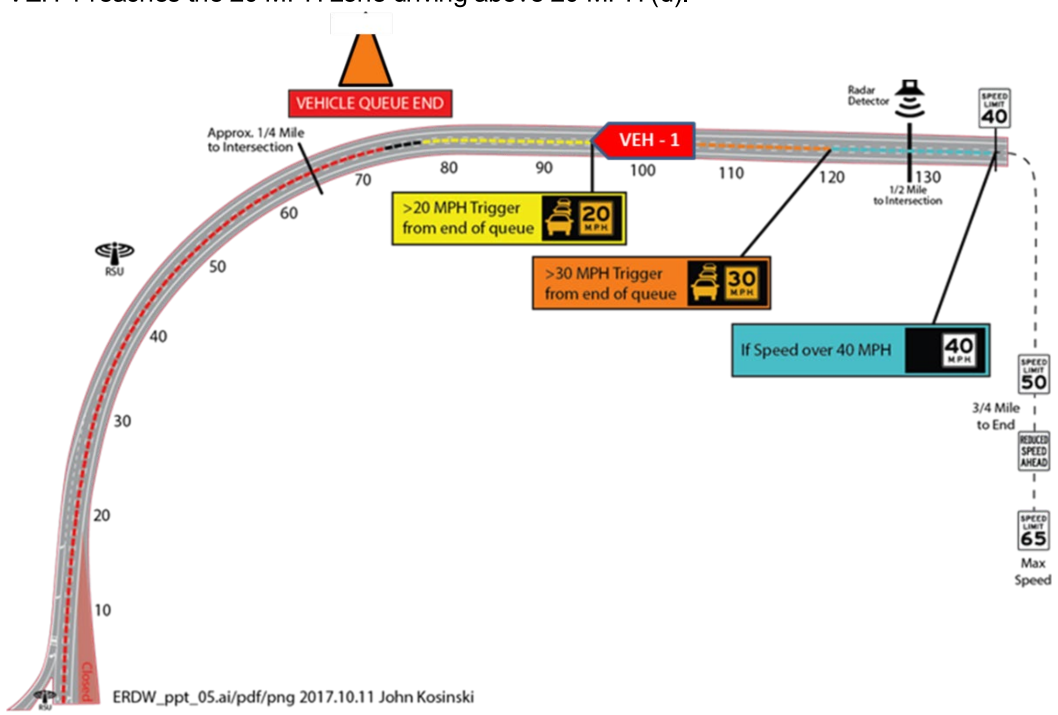
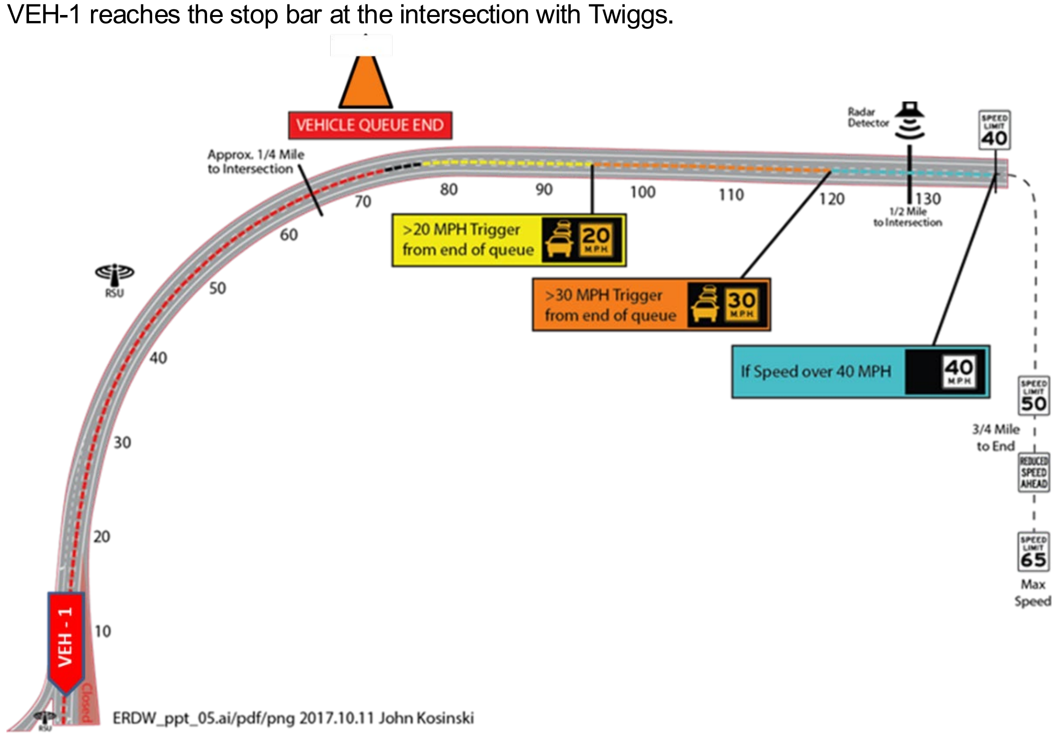
UC	#	Actions	Expected Result	Pass/Fail/Partial + Comments
	9	VEH-1 reaches the 20 MPH zone driving above 20 MPH (d).  	ERDW safety application issues a “20 MPH” warning to the driver per the HMI specification.  	Pass ___ Fail ___ Partial ___ Comments:
	10	VEH-1 reaches the stop bar at the intersection with Twiggs.  	No warning is shown to the driver.	Pass ___ Fail ___ Partial ___ Comments:

Table 91: UC1D2 Scene

Use Case 1: Morning Backup

Demonstration 2: Emergency Electronic Brake Light (EEBL) application

Purpose: To demonstrate EEBL warnings based on vehicle hard braking ahead.

Test Cases: UC1 EEBL_A, UC1 EEBL_B

Requirements:

THEA-UC1-004, THEA-UC1-005, THEA-UC1-006, THEA-UC1-007, THEA-UC1-008, THEA-UC1-011, THEA-SAF-020a

Demonstrator: Phase 3 Participant Driver

Facilitator: Brand Motion

Experience:

Observers ride in the participant vehicle equipped with a mirror HMI. The vehicle travels inbound from the Selmon Expressway via the closed REL towards vehicle ahead. Two demonstration runs are conducted. The first run is conducted with the vehicle ahead performing heavy braking in the same lane. The second run is conducted with the vehicle ahead performing heavy braking in an adjacent lane.

Expectation:

- Run 1, heavy braking ahead in the same lane: Warning issued on HMI
- Run 2, heavy braking ahead in adjacent lane: No warning issued on HMI

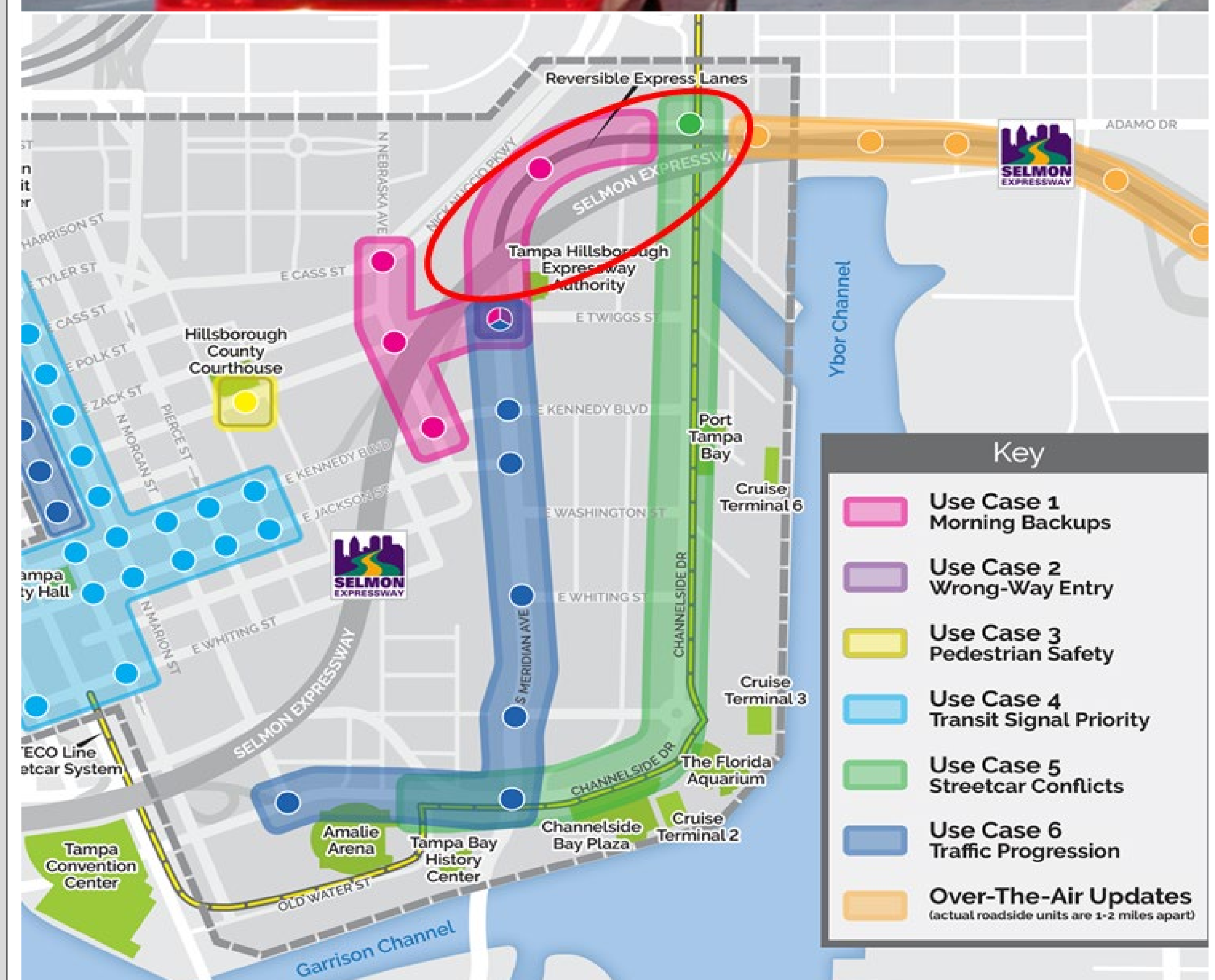


Table 92: UCD2 Actions

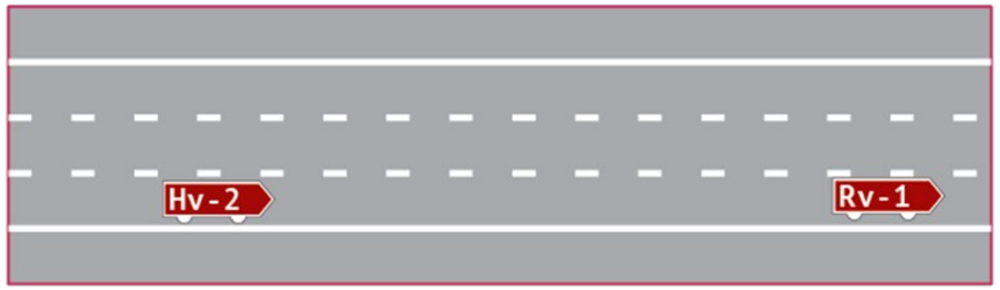
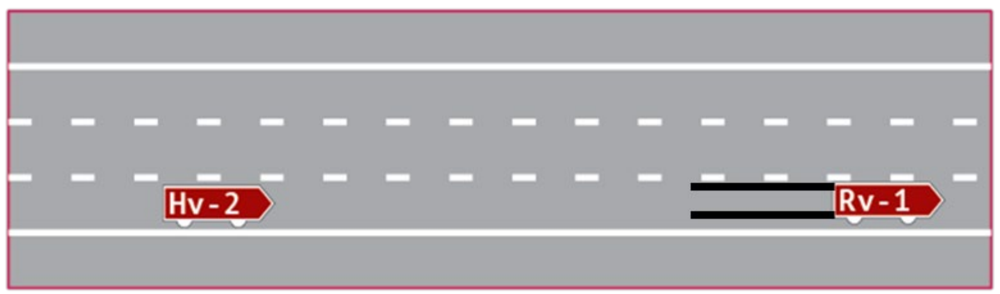
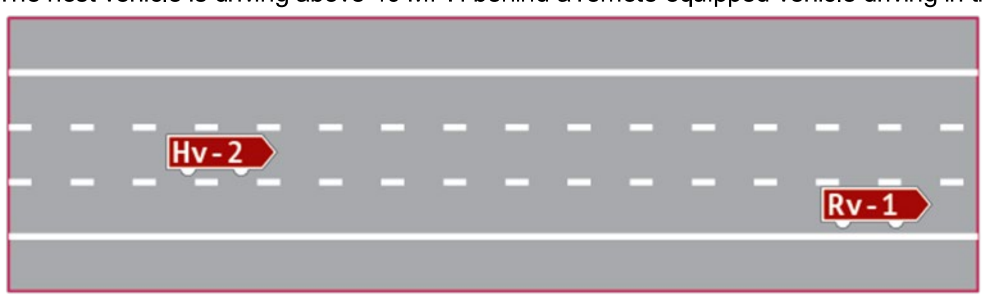
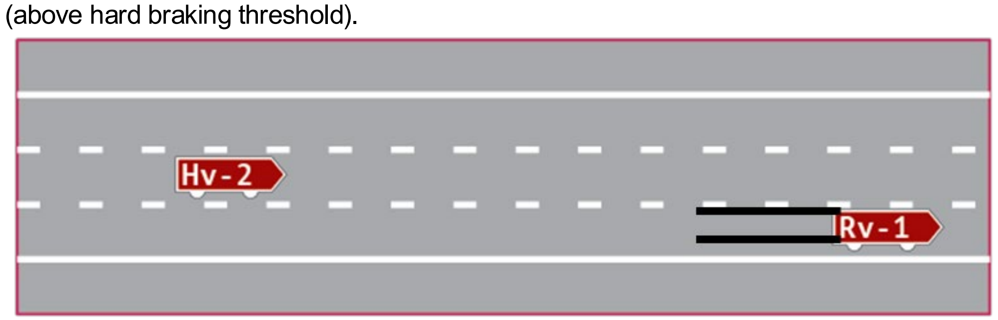
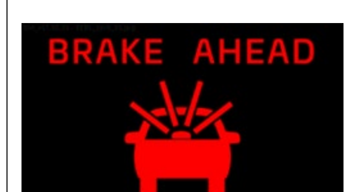
#	Actions	Expected Result	Pass/Fail/Partial + Comments
1	Host vehicle is driving above 40 MPH behind a remote equipped vehicle driving in the same lane ahead. 	No warning is shown to the driver.	Pass ___ Fail ___ Partial ___ Comments:
2	The remote vehicle hard brakes (above the hard-braking threshold) ahead of the host vehicle. 	Emergency Electronic Brake Light (EEBL) safety application issues a warning to the driver of the Host Vehicle per the HMI specification. 	Pass ___ Fail ___ Partial ___ Comments:
3	The host vehicle is driving above 40 MPH behind a remote equipped vehicle driving in the adjacent lane ahead. 	No warning is shown to the driver.	Pass ___ Fail ___ Partial ___ Comments:
4	The host vehicle is driving above 20 MPH behind a remote equipped vehicle driving in the adjacent lane ahead (above hard braking threshold). 	Lane Specific: No warning is shown to the driver. Road Level: Emergency Electronic Brake Light (EEBL) safety application issues a warning to the driver of the Host Vehicle per the HMI specification. 	Pass ___ Fail ___ Partial ___ Comments:

Table 93: UC1D3 Scene

Use Case 1: Morning Backup

Demonstration 3: Forward Collision Warning (FCW) application

Purpose: To demonstrate FCW warnings based on overtaking a vehicle ahead.

Test Cases: UC1 FCW_A, UC1 FCW_B

Requirements: THEA-UC1-008, THEA-UC1-009, THEA-UC1-010, THEA-UC1-011, THEA-SAF-020a

Demonstrator: Phase 3 Participant Driver

Facilitator: Brand Motion

Experience:

Observers ride in the participant vehicle equipped with a mirror HMI. The participant vehicle travels inbound from the Selmon Expressway via the closed REL towards vehicle ahead. Two demonstration runs are conducted. The first run is conducted with the participant vehicle approaching the stopped vehicle ahead to within a close distance, and then swerving to pass the stopped vehicle ahead. The second run is conducted with the participant vehicle approaching the stopped vehicle in an adjacent lane ahead with a greater distance and then passing the stopped vehicle ahead.

Expectation:

- Run 1, swerving to avoid stopped vehicle: Warning issued on HMI
- Run 2, normal passing stopped vehicle: No warning issued on HMI

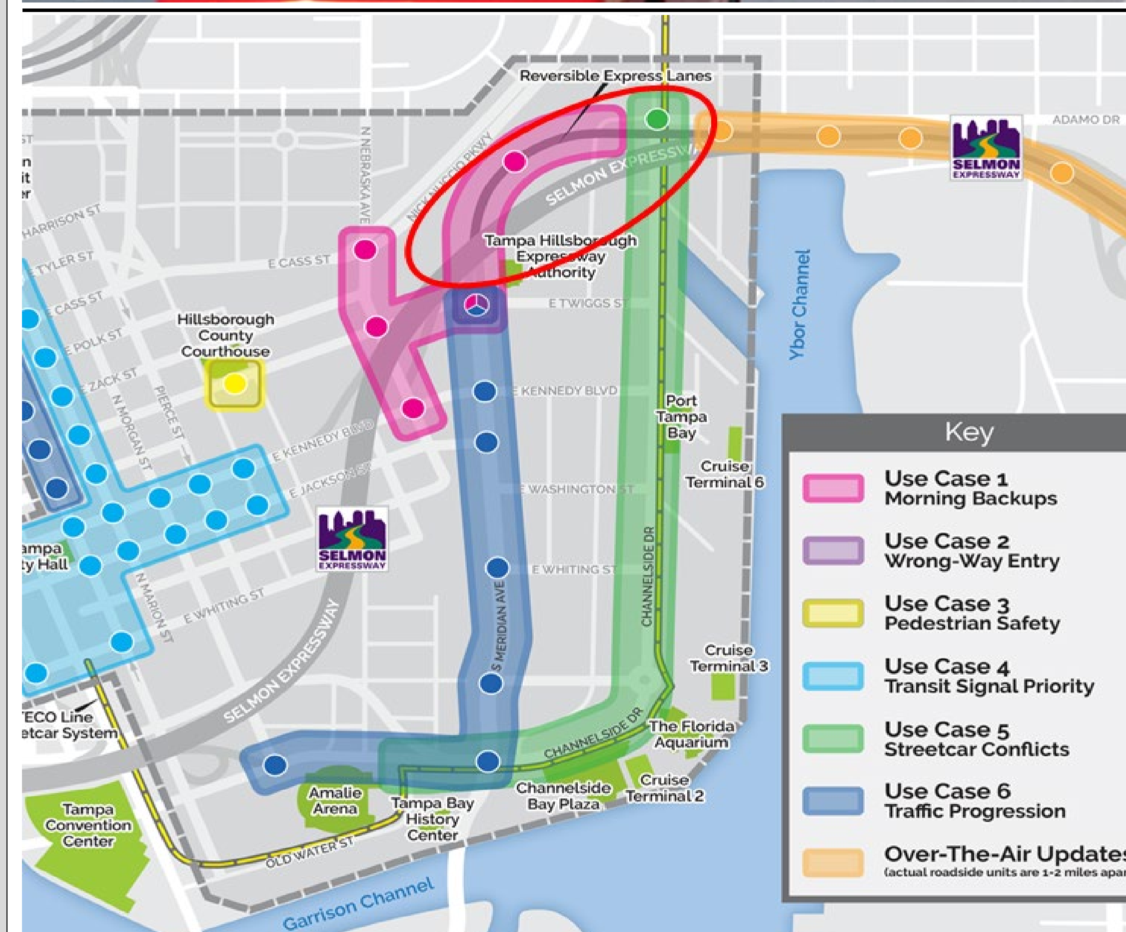
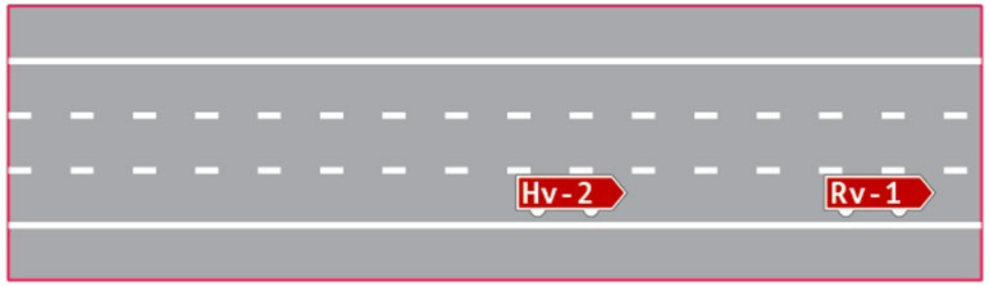
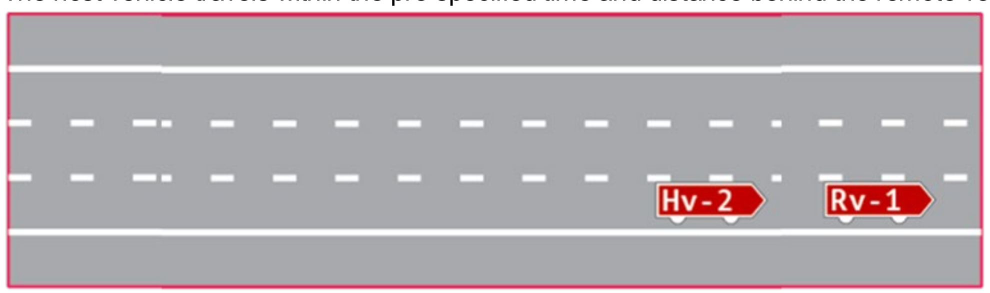
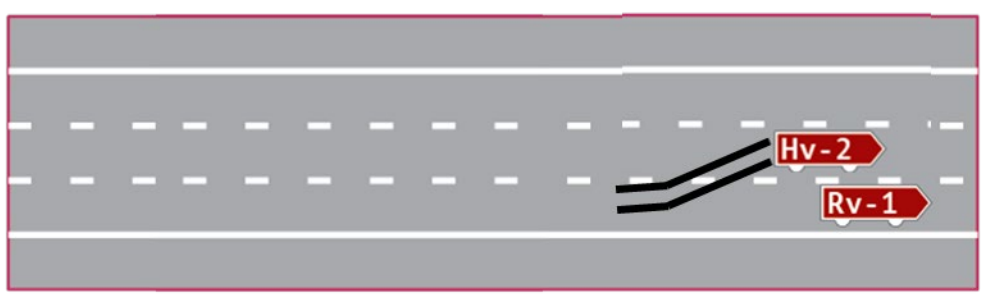
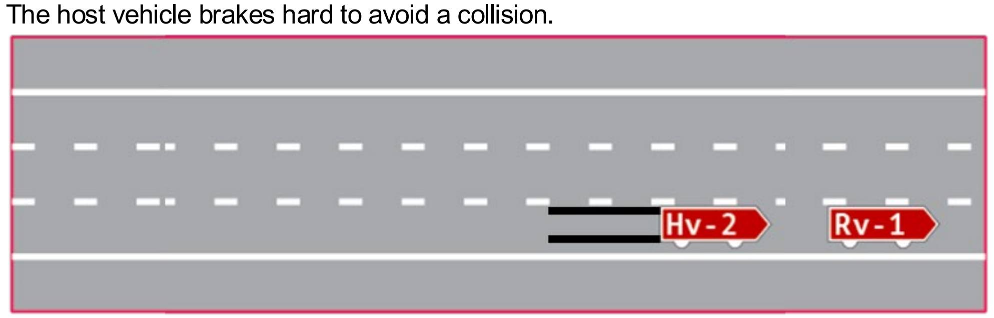


Table 94: UC1D3 Actions

#	Actions	Expected Result	Pass/Fail/Partial + Comments
1	The host vehicle is driving above 40 MPH behind a stopped, remote equipped vehicle in the same lane ahead.  	No warning is shown to the driver.	Pass ___ Fail ___ Partial ___ Comments:
2	The host vehicle travels within the pre-specified time and distance behind the remote vehicle.  	Forward Collision Warning (FCW) safety application issues a warning to the driver of the host vehicle per the HMI specification. 	Pass ___ Fail ___ Partial ___ Comments:
3	The host vehicle swerves out of the lane to avoid a collision.  The host vehicle brakes hard to avoid a collision.  	No warning is shown to the driver.	Pass ___ Fail ___ Partial ___ Comments:

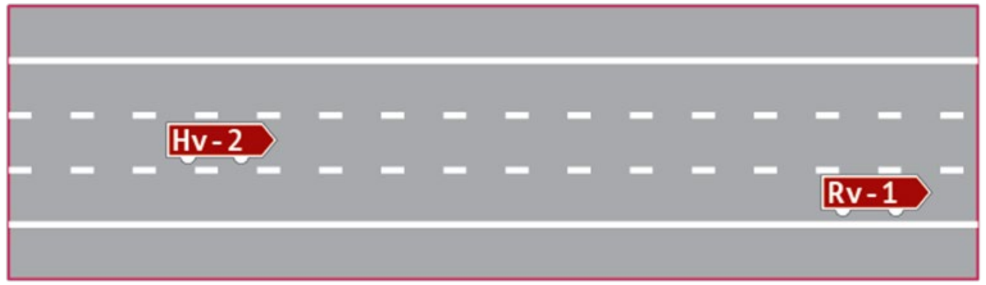
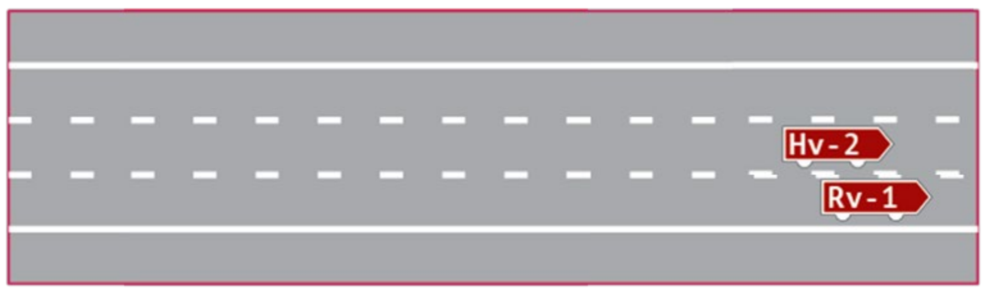
#	Actions	Expected Result	Pass/Fail/Partial + Comments
4	The host vehicle is driving above 40 MPH behind a stopped, remote equipped vehicle in the adjacent lane ahead. 	No warning is shown to the driver.	Pass ___ Fail ___ Partial ___ Comments:
5	The host vehicle passes the remote stopped vehicle in the adjacent lane. 	No warning is shown to the driver.	Pass ___ Fail ___ Partial ___ Comments:

Table 95: UC2D1 Scene

Use Case 2: Wrong-Way Entry

Demonstration 1: Left Turn into Oncoming Traffic

Purpose: To demonstrate vehicle alerts and warnings when turning illegally into oncoming traffic on the inbound REL in the morning.

Test Cases: UC2 WWE_A

Requirements: THEA-UC2-010, THEA-UC2-011, THEA-UC2-012, THEA-UC2-016, THEA-UC2-018a, THEA-UC2-018b, THEA-SAF-020a

Demonstrator: Phase 3 Participant Driver

Facilitator: Brand Motion

Experience:

Observers ride in the participant vehicle equipped with a mirror HMI. The participant vehicle travels eastbound on Twiggs and then turns left toward the inbound REL in the illegal direction.

Expectation:

- HMI issues DO NOT ENTER graphic before the wrong-way violation occurs
- HMI issues WRONG WAY graphic after the wrong-way violation occurs

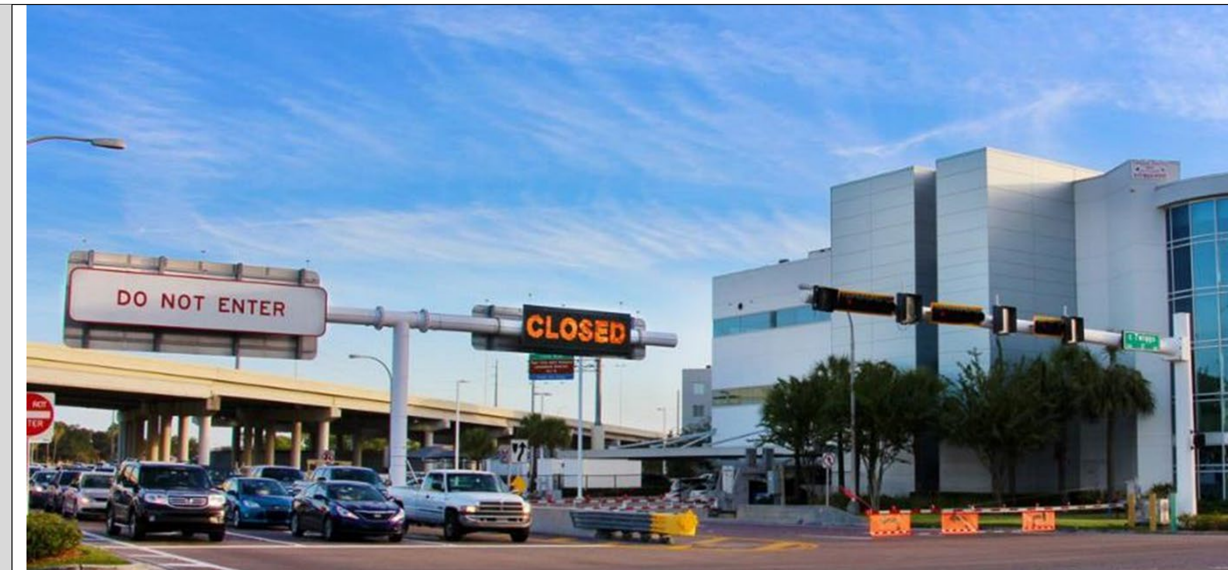
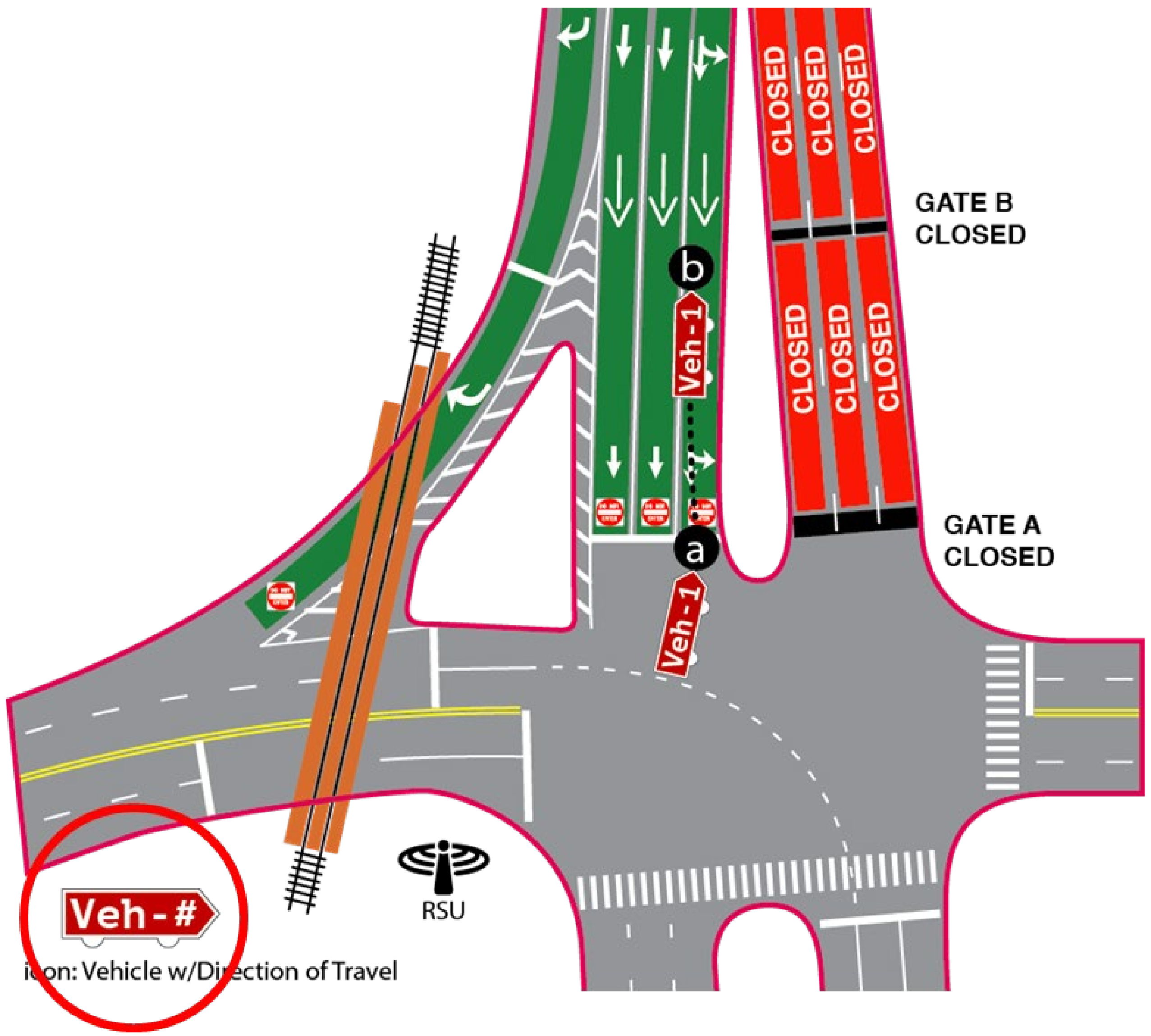
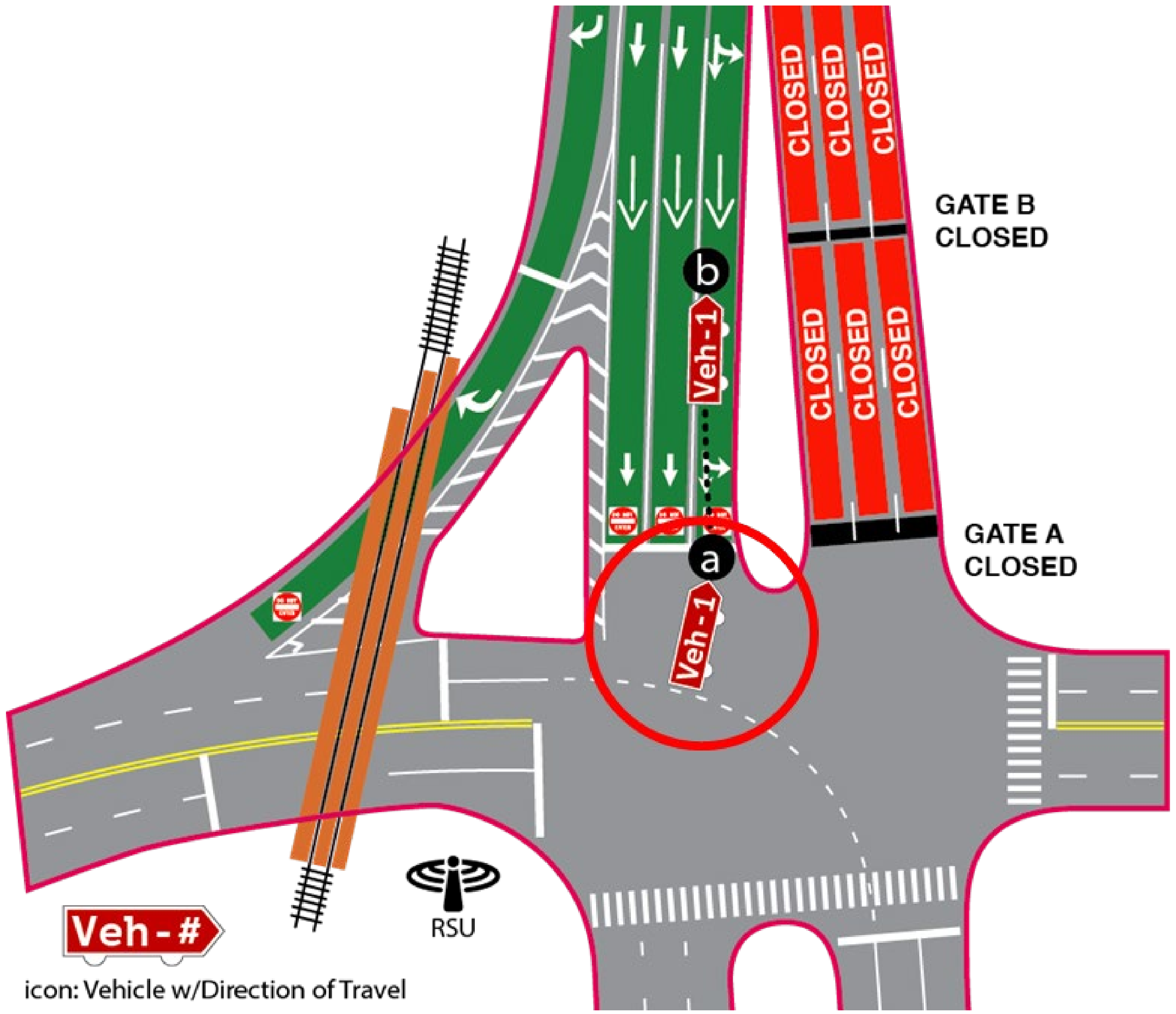
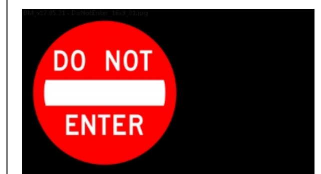


Table 96: UC2D1 Actions

#	Actions	Expected Result	Pass/Fail/Partial + Comments
1	A vehicle approaches the intersection traveling eastbound on Twiggs. 	No warning is shown to the driver.	Pass ___ Fail ___ Partial ___ Comments:

#	Actions	Expected Result	Pass/Fail/Partial + Comments
2	A vehicle turns left and approaches the inbound lanes (a).  	WWE safety application issues a "Do Not Enter" warning to the driver per the HMI specification.  	Pass ___ Fail ___ Partial ___ Comments:

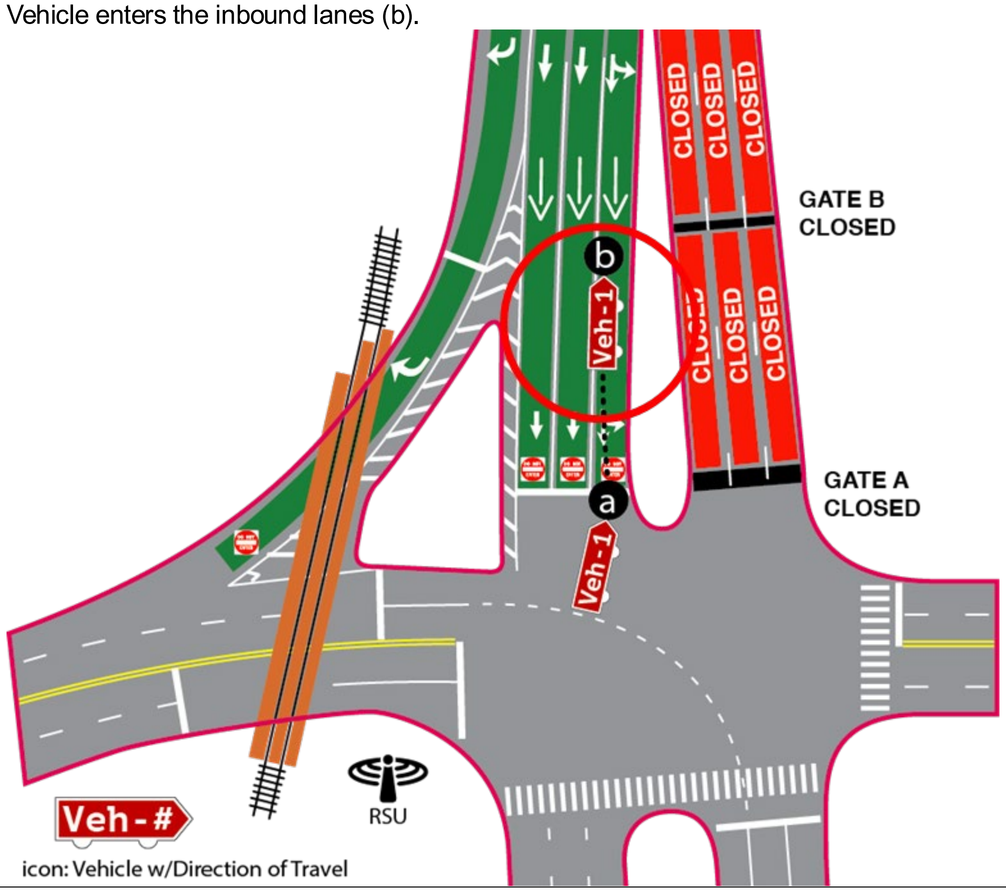
#	Actions	Expected Result	Pass/Fail/Partial + Comments
3	Vehicle enters the inbound lanes (b).  	WWE safety application issues a “Wrong-Way Entry” warning to the driver per the HMI specification.  	Pass ___ Fail ___ Partial ___ Comments:

Table 97: UC2D2 Scene

Use Case 2: Wrong-Way Entry

Demonstration 2: Left Turn into Closed Lane

Purpose: To demonstrate vehicle alerts and warnings when turning illegally into a closed egress lane in the morning.

Test Cases: UC2 WWE_B

Requirements:

THEA-UC2-001, THEA-UC2-010, THEA-UC2-011, THEA-UC2-012, THEA-UC2-016, THEA-UC2-018a, THEA-UC2-018b, THEA-SAF-020a

Demonstrator: Phase 3 Participant Driver

Facilitator: Brand Motion

Experience:

Observers ride in the participant vehicle equipped with a mirror HMI. The participant vehicle travels eastbound on Twiggs and then turns left toward the closed egress lane with the dropped barrier.

Expectation:

- HMI issues DO NOT ENTER graphic before the wrong-way violation occurs
- HMI issues NO TRAVEL LANE graphic after the wrong-way violation occurs

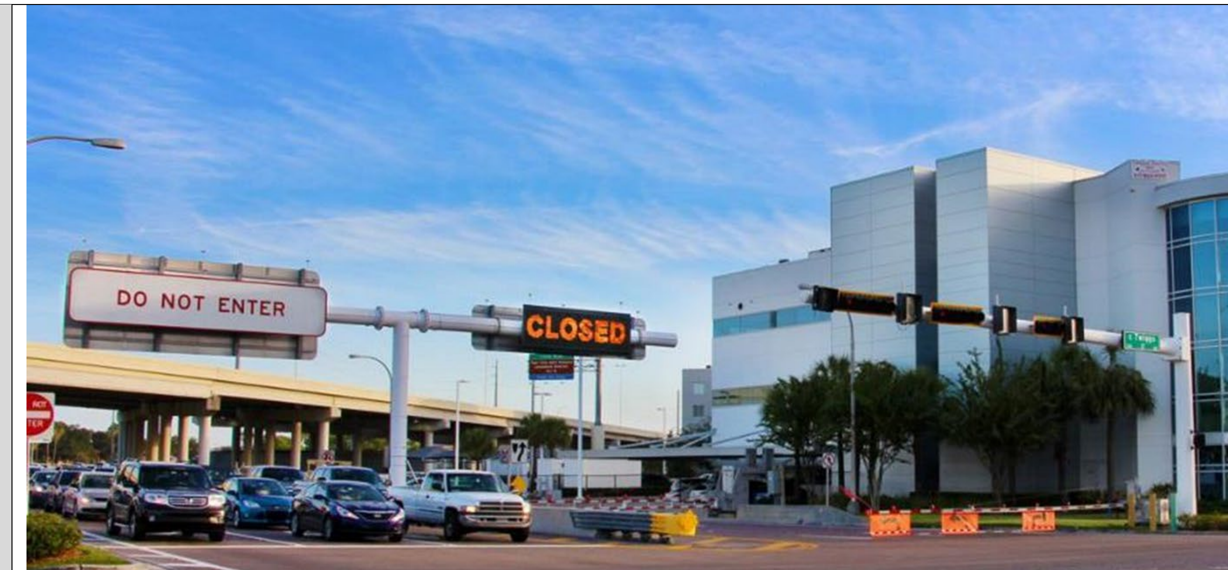
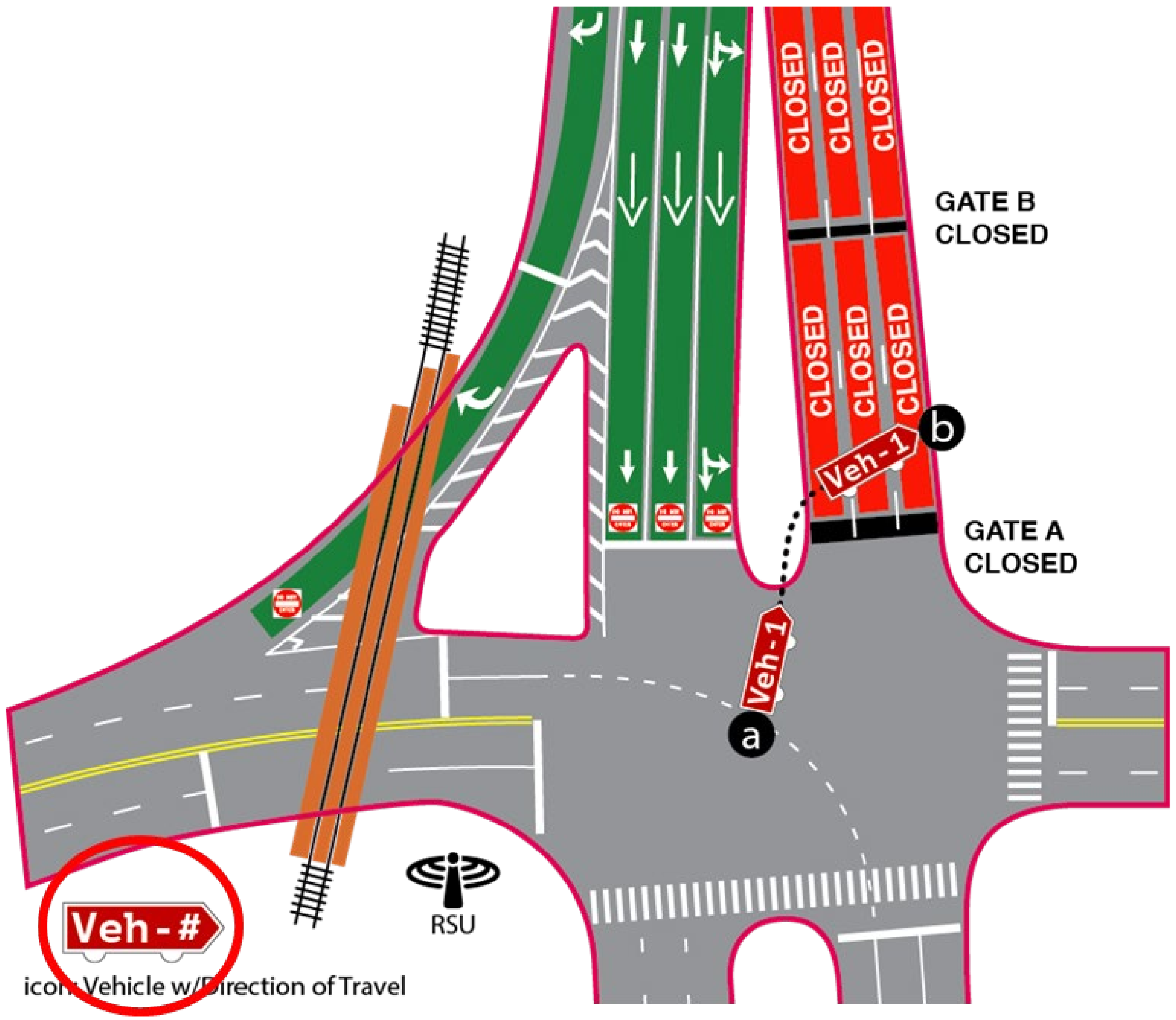
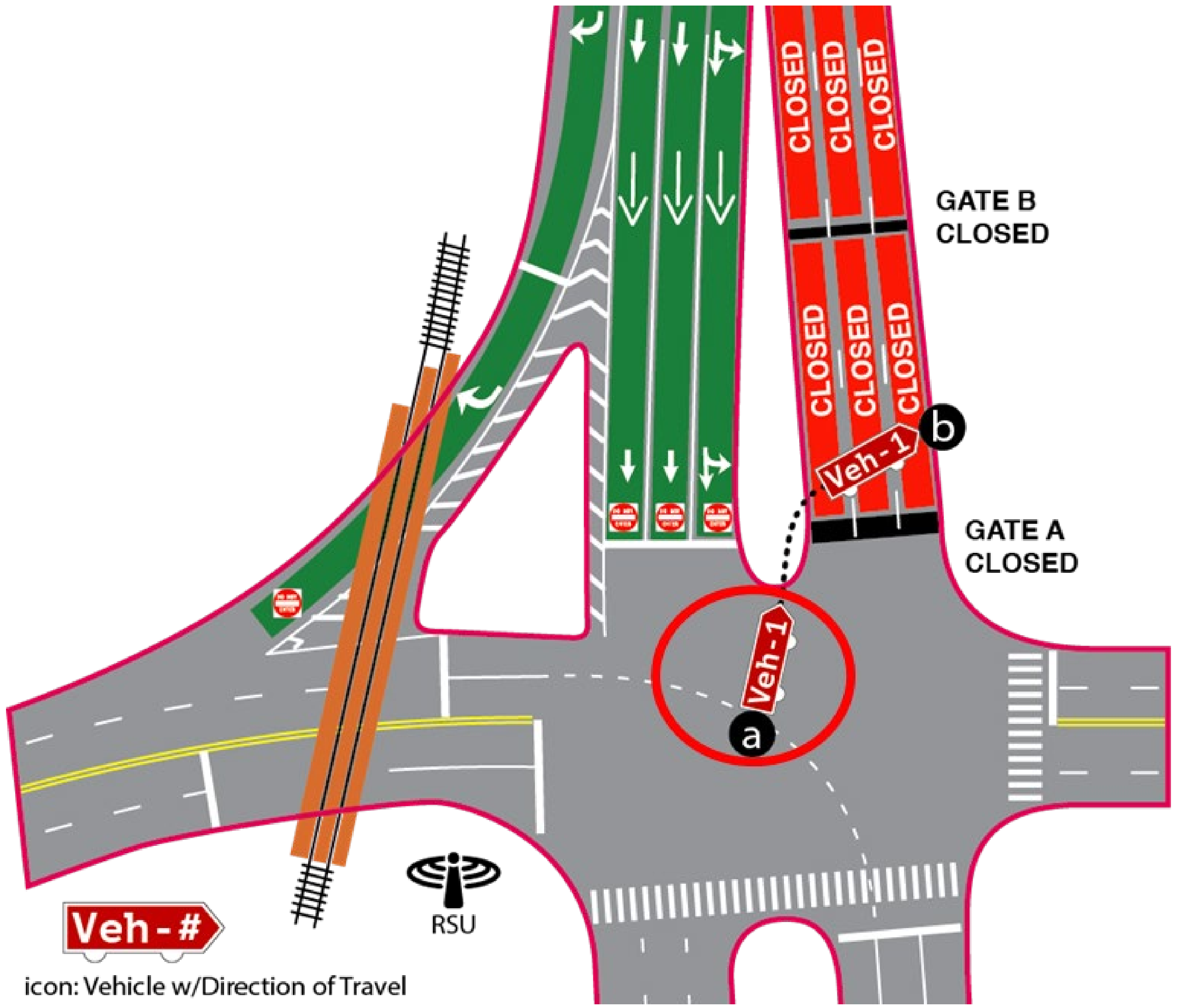
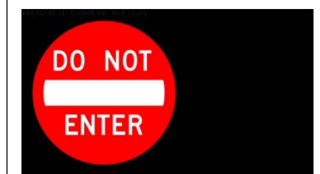


Table 98: UC2D2 Actions

#	Actions	Expected Result	Pass/Fail/Partial + Comments
1	A vehicle approaches the intersection traveling eastbound on Twiggs.  	No warning is shown to the driver.	Pass ___ Fail ___ Partial ___ Comments:

#	Actions	Expected Result	Pass/Fail/Partial + Comments
2	The vehicle makes a left turn on to a closed section of the REL (a).  	WWE safety application issues a “Do Not Enter” warning to the driver per the HMI specification.  	Pass ___ Fail ___ Partial ___ Comments:

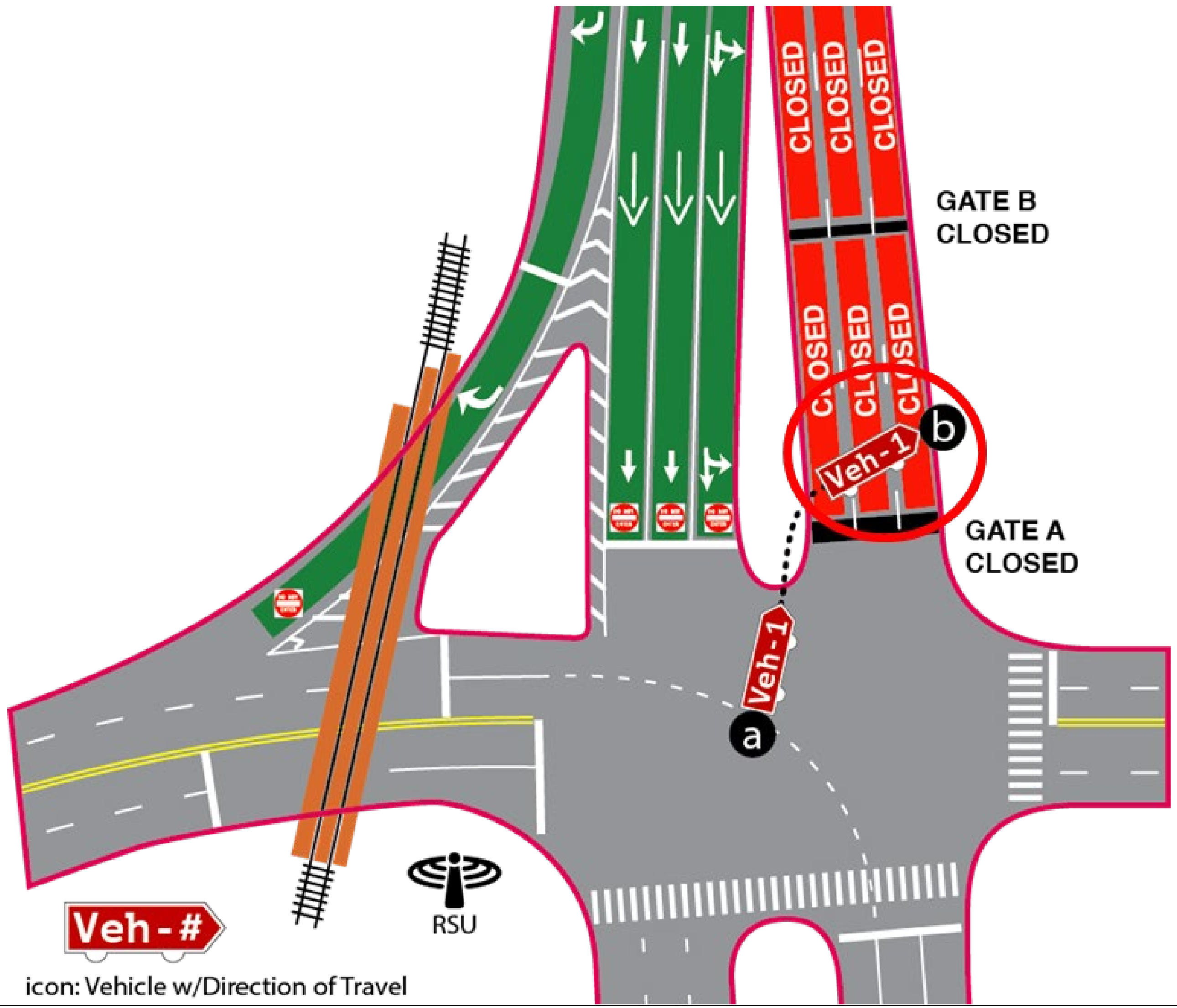
#	Actions	Expected Result	Pass/Fail/Partial + Comments
3	The vehicle enters the closed section of the REL (b).  	WWE safety application issues a “No Travel Lane” warning to the driver per the HMI specification. 	Pass ___ Fail ___ Partial ___ Comments:

Table 99: UC2D3 Scene

Use Case 2: Wrong-Way Entry

Demonstration 3: Inbound into Closed Lane

Purpose: To demonstrate vehicle alerts and warnings when entering inbound illegally into a closed egress lane in the morning.

Test Cases: UC2 WWE_C

Requirements:

THEA-UC2-001, THEA-UC2-010, THEA-UC2-011, THEA-UC2-012, THEA-UC2-016, THEA-UC2-018a, THEA-UC2-018b, THEA-SAF-020a

Demonstrator: Phase 3 Participant Driver

Facilitator: Brand Motion

Experience:

Observers ride in the participant vehicle equipped with a mirror HMI. The participant vehicle travels inbound on the REL towards the outbound egress lanes.

Expectation:

- HMI issues DO NOT ENTER graphic before the wrong-way violation occurs
- HMI issues NO TRAVEL LANE graphic after the wrong-way violation occurs

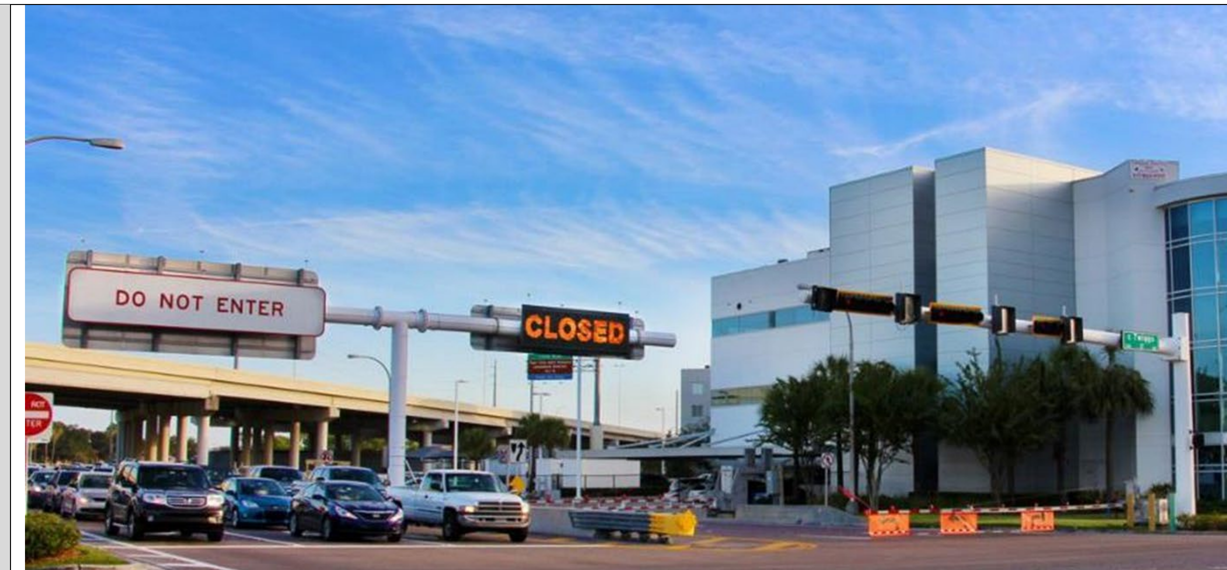
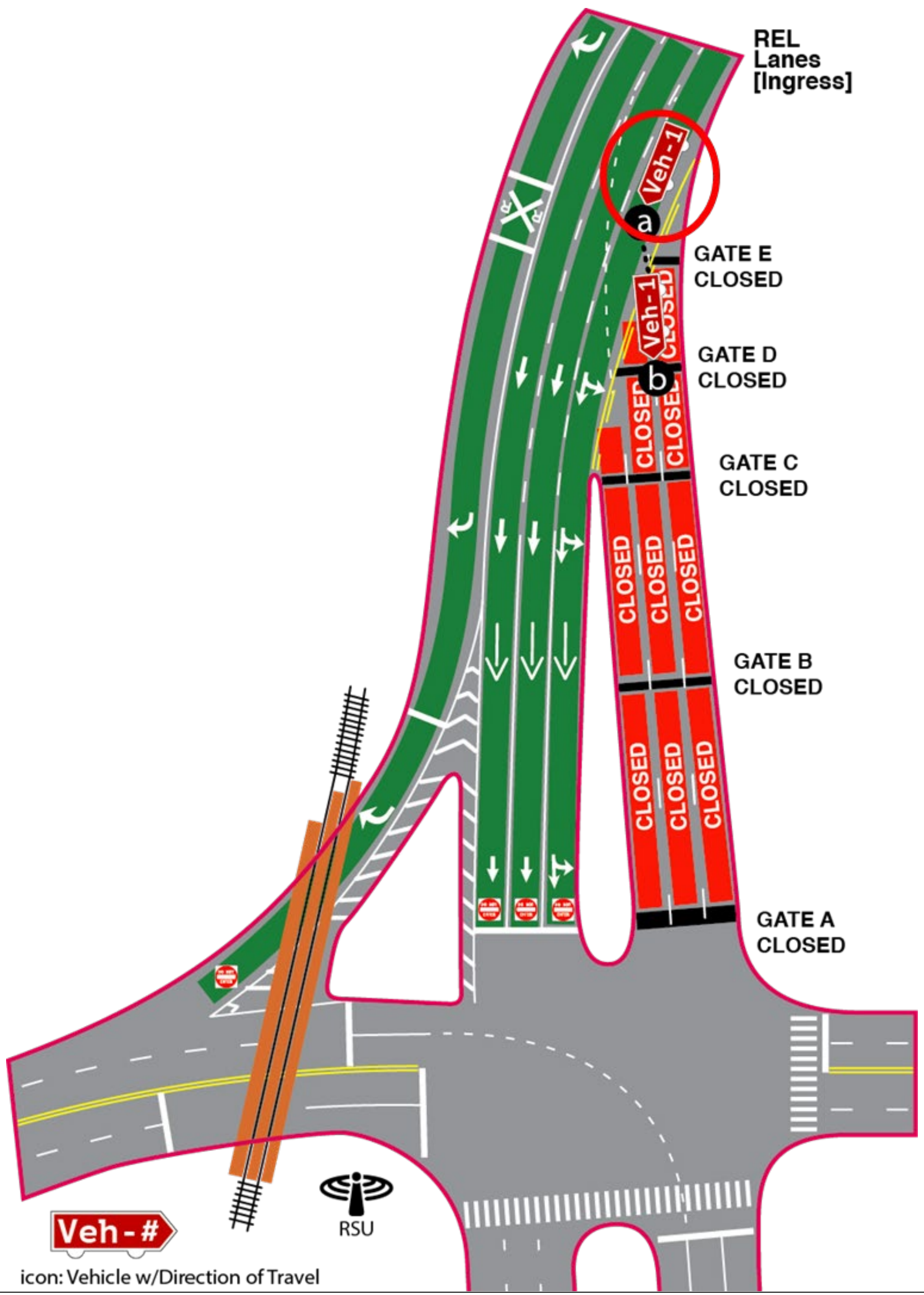
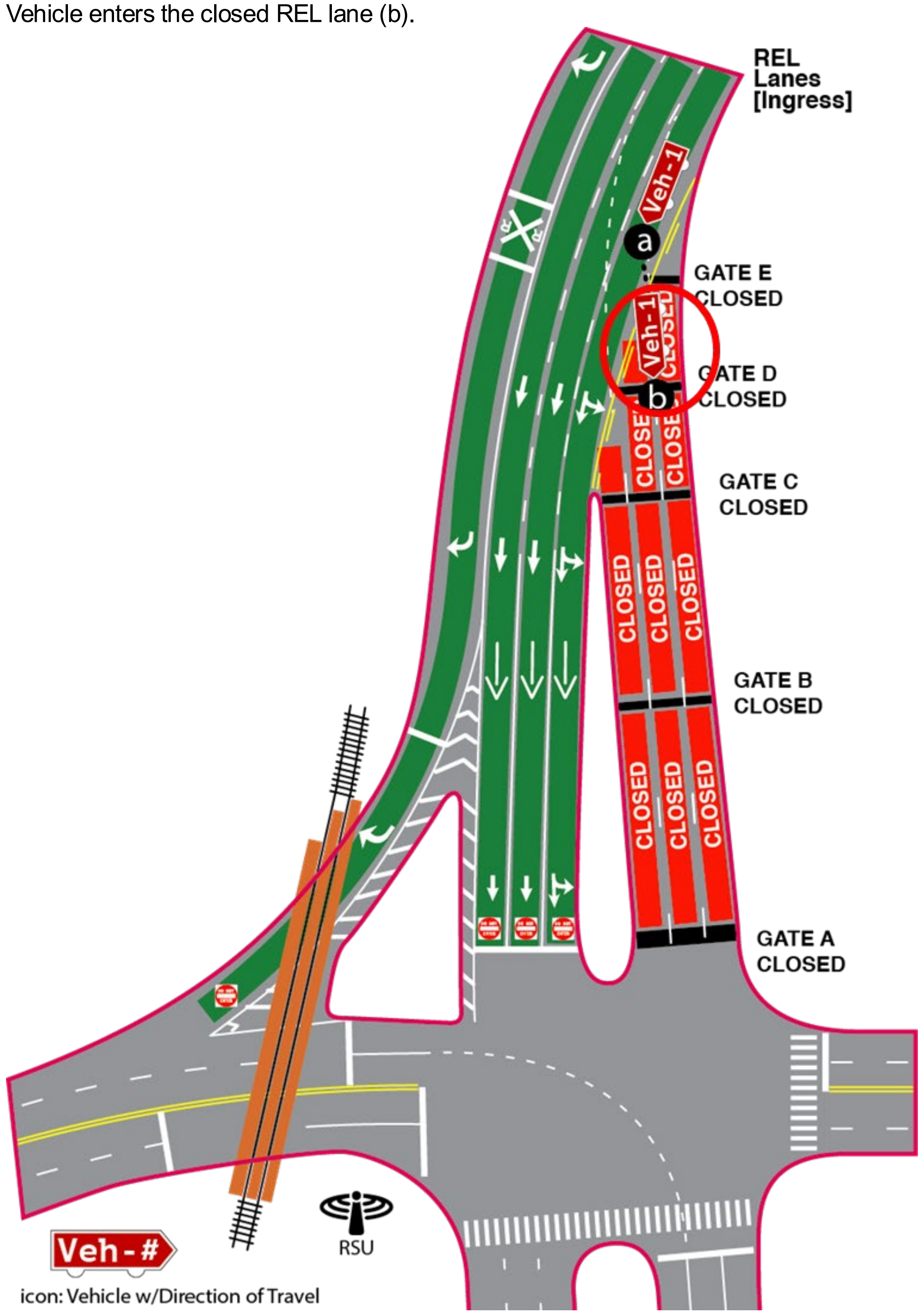


Table 100: UCD3 Actions

#	Actions	Expected Result	Pass/Fail/Partial + Comments
1	Vehicle is traveling south on the inbound lane REL (a). 	No warning is shown to the driver.	Pass ___ Fail ___ Partial ___ Comments:

#	Actions	Expected Result	Pass/Fail/Partial + Comments
2	Vehicle enters the closed REL lane (b).  	WWE safety application issues a "No Travel Lane" warning to the driver per the HMI specification. 	Pass ___ Fail ___ Partial ___ Comments:

#	Actions	Expected Result	Pass/Fail/Partial + Comments

Table 101: UC2D4 Scene

Use Case 2: Wrong-Way Entry

Demonstration 4: Inbound Head-On into Wrong Way Violator

Purpose: To demonstrate vehicle alerts and warnings with an a.m. MAP when vehicle legally traveling inbound on the REL approaches a wrong-way violator.

Test Cases: UC2 WWE_D

Requirements:

THEA-UC2-001, THEA-UC2-010, THEA-UC2-011, THEA-UC2-012, THEA-UC2-15b, THEA-UC2-15c, THEA-UC2-15d, THEA-UC2-016, THEA-UC2-018a, THEA-UC2-018b, THEA-SAF-020a

Demonstrator: Two Phase 3 Participant Drivers

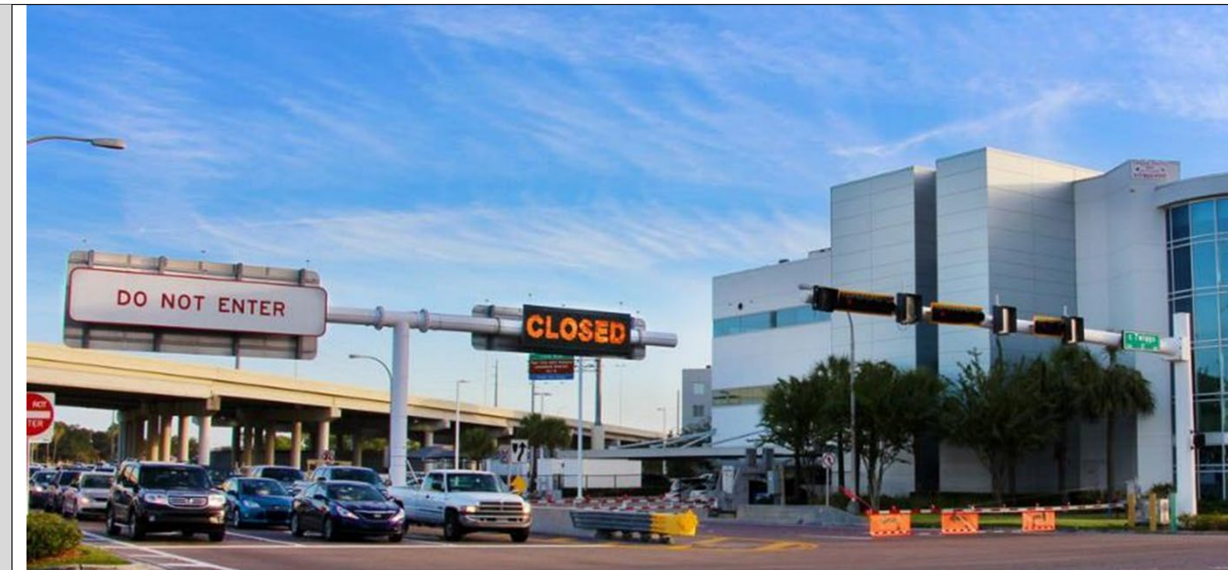
Facilitator: Brand Motion

Experience:

Observers are split into two groups - Group 1 and Group 2. The two groups ride successively in two participant vehicles equipped with a mirror HMI. Observer Group 1 first rides in Participant Vehicle 1 to demonstrate the violator warnings. Participant Vehicle 1 travels inbound on the REL towards a Participant Vehicle 2 wrong-way violator. Observer Group 1 then moves to Participant Vehicle 2 to observe crash warnings while Observer Group 2 rides in Participant Vehicle 1.

Expectation:

- Participant Vehicle 2 HMI issues DO NOT ENTER graphic before the wrong-way violation occurs to the violating driver
- Participant Vehicle 2 HMI issues WRONG-WAY graphic to the violating driver after the wrong-way violation occurs
- Roadside vehicle detector senses unequipped vehicles entering in the wrong direction
- Participant Vehicle 1 HMI issues WRONG-WAY VEHICLE graphic to the legal inbound driver after the wrong-way violation occurs



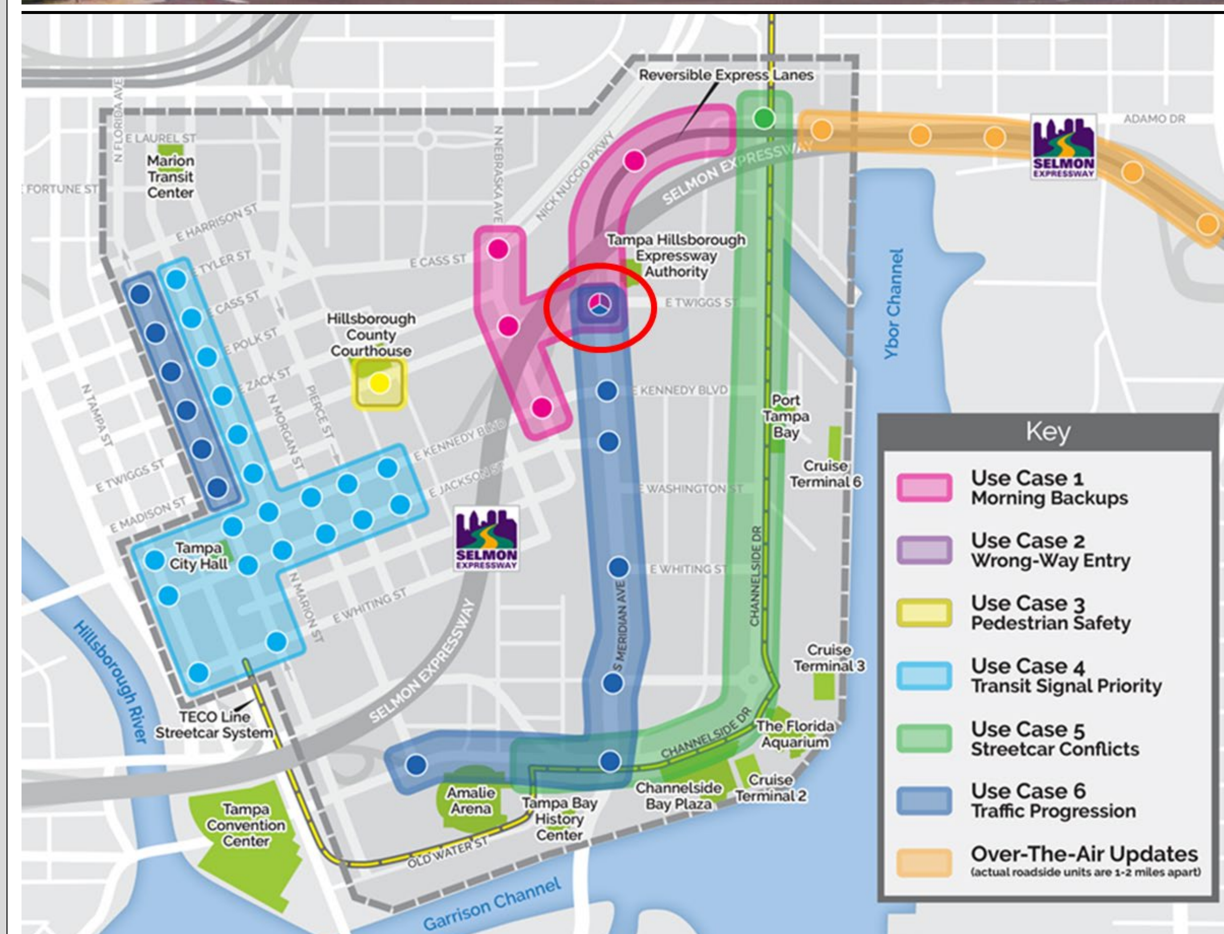
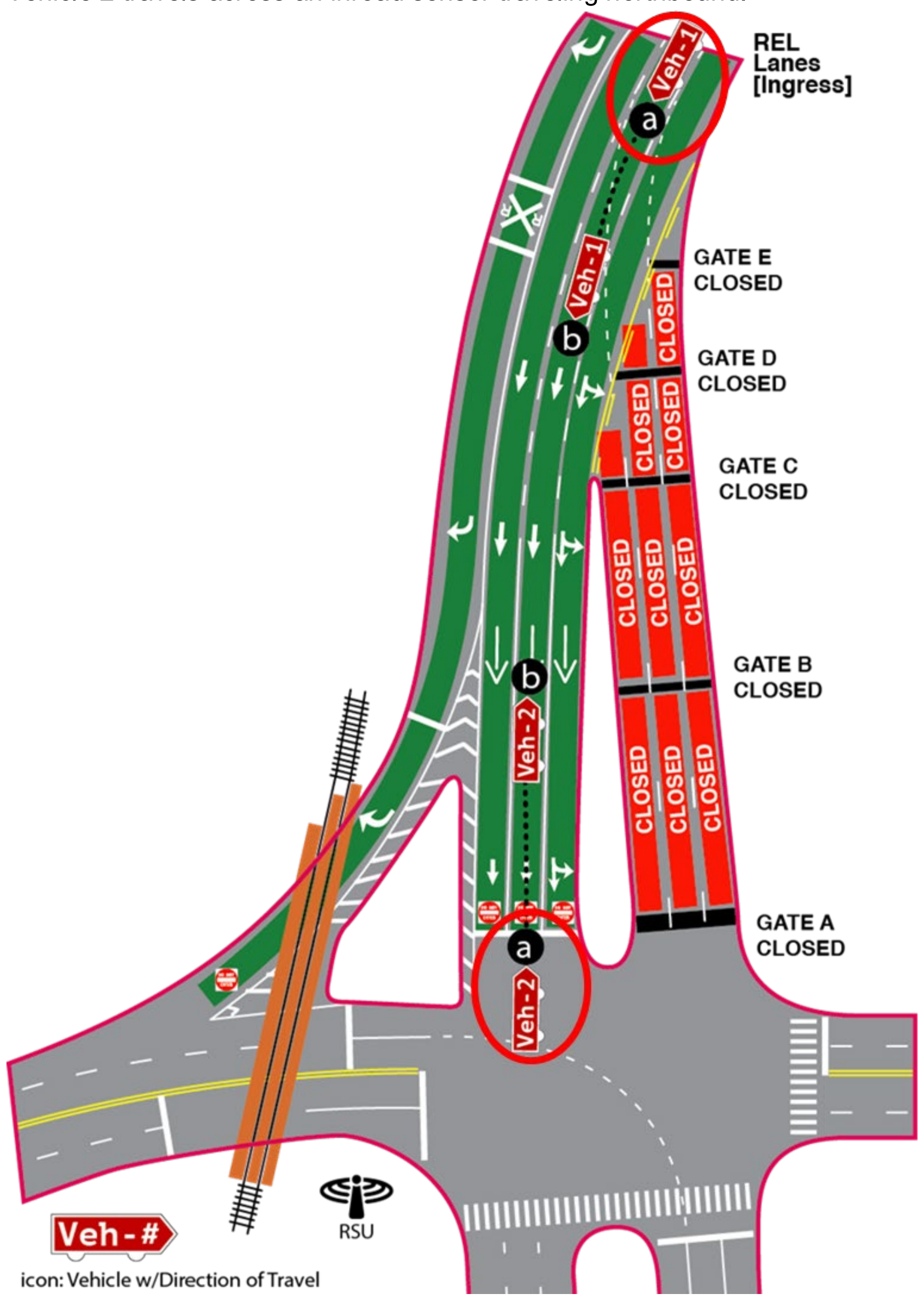
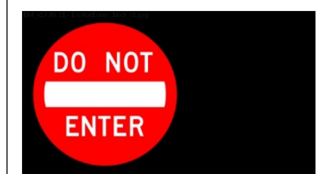
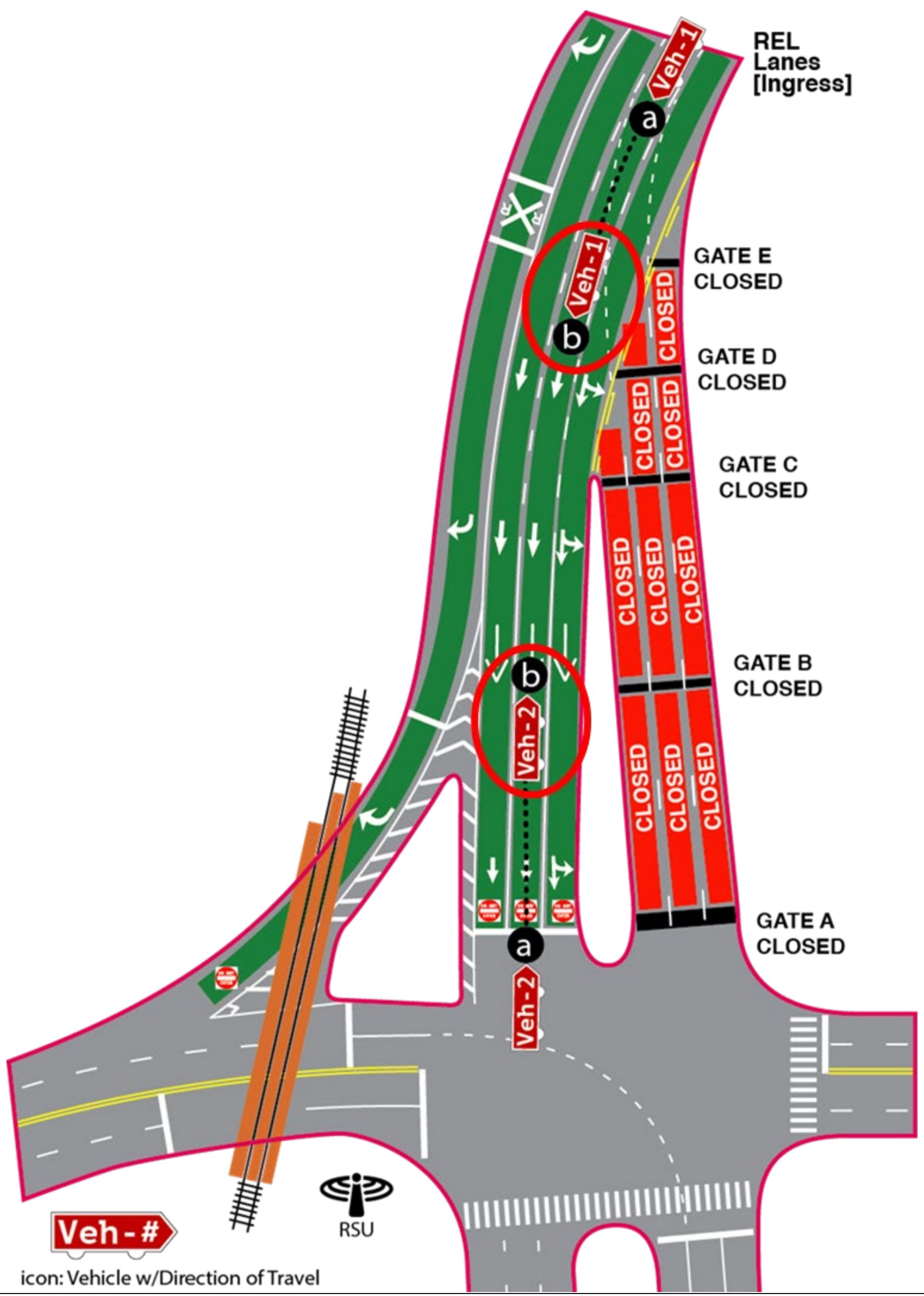


Table 102: UC2D4 Actions

#	Actions	Expected Result	Pass/Fail/Partial + Comments
1	Vehicle 1 is approaching Twiggs Meridian intersection coming from the REL (a). Vehicle 2 travels across an inroad sensor traveling northbound. 	Vehicle 1: No warning is shown to the driver. Vehicle 2: WWE safety application issues a “Do Not Enter” warning to the driver per the HMI specification. 	Pass ___ Fail ___ Partial ___ Comments:

#	Actions	Expected Result	Pass/Fail/Partial + Comments
2	Vehicle 2 travels across an inroad sensor traveling northbound.	Radar detects that a vehicle is going the wrong way and relays the information to the RSU, which broadcasts it to vehicles traveling southbound on the REL.	Pass ___ Fail ___ Partial ___ Comments:
3	Vehicle 1 continues to approach the Twiggs Meridian intersection coming from the REL (b). Vehicle 2 enters the inbound lanes going northbound on the REL (b).  	Vehicle 1: WWE safety application issues a “Wrong-Way Vehicle Ahead” warning to the driver per the HMI specification.  Vehicle 2: WWE safety application issues a “Wrong-Way Entry” warning to the driver per the HMI specification.  	Pass ___ Fail ___ Partial ___ Comments:

The following evening use cases were deleted from the Operational Demonstration by agreement of the AOR:

- UC2D5
- UC2D6

The closed Reversible Express Lane was not opened to conduct the two evening use case demonstrations. Nonetheless, the evening test cases remain in the Operational Readiness Test Plan as a test verification of the evening map plans.

Table 103: UC2D7 Scene

Use Case 2: Wrong-Way Entry

Demonstration 7: Intersection Movement Assist (IMA)

Purpose: To demonstrate the alerts and warnings between two vehicles on a perpendicular crash course.

Test Cases: UC2 IMA_A, THEA-SAF-011

Requirements: THEA-UC2-001, THEA-UC2-003, THEA-UC2-003a, THEA-SAF-020a

Demonstrator: Two Phase 3 Participant Drivers

Facilitator: Brand Motion

Experience:

Observers ride in a participant vehicle equipped with a mirror HMI. Because IMA is a V2V application without the participation of the roadside equipment, this IMA demonstration is conducted at the Hillsborough Community College (HCC) backlot facility. Cones are set up to simulate an intersection. The IMA alerts and warnings will be studied at the intersection of Twiggs/Meridian, as shown. At the last demonstration step, the OBU is disabled as failed to demonstrate safe vehicle operation with a failed OBU.

Expectation:

- HMI issues IMA warning when the two vehicles are on a perpendicular crash course

Table 104: UC2D7 Actions

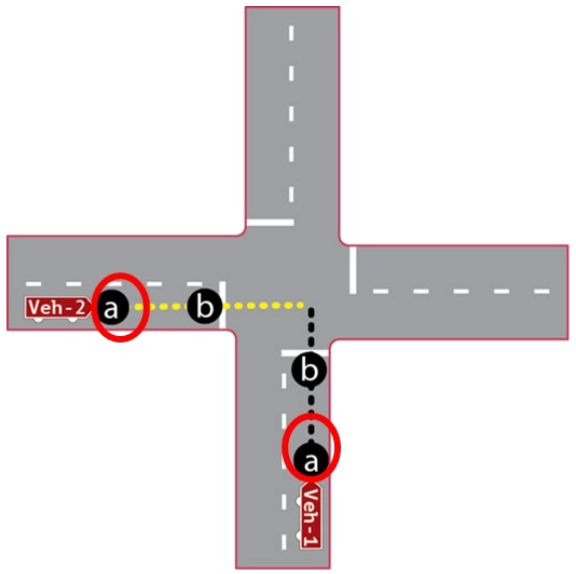
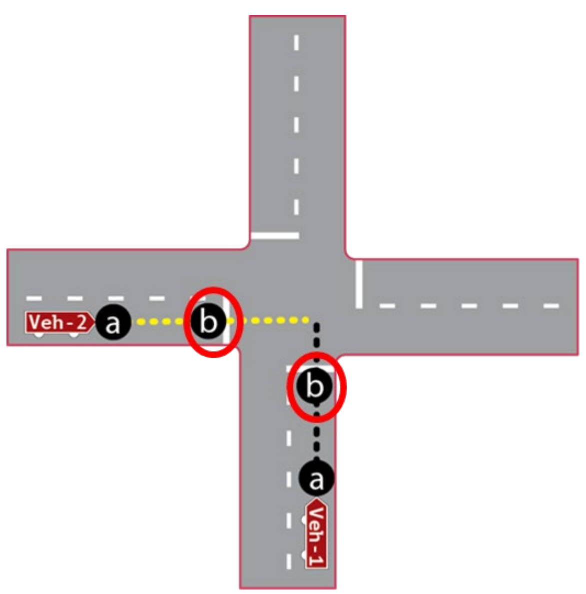
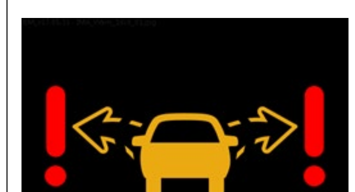
#	Actions	Expected Result	Pass/Fail/Partial + Comments
1	Vehicle 1: Vehicle is approaching the intersection driving north (a). Vehicle 2: Vehicle is approaching the intersection driving east (a).  	No warning is shown to the driver.	Pass ___ Fail ___ Partial ___ Comments:
2	Vehicle 1: Vehicle continues to approach the intersection driving north (b). Vehicle 2: Vehicle continues to approach the intersection driving east (b).  	IMA safety application issues an "IMA" warning to both drivers per the HMI specification. 	Pass ___ Fail ___ Partial ___ Comments:

Table 105: UC3D1 Scene

Use Case 3: Pedestrian Conflicts/Safety

Demonstration 1: PED-X

Purpose: To demonstrate the silent crash alerts generated by the PID for the research staff.

Test Cases: PED-X

Requirements:

THEA-UC3-001, THEA-UC3-002, THEA-UC3-003, THEA-UC3-008, THEA-UC3-009, THEA-UC3-011, THEA-UC3-012, THEA-UC3-015, THEA-UC3-016, THEA-UC3-016a, THEA-UC3-016b, THEA-SAF-020a

Demonstrator: Phase 3 Participant Driver

Facilitator: Siemens

Experience:

Observers riding in a participant vehicle equipped with a mirror HMI approach a midblock, non-signalized crosswalk. The demonstration is conducted at the Hillsborough Community College (HCC) backlot facility. A simulated non-signalized crosswalk will be set up. The observers standing near the crosswalk see a mock pedestrian smartphone in the approach of the participant vehicle. The observers experience multiple test runs with pedestrians:

- Stationary on the curb
- In the center of the travel lane, clearing the travel lane before the car arrives
- On the curb, walking towards the travel lane on a collision course when the car arrives

Expectation:

- Before the vehicle reaches the smartphone, no phone alerts are generated
- When the vehicle nears the smartphone, phone alerts are generated
- HMI warnings when on a crash course with a pedestrian
- No HMI warnings when pedestrians are visible but not on a crash course

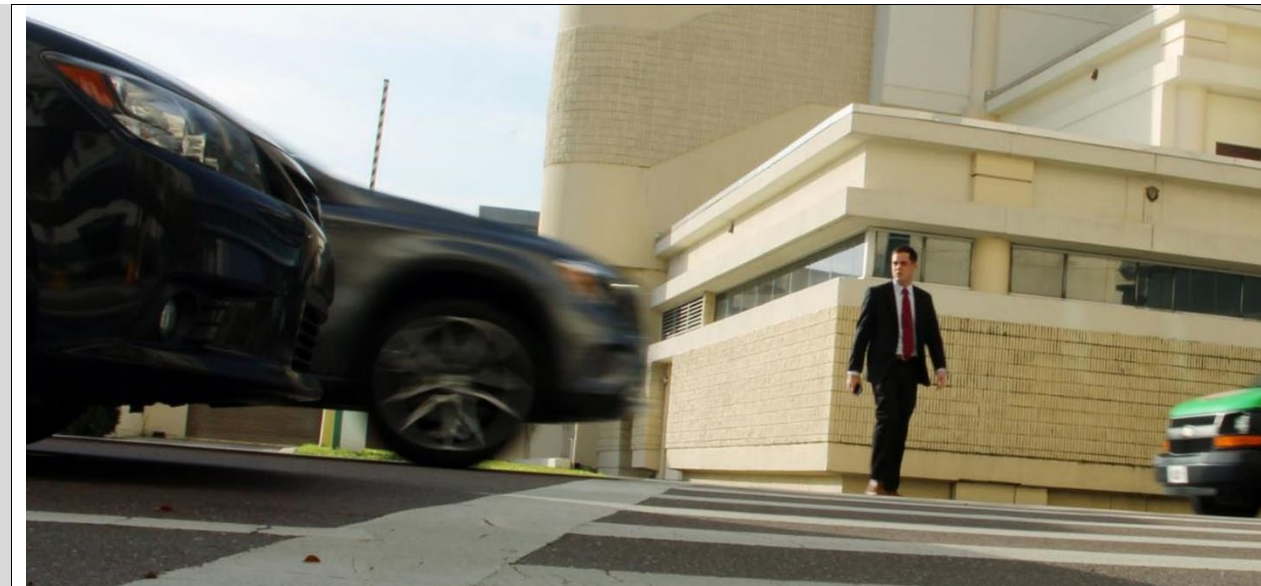
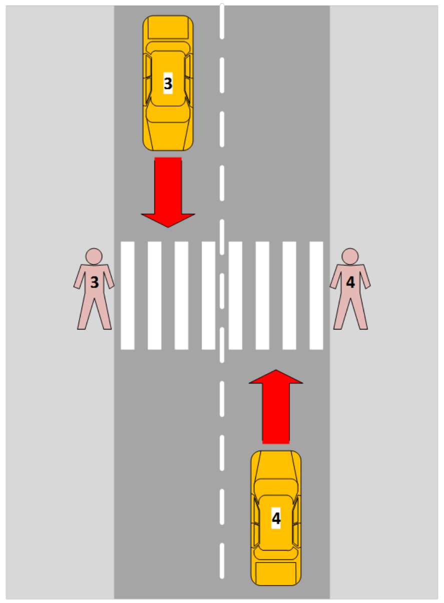
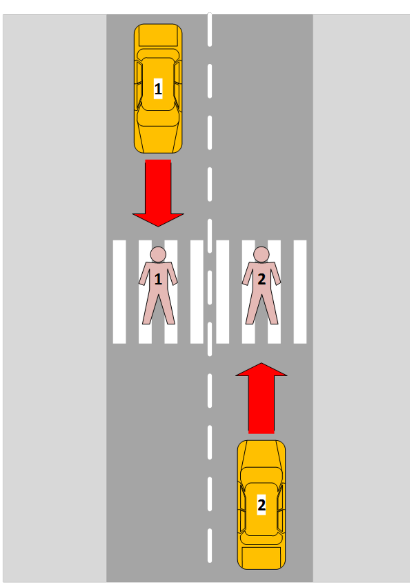
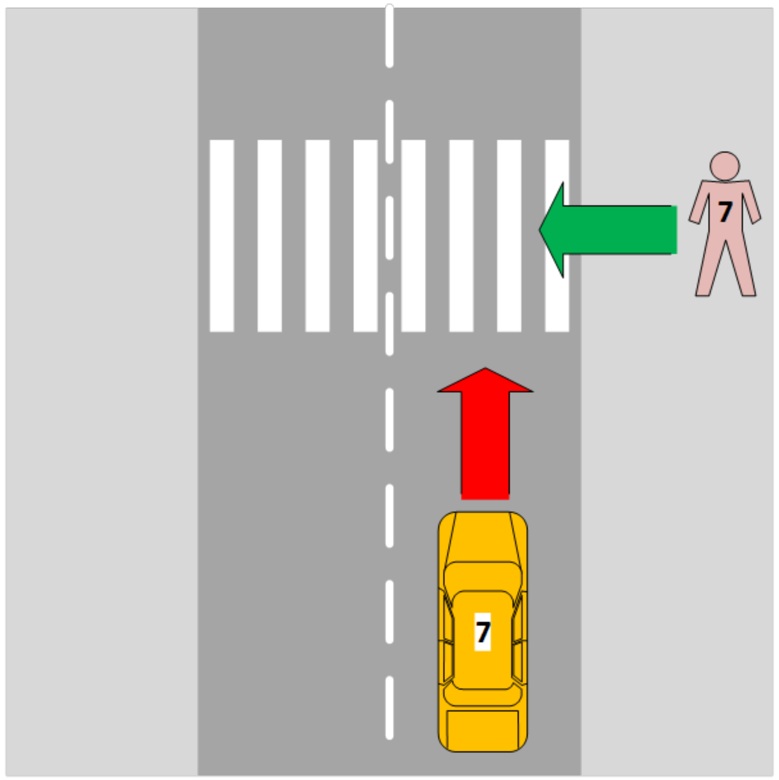
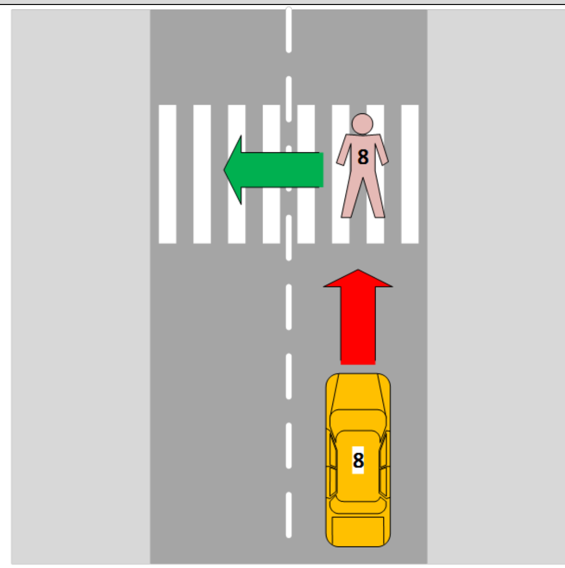
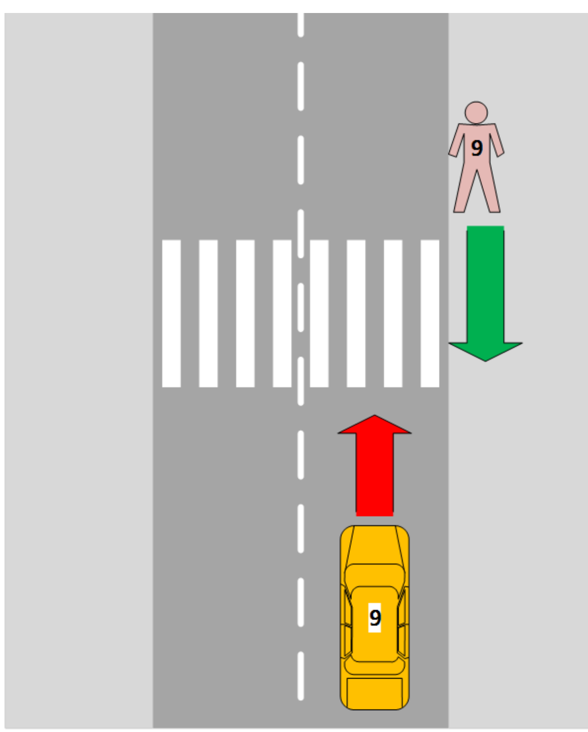


Table 106: UC3D1 Actions

#	Actions	Expected Result	Pass/Fail/Partial + Comments
1	Vehicle 3 approaches, passes, and departs the crosswalk in the direction shown. 	No PCW alert is issued by the HMI.	Pass ___ Fail ___ Partial ___ Comments:
3	Vehicle 1 approaches, passes, and departs the crosswalk in the direction shown. 	PID1 logs a crash alert.	Pass ___ Fail ___ Partial ___ Comments:

#	Actions	Expected Result	Pass/Fail/Partial + Comments
4	Vehicle approaches with a pedestrian on the sidewalk approaching the crosswalk on a crash course with the vehicle.  	PCW alert from OBU per the HMI specification. 	Pass ___ Fail ___ Partial ___ Comments:
5	A vehicle approaches a pedestrian not on a crash course with the vehicle.	No PCW alert is issued by the HMI.	Pass ___ Fail ___ Partial ___ Comments:

#	Actions	Expected Result	Pass/Fail/Partial + Comments
			
6	A vehicle approaches a pedestrian walking head-on to a car but on the sidewalk (conducted impromptu during UC3D1). 	No PCW alert is issued by the HMI.	Pass ___ Fail ___ Partial ___ Comments:
7	Vehicle approaches with two pedestrians involved (conducted impromptu during UC3D1): • Pedestrian 10 in crosswalk walking to the right on a crash trajectory.	First PCW alert from OBU per the HMI specification for Pedestrian 10.	Pass ___ Fail ___ Partial ___

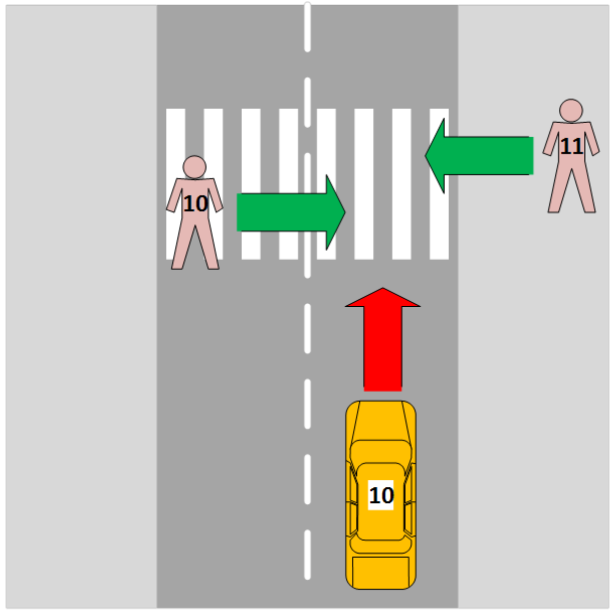
#	Actions	Expected Result	Pass/Fail/Partial + Comments
	• Pedestrian 11 is on the curb walking to the left on a crash trajectory from a greater distance than Pedestrian 10.  	 No PCW alert is issued by the HMI for Pedestrian 10 clearance. Second PCW alert from OBU per the HMI specification for Pedestrian 11. 	Comments:

Table 107: UC4D1 Scene

Use Case 4: Transit Priority

Demonstration 1: TSP

Purpose: To demonstrate bus transit priority functionality.

Test Cases: TSP_A, TSP_B, TSP_C

Requirements:

THEA-UC4-001, THEA-UC4-002, THEA-UC4-003, THEA-UC4-004, THEA-UC4-005, THEA-UC4-007, THEA-UC4-008, THEA-UC4-009, THEA-UC4-013, THEA-SAF-020a

Demonstrator: Phase 3 Transit Operator

Facilitator: Siemens

Experience:

Observers ride in the bus on the transit corridor.
Pedestrians near the transit stop receive PID warning at bus approach and departure.

Expectation:

- The HMI may or may not display transit priority asserted, depending upon the bus position.
- Pedestrians receive PID warning when the bus stops.
- Pedestrians receive PID warning when the nearby bus departs.

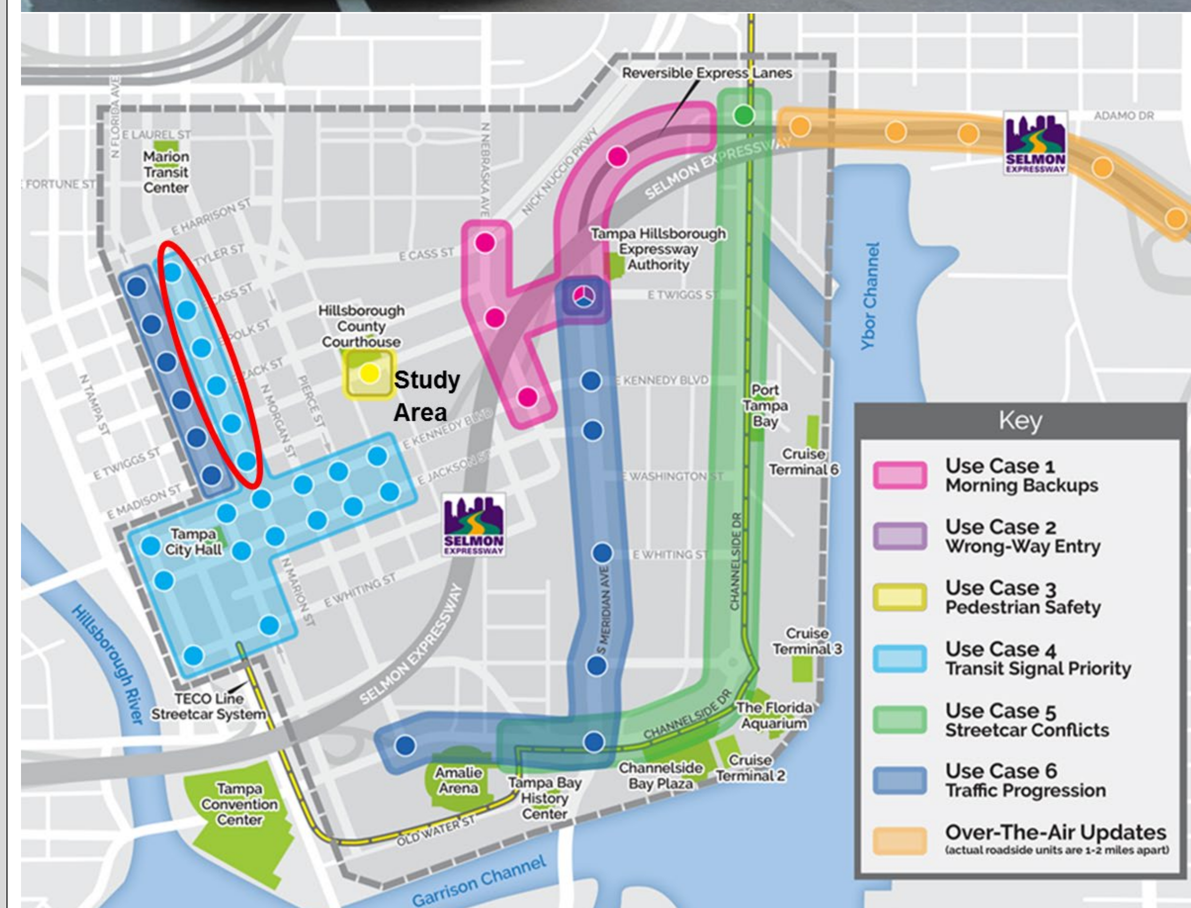
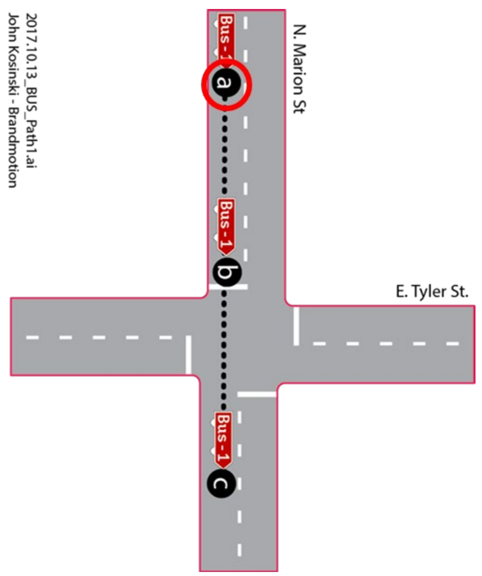
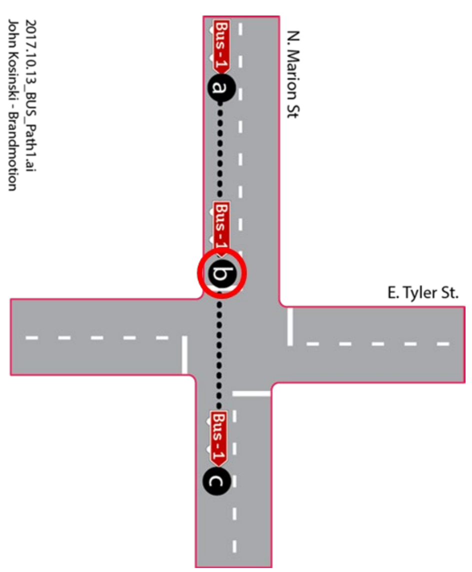


Table 108: UC4D1 Actions

#	Actions	Expected Result	Pass/Fail/Partial + Comments
1	Stop vehicle north of Tyler Street on Marion Street pointing south. Wait until signal head turns green, then depart seconds later.  	Bus OBU broadcasts SRM to RSU as verified by green heartbeat on HMI; no warning is displayed.	Pass ___ Fail ___ Partial ___ Comments:
2	Monitor driver HMI for Signal Status Message (SSM) status to show priority is granted.  	Driver HMI shows priority granted per the HMI specification.  Verify that CU placed Green Hold on Phase 2.	Pass ___ Fail ___ Partial ___ Comments:

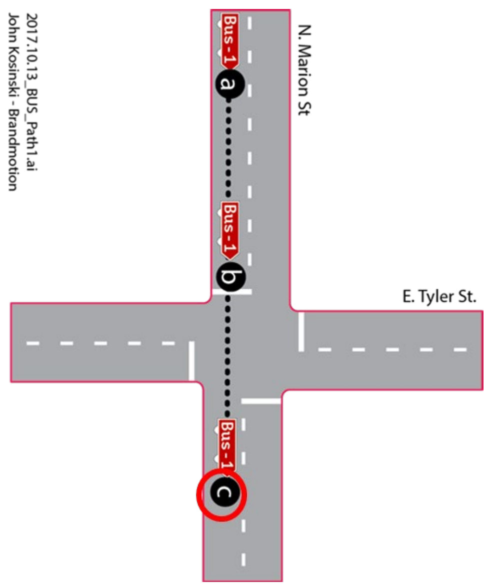
#	Actions	Expected Result	Pass/Fail/Partial + Comments
3	Monitor CU status to show that priority was granted. 	Verify that CU placed Green Hold on Phase 2.	Pass ___ Fail ___ Partial ___ Comments:
4	Bus stops at an intersection.	Pedestrian: Receives warning on PID that bus in the area has stopped driving.	Pass ___ Fail ___ Partial ___ Comments:
5	Bus departs the transit stop.	Pedestrian: Receives warning on PID that bus in the area is starting.	Pass ___ Fail ___ Partial ___ Comments:

Table 109: UC5D1 Scene

Use Case 5: Streetcar Conflicts

Demonstration 1: VTRFTV

Purpose: To demonstrate the silent crash alerts generated by the PID for the research staff and pedestrian crash warnings to the driver.

Test Cases: VTRFTV_A, VTRFTV_B,

Requirements:

THEA-UC5-005, THEA-UC5-005, THEA-UC5-008b, THEA-UC5-009, THEA-UC5-009a, THEA-UC5-009c, THEA-SAF-020a

Demonstrator: Phase 3 Transit Operator and Phase 3 Participant Vehicle

Facilitator: Brand Motion

Experience:

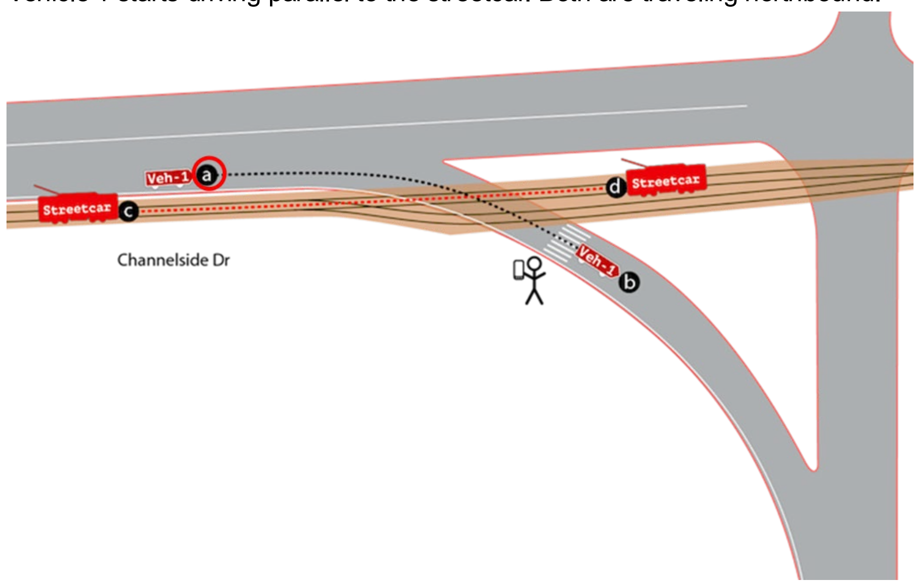
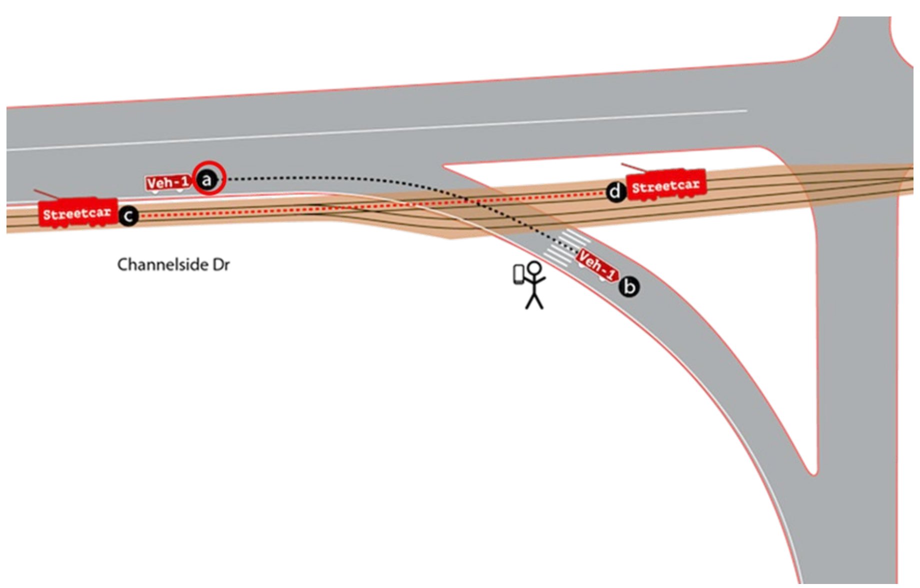
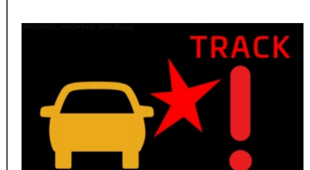
Observers ride in the streetcar on the streetcar rail line, with the participant vehicle traveling alongside to the left. Two runs are conducted.

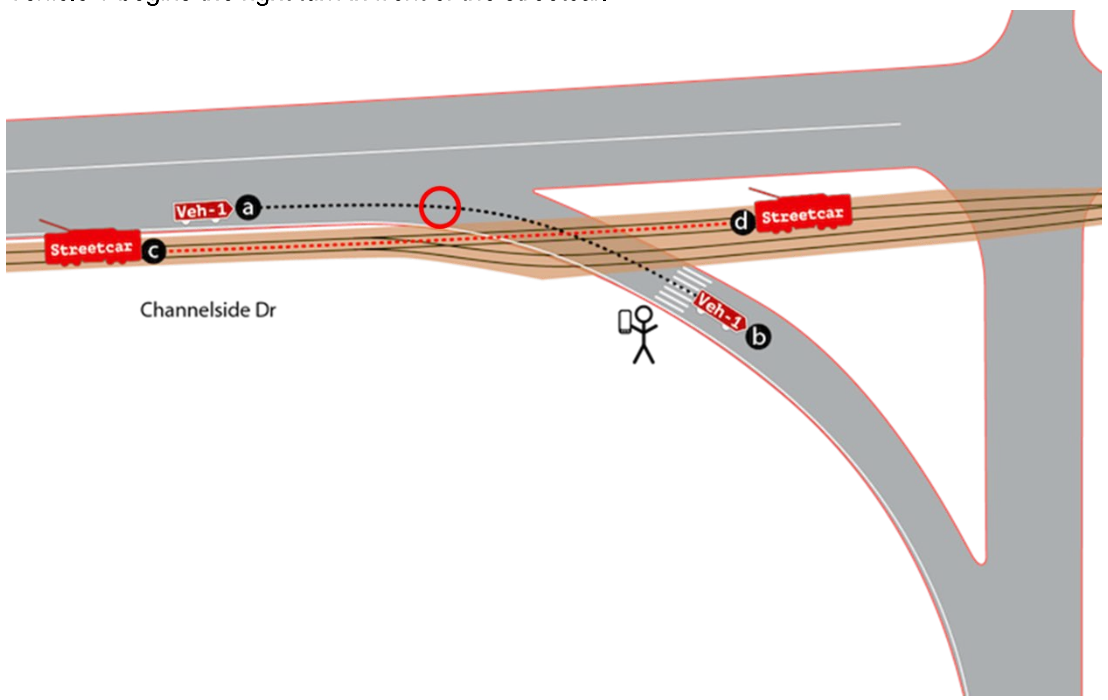
- Run 1: Observers ride in the streetcar
- Run 2: Observers ride in the participant vehicle

Expectation:

- Vehicle HMI warns participant vehicle of streetcar movement to avoid right turns in front of the streetcar
- Streetcar HMI warns streetcar operator of vehicle nearby

Table 110: UC5D1 Actions

#	Actions	Expected Result	Pass/Fail/Partial + Comments
1	Vehicle 1 starts driving parallel to the streetcar. Both are traveling northbound.  	Vehicle 1: No warning is shown to the driver. Streetcar: No warning is shown to the streetcar operator.	Pass ___ Fail ___ Partial ___ Comments:
2	Vehicle 1 turns on its right-turn signal.  	Vehicle 1: Vehicle Turning Right in Front of Transit Vehicle (VTRFTV) safety application issues a “Streetcar” pre-warning to the driver per the HMI specification.  Streetcar: VTRFTV safety application issues a “Vehicle on track” pre-warning to the streetcar operator per the HMI specification.  	Pass ___ Fail ___ Partial ___ Comments:

#	Actions	Expected Result	Pass/Fail/Partial + Comments
3	Vehicle 1 begins the right turn in front of the streetcar.  	Vehicle 1: VTRFTV safety application issues a "Streetcar" warning to the driver per the HMI specification.  Streetcar: VTRFTV safety application issues a "Vehicle on Track" warning to the streetcar operator per the HMI specification.  Streetcar OBU VTRFTV is received by the Master Server. Streetcar OBU VTRFTV is received by PID.	Pass ___ Fail ___ Partial ___ Comments:
4	Vehicle 1 starts driving parallel to the streetcar. Both are traveling northbound.	Vehicle 1: No warning is shown to the driver. Streetcar: No warning is shown to the streetcar operator. Vehicle 1: No VTRFTV warning is received by the Master Server. Streetcar: No VTRFTV warning is received by PID.	Pass ___ Fail ___ Partial ___ Comments:

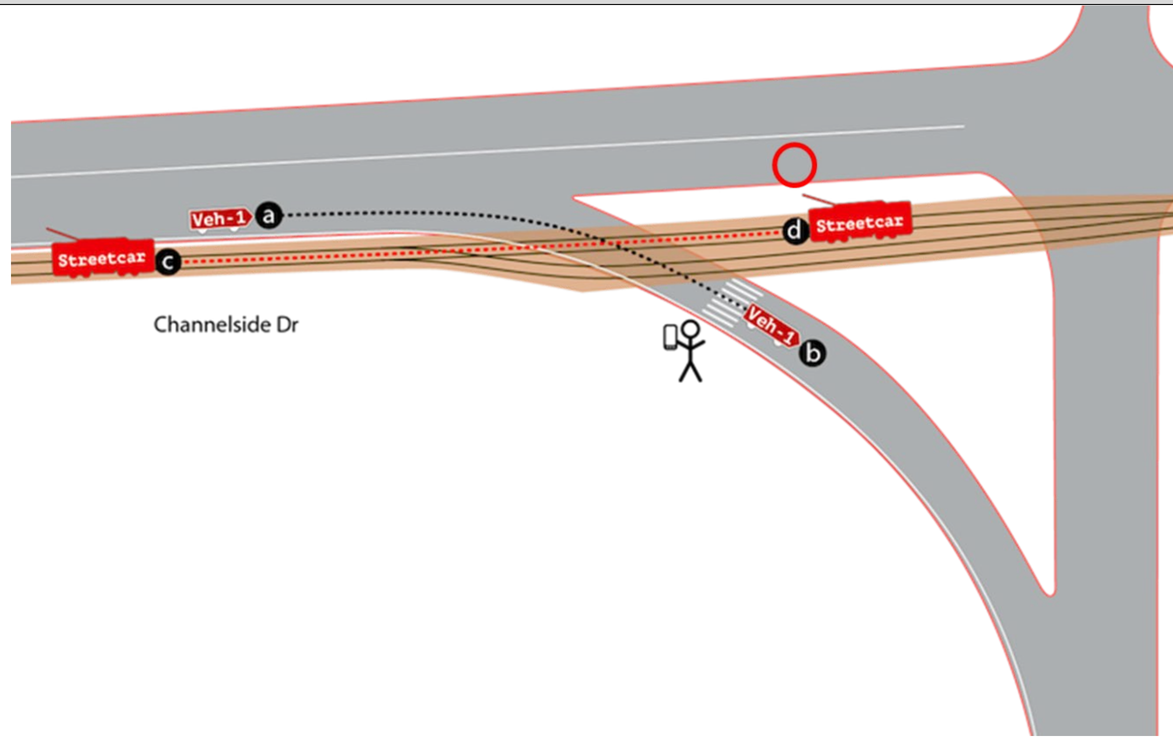
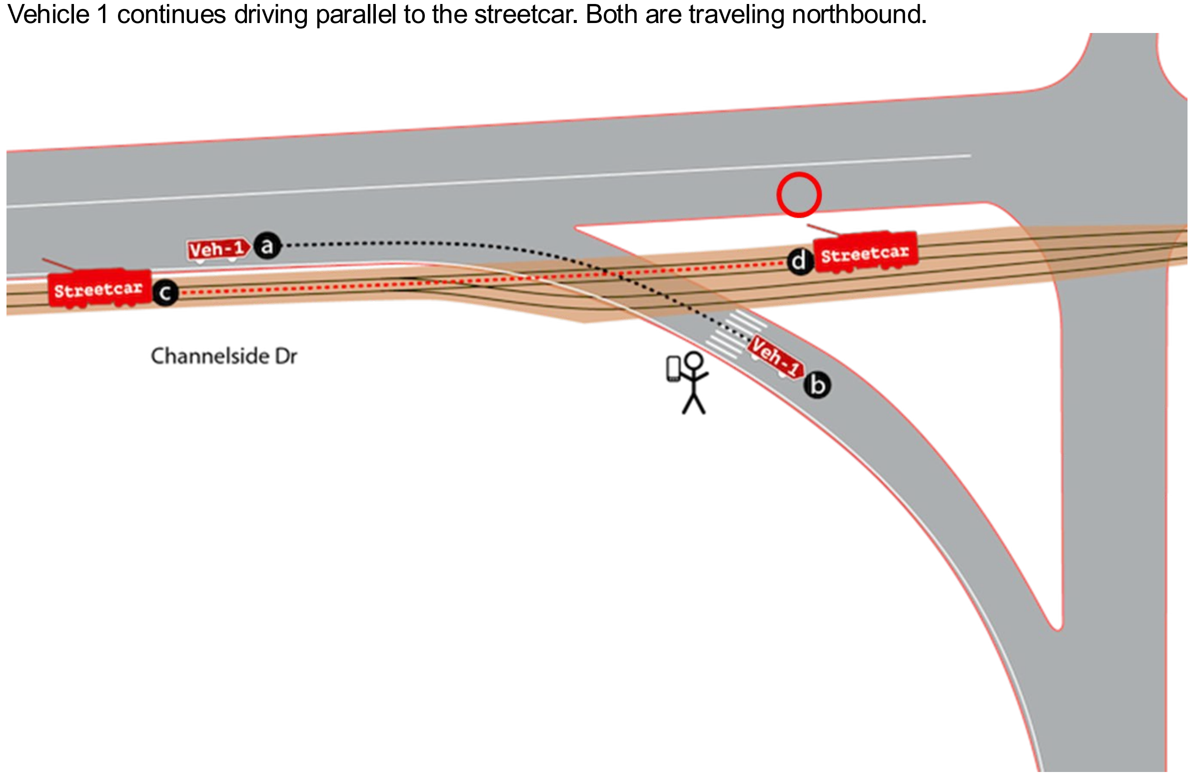
#	Actions	Expected Result	Pass/Fail/Partial + Comments
			
5	Vehicle 1 continues driving parallel to the streetcar. Both are traveling northbound. 	Vehicle 1: No warning is shown to the driver. Streetcar: No warning is shown to the streetcar operator.	Pass ___ Fail ___ Partial ___ Comments:

Table 111: UC6D1 Scene

Use Case 6: Traffic Progression

Demonstration 1: I-SIG Support

Purpose: To demonstrate the ability to support I-SIG and to select between “before” signal plans and I-SIG signal plans for research.

Test Cases: I-SIG, SAF_B

Requirements:

THEA-UC6-018, THEA-UC6-018b, THEA-UC6-018c, THEA-UC6-018d, THEA-UC6-018e, THEA-UC6-018f, THEA-SAF-020a

Demonstrator: Siemens staff, City of Tampa TMC staff

Facilitator: Siemens

Experience:

Observers will see the RSU system console showing received BSMs, plus status showing MMITSS is Enabled and services are Active. Because the demonstration is conducted in live traffic, the intersection of Meridian and Whiting was selected as a T intersection with little impact to traffic flow during the demonstration.

Expectation:

- BSMs are being received by RSU
- MMITSS is installed, enabled, and active
- MMITSS is reporting queue lengths for use by ERDW
- TMC operators can switch between regular signal plans and I-SIG signal plans
- When switched to I-SIG signal plan, I-SIG is guiding the controller phase selection

Table 112: UC6D1 Actions

#	Actions	Expected Result	Pass/Fail/Partial + Comments
1	Check RSU monitor for received BSMs.	BSMs are being received by the RSU.	Pass ___ Fail ___ Partial ___ Comments:
2	Check MMITSS Controller for status.	MMITTS status is “Enabled,” and MMITSS services are “Active.”	Pass ___ Fail ___ Partial ___ Comments:
3	At the RSU UI, view stored queue length estimates from MMITSS.	Queue length estimates for Meridian are shown.	Pass ___ Fail ___ Partial ___ Comments:
4	At the TMC, switch from regular signal plan to I-SIG signal plan with the controller running free.	At TMC, check that signal phases are affected by I-SIG at Meridian/Whiting.	Pass ___ Fail ___ Partial ___ Comments:

Table 113: UC6D2 Scene

Use Case 6: Traffic Progression

Demonstration 2: PED-SIG Support

Purpose: To demonstrate the ability to support PED-SIG on two crosswalks with different alignment.

Test Cases: PED-SIG_A, PED-SIG_B

Requirements:

THEA-UC6-018, THEA-UC6-018b, THEA-UC6-018c, THEA-UC6-018d, THEA-UC6-018e, THEA-UC6-018f, THEA-SAF-020a

Demonstrator: Phase 3 Participant with Smartphone

Facilitator: Siemens

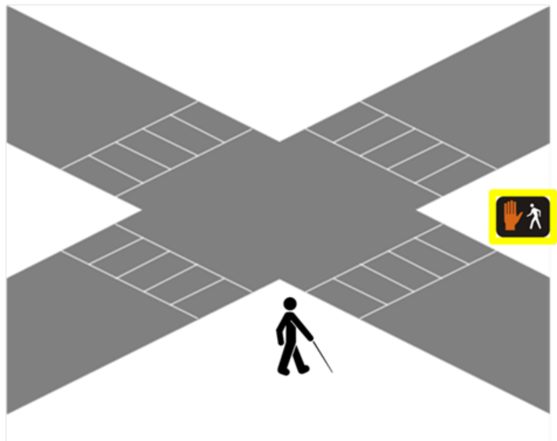
Experience:

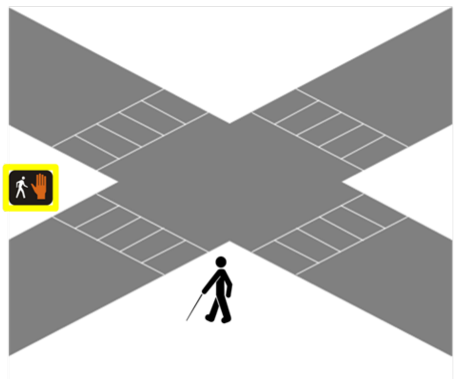
Observers will watch the participant launch the PED-SIG app on a smartphone and place pedestrian calls on two different crosswalks at Meridian and Whiting.

Expectation:

- The pedestrian call is placed from the smartphone on two different crosswalks
- Traffic signal responds with a pedestrian phase for each crosswalk
- WALK countdown is displayed on the smartphone, along with audible and haptic indications

Table 114: UC6D2 Actions

#	Actions	Expected Result	Pass/Fail/Partial + Comments
1	Position pedestrian facing north/south lanes. 	Pedestrian presence has no effect. PID displays "Approach Intersection," "Approach Crosswalk."	Pass ___ Fail ___ Partial ___ Comments:
2	Align PID parallel to the sidewalk, pointed towards the crosswalk. 	Pedestrian presence has no effect. PID displays "Point Device at Crosswalk."	Pass ___ Fail ___ Partial ___ Comments:
3	Press "Request Cross" to request WALK service. 	Traffic Controller Active Screen displays WALK CALL service request for that crosswalk.	Pass ___ Fail ___ Partial ___ Comments:
4	Observe PID screen, pedestrian signal, and CU Active Status screen. 	DON'T WALK phase for that crosswalk is displayed on PID screen, DON'T WALK signal, and CU Active Status Screen.	Pass ___ Fail ___ Partial ___ Comments:
5	Observe PID screen, pedestrian signal, and CU Active Status screen. 	WALK phase for that crosswalk is displayed on PID screen, WALK signal, and CU Active Status screen. PID emits "WALK" phrase.	Pass ___ Fail ___ Partial ___ Comments:
6	Observe PID screen, pedestrian signal, and CU Active Status screen. 	Time remaining is displayed. The PID supports WALK extension, but the controller used does not. PID emits countdown.	Pass ___ Fail ___ Partial ___ Comments:

#	Actions	Expected Result	Pass/Fail/Partial + Comments
7	Position pedestrian facing east/west lanes. 	Pedestrian presence has no effect. PID displays “Approach Intersection,” “Approach Crosswalk.”	Pass ___ Fail ___ Partial ___ Comments:
8	Align PID parallel to the sidewalk, pointed towards the crosswalk. 	Pedestrian presence has no effect. PID displays ”Point Device at Crosswalk.”	Pass ___ Fail ___ Partial ___ Comments:
9	Press PID screen to request WALK service. 	Traffic Controller Active Screen displays WALK CALL service request for that crosswalk.	Pass ___ Fail ___ Partial ___ Comments:
11	Observe PID screen, pedestrian signal, and CU Active Status screen. 	DON’T WALK phase for that crosswalk is displayed on PID screen, DON’T WALK signal, and CU Active Status Screen.	Pass ___ Fail ___ Partial ___ Comments:
12	Observe PID screen, pedestrian signal, and CU Active Status screen. 	WALK phase for that crosswalk is displayed on PID screen, WALK signal, and CU Active Status screen. PID emits “WALK” phrase.	Pass ___ Fail ___ Partial ___ Comments:
13	Observe PID screen and the pedestrian signal. 	Time remaining is displayed. The PID supports WALK extension, but the controller used does not . PID emits countdown.	Pass ___ Fail ___ Partial ___ Comments:
14	Observe PID screen and the pedestrian signal.	DON’T WALK phase for that crosswalk is displayed on PID screen, pedestrians signal, and CU Active Status screen. PID emits DON’T WALK phase.	Pass ___ Fail ___ Partial ___ Comments:

#	Actions	Expected Result	Pass/Fail/Partial + Comments
			

3.5 Demonstration Requirement Verification

3.5.1 Vehicle-Specific Demonstration Procedures

Vehicle-Specific Demonstration Procedures verify vehicle system requirements designated as “D” verification method with no associated test cases. All vehicle-specific demonstrations are conducted in the THEA parking lot.

Table 115: Vehicle-Specific Demonstration Procedures

Vehicle-Specific Demonstration Procedures Requirements: THEA-SAF-011, THEA-SGD-001, THEA-MNT-008, THEA-MNT-009, THEA-MNT-010, THEA-MNT-012, THEA-MNT-013 Facilitators: Global 5 and Brand Motion				
#	**Demonstrator**	**Actions**	**Expected Result**	**Pass/Fail/Partial + Comments**
1	Phase 3 participant	The participant is told that his/her vehicle was just involved in a crash.	Participant schedules vehicle for inspection within 14 days using the service appointment process.	Pass ___ Fail ___ Partial ___ Comments:
2	Phase 3 OBU maintenance staff	Connect to each OBU type and display the BSMs stored locally in the OBU.	The BSMs are stored locally in each OBU log.	Pass ___ Fail ___ Partial ___ Comments:
3	Phase 3 OBU maintenance staff	Disable OBU as failed while the vehicle is operating. Compare HMI operation to the participant training to identify failed OBU.	HMI operation during OBU failure matches the participant training.	Pass ___ Fail ___ Partial ___ Comments:
4	Phase 3 OBU maintenance staff	Replace OBU on participant vehicle.	Successful OBU replacement is completed within the appointment time.	Pass ___ Fail ___ Partial ___ Comments:
5	Phase 3 OBU maintenance staff	Run diagnostic procedure on replaced OBU.	Diagnostic procedure indicates successful OBU replacement.	Pass ___ Fail ___ Partial ___ Comments:

Vehicle-Specific Demonstration Procedures Requirements: THEA-SAF-011, THEA-SGD-001, THEA-MNT-008, THEA-MNT-009, THEA-MNT-010, THEA-MNT-012, THEA-MNT-013 Facilitators: Global 5 and Brand Motion				

3.5.2 Infrastructure-Specific Demonstration Procedures

Infrastructure-specific Demonstration Procedures verify roadside equipment system requirements designated as "D" verification method with no associated test cases. Infrastructure-specific demonstrations are conducted at the City of Tampa TMC.

Table 116: Infrastructure-Specific Demonstration Procedures

Infrastructure-Specific Demonstration Procedures Requirements: THEA-SGD-002 Facilitators: Siemens				
#	**Demonstrator**	**Actions**	**Expected Result**	**Pass/Fail/Partial + Comments**
1	Phase 3 RSU support staff	Connect to RSU service console and display data stored locally in the RSU.	RSU local data display includes Alerts, SPaTs, PSMs, TIMs, SSMs, BSMs, and SRMs.	Pass ___ Fail ___ Partial ___ Comments:

3.5.3 Back Office-Specific Demonstration Procedures

Back Office-Specific Demonstration Procedures verify back-office data collection requirements designated as "D" verification method with no associated test cases. Back office-specific demonstrations are conducted at the City of Tampa TMC and CUTR.

Table 117: Back Office-Specific Demonstration Procedures

Back Office-Specific Demonstration Procedures

Requirements: THEA-SAF-004, THEA-PFM-006, THEA-PFM-007

Facilitators: Siemens

#	Demonstrator	Actions	Expected Result	Pass/Fail/Partial + Comments

1	Phase 3 CUTR Research Staff	From the research server, demonstrate one or more routine reports that are (or planned to be) automated during Phase 3, including:
		• Display formats of example automated reports.
		• Display example data logged from RSU message within the dialog.
		• Display example data logged from OBU message within the dialog.
		• Identify data sources: Master Server, Traffic Server, and Travel Time.
		• Explain automation scripts used to create example reports.
			Reports showing predictable RSU and OBU message dialogs that have been or will be automated with rules:
			• BSM, Alerts, and Warnings from OBU to RSU demonstrated in example daily report are correct.
			• TIMs from RSU to OBU demonstrated in example daily report are correct.
			• OBU BSM data contains encrypted identifier in CUTR secure database per the PMP.
			• Data for distribution is shown processed per the "PII Removal" section of the PMP.
			• Data collected matches the data source, for example:
			  o BSMs sourced by the Master Server.
			  o Stops on Green sourced by Traffic Server.
			  o Bluetooth travel time sourced by Travel Time Server.
			• Example scripts are appropriate for access to data sources.
				Pass ___ Fail ___ Partial ___
				
				Comments:

2	Phase 3 CUTR Research Staff	From the research server, demonstrate one or more routine reports that are (or planned to be) collected manually during Phase 3, including:
		• Display formats of example automated reports.
		• Display example data logged from RSU message within the dialog.
		• Display example data logged from OBU message within the dialog.
		• Identify data sources: Master Server, Traffic Server, and Travel Time
		• Explain manual commands used to create example reports.
			Reports showing predictable RSU and OBU message dialogs that are planned to be collected manually:
			• BSM, Alerts, and Warnings from OBU to RSU demonstrated in example manual report are correct.
			• TIMs from RSU to OBU demonstrated in example manual report are correct.
			• OBU BSM data contains encrypted identifier in CUTR secure database per the PMP.
			• Data for distribution is shown processed per the "PII Removal" section of the PMP.
			• Data collected matches the data source, for example:
			  o BSMs sourced by the Master Server.
			  o Stops on Green sourced by Traffic Server.
			  o Bluetooth travel time sourced by Travel Time Server.
			• Example manual commands are appropriate for access to data sources.
				Pass ___ Fail ___ Partial ___
				
				Comments:

3	Phase 3 City of Tampa Staff	From the TMC, display the RSU management map of the pilot study area.	Area map displays the RSU locations and the operational status of each RSU.	Pass ___ Fail ___ Partial ___ Comments:

3.6 Inspection Requirements Verification

Inspection Procedures verify system requirements designated as "I" verification method with no associated test cases or demonstration procedures. Inspection is a non-destructive examination of equipment, documents, photos, electronic data files, demonstrated as a set of live, real-time activities conducted at THEA headquarters. The inspection may involve simple physical manipulation and measurements.

3.6.1 Safety

Table 118: Safety Requirement Inspection

Requirement ID	VM	Requirement Phrase	Configuration	Verified by Examination of	Pass/Fail/Partial/Comment
THEA-SAF-001	I	Standards certification	OBU and RSU as installed	OBU certification, RSU statement of compliance	Pass ___ Fail ___ Partial ___ Comment:
THEA-SAF-007	I	PID application failure	PID Failure	PED-SIG test report of failure during development	Pass ___ Fail ___ Partial ___ Comment:
THEA-SAF-014	I	User interface approval	Vehicle HMI and central screens	Approval by THEA, City of Tampa, CUTR, HART	Pass ___ Fail ___ Partial ___ Comment:
THEA-SAF-020	I	Vehicle installer approval	Vehicle equipment installation	Brand Motion installer approval	Pass ___ Fail ___ Partial ___ Comment:
THEA-SAF-021	I	Infrastructure installer approval	Infrastructure equipment installation	Siemens installer approval	Pass ___ Fail ___ Partial ___ Comment:

3.6.2 Security

Table 119: Security Requirement Inspection

Requirement	VM	Requirement Phrase	Configuration	Verified by Examination of	Pass/Fail/Partial/Comment
THEA-SEC-001	I	OBU IEEE 1609.2 compliance	OBUs as installed	OBU certification for each type	Pass ___ Fail ___ Partial ___ Comment:
THEA-SEC-001a	I	RSU IEEE 1609.2 compliance	RSUs as installed	RSU statement of compliance	Pass ___ Fail ___ Partial ___ Comment:
THEA-SEC-002	I	Non-DSRC encryptions	RSUs as installed	Encrypted message files	Pass ___ Fail ___ Partial ___ Comment:
THEA-SEC-003	I	SCMS implementation	Production SCMS	Production SCMS security credentials	Pass ___ Fail ___ Partial ___ Comment:
THEA-SEC-004	I	PII removal	Master Server as installed	Data files of OBU data after PII removal	Pass ___ Fail ___ Partial ___ Comment:
THEA-SEC-005	I	Intrusion detection monitoring	Master Server as installed	Data Privacy Plan Breach Detection, Remediation	Pass ___ Fail ___ Partial ___ Comment:
THEA-SEC-006	I	RSU firewall	RSUs as installed	RSU service console firewall	Pass ___ Fail ___ Partial ___ Comment:
THEA-SEC-006a	I	OBU firewall	OBUs as installed	OBU service console firewall	Pass ___ Fail ___ Partial ___ Comment:
THEA-SEC-014	I	Access to participant data	Master Server as installed	Master Server access security policy	Pass ___ Fail ___ Partial ___ Comment:
THEA-SEC-019	I	Use of temporary IDs	Master Server as installed	Master Server data files after PII removal	Pass ___ Fail ___ Partial ___ Comment:
THEA-SEC-023	I	OBU bootstrap access	OBUs as installed	OBU physical access	Pass ___ Fail ___ Partial ___ Comment:
THEA-SEC-023a	I	RSU bootstrap access	RSUs as installed	RSU physical access	Pass ___ Fail ___ Partial ___ Comment:
THEA-SEC-072	I	Unused port tamper seal	RSUs, OBUs as installed	Unused port seals	Pass ___ Fail ___ Partial ___ Comment:

Note: Absent misbehavior detection requirements, messages received by OBUs without valid signatures are not reported. Misbehavior detection is a current topic of USDOT, with Siemens developing misbehavior detection for verification in the THEA pilot.

3.6.3 Performance

Table 120: Performance Requirement Inspection

Requirement	VM	Requirement Phrase	Configuration	Verified by Examination of	Pass/Fail/Partial/Comment
THEA-PFM-001	I	Collect "Before" data	CUTR Server as installed	Examples of collected data before treatment	Pass ___ Fail ___ Partial ___ Comment:
THEA-PFM-002	I	Store "Before" data	CUTR Server as installed	Files of stored collected data before treatment	Pass ___ Fail ___ Partial ___ Comment:

Requirement	VM	Requirement Phrase	Configuration	Verified by Examination of	Pass/Fail/Partial/Comment
THEA-PFM-003	I	Collect performance data	CUTR Server as installed	Examples of collected performance data	Pass ___ Fail ___ Partial ___ Comment:
THEA-PFM-004	I	Store performance data	CUTR Server as installed	Files of stored performance data	Pass ___ Fail ___ Partial ___ Comment:
THEA-PFM-005	I	Before-After comparison	CUTR Server as installed	Analysis done by CUTR server for each CV app	Pass ___ Fail ___ Partial ___ Comment:
THEA-PFM-012	I	Data collected	Concert Server as installed	System design document for data collection	Pass ___ Fail ___ Partial ___ Comment:
THEA-PFM-012a	I	Travel time computation	Concert Server as installed	System design document for link travel time	Pass ___ Fail ___ Partial ___ Comment:
THEA-PFM-012b	I	Arrival on green	Centracs Server as installed	Arrival data screens in Centracs	Pass ___ Fail ___ Partial ___ Comment:
THEA-PFM-012c	I	Bus arrival schedule	HART Server as installed	Bus performance screen	Pass ___ Fail ___ Partial ___ Comment:
THEA-PFM-012d	I	Research data collected	CUTR Server as installed	Data collection examples	Pass ___ Fail ___ Partial ___ Comment:
THEA-PFM-013	I	Research data stored	CUTR Server as installed	Files of data stored	Pass ___ Fail ___ Partial ___ Comment:

3.6.4 Information Management

Table 121: Information Management Requirement Inspection

Requirement	VM	Requirement Phrase	Configuration	Verified by Examination of	Pass/Fail/Partial/Comment
THEA-INM-001	I	Review participant PII	Master Server as installed	Collected PII	Pass ___ Fail ___ Partial ___ Comment:
THEA-INM-002	I	Separate PII storage	Master Server as installed	Stored PII data separately from CV data	Pass ___ Fail ___ Partial ___ Comment:
THEA-INM-003	I	PII login	Master Server as installed	Login procedure for PII data	Pass ___ Fail ___ Partial ___ Comment:
THEA-INM-004	I	PII removal	Master Server as installed	Data destined for RDE	Pass ___ Fail ___ Partial ___ Comment:

3.6.5 System Generated Data

Table 122: System Data Requirement Inspection

Requirement	VM	Requirement Phrase	Configuration	Verified by Examination of	Pass/Fail/Partial/ Comment
THEA-SGD-003	I	OBU to RSU data transfer	OBU and RSU as installed	RSU data from OBU and security method	Pass ___ Fail ___ Partial ___ Comment:
THEA-SGD-004	I	RSU to Master Server transfer	RSU, Master Server as installed	Master server data from RSU and security method	Pass ___ Fail ___ Partial ___ Comment:
THEA-SGD-007	I	Archived data security	Master Server as installed	Archived data file, security, redundancy methods	Pass ___ Fail ___ Partial ___ Comment:
THEA-SGD-008	I	Password Access	Master Server as installed	Inspect login hierarchy policy and design	Pass ___ Fail ___ Partial ___ Comment:
THEA-SGD-009	I	Authorized per SMOC	Master Server as installed	Hierarchy access policy compared to SMOC	Pass ___ Fail ___ Partial ___ Comment:

3.6.6 Maintainability

Table 123: Maintainability Requirement Inspection

Requirement	VM	Requirement Phrase	Configuration	Verified by Examination of	Pass/Fail/Partial/Comment
THEA-MNT-001	I	Failure response time	RSUs as installed	RSU service response policy	Pass ___ Fail ___ Partial ___ Comment:
THEA-MNT-002	I	Restoration time	RSUs as installed	RSU service restoration policy	Pass ___ Fail ___ Partial ___ Comment:
THEA-MNT-003	I	RSU hardware service policy	RSUs as installed	RSU service contract	Pass ___ Fail ___ Partial ___ Comment:
THEA-MNT-004	I	RSU software app issues	RSUs as installed	RSU software app maintenance	Pass ___ Fail ___ Partial ___ Comment:
THEA-MNT-005	I	RSU planned maintenance	RSUs as installed	RSU planned maintenance process	Pass ___ Fail ___ Partial ___ Comment:
THEA-MNT-006	I	RSU off-peak maintenance	RSUs as installed	RSU planned maintenance process	Pass ___ Fail ___ Partial ___ Comment:
THEA-MNT-007	I	OBU failure log entries	OBUs as installed	OBU failure log examples by TOD	Pass ___ Fail ___ Partial ___ Comment:

3.6.7 Reliability

Table 124: Reliability Requirement Inspection

Requirement	VM	Requirement Phrase	Configuration	Verified by Examination of	Pass/Fail/Partial/Comment
THEA-SRL-002	I	RSU data deletion	RSUs as installed	RSU data deletion method documentation	Pass ___ Fail ___ Partial ___ Comment:
THEA-SRL-003	I	OBU data deletion	OBUs as installed	OBU data deletion method documentation	Pass ___ Fail ___ Partial ___ Comment:

3.6.8 Policy and Regulation

Table 125: Policy Regulation Requirement Inspection

Requirement	VM	Requirement Phrase	Configuration	Verified by Examination of	Pass/Fail/Partial /Comment
THEA-PAR-001	I	RSU licensing	RSUs as installed	FCC license, FDOT license	Pass ___ Fail ___ Partial ___ Comment:

3.7 Demonstration Data

Table 126: Demonstration Data

Use Case	Apps	Location	Data Before	Data During	Data After	Pass
Morning Backup	ERDW	Inbound REL	None	Alerts, Warnings, BSMs	Alerts, Warnings, BSMs	Data After = Demo
	EEBL	Inbound REL	None	Alerts, Warnings, BSMs	Alerts, Warnings, BSMs	Data After = Demo
	FCW	Inbound REL	None	Alerts, Warnings, BSMs	Alerts, Warnings, BSMs	Data After = Demo
	I-SIG	Twiggs/Meridian	South Phase	Southbound Phase	Southbound Phase	Calls, Omits, Holds
Wrong-Way Entry	WWE	REL Entrance	None	Alerts, Warnings, BSMs	Alerts, Warnings, BSMs	Data After = Demo
	IMA	REL Entrance	None	Alerts, Warnings, BSMs	Alerts, Warnings, BSMs	Data After = Demo
	I-SIG	REL Entrance	North Phase	Northbound Phase	Northbound Phase	NB Omits
Pedestrian Safety	PED-X	Courthouse	None	Alerts, Warnings, BSMs, PSMs	Alerts, Warnings, BSMs, PSMs	Data After = Demo
	PTMW	Marion Avenue	None	Alerts, Warnings, BSMs, TIMs	Alerts, Warnings, BSMs, TIMs	Data After = Demo
	I-SIG	Meridian Avenue	None	PED Phase	PED Phase	PED Phase=Demo
	PED-SIG	Meridian Avenue	PED Phase	PED Phase	PED Phase	PED Phase=Demo
Transit Priority	I-SIG	Marion Avenue	Phase Timing	Phase Timing	Phase Timing	GREEN Extension
	TSP	Marion Avenue	SRM,SSM,TIM	SRM, SSM, TIM	SRM, SSM, TIM	TIM = SSM
Streetcar Conflicts	VTRFTV	Channelside Drive	None	Alerts, Warnings, BSMs	Alerts, Warnings, BSMs	Data After = Demo
	PCW	Channelside Drive	None	Alerts, Warnings, BSMs	Alerts, Warnings, BSMs	Data After = Demo
	I-SIG	Channelside Drive	Phase Timing	Phase Timing	Phase Timing	Calls, Omits, Holds
Traffic Progression	I-SIG	Meridian Avenue	Phase Timing	Phase Timing	Phase Timing	Calls, Omits, Holds

	PDETM	Meridian Avenue	TMC Travel Time, Speed, Counts, Stops on Green	Concert Travel Time, Speed, Counts TMC Stops on Green	Concert Travel Time, Speed, Counts TMC Stops on Green	Concert Travel Time, Speed, Counts TMC Stops on Green

3.8 Demonstration Schedule

Table 127: Demonstration Schedule

Date	Time	UC	Demonstration	Locations	Support
Tue, 4/24/18	0900-1030		Intro, Overview of 3-days	THEA	Anna/Johnson/ Burcham
	1030-1130	1	ERDW, EEBL, FCW	Closed REL	Siemens/drivers
	1130-1230	2	WWE	Closed REL	Siemens/drivers
	1230-1330		Lunch	On your own	
	1330-1430		Master Server/CUTR Server -Specific	THEA	Concas/THEA IT
	1430-1530	6	I-SIG, PED-SIG	Meridian/Whiting	Siemens/drivers
	1530 - 1600		Travel	Marion Transit Center	
	1600-1700	4	TSP	Marion/Tyler	HART/Siemens
			PTMW	Marion /Tyler	HART/Siemens
Wed, 4/25/18	0830-0900		Review Day1/Overview of Day 2	THEA	Anna/Johnson/ Burcham
	0900-0930	5	VTRFTV	Channelside /Adamo	HART/drivers
	0930-1030	6	PDETM/RSU Management	TMC	Siemens/COT
	1030-1100		Travel		
	1100-1200	3	PCW, PEDX, IMA	HCC	Siemens/drivers
	1200-1300		Lunch	On your own	
	1300-1630		Infrastructure-specific demos	THEA	Siemens
			Vehicle-specific demos	THEA	Brand Motion
Thu, 4/26/18	Open		ORDP Wrap-up Phase 3 Launch	THEA	Frey/Johnson
	Open		Demo backup day		

3.9 Demonstration Results

3.9.1 Results Document

Each demonstration action table includes a column for PASS___FAIL___PARTIAL, along with a COMMENT area for each observer. After completion of the demonstration, the comments from all observers are consolidated into a final version of this document, which is the Demonstration Results deliverable.

3.9.2 Task H Deliverable Plan

Required deliverables per Task H are summarized in the Operational Readiness Report:

- Final Installation and Operational Readiness Schedule of actual vs. plan completion dates
- Final IORS with Risk Register indicating the risks that were encountered and mitigated
- Test Results populated into the Test Procedures section extracted from the final ORP
- Operational Readiness Demonstrations results extracted from the final ORP

4. Glossary

Table 128: Glossary

ACRONYM	DEFINITION
BRT	Bus Rapid Transit
BSM	Basic Safety Message
BT	Bluetooth
CAMP	Crash Avoidance Metrics Partnership
CBD	Central Business District
ConOps	Concept of Operations
CM	Configuration Management
CMS	Central Management System
CoT	City of Tampa
COTS	Commercial-Off-the-Shelf
CU	Controller Unit
CUTR	Center for Urban Transportation Research, University of South Florida
CV	Connected Vehicle
CVRIA	Connected Vehicle Reference Implementation Architecture
DER	Distinguished Encoding Rules
Detector	Infrastructure device that senses moving objects
DMS	Dynamic Message Sign
DSRC	Dedicated Short-Range Communications
EEBL	Emergency Electronic Brake Light
ERDW	End of Ramp Deceleration Warning
FCW	Forward Collision Warning
FHWA	Federal Highway Administration
g	Gravity Force
HART	Hillsborough Area Regional Transit
HMI	Human Machine Interface
HW	Hardware
ICD	Interface Control Document
I	Infrastructure
ICD	Interface Control Document
IEEE	Institute of Electronic and Electrical Engineers
IMA	Intersection Movement Assist
Incident	Unplanned random traffic event that adversely affects normal traffic operations
ISG	Infrastructure Sensor Gateway

ACRONYM	DEFINITION
I-SIG	Intelligent Signal software application
ITS	Intelligent Transportation System
JPO	Joint Program Office
LTP	Level Test Plan
MAFB	MacDill Air Force Base
MAP	Map message conformant to SAE standard J2735-2016
MMITSS	Multi-Modal Intelligent Traffic Signal System
MOU	Memorandum of Understanding
MTP	Master Test Plan
NEMA	National Electrical Manufacturers Association
NMEA	National Marine Electronics Association
NTSC	National Television System Committee
O&M	Operations and Maintenance
OBE	On-Board Equipment
OBU	On-Board Unit
OCIT	Open Communications Interfaces for Traffic Systems
OCPI	Open Content Provider Interface
ORD	Operational Readiness Demonstration
ORDP	Operational Readiness Demonstration Plan
ORTP	Operational Readiness Test Plan
ORP	Operational Readiness Plan
ORR	Operational Readiness Report
OS	Operating System
OSADP	Open Source Application Development Portal
PAN	Personal Area Network
PCW	Pedestrian Collision Warning
PDETM	Probe Data Enabled Traffic Monitoring
PED	Pedestrian
PED-SIG	Mobile Accessible Pedestrian Signals System
PED-X	Pedestrian in a Signalized Crosswalk
PID	Personal Information Devices
PII	Personally-Identifiable Information
PSA	Pedestrian Safety Application
PID	Personal Information Device, such as a smartphone
PTMW	Pedestrian Transit Movement Warning
QG	Quality Gate
RDE	Research Data Exchange
REL	Reversible Express Lanes
RLV	Red Light Violation
RSE	Roadside Equipment
RSU	Roadside Unit

ACRONYM	DEFINITION
SAE	Society of Automotive Engineers
SCMS	Security Credential Management System
SEP	Systems Engineering Process
SPaT	Signal Phase and Timing message conformant to SAE standard J2736-2016
SW	Software
TC	Test Case
THEA	Tampa Hillsborough Expressway Authority
TIM	Traveler Information Message
TMC	Transportation Management Center
TMDD	Traffic Management Data Dictionary
TSP	Transit Signal Priority
UC	Use Case
USDOT	United States Department of Transportation
V	Vehicle
V2I	Vehicle-To-Infrastructure
V2V	Vehicle-To-Vehicle
V2X	Vehicle-To-Everything
VIN	Vehicle Identification Number
VM	Verification Method
VTRFTV	Vehicle Turning Right in Front of a Transit Vehicle
WWE	Wrong-Way Entry
X	Everything

Appendix A

During the week of April 23, 2018, the Tampa Hillsborough Expressway Authority (THEA) conducted an Operational Readiness Demonstration (ORD) for the United States Department of Transportation (USDOT) Intelligent Transportation Systems (ITS) Joint Program Office (JPO). The THEA Connected Vehicle (CV) Pilot (referred hereafter as the Pilot) completed the design and development of the CV apps. As this point in the project, the Pilot was prepared to perform the ORD. The purpose of the ORD was to demonstrate the Pilot had completed initial integration testing of the infrastructure, Roadside Units (RSUs), the in-vehicle systems, Onboard Units (OBUs), and the associated applications (apps) to the USDOT staff.
The apps demonstrated were:

- Forward Collision Warning (FCW)
- Emergency Electronic Brake Light (EEBL) warning
- End of Ramp Deceleration Warning (ERDW)
- Wrong-Way Entry (WWE)

The Pilot had successfully tested these apps repeatedly before the ORD. During the ORD, these apps began to work inconsistently to the point where some apps would not work at all. Because of this inconsistency, a device, the 3M Sniffer, used by the Pilot to monitor the transmissions on the dedicated short-range communications (DSRC) channels was brought online to see if there were any issues with the DSRC channels the Pilot was using. After monitoring and analyzing the *.pcap files captured, it was determined there was interference being broadcast on these channels. The interference was so substantial that the basic safety messages (BSMs) and traveler information messages (TIMs) could not be transmitted or received. The CV communications are designed to transmit messages when there is no activity on the channel. Because of the high volume of interference on the channel, it was a rare case when the messages were able to be successfully broadcast.

As a result of this interference, the ORD was not successful. USDOT required the Pilot to determine the cause of the interference, address the interference, and then create and perform a System Reliability Test (SRT). The SRT was to demonstrate the apps performed reliably without interference present.

The cause of the interference was identified. A local HamWAN operator, a valid secondary licensed user, was broadcasting on the DSRC channels the Pilot was using. The HamWAN broadcast was a continuous stream of data; it did not listen for other traffic, but instead, just broadcast its data without pausing. Because the CV apps are designed per specification to listen and not broadcast until the channel is available, the DSRC messages were rarely being broadcast. The result of this interference caused the Pilot apps to, at best, work intermittently or not at all.
Once the HamWAN operator was identified, the operator was contacted, and several meetings ensued to discuss if both the HamWAN and Pilot could coexist on the DSRC channels. If a secondary operator is shown to interfere with the operation of CV safety apps, the secondary operator is required to vacate the channels. The HamWAN operator agreed to temporarily change the direction of his antennas such that the DSRC channels he was using would not be transmitted in the Tampa Central Business District (CBD).

Following this agreement, the THEA team planned a system reliability test the week of June 11th, 2018. During these tests, the THEA team conducted extensive testing of each application list above. Each vendor OBU (Sirius XM, Savari, and Commsignia) were tested. For each OBU, each application was tested ten times to prove the CV apps worked as designed without the secondary interference. Each test was video recorded for proof the apps worked correctly. Below is a table for each vendor and app showing each test run and the result of the test. The video filename is provided if the reader chooses to review each test run for each OBU vendor.

Table 129: OBU Vendor

OBU Vendor	App Tested	Result	Comment	Video Filename
Sirius XM	EEBL 1	Pass		Sirius XM EEBL 1.MOV
	EEBL 2	Pass		Sirius XM EEBL 2.MOV
	EEBL 3	Pass		Sirius XM EEBL 3.MOV
	EEBL 4	Pass		Sirius XM EEBL 4.MOV
	EEBL 5	Pass		Sirius XM EEBL 5.MOV
	EEBL 1a Test Case A	Pass		Sirius XM EEBL Test Case 1a.MOV
	EEBL 1aa Test Case A	Pass		Sirius XM EEBL Test Case 1aa.MOV
	EEBL 1aaa Test Case A	Pass		Sirius XM EEBL Test Case 1aaa.MOV
	EEBL 2a Test Case	Pass		Sirius XM EEBL Test Case 2a.MOV
	EEBL 2aa Test Case	Pass		Sirius XM EEBL Test Case 2aa.MOV
	EEBL 3a Test Case	Pass		Sirius XM EEBL Test Case 3a.MOV
	EEBL 3aa Test Case	Fail		Sirius XM EEBL Test Case 3aa.MOV
	EEBL 4a Test Case	Pass		Sirius XM EEBL Test Case 4a.MOV
	EEBL 4aa Test Case	Fail		Sirius XM EEBL Test Case 4aa.MOV
	EEB5a Test Case	Pass		Sirius XM EEBL Test Case 5a.MOV
	EEBL 5aa Test Case	Fail		Sirius XM EEBL Test Case 5aa.MOV
	EEBL 6aa Test Case	Fail		Sirius XM EEBL Test Case 6aa.MOV
	EEBL 7aa Test Case	Fail		Sirius XM EEBL Test Case 7aa.MOV

OBU Vendor	App Tested	Result	Comment	Video Filename
	EEBL 8aa Test Case	Fail		Sirius XM EEBL Test Case 8aa.MOV
	EEBL 9aa Test Case	Pass		Sirius XM EEBL Test Case 9aa.MOV
	EEBL 10aa Test Case	Pass		Sirius XM EEBL Test Case 10aa.MOV
	EEBL 11aa Test Case	Pass		Sirius XM EEBL Test Case 11aa.MOV
	ERDW 1 Short Queue	Fail	Received 40 and 30 warnings only	Sirius XM Short Queue Test 1 .MOV
	ERDW 2 Short Queue	Fail	No warnings received	Sirius XM Short Queue Test 2 .MOV
	ERDW 3 Short Queue	Pass		Sirius XM Short Queue Test 3 .MOV
	ERDW 4 Short Queue	Pass		Sirius XM Short Queue Test 4 .MOV
	ERDW 5 Short Queue	Pass		Sirius XM Short Queue Test 5 .MOV
	ERDW 6 Short Queue	Pass	False FCW received. Not relevant to communication test	Sirius XM Short Queue Test 6 .MOV
	ERDW 7 Short Queue	Pass		Sirius XM Short Queue Test 7 .MOV
	ERDW 8a Short Queue	Pass		Sirius XM Short Queue Test 8a .MOV
	ERDW 8b Short Queue	Pass	False FCW received. Not relevant to communication test	Sirius XM Short Queue Test 8b .MOV
	ERDW 9 Short Queue	Pass	False FCW received. Not relevant to this testing	Sirius XM Short Queue Test 9 .MOV
	ERDW 10 Short Queue	Pass		Sirius XM Short Queue Test 10 .MOV
	ERDW 11 Short Queue	Pass		Sirius XM Short Queue Test 11 .MOV
	ERDW 12 Short Queue	Pass	FCW received due to vehicle on shoulder. Not relevant to this testing	Sirius XM Short Queue Test 12 .MOV

OBU Vendor	App Tested	Result	Comment	Video Filename
	ERDW 13 Short Queue	Pass		Sirius XM Short Queue Test 13 .MOV
	ERDW 14 Short Queue	Pass	False FCW received. Not relevant to this testing	Sirius XM Short Queue Test 14 .MOV
	ERDW 15 Short Queue	Pass	False FCW received. Not relevant to this testing	Sirius XM Short Queue Test 15 .MOV
	ERDW 1 Long Queue	Pass	Received false positive FCW near end of Reversible Express Lanes (REL)	Sirius XM Long Queue Test 1.MOV
	ERDW 2 Long Queue	Pass		Sirius XM Long Queue Test 2.MOV
	ERDW 3 Long Queue	Pass		Sirius XM Long Queue Test 3.MOV
	ERDW 4 Long Queue	Pass		Sirius XM Long Queue Test 4.MOV
	ERDW 5 Long Queue	Pass		Sirius XM Long Queue Test 5.MOV
	ERDW 6 Long Queue	Pass		Sirius XM Long Queue Test 6.MOV
	ERDW 7 Long Queue	Pass		Sirius XM Long Queue Test 7.MOV
	ERDW 8 Long Queue	Pass		Sirius XM Long Queue Test 8.MOV
	ERDW 9 Long Queue	Pass		Sirius XM Long Queue Test 9.MOV
	ERDW 10 Long Queue	Fail	Only 40 mph warning received	Sirius XM Long Queue Test 10.MOV
	ERDW 11 Long Queue	Fail	No warnings received	Sirius XM Long Queue Test 11.MOV
	ERDW 12 Long Queue	Fail	No warnings received	Sirius XM Long Queue Test 12.MOV
	ERDW 13 Long Queue	Pass		Sirius XM Long Queue Test 13.MOV
	ERDW 14 Long Queue	Pass		Sirius XM Long Queue Test 14.MOV
	ERDW 15 Long Queue	Pass		Sirius XM Long Queue Test 15.MOV
	PCW 1	Pass		Sirius XM PCW 1.mp4
	PCW 2	Pass		Sirius XM PCW 2.mp4
	PCW 3	Fail		Sirius XM PCW 3.mp4
	PCW 4	Pass		Sirius XM PCW 4.mp4
	PCW 5	Pass	No sound; was not turned on	Sirius XM PCW 5.mp4
	PCW 6	Pass		Sirius XM PCW 6.mp4
	PCW 7	Pass		Sirius XM PCW 7.mp4

OBU Vendor	App Tested	Result	Comment	Video Filename
	PCW 8	Pass		Sirius XM PCW 8.mp4
	PCW 9	Fail	Heading issue with LiDAR	Sirius XM PCW 9.mp4
	PCW 10	Fail	Heading issue with LiDAR	Sirius XM PCW 10.mp4
	PCW 11	Fail	PSM not received from RSU/LiDAR	Sirius XM PCW 11.mp4
	VTRFTV Vehicle 1 Test Case A	Fail		Sirius XM VTRFTV Vehicle Test Case A 1.MOV
	VTRFTV Vehicle 2 Test Case A	Pass		Sirius XM VTRFTV Vehicle Test Case A 2.MOV
	VTRFTV Vehicle 3 Test Case A	Pass		Sirius XM VTRFTV Vehicle Test Case A 3.MOV
	VTRFTV Vehicle 4 Test Case A	Pass		Sirius XM VTRFTV Vehicle Test Case A 4.MOV
	VTRFTV Vehicle 5 Test Case A	Pass		Sirius XM VTRFTV Vehicle Test Case A 5.MOV
	VTRFTV Vehicle 1 Test Case B	Fail		Sirius XM VTRFTV Vehicle Test Case B 1.MOV
	WWE 1 Test Case A	Pass		Sirius XM WWE Test Case A 1.MOV
	WWE 2 Test Case A	Pass		Sirius XM WWE Test Case A 2.MOV
	WWE 3 Test Case A	Pass		Sirius XM WWE Test Case A 3.MOV
	WWE 4 Test Case A	Pass		Sirius XM WWE Test Case A 4.MOV
	WWE 5 Test Case A	Pass		Sirius XM WWE Test Case A 5.MOV
	WWE 6 Test Case A	Pass		Sirius XM WWE Test Case A 6.MOV
	WWE 7 Test Case A	Pass		Sirius XM WWE Test Case A 7.MOV
	WWE 8 Test Case A	Pass		Sirius XM WWE Test Case A 8.MOV
	WWE 9 Test Case A	Pass		Sirius XM WWE Test Case A 9.MOV
	WWE 10 Test Case A	Pass		Sirius XM WWE Test Case A 10.MOV
	WWE 11 Test Case A	Pass		Sirius XM WWE Test Case A 11.MOV

OBU Vendor	App Tested	Result	Comment	Video Filename
	WWE 12 Test Case A	Pass		Sirius XM WWE Test Case A 12.MOV
	WWE 13 Test Case A	Pass		Sirius XM WWE Test Case A 13.MOV
	WWE 14 Test Case A	Pass		Sirius XM WWE Test Case A 14.MOV
	WWE 15 Test Case A	Pass		Sirius XM WWE Test Case A 15.MOV
	WWE 1 Test Case B	Pass		Sirius XM WWE Test Case B 1.MOV
	WWE 2 Test Case B	Pass		Sirius XM WWE Test Case B 2.MOV
	WWE 3 Test Case B	Pass		Sirius XM WWE Test Case B 3.MOV
	WWE 4 Test Case B	Fail		Sirius XM WWE Test Case B 4.MOV
	WWE 5 Test Case B	Fail		Sirius XM WWE Test Case B 5.MOV
	WWE 6 Test Case B	Pass		Sirius XM WWE Test Case B 6.MOV
	WWE 7 Test Case B	Fail		Sirius XM WWE Test Case B 7.MOV
	WWE 8 Test Case B	Fail		Sirius XM WWE Test Case B 8.MOV
	WWE 9 Test Case B	Fail		Sirius XM WWE Test Case B 9.MOV
	WWE 10 Test Case B	Fail	Alert too late	Sirius XM WWE Test Case B 10.MOV
	WWE 11 Test Case B	Fail	Alert too late	Sirius XM WWE Test Case B 11.MOV
	WWE 12 Test Case B	Fail	Alert too late	Sirius XM WWE Test Case B 12.MOV
	WWE 13 Test Case B	Fail	Alert too late	Sirius XM WWE Test Case B 13.MOV
	WWE 14 Test Case B	Fail	Alert too late	Sirius XM WWE Test Case B 14.MOV
	WWE 15 Test Case B	Fail	Alert too late	Sirius XM WWE Test Case B 15.MOV
	WWE 1 Test Case C	Pass		Sirius XM WWE Test Case C 1.MOV
	WWE 2 Test Case C	Pass		Sirius XM WWE Test Case C 2.MOV
	WWE 3 Test Case C	Pass		Sirius XM WWE Test Case C 3.MOV
	WWE 4 Test Case C	Pass		Sirius XM WWE Test Case C 4.MOV

OBU Vendor	App Tested	Result	Comment	Video Filename
	WWE 5 Test Case C	Pass		Sirius XM WWE Test Case C 5.MOV
	WWE 6 Test Case C	Pass		Sirius XM WWE Test Case C 6.MOV
	WWE 7 Test Case C	Pass		Sirius XM WWE Test Case C 7.MOV
	WWE 8 Test Case C	Pass		Sirius XM WWE Test Case C 8.MOV
	WWE 9 Test Case C	Pass		Sirius XM WWE Test Case C 9.MOV
	WWE 10 Test Case C	Pass		Sirius XM WWE Test Case C 10.MOV
	WWE 11 Test Case C	Pass		Sirius XM WWE Test Case C 11.MOV
	WWE 12 Test Case C	Pass		Sirius XM WWE Test Case C 12.MOV
	WWE 13 Test Case C	Fail	Incorrect symbols initially are shown	Sirius XM WWE Test Case C 13.MOV
	WWE 14 Test Case C	Pass		Sirius XM WWE Test Case C 14.MOV
	WWE 15 Test Case C	Pass		Sirius XM WWE Test Case C 15.MOV
Savari	EEBL 1	Pass		Savari EEBL 1.MOV
	EEBL 2	Pass		Savari EEBL 2.MOV
	EEBL 3	Pass		Savari EEBL 3.MOV
	EEBL 4	Pass		Savari EEBL 4.MOV
	EEBL 5	Pass		Savari EEBL 5.MOV
	ERDW 1 Short Queue		No video	
	ERDW 2 Short Queue	Pass		Savari Short Queue Test 2.MOV
	ERDW 3 Short Queue		No video	
	ERDW 4 Short Queue		No video	
	ERDW 5 Short Queue		No video	
	ERDW 6 Short Queue		No video	

OBU Vendor	App Tested	Result	Comment	Video Filename
	ERDW 7 Short Queue		No video	
	ERDW 8 Short Queue		No video	
	ERDW 9 Short Queue		No video	
	ERDW 10 Short Queue	Pass		Savari Short Queue Test 10.MOV
	ERDW 1 Long Queue	Pass		Savari Long Queue Test 1.MOV
	ERDW 2 Long Queue	Pass		Savari Long Queue Test 2.MOV
	ERDW 3 Long Queue	Pass		Savari Long Queue Test 3.MOV
	ERDW 4 Long Queue	Pass		Savari Long Queue Test 4.MOV
	ERDW 5 Long Queue	Pass		Savari Long Queue Test 5.MOV
	ERDW 6a Long Queue	Pass		Savari Long Queue Test 6a.MOV
	ERDW 6b Long Queue	Pass		Savari Long Queue Test 6b.MOV
	ERDW 8 Long Queue	Pass		Savari Long Queue Test 8.MOV
	ERDW 9 Long Queue	Pass		Savari Long Queue Test 9.MOV
	ERDW 10 Long Queue	Pass		Savari Long Queue Test 10.MOV
	ERDW 11 Long Queue	Pass		Savari Long Queue Test 11.MOV
	ERDW 12 Long Queue	Pass		Savari Long Queue Test 12.MOV
	ERDW 13 Long Queue	Pass		Savari Long Queue Test 13.MOV
	ERDW 14 Long Queue	Pass		Savari Long Queue Test 14.MOV
	ERDW 15 Long Queue	Pass		Savari Long Queue Test 15.MOV
	PCW 1	Pass		Savari PCW 1.mp4
	PCW 2	Pass		Savari PCW 2.mp4
	VTRFTV Trolley 1 Test Case A	Fail		Savari VTRFTV Trolley Test Case A 1.MOV

OBU Vendor	App Tested	Result	Comment	Video Filename
	VTRFTV Trolley 1a Test Case A	Pass		Savari VTRFTV Trolley Test Case A 1a.MOV
	VTRFTV Trolley 2 Test Case A	Pass		Savari VTRFTV Trolley Test Case A 2.MOV
	VTRFTV Trolley 3 Test Case A	Pass		Savari VTRFTV Trolley Test Case A 3.MOV
	VTRFTV Trolley 4 Test Case A	Pass		Savari VTRFTV Trolley Test Case A 4.MOV
	VTRFTV Trolley 1 Test Case B	Pass		Savari VTRFTV Trolley Test Case B 1.MOV
	VTRFTV Trolley 8 Test Case A	Pass		Savari VTRFTV Trolley Test Case A 8.MOV
g	WWE 1 Test Case A	Pass		Savari WWE Test Case A 1.MOV
	WWE 2 Test Case A	Pass		Savari WWE Test Case A 2.MOV
	WWE 3 Test Case A	Pass		Savari WWE Test Case A 3.MOV
	WWE 4 Test Case A	Pass		Savari WWE Test Case A 4.MOV
	WWE 5 Test Case A	Pass		Savari WWE Test Case A 5.MOV
	WWE 6 Test Case A	Pass		Savari WWE Test Case A 6.MOV
	WWE 7 Test Case A	Pass		Savari WWE Test Case A 7.MOV
	WWE 8 Test Case A	Pass		Savari WWE Test Case A 8.MOV
	WWE 9 Test Case A	Pass		Savari WWE Test Case A 9.MOV
	WWE 10 Test Case A	Pass		Savari WWE Test Case A 10.MOV
	WWE 11 Test Case A	Pass		Savari WWE Test Case A 11.MOV
	WWE 12 Test Case A	Pass		Savari WWE Test Case A 12.MOV
	WWE 13 Test Case A	Pass		Savari WWE Test Case A 13.MOV
	WWE 14 Test Case A	Pass		Savari WWE Test Case A 14.MOV

OBU Vendor	App Tested	Result	Comment	Video Filename
	WWE 15 Test Case A	Pass		Savari WWE Test Case A 15.MOV
	WWE 1 Test Case B	Pass		Savari WWE Test Case B 1.MOV
	WWE 2 Test Case B	Pass		Savari WWE Test Case B 2.MOV
	WWE 3 Test Case	Pass		Savari WWE Test Case B 3.MOV
	WWE 4 Test Case B	Pass		Savari WWE Test Case B 4.MOV
	WWE 5 Test Case B	Pass		Savari WWE Test Case B 5.MOV
	WWE 6 Test Case B	Pass	Notice the IMA as they pull out of the parking lot. It is legitimate as the Tahoe (Sirius XM) is passing by	Savari WWE Test Case B 6.MOV
	WWE 7 Test Case B	Pass		Savari WWE Test Case B 7.MOV
	WWE 8 Test Case B	Pass		Savari WWE Test Case B 8.MOV
	WWE 9 Test Case B	Pass		Savari WWE Test Case B 9.MOV
	WWE 10 Test Case B	Pass		Savari WWE Test Case B 10.MOV
	WWE 11 Test Case B	Pass		Savari WWE Test Case B 11.MOV
	WWE 12 Test Case B	Pass		Savari WWE Test Case B 12.MOV
	WWE 13 Test Case B	Pass		Savari WWE Test Case B 13.MOV
	WWE 14 Test Case B	Pass		Savari WWE Test Case B 14.MOV
	WWE 15 Test Case B	Pass		Savari WWE Test Case B 15.MOV
	WWE 1 Test Case C	Pass		Savari WWE Test Case C 1.MOV
	WWE 2 Test Case C	Pass		Savari WWE Test Case C 2.MOV
	WWE 3 Test Case C	Pass		Savari WWE Test Case C 3.MOV
	WWE 4 Test Case C	Pass		Savari WWE Test Case C 4.MOV
	WWE 5 Test Case C	Pass		Savari WWE Test Case C 5.MOV
	WWE 6 Test Case C	Pass	Anomaly, 40 MPH warning should not have shown	Savari WWE Test Case C 6.MOV

OBU Vendor	App Tested	Result	Comment	Video Filename
	WWE 7 Test Case C	Pass		Savari WWE Test Case C 7.MOV
	WWE 8a Test Case C	Pass		Savari WWE Test Case C 8a.MOV
	WWE 8b Test Case C	Pass		Savari WWE Test Case C 8b.MOV
	WWE 9 Test Case C	Pass		Savari WWE Test Case C 9.MOV
	WWE 10 Test Case C	Pass		Savari WWE Test Case C 10.MOV
	WWE 11 Test Case C	Pass		Savari WWE Test Case C 11.MOV
	WWE 12 Test Case C	Pass		Savari WWE Test Case C 12.MOV
	WWE 13 Test Case C	Pass		Savari WWE Test Case C 13.MOV
	WWE 14 Test Case C	Pass		Savari WWE Test Case C 14.MOV
	WWE 15 Test Case C	Pass		Savari WWE Test Case C 15.MOV

As shown in the table above, there were 115 Sirius XM and 84 Savari tests performed for a total of 199. There are several ways to analyze this data. The table below provides the analysis method and the percentage of successful tests for that method.

Table 130: Analysis Method

Analysis Method	Percent Successful	
Total Tests Executed	84%	
Sirius XM Total Tests Executed	74%	
Sirius XM EEBL	73%	
Sirius XM ERDW	84%	
Sirius XM PCW	55%	Note: The majority of the failures were due to heading issues with the LiDAR that have been corrected
Sirius XM VTRFTV	67%	
Sirius XM WWE	73%	
Savari Total Tests Executed	99%	
Savari EEBL	100%	
Savari ERDW	100%	
Savari PCW	100%	

Analysis Method	Percent Successful	
Savari VTRFTV	86%	
Savari WWE	100%	

To further demonstrate the Pilot apps functioned as designed, the second round of reliability testing was performed the week of August 27, 2018. This testing not only demonstrated the reliability of the Pilot apps but also was the initial testing of the data log transfer from the OBU to the RSU to the Master Computer to the Performance Measurement Server. The results of the data log testing are discussed in Appendix A. Appendix A consists of the initial testing for Emergency Electronic Brake Light Warning, End of Ramp Deceleration Warning, Forward Collision Warning, Intersection Movement Assist, Vehicle Turning Right in Front of Transit Vehicle, and Wrong-Way Entry. As can be seen in these reports, the initial testing was mostly successful. Vehicle generates warnings that were transferred from the OBU to the RSU; the RSU to the Master Server; and the Master Server to the Performance Measurement Server.

Finally, during the week of January 7, 2019, a final test of the Pilot app reliability was performed that included final testing of the data log transfer. The results of this test are shown in the table below.

Table 131: OBU Vendor

OBU Vendor	App Tested	Result	Supporting Documentation
Sirius XM	ERDW 1 Long Queue	Pass	See Appendix B
	ERDW 2 Long Queue	Pass	See Appendix B
	ERDW 3 Long Queue	Pass	See Appendix B
	ERDW 4 Long Queue	Pass	See Appendix B
	ERDW 5 Long Queue	Pass	See Appendix B
	ERDW 1 Short Queue	Pass	See Appendix B
	ERDW 2 Short Queue	Pass	See Appendix B
	ERDW 3 Short Queue	Pass	See Appendix B
	ERDW 4 Short Queue	Pass	See Appendix B
	ERDW 5 Short Queue	Pass	See Appendix B
	WWE 1	Pass	See Appendix B
	WWE 2	Pass	See Appendix B
	WWE 3	Pass	See Appendix B
	WWE 4	Pass	See Appendix B
	WWE 5	Pass	See Appendix B
	PCW 1	Fail Heading issue with LiDAR	See Appendix B
	PCW 2	Fail Heading issue with LiDAR	See Appendix B
	PCW 3	Pass	See Appendix B
	PCW 4	Pass	See Appendix B
	PCW 5	Pass	See Appendix B
Savari	WWE 1	Pass	See Appendix B
	WWE 2	Pass	See Appendix B
	WWE 3	Pass	See Appendix B
	WWE 4	Pass	See Appendix B

OBU Vendor	App Tested	Result	Supporting Documentation
	WWE 5	Pass	See Appendix B

Appendix A (continued)
OBU Data Log Post-Test Assessment Emergency Electronic Braking Light (EEBL)

Background

During August 28-30, 2018, the Tampa CV Pilot team conducted a series of tests to assess the generation and over-the-air transfer of OBU Logs. Tests were conducted using one vehicle for each vendor providing OBUs: Savari and Sirius XM. Test vehicles were identified using unique vehicle IDs.

Assessment

CUTR assessed the OBU logs following this procedure:

1. Obtain total count of DataLogMessages
    a. Total count for the entire period by the vendor
    b. Total count by test day (28, 29, 30) by the vendor
2. Obtain total count of EventTypes within DataLogMessages
    a. Total count for the entire period by the vendor
    b. Total count by test day (28, 29, 30) by the vendor
3. Extract at random two observations for each EventType (two per OBU vendor)
    a. Analyze content and compare to specs
    b. Analyze content to identify problems in metrics and units of measure
    c. Analyze content vs. PMESP requirements.

Summary Statistics

Table 132 reports the count of OBU logs uploaded to THEA Master Server during the timeframe, split by OBU vendor. Highlighted in red are events that were either unsuccessfully generated or recorded, and events that were not yet implemented at the time of testing.

Table 132: OBU Logs by Event Type

Event Type	Savari	Sirius XM	Total
sentBSM	24,052	296	24,348
receivedBSM	6,121	2,111	8,232
receivedMAP	2,209	6	2,215
receivedSPaT	77,419	1,510	78,929
receivedTIM	20,645	2,355	23,000
sentSRM	94	0	94
receivedSSM	826	0	826
receivedPSM	1,539	763	2,302
warningEEBL	12	2	14
warningERDW	3,323	0	3,323
warningFCW	244	9	253
warningIMA	91	3	94
warningPCW	0	2	2
warningVTRFTV	0	4	4
warningWWE	1,837	3	1,840
smartBreadCrumb	0	85	85
sysMonHealth	3,642	10	3,652
sysMonOTA	0	2	2
Total	***142,054***	***7,161***	***149,215***

Event Type Analysis

Emergency Electronic Braking Light (EEBL)

Reference Document: System Design Document (SDD), Section 3.3.2.7

The EEBL application is designed to alert the driver of the host vehicle an equipped car that is exceeding the predetermined deceleration in upstream traffic. This provides downstream OBU equipped drivers with additional time to look for, and assess situations developing ahead.

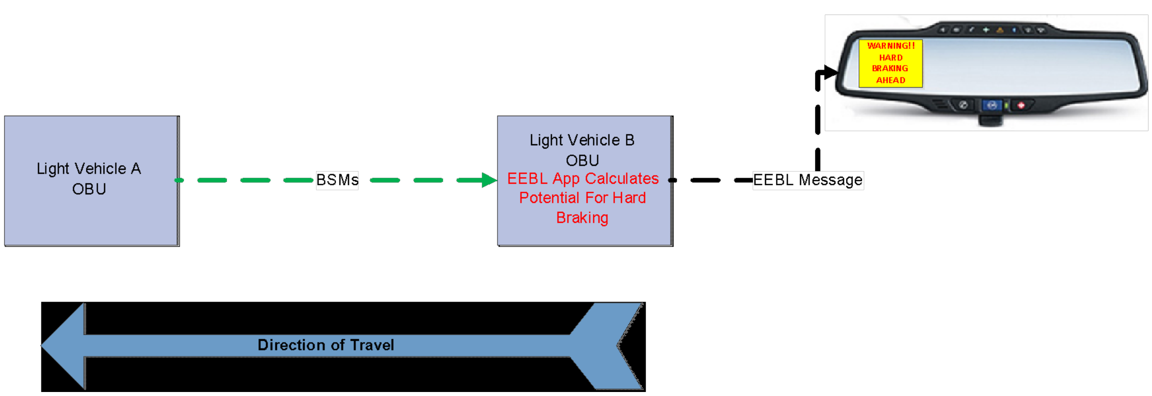


Figure 45: EEBL Functional Flow, SDD, pp. 66
Source: SDD

The EEBL app receives BSMs from one or more vehicles ahead. Using the BSMs, if EEBL determines any vehicles in the same lane braking/stopping suddenly, the app issues a warning to the driver. This application is particularly useful when the driver's line of sight is obstructed by other vehicles or bad weather conditions (e.g., fog, heavy rain). The variables and timing of when the message is displayed to the driver and how long it will stay on must be configurable.

Performance Evaluation and Measurement Data Requirements

To conduct the safety evaluation of EEBL, CUTR needs the following data as specified under the "WarningEventData" in DataLog_v1.3. Table 133 reports the requirements.

Table 133: EEBL Data Requirements

Field	Description
id	Unique ID of the warning event
driverWarn	True, if the driver was warned; false otherwise
isControl	True, if the driver was part of a control group
isDisabled	True, if HMI was disabled, false otherwise
hvBSM	Host Vehicle BSM of this vehicle; from J2735ASN-20160
rvBSM	Remote Vehicle BSM of the vehicle which triggered the warning

In addition, Part II pathHistory of hvBSM and rvBSM should contain a minimum of 15 seconds of path history (elements: latOffset, lonOffset, elevationOffset, timeOffset) to reconstruct the HV and RV paths before and after the EEBL is issued. *The minimum required before-after timeframe is 15 seconds.*

Analysis Results

Table 134 reports the number of EEBL events warnings issued during the test timeframe by OBU vendor. Savari logged 12 events over about 30 minutes of testing. Sirius XM generated one log per event (Table 4). This issue was discussed during the post-briefing sessions and pointed to the interpretation regarding the frequency at which warning events should be logged (e.g., one logged event vs. multiple logged events triggered after the first one). On day 30, Sirius generated one log containing one EEBL event.

Table 134: Number of EEBL within OBU Logs by Vendor

Vendor	*sum*	*min*	*max*
Savari	12	1	1
Sirius XM	2	1	1
Total	*14*		

Table 135: EEBL First and Last Event

Vendor	*Day*	*First Log*	*Last Log*
Savari	29	10:41:11.048	11:11:05.736
Sirius	29	12:47:21.244	12:47:21.244
Sirius	30	09:44:04.857	09:44:04.857

Content Analysis

Table 136 reports the results from the content analysis of a random sample.

Table 136: Random Sample Content Analysis

	Successful (Y/N)		Notes
Field	Savari	Sirius XM	
id	N	Y	Savari id lacks content. Field only contains <id>00000000</id>. Sirius XM creates an id (e.g., <id> 54C6CAD6 </id>). Need to verify it is random
driverWarn	Y	Y	Content checked for test vehicles. Need to verify on participant vehicles once data are available
isControl	Y	Y	Content checked for test vehicles. Need to verify on participant vehicles once data are available
isDisabled	Y	Y	Content checked for test vehicles. Need to verify on participant vehicles once data are available
hvBSM	Y	Y	Savari consistently produces hvBSM with Path History covering more than +/- 15 secs. Need to ensure high frequency between offset points. Sirius XM Path History is too short. Problem: the hvBSM vehicle id identifies the Savari vehicle (6A000028), while it should identify the host vehicle (i.e., Sirius XM device ID 2147483690). Savari IMA lists device id 1778384936, hvBSM 6A000028 (i.e., 1778384936) and rvBSM id 52B75573 (FOP ID 12014963)
rvBSM	Y	N	Savari consistently produces hvBSM with Path History covering more than +/- 15 secs. Sirius XM did not produce rvBSM.

Sirius XM

Sirius generated a total of three EEBLs, two on day 29 and one on day 30. On day 29, Sirius XM OBU logs did not successfully decrypt HV BSMs content and did not have any RV BSM in their five logs. On day 30, Sirius XM solved the decryption issues but generated only hvBSM. Table 137 reports the path history data from the hvBSM generated within Data Log Event of Thursday, August 30, 2018, 9:32:09.182 a.m.. Total path history time is 50.87 seconds. **More importantly, Sirius XM hvBSM vehicle id identifies the Savari vehicle (6A000028), while it should identify the host vehicle (i.e., Sirius XM device ID 2147483690). Savari IMA lists device id 1778384936, hvBSM 6A000028 (i.e., 1778384936) and rvBSM id 52B75573 (FOP ID 12014963).** Therefore, while Table 137 reports path history points belonging to Savari instead of Sirius.

Table 137: hvBSM Path History – Sirius XM

Path History Point	*Vehicle*	*latOffset**	*lonOffset**	*timeOffset****
1	hvBSM	-479	190	2383
2	hvBSM	-578	1346	2839

Path History Point	Vehicle	latOffset*	lonOffset*	timeOffset***
3	hvBSM	-136	5061	3564
4	hvBSM	806	7771	4090
5	hvBSM	2079	9525	4491
6	hvBSM	3848	10577	4871
7	hvBSM	5104	10708	5145
8	hvBSM	5707	10208	5392
9	hvBSM	5626	9451	5643
10	hvBSM	1145	1700	7470

**1/10th micro degrees; ** 10cm units; ***units of 10 milliseconds*

Savari

The test involved interaction at HCC campus with a friends-of-the-Pilot (FOP) vehicle (ID12014963), which is equipped with a Sirius XM OBU. Note that per SDD specs, EEBL is issued to both vehicles, but the sample data were recorded only for Savari HV.

The first sample is timed at 10:36:12.879 a.m. and the second sample is timed at 10:35:12.891 a.m.. Table 138 reports path history data from the first sample. The two samples appear to report data for the same EEBL event. Both samples contain the same path history reported in Table 138. Having the unique random id for the two events would confirm this assumption. Total path history time for the HV was 60.99 seconds (point 1 through point 10), and 48.84 seconds for RV (point 1 through point 10).

Table 138: hvBSM, rvBSM Path History – Savari

Path History Point	Vehicle	latOffset*	lonOffset*	timeOffset***
1	hvBSM	-1986	-3540	310
2	hvBSM	-3066	-6191	576
3	hvBSM	-3212	-9412	1202
4	hvBSM	-3089	-10722	4036
5	hvBSM	-2625	-11004	4251
6	hvBSM	-2311	-10588	4446
7	hvBSM	-2810	-7369	5106
8	hvBSM	-2789	-5490	5364
9	hvBSM	-1622	-2303	5734
10	hvBSM	1054	4168	6409
1	rvBSM	-4470	-7489	686
2	rvBSM	-5927	-10469	1013
3	rvBSM	-6347	-13017	1370
4	rvBSM	-6423	-14218	2265
5	rvBSM	-5974	-14653	2602

Path History Point	*Vehicle*	*latOffset**	*lonOffset**	*timeOffset****
6	rvBSM	-5468	-14377	2856
7	rvBSM	-5959	-12604	3349
8	rvBSM	-6062	-11158	3625
9	rvBSM	-4490	-8667	4196
10	rvBSM	-1064	-324	5570

**1/10th micro degrees; ** 10cm units; ***units of 10 milliseconds*

Figure 3 maps the history point for HV (green) and RV (orange), in addition to the anchor point (labeled with zero), with arrows showing movement from points 10 to 8.

Figure 3 EEBL – Savari
Source: CUTR

OBU Data Log Post-Test Assessment End of Ramp Deceleration Warning (ERDW)

Background

During August 28-30, 2018, the Tampa CV Pilot team conducted a series of tests to assess the generation and over-the-air transfer of OBU Logs. Tests were conducted using one vehicle for each vendor providing OBUs: Savari and Sirius XM. Test vehicles were identified using unique vehicle IDs.

Assessment

CUTR assessed the OBU logs following this procedure:

1. Obtain total count of DataLogMessages
   a. Total count for the entire period by the vendor
   b. Total count by test day (28, 29, 30) by the vendor
2. Obtain total count of EventTypes within DataLogMessages
   a. Total count for the entire period by the vendor
   b. Total count by test day (28, 29, 30) by the vendor
3. Extract at random two observations for each EventType (two per OBU vendor)
   a. Analyze content and compare to specs
   b. Analyze content to identify problems in metrics and units of measure
   c. Analyze content vs. PMESP requirements.

Summary Statistics

Table 139 reports the count of OBU logs uploaded to THEA Master Server during the timeframe, split by OBU vendor. Highlighted in red are events that were either unsuccessfully generated or recorded, and events that were not yet implemented at the time of testing.

Table 139: OBU Logs by Event Type

Event Type	Savari	Sirius XM	Total
sentBSM	24,052	296	24,348
receivedBSM	6,121	2,111	8,232
receivedMAP	2,209	6	2,215
receivedSPaT	77,419	1,510	78,929
receivedTIM	20,645	2,355	23,000
sentSRM	94	0	94
receivedSSM	826	0	826
receivedPSM	1,539	763	2,302
warningEEBL	12	2	14
warningERDW	3,323	0	3,323
warningFCW	244	9	253
warningIMA	91	3	94
warningPCW	0	2	2
warningVTRFTV	0	4	4
warningWWE	1,837	3	1,840
smartBreadCrumb	0	85	85
sysMonHealth	3,642	10	3,652
sysMonOTA	0	2	2
Total	***142,054***	***7,161***	***149,215***

Event Type Analysis

End of Ramp Deceleration Warning (ERDW)

Reference Document: System Design Document (SDD), Section 3.2.2.1

“The ERDW (end of ramp deceleration warning) application shall provide advance warning to vehicles on the REL driving inbound. The HMI warning shall recommend a safe speed, which will allow the vehicle to stop before it reaches the end of the queue/stopped traffic. The following graphic shows two examples to illustrate the concept.”

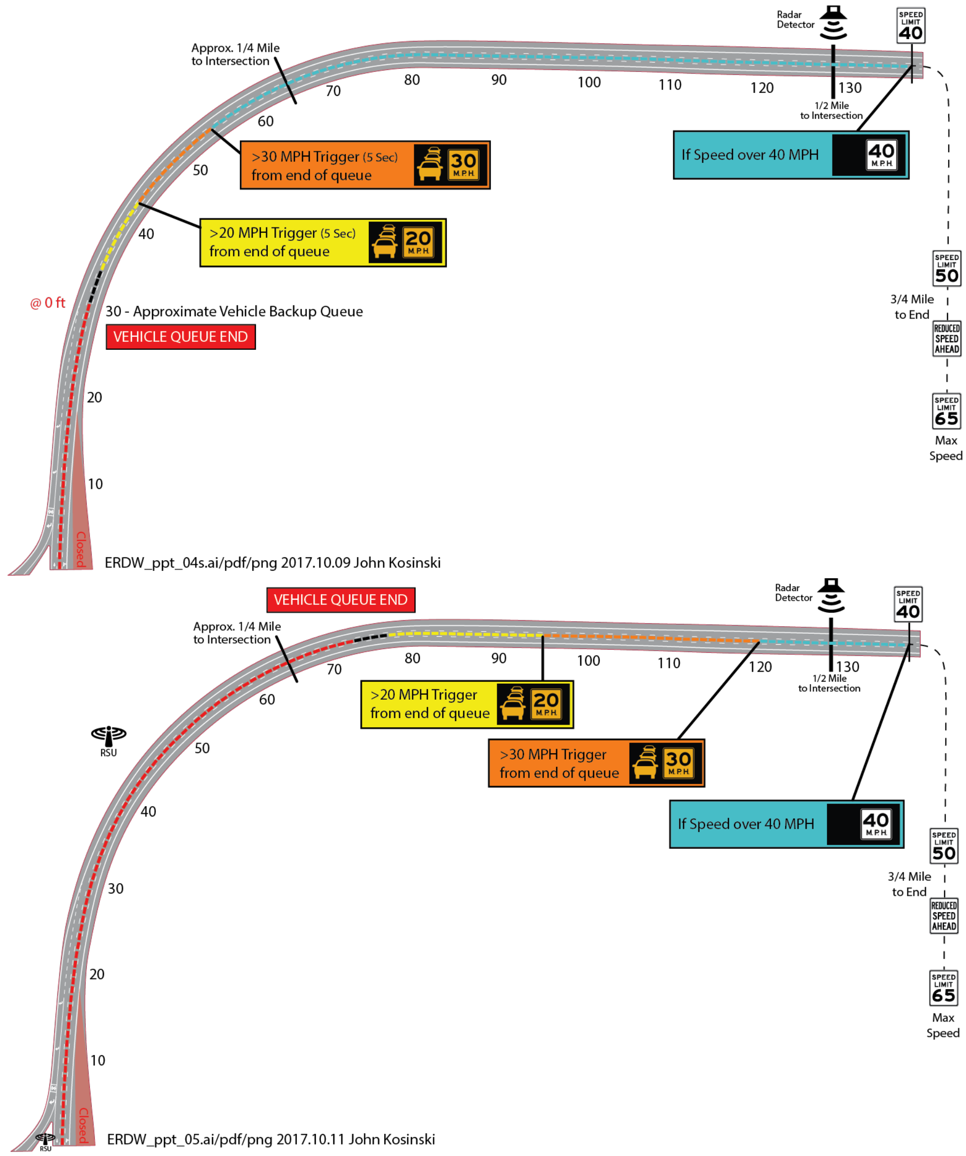


Figure 1: ERDW concept of speed recommendation zones for two traffic situations – SDD, pp. 22
Source: SDD

The top example shows a situation with a short queue of vehicles waiting for green at the intersection of Twiggs and Meridian. In this situation, the RSU would broadcast a series of recommended speed zones that apply to road segments of the REL. Each zone has a recommended speed, and speeds decrease along the path of a vehicle from one zone to the next until the final zone is reached.
The system will use three speed zones. The 40 MPH speed zone represents the point along the REL from where the 40 MPH speed limit is posted until the end of the ramp at the intersection. The other two speed zones are overlaid and represent recommended speeds of 30 MPH and 20 MPH. Speed zone length and location are configurable on the RSU by defining the content of the TIM being broadcast for this queue length." [SDD, pp.22-23]

Performance Evaluation and Measurement Data Requirements

Table 140 reports the requirements to conduct the safety evaluation of ERDW.

Table 140: EEBL Data Requirements

Field	Description
Id	Unique ID of ERDW warning event
driverWarn	True, if the driver was warned; false otherwise
isControl	True, if the driver was part of a control group
isDisabled	True, if HMI was disabled, false otherwise
hvBSM	Host Vehicle BSM of this vehicle; from J2735ASN-20160
sentBSM	Sent BSM
erdwSpeed	Recommended speed value (20, 30, 40) for which an ERDW was triggered
receivedTIM	Received TIM (within Data Log containing ERDW warning)

In addition, Part II pathHistory of hvBSM contain a minimum of 15 seconds of path history (elements: latOffset, lonOffset, elevationOffset, timeOffset) to reconstruct the HV patch and after the ERDW is issued.

Analysis Results

During testing, while Sirius XM generated warnings, these were not received by the RSUs. On day 28, Savari generated a total of 3,323 logs, each containing a minimum of one ERDW. Table 141 reports the number of ERDW events warnings issued during the test timeframe by OBU vendor. Savari logged 12,623 events between 13:50:31.757 p.m. and 14:39:08.436 p.m. This issue was discussed during the post-briefing sessions and pointed to the interpretation regarding the frequency at which warning events should be logged.

Table 141: Number of EEBL within OBU Logs by Vendor

Vendor	*sum*	*min*	*max*
Savari	12,623	1	7
Sirius XM	n.a.	n.a.	n.a.
Total	*12,623*		

n.a. means not available

Content Analysis

Table 142 reports the results from the content analysis of a random sample.

Table 142: Random Sample Content Analysis

Field	Successful (Y/N)		Notes
Id	Savari	Sirius XM	No ERDW content from Sirius XM. Savari creates an id but filled with zeros (e.g., <id>00000000</id>).
driverWarn	N	N	No ERDW content from Sirius XM. Content present in Savari. Need to verify on participant vehicles once data are available
isControl	Y	N	No ERDW content from Sirius XM. Content checked for test vehicles. Need to verify on participant vehicles once data are available
isDisabled	Y	N	No ERDW content from Sirius XM. Content checked for test vehicles. Need to verify on participant vehicles once data are available
hvBSM	Y	N	No ERDW content from Sirius XM. Savari consistently produces hvBSM with Path History. ***The number of path history points varies greatly over the 3,323 observed ERDW. History points vary from 6 to 144 within a single OBU log***
sentBSM	Y	N	No ERDW content from Sirius XM. Savari content check passed. ***Relevant redundancy between sentBSM and hvBSM (same anchor and path history points). To collect necessary data is necessary to increase the number of sentBSM per Data Log Event.***
erdwSpeed	N	N	No ERDW content from Sirius XM. Savari constantly reports speed=0 (<erdwSpeed>0</erdwSpeed>)
receivedTIM	Y	N	Savari TIMs on ERDW point correctly to RSU 1 (REL, Pole A-1-P9 Curve). Some issues related to TIMs received by Sirius XM. TIM element GeographicalPath coordinates point to locations outside of Florida (e.g., Colorado). See TIM Map here: https://drive.google.com/open?id=1T7IYxIXXHSidaTPr-DHL8jPm_5FyvnkU&usp=sharing Also, some TIMs messages in Sirius XM OBU logs had fielded that appear not have been properly decoded.

Sirius XM

Sirius XM generated warnings, but the warnings were not received by the RSUs. CUTR could not analyze their content.

Savari

The tests were conducted on the REL. Random samples were drawn from the 3,323 ERDW events. Figure 2 maps a potential test involving a U-turn on the REL past RSU 1. As detailed in Table 142, no erdwSpeed data were produced, though TIM reported the advisory speed (example below 40 mph) in the IT IS speed advisory nodes.

Figure 2 EEBL – Savari – Sent BSM and Path History Points (anchor point is zero)
Source: CUTR

OBU Data Log Post-Test Assessment Forward Collision Warning (FCW)

Background

During August 28-30, 2018, the Tampa CV Pilot team conducted a series of tests to assess the generation and over-the-air transfer of OBU Logs. Tests were conducted using one vehicle for each vendor providing OBUs: Savari and Sirius XM. Test vehicles were identified using unique vehicle IDs.

Assessment

CUTR assessed the OBU logs following this procedure:

1. Obtain total count of DataLogMessages
    a. Total count for the entire period by the vendor
    b. Total count by test day (28, 29, 30) by the vendor
2. Obtain total count of EventTypes within DataLogMessages
    a. Total count for the entire period by the vendor
    b. Total count by test day (28, 29, 30) by the vendor
3. Extract at random two observations for each EventType (two per OBU vendor)
    a. Analyze content and compare to specs
    b. Analyze content to identify problems in metrics and units of measure
    c. Analyze content vs. PMESP requirements.

Summary Statistics

Table 143 reports the count of OBU logs uploaded to THEA Master Server during the timeframe, split by OBU vendor. Highlighted in red are events that were either unsuccessfully generated or recorded, and events that were not yet implemented at the time of testing.

Table 143: OBU Logs by Event Type

Event Type	Savari	Sirius XM	Total
sentBSM	24,052	296	24,348
receivedBSM	6,121	2,111	8,232
receivedMAP	2,209	6	2,215
receivedSPaT	77,419	1,510	78,929
receivedTIM	20,645	2,355	23,000
sentSRM	94	0	94
receivedSSM	826	0	826
receivedPSM	1,539	763	2,302
warningEEBL	12	2	14
warningERDW	3,323	0	3,323
warningFCW	244	9	253
warningIMA	91	3	94
warningPCW	0	2	2
warningVTRFTV	0	4	4
warningWWE	1,837	3	1,840
smartBreadCrumb	0	85	85
sysMonHealth	3,642	10	3,652
sysMonOTA	0	2	2
Total	***142,054***	***7,161***	***149,215***

Event Type Analysis

Forward-Collision Warning (FCW)

Reference Document: System Design Document (SDD), Section 3.3.2.6
FCW responds to a direct and imminent threat ahead of the host vehicle (HV). The FCW app receives BSMs from the lead vehicle OBU. Using the lead vehicle BSM data, FCW calculates crash trajectories to determine if the trailing vehicle (i.e., HV) is about to rear-end the leading vehicle. If FCW determines that the trailing vehicle (HV) is going to crash into the lead vehicle, a warning is issued to the driver. The FCW app HMI shall warn the driver no more than once when multiple warnings are received within a configurable timeframe.

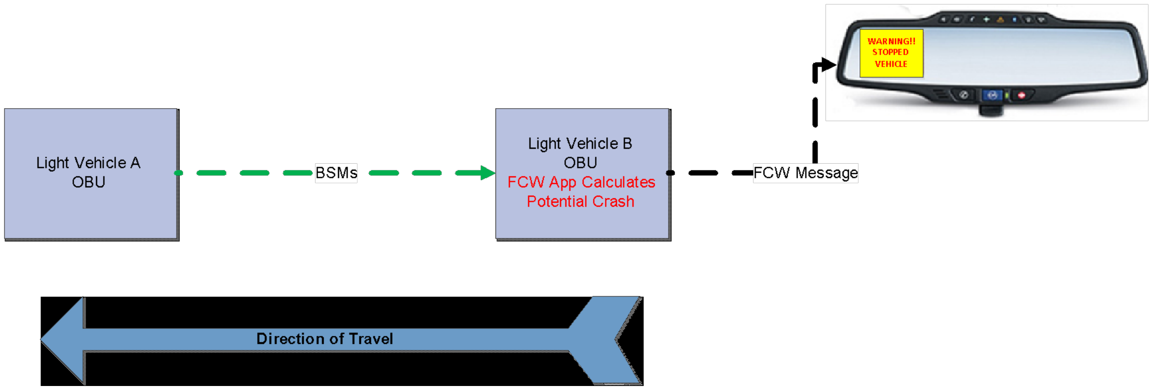


Figure 1 FCW Functional Flow - SDD, pp. 67
Source: SDD

The host vehicle (HV) or the vehicle with the FCW is also the trailing vehicle. On the same lane with two vehicles traveling in the same direction, the HV identifies the vehicle behind the lead vehicle or remote vehicle (RV).

Performance Evaluation and Measurement Data Requirements

To conduct the safety evaluation of FCW, CUTR needs the following data as specified under the “WarningEventData” in DataLog_v1.3. Table 144 reports the requirements.

Table 144: FCW Data Requirements

Field	Description
id	Unique ID of the warning event
driverWarn	True, if the driver was warned; false otherwise
isControl	True, if the driver was part of a control group
isDisabled	True, if HMI was disabled, false otherwise
hvBSM	Host Vehicle BSM of this vehicle; from J2735ASN-20160
rvBSM	Remote Vehicle BSM of the vehicle which triggered the warning

In addition, Part II pathHistory of hvBSM and rvBSM should contain a minimum of 15 seconds of path history (elements: latOffset, lonOffset, elevationOffset, timeOffset) to reconstruct the HV and RV paths before and after the FCW is issued. *The minimum required before-after timeframe is 15 seconds.*

Analysis Results

Table 145 reports the number of FWC warnings issued during the test timeframe by OBU vendor. In a few instances, OBU logs contained two FCW warnings. In particular, Savari logged 317 events over about 30 minutes of testing, compared to the much lower number of Sirius XM (Table 146). This issue was discussed during the post-briefing sessions and pointed to the interpretation regarding the frequency at which warning events should be logged (e.g., one logged event vs. multiple logged events triggered after the first one).

Table 145: Number of FCW within OBU Logs by Vendor

Vendor	*sum*	*min*	*max*
Savari	317	1	2
Sirius XM	11	1	1
Total	*328*		

Table 146: FCW First and Last Event

Vendor	*Day*	*First Log*	*Last Log*
Savari	29	10:40:51.744	11:11:37.657
Sirius	29	11:23:36.231	12:49:29.526
Sirius	30	09:42:08.349	11:26:05.359

Content Analysis

Table 147 reports the results from the content analysis of a random sample.

Table 147: Random Sample Content Analysis

	Successful (Y/N)		**Notes**
Field	**Savari**	**Sirius XM**	
id	N	Y	Savari id lacks content. Field only contains <id>00000000</id>. Sirius XM creates an id (e.g., <id>B2A6EDF1</id>). Need to verify it is random
driverWarn	Y	Y	Content checked for test vehicles. Need to verify on participant vehicles once data are available
isControl	Y	Y	Content checked for test vehicles. Need to verify on participant vehicles once data are available
isDisabled	Y	Y	Content checked for test vehicles. Need to verify on participant vehicles once data are available
hvBSM	Y	Y	Savari consistently produces hvBSM with Path History covering more than +/- 15 secs. Need to ensure high frequency between offset points. Sirius XM Path History is too short.
rvBSM	Y	N	Savari consistently produces hvBSM with Path History covering more than +/- 15 secs. Sirius XM produced only one rvBSM event, likely a false positive outside of the testing environment.

Sirius XM

On day 29, Sirius XM OBU logs did not successfully decrypt HV BSMs content and did not have any RV BSM in their five logs. On day 30, Sirius XM solved the decryption issues, but both HV and RV BSM content appear only on the last OBU log with the timestamp 11:26:05.359 a.m. Table 148 reports the path history points ranked in chronological sequence from most recent to less recent. It shows that BSM path history content in this log is incomplete in terms of the number of data points that are expected to be collected over the +/- 15-second timeframe. HV contains two-path history points: total time 2.2 seconds and RV contains three path history points totaling 33.3 seconds (average 1.7 seconds in between points).

Table 148: hvBSM, rvBSM Path History - Sirius XM

Path History Point	Vehicle	latOffset*	lonOffset*	timeOffset***
1	hvBSM	1527	-2224	74
2	hvBSM	5771	-8957	294
1	rvBSM	4671	171	9365
2	rvBSM	14818	-246	11737
3	rvBSM	27280	-266	12669

**1/10th micro degrees; ** 10cm units; ***units of 10 milliseconds*

Finally, this FCW event seems a false positive involving a participant vehicle (RV), as shown in Figure 2.

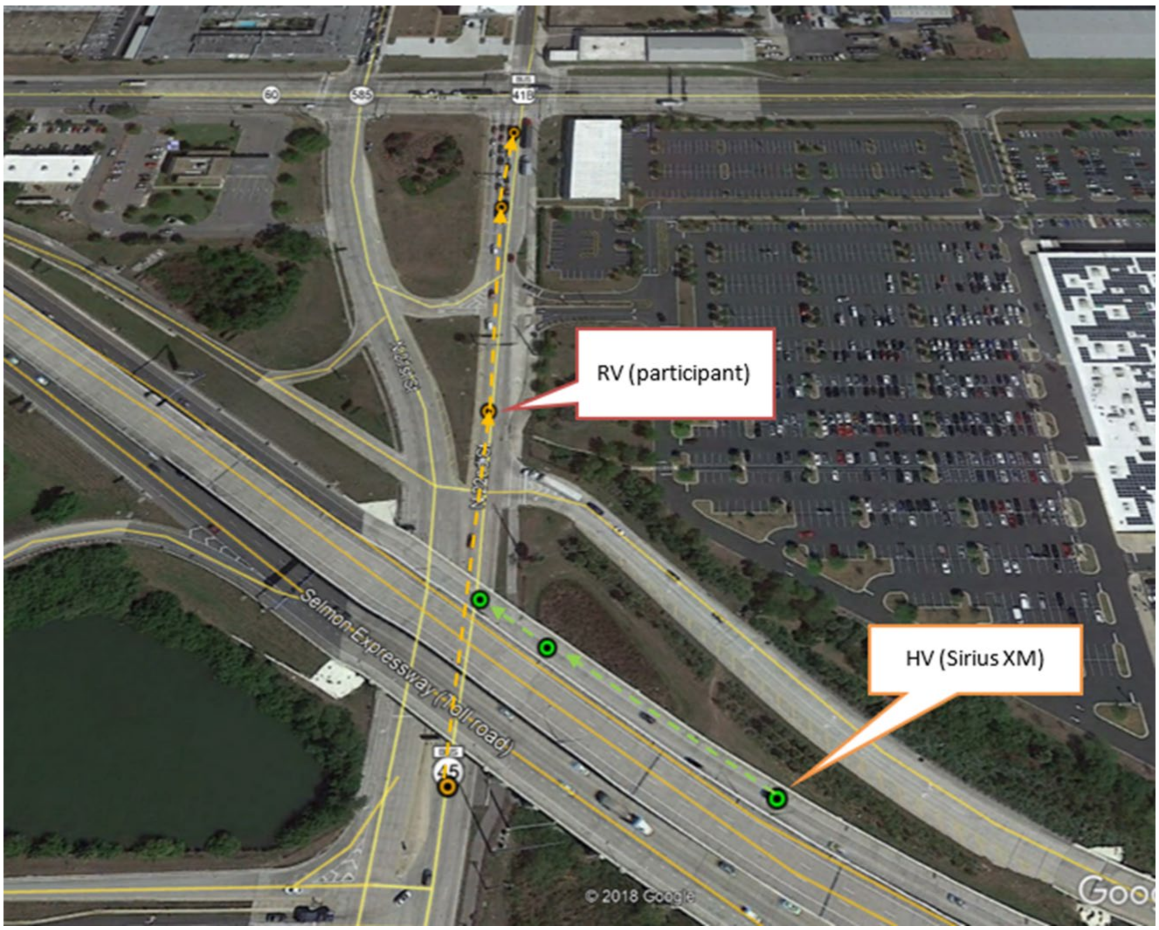


Figure 2 FCW – Sirius XM
Source: Google

Savari

CUTR analyzed two samples out FCW tests were conducted at HCC, as indicated in Table 147. The first sample is timed at 10:40:59.399 a.m., and the second sample is timed at 11:11:37.666. Table 149 reports path history data from the first sample. The two samples appear to report data for only one FCW event. This was confirmed by the overlapping the path history points from the two samples on Google Earth. Table 149 reports the path history data in chronological order.

Table 149: hvBSM, rvBSM Path History – Savari

Path History Point	Vehicle	latOffset*	lonOffset*	timeOffset***
1	hvBSM	2110	4444	522
2	hvBSM	2428	4865	1168
3	hvBSM	3135	4629	1816
4	hvBSM	3129	3770	2133
5	hvBSM	-392	-1361	3093
6	hvBSM	-3962	-6058	4520
7	hvBSM	-4035	-6686	4908
8	hvBSM	-3474	-7335	5412
9	hvBSM	-2899	-7212	5760
10	hvBSM	-2492	-5237	6261
11	hvBSM	1809	4324	7423
1	rvBSM	1920	4148	549
2	rvBSM	2839	5858	1876
3	rvBSM	3313	6082	2161
4	rvBSM	3622	5538	2396
5	rvBSM	2829	3857	2711
6	rvBSM	-3301	-4562	5324
7	rvBSM	-3564	-5240	5669
8	rvBSM	-3236	-5881	5923
9	rvBSM	-2608	-5838	6137
10	rvBSM	-1912	-4126	6452
11	rvBSM	421	1570	7053

**1/10th micro degrees; ** 10cm units; ***units of 10 milliseconds*

Figure 3 maps the history point for HV (green) and RV (orange), in addition to the anchor point (labeled with zero). There appears to be sufficient data for an assessment of the FCW (identified at sequence 6-5-4).

Figure 3 FCW Savari
Source: CUTR

OBU Data Log Post-Test Assessment Intersection Movement Assist (IMA)

Background

During August 28-30, 2018, the Tampa CV Pilot team conducted a series of tests to assess the generation and over-the-air transfer of OBU Logs. Tests were conducted using one vehicle for each vendor providing OBUs: Savari and Sirius XM. Test vehicles were identified using unique vehicle IDs.

Assessment

CUTR assessed the OBU logs following this procedure:

1. Obtain total count of DataLogMessages
    a. Total count for the entire period by the vendor
    b. Total count by test day (28, 29, 30) by the vendor
2. Obtain total count of EventTypes within DataLogMessages
    a. Total count for the entire period by the vendor
    b. Total count by test day (28, 29, 30) by the vendor
3. Extract at random two observations for each EventType (two per OBU vendor)
    a. Analyze content and compare to specs
    b. Analyze content to identify problems in metrics and units of measure
    c. Analyze content vs. PMESP requirements.

Summary Statistics

Table 150 reports the count of OBU logs uploaded to THEA Master Server during the timeframe, split by OBU vendor. Highlighted in red are events that were either unsuccessfully generated or recorded, and events that were not yet implemented at the time of testing.

Table 150: OBU Logs by Event Type

Event Type	Savari	Sirius XM	Total
sentBSM	24,052	296	24,348
receivedBSM	6,121	2,111	8,232
receivedMAP	2,209	6	2,215
receivedSPaT	77,419	1,510	78,929
receivedTIM	20,645	2,355	23,000
sentSRM	94	0	94
receivedSSM	826	0	826
receivedPSM	1,539	763	2,302
warningEEBL	12	2	14
warningERDW	3,323	0	3,323
warningFCW	244	9	253
warningIMA	91	3	94
warningPCW	0	2	2
warningVTRFTV	0	4	4
warningWWE	1,837	3	1,840
smartBreadCrumb	0	85	85
sysMonHealth	3,642	10	3,652
sysMonOTA	0	2	2
Total	***142,054***	***7,161***	***149,215***

Event Type Analysis

Intersection Movement Assist (IMA)

Reference Document: System Design Document (SDD), Section 3.3.2.8
The IMA application is intended to warn the driver when it is not safe to enter an intersection due to high collision probability with other equipped vehicles especially useful when something is blocking the driver's view of opposing or crossing traffic.

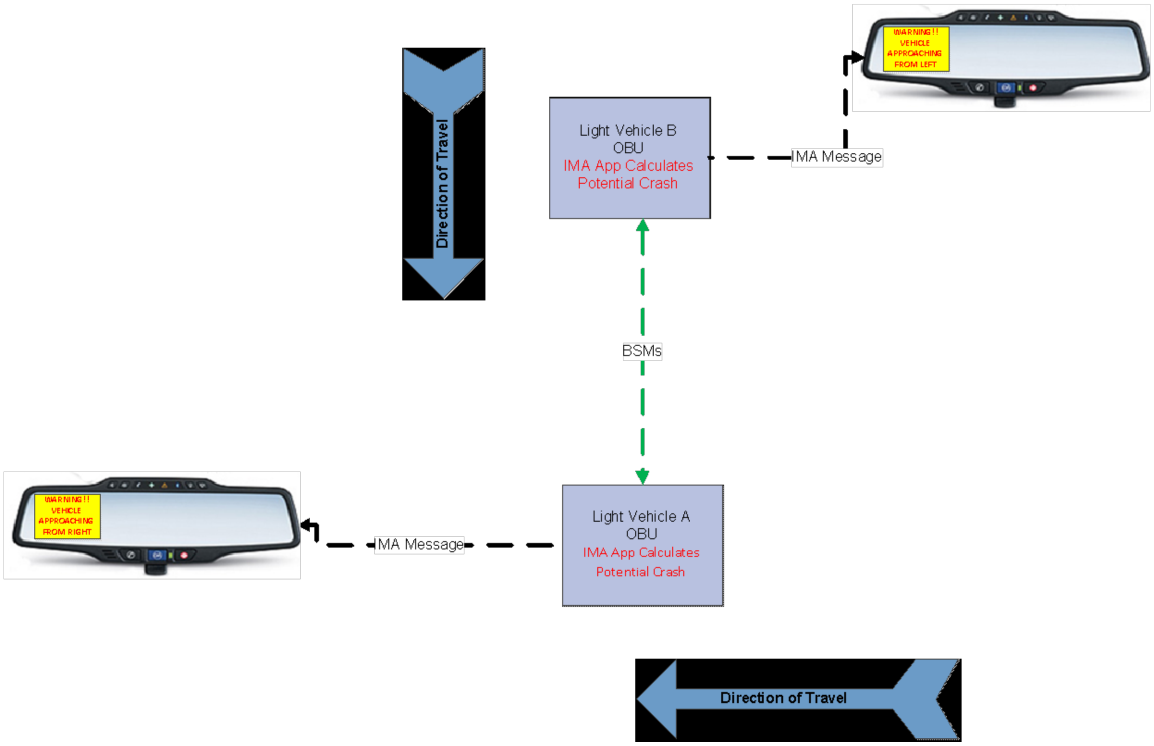


Figure 46: IMA Functional Flow –SDD, pp. 67
Source: SDD

The IMA app receives BSMs from vehicles approaching the intersection adjacent to the vehicle equipped with IMA. If IMA determines there is a high probability of a collision using relative position, speed and heading of vehicles approaching the intersection, the app warns the driver. The variables and timing of when the message is displayed to the driver and how long it will stay on must be configurable. The variables and timing of when the message is displayed to the driver and how long it will stay on are configurable and set to provide a timely warning.

Performance Evaluation and Measurement Data Requirements

To conduct the safety evaluation of IMA, CUTR needs the following data as specified under the “WarningEventData” in DataLog_v1.3. Table 2 reports the requirements.

Table 151: IMA Data Requirements

Field	Description
id	Unique ID of the warning event
driverWarn	True, if the driver was warned; false otherwise
isControl	True, if the driver was part of a control group
isDisabled	True, if HMI was disabled, false otherwise
hvBSM	Host Vehicle BSM of this vehicle; from J2735ASN-20160
rvBSM	Remote Vehicle BSM of the vehicle which triggered the warning

In addition, Part II pathHistory of hvBSM and rvBSM should contain a minimum of 15 seconds of path history (elements: latOffset, lonOffset, elevationOffset, timeOffset) to reconstruct the HV and RV paths before and after the IMA is issued. *The minimum required before-after timeframe is 15 seconds.*

Analysis Results

Table 152 reports the number of OBU logs containing FWC warnings issued during the test timeframe by OBU vendor. In a few instances, OBU logs contained two IMA warnings. In particular, Savari logged 105 events over about 30 minutes of testing. Sirius XM generated two logs in a little over one minute (Table 153). This issue was discussed during the post-briefing sessions and pointed to the interpretation regarding the frequency at which warning events should be logged (e.g., one logged event vs. multiple logged events triggered after the first one). On day 30, Sirius generated one log containing one IMA event.

Table 152: Number of IMA within OBU Logs by Vendor

Vendor	*sum*	*min*	*max*
Savari	105	1	2
Sirius XM	3	1	1
Total	*108*		

Table 153: IMA First and Last Event

Vendor	*Day*	*First Log*	*Last Log*
Savari	29	10:40:51.360	11:12:06.974
Sirius	29	12:49:28.235	12:49:29.328
Sirius	30	09:45:19.029	09:45:19.029

Content Analysis

Table 154 reports the results from the content analysis of a random sample.

Table 154: Random Sample Content Analysis

	Successful (Y/N)		Notes
Field	**Savari**	**Sirius XM**	
Id	N	Y	Savari id lacks content. Field only contains <id>00000000</id>. Sirius XM creates an id (e.g., <id> 03D54CBB </id>). Need to verify it is random
driverWarn	Y	Y	Content checked for test vehicles. Need to verify on participant vehicles once data are available
isControl	Y	Y	Content checked for test vehicles. Need to verify on participant vehicles once data are available
isDisabled	Y	Y	Content checked for test vehicles. Need to verify on participant vehicles once data are available

	Successful (Y/N)		Notes
hvBSM	Y	Y	Savari consistently produces hvBSM with Path History covering more than +/- 15 secs. Need to ensure high frequency between offset points. Sirius XM Path History is too short. **Problem: the hvBSM vehicle id identifies the Savari vehicle (6A000028), while it should identify the host vehicle (i.e., Sirius XM device ID 2147483690). Savari IMA lists device id 1778384936, hvBSM 6A000028 (i.e., 1778384936) and rvBSM id 52B75573 (FOP ID 12014963)**
rvBSM	Y	N	Savari consistently produces hvBSM with Path History covering more than +/- 15 secs. Sirius XM did not produce rvBSM.

Sirius XM

Sirius generated a total of three IMAs, two on day 29 and one on day 30. On day 29, Sirius XM OBU logs did not successfully decrypt HV BSMs content and did not have any RV BSM in their five logs. On day 30, Sirius XM solved the decryption issues but generated only hvBSM. Table 155 reports the path history data from the hvBSM. Total path history time is 110.46 seconds. **More importantly, Sirius XM hvBSM vehicle id identifies the Savari vehicle (6A000028), while it should identify the host vehicle (i.e., Sirius XM device ID 2147483690). Savari IMA lists device id 1778384936, hvBSM 6A000028 (i.e., 1778384936) and rvBSM id 52B75573 (FOP ID 12014963)**

Table 155: hvBSM Path History – Sirius XM

Path History Point	*Vehicle*	*latOffset**	*lonOffset**	*timeOffset****
1	hvBSM	763	486	1919
2	hvBSM	1655	391	2283
3	hvBSM	2091	-338	2640
4	hvBSM	1872	-1352	2998
5	hvBSM	-3127	-10085	4627
6	hvBSM	-3642	-10785	7262
7	hvBSM	-4301	-10723	11259
8	hvBSM	-4400	-9567	11715
9	hvBSM	-3958	-5852	12440
10	hvBSM	-3016	-3142	12965

**1/10th micro degrees; ** 10cm units; ***units of 10 milliseconds*

Savari

The test involved interaction at HCC campus with a friends-of-the-Pilot (FOP) vehicle (ID12014963), which is equipped with a Sirius XM OBU. Note that per SDD specs, IMA is issued to both vehicles, but the sample data were recorded only for Savari HV.
The first sample is timed at 10:40:54.130 a.m., and the second sample is timed at 11:06:19.037 a.m. Table 156 reports path history data from the first sample. The two samples appear to report data for only one IMA event. This was confirmed by the overlapping the path history points from the two samples on Google Earth. Table 156 reports the path history data in chronological order. Having the

unique random id for the two events would confirm this assumption. Total path history time for the HV was 133.96 seconds (point 1 through point 15), and 73.41 seconds for RV (point 1 through point 12).

Table 156: hvBSM, rvBSM Path History – Savari

Path History Point	*Vehicle*	*latOffset**	*lonOffset**	*timeOffset****
1	hvBSM	1001	21	164
2	hvBSM	2400	38	5925
3	hvBSM	2719	580	6160
4	hvBSM	2436	1184	6336
5	hvBSM	1697	1076	6571
6	hvBSM	27	1106	6981
7	hvBSM	-764	809	7176
8	hvBSM	-904	186	7340
9	hvBSM	-410	-80	7964
10	hvBSM	2312	-131	12363
11	hvBSM	2694	355	12560
12	hvBSM	2446	1074	12734
13	hvBSM	1588	1449	12938
14	hvBSM	-653	1124	13377
15	hvBSM	-1155	649	13560
1	rvBSM	-37	-2884	286
2	rvBSM	-158	-4967	3644
3	rvBSM	494	-6145	4206
4	rvBSM	1300	-6529	4470
5	rvBSM	2136	-6124	4746
6	rvBSM	2611	-4955	5002
7	rvBSM	2285	-117	5652
8	rvBSM	1754	4370	6370
9	rvBSM	1275	5607	6811
10	rvBSM	528	6050	7128
11	rvBSM	-39	5828	7352
12	rvBSM	-76	3996	7627

**1/10th micro degrees; ** 10cm units; ***units of 10 milliseconds*

Figure 3 maps the history point for HV (green) and RV (orange), in addition to the anchor point (labeled with zero). There appears to be sufficient data for an assessment of the IMA (identified at the sequence: HV 7-6-5; RV 10-9-8).

Figure 3 IMA – Savari
Source: CUTR

OBU Data Log Post-Test Assessment Vehicle Turning Right in Front of Transit Vehicle (VTRFTV)

Background

During August 28-30, 2018, the Tampa CV Pilot team conducted a series of tests to assess the generation and over-the-air transfer of OBU Logs. Tests were conducted using one vehicle for each vendor providing OBUs: Savari and Sirius XM. Test vehicles were identified using unique vehicle IDs.

Assessment

CUTR assessed the OBU logs following this procedure:

1. Obtain total count of DataLogMessages
   a. Total count for the entire period by the vendor
   b. Total count by test day (28, 29, 30) by the vendor
2. Obtain total count of EventTypes within DataLogMessages
   a. Total count for the entire period by the vendor
   b. Total count by test day (28, 29, 30) by the vendor
3. Extract at random two observations for each EventType (two per OBU vendor)
   a. Analyze content and compare to specs

b. Analyze content to identify problems in metrics and units of measure
c. Analyze content vs. PMESP requirements.

Summary Statistics

Table 157 reports the count of OBU logs uploaded to THEA Master Server during the timeframe, split by OBU vendor. Highlighted in red are events that were either unsuccessfully generated or recorded, and events that were not yet implemented at the time of testing.

Table 157: OBU Logs by Event Type

Event Type	Savari	Sirius XM	Total
sentBSM	24,052	296	24,348
receivedBSM	6,121	2,111	8,232
receivedMAP	2,209	6	2,215
receivedSPaT	77,419	1,510	78,929
receivedTIM	20,645	2,355	23,000
sentSRM	94	0	94
receivedSSM	826	0	826
receivedPSM	1,539	763	2,302
warningEEBL	12	2	14
warningERDW	3,323	0	3,323
warningFCW	244	9	253
warningIMA	91	3	94
warningPCW	0	2	2
warningVTRFTV	0	4	4
warningWWE	1,837	3	1,840
smartBreadCrumb	0	85	85
sysMonHealth	3,642	10	3,652
sysMonOTA	0	2	2
Total	***142,054***	***7,161***	***149,215***

Event Type Analysis

Vehicle Turning Right in Front of Transit Vehicle (VTRFTV)

Reference Document: System Design Document (SDD), Section 3.3.2.5

The VTRFTV app HMI warns the streetcar operator of an equipped vehicle turning right at the intersection the streetcar is approaching, using the BSMs that are being sent and received, if the app determines the vehicles are on a potential collision trajectory. Once a blinker of the equipped vehicle that is approaching the intersection is engaged while passing the streetcar as well as the trajectory and speed determined by the OBU match that of the potential collision, the streetcar OBU will give the streetcar driver a warning. The equipped vehicle receives a warning that they are on a collision course with streetcar as well. The Streetcar OBU would also put a special ITIS code to SpecialVehicleExtensions.description.typeEvent and SpecialVehicleExtensions.description.description in the BSM once noticing that the blinker in the vehicle was engaged which would then be received by the RSU at the intersection and sent out as a warning message to nearby pedestrians equipped with a Personal Information Devices (PID). Refer to section 3.4.2.2 for a description of the pedestrian interface. The variables and timing of when the message is displayed to the driver and how long it will stay on must be configurable.

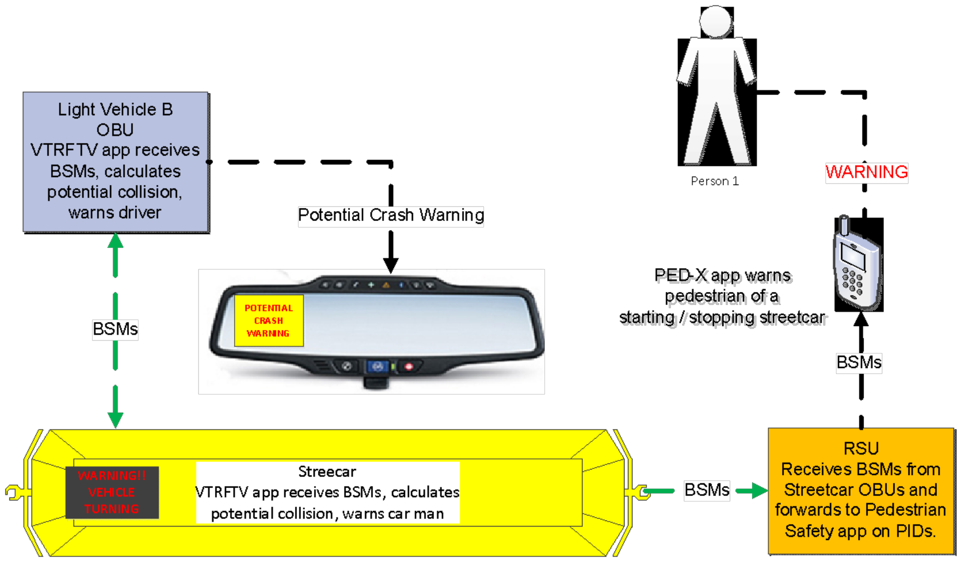


Figure 42: VTRFTV Functional Flow, SDD pp.63
Source: SDD
Note: Figure not updated. PED-X warning removed from the app list

Performance Evaluation and Measurement Data Requirements

To conduct the safety evaluation, CUTR needs the following data as specified under the "WarningEventData" in DataLog_v1.3. Table 158 reports the requirements.

Table 158: VTRFTV Data Requirements

Field	Description
id	Unique ID of the warning event
driverWarn	True, if the driver was warned; false otherwise
isControl	True, if the driver was part of a control group
isDisabled	True, if HMI was disabled, false otherwise
hvBSM	Host Vehicle BSM of this vehicle; from J2735ASN-20160
rvBSM	Remote Vehicle BSM of the vehicle which triggered the warning

In addition, Part II pathHistory of hvBSM and rvBSM should contain a minimum of 15 seconds of path history (elements: latOffset, lonOffset, elevationOffset, timeOffset) to reconstruct the HV and RV paths before and after the warning is issued. *The minimum required before-after timeframe is 15 seconds.*

Analysis Results

Only Sirius was able to generate OBU logs for upload to THEA Master Server. Four OBU logs were generated on day 30, with the first OBU log recorded at 09:16:10.333 a.m. and the last one recorded at 09:19:38.227 a.m.
Table 159 reports the total number of VTRFTV warning events. The content analysis results are reported in Table 160.

Table 159: Number of VTRFTV within OBU Logs by Vendor

Vendor	*sum*	*min*	*max*
Savari	n.a.	n.a.	n.a.
Sirius XM	5	1	2
Total	*5*		

n.a. means not available

Table 160: Content Analysis Results

	Successful (Y/N)		Notes
Field	**Savari**	**Sirius XM**	
id	N	Y	No content from Savari. Sirius XM creates an id (e.g., <id>F866F149</id>). Need to verify it is random
driverWarn	N	Y	No content from Savari. Content checked for test vehicles. Need to verify on participant vehicles once data are available
isControl	N	Y	No content from Savari. Content checked for test vehicles. Need to verify on participant vehicles once data are available
isDisabled	N	Y	No content from Savari. Content checked for test vehicles. Need to verify on participant vehicles once data are available
hvBSM	N	Y	No content from Savari. Sirius XM generated content on Part I, but path history content is too short for evaluation. **hvBSM vehicle id identifies the Savari vehicle (6A000028), while it should identify the host vehicle (i.e., Sirius XM device ID 2147483690).**
rvBSM	N	N	No content from Savari. Sirius XM did not produce rvBSM.

OBU Data Log Post-Test Assessment Wrong-Way Entry Warning (WWE)

Background

During August 28-30, 2018, the Tampa CV Pilot team conducted a series of tests to assess the generation and over-the-air transfer of OBU Logs. Tests were conducted using one vehicle for each vendor providing OBUs: Savari and Sirius XM. Test vehicles were identified using unique vehicle IDs.

Assessment

CUTR assessed the OBU logs following this procedure:

1. Obtain total count of DataLogMessages
    a. Total count for the entire period by the vendor
    b. Total count by test day (28, 29, 30) by the vendor
2. Obtain total count of EventTypes within DataLogMessages
    a. Total count for the entire period by the vendor
    b. Total count by test day (28, 29, 30) by the vendor
3. Extract at random two observations for each EventType (two per OBU vendor)
    a. Analyze content and compare to specs
    b. Analyze content to identify problems in metrics and units of measure
    c. Analyze content vs. PMESP requirements.

Summary Statistics

Table 161 reports the count of OBU logs uploaded to THEA Master Server during the timeframe, split by OBU vendor. Highlighted in red are events that were either unsuccessfully generated or recorded, and events that were not yet implemented at the time of testing.

Table 161: OBU Logs by Event Type

Event Type	Savari	Sirius XM	Total
sentBSM	24,052	296	24,348
receivedBSM	6,121	2,111	8,232
receivedMAP	2,209	6	2,215
receivedSPaT	77,419	1,510	78,929
receivedTIM	20,645	2,355	23,000
sentSRM	94	0	94
receivedSSM	826	0	826
receivedPSM	1,539	763	2,302
warningEEBL	12	2	14
warningERDW	3,323	0	3,323
warningFCW	244	9	253
warningIMA	91	3	94
warningPCW	0	2	2
warningVTRFTV	0	4	4
warningWWE	1,837	3	1,840
smartBreadCrumb	0	85	85
sysMonHealth	3,642	10	3,652
sysMonOTA	0	2	2
Total	***142,054***	***7,161***	***149,215***

Event Type Analysis

Wrong-Way Entry Warning (WWE)

Reference Document: System Design Document (SDD), Section 3.3.2.2
As mentioned in section 3.2.2.2 of this document, the WWE app is designed to warn OBU equipped vehicles trying to wrong way enter an RSU equipped intersection, which provides the MAP and SPaT messages through DSRC. The specific intersection used for this study is at Twiggs Street and Meridian Avenue.

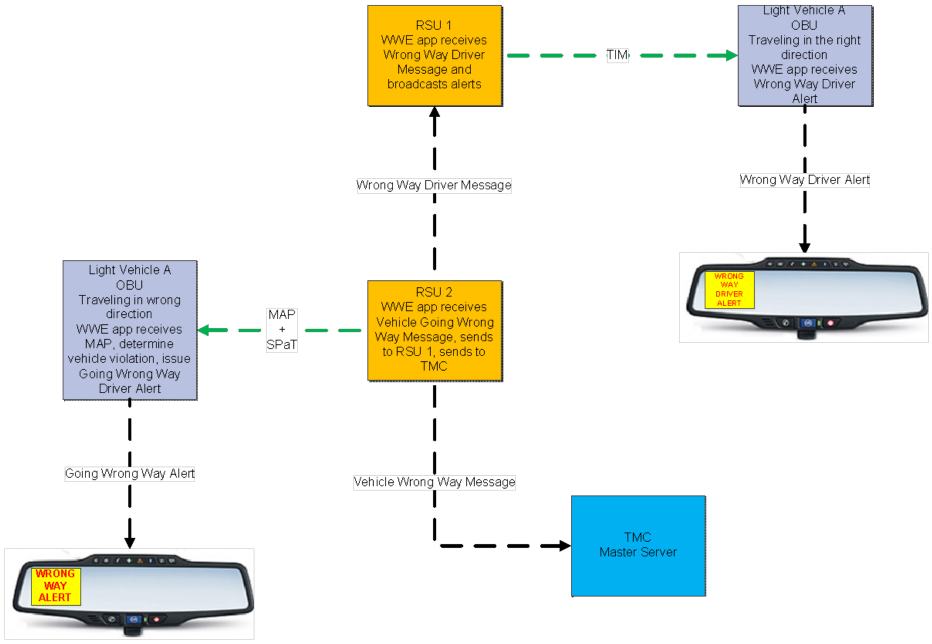


Figure 1: WWE Functional Flow, SDD (pp.59)
Source: SDD

The app has multiple levels of warning. The driver would receive a first-level warning when their OBU equipped vehicle is on a path that is projected to enter a part of the intersection that would make them go the wrong way based on their trajectory and speed (labeled with 1 in Figure 3-29 and Figure 3-30). If the vehicle continues to go up a road in the wrong way manner, the driver of the vehicle will receive a second warning letting them know that they are already going the wrong way (labeled with 2 in Figure 3-29 and Figure 3-30). There is also another warning message displayed to the driver using this app where the equipped vehicle finds itself in an area where no traffic is allowed which is specific to the REL exit (labeled with 3 in Figure 3-29 and Figure 3-30). Another feature of the app is that it will warn the drivers of equipped vehicles of a wrong-way driver approaching them on the REL based on a TIM that would be broadcast by the RSU.

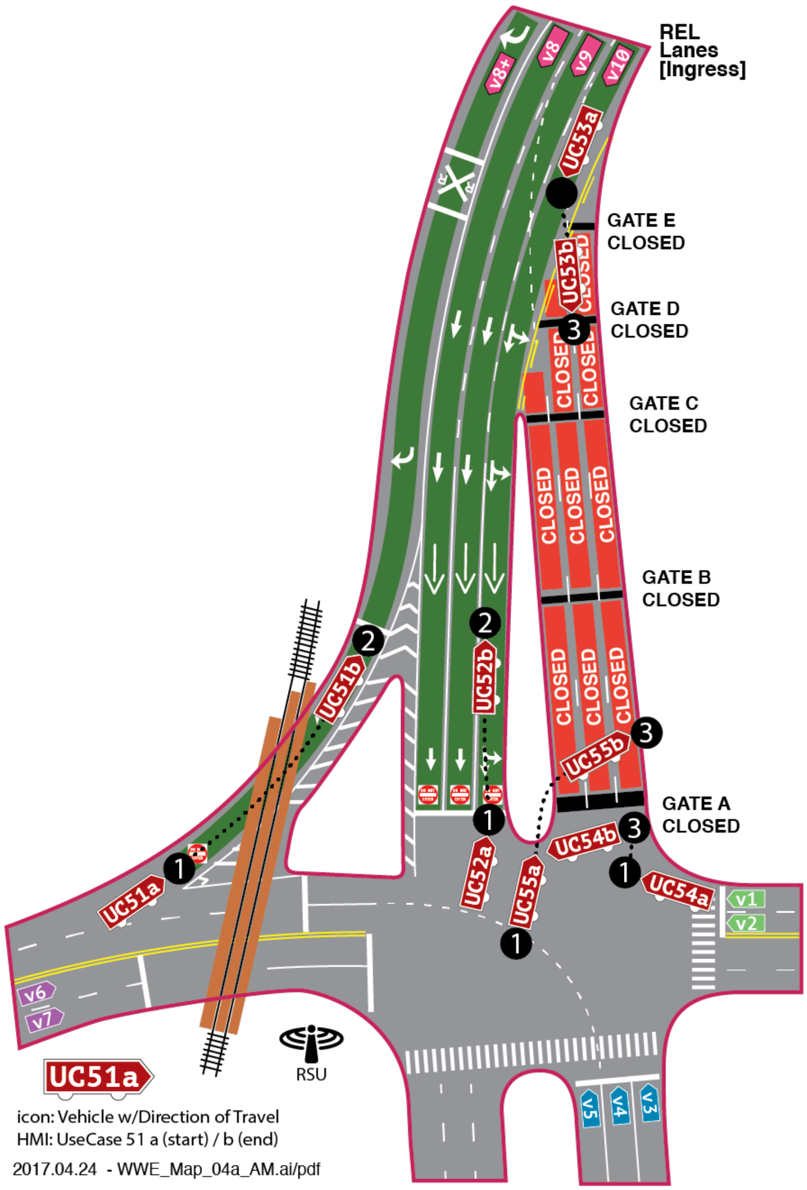


Figure 2: Morning REL, SDD (pp.60)
Source: SDD

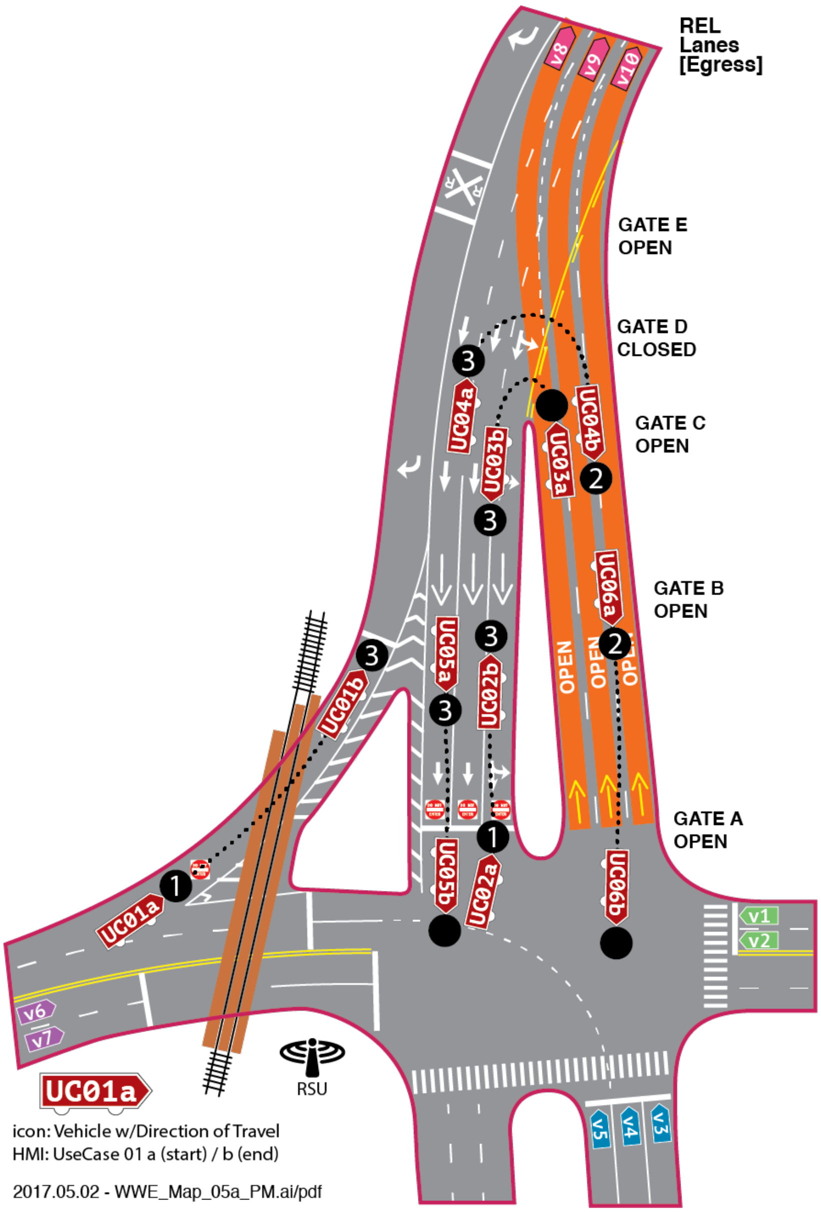


Figure 3: Afternoon REL, SDD (pp.61)
Source: SDD

As previously mentioned, this app is not specific to the intersection shown in figures above and should function in any intersection that can provide the MAP and SPaT messages to the vehicle OBU.

Performance Evaluation and Measurement Data Requirements

To conduct the safety evaluation of WWE, CUTR needs the following data as specified under the "WarningEventData" in DataLog_v1.3. Table 162 reports the requirements.

Table 162: FCW Data Requirements

Field	Description
id	Unique ID of the warning event
driverWarn	True, if the driver was warned; false otherwise
isControl	True, if the driver was part of a control group
isDisabled	True, if HMI was disabled, false otherwise
hvBSM	Host Vehicle BSM of this vehicle; from J2735ASN-20160
receivedSPaT	The SPaT message received from RSU that contains the lane configuration and lane status.

In addition, Part II pathHistory of hvBSM should contain a minimum of 15 seconds of path history (elements: latOffset, lonOffset, elevationOffset, timeOffset) to reconstruct the HV and RV paths before and after the WWE is issued. *The minimum required before-after timeframe is 15 seconds.*

Analysis Results

Table 163 reports the number of OBU logs containing WWE warnings issued during the test timeframe by OBU vendor. In a few instances, OBU logs contained more than one warning. In particular, Savari logged 3395 events over about four minutes and 44 sec during one test, compared to the much lower frequency of Sirius XM (Table 4). This issue was discussed during the post-briefing sessions and pointed to the interpretation regarding the frequency at which warning events should be logged (e.g., one logged event vs. multiple logged events triggered after the first one).

Table 163: Number of WWE within OBU Logs by Vendor

Vendor	***sum***	***min***	***max***
Savari	4312	1	
Sirius XM	3	1	1
Total	***4315***	***1***	

Table 164: WWE First and Last Event

Vendor	*Day*	*First Log*	*Last Log*
Savari	28	13:50:31.959	13:55:16.927
Sxm	30	14:32:49.264	14:40:05.564

Content Analysis

Table 165 reports the results from the content analysis of a random sample.

Table 165: Content Analysis for WWE Event

Field	**Successful (Y/N)**		**Notes**
	Savari	**Sirius XM**	
id	N	Y	Savari id lacks content. Field only contains <id>00000000</id>. Sirius XM creates an id (e.g., <id>4D4E65BD</id>). Need to verify it is random
driverWarn	Y	Y	Content checked for test vehicles. Need to verify on participant vehicles once data are available
isControl	Y	Y	Content checked for test vehicles. Need to verify on participant vehicles once data are available
isDisabled	Y	Y	Content checked for test vehicles. Need to verify on participant vehicles once data are available
hvBSM	Y	Y	Savari produces hvBSM with Path History covering more than +/- 15 secs. Need to ensure high frequency between offset points. On Sirius warnings, the hvBSM data contained SPaT message information instead and the BSM path history of the other two WWE events re exactly the same.
receivedSPaT		Y	Content checked for test vehicles. Need to verify on participant vehicles once data are available

The CUTR team also looked at the TIM message received, during the WWE event. Based on the TIM spreadsheet referenced in the ICD, the TIM information has to provide the start time in "minutesOfTheYear" and the duration time in minutes of the WWE event. Also, the priority is set to 7 for WWE (see Figure 4). Instead, this priority number seems to be either 3 or 6. In addition, the TIM message includes the itis code 1793 to warn oncoming traffic warning of wrong-way driving vehicle. This was observed at RSU1 on the REL.

ERDW	WWE	Field Name	Field Type	ASN.1 Structural Type	ASN.1 Primitive Type	Comments
N	N	msgCrc	MsgCRC	OPTIONAL	OCTET STRING (SIZE(2))	Unclear how this CRC would be calculated and then later verified being in the middle of a larger UPER message
O	O	startYear	DYear	OPTIONAL		
R	R	startTime	MinuteOfTheYear		INTEGER (0..527040)	ERDW: Time when this speed recommendation goes into effect. This would usually be a past point in time. WWE: Time when wrong-way driver warning was issued
R	R	duratonTime	MinutesDuration		INTEGER (0..32000)	Duration of validity of this speed recommendation or wrong-way driver warning.
R	R	priority	SignPriority		INTEGER (0..7)	ERDW: 4 WWE: 7
		-- Part II, Applicable Regions of Use				
			GeographicalPath			
		-- Part III, Content				
R	R	sspMsgRights1	SSPindex		INTEGER (0..31)	Set value to zero
R	R	sspMsgRights2	SSPindex		INTEGER (0..31)	Set value to zero
R	R	content		CHOICE		
R	R	advisory	ITIS.ITIScodesAndText	SEQUENCE (SIZE(1..100))		
R	R	item		CHOICE		
R	R	itis	ITIScodes		INTEGER (0..65535)	ERDW: Used by a reduced speed recommendation zone. Advice for 20 MPH speed for example: speed-limit (268), n20 (12564), mPH (8720) WWE: Used to warn oncoming traffic of wrong-way driver: vehicle-traveling-wrong-way (1793)
N	N	text	ITIStext		IA5String (SIZE(1.500))	
N	N	workZone	WorkZone	SEQUENCE (SIZE(1..16))		

Figure 4 TIM Message Frame, ICD (pp 86)
Source: ICD

Sirius XM

On day 30, Sirius XM OBU logs show three WWE warning events with timestamps:

1. Thursday, August 30, 2018, 2:32:49.264 p.m.
2. Thursday, August 30, 2018, 2:39:06.260 p.m.
3. Thursday, August 30, 2018, 2:40:05.564 p.m.

The first event has message id: A0272CE9 and in the place of the hvBSM it shows the SPaT information. The second event with id: 232F31D9 shows a path history that positions the vehicle in the HCC parking lot, as shown in Table 166 and Figure 5. The third event with id: 4D4E65BD shows the hvBSM content exactly the same as in the second event that was logged previously. The assumption is that this is the same event with an escalation of warning level.
Table 166 reports the path history points ranked in chronological sequence from most recent to less recent. It shows that BSM path history content in the second and third log. HV contains 13 path history points: total time 1.1 minutes (average 5.25 seconds in between points).

Table 166: hvBSM, Path History - Sirius XM

Path History Point	*latOffset**	*lonOffset**	*elevationOffset***	*timeOffset****
1	-558	-601	7	13737
2	-999	-1334	11	14259
3	-1755	-1362	12	14453
4	-2411	-775	11	14677
5	-2808	298	11	14954
6	-3038	2326	11	15351
7	-2953	7794	8	16269
8	-2226	8581	8	16473
9	-1214	8722	8	16706
10	-591	8052	7	16896
11	-474	7002	7	17153
12	-626	3252	4	18204
13	-781	-476	7	20562

**1/10th micro degrees; ** 10cm units; ***units of 10 milliseconds*

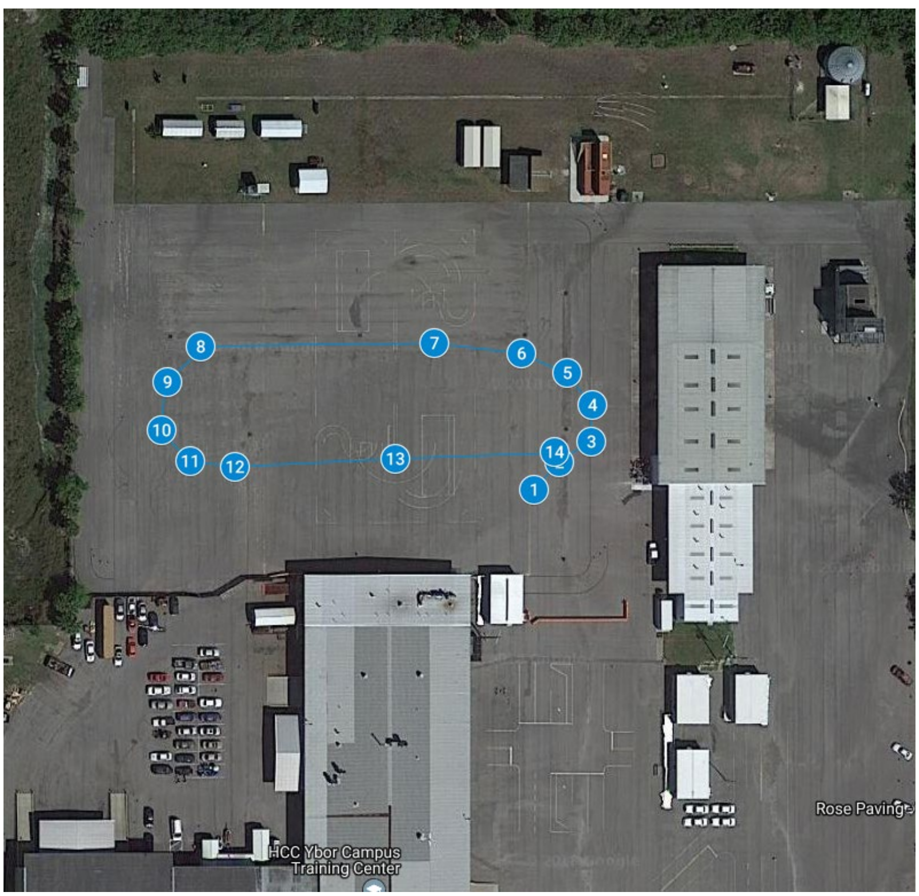


Figure 5 WWE – Sirius XM

Source: CUTR

Savari

The CUTR team analyzed two samples for WWE test conducted at the REL as indicated in Table 7. The first sample is timed at 8/28/2018, 2018, 13:50:31.959, and the second at 8/28/2018 13:51:31.902. Table 167 reports path history data from the two samples, which appear to report data for one WWE event with multiple warning events as discussed previously.

Table 167: hvBSM, Path History - Savari

Path History Point	*latOffset**	*lonOffset**	*timeOffset****	*elevationOffset***
1	101	97	36	191
2	-283	328	84	352
3	-790	870	8	2196
4	-3160	555	17	2790
5	-5946	-23	2	4944
6	-10425	-1521	2	5317
7	-14108	-3508	-6	5549
1	7448	491	-30	1078
2	8493	230	-36	1359
3	8997	-758	-37	1581
4	9249	-3666	-44	1964
5	9208	-6568	-43	2417
6	8739	-7257	-50	2709
7	7743	-7345	-56	3262
8	4241	-7135	-82	3998
9	3324	-6995	-96	4440
10	3187	-6419	-100	4783
11	3760	-6016	-106	5176
12	4001	-6060	-116	6007

**1/10th micro degrees; ** 10cm units; ***units of 10 milliseconds*

Figures 6 and 7 maps the history point for HV, in addition to the anchor point (labeled with one). There appears to be sufficient data for an assessment of the WWE.
Note: There seems to be no way to identify the kind of warning picture or message the driver receives on HMI for the WWE. Since there are multiple and escalating warnings, this is important to identify.

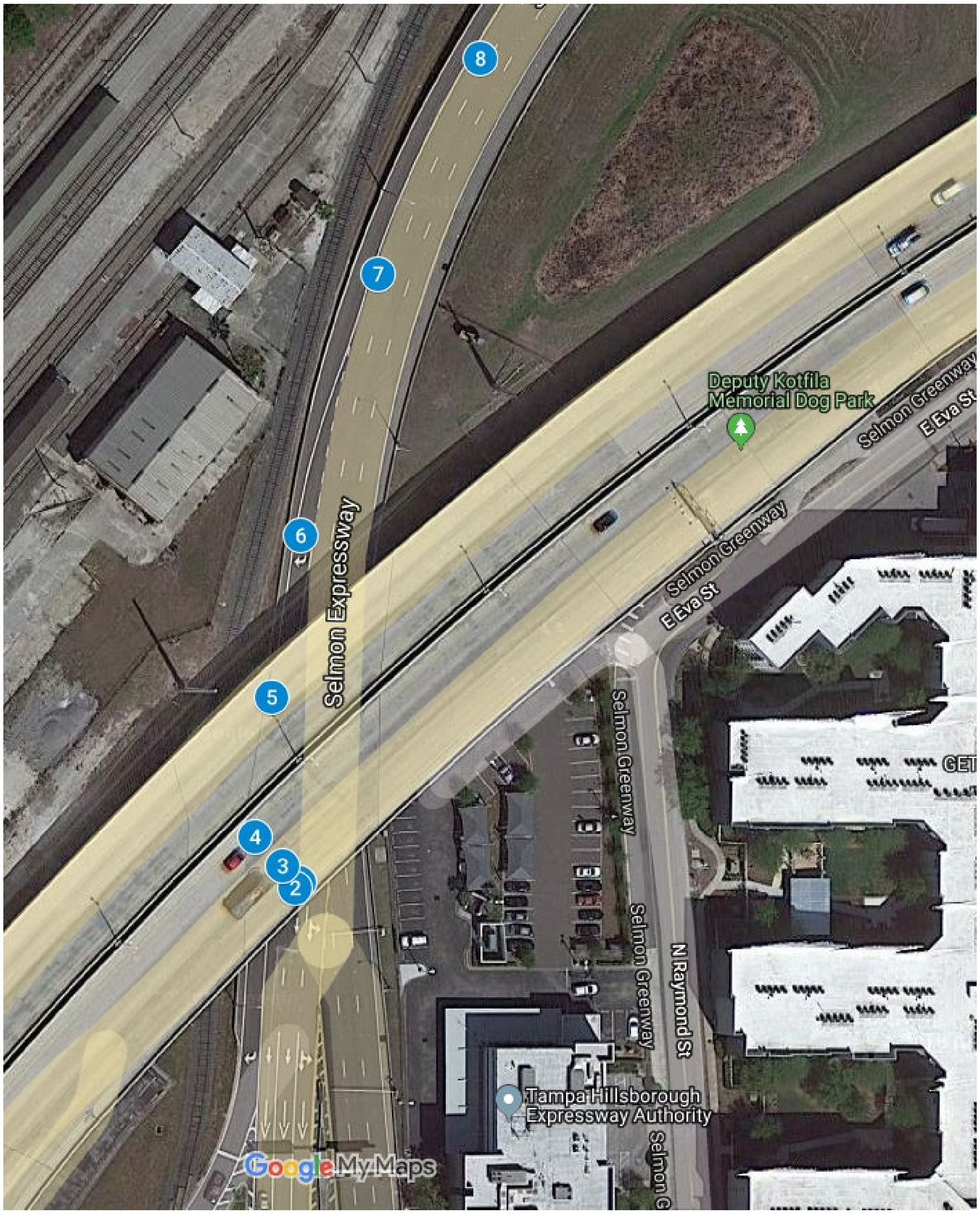


Figure 6 WWE – Savari
Source: Google MyMaps

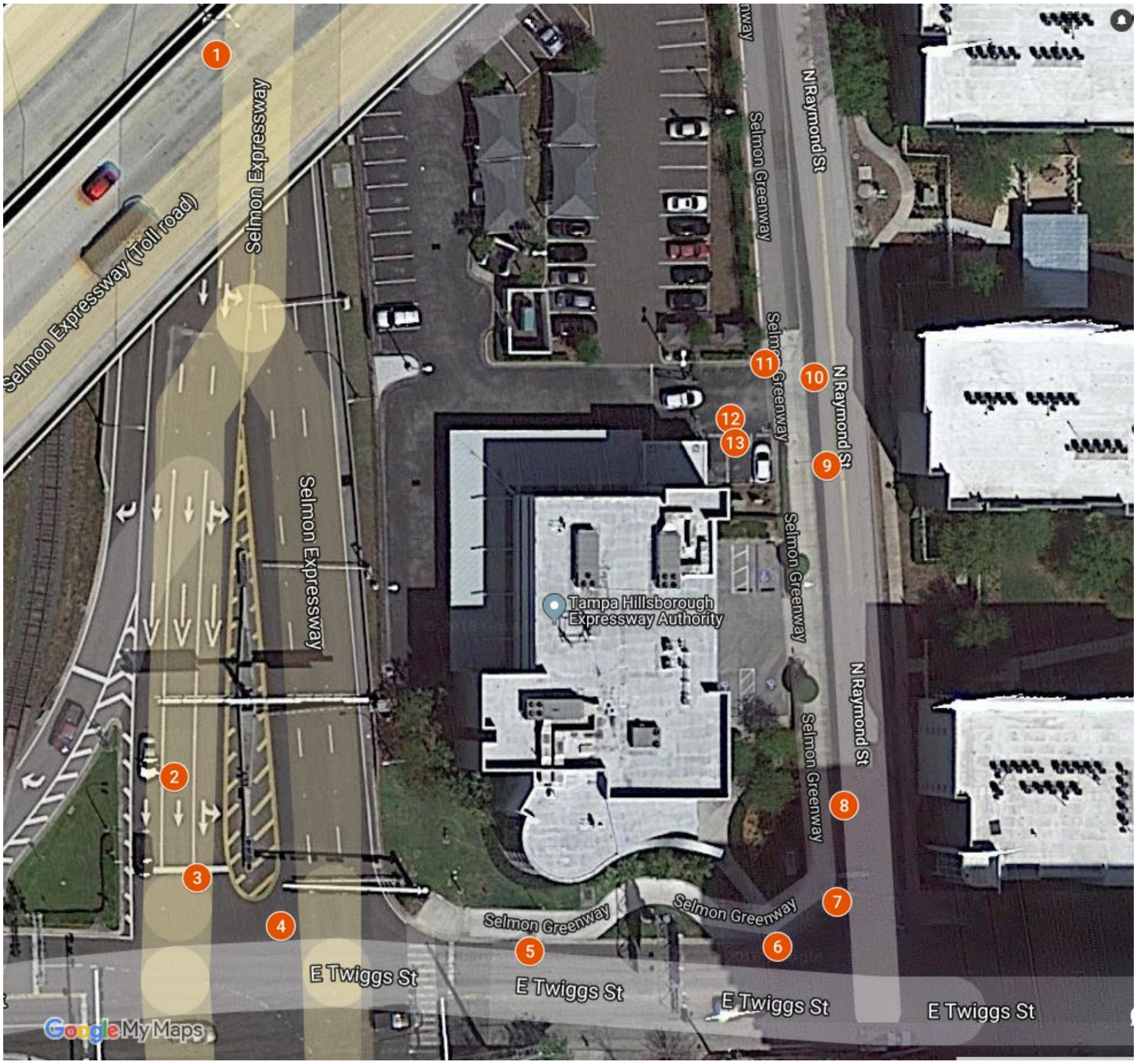


Figure 7. WWE(2) – Savari
Source: Google MyMaps

Appendix B

Table 168: App Action

App	Case	Step	Action	Expected Result	P/F	Comment/Anomaly
OTA	1	1	Update the software OTA to the latest	Mirror shows new firmware version		
WWE			Approach REL set up with incoming traffic (morning) going up as shown by UC52a.	Display "Do not enter" warning on the mirror		1 ✓
		2	Continue up the REL as shown in UC52b	Display "Wrong Way" warning on the mirror		1 ✓ 5 ✓ ✓
		3	Repeat five times			
WWE	3		In the morning scenario, drive down the REL towards the Twiggs intersection while another car is going the wrong way triggering the sensor	Display "Wrong-Way Driver" alert		2-DNGA
		2	Repeat five times			
WWE	4	1	In the evening scenario, approach REL at UC02a	Display "Do not Enter" warning		
		2	Continue on the path to UC02b	Display "no vehicle" warning		
		3	Continue on the path from UC04a to UC04b	Display "wrong way" warning		
		4	Repeat five times			

App	Case	Step	Action	Expected Result	P/F	Comment/Anomaly
ERDW	5	1	With LONG QUEUE TIM set up, a vehicle approaches 40 MPH zone but has not reached it yet	No warning		

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