Integrated Vehicle-To-Infrastructure Prototype (IVP)

IVP System Requirements

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16. Abstract

The purpose of the Integrated Vehicle-to-Infrastructure Prototype (IVP) project is to identify, develop, construct, test, and deploy for the USDOT a single Vehicle-to-Infrastructure (V2I) prototype interface system that can support an integrated deployment of multiple dynamic mobility, safety, and environmental applications. The Battelle Team is developing and testing this integrated V2I prototype system to be capable of supporting a full complement of Connected Vehicle applications based on Dedicated Short Range Communications (DSRC).

IVP is an interface system that supports the collection, integration and dissemination of data between infrastructure and vehicles for a wide variety of applications such as signal phase and timing, mapping (intersections and road segments), other roadside equipment (e.g., dynamic message signs, detectors), positioning corrections, communications (DSRC, cellular), and road condition and weather data.

This document defines the system requirements for the IVP platform and message handlers recommended for demonstration and testing.

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V2I, I2V, Integrated V2I Prototype, IVP	

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Chapter 1 Scope

Over the past several years, the U.S. Department of Transportation (USDOT) has aggressively pursued the development, deployment, and assessment of a full range of advanced applications and supporting capabilities and technologies all focused on capturing and demonstrating the full potential of communications between connected vehicles, travelers, and infrastructure to enhance safety, mobility, and the environment. This effort has spanned several agencies and programs across USDOT.

While the potential benefits of Connected Vehicle technology have been demonstrated, the interfaces for each application have been developed in isolation, based on the developer's interpretation of the existing standards. For example, the Signal Phase and Timing (SPaT) prototype system defined vehicle-to-infrastructure (V2I) interfaces including mapping, positioning, communications requirements, and system interfaces based on the existing SAE J2735 for Dedicated Short Range Communications (DSRC) and the NTCIP standards for communication between devices and traffic signal controller. Researchers modified and extended the existing standards to meet the requirements of the SPaT and related messages for the transmission of signal information to connected vehicles. Similarly, other applications such as Intelligent Network Flow Optimization (INFLO) and Applications for the Environment: Real-time Information Synthesis (AERIS) also have mapping, positioning, communications requirements, and system interfaces specific to their own applications. Maintain multiple communications and interface systems to carry out similar functions is inefficient. Widespread acceptance and implementation of connected vehicle depends on a single, integrated V2I interface that supports multiple applications and technologies.

The purpose of the Integrated V2I Prototype (IVP) Development Project is to identify, develop, construct, test, and deploy a single interface system that supports an integrated deployment of multiple dynamic mobility, safety, and environmental applications. The Battelle Team is developing and testing this integrated V2I prototype system to be capable of supporting a full complement of Connected Vehicle applications based on Dedicated Short-Range Communications (DSRC).

Document Identification

Task 3 of the IVP Project prescribes the development of system requirements for the IVP. This task addresses both an assessment of the prior systems engineering work, tailored to meet the specific requirements of this prototype, along with any new user needs and associated requirements necessary to fulfill the stated goals of the prototype. This document defines the requirements for the IVP platform and message handlers recommended for development in Task 4 and subsequent demonstration and test in Task 5.

Document Overview

The content of this document was generated through the incorporation of previously documented information related to the applications that the IVP may need to support, as well as the results of additional requirements analysis and design work performed specific to this implementation of an Integrated V2I Prototype. While it is not intended to duplicate the previous efforts, this document has been prepared to be standalone in its content. However, this document does assume the reader has familiarity with IVP, SPaT, and the overall Connected Vehicle initiative.

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

Section 2 Referenced Documents describes the external documentation utilized and referenced throughout this report.

Section 3 Requirements provides an introduction to and the IVP requirements applicable to the IVP Platform and for Message Handlers and Applications recommended for development in Task 4 and subsequent demonstration and test in Task 5 of the project.

Appendix A: Acronyms and Abbreviations describes acronyms and abbreviations used in the document.
Appendix B: Terms and Definitions defines unique terms and definitions used in the document.

IVP Project Objectives

The objective of the Integrated V2I Prototype (IVP) project is to identify, develop, implement, test, document and deploy a roadside prototype system that supports an integrated, interoperable deployment of multiple V2I safety, mobility, and environmental applications. IVP is an interface system that supports the collection, integration and dissemination of data between infrastructure and vehicles for a wide variety of applications such as:

- Signal Phase and Timing
- Mapping (Intersections and Road Segments)
- Other Roadside Equipment (i.e. signage, detectors)
- Positioning Corrections
- Communications (DSRC, cellular)
- Security (Over-the-air-security)
- Road Condition and Weather Data

The purpose of this scope of work is to develop and test an Integrated Vehicle-to-Infrastructure (V2I) Prototype System which provides a full complement of infrastructure capability supporting V2I communications-based, connected vehicle applications, and to document the design and prototype to enable subsequent implementation activities by other parties. This activity will integrate the results of other research and development, conducted under the connected vehicle program and elsewhere, to provide the basis for moving the V2I connected vehicle research program toward implementation.

The system-of-interest for the prototype consists of enhanced roadside processing components. These include infrastructure roadside components and central back office system components. Infrastructure components may include a broad array of devices such as signal controllers, weather and pavement sensors, message signs, vehicle detection systems, traffic counter, speed

detection, and many more. The roadside component of infrastructure often interfaces with central systems, typically identified as a Traffic Management Entity (TME).

IVP Project Overview

This project is organized in seven tasks:

Task 1: Project and Systems Engineering Management - The objective of Task 1 is to both establish and implement the baseline policies and procedures that will guide the conduct of the program, including program management, systems engineering management, work breakdown structure, and schedule. Its purpose is to ensure quality, consistency, and rigor in all phases of the program.

Task 2: Foundational Assessment of V2I Applications - The objectives of this task are to gather and consolidate stakeholder needs and requirements from V2I applications pertaining to the foundational technology areas of mapping, positioning, communications, as well as SPaT and related messages; and assess the state of development of foundational technologies to meet those requirements.

Task 3: Prototype Integration Planning - The high level objective of Task 3 is to assess results of Task 2 and perform the analysis and planning required to build and integrate the prototype in Task 4 and conduct full system testing in Task 5. Detailed objectives for the task include:

- Support USDOT selection (with stakeholder input) of the applications and capabilities to be supported by prototype to be developed in Task 4 (based on assessments in Task 2)
- Down select requirements from Task 2 to establish the requirements for the Task 4 Prototype, with traceability
- Develop comprehensive interface control document (ICD) for the all Prototype interfaces
- Develop high level design of the Prototype (including components and attributes)
- Develop Plans for Integration and for Testing of the Prototype
- Throughout the task, engage stakeholders to build awareness and gather technical feedback

Task 4: Prototype Integration / Build - The objective of this task is to document and build a prototype of the infrastructure systems (and components) that satisfy the needs and requirement of the Connected Vehicle community as generated from years of prior research activities, and as documented and agreed to under the work performed in Task 2 of this Task Order Proposal Request (TOPR). This prototype will be based on the integration of the major subsystems that have been previously developed and demonstrated for USDOT, and will be augmented to ensure that the capabilities of this system support the expressed needs, and that this system can be thoroughly tested.

Task 5: Full System Testing - Under this task, the Battelle Team will perform full system testing of the Integrated Prototype. The intent of the testing is to verify that the prototype, once fully integrated, fulfills the requirements identified in Task 3.

Task 6: Documentation / Stakeholder Review and Outreach - The purpose of this task is to finalize the documentation associated with the Integrated V2I Prototype, including detailed guidance for deploying agencies, along with operations and maintenance details; and to disseminate this information to stakeholder via workshops and training.

Task 7: OPTIONAL: Implement V2I Prototype at Alternate Field Location - The purpose of this optional Task 7 is to demonstrate the accuracy and robustness of the documentation produced in previous steps and the ability to readily deploy this capability, along with the associated hardware, at a site independent of the current TFHRC location.

Chapter 2 Referenced Documents

The following documents were reference or consulted as part of the development of the material contained in this report.

Positioning Technology

- Vehicle Positioning Trade Study for ITS Applications. FHWA-JPO-12-064. (April 2012)

Mapping Technology

- Mapping Assessment for Connected Vehicle Highway Network (Task 2 Report). FHWA-PROJ-11-0050.
- Mapping Technology Assessment for Connected Vehicle Highway Network Applications (Task 3 Mapping Technology Final Interim Report). FHWA-PROJ-11-0050. (Feb 2011)

Signal Phase and Timing (SPaT)

- Signal Phase and Timing (SPaT) Applications, Communications Requirements, Communications Technology Potential Solutions, Issues and Recommendations, Final Report. FHWA-JPO-13-002. (April 2012)

Communications Security

- An Approach to Communications Security for a Communications Data Delivery System for V2V/V2I Safety: Technical Description and Identification of Policy and Institutional Issues. FHWA-JPO-11-130. (Nov 2011)
- Enabling a Secure Environment for Vehicle-to-Vehicle (V2V) and Vehicle-to-Infrastructure (V2I) Transactions, April 2012 Public Workshop Proceedings. FHWA-JPO-12-072. (June 2012)

Infrastructure Components

- AASHTO Connected Vehicle Infrastructure Deployment Analysis. FHWA-JPO-11-090. (June 2011)

Non Passenger Vehicles

- White Paper: Scope of the Smart Roadside Initiative (April 2010)

Core System for USDOT Next Generation ITS

- Core System - Concepts of Operations (ConOps) (Oct 2011)
- Core System - Architecture Document (SAD) (Oct 2011)
- Core System - System Requirements Specification (SyRS) (Oct 2011)
- Core System – Risk Assessment Report (RAR) (Oct 2011)
- Core System – Standards Recommendations Report (Oct 2011)

Vehicle to Infrastructure (V2I) Safety Applications

Cooperative Intersection Collision Avoidance Systems – Stop Sign Assist

- CICAS Stop Sign Assist (CICAS-SSA) Concept of Operations Version 1.0 (March 2008)
- Determination of the Alert and Warning Timing for the Cooperative Intersection Collision Avoidance System – Stop Sign Assist Using Macroscopic and Microscopic Data: CICAS-SSA, Report #1 (2010)
- The Design of a Minimal Sensor Configuration for a Cooperative Intersection Collision Avoidance System – Stop Sign Assist: CICAS-SSA, Report #2 (2010)
- Macroscopic Review of Driver Gap Acceptance and Rejection Behavior at Rural Thru-Stop Intersections in the US – Data Collection Results in Eight States: CICAS-SSA, Report #3 (2010)
- Sign Comprehension, Considering Rotation and Location, using Random Gap Simulation for a Cooperative Intersection Collision Avoidance System – Stop Sign Assist: CICAS-SSA, Report #4 (2010)
- Validation Study – On-Road Evaluation of the Cooperative Intersection Collision Avoidance System – Stop Sign Assist Sign: CICAS-SSA, Report #5 (2010)

Cooperative Intersection Collision Avoidance Systems for Violations

- CICAS-V Concept of Operations, Final Phase I Release v3.01 (Appendix B) (August 2008)
- CICAS-V, System Requirements Specification, v3.01, (2008)
- CICAS-V High-Level Requirements Specifications, Final Phase I Release v4.01 (Appendix C-1) (August 2008)
- CICAS-V High-Level Requirements Specifications, Final Phase I Release v3.01 (Appendix C-2) (August 2008)
- CICAS Limited to Stop Sign and Traffic Signal Violations (CICAS-V) Phase I Final Report (Sept 2008)

Cooperative Intersection Collision Avoidance Systems - Signalized Left Turn Assist

- CICAS Signalized Left Turn Assist and Traffic Signal Adaptation (CICAS-SLTA), Final Report for Task Order 6608 UCB-ITS-PRR-2010-20 (April 2010)

FHWA V2I Safety Applications Project

- Accelerated Vehicle-to-Infrastructure (V2I) Safety Applications Concept of Operations Document. FHWA Office of Safety Research and Development, Turner-Fairbank Highway Research Center. FHWA-JPO-13-058. (2012).
- Accelerated Vehicle-to-Infrastructure (V2I) Safety Applications System Requirements Document. FHWA Office of Safety Research and Development, Turner-Fairbank Highway Research Center. FHWA-JPO-13-059. (2012).
- Vehicle-to-Infrastructure (V2I) Safety Applications Concept of Operations Document. FHWA Office of Safety Research and Development, Turner-Fairbank Highway Research Center. FHWA-JPO-13-060. (2013).
- Vehicle-to-Infrastructure (V2I) Safety Applications System Requirements Document. FHWA Office of Safety Research and Development, Turner-Fairbank Highway Research Center. FHWA-JPO-13-061. (2013).

Road Weather Applications

- Road Weather Connected Vehicle Applications Briefing on Preliminary Benefit-Cost Analysis (June 2013)
- Concept of Operations for Road Weather Connected Vehicle Applications FHWA-JPO-13-047 (Feb 2013)

Mobility and Environment Applications

- Vehicle Information Exchange Needs for Mobility Applications Version 2.0. FHWA-JPO-12-021. (Aug 2012)
- Vision and Operational Concept for Enabling Advanced Traveler Information Services. FHWA-JPO-12-052. (May 2012)

Intelligent Network Flow Optimization (INFLO)

- Concept Development and Needs Identification for INFLO: Report on Stakeholder Input on Transformative Goals, Performance Measures and High Level User Needs for INFLO. FHWA-JPO-13-010. (April 2012)
- Concept Development and Needs Identification for Intelligent Network Flow Optimization (INFLO) Concept of Operations (June 2012)

Multi-Modal Intelligent Traffic Signal System (MMITSS)

- MMITSS Final System Requirements Document Version 4.0 (March 2012)
- Multi-Modal Intelligent Traffic Signal System (MMITSS) Final Concept of Operations Version 3.1 (Dec 2012)
- MMITSS System Design Version 1.0 (May 2013)
- 5.9 GHz Dedicated Short Range Communication Vehicle-based Road and Weather Condition Application Message Requirements – Final Version 2.0 (Aug 2013)

Response, Emergency Staging, Communications, Uniform Management, and Evacuation (R.E.S.C.U.M.E.)

- Response, Emergency Staging, Communications, Uniform Management, and Evacuation (R.E.S.C.U.M.E.) Concept of Operations v2.0 (Sep 2012)

Integrated Dynamic Transit Operations (IDTO)

- Report on Functional and Performance Requirements and High-Level Data and Communication Needs for Integrated Dynamic Transit Operations (IDTO). FHWA-JPO-12-085. (Aug 2012)

Applications for the Environment: Real-time Information Synthesis

- Applications for the Environment: Real-time Information Synthesis State-of-the-Practice Support (AERIS) – Final Report State-of-the-Practice Scan of Behavioral and Activity-Based Models FHWA-JPO-11-133 (June 2011)
- AERIS – State-of-the-Practice Assessment of Technology to Enable Environmental Data Acquisition FHWA-JPO-11-134 (June 2011)
- AERIS - State-of-the-Practice Scan of Environmental Models – Final Report FHWA-JPO-11-135 (June 2011)
- AERIS - Applications State of the Practice Assessment Report FHWA-JPO-11-139 (Aug 2011)
- AERIS - Techniques for Evaluating the Environmental Impacts of ITS Deployment FHWA-JPO-11-142 (Aug 2011)
- An AERIS Data Environment Based on Existing Systems Development – Final Report FHWA-JPO-11-144 (Aug 2011)
- AERIS ConOps and Modeling Workshop (March 26 – 27, 2013)
- AERIS Dynamic Eco-Lanes Transformative Concept Workshop (March 26 – 27, 2013)
- AERIS Dynamic Low Emissions Zones Transformative Concept Workshop (March 26 – 27, 2013)
- AERIS Eco-Signal Operations Transformative Concept Workshop (March 26 – 27, 2013)

Connected Vehicle Applications

- Roadway Geometry and Inventory Trade Study for IntelliDrive Applications FHWA-HRT-10-073 (Nov 2010)

Society of Automotive Engineers (SAE) Documents

- SAE J1211. Handbook for Robustness Validation of Automotive Electrical/Electronic Modules.
- SAE J1850 VPW, J1850 PWM. Class B Data Communications Network Interface (June 2006).
- SAE J1939 Recommended Practice for a Serial Control and Communications Vehicle Network
- SAE J2735:2015 Dedicated Short Range Communications (DSRC) Message Set Dictionary

- SAE J2178 Class B Data Communication Network Messages-Detailed Header Formats and Physical Address Assignments

Institute of Electrical and Electronics Engineers (IEEE) Documents

- 1220-2005 IEEE Standard for Application and Management of the Systems Engineering Process
- 1362-1998 (R2007) IEEE Standard for Information Technology – System Definition – Concept of Operations (ConOps) Document

American Association of State Highway &Transportation Officials (AASHTO) Documents

- The Green Book A Policy on Geometric Design of Highways and Streets, 6th edition. 2011

American Society of Civil Engineers (ASCE) Documents

- Structural Design for Physical Security. Task Committee; Structural Engineering Institute ISBN 978-0-7844-0457-7 (1999).

USDOT Documents

- FHWA Reference Guide. FHWA Functional Classification Guidelines. Revised 1989.
- Human Factors Design Guidelines for Advanced Traveler Information Systems (ATIS) and Commercial Vehicle Operations (CVO) FHWA–RD–98–057 (1998)
- Kiefer, R.J., LeBlanc, D., Palmer, M., Salinger, J., Deering, R., & Shulman, M. 1999. Forward Collision Warning Systems: Development and Validation of Functional Definitions and Evaluation Procedures for Collision Warning/Avoidance Systems DOT HS¬ 808 964
- Talmadge, S., Chu, R., Eberhard, C., Jordan, K., and Moffa, P. (2000). Development of performance specifications for collision avoidance systems for lane change crashes DOT HS 809 414
- Traffic Monitoring Guide, May 2001,
- Rose, Elisabeth R. and Ullman, Gerald L. (2003). Evaluation of Dynamic Speed Display Signs (DSDS). FHWA/TX-04/0-4475-1
- Lee, S.E., Knipling, R.R., DeHart, M.C., Perez, M.A., Holbrook, G.T., Brown, S.B., et al. (2004). Vehicle-Based Countermeasures for Signal and Stop Sign Violations: Task 1. Intersection Control Violation Crash Analyses, Task 2. Top-Level system and Human Factors Requirements DOT HS 809 716
- In-Vehicle Display Icons and Other Information Elements, Volume I: Guidelines (2004) FHWA-RD-03-065
- Crash Warning System Interfaces: Human Factors Insights and Lessons Learned, Final Report DOT HS 810 697 (2007)
- Traffic Signal Timing Manual FHWA-HOP-08-024
- Manual on Uniform Traffic Control Devices for Streets and Highways, 2009 edition MUTCD-09
- Visual-Manual NHTSA Driver Distraction Guidelines for In-Vehicle Electronic Devices NHTSA-2010-0053
- Vehicle Safety Communications – Applications Final Report (2011) DOT HS 811 492A
- Core System : System Architecture Document (SAD) – Sept. 2011
- National ITS Architecture, Version 7.0

Battelle IVP Project Documents

- Integrated V2I Prototype Development Project Management Plan 100036384-0101 (Sept 2013)
- Integrated V2I Prototype Development Systems Engineering Management Plan 100036384-0103 (Sept 2013)
- Integrated V2I Prototype Development Project, IVP Application Needs and Architecture Document (100036384-0202) (Sept 2014)

Institute of Transportation Engineers (ITE) Standards

- ITE ATC Transportation Controller (ATC) v5.2b
- ITE Traffic Management Data Dictionary (TMDD) Standard v3.03 for the Center-to-Center Communications.

National Marine Electronics Association

- NMEA 0183 Interface Standard.

National Transportation Communications for Intelligent Transportation System Protocol (NTCIP) Standards

- NTCIP 1103 Transportation Management Protocols.
- NTCIP 1204 v03 Object Definitions for Environmental Sensor Stations (ESS) Standard.
- NTCIP 1203 v02 Object Definitions for Dynamic Message Signs (DMS) Standard.
- NTCIP 1209 v02 Object Definitions for Transportation Sensor Systems (TSS).

Radio Technical Commission for Maritime Services

- RTCM 10403.2, Differential GNSS (Global Navigation Satellite Systems) Services – Version 3

Transportation Research Board (TRB)

- National Cooperative Highway Research Program (NCHRP) Report 600. Human Factors Guidelines for Road Systems, 2nd edition. (2012).

Chapter 3 IVP System Architecture and Component Descriptions

Introduction

This section provides an overview of the IVP architecture necessary to understand the organization and structure of the IVP requirements. This architecture was developed from an assessment of relevant Connected Vehicle application needs. The assessment and architecture documented in the IVP Application Needs and Architecture Document provides the foundation for the IVP system requirements, as well as the design and implementation of a prototype IVP.

The IVP project was conceived to address the challenge of multiple connected vehicle applications. Messages need to be received, processed, and routed between numerous devices. Messages are transmitted through a number of communication interfaces of various hardware and software protocols, each with a different time delay or "latency." Functions required of an IVP include

- Integrating data from multiple sources and compiling messages for delivery to vehicles, drivers, and nomadic devices via multiple communication methods
- Obtaining and aggregating data from multiple vehicles and nomadic devices and delivery to the Traffic Management Entity (TME)
- Distributing TME messages to vehicles

The IVP is envisioned to serve a "local" area, that is, it supports a fixed location on a roadway, such as a signalized or highway intersection, or the entrance to a reduced speed zone due to curve, school, or lane closure ahead. The Traffic Management Entity, which might serve an entire metropolitan area, is responsible for central, rather than local, control of signals, message signs, and other devices. The TME is partially automated, but it has human staff making real-time decisions; an IVP is fully automatic—a computer with software. Two-way communication is necessary between a TME and the many IVPs that might be in its area.

Some of the functions of an IVP could be carried out remotely, through a TME for example. Other applications require communications with lower latency (i.e., faster delivery) than can be supported by a remote operations center and some of the locations may not have access to high-speed communications. "Local" applications are those that an IVP can carry out entirely autonomously, such as red light violation warning (RLVW). Other applications, for example, speed harmonization (SPD-HARM), cannot be performed locally because they require coordination of several IVPs through the TME.

Examples of applications requiring message handling and processing by local infrastructure include:

- Reduced Speed (Work Zone) Warning and Spot Weather Information Warning, where the IVP can compute safe speeds and safe stopping distances using real time weather and road condition data
- Weather Responsive Traffic Management, where the IVP can aggregate weather data from vehicles for efficient communication to the TME
- Multi-Modal Intelligent Traffic Signal System (MMITSS) "Intersection level" functions including MAP and Signal Phase and Timing (SPaT) broadcast manager, equipped vehicle tracker, priority request server, and interface to traffic signal controller

The IVP is not the same as a Road Side Unit (RSU). The RSU typically has a single function and communication interface. The IVP, in contrast, supports a large number of interfaces for communication between other infrastructure components, vehicles, and traffic management systems. The IVP will not only exchange data but will also process and handle messages.

As currently envisioned, DSRC radios will be external to the IVP rather than an internal component.

Researchers in connected vehicle technology have long recognized that some messages need to be transmitted more quickly than others. They have adopted the network communications term of "latency" or delay in transmitting a message. A channel with low latency delivers a message than does a channel with high latency. Table 3-1 describes the latency needs of three classes of messages handled by an IVP.

Table 3-1. Levels of Communication Latency and Messages That Use Them

Latency and Typical Delay	Channel	Elapsed Time Between	Description of Data and Example Messages
Low: milliseconds	DSRC	seconds or less	Rapidly changing data supporting local crash imminent applications • SPaT • Vehicle position (via BSM)
High: hundreds of milliseconds	Cellular or other IP	minutes	Regularly changing data supporting mobility applications • Weather • Text for DMS
Very High	Either of the above, when it is available	weeks to months	Quasi-static or occasionally changing data supporting all applications • Map

While the assessment is not intended to be technology specific, in general, it can be said that rapidly changing data must be communicated via DSRC. More slowly changing data may be communicated by cellular or DSRC. Quasi-static data, which changes infrequently, may be transmitted by any available communications channel.

System Architecture

As an introduction, Figure 0-1 shows a simplified view of the IVP Architecture. The IVP Platform is the middle, green box in the figure. The platform obtains input data from the infrastructure based systems, vehicles, and the traffic management entity. The IVP accepts messages according to whatever protocol or format these devices ordinarily use. The IVP performs computations and processes the data. It then sends the outputs to infrastructure components, vehicles, and TME in the necessary formats to display the results to drivers and system stakeholders.

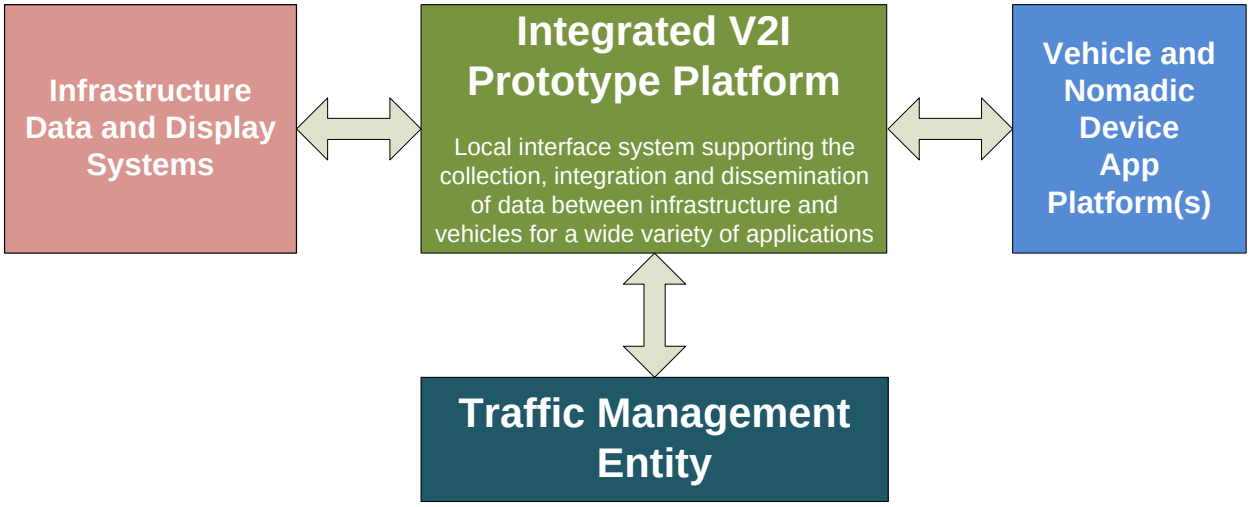

Figure 0-1. Simplified View of the IVP Architecture

Figure 0-2 presents the detailed view of this architecture developed in the IVP Application Needs and Architecture Document. Again, the IVP Platform is the middle, green box. On the left of the figure are boxes representing the infrastructure-based systems that interact with the platform, including infrastructure-based sensors, traffic signal controllers, and dynamic roadside message signs. Below the IVP platform are boxes representing the Traffic Management Entity and the Administrative Local/Back Office User Interface. On the right of the figure are blue boxes representing mobile vehicle and nomadic device interfaces, with driver interfaces. Between the green IVP and the blue vehicle are boxes representing low and high latency communication interfaces between the IVP and vehicles, along with support from the Security Certificate Manager and GPS positioning input.

The central green IVP box represents the hardware and software operating platform for the IVP. Inside the green IVP box are a number of small light green message handlers and applications which are "programs" which run on the IVP platform which collect, process, integrate and disseminate data between infrastructure, vehicles and the TME. This architectural diagram identifies twelve potential message handling needs:

- Positioning Correction Message Handler
- Map Message Handler (including static signage map)
- Traffic and Rail Signal Message Handler
- Vehicle Detection and BSM Data Aggregator
- Local Weather and Road Surface Message Handler
- Pedestrian, Bicycle, and Nomadic Device Message Handler
- INFLO Message Handler
- V2I Safety Application Infrastructure Platform
- Road Weather Message Handler
- MMITSS Roadside Processor
- AERIS/Ecodriving Message Handler
- FRATIS Message Handler

However, more are expected to be added as Connected Vehicle V2I technology evolves. The IVP is to be designed as a scalable platform that supports a variety of application needs. The basis for the function of each of the programs is described and discussed in more detail the IVP Application Needs and Architecture Document.

Around the periphery of the IVP Platform are dark green boxes that represent the external interfaces through which the IVP exchanges data with external systems. These include

- Infrastructure Systems Sensor Interface(s)
- Traffic Signal Controller Interface.
- Roadside Signage Message Service
- Traffic Management Entity Interface
- Local/Back Office User Systems Interface
- High Latency Message Service
- Corridor Peer-to-Peer Message Service
- Low Latency Wireless Message Service

The interfaces are physical hardware and software interfaces that support communication and exchange of messages. The interfaces were first identified through review of the application needs, discussed in IVP Application Needs and Architecture Document, and then were grouped as shown in the figure on the basis of

- Common communications and message standards
- Message latency
- Location and nature of the data source

The basis for and the function of each of the interfaces is described and discussed in more detail in IVP Application Needs and Architecture Document.

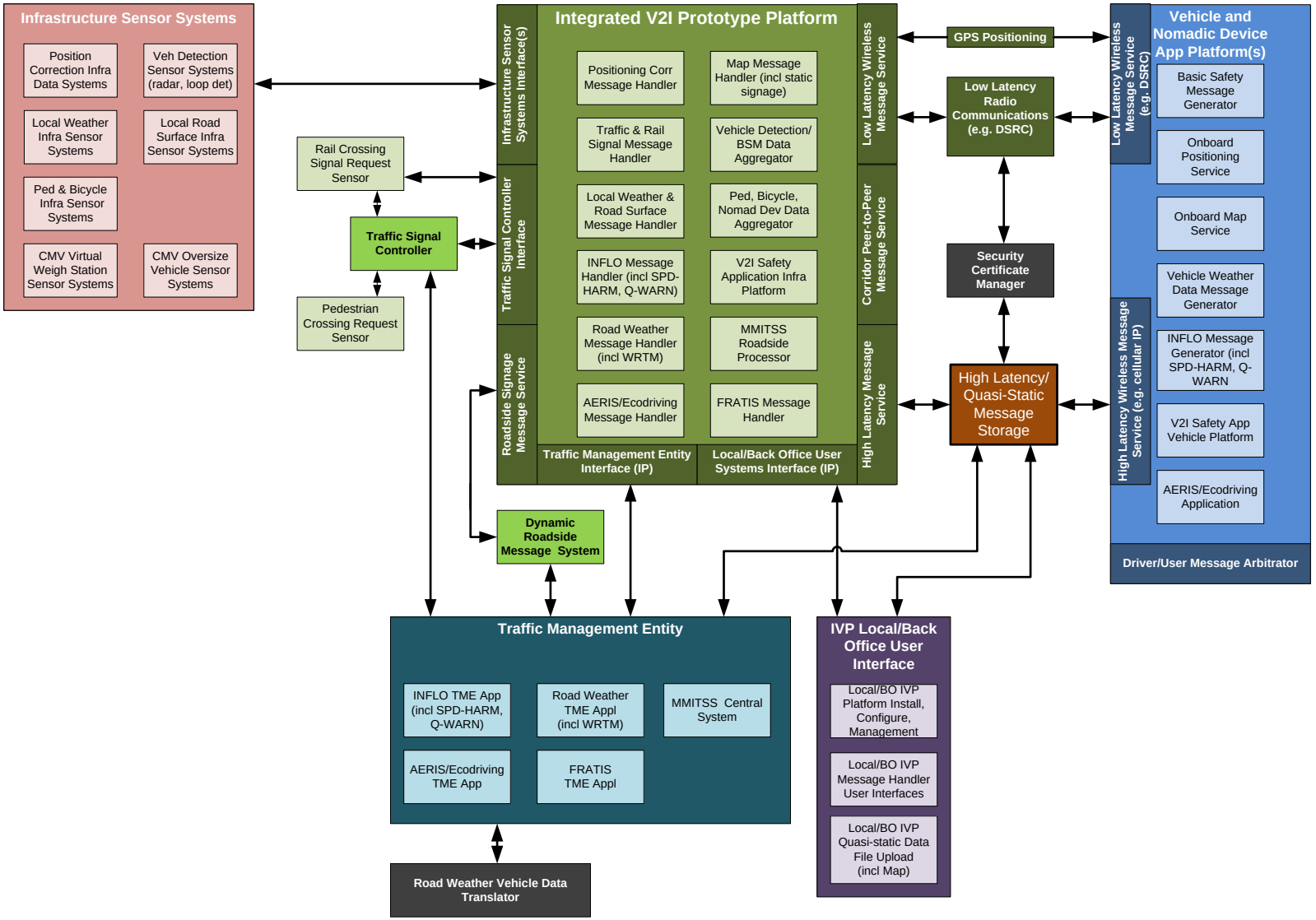

Figure 0-2. Detailed View of the IVP Functional Architecture

Recommended IVP Test and Demonstration Prototype

The objective of this program is to build, deploy, test, and demonstrate an IVP Prototype Device. The exercise described in IVP Application Needs and Architecture Document resulted in a far-reaching view of the potential application needs for the IVP as these needs are currently understood. It would be premature, however, to attempt to develop and test a comprehensive IVP to support all applications needs identified. Connected Vehicle technology and these applications and the definition of their needs are continuing to evolve. As an example, map descriptions are developed for intersections, but a comprehensive strategy for defining maps for other road configurations is still evolving. As envisioned as part of the scope of this work, it is recommended that a prototype IVP be developed which will demonstrate core IVP capabilities and which will support deployment of a few selected applications. This core prototype system will include "downselected" capabilities.

The net result of this set of recommendations is a down-selection to identify the recommended set of capabilities for the IVP for testing and demonstration, illustrated in Figure 0-3 and Figure 0-4.

IVP Hardware Platform

In the IVP Application Needs and Architecture Document Battelle recommended that the IVP hardware platform support the hardware interfaces shown in Figure 0-3 and Figure 0-4. Battelle recommends the selection of a hardware operating platform that contains sufficient hardware communication interfaces to support the interface needs shown. The prototype should be able to demonstrate the capability to exchange data with external entities across the external hardware interfaces illustrated in the figures.

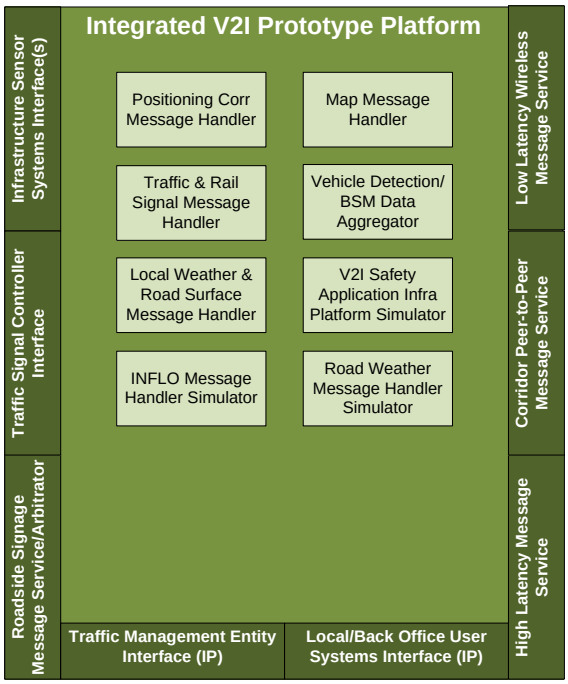

Figure 0-3. View of the IVP System show the Recommended Interfaces, Message Handlers and Simulators for Prototype Demonstration.

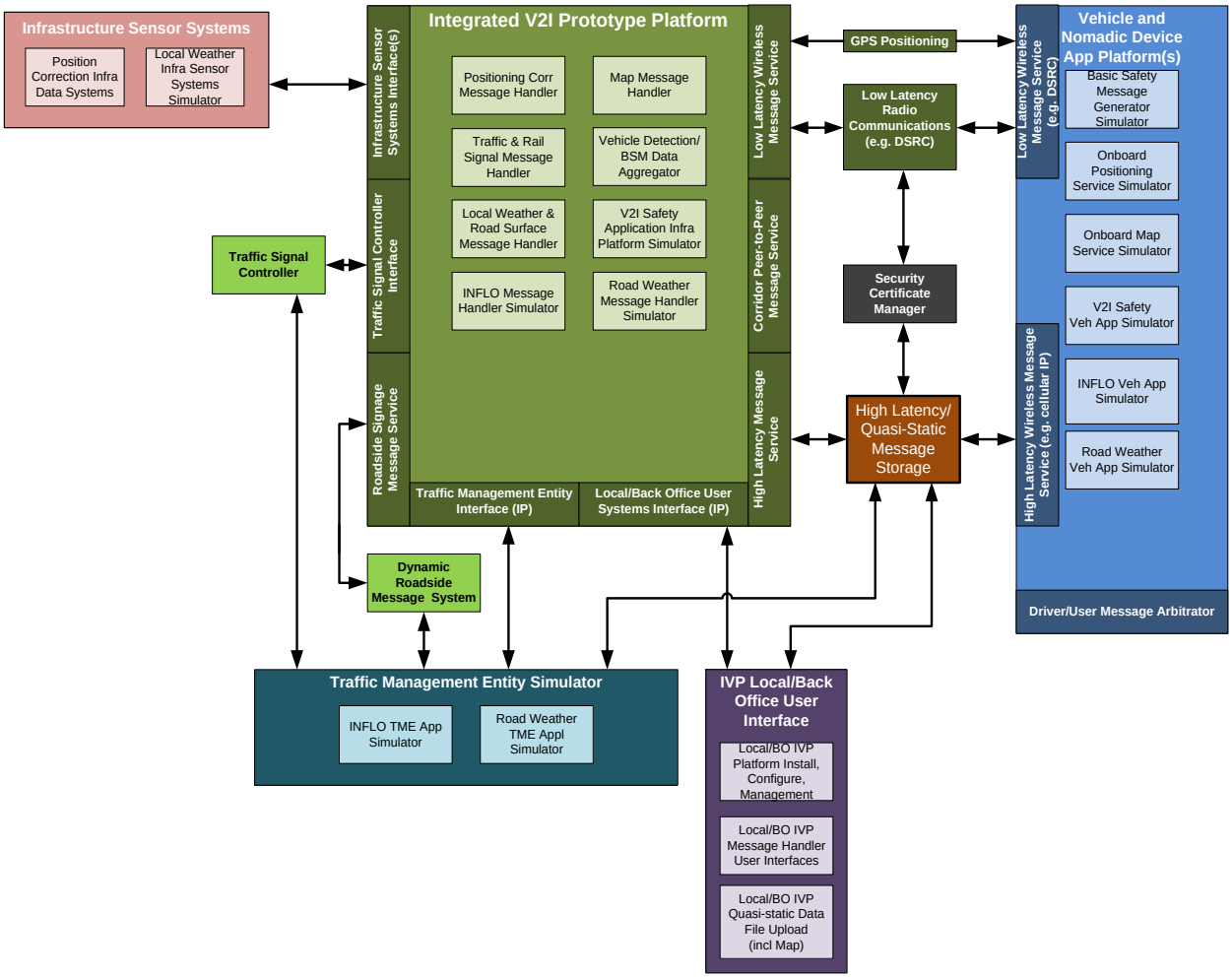

Figure 0-4. Recommended IVP Test Prototype System Configuration (downselected)

IVP Recommended Core Message Handlers

The IVP Application Needs and Architecture Document illustrates the need for core message handlers that support data exchange for a large number and wide variety of applications. Battelle recommended that the IVP be developed to support these core message handlers:

- Positioning Correction Message Handler
- Map Message Handler
- Traffic and Rail Signal Message Handler
- Vehicle Detection and BSM Data Aggregator
- Local Weather and Road Surface Message Handler

The needs and requirements for these applications are evolving and will continue to evolve for some time to come. These core message handlers should be prototyped to the degree that they can support the needs of applications currently being demonstrated, recognizing that the handlers will continue to evolve as connected vehicle technology applications evolve.

System Components and Interfaces

As illustrated in Figure 0-2Figure 0-4, there many components which make up the System-of-Interest (SOI) and supporting components. These components include:

System-Of-Interest Components

- Integrated V2I Prototype Platform (IVP Platform)

Supporting Components

- Infrastructure Sensor Systems
- Traffic Signal Controller
- Roadside Signage System
- Traffic Management Entity
- Local/Back Office User Interface
- Vehicle and Nomadic Device Application Platform
- High Latency/Quasi Static Message Storage

Core Message Handlers

- Position Correction Message Handler
- Map Message Handler
- BSM/Approaching Vehicle Aggregator
- Traffic and Rail Signal Message Handler
- Local Weather and Road Surface Message Handler
- Roadside Signage DMS Arbitrator

Application Message Handler Example

- INFLO Message Handler Simulator

IVP Platform External Interfaces

- Infrastructure Sensor Systems Interface
- Traffic Signal Controller Interface
- Roadside Signage Message Service Interface
- Traffic Management Entity Interface
- Administrative Local/Back Office User Interface
- High Latency/Quasi-Static Message Service
- Corridor Peer-to-Peer Message Service Interface
- Low Latency Message Service Interface

Core Message Handlers

Task 2 efforts identified six "core" message handlers that are needed for the IVP that process data used frequently by many applications. Each core message handler may handle one or more types of data in bundles. The data bundles are grouped under message handlers on the basis of

- Data type, processing need and, where applicable, integration
- Input source and output destination
- Latency/refresh rate
- Applicable range
- Legacy systems

The function of each handler, its data source(s) and its message output(s) are summarized below.

Table 3-2. Core Messages and Message Handlers Identified in the Investigation

No.	Message Handlers	Messages and Data Bundle
1	Position Correction Message Handler	Position Correction Message
2	Map Message Handler	Local Map Message Traffic Signage Data
3	BSM/ Approaching Vehicle Aggregator	Approaching Vehicle Message BSM (V2I) Vehicle Weather Data Oversize Vehicle Detection Data
4	Traffic & Rail Signal Message Handler	SPaT Message Rail Crossing SPaT Ped Crossing SPaT
5	Local Weather and Road Surface Message Handler	Local Weather Message Local Road Surface Condition Message
6	Roadside Signage DMS Arbitrator *(when multiple applications reside on IVP)*	Dynamic Roadside Signage Message

Position Correction Message Handler

Practically all Connected Vehicle applications need to know the position of the vehicle within its environment, defined by map messages below. While V2V applications need to understand the position of their vehicle relative to other vehicles, V2I and I2V applications need to know the position of their vehicle in relation to the road way, its lanes, message signs and other roadway assets. The level of GPS position accuracy required varies with the application. For this discussion, the term road-level accuracy is used to when applications need to determine the mile-marker of the vehicle along a linear reference frame mapping system. Lane-level accuracy is needed when messaging is dependent upon the lane the vehicle such as when traversing intersections.

GPS position technology is evolving and accuracy depends upon the technology and products used. In general, lane-level accuracy requires position correction data from an external source in addition to data from GPS satellites. Commonly used format for position correction data is the Radio Technical Commission for Maritime Services or RTCM standard.

This investigation assumed that applications requiring lane-level accuracy require a position correction message from a Position Correction Message Handler. The position correction depends upon location, the number and type of satellites present above the horizon, atmospheric distortions and other factors. Position correction data is available from different infrastructure based equipment. The data may be available locally or over the internet depending upon the systems used. The Position Correction Message Handler obtains the core data, formats it for communication and distributes it for use by vehicles. The rate of change of position correction data is of the order of seconds to a minute, such that it can be communicated to vehicles by both High and Low Latency communications.

Map Message Handler

Practically all V2I and I2V applications need to know the position of their vehicle in relation to the road way, its lanes, message signs and other roadway assets. The environment is described in Map messages. In addition to geometric descriptions of the roadway, some applications also need to know the location and message on roadside signs, both fixed and dynamic, to ensure consistency and synchronicity of in-vehicle messages to avoid confusing the driver.

As with positioning, some applications require linear road-level accurate maps, while others require lane-level accurate maps, such as at intersections.

Map data changes infrequently. Map data is developed externally and may be uploaded to an IVP in a data file or from a TME when backhaul communications are available. The map data output from Map Message Handler may be distributed to vehicles via High and Low Latency communications. Map data may also be obtained by vehicles from high-latency communications.

BSM/Approaching Vehicle Aggregator

The IVP needs assessment found that many applications need vehicle data, such as location, speed, and heading as well as environmental data such as temperature and barometric pressure. While it is expected that this data can be provided entirely by Connected Vehicle Basic Safety Messages (BSMs) in the future, when market penetration nears 100%, in the near term the applications need data from the infrastructure such as from loop detectors and/or radar based vehicle detectors, as well as connected vehicle systems. Most applications need only a subset of the BSM data typically broadcast by vehicles at 10 Hz. Hence, the needs assessment identified the need for a BSM/Approaching Vehicle Data Aggregator that collects, integrates and bundles approaching vehicle data from BSMs and the infrastructure for easy consumption and processing by the application. The bundled output data and information from the aggregator may be used by both infrastructure application components operating direction on the IVP (e.g. Curve Speed Warning) and by the Traffic Management Entity (e.g. Road Weather TME App).

Traffic and Rail Signal Message Handler

Many safety and mobility connected vehicle applications leverage or integrate with traffic signal controllers. The Traffic and Rail Signal Message Handler provides Signal Phase and Timing Data to approaching vehicles, including communicating Priority Service Requests from vehicles to the traffic signal controller and providing approaching train data to approaching vehicles. The input data for this message handler is obtained from a Traffic Signal Controller and from a Rail Signal Controller (Shunt Closure Sensor). Because traffic signal controller data supports both crash imminent safety and mobility applications, the output from this message handler is distributed to vehicles via Low Latency communications.

Local Weather and Road Surface Message Handler

Weather and road surface conditions significantly affect safety and mobility and relevant weather data are used by many V2I and I2V applications. The Local Weather and Road Surface Message Handler provides local weather and road surface data to approaching vehicles. The input data for this message handler is obtained from local sensors such as RWIS ESS infrastructure sensors. The output from this message handler is distributed to

- Applications running on the IVP (e.g. Spot Weather Information and Curve Speed Warning applications)
- Vehicles via High and Low Latency communications for use by vehicle application components
- TME for use by Road Weather, INFLO and other mobility applications.

Roadside Signage DMS Arbitrator

Some V2I and I2V applications need to display messages to drivers via roadside signage such as dynamic message signs. These applications require that the IVP have an output interface for communications to the DMS.

If only a single IVP application utilizes the DMS, then the application output may be communicated directly to the DMS interface. However, if more than one application operating on the IVP may send data to the DMS, then prioritization and arbitration of DMS messages may be required. In this case a Roadside Signage DMS Arbitrator is needed to prioritize and arbitrate DMS messages according to a predetermine schema. The input for this message arbitrator is from local applications operating on the IVP and TME applications that deliver messages to local DMS. The output is the local DMS. Note that this arbitrator is intended to support locally controlled DMS and not centrally controlled DMS.

IVP External Interfaces

The IVP obtains data from one or more sources, processes the data and distributes it one or more recipients. Each source and recipient requires a standardized hardware and software interface. Similar to the core message handlers described above, eight primary data interfaces were found to be needed to support the data exchange needs for the applications under consideration.

These interfaces and the systems they exchange data with are illustrated in the IVP Functional Architecture shown in Figure 0-4. Following is an overview of each of these interfaces.

Infrastructure Sensor Systems Interface

The purpose of some I2V applications is to capture data from infrastructure systems, process and integrate it and deliver the result to vehicles. The IVP provides a convenient, versatile local platform to support this need for capturing, processing and distributing infrastructure based sensor data to vehicles. The IVP Infrastructure Sensor Systems Interface supports the needs of a number of applications to capture data from local infrastructure-based sensors such as

- Vehicle detection (e.g. radar, loop detector, etc.)
- Local weather sensors (e.g. RWIS, ESS)
- Road surface condition sensors (e.g. temperature and ice sensors)
- Pedestrian/bicycle sensors, (non Traffic Signal Controller based)

These sensors are common in transportation applications. Less common sensors that may be supported by this interface include Commercial Motor Vehicle (CMV) virtual weigh station and oversize vehicle sensors. Their interfaces are typically governed by the NTCIP Family of Standards.

Traffic Signal Controller Interface

One of the key IVP interfaces is the Traffic Signal Controller Interface, which supports communications with Traffic Signal Controller Systems and Rail Crossing Signal Request Sensors. The IVP supports an important role here of delivering Signal Phase and Timing data to approaching vehicles, of capturing service request messages from connected vehicles and delivering it to Traffic Signal controllers and of delivering Service Status Messages back to connected vehicles. Traffic Signal Controller technology is well developed and, while Traffic Signal Controllers and the IVPs could potentially be integrated in the future, in the near term they are separate entities exchanging these messages across this IVP interface. This interface typically governed by NTCIP 1202 - Object Definitions for Actuated Traffic Signal Controller (ASC) Units.

Rail crossing signal sensors are integrated with this interface because rail signals are sometimes integrated with adjacent traffic signals systems. For the case of standalone rail crossing signals, the interface includes the standard 2-wire rail signal interface to capture approaching train indicators.

This interface supports a number of applications which issue priority signal requests, such as transit bus applications, emergency vehicle applications, FRATIS applications and MMITSS applications.

Due to the highly integrated nature of Pedestrian Signal Requests with Traffic Signal Controllers, they exchange messages with the IVP through the same interface.

Roadside Signage Message Service Interface

Many of the V2I and I2V applications considered, such as Curve Speed Warning, must deliver outputs to local DMS Roadside Signage Systems to provide visual safety warnings and other relevant information to drivers in vehicles that may not be equipped with connected vehicle displays. This is particularly important for those applications which may operate only on a local computer platform, capturing data from infrastructure based sensors and delivering it to approaching drivers without backhaul communications to a traffic management center. The IVP supports this need with the Roadside Signage Message Service Interface. This interface typically governed by NTCIP 1203 Object Definitions for Dynamic Message Signs (DMS).

The DMS may also communicate directly with the Traffic Management Entity. There are some applications which route their messages through the Traffic Management Entity for display. It is expected that the DMS will be interfaced to either the IVP or the Traffic Management Entity, but not both.

Traffic Management Entity Interface

While many Connected Vehicle Applications operate completely autonomously, capturing data locally without interface to a Traffic Management Entity, many others are intended to capture data along an arterial or highway corridor, process it and return messages to vehicles throughout the corridor. The IVP supports these applications by capturing local data, performing preprocessing and bundling and delivering that to a Traffic Management Entity for centralized processing. It also supports obtaining messages from the Traffic Management Entity and distributing it to nearby vehicles to support coordinated, synchronized messaging. Applications needing this support include

- Intelligent Traffic Signal System
- Traffic Signal Priorities for Transit, Freight, Emergency Vehicles
- INFLO SPD-HARM
- Weather Responsive Traffic Management
- AERIS EcoDriving

The IVP includes an Internet Protocol Interface with continuous broadband communications to a Traffic Management Entity to support these needs. This interface is typically governed by Traffic Management Data Dictionary (TMDD) Standard v3.03 for the Center-to-Center Communications, IEEE Standards for Local Area Networks and IEEE 1512 - Family of Standards for Incident Management Message Sets.

(IEEE 1512 family of standards supports the exchange of incident-related data between transportation, public safety, and other responding agencies.)

The IVP Traffic Management Entity Interface supports interaction with multiple regional or corridor level applications with TME based processing. The Road Weather Vehicle Data Translator is currently shown as separate from the Traffic Management Entity, exchanging data through the TME. However, it could have components operating within the TME.

The TME interface to High-Level Quasi-Static Message Storage is discussed below.

Administrative Local/Back Office User Interface

The IVP itself requires an administrative interface to support installation, configuration, maintenance and health monitoring of the IVP, the message handlers and the applications which reside on it. This interface supports both Ethernet for local onsite access or IP communications for remote access from a back office or from traffic management entity. While this interface supports administrative activities for applications and the IVP, the TME interface supports the function and operation of the applications themselves. This interface is treated separately from the TME interface because of the nature of its functions and because these functions may be performed onsite or remotely, whereas the TME is remote. This interface supports a technical user interface for installation, configuration and management of the IVP and for message handlers and applications installed on the IVP, either from a local laptop or back office. It may also support a user Interface for local control of message handlers and applications (e.g. input and control by construction users of Work Zone safety application, input and control by enforcement officer of traffic signal control). Finally this interface supports upload of quasi-static data files to the IVP such as maps for use by message handlers and applications. This interface is typically governed by TMDD v3.03, NTCIP 2306 standards.

The Local/Back Office Interface to High-Level Quasi-Static Message Storage is discussed below.

High Latency/Quasi-Static Message Service

A number of applications need data, such as maps which may change occasionally, such as monthly, yearly or sporadically. The vehicle could obtain the map data through low-latency DSRC if available, or could obtain it through cellular IP download. Such data do not need to be broadcast at 10 Hz, but could be stored in a central repository and retrieved by vehicles when needed. For example, large maps could be retrieved prior to a trip when a broadband internet connection is available. Some applications on the IVP may upload data to a central repository while others may need to download data from the repository for special purposes. The High/Latency/Quasi-Static Message Service on the IVP supports the upload and download of High Latency Messages and Quasi-Static Data to central repositories.

The high latency message service interface supports upload and download of high latency messages and quasi-static data to central repositories. The Traffic Management Entity and the Local/BackOffice User Interface could upload and download messages and data files to the repository as well. The repository has an interface to the Security Certificate Management to provide security credentials for messages. While the concepts for this repository are evolving, it is expected that its interfaces and messages will be governed by IEEE 802.11p and 1609.x, SAE J2735, and potentially new standards.

Corridor Peer-to-Peer Message Service Interface

Multiple IVPs may be placed along arterial or highway corridors to provide coordinated communication between traffic signals and signage for applications such as MMITSS. Inter IVP communications are supported by the Corridor Peer-to-Peer Message Service Interface. The implementation of this interface is under consideration and discussion. At this point it is expected to be an Ethernet/IP interface governed by TMDD v3.03, NTCIP 2306, and others.

Low Latency Message Service Interface

Some of the V2I and I2V applications must deliver advisories, alerts and warnings to vehicles and drivers to help prevent or mitigate crashes. In most cases, these applications need to process and deliver messages within milliseconds. These messages will be delivered through low latency message service interface. This wireless message interface supports data exchanges that must take place within milliseconds such as the delivery of SPaT data for traffic signal violation warnings. These messages are also "local" in the sense that they are only of interest to vehicles approaching a potential crash zone such as an intersection or dangerous curve.

For implementation, DSRC has been selected as the low latency communications method for connected vehicles. This interface is typically governed by **IEEE 802.11p and 1609.x, SAE J2735.**

GPS signal has been included in this interface as a critically important low latency data source for timing synchronization. Time synchronization from a common source is critical for the accurate functioning of all connected vehicle applications and GPS signal has been chosen as that universal source. Applications and message handlers operating on the IVP do not generally require the location of the IVP, but they do provide position correction data and map data that enable vehicles to determine their position on the roadway and relative to their environment. Vehicles obtain their own GPS signal for both time synchronization and location.

The Low Latency Message Service Interface supports IVP low latency data exchange with vehicles. While a low latency wireless radio could be included as a component within the IVP, a strategic implementation choice was made by the U.S. DOT and the project team to treat the radio as a separate device to which the IVP communicates. The low latency radio communication system has an interface to the Security Certificate Management system to provide security credentials for messages.

Chapter 4 Requirements

This section of the document enumerates the IVP system requirements developed from the assessment and architecture documented in the IVP Application Needs and Architecture Document and assessment of the needs of the application that may be supported by the IVP.

Structure of the Requirements

The requirements for the IVP are organized by component and category. Requirements are provided for the following components

- 01 IVP Platform Requirements
- 02 Message Handler Common Requirements
- 03 Positioning Correction Message Handler Requirements
- 04 Map Message Handler Requirements
- 05 BSM/Vehicle Data Aggregator Requirements
- 06 Dynamic Roadside Message Arbitrator Requirements
- 07 Traffic & Rail Signal Message Handler Requirements
- 08 Local Weather & Road Surface Message Handler Requirements
- 11 INFLO Speed Harmonization Message Handler Requirements
- 12 INFLO Queue Warning Message Handler Requirements

Section 01 IVP Platform Requirements describes the functionality and performance requirements for the supporting hardware and operating system, including identification of required hardware and software interfaces. Section 02 Message Handler Common Requirements describes requirements common to all message handlers and applications operating on the IVP. Sections 03 through 08 describe requirements specific to each of the identified *core* message handlers. Sections 11 and 12 describe requirements specific to two applications provided as examples of application specific message handlers.

The requirements for Message Handlers and Applications are organized in four categories for consistency and accessibility:

- AA.01 Applicable Standards and Documents
- AA.02 Functional Requirements
- AA.03 Data Input Requirements
- AA.04 Data Output Requirements

Here AA is the component number from the list above. Requirements for the IVP Platform have additional requirements enumerated under the following categories:

- AA.05 Computation and Communication Performance Requirements
- AA.06 Operational Performance Requirements
- AA.07 Supportability Requirements
- AA.08 Security Requirements
- AA.09 Human Factors, Health and Safety Requirements

- AA.10 Installation and Setup Requirements
- AA.11 Operation, Maintenance and Diagnostic Requirements
- AA.12 Documentation Requirements
- AA.13 Staffing and Training Requirements
- AA.14 Physical and Environmental Performance Requirements

Structure and Format of the Performance Requirements

Each requirement in the following tables includes the following elements:

- **Unique Identifier** of the form **[A.B.CC.DD],** described in more detail below.
- **Requirement Title** describes the topic of the requirement. **Requirement Titles** are presented in bold face type for readability.
- **Requirement Statement** provides the specific requirement which is subject to verification and validation, and represents the description of design, development, behavior, operation, performance, etc. of the application. **Requirement Statements** are presented in bold type face to distinguish them from supporting text including the ***Requirements Elaboration.***
- ***Requirements Elaboration*** provides supporting text for the **Requirement Statement** that aids in understanding, interpretation and application of the **Requirement Statement** where needed. Requirements Elaboration text is presented in italics type face to distinguish it from the **Requirements Statement**. ***Requirements Elaboration*** is not necessarily subject to verification and validation, but may be useful in establishing methods and acceptance criteria for verification and validation.
- Verification Method describes how the performance requirements will be verified, whether by Inspection (I), Demonstration (D), Test (T) or Analysis (A). Each of these is described in more detail below.

Performance Requirements Identifier Structure

Requirements for the IVP are organized and numbered by the component, and requirement category. For consistency and accessibility the requirements are uniquely identified by a four element number of the format [AA.BB.CC] where AA designates component, BB designates the application category and DD is the unique requirement number within the category.

The [AA] designators for the application components are

- [01.BB.CC] IVP Platform Requirements
- [02.BB.CC] Message Handler Common Requirements
- [03.BB.CC] Positioning Correction Message Handler Requirements
- [04.BB.CC] Map Message Handler Requirements
- [05.BB.CC] BSM/Vehicle Data Aggregator Requirements
- [06.BB.CC] Dynamic Roadside Message Arbitrator Requirements
- [07.BB.CC] Traffic & Rail Signal Message Handler Requirements
- [08.BB.CC] Local Weather & Road Surface Message Handler Requirements
- [11.BB.CC] INFLO Speed Harmonization Message Handler Requirements
- [12.BB.CC] INFLO Queue Warning Message Handler Requirements

The [BB] designator for the requirement categories are

- [AA.01.CC] Applicable Standards and Documents
- [AA.02.CC] Functional Requirements
- [AA.03.CC] Data Input Requirements
- [AA.04.CC] Data Output Requirements
- [AA.05.CC] Computation and Communication Performance Requirements

- [AA.06.CC] Operational Performance Requirements
- [AA.07.CC] Supportability Requirements
- [AA.08.CC] Security Requirements
- [AA.09.CC] Human Factors, Health and Safety Requirements
- [AA.10.CC] Installation and Setup Requirements
- [AA.11.CC] Operation, Maintenance and Diagnostic Requirements
- [AA.12.CC] Documentation Requirements
- [AA.13.CC] Staffing and Training Requirements

Requirements Verification Methods

The verification method describes how the performance requirements will be verified in order to ascertain that the system of interest conforms to the requirements in this specification. The four potential methods of verification include the following.

Analysis is a verification method that utilizes established technical or mathematical models or simulations, algorithms, charts, graphs, circuit diagrams, or other scientific principles and procedures to provide evidence that stated requirements are met.

Demonstration is a verification method that generally denotes the actual operation, adjustment, or re-configuration of items to provide evidence that the designed functions were accomplished under specific scenarios.

Inspection is a verification method that consists of investigation, without the use of special laboratory appliances or procedures, of items to determine conformance to those specified requirements. Examination is generally nondestructive and typically includes the use of sight, hearing, smell, touch; and/or simple physical manipulation of the system when it is safe to do so. Inspection can also be applied to the project work products. For instance, verifying that software is developed using a certain programming language would be verified by inspection.

Testing is a verification method that generally denotes the determination of properties by instrumentation and measurement. This method includes functional operation, and involves the application of established scientific principles and procedures.

IVP System Requirements

The following tables catalog the requirements for the IVP system including the IVP hardware and software platform and the message handlers recommended for test and implementation, organized as described above.

Rqmt. No.	Requirement Title	Requirement Statement	Elaboration	Verif. Method (I,D,T,A)
01	**IVP Platform Requirements**			
01.01	**IVP Platform Interfaces and Interface Specifications**			
[01.01.01]	UTC Time Source	The IVP Platform shall have an interface to a Coordinated Universal Time (UTC) source.	The IVP Platform time source must be the same as that of nearby vehicles to support time synchronization of infrastructure and vehicle applications. This requirement may be satisfied through a GPS receiver.	D
[01.01.03]	Infrastructure Sensor Systems Interface Specifications	Each Infrastructure Sensor Systems interface for capturing data from Environmental Sensor Stations shall implement NTCIP 1204 v03 Object Definitions for Environmental Sensor Stations (ESS) Standard.	This requirement is optional. It is only mandatory when the IVP Platform will support applications which obtain data from local ESS.	D
[01.01.04]	Weather Data Environment	The Weather Data Environment Interface shall implement Internet Protocol messages for the secure exchange of messages between Platform Message Handler/Applications and the Weather Data Environment.	This requirement is optional. It is only mandatory when the IVP Platform will support applications which obtain data from a Weather Data Environment. Note: The specific message sets to be exchanged are defined by the housed message handlers and applications.	D
[01.01.05]	Vehicle Speed Sensor Systems Interface Specifications	Each Vehicle Speed Sensor Systems Interface shall implement NTCIP 1209 v02 Object Definitions for Transportation Sensor Systems (TSS)	This requirement is optional. It is only mandatory when the IVP Platform will support applications which obtain data from an Infrastructure based Vehicle Speed Sensor Systems.	D

Rqmt. No.	Requirement Title	Requirement Statement	Elaboration	Verif. Method (I,D,T,A)
[01.01.07]	Traffic Signal Controller Interface Specifications 1	Each Traffic Signal Controller interface shall implement NTCIP 1202:2005 V02.19 Object Definitions for Actuated Traffic Signal Controllers (ASC) Standard.	This requirement is optional. It is only mandatory when the IVP Platform will support applications which obtain data from Traffic Signal Controllers.	D
[01.01.08]	Traffic Signal Controller Interface Specifications 2	Each Traffic Signal Controller interface shall implement NTCIP 1211:2008 V01.38 Object Definitions for Signal Control and Prioritization (SCP) Standard.		D
[01.01.10]	Roadside Signage Interface Specifications	Each Roadside Signage interface shall implement NTCIP 1203 v02 Object Definitions for Dynamic Message Signs (DMS) Standard.	This requirement is optional. It is only mandatory when the IVP Platform will support applications which interface with a DMS	D
[01.01.11]	Traffic Management Entity Interface	The IVP Platform shall have a Traffic Management Entity Interface.		D
[01.01.12]	Traffic Management Entity Interface Specifications	Each Traffic Management Entity Interface shall implement Internet Protocol messages for the secure exchange of messages between Platform Message Handler/Applications and a Traffic Management Entity.	Note: The specific message sets to be exchanged are defined by the housed message handlers and applications.	D
[01.01.13]	Local Interface	The IVP Platform shall have a TIA/EIA-568 8P8C (Ethernet port) for local systems interface for the secure exchange of IP data between the Platform and a locally connected computer.		D
[01.01.14]	Remote Internet Protocol Interface	The IVP Platform shall have a Internet Protocol interface for the secure exchange of IP data between the Platform and a remote computer system.		D

Rqmt. No.	Requirement Title	Requirement Statement	Elaboration	Verif. Method (I,D,T,A)
[01.01.15]	High Latency Message Service	The IVP Platform shall have a High Latency Message Service for exchange of messages with High Latency/Quasi-Static Message Storage.	Infrastructure and Vehicle Application Components exchange high latency messages wirelessly through High Latency Message Storage. For example, the IVP Platform and vehicle applications may exchange messages through cloud-based storage media. Vehicles exchange messages with the cloud-based storage via cellular communications.	D
[01.01.16]	High Latency Message Service Specifications	The High Latency Message Service shall implement secure exchange of SAE J2735:2015 messages.	This messages set includes, but is not limited to MAP, SPAT, TIM, RSA, and RTCM.	D
[01.01.17]	Low Latency Message Service	The IVP Platform shall have a Low Latency Wireless Message Service for exchange of messages with a DSRC Radio.	Interface protocols with the DSRC radio are defined by the application design document based on the specific DSRC manufacture.	D
[01.01.18]	Low Latency Message Service Specifications	The Low Latency Wireless Message Service shall implement SAE J2735:2015 Dedicated Short Range Communications (DSRC) Message Set Dictionary.	This messages set includes, but is not limited to MAP, SPAT, TIM, RSA, and RTCM.	D
[01.01.20]	Peer-to-Peer Interface	The IVP Platform shall have a Peer-to-Peer Interface for exchange of messages between Platform Message Handler/Applications on like Platforms.		D
[01.01.21]	Peer-to-Peer Interface Specifications	Each Peer-to-Peer interface shall implement Internet Protocol messages between like platforms.	Note: The content and format of the specific message sets to be exchanged are defined by the message handler or application design document.	D
[01.01.22]	Position Correction Data Interface	The IVP Platform shall have an Interface for obtaining GPS Position Correction Data.		D

Rqmt. No.	Requirement Title	Requirement Statement	Elaboration	Verif. Method (I,D,T,A)
[01.01.23]	Position Correction Data Interface Specifications	Each Position Correction Data interface shall implement Radio Technical Commission for Maritime Services (RTCM) 10402.3 and RTCM 10403.0 standards.		D
[01.01.24]	Pedestrian and Bicycle Sensor Systems	When the IVP Platform will support Applications which obtain data from local Infrastructure-based Pedestrian and Bicycle Sensor Systems, the IVP Platform shall have a Pedestrian and Bicycle Sensor Systems Interface.	The content and format of the specific message sets to be exchanged are defined by the application design document based on the specific manufacture.	D
[01.01.26]	Commercial Motor Vehicle Infrastructure Sensor Systems	When the IVP Platform will support Applications which require data from roadside Commercial Motor Vehicle Infrastructure Sensor Systems, the IVP shall have a Commercial Motor Vehicle Infrastructure Sensor Systems Interface.	For example, for capturing data from Virtual Weigh Station Sensor Systems and/or Oversize Vehicle Sensor Systems. The content and format of the specific message sets to be exchanged are defined by the application design document based on the specific manufacture.	D
01.02	**IVP Platform Requirements**			
[01.02.01]	Platform Specification	The IVP Platform shall conform to Institute for Transportation Engineers (ITE) ATC Transportation Controller Standard v05.2b.		D
[01.02.02]	ATC Engine Board Specifications	The IVP Platform shall include an ATC engine board compliant to ATC standard 5.2b and proposed version 6.10.		D
[01.02.03]	ATC Engine Board Processor	The IVP Platform engine board shall include a PowerPC 83XX family processor with QUICC engine.		D
[01.02.04]	ATC Engine Board DRAM Memory	The IVP Platform engine board shall have a minimum of the following memory: 128Mbytes of DDR2 DRAM memory used for application and OS		D

Rqmt. No.	Requirement Title	Requirement Statement	Elaboration	Verif. Method (I,D,T,A)
		program execution, and be more than the minimum required for the deployed application in the IVP system.		
[01.02.05]	ATC Engine Board Flash Memory	The IVP Platform engine board shall have a minimum of the following memory: 64Mbytes of FLASH memory used for storage of OS Software and user applications and be more than the minimum required for the deployed applications in the IVP system.		D
[01.02.06]	ATC Engine Board SRAM Memory	The IVP Platform engine board shall have a minimum of the following memory: 2Mbytes of SRAM memory used for non-volatile parameter storage		D
[01.02.07]	ATC Engine Board Ports	The IVP Platform engine board shall provide the seven ATC serial ports, Ethernet, USB and all other control signal required by ATC standard.		D
[01.02.08]	ATC Engine Board Operating System	The IVP Platform operating system shall be Linux 2.6.35 or later		D
[01.02.09]	IVP Platform System Architecture	The IVP Platform hardware (memory, processor, storage) shall support the collection, processing, integration, and dissemination of data between infrastructure and vehicles for the given number of deployed applications at the infrastructure.	The applications to be installed on each IVP will depend upon the needs at the location where it is located.	D
[01.02.10]	Processing Hardware Resources	The IVP Platform computational processor speed shall be greater than or equal to the processing speed required for all installed applications to achieve their data processing performance requirements when operating simultaneously.		A
[01.02.13]	Configuration, data and log file storage	The IVP Platform shall store configuration, application data and log files in nonvolatile memory.	Application data may contain static infrastructure data such as road map and geometry generated elsewhere.	D

Rqmt. No.	Requirement Title	Requirement Statement	Elaboration	Verif. Method (I,D,T,A)
[01.02.14]	Interfaces - Uploading and Downloading of Application Data and Log Files	The IVP Platform shall support secure, local and remote uploading and downloading of application data and log files.		D
[01.02.16]	Common Time Source	The IVP Platform shall provide UTC Time to all installed Message Handlers, Applications and Message Arbitrators.		D
[01.02.17]	Security Protocols	The IVP Platform shall implement Security Protocols in accordance in the current version of NTCIP 1103 Transportation Management Protocols.	The IVP Platform is expected to support NTCIP 1103 Transportation Management Protocols. The DSRC Radio is expected to support security protocols required for DSRC message communications.	D
[01.02.18]	Logging Service	The IVP Platform shall provide a logging service for use by all installed applications.		D
[01.02.19]	Interfaces - Maintenance	The IVP Platform shall have a Maintenance Interface to support installation, configuration, upgrades and detailed diagnostics of the Component.		D
[01.02.20]	Interfaces - Maintenance Local and Remote Access	The IVP Platform Maintenance Interface shall be accessible by both local and remote users.		D
[01.02.21]	IP Message Routing	The IVP Platform shall forward all IP messages over the appropriate interface, based on the destination address of the IP message.		D
[01.02.22]	IP Message Processing	The IVP Platform shall forward all accepted IP messages on a “First In – First Out (FIFO) basis in the absence of a configured QOS policy.		D
[01.02.23]	Traffic Controller Interface – Receive Message	The IVP Platform shall accept any message received from a connected traffic controller without authentication.		D

Rqmt. No.	Requirement Title	Requirement Statement	Elaboration	Verif. Method (I,D,T,A)
[01.02.24]	Common - Position Correction Message Handler	The IVP shall have a Position Correction Message Handler.	Refer to IVP Position Correction Message Handler Requirements in this Document. The following is referenced for guidance. Where position correction data are available, the Position Correction Message Handler supports -obtaining position correction data from the Position Correction Data Interface in accordance Radio Technical Commission for Maritime Services (RTCM) 10402.3 and RTCM 10403.0 standards, -Message processing and formatting, and -Distribution of SAE J 2735 RTCM Correction messages (to Local Vehicles) through Low and High Latency Message Service.	D

Rqmt. No.	Requirement Title	Requirement Statement	Elaboration	Verif. Method (I,D,T,A)
[01.02.25]	Common - Map Message Handler	The IVP Platform shall have a Map Message Handler.	Refer to IVP Map Message Handler Requirements in this document. The following is referenced for guidance. The Map Message Handler supports -obtaining Local Map Data Input from the Local/Back Office User Interface, message processing and formatting, and message distribution (to Local Vehicles) through Low and High Latency Message Service, and -collection of Traffic Signage Data Input from Local/Back Office User Interface, message processing and formatting, and message distribution (to Local Vehicles) through Low and High Latency Message Services.	D
[01.02.26]	Common - BSM/Vehicle Data Aggregator	The IVP Platform shall have a BSM/Vehicle Data Aggregator.	The following is referenced for guidance. The BSM/Vehicle Data Aggregator supports -obtaining Approaching Vehicle Input Data through the Infrastructure Data Systems Interface, message processing and formatting, and message distribution through the IVP Platform local communications to other IVP Message Handlers and Applications, -obtaining BSMs through Low Latency Message Services, aggregating the data to identify approaching vehicles, message processing and formatting, and	D

Rqmt. No.	Requirement Title	Requirement Statement	Elaboration	Verif. Method (I,D,T,A)
			message distribution through the IVP Platform local communications to other IVP Message Handlers and Applications.	
[01.02.27]	Common - Dynamic Roadside Message Arbitrator	The IVP Platform shall have a Dynamic Roadside Message Arbitrator.	The following is referenced for guidance. The Dynamic Roadside Message Arbitrator supports -obtaining DMS Input Data from locally running V2I Safety and other applications, message processing and formatting, arbitrating message priorities and message distribution (to Local Drivers) through Roadside DMS Interface.	D

Rqmt. No.	Requirement Title	Requirement Statement	Elaboration	Verif. Method (I,D,T,A)
[01.02.28]	Common - Traffic & Rail Signal Message Handler	The IVP Platform shall have a Traffic & Rail Signal Message Handler.	The following is referenced for guidance. The Traffic & Rail Signal Message Handler supports -exchanging Local SPaT Data Input and Output through the Traffic Signal Controller Interface, message processing and formatting, and message exchange (to Local Vehicles) through Low and High Latency Message Services, and -obtaining Rail Crossing Signal Input Data through the Rail Crossing Signal Input Interface, message processing and formatting, and message output (to Local Vehicles) through Low and High Latency Message Services	D

Rqmt. No.	Requirement Title	Requirement Statement	Elaboration	Verif. Method (I,D,T,A)
[01.02.29]	Common - Local Weather & Road Surface Message Handler	The IVP Platform shall have a Local Weather & Road Surface Message Handler.	The following is referenced for guidance. The Local Weather & Road Surface Message Handler supports -Obtaining Local Weather Input Data through the Infrastructure Data Systems Interface, message processing and formatting, and message distribution through the IVP Platform local communications to other IVP Message Handlers and Applications, -Obtaining Local Weather Input Data through the Weather Data Environment, message processing and formatting, and message distribution through the IVP Platform local communications to other IVP Message Handlers and Applications, -Obtaining Local Road Surface Conditions Input Data through the Infrastructure Data Systems Interface, message processing and formatting, and message distribution through the IVP Platform local communications to other IVP Message Handlers and Applications, -Obtaining Local Road Surface Conditions Input Data through the Weather Data Environment, message processing and formatting, and message distribution through the IVP Platform local communications to	D

Rqmt. No.	Requirement Title	Requirement Statement	Elaboration	Verif. Method (I,D,T,A)
			other IVP Message Handlers and Applications.	

Rqmt. No.	Requirement Title	Requirement Statement	Elaboration	Verif. Method (I,D,T,A)
[01.02.30]	V2I Safety - CSW Application and Messages	The IVP Platform shall be capable of supporting the functional and performance requirements of the Infrastructure Component of a Curve Speed Warning (CSW) Application.	The following is referenced for guidance. The IVP Platform may be required to support the Infrastructure Component of a Curve Speed Warning Application. The Infrastructure Component of a Curve Speed Warning Application supports -Obtaining Local Curve Speed Warning Input Data through the Infrastructure Data Systems Interface, message processing and formatting, and message distribution (to Local Vehicles) through Low and High Latency Message Services. -"Vehicle-to-Infrastructure Safety Applications Performance Requirements", Federal Highway Administration, August 2015. This document is a seven volume report that describes performance requirements for six V2I Safety Applications developed by Battelle for the USDOT.	A

Rqmt. No.	Requirement Title	Requirement Statement	Elaboration	Verif. Method (I,D,T,A)
[01.02.31]	V2I Safety - RLVW Application	The IVP Platform shall be capable of supporting the functional and performance requirements of the Infrastructure Component of a Red Light Violation Warning (RLVW) Application.	The following is referenced for guidance. The IVP Platform may be required to support the Infrastructure Component of a Red Light Violation Warning Application. The Infrastructure Component of a Red Light Violation Warning Application supports -Obtaining Local Red Light Timing Input Data through the Traffic Signal Controller Interface, message processing and formatting, and message distribution (to Local Vehicles) through Low and High Latency Message Services. -"Vehicle-to-Infrastructure Safety Applications Performance Requirements", Federal Highway Administration, August 2015. This document is a seven volume report that describes performance requirements for six V2I Safety Applications developed by Battelle for the USDOT.	A

Rqmt. No.	Requirement Title	Requirement Statement	Elaboration	Verif. Method (I,D,T,A)
[01.02.32]	V2I Safety - RSZW Application	The IVP Platform shall be capable of supporting the functional and performance requirements of the Infrastructure Component of a Reduced Speed Zone Warning with Lane Closure (RSZW/LC) Application.	The following is referenced for guidance. The IVP Platform may be required to support the Infrastructure Component of a Reduced Speed Zone Warning with Lane Closure (RSZW/LC) Application. The Infrastructure Component of a Reduced Speed Zone Warning with Lane Closure (RSZW/LC) Application supports -Obtaining Reduced Speed Zone Warning with Lane Closure (RSZW/LC) Input Data through the Local/Back Office User Interface, message processing and formatting, and message distribution (to Local Vehicles) through Low and High Latency Message Services. -"Vehicle-to-Infrastructure Safety Applications Performance Requirements", Federal Highway Administration, August 2015. This document is a seven volume report that describes performance requirements for six V2I Safety Applications developed by Battelle for the USDOT.	A

Rqmt. No.	Requirement Title	Requirement Statement	Elaboration	Verif. Method (I,D,T,A)
[01.02.33]	V2I Safety - SWIW Application	The IVP Platform shall be capable of supporting the functional and performance requirements of the Infrastructure Component of a Spot Weather Information Warning - Reduced Speed (SWIW-RS) Application.	The following is referenced for guidance. The IVP Platform may be required to support the Infrastructure Component of a Spot Weather Information Warning - Reduced Speed (SWIW-RS) Application. The Infrastructure Component of a Spot Weather Information Warning - Reduced Speed (SWIW-RS) Application supports -Obtaining Local Spot Weather Information Warning - Reduced Speed (SWIW-RS) Input Data through the Infrastructure Data Systems Interface, message processing and formatting, and message distribution (to Local Vehicles) through Low and High Latency Message Services. -"Vehicle-to-Infrastructure Safety Applications Performance Requirements", Federal Highway Administration, August 2015. This document is a seven volume report that describes performance requirements for six V2I Safety Applications developed by Battelle for the USDOT.	A

Rqmt. No.	Requirement Title	Requirement Statement	Elaboration	Verif. Method (I,D,T,A)
[01.02.34]	V2I Safety - SWIW Application	The IVP Platform shall be capable of supporting the functional and performance requirements of the Infrastructure Component of a Spot Weather Information Warning - Diversion (SWIW-D) Application.	The following is referenced for guidance. The IVP Platform may be required to support the Infrastructure Component of a Spot Weather Information Warning - Diversion (SWIW-D) Application. The Infrastructure Component of a Spot Weather Information Warning - Diversion (SWIW-D) Application supports -Obtaining Local Spot Weather Information Warning - Diversion (SWIW-D) Input Data through the Infrastructure Data Systems Interface, message processing and formatting, and message distribution (to Local Vehicles) through Low and High Latency Message Services. -"Vehicle-to-Infrastructure Safety Applications Performance Requirements", Federal Highway Administration, August 2015. This document is a seven volume report that describes performance requirements for six V2I Safety Applications developed by Battelle for the USDOT.	A

Rqmt. No.	Requirement Title	Requirement Statement	Elaboration	Verif. Method (I,D,T,A)
[01.02.35]	V2I Safety - SSGA Application	The IVP Platform shall be capable of supporting the functional and performance requirements of the Infrastructure Component of a Stop Sign Gap Assist (SSGA) Application.	The following is referenced for guidance. The IVP Platform may be required to support the Infrastructure Component of a Stop Sign Gap Assist (SSGA) Application. The Infrastructure Component of a Stop Sign Gap Assist (SSGA) Application supports -Obtaining Local Stop Sign Gap Assist (SSGA) Input Data through the Infrastructure Data Systems Interface, message processing and formatting, and message distribution (to Local Vehicles) through Low and High Latency Message Services. -"Vehicle-to-Infrastructure Safety Applications Performance Requirements", Federal Highway Administration, August 2015. This document is a seven volume report that describes performance requirements for six V2I Safety Applications developed by Battelle for the USDOT.	A

Rqmt. No.	Requirement Title	Requirement Statement	Elaboration	Verif. Method (I,D,T,A)
[01.02.36]	V2I Safety - Rail Crossing Violation Warning Application	The IVP Platform shall be capable of supporting the functional and performance requirements of the Infrastructure Component of a Rail Crossing Violation Warning Application.	The following is referenced for guidance. The IVP Platform may be required to support the Infrastructure Component of a Rail Crossing Violation Warning Application. The Infrastructure Component of a Red Light Violation Warning Application supports -Obtaining Local Rail Crossing Timing Input Data through the Traffic Signal Controller Interface, message processing and formatting, and message distribution (to Local Vehicles) through Low and High Latency Message Services. -"Vehicle-to-Infrastructure (V2I) Safety Applications Concept of Operations Document. FHWA Office of Safety Research and Development, Turner-Fairbank Highway Research Center. FHWA-JPO-13-060. March 2013. -"Vehicle-to-Infrastructure Rail Crossing Violation Warning Concept of Operations", FRA Office of Research and Development, John A. Volpe National Transportation Systems Center, June 2015. -"Vehicle-to-Infrastructure Rail Crossing Violation Warning System Requirements Specification", FRA Office of Research and Development,	A

Rqmt. No.	Requirement Title	Requirement Statement	Elaboration	Verif. Method (I,D,T,A)
			John A. Volpe National Transportation Systems Center, June 2015.	

Rqmt. No.	Requirement Title	Requirement Statement	Elaboration	Verif. Method (I,D,T,A)
[01.02.37]	DMA Applications - INFLO Message Handler	The IVP Platform shall be capable of supporting the functional and performance requirements of the Infrastructure Component of an INFLO Message Handler.	The following is referenced for guidance. The INFLO Message Handler supports -obtaining required INFLO Input Data through the Infrastructure Data Systems Interface, Local/Back Office Systems Interface, through the Low and High Latency Message Services, message processing and formatting, and message distribution through High Latency Message Services and TCP/IP communications. -Report on Detailed Requirements for the INFLO Prototype, Federal Highway Administration, December 2013, FHWA-JPO-13-171.	A
[01.02.38]	MMITSS Transit Signal Priority Message Handler	The IVP Platform shall be capable of supporting the functional and performance requirements of the Infrastructure Component of an MMITSS Transit Signal Priority Message Handler.	The following is referenced for guidance. Multi-Modal Intelligent Traffic Signal System (MMITSS) Final System Requirements Document, "Program to Support the Development and Deployment of Cooperative Transportation System Applications" Cooperative Transportation System Pooled Fund Study (CTS PFS), March 2012.	A

Rqmt. No.	Requirement Title	Requirement Statement	Elaboration	Verif. Method (I,D,T,A)
[01.02.39]	MMITSS Pedestrian Mobility Message Handler	The IVP Platform shall be capable of supporting the functional and performance requirements of the Infrastructure Component of an MMITSS Pedestrian Mobility Message Handler.	The following is referenced for guidance. Multi-Modal Intelligent Traffic Signal System (MMITSS) Final System Requirements Document, "Program to Support the Development and Deployment of Cooperative Transportation System Applications" Cooperative Transportation System Pooled Fund Study (CTS PFS), March 2012.	A
[01.02.40]	MMITSS Freight Signal Priority Message Handler	The IVP Platform shall be capable of supporting the functional and performance requirements of the Infrastructure Component of an MMITSS Freight Signal Priority Message Handler.	The following is referenced for guidance. Multi-Modal Intelligent Traffic Signal System (MMITSS) Final System Requirements Document, "Program to Support the Development and Deployment of Cooperative Transportation System Applications" Cooperative Transportation System Pooled Fund Study (CTS PFS), March 2012.	A
[01.02.41]	MMITSS Emergency Signal Preemption Message Handler	The IVP Platform shall be capable of supporting the functional and performance requirements of the Infrastructure Component of an MMITSS Emergency Signal Preemption Message Handler.	The following is referenced for guidance. Multi-Modal Intelligent Traffic Signal System (MMITSS) Final System Requirements Document, "Program to Support the Development and Deployment of Cooperative Transportation System Applications" Cooperative Transportation System Pooled Fund Study (CTS PFS), March 2012.	A

Rqmt. No.	Requirement Title	Requirement Statement	Elaboration	Verif. Method (I,D,T,A)
01.03	**IVP Platform Data Input Requirements**			
01.04	**IVP Platform Data Output Requirements**			
01.05	**IVP Platform Computation and Communication Performance Requirements**			
[01.05.01]	Simultaneous Message Handlers	The IVP Platform shall support simultaneous execution of at least 10 Message Handlers and Applications.		D
01.06	**IVP Platform Operational Performance Requirements**			
01.07	**IVP Platform Supportability Requirements**			
[01.07.01]	Weight, Size, and Shape	The IVP Platform size, weight, and form factor shall support its installation in standard traffic signal controller cabinet (NEMA or ATC), either by itself or in conjunction with other roadside equipment.		D
[01.07.02]	Availability (Hardware)	The IVP Platform shall have an availability to support safety critical operations of 99.99%.		A
[01.07.03]	Maintainability (Hardware)	The hardware architecture of the IVP Platform shall contain hardware components that can be replaced quickly.	To support rapid diagnosis of hardware failures and rapid replacement of failed components	D
[01.07.05]	Interchangeability (Hardware)	All external hardware components interfacing with IVP shall be physically interchangeable with respect to installation and performance.		D
01.08	**IVP Platform Security Requirements**			
[01.08.01]	Physical Protection	The IVP Platform shall be installed in industry standard enclosures which provide physical protection from access.		D
[01.08.02]	DSRC Communications Security	The IVP Platform shall comply with published industry specifications for security of DSRC communications.		D
01.09	**IVP Platform Human Factors, Health and Safety Requirements**			

Rqmt. No.	Requirement Title	Requirement Statement	Elaboration	Verif. Method (I,D,T,A)
[01.09.01]	Safety	The IVP Platform shall not present an electrical shock, mechanical pinch or other safety hazard during installation, maintenance or operation.		D
01.10	**IVP Platform Installation and Setup Requirements**			
[01.10.01]	Setup and Operation	Installation, setup and initiation of operations of the IVP Platform shall be accomplished by one or two persons in less than 60 minutes.		D
[01.10.02]	Software Installation	The IVP Platform shall support installing and maintaining authorized software additions or modifications components by authorized entities over the local or remote interfaces.		D
01.11	**IVP Platform Operation, Maintenance and Diagnostic Requirements**			
[01.11.01]	Function - Self-Diagnostics	The IVP Platform shall perform self-diagnostics upon power up and at configurable periodic intervals.		D
[01.11.02]	Logging - Errors	The IVP Platform shall support logging Platform Level, Application Level and Message Handler level error conditions along with relevant diagnostic context of the error.		D
[01.11.03]	Configured Operations	The IVP Platform shall operate based on current operational parameters for itself and its components using configuration information stored in the Configuration File.		D
[01.11.04]	Configuration Item Storage	The IVP Platform shall store operational configuration information related to the status of the device, its components, its interfaces, and other components to which it may be connected in one or more configuration files.		D
[01.11.05]	Configuration Default	The IVP Platform shall have a default value for each configuration parameter in the Configuration File.		D

Rqmt. No.	Requirement Title	Requirement Statement	Elaboration	Verif. Method (I,D,T,A)
[01.11.06]	Communications Message Storage	The IVP Platform shall be configurable to accept and store (log) transmitted and received communications messages to/from all communications interfaces.		D
[01.11.07]	Communications Message Timestamp	The IVP Platform shall timestamp the each logged communications message with the time sent or time received.	Note: This requirement can be met through PCAP file timestamp features.	D
[01.11.08]	Communications Message Separation by Interface	The IVP Platform shall store messages to/from each communications interface (e.g.. each DSRC radio, each non-DSRC IP interface) in separate files or a combined file based on configuration parameters (default to Combined) in the Configuration File.		D
[01.11.09]	Communications Message Separation by Direction	The IVP Platform shall store communications messages sent to (outbound) and received from (inbound) each interface in separate files or a combined file based on a configuration parameter (default to Combined) in the Configuration File.		D
01.12	**IVP Platform Documentation Requirements**			
01.13	**IVP Platform Staffing and Training Requirements**			
01.14	**IVP Platform Physical and Environmental Performance Requirements**			
[01.14.01]	Device Status Indicator	The IVP Platform shall have external LED indicators that indicate the IVP Platform operational state.		D
[01.14.02]	Environmental Standards and Operating Conditions	The IVP Platform shall conform to the environmental standards and operating conditions for intersection traffic control equipment specified in Institute for Transportation Engineers (ITE) ATC Transportation Controller Standard v05.2b. (or NEMA TW-2-2003?)		A
02	**Message Handler Common Requirements**			
02.01	**Message Handler Common Interfaces and Interface Specifications**			
02.02	**Message Handler Common Functional Requirements**			

Rqmt. No.	Requirement Title	Requirement Statement	Elaboration	Verif. Method (I,D,T,A)
[02.02.01]	Operating Platform	The Message Handler shall operate on the IVP Platform specified under IVP Platform Requirements.		D
[02.02.02]	Vehicle Application Component Data Exchange	The Message Handler shall exchange messages with connected vehicles through the Low Latency Message Interface and the High Latency Message Interface.		D
[02.02.03]	Vehicle Application Component Data Exchange Specifications	Messages exchanged between the Message Handler and the Low Latency Message Interface and the High Latency Message Interface shall conform to SAE J2735:2015 Dedicated Short Range Communications (DSRC) Message Set Dictionary.		D
[02.02.04]	Interfaces - Maintenance	The Message Handler shall have a Maintenance Interface to support installation, configuration, upgrades and detailed diagnostics of the Handler.		D
[02.02.05]	Interfaces - Technical Support Local and Remote Access	The Message Handler Maintenance Interface shall be accessible by both local and remote users.		D
[02.02.06]	Interfaces - Application User Interface	The Message Handler shall have a Message Handler User Interface to display operational status of the handler and to support required user interactions.		D
[02.02.07]	Interfaces - Application User Interface Local and Remote Access	The Message Handler User Interface shall be accessible by both local and remote users.		D
[02.02.08]	Interfaces - Uploading and Downloading of Application Data and Log Files	The Message Handler shall store configuration, data and log files in nonvolatile memory.		D

Rqmt. No.	Requirement Title	Requirement Statement	Elaboration	Verif. Method (I,D,T,A)
[02.02.09]	Interfaces - Uploading and Downloading of Application Data and Log Files	The Message Handler shall support secure, local and remote uploading and downloading of Message Handler data and log files.	The Message Handler should support upload of data files, locally or remotely, containing static infrastructure data such as road map and geometry generated elsewhere.	D
[02.02.10]	Error Handling - General	In the event of an error, the Message Handler shall assume its most restrictive state and should, to the extent possible, recover gracefully from transient error conditions and return to a normal operating condition.	The Message Handler should, to the This requirement refers to errors that are not mitigated by transitioning the handler to its degraded mode.	D
[02.02.11]	Error Handling – Degraded Mode	In the event of a configurable number of consecutive manageable errors, the Message Handler may enter a degraded mode of operation.		D
[02.02.12]	Error Handling – Degraded Mode	Upon entering a degraded mode of operation, the Message Handler shall notify all relevant external components indicating that the Message Handler is operating in its Degraded mode.		D
[02.02.13]	Error Handling – Degraded Mode	Upon recovery from its degraded mode of operation, the Message Handler shall notify all relevant external components indicating that the Message Handler is no longer operating in its Degraded mode.		D
[02.02.15]	Logging - Errors	The Message Handler shall log Handler Level error conditions along with relevant diagnostic context of the error.	Detail and content of log messages is typically controlled via a configuration parameter, specifying more or less detail depending on the component's desired mode of operation.	D
02.03	**Message Handler Common Data Input Requirements**			

Rqmt. No.	Requirement Title	Requirement Statement	Elaboration	Verif. Method (I,D,T,A)
[02.03.01]	Data - Input Validation	The Message Handler shall perform validity checks on all data inputs.		D
[02.03.02]	Data - Input Validation Functional Failure	In the event of an Input Validation Error, the Message Handler shall not issue functional output messages to external component interfaces.		D
[02.03.03]	Data - Erroneous Data Disposition	In the event of an Input Validation Error, the Message Handler shall discard the erroneous data.		D
[02.03.04]	Data - Input Validation Error Recovery	In the event of an Input Validation Error, the Message Handler shall continue to process input data at the prescribed rate and continue operation.	The Message Handler should, to the extent possible, recover gracefully from transient error conditions and return to a normal operating condition.	D
[02.03.07]	Data - Input Validation Error Degraded Operation Recovery	In the event of a configurable number of consecutive Input Validation Errors, the Message Handler shall refresh input data and perform validity checks once per hour.	In the event of multiple consecutive input data errors, the Application Component should enter Degraded Operational Mode in which it periodically checks for corrected input data and resumes operation upon resumption of useable input data.	D
02.04	**Message Handler Common Data Output Requirements**			
02.05	**Message Handler Common Computation and Communication Performance Requirements**			
02.06	**Message Handler Common Operational Performance Requirements**			
[02.06.01]	Lane Level Position Accuracy	Lane Level Position Accuracy shall be defined as a R95 Probability of horizontal position accuracy of less than or equal to 2 meters.	R95 is defined as the radius of a circle centered on the true antenna position that contains 95% of the actual GPS measurements.	A
[02.06.02]	Road Level Position Accuracy	Road Level Position Accuracy shall be defined as a R95 Probability of horizontal position accuracy of less than or equal to 7.5 meters.	R95 is defined as the radius of a circle centered on the true antenna position that contains 95% of the actual GPS measurements.	A

Rqmt. No.	Requirement Title	Requirement Statement	Elaboration	Verif. Method (I,D,T,A)
[02.06.03]	Roadway Classes	The Message Handler shall meet its functional requirements on the functional classes of roadway and levels of service (LOS) on which it will be deployed.	The defined function classes of roadways can be found in FHWA's "Highway Functional Classification: Concepts, Criteria and Procedures", FHWA-PL-13-026 and AASHTO's The defined LOS can be found in “A Policy on Geometric Design of Highways and Streets", AASHTO, 2001	D
[02.06.04]	Roadway Geometry	The Message Handler shall meet its functional requirements on the road geometries on which it will be deployed.	AASHTO's “A Policy on Geometric Design of Highways and Streets", AASHTO, 2001, is referenced for guidance.	D
[02.06.05]	Directional Applicability	The Message Handler shall issue advisories, alerts and wireless messages applicable to the vehicles' direction of travel.		D
[02.06.06]	Mixed Vehicle Traffic	The Message Handler shall issue advisories, alerts, and warnings applicable to all vehicles licensed to operate on the roadway.	Including passenger cars and commercial motor vehicles and transit buses.	D
02.07	**Message Handler Common Supportability Requirements**			
[02.07.01]	Modularity (Software)	The software architecture of the Message Handler shall be organized to co-exist with multiple, independent Message Handler/Application Components on the IVP Platform without conflict or interference.		D
[02.07.02]	Portability (Software)	The Message Handler shall be designed such that platform-dependent code is identified and encapsulated wherever and whenever performance considerations permit.	Aside from industry best-practice design principles, this requirement is meant to reduce the cost of the potential porting of the system software to other host machines and/or operating systems.	A

Rqmt. No.	Requirement Title	Requirement Statement	Elaboration	Verif. Method (I,D,T,A)
[02.07.03]	Vehicle Communication Scalability (Software)	The Message Handler shall support communication with a number of Connected Vehicles scalable up to the number of vehicles that can be physically in communication range of the IVP Platform.		A
02.08	**Message Handler Common Security Requirements**			
[02.08.01]	Access Control	Access to modify the Message Handler and its configuration, data and log files, shall be restricted to personnel authorized by the Operating Agency.		D
02.09	**Message Handler Common Human Factors, Health and Safety Requirements**			
[02.09.01]	Safety	The Message Handler shall not issue inaccurate messages to vehicles or other external components during installation, configuration, operation, or diagnostics.	The application must not create a safety hazard during installation, configuration, operation, or diagnostics.	D
[02.09.02]	Driver Capabilities	The Message Handler shall support the physical and cognitive capabilities of drivers qualified to obtain a driver's license.	National Cooperative Highway Research Program (NCHRP) Report 600A "Human Factors Guidelines for Road Systems" is referenced for Guidance.	A
[02.09.03]	Vital Safety	The Message Handler shall provide explicit indication that messages relating to safe vehicle operation have been vitally assured.	Information vital to system safety must meet a higher threshold of accuracy assurance than operational information. For example: A vehicle speed that is not vitally assured may be used to determine travel time, but not to determine a safe braking distance.	
02.10	**Message Handler Common Installation and Setup Requirements**			

Rqmt. No.	Requirement Title	Requirement Statement	Elaboration	Verif. Method (I,D,T,A)
[02.10.01]	Installation and Maintenance Interface	The Message Handler shall support installation and maintenance of software components over the local and remote access.	Enables system installation and maintenance updates both remotely and locally.	D
[02.10.02]	Installation and Maintenance Entities	Installation and maintenance of the Message Handler software shall be limited to authorized entities.		A
02.11	**Message Handler Common Operation, Maintenance and Diagnostic Requirements**			
[02.11.01]	Function - Self-Diagnostics	The Message Handler shall perform self-diagnostics upon power up and at configurable periodic intervals.		D
[02.11.02]	Operational Mode - Determination	The Message Handler shall determine the operating level/mode of operation based on the results of software errors and/or self-diagnostic tests.		D
[02.11.07]	Automatic Adjustment of Operation Mode	If the Message Handler is configured to communicate with a Traffic Management Entity and Back Office System, the Message Handler shall monitor the Traffic Management Entity and Local/Back Office User Interface and automatically adjust its mode of operation (connected, reachback or standalone) to correspond to errors or failure of the Traffic Management and Back Office Communications. The Message Handler shall monitor its TCP/IP connection to the Traffic Management Entity and Local or Back Office System and automatically adjust its mode of operation (Connected, Reachback or Standalone) as applicable.		D

Rqmt. No.	Requirement Title	Requirement Statement	Elaboration	Verif. Method (I,D,T,A)
[02.11.11]	Operational Status Reporting	While operating in Connected or Reachback mode, the Message Handle shall report operational status to the Traffic Management Entity and Local or Back Office User, upon initiation of communication and at configurable periodic intervals while connected.		D
[02.11.12]	Logging - Error and Diagnostic Data	The Message Handler shall log self-diagnostic test information which contains, at a minimum, the following information: 1. Operational Mode and Online/Offline status 2. Self-diagnostic test information a. Date and time of test b. Test performed c. Result of test (Pass/Fail) d. Actions resulting from Failed Test e. Relevant diagnostic and maintenance data to support debugging.		D
[02.11.14]	Logging - Error and Diagnostic Data Logging Retention	The Message Handler shall maintain historical information of self-diagnostic tests for a configurable period in non-volatile storage.		D
[02.11.15]	Logging - Diagnostic Data Storage Overflow	If diagnostic data exceeds available memory resources, records shall be overwritten on a first in/first out basis.		D
[02.11.16]	Operation Mode – Normal	The Message handler shall support the full operation modes for Connected, Reachback, and/or Standalone operation.	Connected Mode - TCP/IP communications to a Traffic Management Entity and Local or Back Office System are continuously available Reachback Mode - TCP/IP communications to a Traffic	

Rqmt. No.	Requirement Title	Requirement Statement	Elaboration	Verif. Method (I,D,T,A)
			Management Entity and Local or Back Office System are available when requested by the handler. Standalone Mode - Communications with a Traffic Management Entity and Local or Back Office System are not available or not required by the handler.	
[02.11.17]	Operation Mode – Degraded	The Message handler may support a degraded mode of operation due to manageable failures, if applicable.	Result of partial failure, such as failure of an input data validity or vitality check or failure of one or more of the interfaces that supports partial operation only.	
[02.11.18]	Operation Mode – Maintenance	The Message handler shall support a maintenance modes of operation to support installation, updates, and diagnostics of the handler.	When operating in the maintenance mode, the Message handler is off-line.	
[02.11.19]	Operation Mode – Failed	The Message handler shall enter its most restrictive state in the event of unmanageable interface, computational, or self diagnostic failures.	Result of complete or partial failures that prevents the handler from issuing accurate messages to other system components.	
03	**Positioning Correction Message Handler Requirements**			
03.01	**Positioning Correction Message Handler Interfaces and Interface Specifications**			
[03.01.01]	Position Correction Message Input Interface	The Position Correction Message Handler shall obtain Position Correction Input Data from Position Correction Data Providers.	Positon data may come from an internet connection or may be obtained from a local RTCM source.	D
[03.01.02]	Position Correction Message Input Specification	The Position Correction input data shall conform to Radio Technical Commission for Maritime Services (RTCM) 10402.3.		A

Rqmt. No.	Requirement Title	Requirement Statement	Elaboration	Verif. Method (I,D,T,A)
[03.01.03]	Position Correction Message Output Interface 1	The Position Correction Message Handler shall issue Position Correction Message to vehicles through the Low and High Latency Wireless Message Services.		D
[03.01.06]	Position Correction Message Output Specifications	The Position Correction Message shall conform to the MSG_RTCM_Corrections from SAE J2735:2015 Dedicated Short Range Communications (DSRC) Message Set Dictionary.		A
03.02	**Positioning Correction Message Handler Functional Requirements**			
[03.02.01]	Conformance to Common Requirements	The Positioning Correction Message Handler shall conform to Message Handler Common Requirements.		A
[03.02.02]	Position Correction Message Initiation	The Position Correction Message Handler shall obtain Position Correction Input Data upon initiation of the component.		D
[03.02.03]	Position Correction Message Input Refresh Rate	The Position Correction Message Handler shall refresh Position Correction Input Data at a configurable frequency.		D
[03.02.04]	Position Correction Message Issuance	The Position Correction Message Handler shall compile and issue a Position Correction Message to Vehicles once per minute.		D
03.03	**Positioning Correction Message Handler Data Input Requirements**			
[03.03.01]	Position Correction Message Input Content	The Position Correction Message input data shall contain data specified in MSG_RTCM_Corrections from SAE J2735:2015 Dedicated Short Range Communications (DSRC) Message Set Dictionary.		D
03.04	**Positioning Correction Message Handler Data Output Requirements**			
[03.04.01]	Position Correction Message Output Content	The Position Correction Message output data shall contain data specified in MSG_RTCM_Corrections from SAE J2735:2015 Dedicated Short Range Communications (DSRC) Message Set Dictionary.		D

Rqmt. No.	Requirement Title	Requirement Statement	Elaboration	Verif. Method (I,D,T,A)
04	**Map Message Handler Requirements**			
04.01	**Map Message Handler Interfaces and Interface Specifications**			
[04.01.01]	Map Message Handler Data Upload	The Message Handler shall support upload and local storage of Map Message Data on the IVP Platform.		D
[04.01.02]	Map Message Input Interface	The Map Message Handler shall obtain Map Input Data from Map data files uploaded and stored on the IVP Platform.		D
[04.01.03]	Map Message Input Specification	The Map Message Input shall contain data in XML format needed to create a MSG_MapData (MAP) from SAE J2735:2015 Dedicated Short Range Communications (DSRC) Message Set Dictionary.		D
[04.01.04]	Map Message Output Interface 1	The Map Message Handler shall issue Map Message to vehicles through the Low and High Latency Wireless Message Services.		D
[04.01.07]	Map Message Output Specifications	The Map Message shall conform to the MSG_MapData (MAP) from SAE J2735:2015 Dedicated Short Range Communications (DSRC) Message Set Dictionary.		A
04.02	**Map Message Handler Functional Requirements**			
[04.02.01]	Conformance to Common Requirements	The Map Message Handler shall conform to Message Handler Common Requirements.		A
[04.02.02]	Map Message Initiation	The Map Message Handler shall obtain Map Input Data upon initiation of the component.		D
[04.02.03]	Map Message Input Refresh Rate	The Map Message Handler shall refresh Map Input Data based on changes to the current action from the traffic signal controller		D
[04.02.04]	Map Message Issuance	The Map Message Handler shall compile and issue a Map Message to Vehicles once per second.		D
05	**BSM/Vehicle Data Aggregator Requirements**			

Rqmt. No.	Requirement Title	Requirement Statement	Elaboration	Verif. Method (I,D,T,A)
05.01	**BSM/Vehicle Data Aggregator Interfaces and Interface Specifications**			
[05.01.01]	Infrastructure-based Vehicle Speed Sensors Input Interface	The BSM/Vehicle Data Aggregator shall obtain Infrastructure-based Vehicle Speed Data through the Vehicle Speed Sensor Systems Interface.		D
[05.01.03]	Basic Safety Message Input Interface	The BSM/Vehicle Data Aggregator shall obtain Basic Safety Messages through the Low Latency Wireless Message Service.		D
[05.01.04]	Basic Safety Message Input Interface Specifications	The Basic Safety Message messages shall conform to the MSG_BasicSafetyMesaage (BSM) from SAE J2735:2015 Dedicated Short Range Communications (DSRC) Message Set Dictionary.		A
[05.01.05]	BSM/Vehicle Data Aggregator Output Interface	The BSM/Vehicle Data Aggregator shall deliver Aggregator Outputs through the IVP Platform internal communications to other IVP Message Handlers and Applications.		D
05.02	**BSM/Vehicle Data Aggregator Functional Requirements**			
[05.02.01]	Conformance to Common Requirements	The BSM/Vehicle Data Aggregator shall conform to Common Message Handler Requirements.		A
[05.02.02]	Infrastructure-based Vehicle Speed Data Capture Initiation	The BSM/Vehicle Data Aggregator shall obtain Infrastructure-based Vehicle Speed Data upon initiation of the component.		D

Rqmt. No.	Requirement Title	Requirement Statement	Elaboration	Verif. Method (I,D,T,A)
[05.02.03]	Infrastructure-based Vehicle Speed Data Capture Distance	The BSM/Vehicle Data Aggregator shall obtain speed and distance of approaching vehicles from Vehicle Speed Sensor Systems Interface before the vehicles are within the V2I Safety Application Advisory Distance of the subject intersection or hazard entrance.	The V2I Safety Application Advisory Distance is the distance from the beginning of the intersection or hazard to roadside advisory signs plus the sign visibility distance, as defined in the MUTCD Table 2C-4, Guidelines for Advance Placement of Warning Signs. The BSM/Vehicle Data Aggregator does not correlate connected vehicle and infrastructure data. It processes and bundles each independently and issues messages for use by other message handlers and applications.	D
[05.02.04]	Infrastructure-based Vehicle Speed Data Refresh Rate	The BSM/Vehicle Data Aggregator shall refresh the Infrastructure-based Vehicle Speed Data at a configurable frequency.	It is anticipated that the refresh frequency will be between 1 and 10 hertz.	D
[05.02.05]	Basic Safety Message Capture Initiation	The BSM/Vehicle Data Aggregator shall obtain Basic Safety Messages upon initiation of the component.		D
[05.02.06]	Basic Safety Message Capture Distance	The BSM/Vehicle Data Aggregator shall obtain speed and distance of approaching vehicles from Basic Safety Messages before the vehicles are within the V2I Safety Application Advisory Distance of the subject intersection or hazard entrance as defined in the MUTCD-09.	The V2I Safety Application Advisory Distance is the distance from the beginning of the intersection or hazard to roadside advisory signs plus the sign visibility distance, as defined in the MUTCD Table 2C-4, Guidelines for Advance Placement of Warning Signs.	D

Rqmt. No.	Requirement Title	Requirement Statement	Elaboration	Verif. Method (I,D,T,A)
[05.02.07]	Basic Safety Message Refresh Rate	The BSM/Vehicle Data Aggregator shall refresh Basic Safety Messages at a configurable frequency.		D
[05.02.08]	Approaching Vehicle Characterization	The BSM/Vehicle Data Aggregator shall assess Infrastructure-based Vehicle Speed Data and BSM-based Vehicle Speed Data for vehicles approaching the subject intersection or hazard and shall determine the distance, speed and heading of each identified approaching vehicle.	The BSM/Vehicle Data Aggregator does not correlate connected vehicle and infrastructure data. It processes and bundles each independently and issues messages for use by other message handlers and applications.	D
[05.02.09]	Fastest Approaching Vehicle Characterization	The BSM/Vehicle Data Aggregator shall determine the speed, distance, and heading of the fastest approaching vehicle.		D
[05.02.10]	Fastest Approaching Vehicle Message	The BSM/Vehicle Data Aggregator shall report the speed, distance, and heading of the fastest approaching vehicle to other IVP Message Handlers and Applications at a rate of 10 Hz.		D
[05.02.12]	Approaching Vehicle Data Bundle	The BSM/Vehicle Data Aggregator shall combine multiple Approaching Vehicle Data messages in a single message transmitted to the IVP system for use by other IVP Message Handlers and Applications.		D
[05.02.13]	Approaching Vehicle Data Bundle Issuance	The BSM/Vehicle Data Aggregator Approaching Vehicle Data shall be bundled and issued at a configurable frequency between 1 and 10 Hz.		D
[05.02.14]	BSM Part 1 and Part 2 Data Bundle	The BSM/Vehicle Data Aggregator shall combine multiple BSM Part 1 and Part 2 Data messages in a single message transmitted to the IVP system for use by other IVP Message Handlers and Applications.		D
[05.02.15]	BSM Part 1 and Part 2 Data Bundle Issuance	The BSM/Vehicle Data Aggregator BSM Part 1 and Part 2 Data shall be bundled and issued at a configurable frequency.		D

Rqmt. No.	Requirement Title	Requirement Statement	Elaboration	Verif. Method (I,D,T,A)
[05.02.16]	BSM Aggregation Correlation	The BSM/Vehicle Data Aggregator does not correlate connected vehicle and infrastructure data. It processes and bundles each independently and issues messages for use by other message handlers and applications.		
06	**Dynamic Roadside Message Arbitrator Requirements**			
06.01	**Dynamic Roadside Message Arbitrator Interfaces and Interface Specifications**			
[06.01.01]	Roadside Message Arbitrator Input Interface	The Roadside Message Arbitrator shall obtain Roadside Messages through IVP Platform internal communications and storage from other IVP Message Handlers and Applications.		D
[06.01.02]	Roadside Message Arbitrator Input Interface Specifications 1	Roadside Message Input Data shall contain data specified in NTCIP 1203 v02 Object Definitions for Dynamic Message Signs (DMS) Standard.		D
[06.01.03]	Roadside Message Arbitrator Output Interface	The Roadside Message Arbitrator shall issue Roadside Messages to Dynamic Roadside Message Signs through the Roadside Signage Message Service.		D
[06.01.04]	Roadside Message Arbitrator Output Interface Specifications	Roadside Messages Outputs shall conform to NTCIP 1203 v02 Object Definitions for Dynamic Message Signs (DMS) Standard.		A
06.02	**Dynamic Roadside Message Arbitrator Functional Requirements**			
[06.02.01]	Conformance to Common Requirements	The Roadside Message Arbitrator shall conform to Common Message Handler Requirements.		A
[06.02.02]	Schema for Prioritization	The Roadside Message Arbitrator shall have a schema for prioritization and duration of messages for display.	The Roadside Message Arbitrator prioritization schema should be documented for use and implementation by developers of other IVP message handlers and applications.	D

Rqmt. No.	Requirement Title	Requirement Statement	Elaboration	Verif. Method (I,D,T,A)
[06.02.03]	Roadside Message Arbitrator Initiation	The Roadside Message Arbitrator shall obtain Roadside Messages upon initiation of the component.		D
[06.02.04]	Roadside Message Input Refresh Rate	The Roadside Message Arbitrator shall refresh the Roadside Message Inputs at a configurable frequency.		D
[06.02.05]	Roadside Message Prioritization Indicator	In the event that a received Roadside Message does not include a Prioritization Indicator in accordance with Arbitrator specifications, the Arbitrator shall assign a default value and process normally.		D
[06.02.07]	Roadside Message Issuance	The Roadside Message Arbitrator shall compile and issue Roadside Messages in accordance with their prioritization and duration.		D
07	**Traffic & Rail Signal Message Handler Requirements**			
07.01	**Traffic & Rail Signal Message Handler Applicable Standards and Documents**			
[07.01.01]	Traffic & Rail Signal Message Input Interface	The Traffic & Rail Signal Message Handler shall obtain Traffic Signal Input Data from the Traffic Signal Controller Interface.		D
[07.01.02]	Traffic Signal Controller Input Specifications 1	Traffic Signal Input Data shall conform to NTCIP 1202:2005 V02.19 Object Definitions for Actuated Traffic Signal Controllers (ASC) Standard.		A
[07.01.03]	Traffic Signal Controller Input Specifications 2	Traffic Signal Input Data shall conform to NTCIP 1211:2008 V01.38 Object Definitions for Signal Control and Prioritization (SCP) Standard.		A
	Traffic & Rail Signal Message Output Interface	The Traffic & Rail Signal Message Handler shall issue Traffic Signal Messages through the Low Latency Wireless Message Service to the Low Latency Radio Communications Component.		D

Rqmt. No.	Requirement Title	Requirement Statement	Elaboration	Verif. Method (I,D,T,A)
	Traffic & Rail Signal Message Output Specifications	The Traffic & Rail Signal Message Handler shall conform to MSG_SignalPhaseAndTiming Message (SPAT) from SAE J2735:2015 Dedicated Short Range Communications (DSRC) Message Set Dictionary.		A
07.02	**Traffic & Rail Signal Message Handler Functional Requirements**			
[07.02.01]	Conformance to Common Requirements	The Traffic & Rail Signal Message Handler shall conform to Message Handler Common Requirements.		A
[07.02.02]	Conformance to System Interface Requirements for Signal Phase and Timing	The Traffic & Rail Signal Message Handler shall conform to the System Interface Requirements defined in the System Requirements Document for the Signal Phase and Timing and Related Messages for V-I Applications, Final Release, 6/30/2013.		A
07.03	**Traffic & Rail Signal Message Handler Data Input Requirements**			
[07.03.01]	Traffic Signal Controller Data Input Content	The Traffic & Rail Signal Message Handler shall obtain Traffic Signal Message Handler Input Data specified in the System Requirements Document for the Signal Phase and Timing and Related Messages for V-I Applications, Final Release, 6/30/2013.		D
07.04	**Traffic & Rail Signal Message Handler Data Output Requirements**			
[07.04.01]	Traffic Signal Controller Data Output Content	The Traffic Signal Message Output Data shall contain data specified in to MSG_SignalPhaseAndTiming Message (SPAT) from SAE J2735:2015 Dedicated Short Range Communications (DSRC) Message Set Dictionary.		D
08	**Local Weather & Road Surface Message Handler Requirements**			
08.01	**Local Weather & Road Surface Message Handler Interfaces and Interface Specifications**			

Rqmt. No.	Requirement Title	Requirement Statement	Elaboration	Verif. Method (I,D,T,A)
[08.01.01]	Local Weather & Road Surface Message Input Interface 1	The Local Weather & Road Surface Message Handler shall obtain Local Weather & Road Surface Message Input Data from Local Weather & Road Surface Data Providers via the Internet Communication Interface.	For Guidance, Road Weather and Road Surface information is commonly obtained from Road Weather Information System (RWIS) through the Weather Data Environment (https://wxde.fhwa.dot.gov/).	D
[08.01.02]	Local Weather & Road Surface Message Input Interface 2	The Local Weather & Road Surface Message Handler shall obtain Infrastructure-based Local Weather & Road Surface Data through the ESS Interface.		D
[08.01.03]	Local Weather & Road Surface Message Input Specification	The Local Weather & Road Surface Data shall conform to the Provider's Published Specifications.		A
[08.01.04]	Local Weather & Road Surface Message Output Interface	The Local Weather & Road Surface Message Handler shall issue Local Weather & Road Surface Message through the IVP Platform local communications to other IVP Message Handlers and Applications.		D
[08.01.05]	Local Weather & Road Surface Message Output Specifications	The Local Weather & Road Surface Output Message shall conform to the Local Weather & Road Surface Data Provider's Published Specifications.		A
08.02	**Local Weather & Road Surface Message Handler Functional Requirements**			
[08.02.01]	Conformance to Common Requirements	The Local Weather & Road Surface Message Handler shall conform to Message Handler Common Requirements.		D
[08.02.02]	Local Weather & Road Surface Message Initiation	The Local Weather & Road Surface Message Handler shall obtain Local Weather & Road Surface Input Data upon initiation of the component.		D

Rqmt. No.	Requirement Title	Requirement Statement	Elaboration	Verif. Method (I,D,T,A)
[08.02.03]	Local Weather & Road Surface Message Input Refresh Rate	The Local Weather & Road Surface Message Handler shall refresh Local Weather & Road Surface Input Data at a configurable frequency.		D
[08.02.04]	Local Weather & Road Surface Message Issuance	The Local Weather & Road Surface Message Handler shall compile and issue Local Weather & Road Surface Message at a configurable frequency.		D
08.03	**Local Weather & Road Surface Message Handler Data Input Requirements**			
[08.03.01]	Local Weather & Road Surface Message Input Content	The Local Weather & Road Surface Message input data shall contain data specified in the Local Weather & Road Surface Data Provider's Published Specifications.		D
08.04	**Local Weather & Road Surface Message Handler Data Output Requirements**			
[08.04.01]	Local Weather & Road Surface Message Output Content	The Local Weather & Road Surface output data shall contain data specified in the Local Weather & Road Surface Data Provider's Published Specifications.		D
11	**INFLO SPD-HARM Message Handler Requirements**			
11.01	**INFLO SPD-HARM Message Handler Interfaces and Interface Specifications**			
[11.01.01]	SPD-HARM Map Message - Message Specifications	The SPD-HARM shall produce a Traveler Information Messages conforming to the MSG_TravelerInformationMessage (TIM) from SAE J2735:2015 Dedicated Short Range Communications (DSRC) Message Set Dictionary containing the speed harm location and recommended speed information.		A
[11.01.02]	SPD-HARM Local Weather Message - Message Specifications	The SPD-HARM shall receive Local Weather & Road Surface information from the Local Weather and Road Surface Message Handler.		A

Rqmt. No.	Requirement Title	Requirement Statement	Elaboration	Verif. Method (I,D,T,A)
[11.01.03]	SPD-HARM BSM/Vehicle Message - Message Specifications	The SPD-HARM shall receive BSM/Vehicle Message data from the Vehicle Data Aggregator message handler.		A
[11.01.04]	SPD-HARM IVP-TME Message - Message Specifications	The SPD-HARM IVP-TME Message shall conform to the technical specifications of the Traffic Management Data Dictionary (TMDD) Standard v3.03 for the Center-to-Center Communications		A
[11.01.06]	SPD-HARM Recommendation Wireless Message - Message Specifications	The SPD-HARM Recommendation Wireless Message shall conform to MSG_TravelerInformationMessage (TIM) from SAE J2735:2015 Dedicated Short Range Communications (DSRC) Message Set Dictionary.		A
[11.01.07]	SPD-HARM Recommendation Roadside Message - Message Specifications	The SPD-HARM shall produce a recommended speed message and display it to a DMS through the Dynamic Roadside message arbitrator.		A
11.02	**INFLO SPD-HARM Message Handler Functional Requirements**			
[11.02.01]	Conformance to Common Requirements	The INFLO SPD-HARM Message Handler shall conform to Message Handler Common Requirements.		D
[11.02.02]	SPD-HARM Map Message Input	The INFLO SPD-HARM Message Handler shall obtain TIM Message upon initiation of the component.		D
[11.02.03]	SPD-HARM Map Message Refresh	The INFLO SPD-HARM Message Handler shall refresh TIM Message at a configurable frequency.		D
[11.02.05]	SPD-HARM Local Weather & Road Surface Message Input	The INFLO SPD-HARM Message Handler shall obtain Local Weather & Road Surface Message upon initiation of the component.		D
[11.02.06]	SPD-HARM Local Weather & Road Surface Message Refresh	The INFLO SPD-HARM Message Handler shall refresh Local Weather & Road Surface Messages at a configurable frequency.		D

Rqmt. No.	Requirement Title	Requirement Statement	Elaboration	Verif. Method (I,D,T,A)
[11.02.07]	SPD-HARM Local Weather & Road Surface Message Output	The INFLO SPD-HARM Message Handler shall send Local Weather & Road Surface Messages to the TME at a configurable frequency.		D
[11.02.08]	SPD-HARM BSM/Vehicle Data Aggregator Approaching Vehicle Data Bundles Input	The INFLO SPD-HARM Message Handler shall obtain BSM/Vehicle Data Aggregator Approaching Vehicle Data Bundles upon initiation of the component.		D
[11.02.09]	SPD-HARM BSM/Vehicle Data Aggregator Approaching Vehicle Data Bundles Refresh	The INFLO SPD-HARM Message Handler shall refresh BSM/Vehicle Data Aggregator Approaching Vehicle Data Bundles at a configurable frequency.		D
[11.02.10]	SPD-HARM BSM/Vehicle Data Aggregator Approaching Vehicle Data Bundles Output	The INFLO SPD-HARM Message Handler shall send BSM/Vehicle Data Aggregator Approaching Vehicle Data Bundles to the TME at a configurable frequency.		D
[11.02.11]	SPD-HARM BSM/Vehicle Data Aggregator Approaching Vehicle Data Bundles Input	The INFLO SPD-HARM Message Handler shall obtain TME-Based SPD-HARM Recommendations upon initiation of the component.		D
[11.02.12]	SPD-HARM BSM/Vehicle Data Aggregator Approaching Vehicle Data Bundles Refresh	The INFLO SPD-HARM Message Handler shall refresh TME-Based SPD-HARM Recommendations at a configurable frequency.		D
[11.02.13]	SPD-HARM Message Vehicle Output Interface 1	The INFLO SPD-HARM Message Handler shall issue TME-Based SPD-HARM Recommendations Message to vehicles through the Low and High Latency Wireless Message Services.		D
[11.02.14]	SPD-HARM Message Vehicle Output Interface 2	The INFLO SPD-HARM Message Handler shall issue TME-Based SPD-HARM Recommendations Messages through the Low Latency Wireless Message Service to the Low Latency Radio Communications Component.		D

Rqmt. No.	Requirement Title	Requirement Statement	Elaboration	Verif. Method (I,D,T,A)
[11.02.15]	SPD-HARM Message Vehicle Output Interface 3	The INFLO SPD-HARM Message Handler shall issue TME-Based SPD-HARM Recommendations Messages through the High Latency Wireless Message Service to the High Latency Quasi-Static Message Storage.		D
[11.02.16]	SPD-HARM Message Vehicle Output Specifications	The TME-Based SPD-HARM Recommendations Message sent to the Low and High Latency Wireless Message Services shall conform to the MSG_TravelerInformationMessage (TIM) from SAE J2735:2015 Dedicated Short Range Communications (DSRC) Message Set Dictionary.		D
[11.02.17]	SPD-HARM Message Vehicle Output Frequency	The SPD-HARM Recommendation I2V Wireless Message shall be issued to the High and Low Latency Wireless Message Services at 1 Hz.		D
[11.02.18]	SPD-HARM Message Roadside Display Interface	The INFLO SPD-HARM Message Handler shall issue the SPD-HARM Recommendation Roadside Message to the Dynamic Roadside Message Arbitrator.		D
[11.02.19]	SPD-HARM Message Roadside Display Interface Specifications	The TME-Based SPD-HARM Recommendations Message sent to the Dynamic Roadside Message Arbitrator shall conform to the NTCIP 1203 v02 Object Definitions for Dynamic Message Signs (DMS) Standard.		D
[11.02.20]	SPD-HARM Message Roadside Display Frequency	The SPD-HARM Recommendation Roadside Message shall be issued to the Dynamic Roadside Message Arbitrator at 1 Hz.		D
11.03	**INFLO SPD-HARM Message Handler Data Input Requirements**			
[11.03.01]	SPD-HARM TME-IVP Recommendation Message - Message Specifications	The SPD-HARM Message Handler Input (TME-IVP) Message shall contain data specified in the INFLO SPD-HARM System Design Document.	The following is suggested for guidance System Design Document for the INFLO Prototype, FHWA-JPO-13-169.	D

Rqmt. No.	Requirement Title	Requirement Statement	Elaboration	Verif. Method (I,D,T,A)
11.04	**INFLO SPD-HARM Message Handler Data Output Requirements**			
[11.03.01]	SPD-HARM IVP-TME Message - Message Specifications	The SPD-HARM Message Handler Output (IVP-TME) Message shall contain data specified in the INFLO SPD-HARM System Design Document.	The following is suggested for guidance System Design Document for the INFLO Prototype, FHWA-JPO-13-169.	D
12	**INFLO Q-WARN Message Handler Requirements**			
12.01	**INFLO Q-WARN Message Handler Interfaces and Interface Specifications**			
[12.01.01]	Q-WARN Map Message - Message Specifications	The Q-WARN Map Message shall conform to the MSG_MapData (MAP) from SAE J2735:2015 Dedicated Short Range Communications (DSRC) Message Set Dictionary.		A
[12.01.02]	Q-WARN Local Weather Message - Message Specifications	The Q-WARN Local Weather & Road Surface Message shall conform to the Local Weather & Road Surface Data Provider's Published Specifications.		A
[12.01.03]	Q-WARN BSM/Vehicle Message - Message Specifications	The Q-WARN BSM/Vehicle Message shall conform to the MSG_BasicSafetyMesaage (BSM) from SAE J2735:2015 Dedicated Short Range Communications (DSRC) Message Set Dictionary.		A
[12.01.04]	Q-WARN IVP-TME Message - Message Specifications	The Q-WARN IVP-TME Message shall conform to the technical specifications of the current version of Traffic Management Data Dictionary (TMDD) Standard v3.03 for the Center-to-Center Communications		A
[12.01.05]	Q-WARN TME-IVP Recommendation Message - Message Specifications	The Q-WARN TME-IVP Message shall conform to the technical specifications of the current version of Traffic Management Data Dictionary (TMDD) Standard v3.03 for the Center-to-Center Communications		A

Rqmt. No.	Requirement Title	Requirement Statement	Elaboration	Verif. Method (I,D,T,A)
[12.01.06]	Q-WARN Recommendation Wireless Message - Message Specifications	The Q-WARN Recommendation Wireless Message shall conform to MSG_TravelerInformationMessage (TIM) from SAE J2735:2015 Dedicated Short Range Communications (DSRC) Message Set Dictionary.		A
[12.01.07]	Q-WARN Recommendation Roadside Message - Message Specifications	The Q-WARN Recommendation Roadside Signage Message shall conform NTCIP 1203 v02 Object Definitions for Dynamic Message Signs (DMS) Standard.		A
12.02	**INFLO Q-WARN Message Handler Functional Requirements**			
[12.02.01]	Conformance to Common Requirements	The INFLO Q-WARN Message Handler shall conform to Message Handler Common Requirements.		D
[12.02.02]	Q-WARN Map Message Input	The INFLO Q-WARN Message Handler shall obtain Map Message upon initiation of the component.		D
[12.02.03]	Q-WARN Map Message Refresh	The INFLO Q-WARN Message Handler shall refresh Map Message at a configurable frequency.		D
[12.02.04]	Q-WARN Map Message Output	The INFLO Q-WARN Message Handler shall send Map Messages to the TME at a configurable frequency.		D
[12.02.05]	Q-WARN Local Weather & Road Surface Message Input	The INFLO Q-WARN Message Handler shall obtain Local Weather & Road Surface Message upon initiation of the component.		D
[12.02.06]	Q-WARN Local Weather & Road Surface Message Refresh	The INFLO Q-WARN Message Handler shall refresh Local Weather & Road Surface Messages at a configurable frequency.		D
[12.02.07]	Q-WARN Local Weather & Road Surface Message Output	The INFLO Q-WARN Message Handler shall send Local Weather & Road Surface Messages to the TME at a configurable frequency.		D
[12.02.08]	Q-WARN BSM/Vehicle Data Aggregator	The INFLO Q-WARN Message Handler shall obtain BSM/Vehicle Data Aggregator Approaching Vehicle Data Bundles upon initiation of the component.		D

Rqmt. No.	Requirement Title	Requirement Statement	Elaboration	Verif. Method (I,D,T,A)
	Approaching Vehicle Data Bundles Input			
[12.02.09]	Q-WARN BSM/Vehicle Data Aggregator Approaching Vehicle Data Bundles Refresh	The INFLO Q-WARN Message Handler shall refresh BSM/Vehicle Data Aggregator Approaching Vehicle Data Bundles at a configurable frequency.		D
[12.02.10]	Q-WARN BSM/Vehicle Data Aggregator Approaching Vehicle Data Bundles Output	The INFLO Q-WARN Message Handler shall send BSM/Vehicle Data Aggregator Approaching Vehicle Data Bundles to the TME at a configurable frequency.		D
[12.02.11]	Q-WARN BSM/Vehicle Data Aggregator Approaching Vehicle Data Bundles Input	The INFLO Q-WARN Message Handler shall obtain TME-Based Q-WARN Recommendations upon initiation of the component.		D
[12.02.12]	Q-WARN BSM/Vehicle Data Aggregator Approaching Vehicle Data Bundles Refresh	The INFLO Q-WARN Message Handler shall refresh TME-Based Q-WARN Recommendations at a configurable frequency.		D
[12.02.13]	Q-WARN Message Vehicle Output Interface 1	The INFLO Q-WARN Message Handler shall issue TME-Based Q-WARN Recommendations Message to vehicles through the Low and High Latency Wireless Message Services.		D
[12.02.14]	Q-WARN Message Vehicle Output Interface 2	The INFLO Q-WARN Message Handler shall issue TME-Based Q-WARN Recommendations Messages through the Low Latency Wireless Message Service to the Low Latency Radio Communications Component.		D
[12.02.15]	Q-WARN Message Vehicle Output Interface 3	The INFLO Q-WARN Message Handler shall issue TME-Based Q-WARN Recommendations Messages through the High Latency Wireless Message Service to the High Latency Quasi-Static Message Storage.		D

Rqmt. No.	Requirement Title	Requirement Statement	Elaboration	Verif. Method (I,D,T,A)
[12.02.16]	Q-WARN Message Vehicle Output Specifications	The TME-Based Q-WARN Recommendations Message sent to the Low and High Latency Wireless Message Services shall conform to the MSG_TravelerInformationMessage (TIM) from SAE J2735:2015 Dedicated Short Range Communications (DSRC) Message Set Dictionary.		D
[12.02.17]	Q-WARN Message Vehicle Output Frequency	The Q-WARN Recommendation I2V Wireless Message shall be issued to the High and Low Latency Wireless Message Services at 1 Hz.		D
[12.02.18]	Q-WARN Message Roadside Display Interface	The INFLO Q-WARN Message Handler shall issue the Q-WARN Recommendation Roadside Message to the Dynamic Roadside Message Arbitrator.		D
[12.02.19]	Q-WARN Message Roadside Display Interface Specifications	The TME-Based Q-WARN Recommendations Message sent to the Dynamic Roadside Message Arbitrator shall conform to the NTCIP 1203 v02 Object Definitions for Dynamic Message Signs (DMS) Standard.		D
[12.02.20]	Q-WARN Message Roadside Display Frequency	The Q-WARN Recommendation Roadside Message shall be issued to the Dynamic Roadside Message Arbitrator at 1 Hz.		D
12.03	**INFLO Q-WARN Message Handler Data Input Requirements**			
[12.03.01]	Q-WARN TME-IVP Recommendation Message - Message Specifications	The Q-WARN Message Handler Input (TME-IVP) Message shall contain data specified in the INFLO Q-WARN System Design Document.	The following is suggested for guidance System Design Document for the INFLO Prototype, FHWA-JPO-13-169.	D
12.04	**INFLO Q-WARN Message Handler Data Output Requirements**			
[12.03.01]	Q-WARN IVP-TME Message - Message Specifications	The Q-WARN Message Handler Output (IVP-TME) Message shall contain data specified in the INFLO Q-WARN System Design Document.	The following is suggested for guidance System Design Document for the INFLO Prototype, FHWA-JPO-13-169.	D

Appendix A. Acronyms and Abbreviations

AASHTO	American Association of State Highway and Transportation Officials
ASCE	American Society of Civil Engineers
ATIS	Advanced Traveler Information Systems
CAN	Controller Area Network
CICAS	Cooperative Intersection Collision Avoidance Systems
CICAS-SSA	Cooperative Intersection Collision Avoidance System – Stop Sign Assist
CICAS-V	Cooperative Intersection Collision Avoidance System – Violations
ConOps	Concept of Operations
CSW	Curve Speed Warning
DMS	Dynamic Message Sign
DOTs	Departments of Transportation
DSDS	Dynamic Speed Display Signs
DSRC	Dedicated Short Range Communications
DVI	Driver-Vehicle Interface
ESS	Environmental Sensor Station
FHWA	Federal Highway Administration
FRATIS	Freight Advanced Traveler Information System
GID	Geometric Intersection Design
GPS	Global Positioning System
ICWS	Intersection Conflict Warning Systems
ID	Identification
IEEE	Institute of Electrical and Electronics Engineers
ITS	Intelligent Transportation Systems
I2V	Infrastructure-to-Vehicle
JPO	Joint Program Office
MMITSS	Multi-Modal Intelligent Traffic Signal Systems
MUTCD	Manual on Uniform Traffic Control Devices
NHTSA	National Highway Traffic Safety Administration
OBE	Onboard Equipment
RLVW	Red-Light Violation Warning
RSE	Road Side Equipment
RSZW/LC	Reduced Speed Zone Warning with Lane Closure

RTCM	Radio Technical Commission for Maritime Services
RWIS	Road Weather Information System
SAD	System Architecture Document
SAE	SAE International
SPaT	Signal Phase and Timing
SSGA	Stop Sign Gap Assist
SWIW-D	Spot Weather Information Warning – Diversion
SWIW-RS	Spot Weather Information Warning – Reduced Speed
TME	Traffic Management Entity
USDOT	United States Department of Transportation
V2I	Vehicle-to-Infrastructure (Occasionaly this term refers specifically to communication in the direction from the vehicle to the infrastructure, as distinct from I2V. More often, but not always, the term refers to any communication between the vehicle and infrastructure, regardless of the direction that information flows.)
V2V	Vehicle-to-Vehicle

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