Rail Crossing Violation Warning

Architecture and Design Specifications

U.S. Department of Transportation
Federal Railroad Administration

Produced by The U.S. Department of Transportation

with

Support from Battelle under Contract 693JJ6 22 C000037

Federal Railroad Administration

Notice

REPORT DOCUMENTATION PAGE	*Form Approved* *OMB No. 0704-0188*

1. REPORT DATE
2/15/2023

2. REPORT TYPE
Architecture and Design Specification

3. DATES COVERED

4. TITLE AND SUBTITLE
Rail Crossing Violation Warning
Architecture and Design Specification

5a. CONTRACT NUMBER
693JJ6-22-C-000037

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

6. AUTHOR(S)
Gregory Baumgardner, Alejandro Sanchez-Badillo

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Battelle
505 King Avenue
Columbus, Ohio 43201

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
U.S. Department of Transportation
Federal Railroad Administration
Office of Railroad Policy and Development
Office of Research, Development and Technology Washington, DC 20590

10. SPONSOR/MONITOR'S ACRONYM(S)
FRA

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT

13. SUPPLEMENTARY NOTES
Architecture and Design document for the Rail Crossing Violation Warning System

14. ABSTRACT (Maximum 200 words)
The Rail Crossing Violation Warning (RCVW) application provides the means for equipped connected vehicles (CV) on approach to a highway-rail intersection (HRI) to be warned of an imminent violation of an HRI active warning/protective system through the interconnection of a CV Roadside-Based Subsystem (RBS) with track-circuit based train detection systems in place at active HRIs. The system also includes a cloud-based subsystem (CBS) which broadcasts HRI information such as train presence to subscribers.
This document describes the architecture and design for the Vehicle-to-Everything (V2X) Rail Crossing Violation Warning (RCVW) System.
This document supersedes and replaces the RCVW A&D document created under FRA contract number 693JJ6-22 C-000037

15. SUBJECT TERMS
Rail Crossing Violation Warning, RCVW, connected vehicles, CV, Connected Automated Vehicles, CAV, Highway-Rail Intersection, Dedicated Short Range Communications, DSRC, signal phase and timing, SPaT, Map Data, MAP, Institute of Electrical and Electronics Engineers, IEEE, C-V2X, Cloud-Based

16. SECURITY CLASSIFICATION OF:			**17. LIMITATION OF ABSTRACT**	**18. NUMBER OF PAGES**	**19a. NAME OF RESPONSIBLE PERSON**
a. REPORT	**b. ABSTRACT**	**c. THIS PAGE**		54	**19b. TELEPHONE NUMBER** *(Include area code)*

Revision History

Revision	Date	Change Description	Affected Sections/Pages
A	11/29/2019	Initial Release	All
B	7/9/2020	Revision to Include Updated GNSS Solution	Several throughout the document
C	4/03/2023	Revision due to C-V2X technology and the Cloud-based Subsystem	All
D	5/19/2023	Addressing comments from FRA	Several Sections
E	2/15/2024	Design Changes as a result of the CBS Bench Test	Several Sections

Table of Contents

List of Tables

List of Figures

Chapter 1. Scope

This Architecture and Design Specification provides specifications for the Rail Crossing Violation Warning (RCVW) connected vehicle (CV) system and cloud-based messaging system. This document describes the architecture, i.e., the design and integration, of the components that comprise this system including methods of its installation.

The following interfaces are defined herein:

- Roadside-based subsystem (RBS) and vehicle-based subsystem (VBS)
- RBS and the existing highway rail intersection (HRI) controller preemption connection
- RBS and cloud-based subsystem (CBS)
- CBS and third-party stakeholders – authorized subscribers

This document, together with the RCVW Concept of Operations (ConOps) and System Requirements Specification (SRS) documents, provides design details that fulfill the technical objectives of this system.

Chapter 2. Applicable Documents

American Railway Engineering and Maintenance-of-Way Association (AREMA)

- Communications & Signal Manual, Volume 1, Section 3 – Highway-Rail Crossing Warning Systems

United States Department of Transportation (U.S. DOT)

- "Core System of Concept of Operations (ConOps)," US Department of Transportation Research and Innovative Technology Administration ITS Joint Program Office
- DOT HS 812 068, "Human Factors for Connected Vehicles: Effective Warning Interface Research Findings"
- Manual on Uniform Traffic Control Devices (MUTCD) for Streets and Highways, 2009 Edition Including Revision 1 and Revision 2 dated May 2012, US Department of Transportation Federal Highway Administration
- Rail Crossing Violation Warning Concept of Operations
- Rail Crossing Violation Warning System Requirements Specification
- Vehicle-to-Infrastructure (V2I) Hub Design Document, March 2017
- V2I Hub Interface Control Document (ICD), March 2017

Institute of Electrical and Electronic Engineers (IEEE)

- IEEE 802.11p, 2020 Standard for Information technology – Telecommunications and information exchange between systems Local and metropolitan area networks – Specific requirements – Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications
- IEEE 1609, Standards for Wireless Access in the Vehicular Environment (WAVE)
    - IEEE 1609.02019 Standard for Wireless Access in Vehicular Environments (WAVE) Architecture
    - IEEE 1609.22016 – Standard for Wireless Access in Vehicular Environments – Security Services for Applications and Management Messages
    - IEEE 1609.32020 –Standard for WAVE – Networking Services
    - IEEE 1609.42016 –Standard for WAVE – Multi-Channel Operation
    - IEEE 1609.12-2019 Standard for Wireless Access in Vehicular Environments (WAVE) – Identifier Allocations

National Electrical Manufacturers Association (NEMA)

- NEMA TS 2-2021 v.03.08 Standard for Traffic Controller Assemblies with NTCIP Requirements

National Marine Electronics Association (NMEA)

- NMEA-0183 v 4.11 Serial Data Networking

Society of Automotive Engineers (SAE)

- SAE J2735_202211 V2X Communications Message Set Dictionary
- SAE J2945_201712 Dedicated Short-Range Communications (DSRC) Systems Engineering Process Guidance for SAE J2945/X Documents and Common Design Concepts
- SAE J2945/1_202004 On-Board System Requirements for V2V safety Communications
- SAE J2945/2_201810 Dedicated Short-Range Communications (DSRC) Performance Requirements for V2V Safety Awareness
- SAE J2402_201001 Road Vehicles - Symbols for Controls, Indicators, and Tell-Tales

Chapter 3. System Overview

System Overview and Context

The RCVW system will leverage the components and technologies developed under previous U.S. DOT CV deployment projects and will include additional capabilities to enhance the safety of CVs at HRIs.

The RCVW system will consist of three physically separate subsystems: A VBS installed in vehicles, an RBS interconnected with roadside infrastructure at HRIs and a CBS that interfaces to the RBS to provide HRI related information to authorized subscribers via the internet.

These subsystems will share some common hardware and software components, as well as include unique components. The RCVW system in its entirety will include the following components:

- Computing Platform (CP) – The heart of the RCVW system is the CP, utilized in both the VBS and the RBS. The CP includes: a central processor, interfaces to the other supporting subsystems, and RCVW specific software applications.
- Data Communication Radios (DCR) – DCRs will be utilized in both the VBS and the RBS. DCRs and associated protocols will provide low-latency wireless communications between the two systems.
- Data Communication Backhaul – The RBS will be connected to the CBS via a wide-area network (WAN) that is likely to include one or more wireless links. *This connection is not provided by the RCVW system.*
- CBS – The CBS will serve as an intermediary between the RBS and third-party application services to provide HRI activation status via the internet.
- Global Navigation Satellite System (GNSS) – A multi-band GNSS module will be utilized within the VBS, to provide sub-meter positional accuracy. The positional corrections data required to attain this degree of accuracy will be supplied from the RBS via the DCRs. The corrections data will be either provided by a GNSS base station incorporated within the RBS architecture or received from the CBS[1] via the RBS.
- Driver-Vehicle Interface (DVI) - The RCVW interface to the CV driver will be utilized to provide the vehicle driver RCVW warnings and alerts.
- Software Applications – Each of the RCVW subsystems will implement specific software applications based on their specific functionality.

[1] The RBS will have the on-site-configurable option of providing corrections data from a collocated GNSS base station for cases where communication to the CBS is: not possible (i.e., areas with no cellular or internet connectivity) or dependable.

The interface to information sources external to the RCVW system will be managed by the V2I Hub software. The V2I Hub software is a communication platform based on the SAE J2735 and SAE J2945 standards (see Applicable Documents section). This platform was developed for the DOT sponsored V2I Reference Implementation project to support infrastructure communications for CV applications. It consists of a set of integrated plugins to supply and receive information from the RCVW system components. The V2I Hub plugins used by the RCVW application include means to interface with the HRI controller, report HRI activation status, produce the HRI geometry message (MAP), report RBS operational status, facilitate connectivity with the DCRs, and manage GNSS location and its correction data.

The RCVW system leverages the V2I Hub design and documentation. Additional details on the V2I Hub along with supporting documentation and other reference materials are available at www.its.dot.gov/code

The transmission of the HRI activation status from the roadside to the vehicle is the primary use case for RCVW. However, other use cases for the system have emerged that include scenarios that will enhance road user awareness. When compared to the primary use case, these having less stringent latency and reliability requirements, lend themselves well to a cloud-based design. The CBS has been added to the RCVW architecture as an easily accessible way to facilitate communication of HRI information to external applications that may implement these scenarios, many of which are documented in the RCVW System Requirements Specification.

A more descriptive overview of the RCVW System can be found in the "Rail Crossing Violation Warning – Concept of Operations" document.

Chapter 4. System Architecture

This chapter provides an overall system description of the physical design of the RCVW system including the logical organization for each of the hardware used in the system and their corresponding subsystem connections.

RCVW System Architecture Overview

A high-level architectural view of the RCVW System is shown in Figure 1 below. Since the RCVW system was developed on top of the existing V2I Hub software and hardware that were completed on the Integrated V2I Prototype (IVP) and V2I Hub projects, the design of the RCVW system is constrained to that of the system created by these projects. The V2I Hub plugin architecture can be found in the referenced V2I Hub Design document and V2I Hub Interface Control Document (ICD) document. The orange-colored components are existing devices which when interfaced with the RBS, VBS and CBS as shown comprise the RCVW system. Hardware components, their functionality, inputs, outputs, software, communications, and interface details are provided in the following sections of this document.

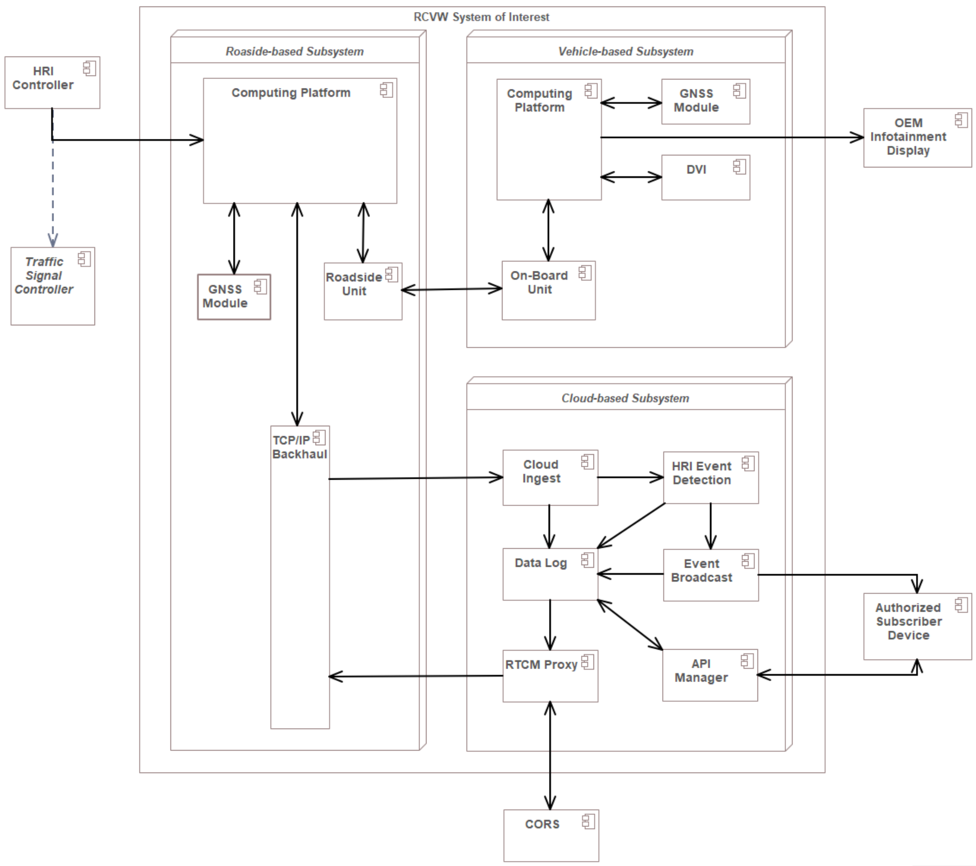


Figure 1. RCVW System Architecture Overview

Source: Battelle

Computing Platform

Identical CPs will be employed by the VBS and RBS. Both CPs will employ the V2I Hub software developed under the IVP and V2I Hub projects. The V2I Hub software allows plugins to share information between each other in a V2I Hub system and broadcast information via Cellular Vehicle-to-Everything (C-V2X) radios. Utilizing the V2I Hub will facilitate a reduction in deployment time and effort through the reuse of plugins already developed for other projects. The VBS will also use the V2I Hub as its main communication hub to receive messages from the RBS and make those messages available to other RCVW VBS plugins. The RCVW plugin on the VBS contains an application to use inputs supplied by other plugins, including J2735 MAP and Signal Phase and Timing (SPaT), and GNSS to determine when an RCVW warning, or an inform alert, will be presented.

Operating System

The Operating System (OS) selected for the CPs is Linux as it allows a flexible platform for product development due to it being open source and easily customized. In addition to the OS layer, the RCVW will be developed using a set of loosely coupled plugins which will be responsible for registering with the V2I Hub. As part of registration, a plugin will notify the hub which message types it will produce and transmit. Each plugin will also identify which message types it will request to receive from the V2I Hub. Plugins can be either message producers, message consumers or both. A high-level overview diagram of the V2I Hub platform is presented below in Figure 2.

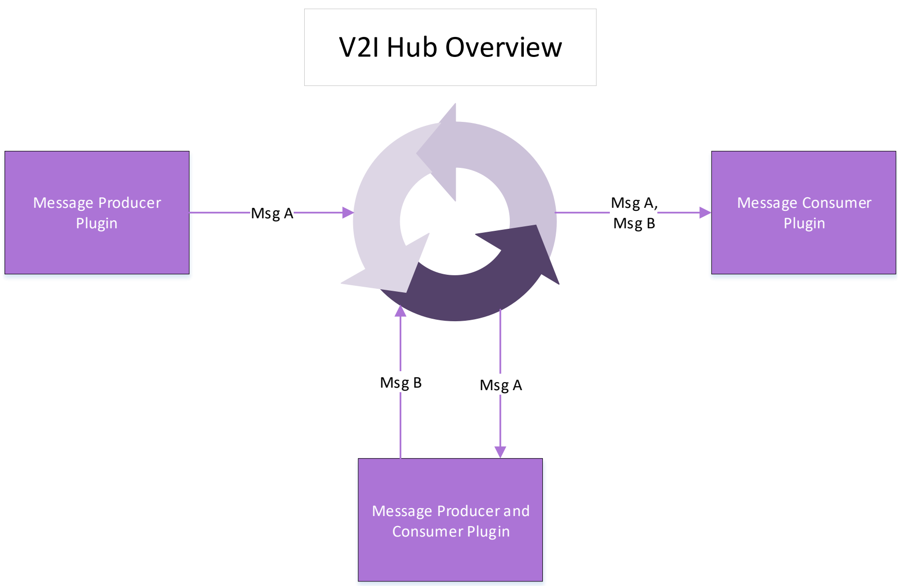


Figure 2. V2I Hub Overview

Source: Battelle

Data Communication Radios

The C-V2X radio transmits and receives messages in accordance with the IEEE 802.11p, 1609.2, and J2735 message standards. Communications from the Roadside Unit (RSU) will be User Datagram Protocol (UDP) immediate forward-raw data payload messages as defined in the RSU 4.1 specification. A sample MAP message is shown below in Figure 3. Table 1 shows a listing of the RCVW radio messages broadcasted by the RBS via the C-V2X radios.

The RCVW system will utilize SPaT, MAP and Radio Technical Commission for Maritime Services (RTCM) corrections messages from the J2735 message set. These messages will be generated by the RBS and broadcasted by a C-V2X radio. The MAP messages will contain the intersection geometry including the vehicle lanes and tracked vehicle lanes (train tracks) for the HRI. These messages will be received and used by the VBS to fix its location when approaching an HRI (i.e., the HRI Hazard Zone or HRI Approach Zone). The SPaT message will contain the status of each lane in the HRI. For example, at a simple HRI with vehicle lanes crossing a train track and no roadway traffic intersection present, when the HRI is not active, the status of the vehicle lanes will be 'permitted movement allowed' and the tracked vehicle lane will be 'stop and remain.' When the HRI is active, the status of the vehicle lanes will be 'stop and remain' and the tracked vehicle lane will be 'permitted movement allowed.' SPaT information will be used by the VBS to determine HRI activation status-based messaging. The RTCM corrections messages will be used for deriving the VBS position solution. For more detail on the format of these messages, refer to the 2020 SAE J2735 DSRC Message Set Dictionary.


```
Version=0.5
Type=MAP
PSID=0xBFF0
Priority=7
TxMode=CONT
TxChannel=172
TxInterval=0
DeliveryStart=
DeliveryStop=
Signature=True
Encryption=False
Payload=3081DE800110810900000000000000001000830101A481C63081C3800102A11BA119A01080
0418054A3B8104CE3585DF82020D0681020040820102820207DB830306162184027D00850102A61
080041804FD888104CE35C39E82020CF68702016E880100A93C303A80020040A234A032A3300404
1C6BCDB304040420EC2B0404FAC8EC280404EF79F1210404EBC4FD660404E65310690404F9621
AA50404095B3F31AA3AA0383006A004800235293006A0048002010C3006A004800231383006A00
4800222113006A0048002010C3006A004800231483006A0048002221185021001
```


Figure 3. Map Data File to be Sent over UDP

Source: usdot-rsu-specification-4-1_final_r1.pdf, version 1, October 31, 2016, section 3.4.4

Table 1. RCVW System Message Types

Common Message Name	PSID[1]	Application	SAE J2735 message
Signal Phase and Timing (SPaT)	0x8002	RCVW	MSG_SignalPhaseAndTiming[2]
MAP message (Geographic Intersection Description)	0x8002	RCVW	MSG_MapData
RTCM correction	0x8000	RCVW	MSG_RTCMcorrections

Source: Battelle

GNSS Receiver

The GNSS receiver within the VBS provides the vehicle's location and speed and sends this information to the CP for the generation of in-vehicle alerts and warnings. The GNSS module interfaces with the CP to gather and process the received RTCM corrections to generate accurate vehicle speed and location (within 1.5-meter accuracy). The RBS can be configured to create its own RTCM corrections via the addition of a GNSS module. A GNSS module will function as a base station generating RTCM messages. These messages will then be communicated to the CP at the RBS and subsequently broadcast via the C-V2X radio.

Driver Vehicle Interface

The Driver Vehicle Interface (DVI) is the how the RCVW communicates warnings and alert messages to the vehicle driver. For example, an inform alert is displayed and announced if a "known" RBS is not operational/broadcasting. Similarly, a warning is displayed and announced if vehicle is on course to violate the HRI and/or the roadway vehicle is stopped within the HRI Hazard Zone.

TCP/IP Backhaul

The Transmission Control Protocol/Internet Protocol (TCP/IP) backhaul is how the RBS will exchange information with the CBS. It will be a low latency high-speed internet connection ethernet / WiFi. Similar to the communication between the RBS and the VBS, the RBS will broadcast both MAP and SPaT messages to the CBS following the SAE J2735 standard. The MAP message will contain the intersection geometry including the vehicle lanes and tracked vehicle lanes for the HRI. The SPaT message will provide the status of each lane in the MAP message along with the corresponding HRI ID. RBS system diagnostic messages will also be transmitted to the CBS as a result of periodic system self-checks. The CBS will transmit RTCM SC-104 correction messages to the RBS which will subsequently be relayed to the VBS following the J2735 standard.
Error! Reference source not found. presents the different messages that will be broadcasted over the backhaul.

[1] PSID: Provider Services Identifier
[2] J2735 script uses SPAT versus SPaT

Table 2. Message Exchange over the Backhaul

Common Message Name	Message Standard	Sent by	Received
Signal Phase and Timing (SPaT)	J2735	RBS	CBS
MAP message (Geographic Intersection Description)	J2735	RBS	CBS
RTCM correction	RTCM SC-104	CBS	RBS
RBS System Diagnostics	TCP/IP	RBS	CBS

Source: Battelle

Cloud Ingest

Cloud service providers generally have advanced capabilities for high-volume data ingest, but many are tailored to Internet of Things (IoT) events that do not require real-time upload. For RCVW, however, the expectation is that the messages will be pushed to the cloud at the same frequency as they will be transmitted to the VBS. That is once per second (1 Hz) for MAP and ten times per second (10 Hz) for SPaT. The RCVW cloud provider offers two potential solutions for rapid incoming messages: Service Bus and Event Hubs. The Service Bus offering uses Advanced Message Queuing Protocol (AMQP) while Event Hubs use partitions like Apache Kafka. Benchmark testing shall be used to determine the more appropriate solution for RCVW.

HRI Event Detection

Cloud based functions are scalable serverless solutions for creating state-driven programs in the cloud. Each incoming SPaT message will trigger a function execution for the specified HRI. When the HRI activation status transitions from inactive to active, or vice versa, the function will create a new HRI Event message. Depending on System Diagnostic messages, the CBS may also generate System Fault events for that HRI.

Data Log

For prototype purposes, the RCVW CBS will log every MAP, SPaT, and RBS operational Status message that it receives as well as every Event Message that it generates into a cloud-based data store. Event Messages will be available in the data log for use in subscriber applications.

Event Broadcast

HRI Event messages including Signal Status and System Faults, that are produced by the CBS will be posted to an Event Streaming Endpoint to support the pushing of messages to a subscriber, for example a TMC, listening for events. In Azure this is facilitated by the Azure Service Bus.

RTCM Proxy

For every received MAP message, which includes the GNSS location of the HRI, the RCVW CBS will initialize a proxy service that uses the Networked Transport of RTCM over IP (NTRIP) protocol to obtain GNSS corrections from a networked base station within the Constantly Operated Reference Station (CORS) network. These corrections are relayed back to RBS over the TCP/IP backhaul and ultimately broadcast over the RBS DCR. It is important to note that a failure of the proxy service or the backhaul network may cause the RCVW VBS to report an error state due to missing corrections.

Application Programming Interface Manager

HRI activation status information retrieval is best implemented through the existing cloud provider's Application Programming Interface (API) management capabilities, allowing for simplified development for the subscriber applications.

Chapter 5. Component Architecture

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in **Error! Reference source not found.**4. This figure identifies the main components and the associated interconnects that are required.

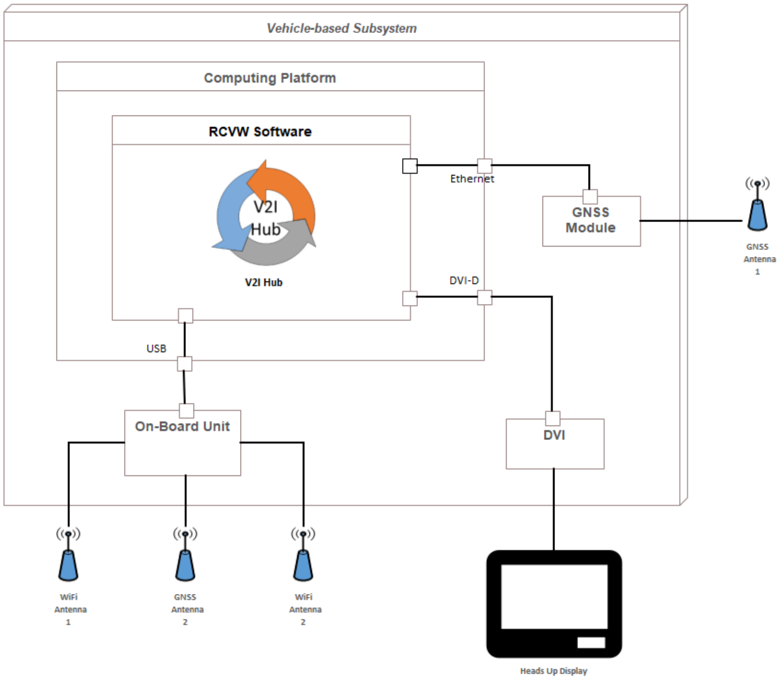


Figure 4. RCVW VBS Block Diagram

Source: Battelle

The hardware for the VBS will consist of the following:

- Computing Platform
- C-V2X Radio
- C-V2X Antenna 1 and C-V2X Antenna 2 and GNSS Antenna
- GNSS Receiver and Antenna
- DVI

Supporting Equipment

- OEM Infotainment System or Heads-up Display

Interfaces

- Computing Platform
- Serial interface to C-V2X On-Board Unit (OBU) DCR
- Ethernet (TCP/IP) interface to GNSS device
- High-Definition Multimedia Interface (HDMI) to Driver Visual Interface / OEM Infotainment System

Computing Platform

The CP will serve as the central hub for all RCVW activity on the CV. This device will communicate with the other RCVW subsystems as well as the external equipment on the CV. The CP will contain the RCVW algorithm which will process all the information it receives from the RBS and the GNSS module to process alerts and warnings to the vehicle driver. The hardware of the CP was chosen from existing commercial options that offer rugged systems specifically designed for advanced vehicle applications. With the desire to use a common CP for both RBS and VBS RCVW systems, the basic requirements of the hardware were to support high-speed Ethernet, TIA/EIA-422, Digital I/O, USB, WiFi and DVI connectivity. While there are existent CPs that integrate C-V2X radio communication along with cellular networking and GNSS, the final design was simplified by decoupling the necessary wireless communication, namely GNSS and C-V2X radio, into external hardware models. The full specifications of the CP can be found in Appendix B.

GNSS

The GNSS module will be used to determine the position of the VBS. The position accuracy of the GNSS must be sufficient to allow placement of the VBS within the lane information provided by the J2735 MAP message. The requirements document specifies a GNSS accuracy of +/-1.5 meters in order to achieve lane-level accuracy for the VBS. The VBS will use an uBlox ZED-F9R RTK multi-band GNSS device which integrates the GNSS measurements with an inertial measurement unit, wheel ticks and RTCM corrections (broadcasted from the RBS) to enhance the positioning resolution. The GNSS device will interface with the CP via a Universal Serial Bus (USB) connection. The full specifications of the GNSS devices can be found in Appendix D.

Data Communication Radio

The VBS will use a C-V2X radio unit to receive the J2735 messages from the RBS. The Danlaw Autolink C-V2X OBU device was selected from several commercially available devices. This unit allows the broadcast of vehicle-to-everything safety communications over the upper 30 megahertz of the 5.9 GHz band and interfaces with the CP via its ethernet port. The unit is equipped with a WiFi, Bluetooth and Long Term Evolution (LTE) interfaces for future functionality expansion. The full specifications of the Data Communication Radios can be found in Appendix C.

Driver Visual Interface

The DVI for displaying and annunciating alerts and warnings will be a commercial-off-the-shelf external LCD display with speakers. The speakers will have adjustable volume allowing the driver to hear the aural annunciations inside a vehicle above ambient noise. A HDMI/DVI-D cable will be used as an interface between the DVI and the CP. The DVI will be receiving the information via its HDMI port and the CP sending it via its DVI-D port.

OEM Infotainment System

The OEM (Original Equipment Manufacturer) Infotainment System is an in-vehicle system produced by the vehicle manufacturer that controls various non-safety critical functions like the radio and climate control. Examples of infotainment systems are the Ford Sync system, Chrysler UConnect, Android Auto and Apple CarPlay. Interfaces to each OEM's infotainment system is vehicle specific. In cases where using an infotainment system is not possible or otherwise impractical, a custom heads-up display will be used.

Software

This RCVW application will be designed to interface with the V2I Hub software platform. The logic required to perform the needed functions will be developed as a set of plugins. Each plugin will perform a single discrete function. The diagram in Figure 5, illustrates the plugins, including how they interact with RCVW system components.

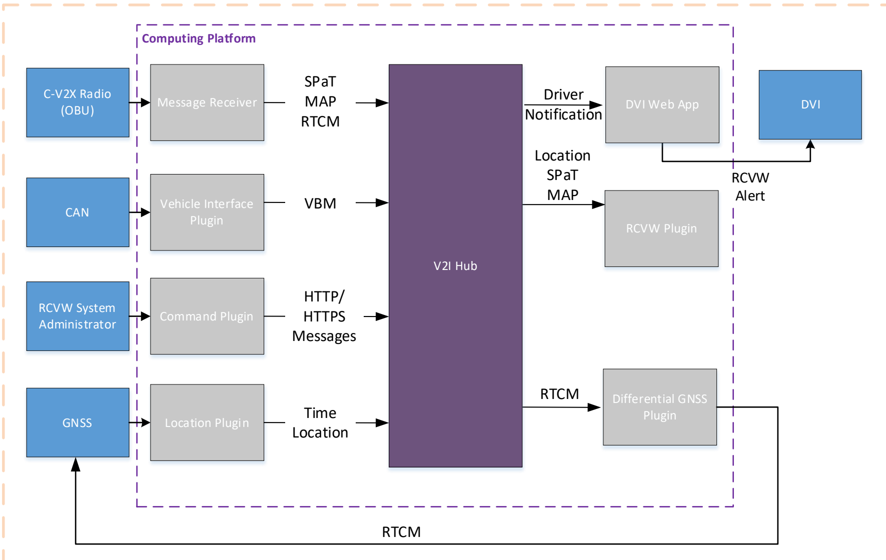


Figure 5. VBS Software Design

Source: Battelle

Table 3 below, provides a brief description of each plugin and its associated data exchange. The internal format of the messages is described in the IVP Design document's IVP Java Script Object Notation (JSON) Message Structure section.

Table 3. RCVW System VBS V2I Hub Plugins

Plugin	Description	Plugin Input	Plugin Output
Location Plugin	This plugin will interface with the GNSS hardware and provide the current location and time information to the rest of the system.	Output stream from GNSS receiver	Location Message
Message Receiver Plugin	The Message receiver plugin relays messages received via the C-V2X radio to the rest of the system.	Messages from C-V2X Radio	SPaT Message MAP Message RTCM Message
DVI Web App	The Driver Notification web application will alert/warn the vehicle driver via visual and audible cues.	RCVW Inform Alerts Clear HRI Warning RCVW System Failure	Suitable audio output annunciated via DVI speakers Events shown on driver display
Vehicle Interface Plugin	The Vehicle Interface plugin will connect to the vehicle's controller area network (CAN) to access Vehicle Basic Messages (VBM).	OBD-II messages	VBM message
RCVW Plugin	The RCVW Plugin processes information from VBS support plugins and the CP to determine if and when to issue driver warnings and alerts.	SPaT Message MAP Message Location Message	Driver Notification Message
Command Plugin	Interfaces with V2I Hub administration portal.	HTTP/HTTPS messages	N/A
Differential GNSS Plugin	This plugin receives J2735 RTCM correction messages and passes the correction information directly to the GNSS receiver.	RTCM Message	N/A

Source: Battelle

Figure 6 below shows the applications and their data flow inside the RCVW VBS. To simplify the diagram, the V2I Hub core message router is not shown. Plugins that produce and send messages to V2I Hub will have a line to the consumer of those messages. Additional details regarding the RCVW application for the VBS are described below.

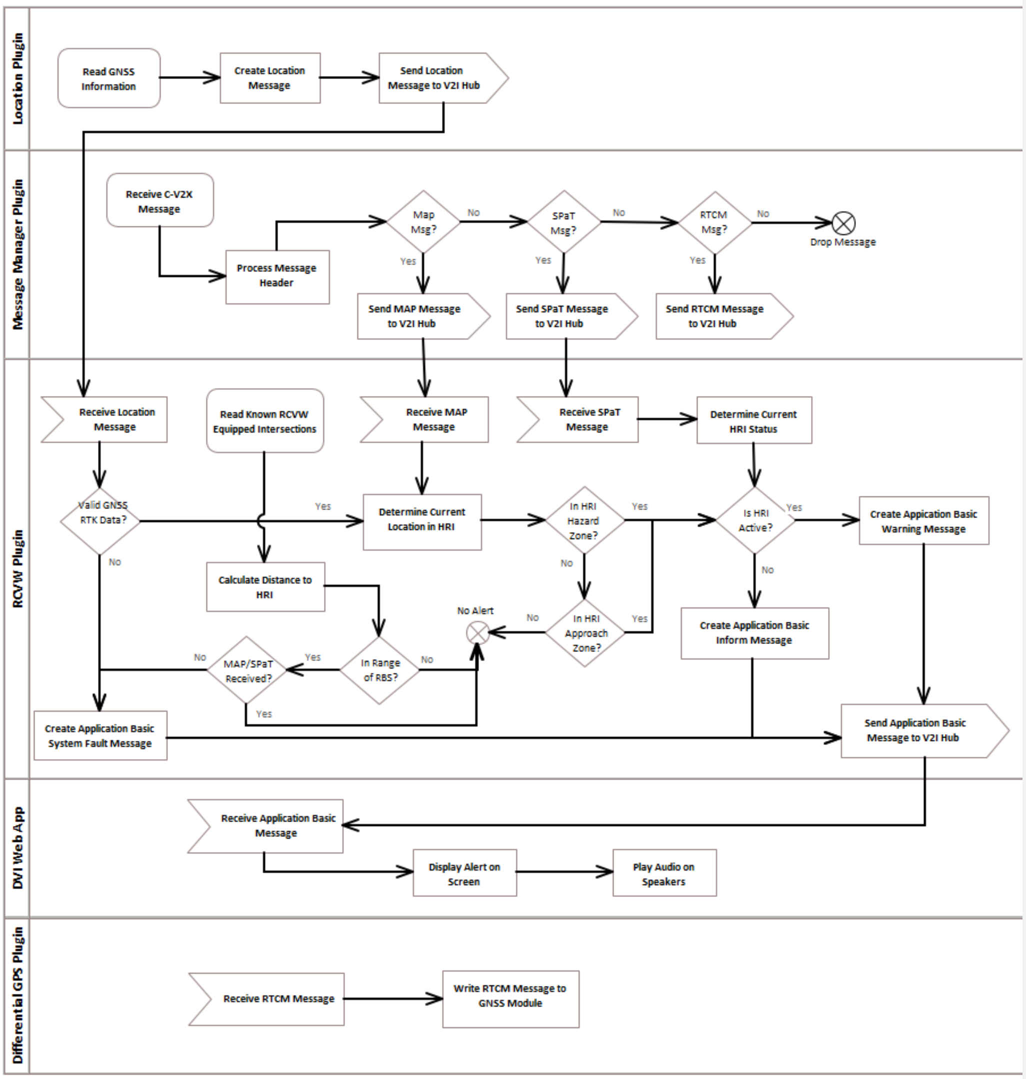


Figure 6. RCVW VBS Application Data Flow

Source: Battelle

VBS Support Plugins

The RCVW application plugin is supported by a suite of plugins designed to interface with the V2I Hub platform. The Message Receiver plugin acts as the interface to the C-V2X radio and converts the received J2735 messages into a generic format used by the V2I Hub platform. The differential GNSS plugin will correct the GNSS position using the correction data from the RTCM J2735 message. The

DVI Web application is responsible for both issuing visual and audible warnings and alerts to the driver and uses notification outputs from the RCVW plugin application to do so.

Vehicle Interface Plugin

The Vehicle Interface Plugin will notify the driver with an alert when the VBS is on track to intercept an HRI and is within nominal C-V2X reception range of a “known” RBS-equipped HRI and has not received any messages. The alert from the Vehicle Interface Plugin will notify the driver that the RBS is not operating properly, and to proceed with caution.

RCVW Application Plugin

The RCVW application plugin continuously executes the RCVW algorithm and actively monitors MAP messages received. Based on the receipt of the MAP message from the RBS and the current vehicle location provided by the Location plugin, the RCVW application plugin will determine if a vehicle is approaching an HRI, and more importantly, its location relative to the HRI. When it has been determined that a vehicle is approaching the HRI, the application plugin will receive the HRI Hazard Zone geoSPaTial information and compute the HRI Approach Zone for a vehicle based on typical operator response time, vehicle characteristics, and instantaneous location and speed. The safe-stopping distance derived by the HRI Approach Zone algorithm ensures that the driver will be provided a timely warning in the event of a predicted rail crossing violation. The RCVW application plugin will monitor the received SPaT messages for the HRI Active status. When a vehicle is within the HRI Approach Zone of an active HRI, the RCVW application plugin will determine if an alert/warning is needed to avert a potential RCVW.

Roadside-based Subsystem

The RBS will wirelessly transmit to approaching vehicles specific details regarding the physical layout of the intersection, HRI activation status, and GNSS corrections. Additionally, the RBS will transmit over TCP/IP to the CBS the layout of intersection, HRI activation status, and its current operational status.

Hardware

A hardware block diagram for the RCVW RBS is shown in **Error! Reference source not found.**. This figure identifies the main components and the associated interconnections that are required.

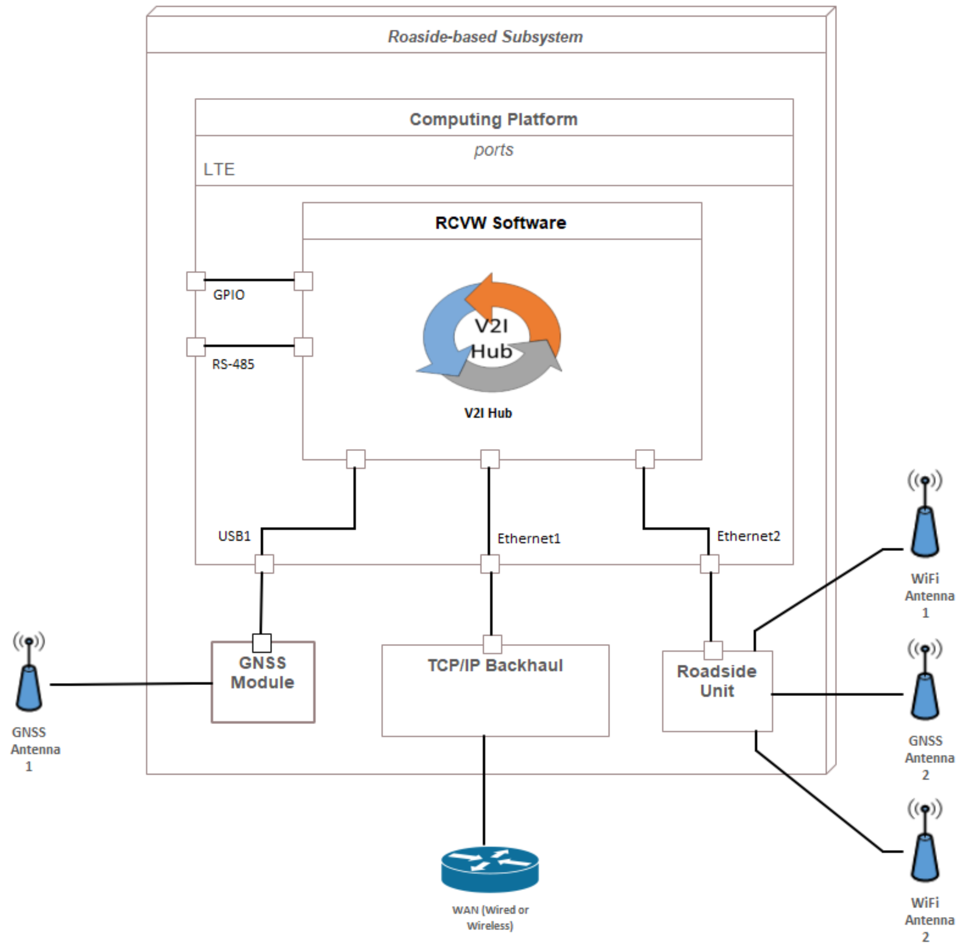


Figure 7. RBS Block Diagram

Source: Battelle

The RBS will consist of the following hardware:

- Computing Platform
- C-V2X Radio
- C-V2X Antenna 1 and C-V2X Antenna 2 and GNSS Antenna
- GNSS Receiver and Antenna
- External TCP/IP backhaul to WAN

Interfaces

- Computing Platform
    - Interface(s) to receive HRI activation status
    - Bi-directional interface(s) with IEEE-1570 device (if present)
    - Serial interface to GNSS device
    - Ethernet interface to C-V2X RSU communication radio
- TCP/IP Backhaul
    - Wireless interface to WAN
    - Wired interface to WAN

Computing Platform

The CP will receive, integrate, generate and distribute the appropriate RCVW related information to both the VBS and the CBS. Specifically, the RBS CP will receive the HRI activation status information from the HRI controller as well as receiving the RTCM corrections from the local GNSS base station or the CBS to create the C-V2X data messages to be broadcasted over the DCR. The RBS CP hardware will be an instance of the CP described in the Vehicle-based subsystem section.

GNSS

The GNSS module located at the RBS will serve as a local RTK base station to generate RTCM corrections. These corrections will be interfaced to the CP to be incorporated into a message that can be broadcasted over the C-V2X DCRs and to be used by the VBS to enhance the accuracy of its location. The RBS will use an uBlox ZED-F9P RTK multi-band GNSS base station. The device will interface with the CP via a USB connection. The full specifications of the GNSS devices can be found in Appendix D.

Data Communication Radios

The RBS will use a C-V2X RSU to transmit the J2735 messages generated by the RBS CP. The Danlaw Routelink C-V2X RSU was selected. Similar to the OBU previously described, the RBS RSU uses the upper 30 megahertz of the 5.9 GHz band to broadcast the HRI related information and interfaces with the CP via a Power Over Ethernet (POE) port. The full specifications of the Data Communication Radios can be found in Appendix C.

Train Detection Signal

The train detection system is the source of the HRI activation status within the RCVW SPaT message. The HRI Active message is initiated by the preemption/train detection signal from the HRI controller.

The suggested connectivity is the built-in DB-15 Data Input-Output (DIO) connector on the CP. Pins 1,2, 10 and 11 are discrete inputs, pin 3 and pin 9 are grounds. Input voltages are between 5-24 V for a logic high and 0-1.5 V for logic low. By wiring the preemption signal to Pin 1 and ground to Pin 9, the HRI status plugin can be set up to detect the train by voltage on Pin 1. Note that the configuration of the pin is zero-based in software (i.e., 0 is the first pin).

The second of two possible configurations for train detection is the IEEE 1570 protocol over a serial TIA/EIA-422 interface. To do this, the RBS system must be connected to an IEEE 1570 device using a serial cable connected to the COM-1 port on the CP. This port should be configured to use TIA/EIA-422 protocol. The HRI status plugin port name must be configured with the serial device name for

COM-1, which should be "/dev/ttyS0". If the port name is left empty, the system assumes that voltage detection is being used at the specified pin. If no device is connected at the COM-1 port or at the DIO pin 1, then the RBS system will always assume that the HRI is active.

Software

The RBS software is designed to provide MAP, SPaT, and RTCM messages so that the VBS may determine if and when inform alerts and/or warnings will be presented to the driver.

The RBS software will be designed to interface with the V2I Hub software platform as a set of plugins. Whenever practical, common functionality between the two subsystems will utilize the same plugins. Figure 8 provides a block diagram showing the design of the software.

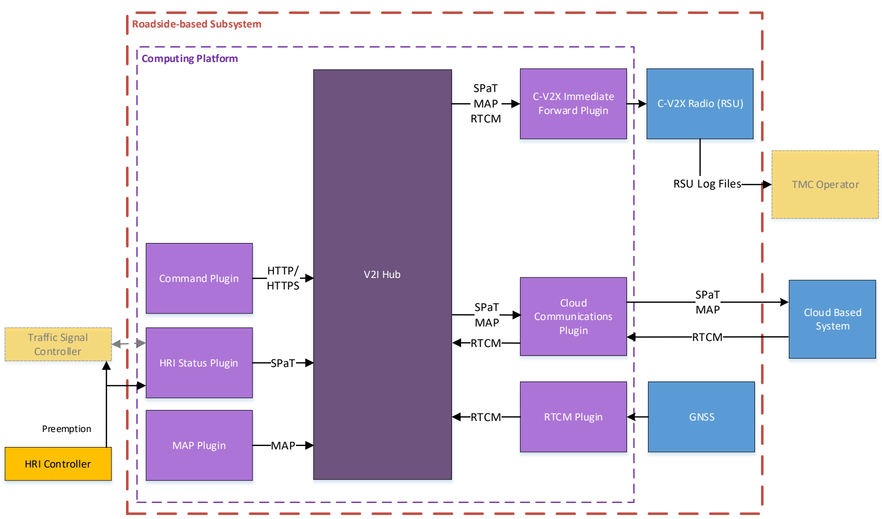


Figure 8. RBS Software Design

Source: Battelle

The core plugins in the RBS provide situational information for the intersection. Both the MAP and SPaT plugins were developed for the V2I Hub project and will be used to the maximum extent practical. Required modifications to the SPaT system include adding functionality to monitor the preemption signal status in order to set the lane status to stop and remain so when the HRI is active. The remaining plugins will support the task of providing the other required information. Table 4 below outlines each plugin to be used in the RBS along, with the messages produced and consumed by each plugin.

Table 4. RCVW System RBS V2I Hub Plugins

Plugin	Description	Plugin Input	Plugin Output
MAP Plugin	The MAP plugin will be responsible for generating the appropriate MAP message for the specific intersection.	HRI geometry loaded from filesystem	MAP Message
HRI Status Plugin	The HRI Status plugin is responsible for interfacing with the HRI controller and generating HRI Activation Status messages. The HRI Status plugin is also responsible for interfacing to the IEEE-1570 device when present.	Output from HRI controller	SPaT Message
C-V2X Immediate Forward Plugin	The C-V2X Immediate forward plugin is responsible for taking internal messages flagged for transmission and ensuring they are sent out via the C-V2X radio.	SPaT Message MAP Message	Input to C-V2X radio to send appropriate message
Location Plugin	This plugin will interact with a GNSS receiver and supply the system with location and time information.	GNSS NEMA Sentences	Time and Location Information
Command Plugin	Interacts with V2I Hub administration portal.	HTTP/HTTPS messages	N/A
RTCM Plugin	The RTCM Plugin is responsible for receiving GNSS corrections from the CBS or the RBS GNSS base station and creating the RTCM correction message	RTCM	RTCM Message

Source: Battelle

More information and details on the dataflow of these plugins can be found in Chapter 6 .

RCVW Cloud component

The CBS will provide an alternative communication mechanism to potentially relay HRI related information to drivers of vehicles that are not equipped with CV technology, as well as any authorized subscribers. The data will be shared between disjointed devices through an intermediary in the cloud facilitating connectivity through a publicly accessible virtual infrastructure.

The CBS will monitor the activation status of the HRIs that are registered in the cloud by means of periodic V2X messages pushed from RBS-equipped HRIs. The HRI activation status will be available for any partner application service to consume. A block diagram of the CBS is provided in Figure 9.

Commented [A1]: Update this graph

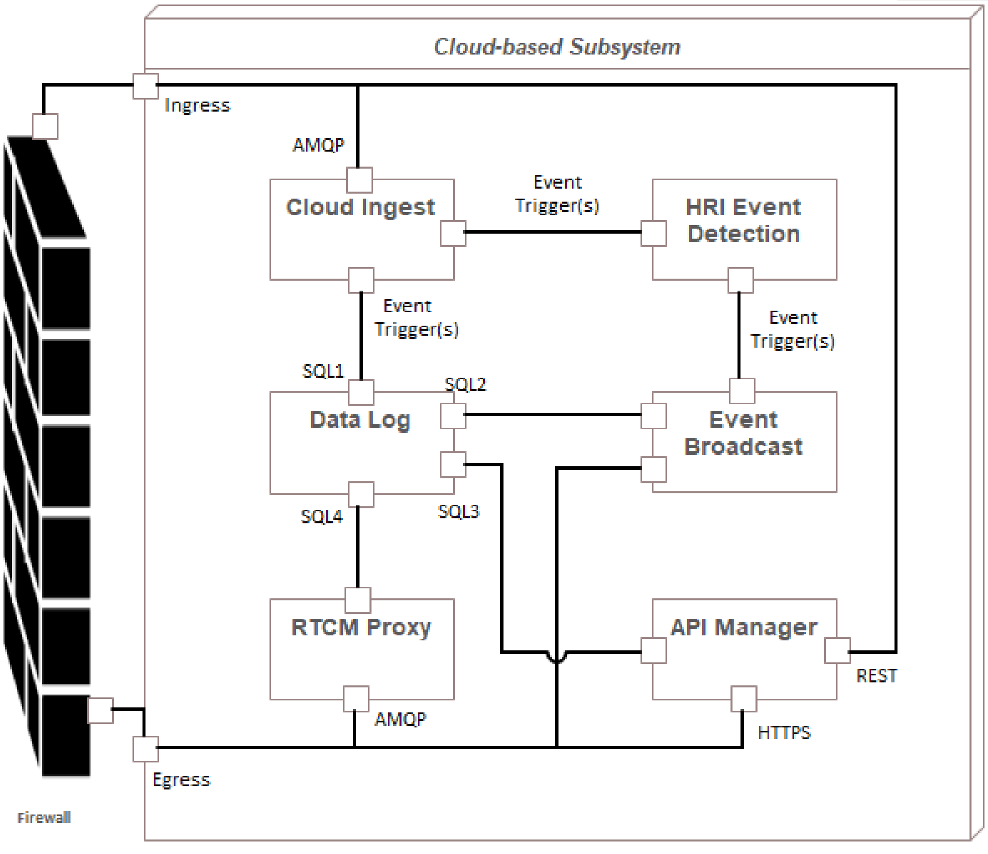


Figure 9. Cloud Based Subsystem Block Diagram

Cloud Software

The CBS component is designed to run within a commercially available cloud environment and compatible with any cloud platform, provided that the following basic set of requirements is established:

- Built-in network firewall
- High-volume, low latency ingest queues
- Automatic function invocation
- Relational data storage
- Easy to create and highly available web-based API support

The MS Azure cloud environment has been selected for the prototype implementation of the CBS due to its native support of each of these features. However, each CBS component is explicitly containerized to support individual deployment independent of the cloud provider. Some of these containers, such as the API Manager, run as a server process supported by Azure Container Apps that directly responds to external requests. Several others, however, execute as short bursts of processing supported by Azure Function Apps in response to system events such as an incoming message.

Cloud Ingest

The key role of the CBS implementation is to receive messages from the RBS as quickly and reliably as possible. The V2I Hub utilizes the Apache Kafka message streaming service for internal communications. Therefore, the Azure Event Hubs are highly attractive for their native support of Kafka streaming and similar constructs such as partitions.

Data Log

While cloud systems provide many advanced data storage options, the nature of the data being stored and shared as part of the RCVW CBS lends itself well to a traditional Structured Query Language (SQL) database. However, the underlying relational database management system (RDBMS) for use in the cloud should consider distinctive features such as native support for JSON in order to log V2I Hub messages without defined schema.

HRI Event Detection

This cloud native code will be invoked automatically upon a new SPaT message ingest. Since the SPaT message signifies the HRI identifier as well as the current state of that HRI, the function must also know the previous state of each HRI. This data must be "persisted" between received messages. Only when the HRI state is different than the persisted value will an HRI Status Event be created. Most other interesting HRI Events include fault situations such as lost connectivity to the RBS, failed RBS software, or message delivery rates dropping below pre-determined thresholds. All new HRI Events are stored in the data log and sent to a broadcast queue.

HRI Event Broadcast

This function will empty out the broadcast queues to the appropriate Event Streaming Endpoint. This is used for scenarios that are only interested in the corresponding HRI preemption signal status and wish to be notified of changes to that status when they occur. In order for easy coding at the subscriber end, the underlying messaging transfer technology will follow the Advanced Message Queuing Protocol (AMQP)[1], which is a publish/subscribe data distribution model.

Commented [A2]: AMQP link to white paper

API Management

The API Management component provides an HTTP-based API that can be used by authenticated subscribers to query data from the data log. The goal is to utilize as many native features in the MS Azure as possible while conforming to the Representational State Transfer (REST) web standard for

[1] AMQP is commonly used for cloud publish/subscribe architectures and is supported by the Microsoft Azure Service Bus. See the *Cloud Access Performance Testing* technical memorandum for details on the assessment of select cloud supported technologies.

APIs. The Azure Data API Builder (DAB) product is a perfect fit for RCVW since it creates a RESTful API directly from a Azure SQL Database table or view. Therefore, the entirety of the HRI Data Log can be exposed through a RESTful query. RCVW does, however, enhance the default capabilities of DAB by including verification of subscription through the use of a unique identifier.

Commented [A3]: Change here

RTCM Proxy

Given a known HRI location, this function will make an HTTPS connection to pre-configured CORS NTRIP casters on behalf of the RBS. The NTRIP protocol requires a GNSS GPS Fixed Data (GGA) National Marine Electronics Association (NMEA) string to seed the location, therefore the RTCM Proxy must generate its own GGA string based on the known location of the HRI. The returned RTCM corrections are forwarded directly to the RBS as a V2I Hub message that will then be picked up by the RTCM plugin on the RBS for forwarding out of the radio.

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

Chapter 6. RCVW Design

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

The RCVW's main function is to provide additional information to the public regarding the activation

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

status of an HRI beyond the existent warning devices. The ConOps describes four distinct

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

information sharing scenarios that are designed into the system, many of which take advantage of the

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

ubiquity of cloud service provider capabilities:

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

1. **RCVW CV Local Safety Messaging**: The driver of a CV approaching an HRI receives in-

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

vehicle alert and/or warning based on HRI activation status, the vehicle speed, and

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

subsequent actions. This is a safety-critical operation.

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

2. **RCVW Cloud-based HRI State Messaging**: The driver of a non-CV in proximity of the HRI

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

receives notifications regarding the current activation status of the HRI by means of a

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

subscription to a cloud service. This is a safety-related operation.

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

3. **RCVW Cloud-based Correction Messaging**: Positioning corrections are proxied from

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

external reference stations for use at an RBS.

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

4. **RCVW Cloud-based HRI Information Messaging**: Immutable HRI information and/or

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

current RBS operational status is disseminated to subscribed applications.

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

These functionalities incorporate diverse elements and different architectural designs. This section

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

will go over a description of the RCVW component architecture and design required to implement

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

each of the messaging scenarios. Additionally, this chapter covers overarching considerations such

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

as the system inputs, outputs, and hardware and software interfaces.

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

RCVW CV Local Safety Messaging Design

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

This section describes the design for the RCVW safety system utilizing a localized CV messaging

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

exchange between the RBS and VBS only. The RCVW system incorporates the following elements

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

as part of its design:

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

- HRI Hazard Zone

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

- HRI Approach Zone

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

- Rail Warning Markings and Signs

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

- Active Warning and Control Devices

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

The HRI Hazard Zone (the area between the stop bars on either side of the grade crossing), is site-

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

specific and static. The geospatial dimensions of the HRI Hazard Zone are a function of vehicle

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

approach direction to the HRI, number of tracks, approach skew, and, where applicable, the type of

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

active warning devices implemented at the HRI (e.g., two quadrant versus four quadrant design). The

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

HRI approach zone is the area in which a vehicle driver approaching an HRI should be aware of any

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

signal (audible or visual) indicating the approach of a train, identify any hazards, and formulate any

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

actions required. All of these factors are used in determining the placement of warning gates and/or

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

stop lines, as specified by the MUTCD and AREMA Communications & Signal Manual. The intention

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

is that the HRI Hazard Zone and end of the HRI Approach Zone closely align with these rail warning

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

markings and device placements. Refer to Chapter 1 of the RCVW System Requirements

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

Specification document for more detail and definitions of the HRI Hazard Zone and HRI Approach

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

Zone.

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

For HRIs equipped with active warning and control devices (i.e. flashing lights and gates as depicted

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

in the right half of Figure 10 **Error! Reference source not found.** below) and interconnected with

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

traffic signal controllers (TSCs) at nearby intersections, a preemption signal is issued when an HRI is

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

active. Code of Federal Regulations Title 49 Part 234 specifies that this signal must be issued at least

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

20 seconds before train arrival. However, factors such as the roadway speed limit, railway speeds,

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

design of the active warning devices, HRI hazard zone size (inclusive of number of tracks), placement

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

of the HRI warning devices, and additional site-specific factors are considered in determining if more

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

than 20 seconds is required.

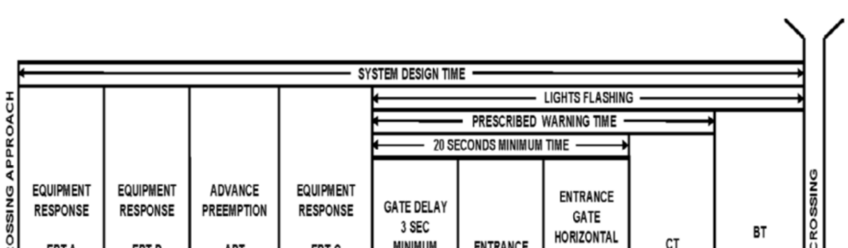
This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.



This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

Figure 10. Warning Time Determination for Typical HRI with 2 Quadrant Gates

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

Source: AREMA Communications & Signal Manual

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

As mentioned in Chapter 4 the RBS CP will rely on the HRI controller for receipt of the preemption

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

signal. The RBS HRI Active message sequence will be triggered upon receipt of this preemption

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

signal. When the RBS receives a preemption signal, it will broadcast an HRI Active message. If a

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

VBS is within the HRI Approach Zone, it may issue alerts, and, if necessary, warnings. It is critical that

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

the VBS receives timely HRI Active messages and issues actionable alerts and warnings. To do this,

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

RCVW uses the current American Association of State and Highway Transportation Officials

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

(AASHTO) Stopping Sight Distance formula (modified to include additional information unique to the

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

implementation). This formula considers factors such as:

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

- Typical perception reaction time

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

- Deceleration rate per vehicle type in both dry and wet conditions

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

- Road grade

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

- Vehicle Speed

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

- Communication and application latency

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

The VBS RCVW algorithm will be conservative in that it *will not calculate or issue alerts or warnings*

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

for vehicles to proceed within the HRI Approach Zone when the HRI is active, regardless of vehicle-

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

condition factors. In other words, it will not encourage vehicle operators to delay taking action to stop

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

within the HRI Approach Zone when an HRI is active or contribute to the perception they can or

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

should proceed (i.e., it effectively ignores virtual or actual “Dilemma Zones”). The “Dilemma Zone” as

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

depicted in Figure 11 is the area within which vehicle operators may become confused as to whether

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

they should attempt to stop or proceed. This dilemma is not considered in the current RCVW system.

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

Therefore, mitigations for this must come outside the technology such as driver training.

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

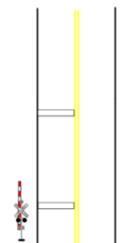
This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.



This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

Figure 11. Dilemma Zone

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

Source: Battelle

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

Local Safety Messaging Data Flows

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

The following is a description of the data flows (described in Chapter 5) between the different V2I

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

plugins used in the RCVW CV Local Safety Messaging. This section provides an overview of the data

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

exchange that takes place between the RBS and the VBS.

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

HRI Geometry Data Flow

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

The HRI geometry data is contained within the MAP message and provides the geographic context for

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

which the HRI Active Message information is applied. The content of a MAP message is used by the

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

VBS CP to construct a detailed layout of each element of the roadway approach to the HRI. The

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

RCVW algorithm will analyze the MAP information to determine if the vehicle is within the HRI

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

Approach Zone and where specifically the vehicle is located relative to the HRI. Each intersection

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

where RCVW is deployed will require a unique MAP message prepared and configured so that the

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

MAP plugin will broadcast its unique information. When the HRI is in proximity to a preempted

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

highway intersection, the RBS will be configured to send MAP messages containing HRI and highway

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

intersection details. This will allow the RCVW system to consider the intersection's SPaT

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

information(see HRI State Data Flow section for more details). Figure 12 shows the data flow of the

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

MAP message and the different V2I hub plugins involved in this process.

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

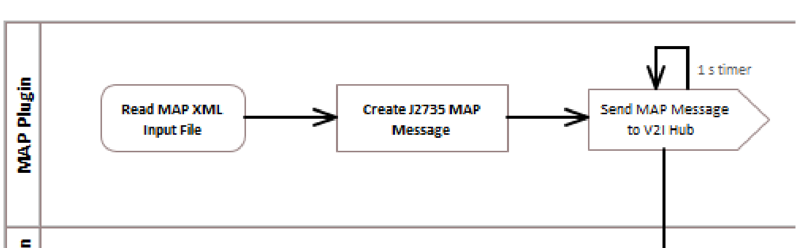
This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.



This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

Figure 12. MAP Message Data Flow

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

Source:Battelle

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

HRI State Data Flow

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

The HRI activation status data is contained within the SPaT messages that are generated by the RBS.

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

This SPaT message contains the HRI activation status as “event status” along with an intersection ID

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

which will be used to correlate the HRI State message to its MAP message. The VBS uses both MAP

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

and SPaT messages to determine “event status” (i.e. stop and remain, protected movement allowed,

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

permissive movement allowed, protected clearance allowed, etc.) of a lane in the MAP message. For

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

the RCVW project, the system will be using the event status “stop and remain” as the trigger for HRI

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

active. Figure 13 shows the data flow of the SPaT message and the different V2I Hub plugins

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

involved in this process.

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

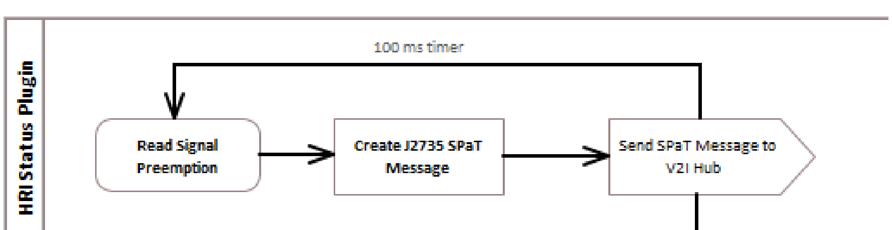
This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.



This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

Figure 13. SPaT Message Data Flow

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

Source:Battelle

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

Position Correction Data Flow

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

The VBS requires the reception of RTCM corrections from a base station to improve GNSS accuracy.

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

The RCVW system is capable of generating these RTCM corrections at the RBS via its GNSS base

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

station or acquiring them via the CBS from CORS. The RTCM Plugin reads the RTCM corrections

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

coming from the RBS GNSS module or the CBS and creates a J2735 correction message. The

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

message is sent to the V2I Hub where the Message Manager plugin receives it, creates the UDP

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

packet and sends it to the RSU for broadcast. Figure 14 shows the flow of the RTCM message in the

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

RCVW RBS System.

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

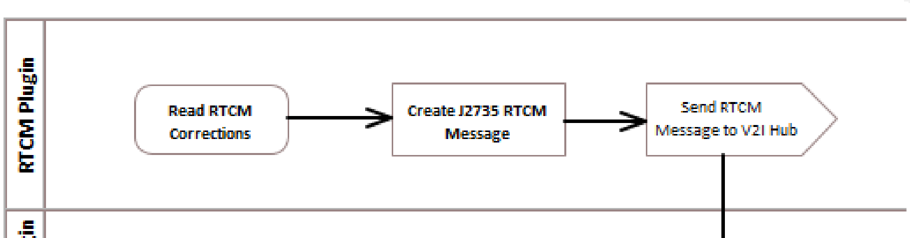
This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.



This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

Figure 14. RTCM Message Data Flow

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

RCVW Cloud-based Messaging Flow

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

The RBS to VBS messaging provides both HRI geometry and activation status through J2735

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

messages. Likewise, the same messages are sent from RBS to CBS over the TCP/IP backhaul. The

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

main difference, therefore, is how the CBS processes the information. It looks for HRI Events, which

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

are basically just a transition of the preemption signal from active to inactive or vice versa. Those

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

Events are logged and are automatically pushed out to subscribers at a known Service Bus

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

Commented [A4]: Correct this

subscription endpoint. Figure 15 and Figure 16 presents the RBS geometry and the RBS State data

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

flow from the RBS to the CBS.

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

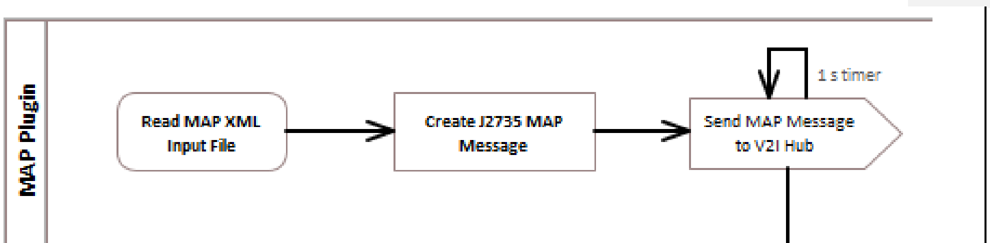
This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.



This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

Figure 15. RBS-CBS Geometry Data Flow

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

Source : Battelle

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

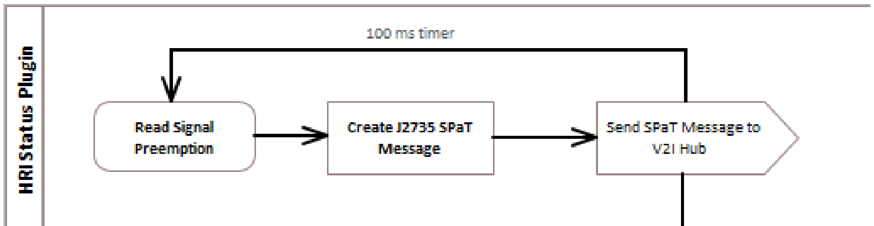
This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.



This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

Figure 16. RBS-CBS Event State Data Flow

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

Source:Battelle

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

RCVW Cloud-based Correction Messaging Design

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

This section describes the RTCM proxying capabilities of the CBS. The CBS components must first

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

determine the location of the HRI from the MAP messages being pushed from each RBS and stored

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

in the data log. Then, an NTRIP connection is made to the CORS network to retrieve the corrections.

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

Those corrections are pushed back to the RBS which is already set up to manage them as if they

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

were generated locally by the RBS GNSS base station. Note that this scenario has no impact to the

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

VBS. The flow of RTCM information from the CBS to the RBS is depicted in Figure 17.

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

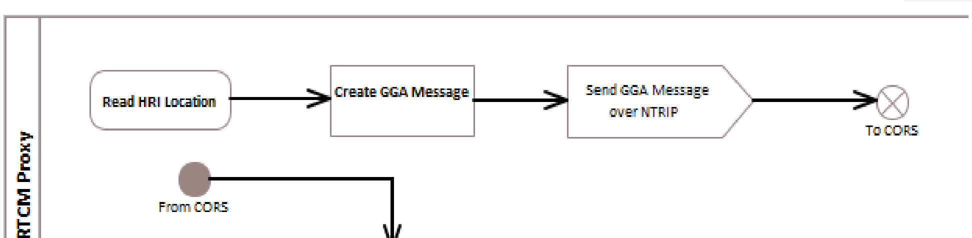
This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.



This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

Figure 17. CBS-RBS Position Correction Data Flow

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

RCVW Cloud-based HRI Information Messaging Design

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

This simple flow details how a subscriber initializes a request for information using a web-based API.

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

The API Management software is responsible for translating this request to SQL commands to issue

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

to the data log and returning the results to the subscriber (see Figure 18). Note that obtaining HRI

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

State data can be achieved using successive queries of the API, thus avoiding the more complicated

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

and asynchronous cloud-based messaging detailed above. The HRI Diagnostic information, used to

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

determine the operational status of the RBS is also obtained in this manner, but requires a unique

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

data flow to also update the changing operational status (see Figure 19).

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

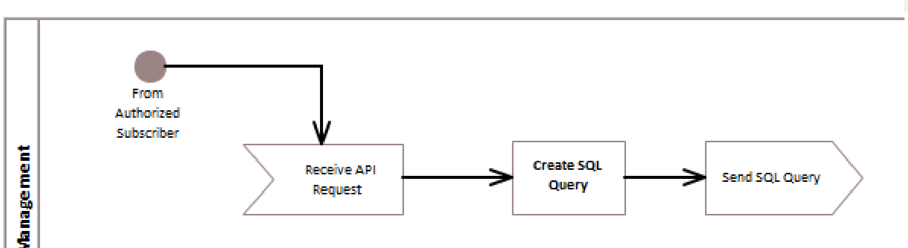
This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.



This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

Figure 18. HRI Information Data Flow

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

Source: Battelle

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

Commented [A5]: Change this

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

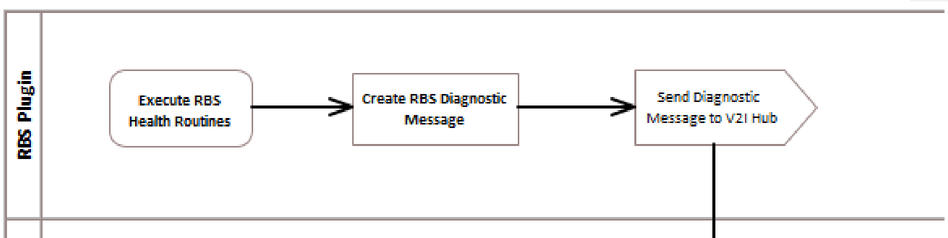
This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.



This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

Figure 19. RBS-CBS Diagnostic Message Data Flow

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

Source: Battelle

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

RCVW System Interfaces

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

The RCVW System will be composed of three subsystems, with interfaces as depicted below in

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

Figure 20**Error! Reference source not found.**. The RBS will provide HRI geometric attributes and

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

HRI activation status to both the VBS and the CBS. Using the information provided by the RBS, the

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

VBS determines when to provide informational alerts, fault alerts. and warnings. Over a dedicated

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

backhaul, the CBS will receive and store the HRI attributes and RBS activation status, and in turn, the

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

CBS will relay HRI/RBS related information to subscribers.

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

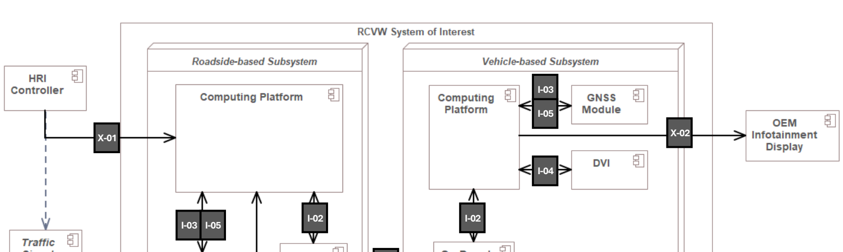
This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.



This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

Figure 20. RCVW System Overview with Interfaces

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

Source: Battelle

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

Table 5 below lists out each of the interfaces connecting the subsystems illustrated above (identified

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

with an “I”), as well as the connections made to external systems (identified with an “X”) and internal

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

software interfaces (identified with an “S”).

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

Table 5. RCVW Subsystem Interfaces

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

Source: Battelle

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

RCVW Inputs and Outputs

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

There are five primary data input types to the RCVW system:

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

The first input type consists of HRI attributes, characteristics and geography that are transmitted in a

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

SAE J2735 MAP message. The characteristics and attributes of the intersection include the lane

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

types (pedestrian, vehicle, etc.), the permitted lane movements (straight, left turn, right turn, etc.), lane

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

direction (approach or egress) and lane connection information to provide the best representation of

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

the intersection to approaching vehicles. The MAP message contains all the HRI information

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

necessary for a vehicle to place itself in the MAP. These messages are transmitted from the RBS to

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

the VBS via C-V2X. The MAP for the HRI is generated manually by hand, ideally using the U.S. DOT

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

ISD Builder Tool for SAE J2735.[1]

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

The second is HRI activation status. The status, either active or inactive, is provided to the RBS by

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

the HRI controller. The HRI activation status will be transmitted by the RBS RSU via the SAE J2735

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

SPaT message. The SPaT information will be used by the VBS RCVW application for determining

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

when an alert or warning should be issued. The source for the HRI activation status may be a

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

voltage-detection circuit hard-wired to the existing train detection system, or from an IEEE 1570

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

device via a TIA/EIA-422 serial communication link.

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

The third is GNSS position and time. Position fix information to determine the position of the VBS in

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

the HRI MAP is a required input for the RCVW algorithm. The position accuracy of the GNSS must be

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

sufficient to allow placement of the VBS within the lane information provided by the J2735 MAP

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

message. The RCVW system utilizes a high precision multi-band RTK enabled GNSS module that

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

provides consistent lane level accuracy.

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

The fourth input consists of vehicle speed and acceleration. Vehicle speed used by the VBS HRI

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

algorithm in addition to other parameters when determining if RCVW warnings and alerts should be

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

displayed, and the changes in speed, i.e. the acceleration of the vehicle, is used to determine if user

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

action is sufficient to cancel an active alert. The speed and acceleration can be acquired directly from

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

the vehicle's CAN , but alternatively are available from the GNSS receiver.

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

The fifth is vehicle type information. This information will be provided via a configuration file at the time

This section contains a detailed description of each system component along with the software and hardware that will be either developed or modified to support the determination of RCVWs for connected vehicles.

Vehicle-based Subsystem

The VBS is a collection of hardware and software for the purpose of alerting/warning the connected vehicle driver of imminent rail crossing violations.

Hardware

A hardware block diagram for the RCVW VBS is shown in Figure 4. This figure identifies the main components and the associated interconnects that are required.

of VBS installation.

Appendix A.Terms, Definitions, and Acronyms

AASHTO	American Association of State and Highway Transportation Officials
AMQP	Advanced Message Queuing Protocol
API	Application Programming Interface
App	Application
APT	Advance Preemption
AREMA	American Railway Engineering and Maintenance-of-Way Association
BT	Buffer Time
CAN	Controller Area Network
CBS	Cloud-based Subsystem
CONOPS	Concept of Operations
CORS	Constantly Operated Reference Station
CP	Computing Platform
CT	Clearance Time
CV	Connected Vehicle
C-V2X	Cellular Vehicle-to-Everything
DCR	Data Communication Radio
DIO	Data Input-Output
DOT	Department of Transportation
DVI	Driver-Vehicle Interface
EIA	Electronic Industries Association
ERT	Equipment Response Timing
GNSS	Global Navigation Satellite Systems
GGA	GPS Fixed Data2
GPIO	General Purpose Input/Output
GPSD	Global Positioning System Device
HDMI	High-Definition Multimedia Interface
HRI	Highway Rail Intersection
HTTP	Hypertext Transfer Protocol
HTTPS	HTTP Secure
ICD	Interface Control Document
IoT	Internet of Things

IEEE	Institute of Electrical and Electronics Engineers
IP	Internet Protocol
IVP	Integrated V2I Prototype
JSON	JavaScript Object Notation
LCD	Liquid Crystal Display
LTE	Long Term Evolution
MAC	Medium Access Control
MAP	HRI Geometry
MQTT	Message Queuing Telemetry Transport
MSG	Message
MUTCD	Manual on Uniformed Traffic Control Devices
NEMA	National Electrical Manufacturers Association
NMEA	National Marine Electronics Association
NTRIP	Networked Transport of RTCM over IP
OBU	On-board Unit (DSRC radio in VBS)
OEM	Original Equipment Manufacturer
OS	Operating System
PHY	Physical Layer
POE	Power Over Ethernet
PSID	Provider Services Identifier
RBS	Roadside-based Subsystem (an RCVW subsystem)
RCVW	Rail Crossing Violation Warning (warning message)
RDBMS	Relational Database Management System
RS-485	Recommended Standard - 485
RSU	Roadside Unit (DSRC radio in RBS)
RTCM	Radio Technical Commission for Maritime Services
RTK	Real-time Kinematics
SAE	Society of Automotive Engineers
SDK	Software Development Kit
SPaT	Signal Phase and Timing
SQL	Structured Query Language
TBD	To Be Determined/Designated

TCP/IP	Transmission Control Protocol/Internet Protocol
TIA	Telecommunications Industries Association
TMC	Traffic Management Center
TSC	Traffic Signal Controller
UDP	User Datagram Protocol
U.S. DOT	United States Department of Transportation
USB	Universal Serial Bus
VBS	Vehicle-based Subsystem (an RCVW subsystem)
V2I	Vehicle-to-Infrastructure
VBM	Vehicle Basic Message
WAN	Wide Area Network
WAVE	Wireless Access in Vehicular Environments
WiFi	Wireless Fidelity
XML	Extensible Markup Language

Appendix B. Neousys Intel CP Specifications

CPU	
CPU Type	Intel® Core™ i5-9500E
CPU Cores	6
CPU Clock (Max)	3 GHz
Memory	
RAM	16GB DDR4-2666
Networking	
Ethernet	10/100/1GB
Ethernet	10/100/1GB
CAN	1x isolated CAN 2.0 port
Power	
DC Input	8~35V DC
Input Connector	3-pin pluggable terminal block for DC input (IGN/ GND/ V+)
OS Support	
Linux	Ubuntu
Inputs/Outputs	
Isolated Analog/Digital/Discrete inputs and outputs	4x isolated DI 4x isolated DO
POE	4x IEEE 802.3at (25.5W) Gigabit PoE+ ports by Intel® I210 - M12 x-coded connector (Nuvo-7200VTC) - RJ45 connector (Nuvo-7204VTC) 8x IEEE 802.3at (25.5W) Gigabit PoE+ ports by Intel® I210 - RJ45 connector (Nuvo-7208VTC)
Storage	
SATA	2x hot-swappable HDD tray for 2.5” HDD/ SSD installation, supporting RAID 0/1
mSATA	1x full-size mSATA port (mux with mini-PCIe)
M.2	1x M.2 2280 M key socket (PCIe Gen3 x4) for NVMe SSD or Intel® Optane™ memory installation
Audio	
Headphone	3.5 mm headphone jack
Microphone	Analog MIC
Connectivity	

Serial	2x software-programmable RS-232/422/485 ports (COM1/ COM2) 2x RS-232 ports (COM3/ COM4)
SD	x1 microSD
USB	4x USB 3.1 Gen2 (10 Gbps) ports 4x USB 3.1 Gen1 (5 Gbps) ports
Environmental Specifications	
Operating Temperature	-25°C ~ 70°C -40°C ~ 70°C (optional)
Storage Temperature	-40°C ~85°C
Humidity	10%~90% , non-condensing
Vibration	Operating, 5 Grms, 5-500 Hz, 3 Axes (w/ mSATA SSD, according to IEC60068-2-64)
Shock	Operating, 50 Grms, Half-sine 11 ms duration (w/ mSATA SSD, according to IEC60068-2-27)
EMC	E-Mark for in-vehicle applications CE/ FCC Class A, according to EN 55032 & EN 55024

Appendix C. C-V2X Radio Specifications

Danlaw RouteLink – On Board Unit	
Physical Interfaces	1 x CAN 1 x LIN 2 x analog inputs
RF Connectors	2 x FAKRA (C-Key) V2X 1 x FAKRA (Z-Key) GNSS
Connectors	20-pin interface connector USB micro-USB Ethernet
Processors	Main - Dual core @ 800 MHz, Secondary – supervisor and vehicle interface
Memory	8 GB eMMC, 1 GB RAM
V2X Radios	Single Channel with diversity
Temperature	-25°C ~ 58°C
Danlaw RouteLink – Roadside Unit	
Interfaces	2x C-V2X Radios 1x WiFi 1x Ethernet 1x Cellular
Antenna Connectors	2 N-Type Female C-V2X
Processor	800 MHz, iMX6 Dual Core
Memory	1 GB DDR RAM
Temperature	-34ºC to +74ºC
Standard Support	IEEE 802.11p, IEEE 1609.2, IEEE1609.3, IEEE 1069.4, SAE J2735, NTCIP, SNMP, USDOT v4.1 RSU specification
Power	IEEE 802.3at POE

Appendix D. GNSS devices

UBLOX ZED-F9P Eval US – RSU Unit	
Frequency	1.2276GHz ~ 1.575GHz
Data Rate (Max)	921.6 kbps
Modulation	Beidu Galileo GLONASS GNSS GPS
Protocols	NMEA UBX RTCM
Voltage Supply	3.3V
Operating Temperature	-40°C ~ 85°C
Interfaces	Micro USB port GNSS Data/Power Supply
Antennas	SMA connector for active multi-band GNSS antenna SMA connector for UHF antenna
UBLOX ZED-F9R GNSS Evaluation Board – On Board Unit	
Frequency	1.207GHz, 1.227GHz, 1.246GHz, 1.561GHz, 1.575GHz, 1.602GHz
Data Rate (Max)	921.6 kbps
Modulation	Beidu Galileo GLONASS GNSS GPS
Protocols	NMEA UBX RTCM Automotive Dead Reckoning (Wheel Tick and direction input supported)
Voltage Supply	3.3V
Operating Temperature	-40°C ~ 85°C
Interfaces	Configurable CAN interface Micro USB port GNSS Data/Power Supply
Antenna	SMA connector for active multi-band GNSS antenna

U.S. Department of Transportation
Federal Railroad Administration
1200 New Jersey Avenue, SE
Washington, DC 20590

202-366-4000
www.railroads.dot.gov

U.S. Department of Transportation