Rail-Crossing Violation Warning (RCVW) Standard Operating Procedures – Hardware and Software Configuration - Draft

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14. ABSTRACT (Maximum 200 words)

This document details the procedures needed to install and configure the RCVW connected vehicle (CV) prototype application in a VBS and an RBS. Specifically, this document offers instructions to configure the system to a specific vehicle used and deployment location. The standard operating procedures laid out in this document are crucial to the proper functionality since the RCVW application performance depends on the proper installation and configuration of the system.

15. SUBJECT TERMS

Rail Crossing Violation Warning, V2I, Connected Vehicles, Standard Operating Procedure, Hardware, Software, Safety Application

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Introduction

Overview

This guide details the instructions for installing and configuring the prototype system for the Rail-Crossing Violation Warning (RCVW) Phase II application. This includes both hardware setup and software installation for the Vehicle-based Subsystem (VBS) and the Roadside-based Subsystem (RBS). Details on how to create an appropriate map for the highway-rail intersection (HRI), setting up connectivity to the HRI Controller preemption signal, and broadcasting real-time kinematic (RTK) position corrections from the RBS to theVBS are detailed in a separate document [see RCVW Standard Operating Procedures – SPAT,MAP and RTCM Messaging]. (Baumgardner, 2021).

Vehicle based Subsystem

The VBS consists of the following hardware (see Figure 1):

A. Neousys Intel Central Processing Unit (CPU) running V2I Hub1 software with the following plug-ins: VehicleInterface, MessageReceiver, Location, Command, and RCVW.

B. Cohda MK5 On-Board DSRC radio.

C. U-blox C099-F9P Multi-Band, Multi-Constellation RTK GNSS Device.

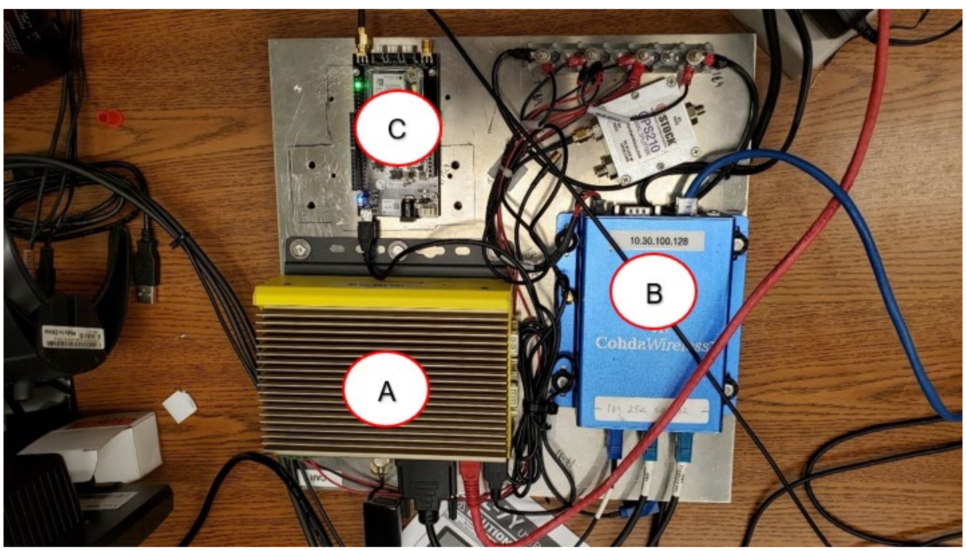

Figure 1. VBS Device-Mounting Plate

The VBS system has the following interconnections (see Figure 2):

- The DVI receives power from a vehicle's auxiliary power outlet and connects to the Neousys Intel CPU's DVI/Video Graphics Array (VGA) interface via a High-Definition Multimedia Interface (HDMI) cable.

[1] For more information on the V2I Hub Software platform visit the following link : https://github.com/RCVWPHASEII/V2I-Hub/tree/master/Support%20Documents

- The Terminal Block is connected to the vehicle's auxiliary power outlet.
- The Neousys Intel CPU and the Cohda MK5 On-Board Unit (OBU) DSRC radio receive power from the Terminal Block and interconnect via an ethernet cable.
- Controller Area Network (CAN) cable is connected from the vehicle's On-Board Diagnostics (OBD) II interface to the Neousys Intel CPU's OBD II input, this is optional (see VBS CAN Interface on page 15).
- ZED-F9P RTK GNSS module connects to the Neousys CPU via a Universal Serial Bus (USB) cable.
- Two antennas are magnetically attached to the roof of the vehicle. One is a combination of a DSRC/GPS antenna which connects to the Cohda MK5 On-Board DSRC radio's Fakra connector and the second is a multiband GNSS antenna which connects to the ZED-F9P RTK GNSS module's Subminiature version A (SMA) interface.

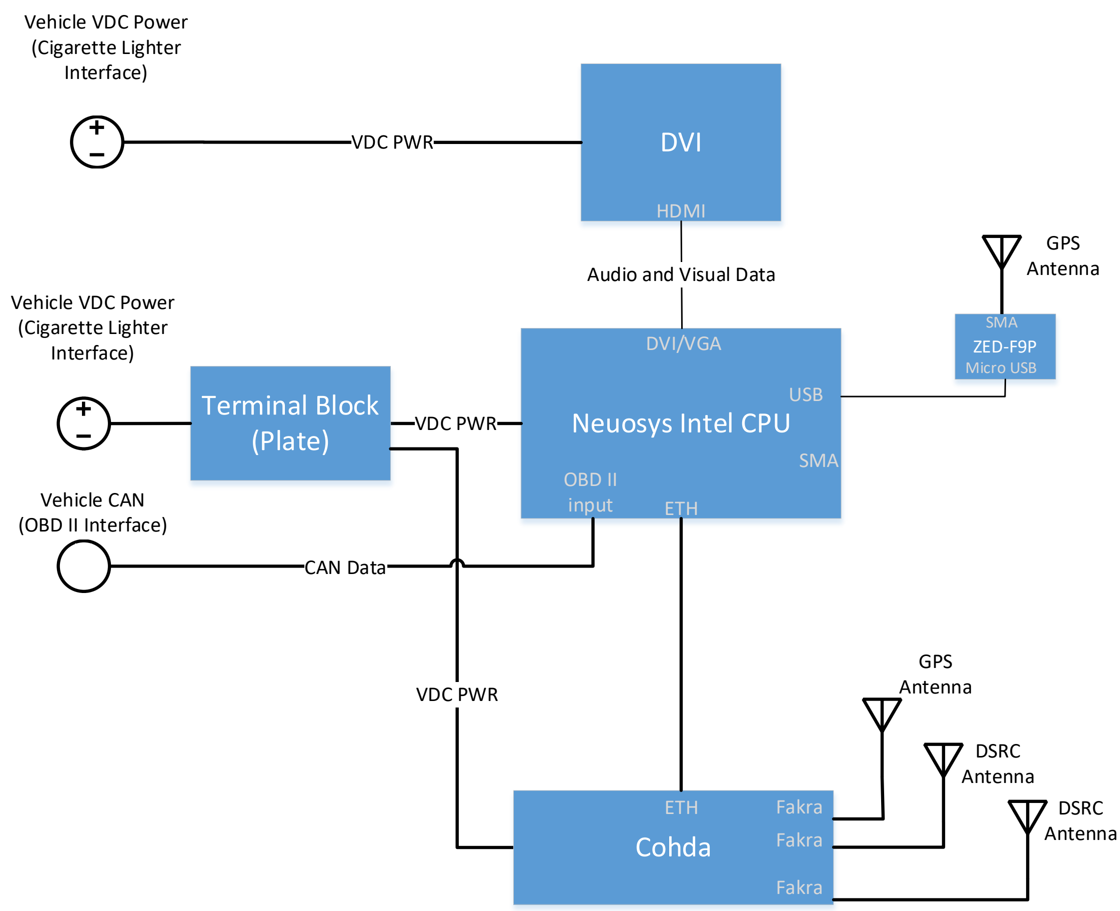

Figure 2. VBS Hardware

Roadside-based Subsystem

The RBS is composed of a CPU, a GNSS base station, a Roadside Unit (RSU) DSRC radio, a Power Over Internet (PoE) Injector, a GNSS antenna for the base station and a GPS and DSRC antennas for the DSRC radio.

The RBS is composed of the following hardware, see Figure 3.

A. Neousys Intel CPU running V2I Hub software with the MAP, HRIStatus, DSRCMessageManager, MessageReceiver, Location and Radio Technical Commission for Maritime Services (RTCM) software plugins.

B. Cohda MK5 4.0 RSU DSRC radio and antennas.

C. Multi-Band, Multi-Constellation RTK GNSS Device (Base Station).
   - U-blox C099-F9P application board.

D. PoE Injector to supply the RSU with power.
   - Linksys LACPI30.

The following hardware varies depending on the method used to receive the preemption signal from the HRI Controller

E. Directly from the HRI Controller.

F. Via an IEEE 1570 Serial Communication device.

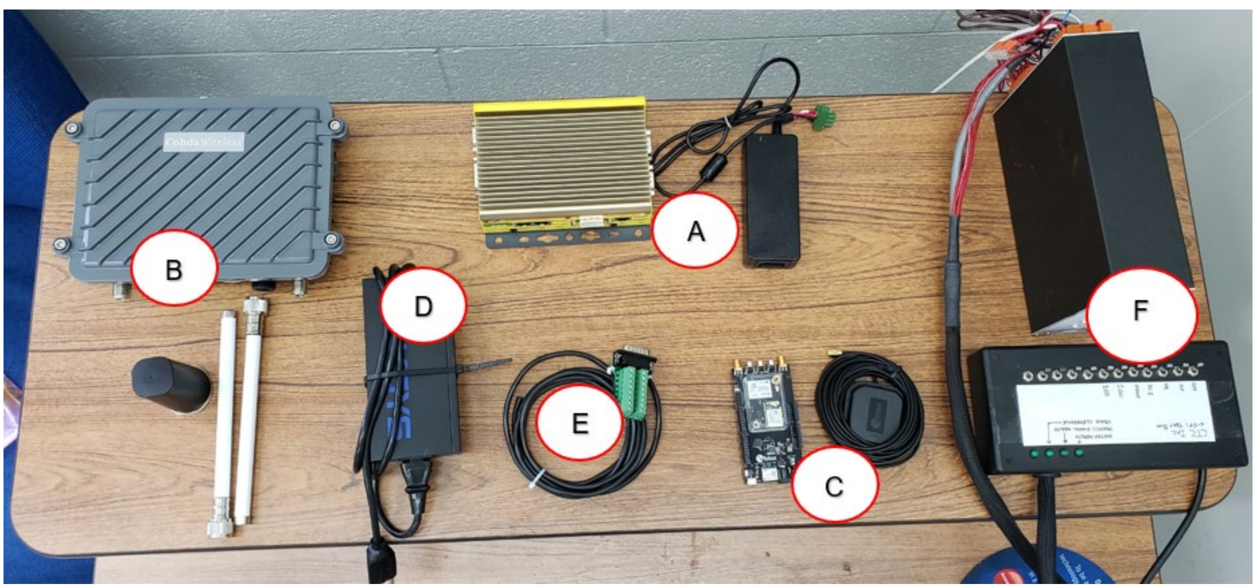

Figure 3. RBS System Components

The RBS has the following connections (see Figure 4):

- DSRC and GPS antennas are connected to the DSRC Radio via N-Type connectors.
- U-blox C099-F9P application board connects to the Neousys CPU via a USB cable.
- GNSS antenna connects to the U-blox C099-F9P application board SMA connector.

Ethernet cables interconnect as follows:

- Neousys CPU to the data / IN port of the PoE injector.
- PoE injector P+D / OUT port to the Roadside DSRC Radio.

The Neousys Intel CPU and PoE injector needs 110 Volts of Alternating Current (VAC) power from an accessible power outlet.

If using an IEEE-1570 device to receive a preemption message, the following connection is needed:

- IEEE-1570 serial communication interface connects to the Neousys Intel CPU via a TIA/EIA-422 compliant cable and DB9 connector.

If using the preemption signal directly from HRI Controller, the following connection exists:

- Signal and ground cable connection to the Neousys CPU's Digital Input and Output (DIO) port.

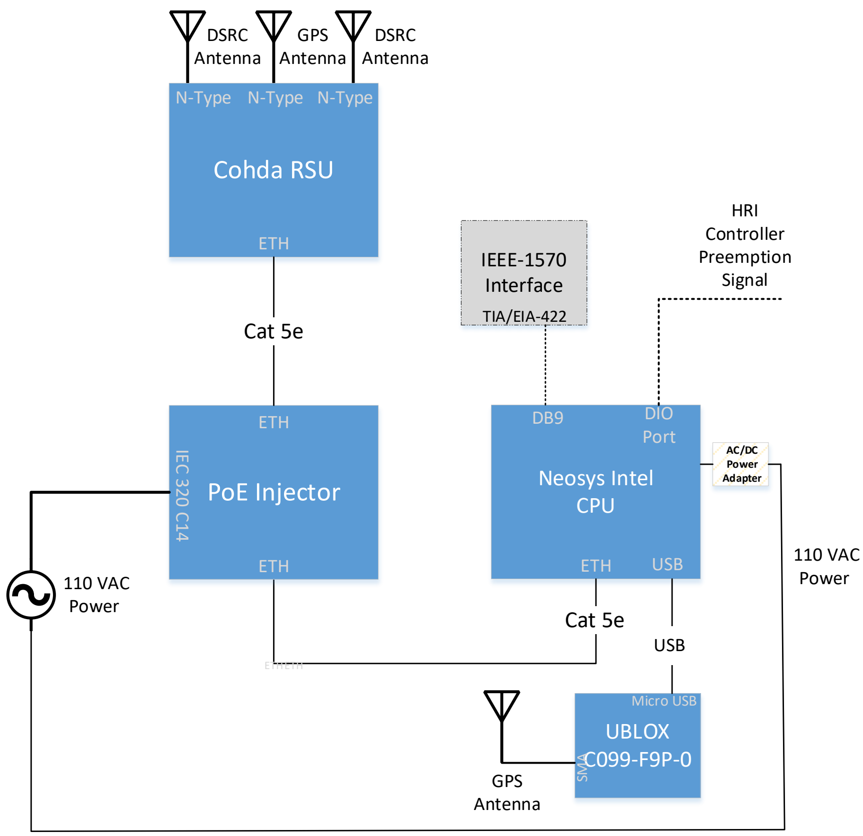

Figure 4. Roadside Connections

Hardware Mounting

The following are instructions to install the RCVW's Vehicle and Roadside subsystems.

Vehicle based Subsystem equipment mounting

First the VBS device-mounting plate must be mounted on a flat surface inside the test vehicle. Possible locations could be the back seat, back seat floor or the vehicle's trunk. The terminal block needs to be within reach of an auxiliary power outlet to receive power.

Once a location has been selected for the device-mounting plate, the GNSS antenna needs to be mounted. Place the GNSS antenna (see Figure 5) on the roof of the vehicle. Ensure that the antenna is located in the center of the vehicle as much as possible and away from any obstruction. The antenna needs to have a clear hemispheric view of the sky. The antenna provided with the RCVW prototype has a magnetic base which eliminates the need of additional mounting hardware. Once the antenna is mounted, X and Y coordinates for the location of the antenna need to be measured and recorded (these values need to be recorded in meters since the RCVW system uses the metric system for its calculations). Assume that the left front corner of the vehicle is coordinate (0,0), positive values for the X coordinates are left to right and positive values for Y coordinates are front to back of the vehicle. See Figure 6.

Figure 5. uBlox GNSS antenna

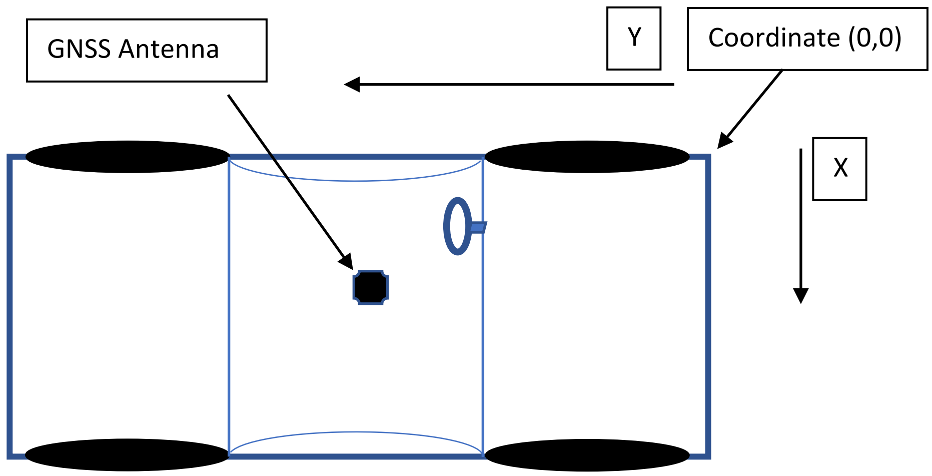

Figure 6. GNSS Antenna Location

The height of the antenna, in meters, with reference to the ground needs to be recorded. Route the antenna cable through a vehicle window and connect it to the SMA connector labeled ZED of the GNSS Module (See Figure 7). Note that the GNSS module is equipped with two SMA interfaces. The length of the vehicle in meters from front bumper to rear bumper should be recorded as well.

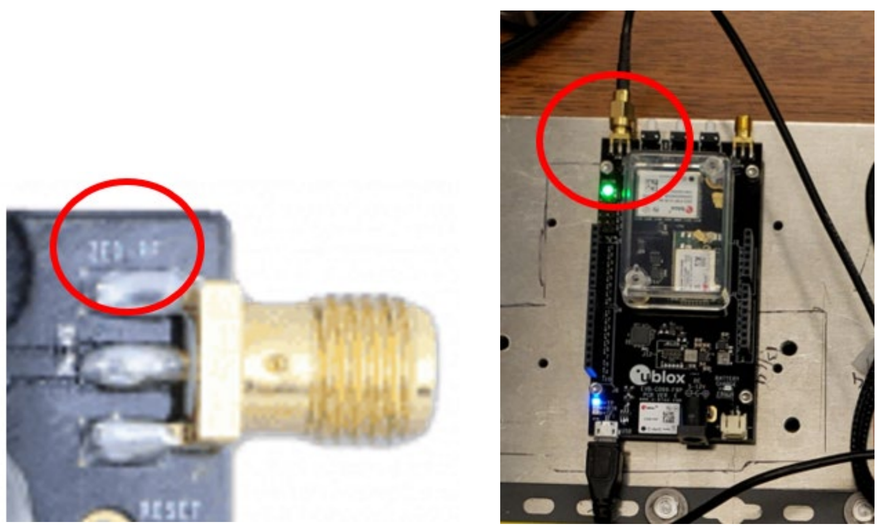

Figure 7. GNSS Antenna Connection

Locate the DSRC/GPS radio antenna (see Figure 8) and place it on the roof of the vehicle ensuring to not block the sky view of the GNSS antenna. Route the antenna cables through a vehicle window and connect each of the three cable terminations to the On-Board unit DSRC radio. (See Figure 9). Figure 10 shows a typical antenna installation on the roof of an Acura MDX vehicle with the blue box showing the DSRC antenna and the red box showing the GNSS antenna.

Figure 8. DSRC/GPS Radio Antenna

Figure 9. On-Board DSRC Radio connections

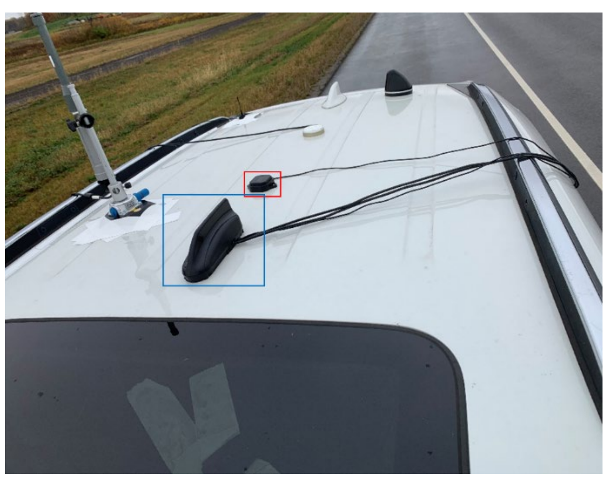

Figure 10. RCVW Antenna placements

The DVI is equipped with a RAM ® Mount base with ball (see Figure 11) which attaches to a RAM Pod HD vehicle mount (see Figure 12).

Figure 11. RAM Ball mount attached to DVI

Figure 12. RAM Pod HD vehicle mount

The RAM Pod vehicle mount is a no drill mount that attaches to an existing seat rail bolt or seat track. No drilling or modifications to the vehicle are required. The RAM vehicle mount should be installed using the seat rail bolt or seat track of the front passenger seat. Instructions on how to install the RAM Pod HD vehicle mount can be found in Appendix B. A typical installation of the mount and DVI can be seen in Figure 13.

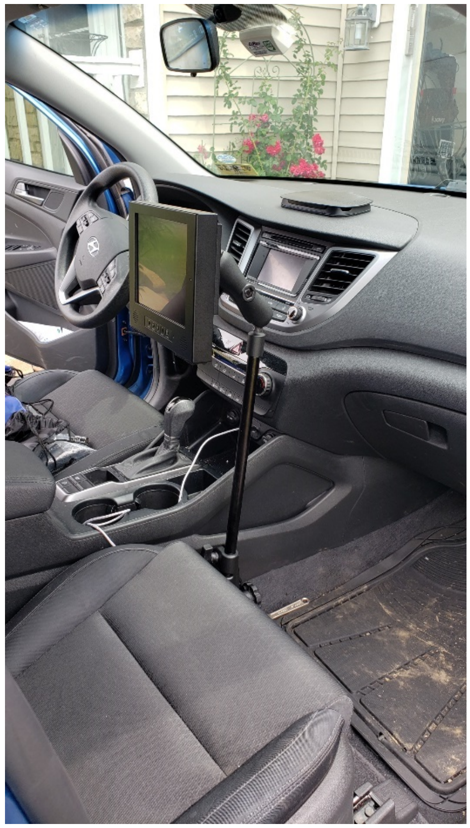

Figure 13. RAM Pod Vehicle Mount and DVI installation

Once the mount and DVI are installed, locate the DVI power connector and attach it to the DVI port labeled DC 12-24V. Locate the HDMI cable and attach it to the DVI port labeled HDMI IN (See Figure 14 for reference).

Figure 14. DVI Connectors

Connect the other end of the HDMI cable to the Neousys CPU's DVI/VGA port. See red rectangle on Figure 15.

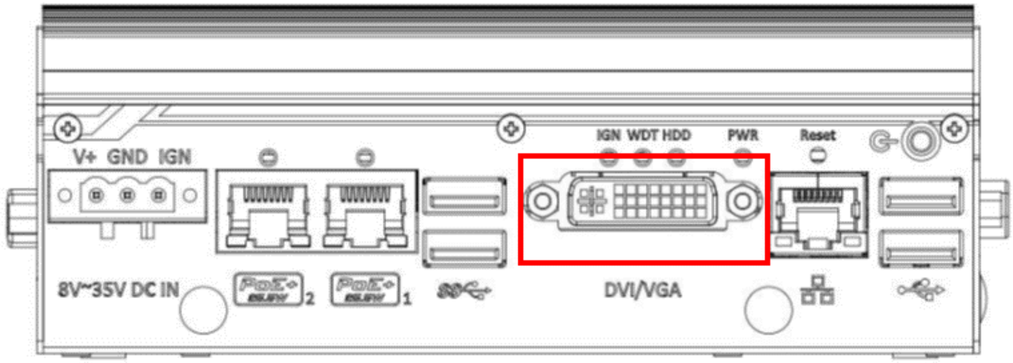

Figure 15. Neousys Intel CPU ports

Finally, connect the DVI and the Terminal Block power connector to auxiliary power outlets.

VBS CAN Interface

The RCVW-II system is capable of receiving vehicle speed from two sources, the GNSS module and the vehicle's OBD-II port (CAN data). However, the use of the CAN source could be a challenging task since every Original Equipment Manufacturer (OEM) uses proprietary information to encode this data and it's not readily available to the public. The recommended configuration is to not connect the CAN interface, which will result in the system automatically using the speed data coming from the GNSS module. If CAN information is readily available and there is some other requirement necessitating the use of CAN-based speed, please refer to Appendix C for instructions on how to connect the interface and programming the VehicleInterface plugin.

Roadside based Subsystem equipment mounting

The following should be considered before installing the Roadside Subsystem:

- A National Electrical Manufacturers Association (NEMA) rated enclosure is required to house the Roadside Neousys CPU, U-blox C099-F9P base station, and PoE injector to protect them from the environment.
- The Roadside subsystem requires 110 VAC power.
- The GNSS Base Station Antenna's precise longitude, latitude and elevation is needed for the base station to produce accurate RTCM corrections. For this purpose, a survey grade GPS device is needed to acquire the RTK antenna coordinates.
- If interfacing with an operating railroad, consult with authorized railroad personnel for connectivity.

Install the RBS Neousys Intel CPU and the U-blox C099-F9P application board (GNSS base station) and place them side by side within the specified RBS enclosure. Use the vendor provided USB cable and connect the micro USB end to the U-blox C099-F9P (see Figure 16) and the other end to one of the Roadside Neousys USB ports (see red rectangles on Figure 18).

Figure 16. U-blox C099-F9P USB connection

Install the PoE injector within the specified enclosure. Connect an ethernet cable to the data / IN port of the PoE injector (see red rectangle on Figure 17) and connect the other end of the ethernet cable to the Neousys CPU's ethernet port (see blue rectangle on Figure 18).

Figure 17. PoE Injector Data In Port

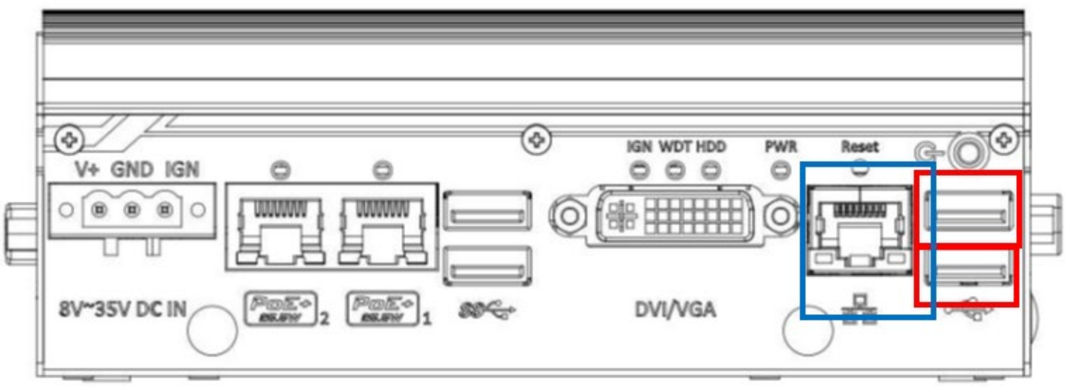

Figure 18. Neousys USB / Ethernet Ports

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Install the Cohda MK5 4.0 RBS DSRC radio and connect the DSRC radio antennas and GPS antenna to the unit (see Figure 19).

Figure 19. RBS DSRC Radio Antennas

The VBS DSRC radio/antenna must have a clear line of sight to the RBS DSRC radio/antenna as it approaches the HRI. An optimal installation location for the RBS DSRC radio/antenna is 7 to 10 meters above ground. An alternative is to place a portable telescopic pole with a base alongside the HRI and mount the RBS DSRC radio/antenna to it. Before finalizing the mounting of the RBS DSRC radio/antenna, connect an ethernet cable to its ethernet port and connect the other end of the cable to the PoE injector's P+D / Out port

The next step is to position and connect the GNSS base station antenna. The GNSS base station antenna needs to be positioned in a location where it will be able to have an obstruction free satellite view and stable enough to prevent excessive movement and vibrations. Camera tripods have been used in the past for this purpose. Ensure that when the antenna is mounted to the selected hardware, the antenna surface is not covered by tape or any other material as it will affect the satellite signal reception. The base station requires precise Longitude, Latitude, and Elevation of the antenna. Once the optimal location has been selected, use survey-grade equipment to acquire its longitude and latitude and elevation. Next, measure the height of the antenna in centimeters from its base to the ground and add this to the elevation recorded by the survey-grade system. Mark the location with a survey nail for future use. Once the antenna has been positioned, connect it to the SMA port of the U-blox C099-F9P (see Figure 20). Note that the GNSS module is equipped with two SMA interfaces. Ensure that the GNSS antenna is connected to the interfaced marked ZED.

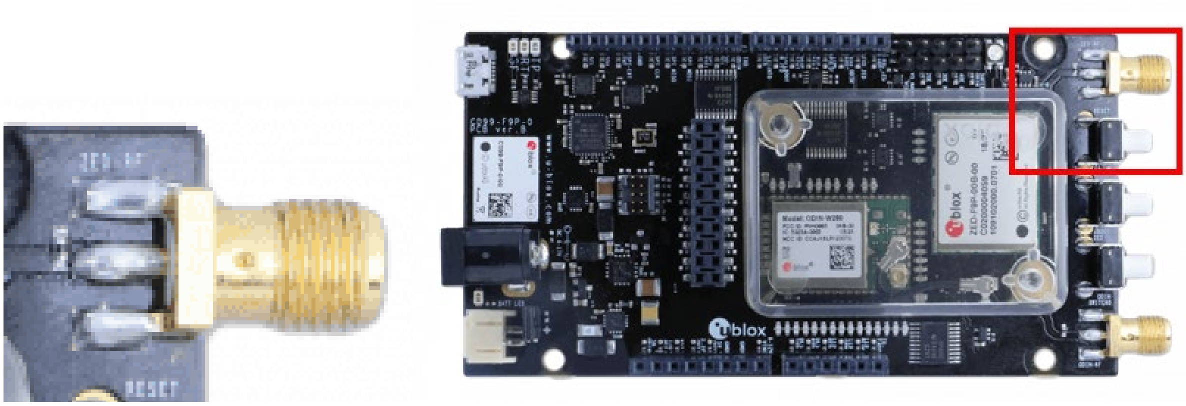

Figure 20. GNSS Base Station Antenna Connection

The next step is to connect the HRI Controller preemption signal cable. Refer to the *RCVW Standard Operating Procedures – SPAT, MAP and RTCM Messaging* (Baumgardner, 2021) for more details. The RCVW RBS is designed to receive a DC voltage level preemption signal directly from an HRI Controller, or indirectly from an IEEE 1570 compliant device. When directly from the HRI Controller, a two-conductor DB-15 cable is required for connecting the HRI Controller to the Neousys CPU 22. (See Figure 21)

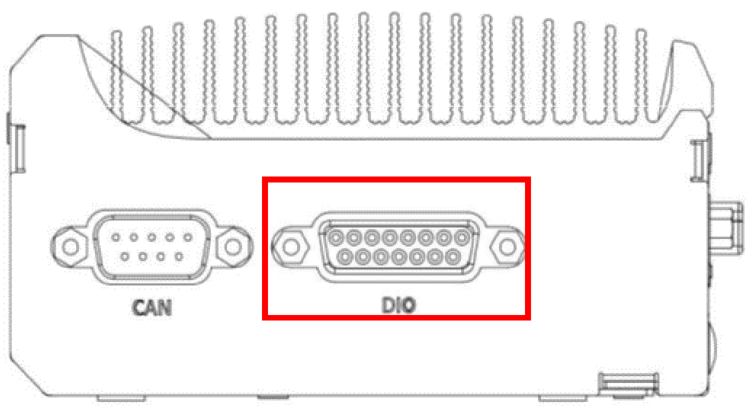

Figure 21. DIO Port of the Neousys Intel CPU

If an IEEE-1570 compliant device is used, the IEEE 1570 device includes a TIA/EIA-422 interface that connects to the COM1 port of the Neuosys Intel CPU (See Figure 22).

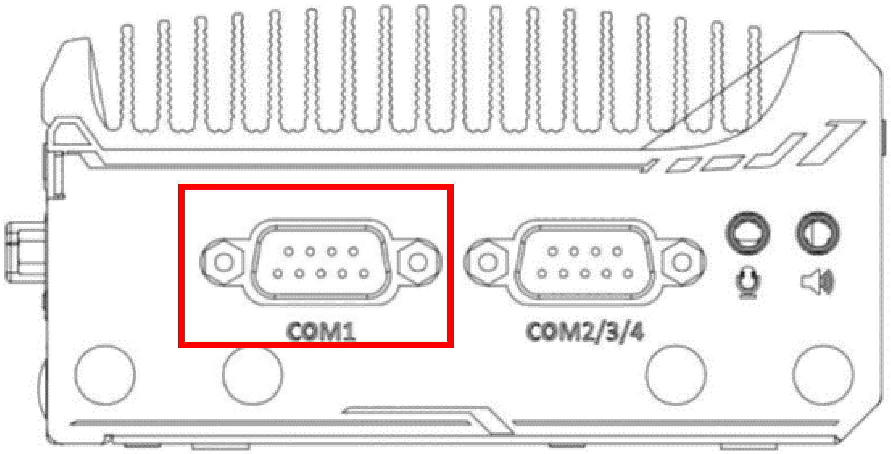

Figure 21. COM ports of the Neousys Intel CPU

Coordinate ,with the railroad to install the cable to the HRI Controller or IEEEE 1570 device. Instructions on configuring the RBS Neuosys CPU for both methods is provided in the section *Roadside Based Subsystem Parameters Configuration* of this document.

Figure 23 shows a typical installation of RBS antennas for testing. The RTK GNSS base station antenna can be seen within blue square. The DSRC radio/antenna is mounted on a portable telescopic pole and can be seen within the yellow square. Mock crossing equipment can be seen within the red square.

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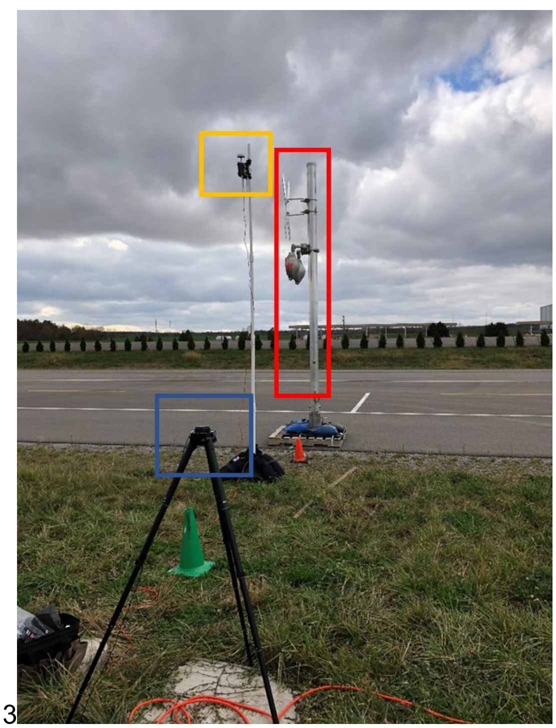


Figure 22. Typical Installation of Antennas in a Mock Crossing

System Configuration

This section provides the instructions to configure both the RBS and VBS according to the test vehicle being used and the location of the HRI. The section provides instructions on how to access the administration web portal which allows configuration of different system parameters.

Connect to the RCVW Central Processing Unit

In order to configure and manage the RCVW system, an external computer is required. The external device should be cabeled directly to the RCVW Neousys CPU using a standard Ethernet cable, or through an Ethernet-based Local Area Network (LAN). See Figure 24 and Figure 25, respectively:

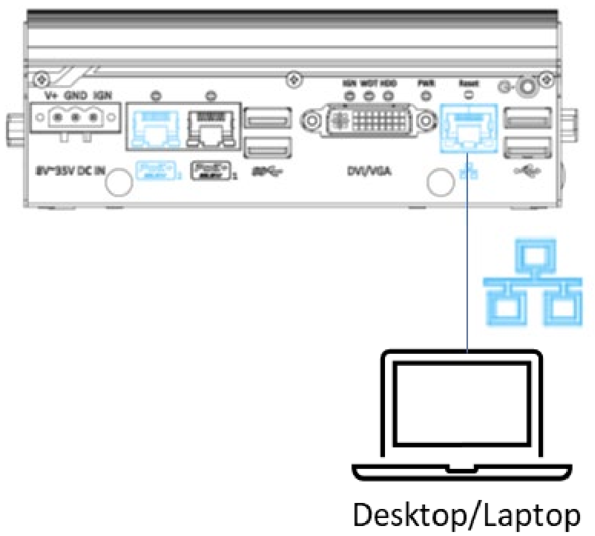


Figure 23. Direct CPU Connection

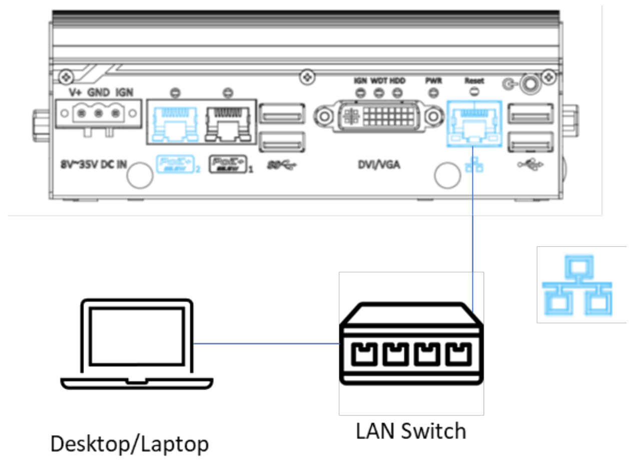
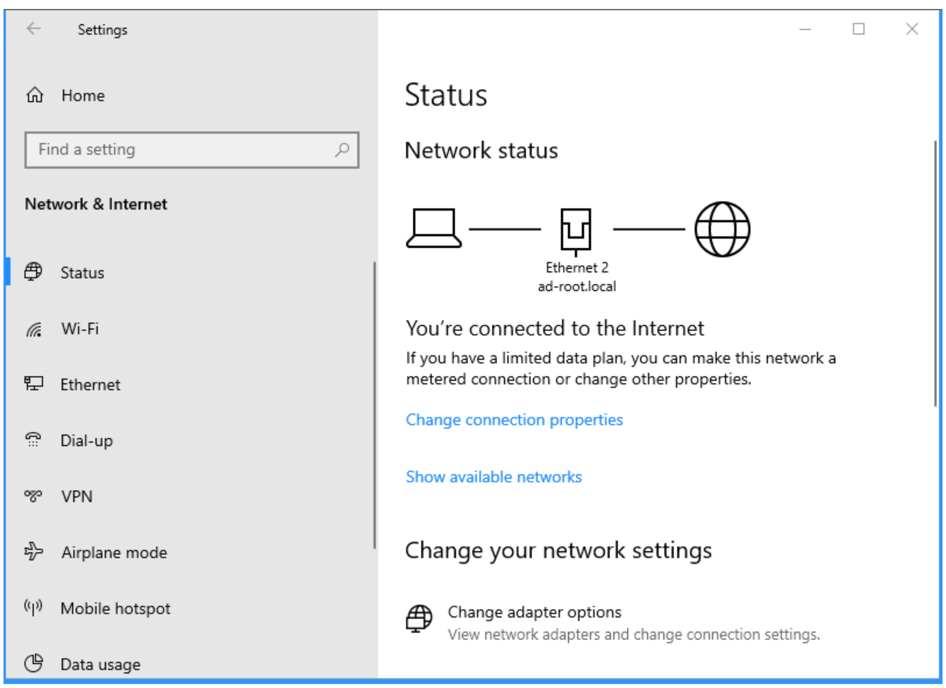
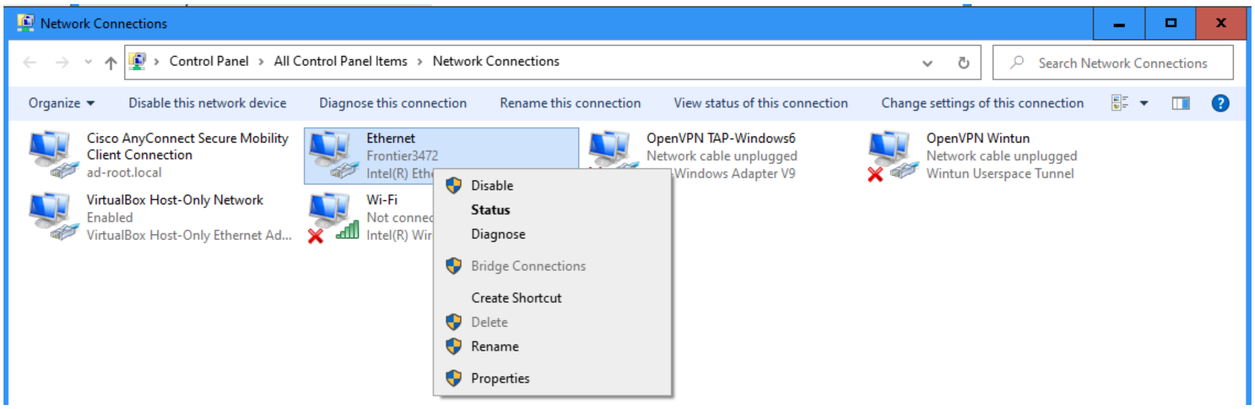


Figure 24. LAN Connection

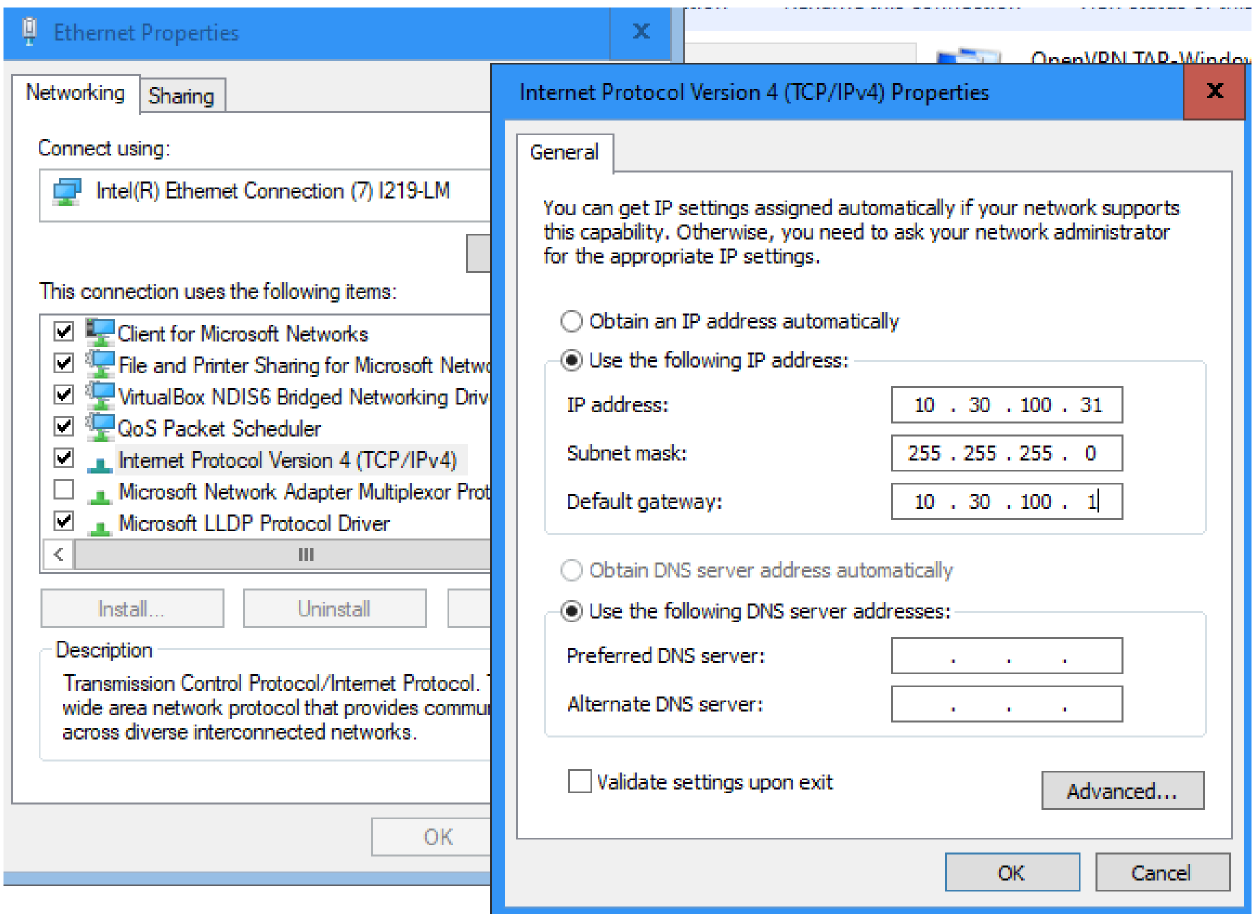
In either setup, the desktop or laptop Ethernet settings must use the same Internet Protocol (IP) subnet as the RCVW CPU, which is 10.30.100.0/24. For a Windows-based system, go to the Network and Internet settings:



Click on **Change adapter options** and bring up the Ethernet **Properties** menu.



You may have to enter an Administrator password. Set the **Internet Protocol Version 4 (TCP/IPv4)** properties to use some IP address within 10.30.100.10 – 10.30.100.50, plus a 255.255.255.0 Subnet mask. The Gateway can optionally be 10.30.100.1.



After saving the settings ping the IP address labeled on the RCVW Neousys CPU. For example, open up a Command Prompt (CMD) window and type:

```
C:\Users>ping 10.30.100.230

Pinging 10.30.100.230 with 32 bytes of data:
Reply from 10.30.100.230: bytes=32 time=59ms TTL=63
Reply from 10.30.100.230: bytes=32 time=57ms TTL=63
Reply from 10.30.100.230: bytes=32 time=66ms TTL=63

Ping statistics for 10.30.100.230:
    Packets: Sent = 3, Received = 3, Lost = 0 (0% loss),
Approximate round trip times in milli-seconds:
    Minimum = 57ms, Maximum = 66ms, Average = 60ms
```

Administration Web Portal

The RCVW software comes pre-configured and optimized for use. However, the RCVW system is programmable through a set of configuration parameters allowing for customization to be performed based on the specific deployment. These parameters can be modified individually through the administration portal of the VBS Computing Platform.

The RCVW Computing Platform does **not** come installed with the portal itself, but instead with the software needed to perform remote administration. Therefore, the administration portal files should be loaded directly onto the desktop or laptop used for connectivity with RCVW.

The portal files can be found at the following URL:

https://github.com/RCVWPHASEII/V2I-Hub

Under the Code button, select **Download ZIP** to copy the files down to the desktop or laptop. The **v2i-webportal** sub-folder can be extracted from this ZIP download to anywhere on the local machine. Using File Explorer, browse to the extracted **v2i-webportal** folder and double-click the **index,html** file to open up the administration web-portal in a local browser.

Connection and operation of the administration portal has been thoroughly documented here:

https://github.com/RCVWPHASEII/V2I-Hub/blob/master/Support%20Documents/V2I_Hub_PluginProgrammingGuide_Final.pdf

The RCVW configurable parameters can be modified via the administration portal of the vehicle Computing Platform under the **RCVW** plugin **Configuration**.

The following is a list of the RCVW configurable parameters along with their description.

Table 1. RCVW Configurable Parameters

Key	Default	Description
Message Expiration	2000	Parameter used to enter the amount of time in milliseconds to wait before issuing a warning indicating that current message data is “stale”.

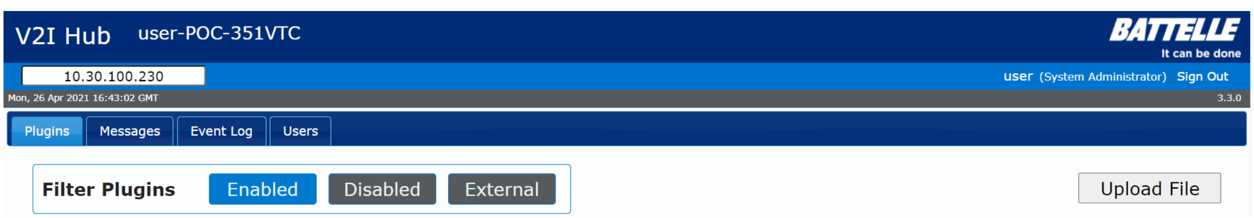
Key	Default	Description
Output Interface	0	Parameter used to input the value that corresponds to the type of interface that the application needs to display its messages on. 0=Digital Visual Interface (DVI), 1=Ford SYNC, 2=Android Auto.
Distance to HRI	480	The defult maximum distance (in meters) away from an equipped HRI that a system fault may be issued due to communication failure. This is a configurable site specific value. When the VBS is within this distance of the HRI, the system checks for MAP and SPAT expiration timeout, if the GNSS system achieved an RTK fix and if location messages are being received at the configured rate.
HRI Locations	":"{ \"HRIs\": [\n {\"Latitude\":0, \"Longitude\":0, \"HRIName\":\"Hilliard-Davidson\"}\n] }",	This parameter shows the JavaScript Object Notation (JSON) data defining a list of equipped HRI locations loaded into the system.
Extended Intersection	0.1	The percentage to add to the radius of the intersection divided by 100. i.e. in this case the percentage to be added is 10%. So the value to enter is 10/100 = 0.1.
HRI Warning Threshold Speed	1.0	The maximum vehicle speed in meters per second for which the HRI warning will be active if the vehicle is in the HRI and moving. If the vehicle's speed falls below this threshold, a warning will be issued to the driver.
Use Calculated Deceleration	false	Use calculated deceleration to determine if vehicle will stop before HRI in addition to velocity-based warning calculation.
Log Level	DEBUG	The logging level of the RCVW system. Options are: ERROR, WARNING, INFO, DEBUG, DEBUG1, DEBUG2, DEBUG3, DEBUG 4. All other messages at levels above the one you choose will also be logged.
V2 Antenna Placement X	0.5	Antenna placement X with respect to front left corner of vehicle in meters.
V2 Antenna Placement Y	2.5	Antenna placement Y with respect to front left corner of vehicle in meters.
V2 Antenna Placement Height	1.5	Antenna height with respect to the road surface in meters.
V2 GPS Error	3.12	GPS longitudinal error in meters. The system uses this value directly in the RCVW calculation formula to calculate the issuing of alerts and warnings. This value represents the longitudinal error of the GNSS system. It is a configurable parameter and as such it can be modified according to the system and vehicle performance. The default value of 3.12 was selected as a result of preliminary testing to show good system performance.

Key	Default	Description
V2 Reaction Time	2.5	Perception-Reaction time in seconds. AASHTO uses the term “Perception-reaction” time and it represents the time it takes for a road user to 1) realize that action is needed due to a road condition, 2) decide what action to take and 3) start the action.
V2 Communication Latency	0.3	Communication latency in seconds. The system uses this value directly in the RCVW calculation formula to calculate the issuing of alerts and warnings. This parameter accounts for DSRC radio signal communication latencies and IEEE 1570 data package reception latencies (if used). The default value of 0.3 is based upon RCVW system requirements VBS-22 and RBS -21 (see Appendix D) for allowable communication latency.
V2 Application Latency	0.085	Application latency in seconds. The system uses this value directly in the RCVW calculation formula to calculate the issuing of alerts and warnings. It considers the latency of the whole RCVW application for processing data and issuing warnings and alerts. The default value of 0.085 is based upon RCVW system requirement VBS-23 (see Appendix D) for allowable application latency.
V2 Deceleration Car	3.4	Minimum expected controlled deceleration for a car in $\frac{m}{s^2}$.
V2 Deceleration Light Truck	2.148	Minimum expected controlled deceleration for a light truck in in $\frac{m}{s^2}$.
V2 Deceleration Heavy Truck	2.322	Minimum expected controlled deceleration for a heavy truck in in $\frac{m}{s^2}$.
V2 Vehicle Type	1	Vehicle type, 1 = Car, 2 = Light Truck, 3 = Heavy Truck.
V2 Vehicle Length	4.8	The length of the vehicle in meters.
V2 Use Vehicle Based Measurement (VBM) Deceleration	false	Use VBM deceleration to determine if vehicle will stop before HRI in addition to velocity-based warning calculation.
V2 Log SPAT	false	Log SPaT messages at DEBUG level.
V2 Critical Message Expiration	500	The amount of time in milliseconds to wait before issuing a warning that the current critical message data is “stale”.
V2 Use Config Grade	false	If False, the system will use the grade directly from the receiving MAP. If True, the system will use the V2 Grade configurable variable for grade calculations.
V2 Grade	0	If Parameter V2 Use Config Grade is set to True, this grade value will be used in warning distance calculations. The value is defined as change in height over change in distance.

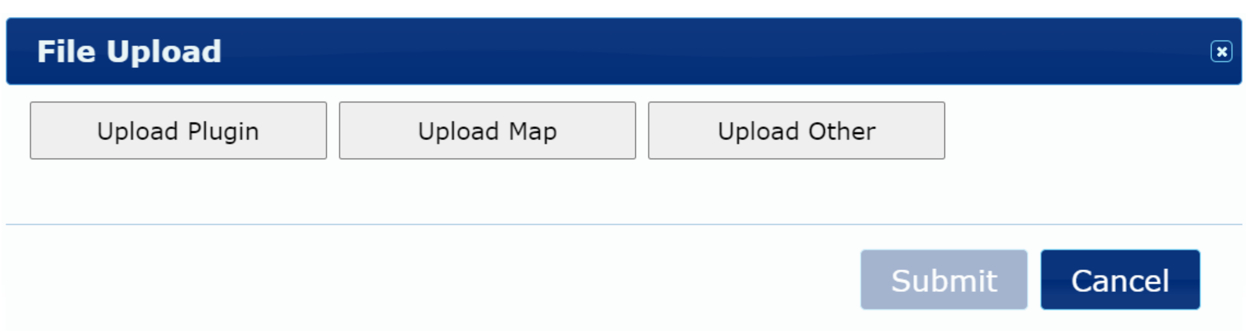
Key	Default	Description
V2 Check RTK	true	If enabled check location message for RTK fix while in range of HRI. If enabled and the location message does not show an RTK fix, a system fault is issued.
V2 Check Location Frequency	true	If set to true, the system will check the Location Message reception rate. If the rate of location messages falls below the value of the parameter shown in V2 Minimum Location Frequency, a System Fault message is issued.
V2 Location Frequency Sample Size	30	This parameter is used if V2 Check Location Frequency is set to true. It is the number of location messages to sample to determine frequency.
V2 Minimum Location Frequency	8	This is the minimum allowed average location message frequency in messages per second.
V2 Max Heading Change	45	The maximum allowed heading change in degrees before ignoring the new position.

Upload a MAP file to the Roadside Computing Platform

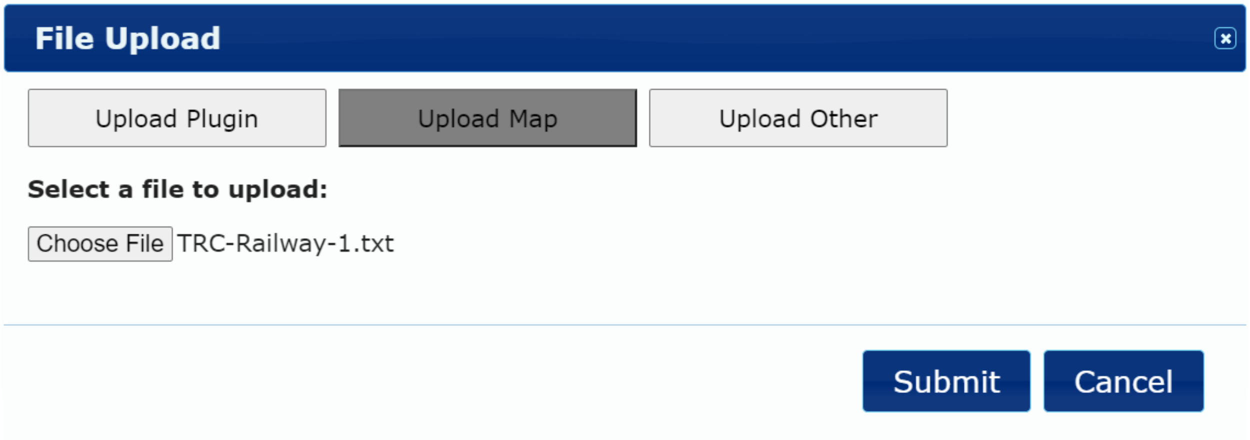
Once a MAP file has been created following the instructions presented in the *RCVW Standard Operating Procedures – SPAT, MAP and RTCM messaging* document (Baumgardner, 2021) it can be uploaded directly into the RBS Computing Platform by connecting to the administration portal at the IP address of the RBS device. On the main screen click on **Upload File**:



The File Upload dialog should appear:



Select **Upload Map**, and then **Choose File**, then select the MAP **.txt** file you created from the SOP. That file should be listed in the dialog.



Once you click **Submit**, the MAP file will be uploaded to the appropriate location on the device and will be available for selection in the programming step.

Vehicle Based Subsystem Parameters Configuration

Vehicle characteristics as well as GNSS antenna location need to be entered every time the GNSS antenna is repositioned on the roof of the vehicle. Once the parameters are entered, they remain in memory and will be used for calculations until they are manually changed. Follow the procedure presented in the Connect to the RCVW CPU section before proceeding through this section.

The following are the parameters that need to be entered into the vehicle based sub-system:

- IP of the VBS DSRC radio.
- Make, Model, and year of the vehicle.
- Vehicle Type i.e. Car, Light Duty Truck, Heavy Duty Truck.
- Length of the vehicle in meters.
- Lateral antenna offset position in meters (X coordinate from the front left corner of the vehicle).
- Longitudinal antenna offset position in meters (Y coordinate from the front left corner of the vehicle).
- Antenna height in meters with relation to the road surface.

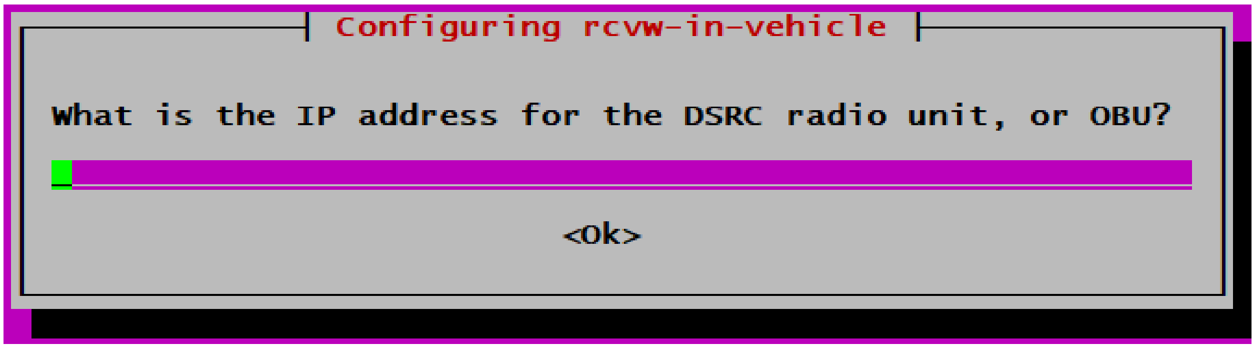
A set of installation scripts, complete with prompts for specific deployment details, have been provided to configure the device with the standard setup. These, and other troubleshooting commands, are only available within a Linux shell. Open up a terminal program on the desktop or laptop computer (Windows PowerShell or PuTTY, for example) and connect to the RCVW Computing Platform through SSH (use the IP labeled on the VBS CPU). When prompted, logon to the device as **user** with the password **RCVW@pplication**. This should bring up a command prompt like the following:

```
user@user-POC-351VTC:~$
```

To access the programming scripts run the following command :

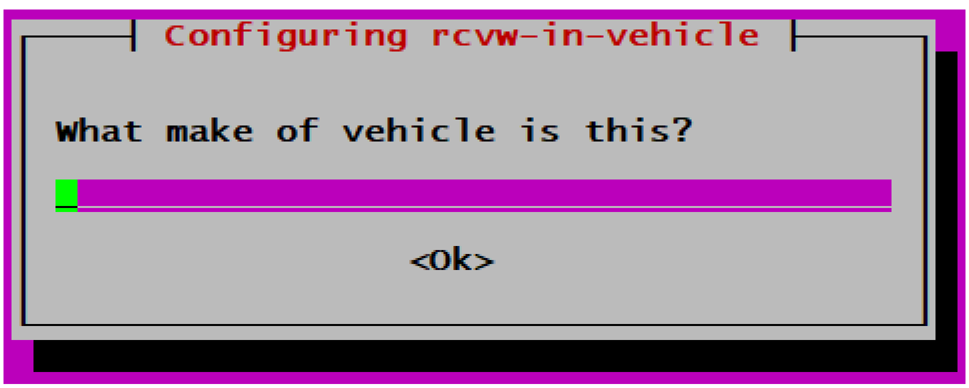
```
user@user-POC-351VTC:~$ sudo dpkg-reconfigure rcvw-in-vehicle
```

The first window that will be presented will ask for the IP address of the rcvw-in-vehicle DSRC radio. Enter the IP address of the DRSC Radio (See the label on the radio) and click enter.

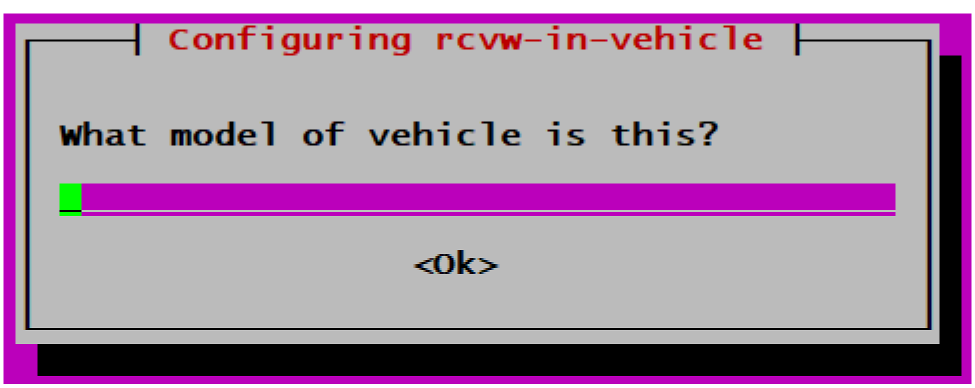


The remaining prompts require knowledge of the vehicle being installed, its type and the position of the GPS antenna.

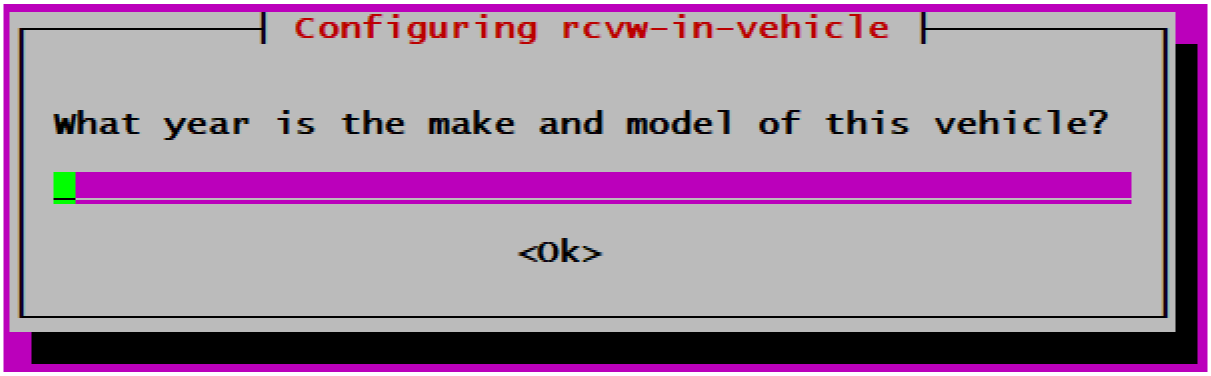
Enter the make of the vehicle.



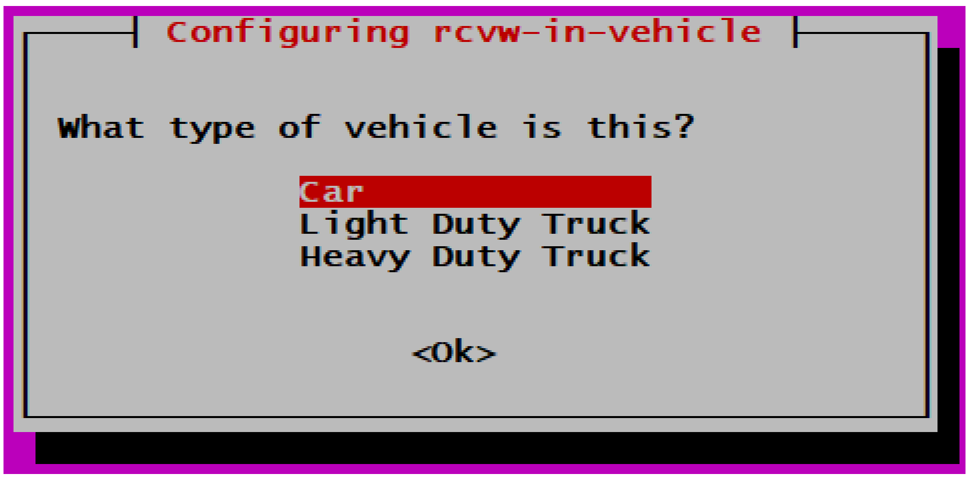
Enter the model of the vehicle.



Enter the year of the vehicle make and model.

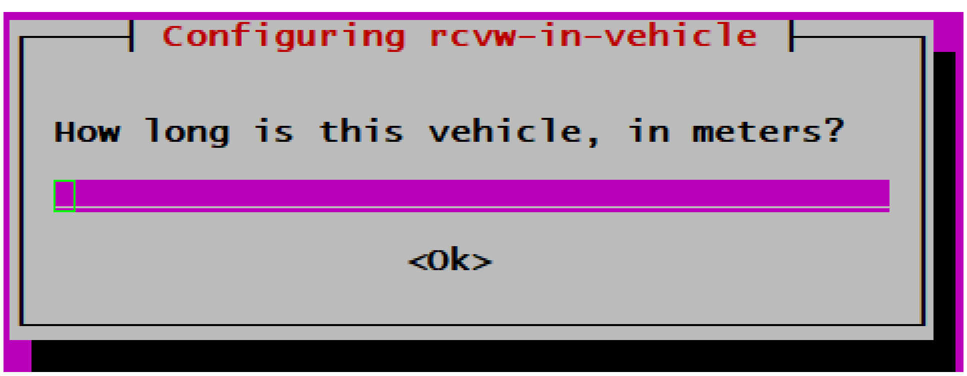


Select whether this vehicle is a light auto, light-duty truck, or a heavy-duty truck.

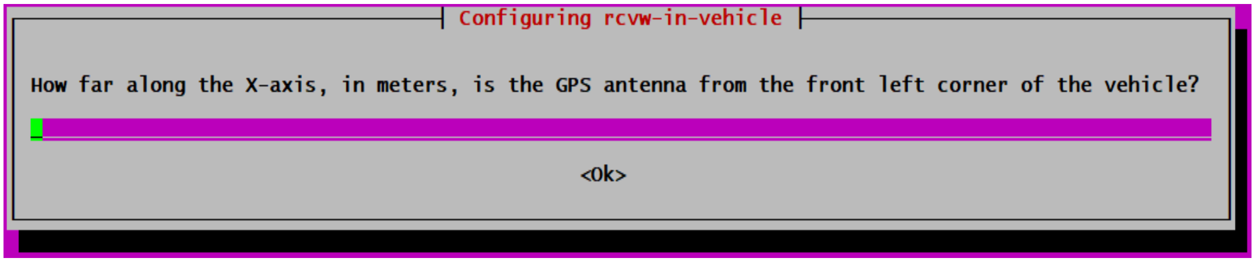


The following parameters will be entered based on the antenna position and vehicle length recorded when installing the equipment (see *VBS equipment mounting section*).

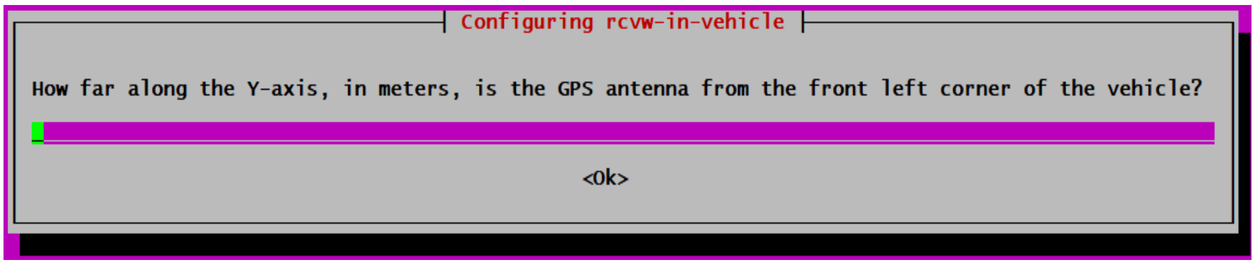
Enter the length of the vehicle.



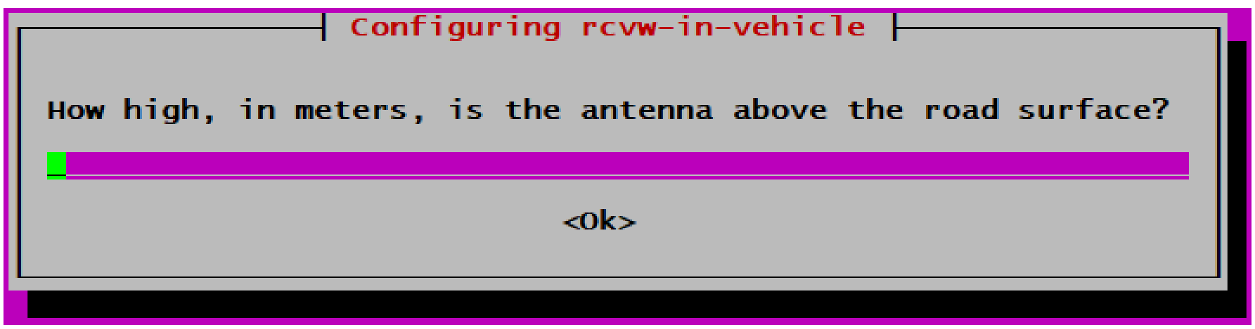
Enter the lateral antenna offset position from the front left corner of the vehicle, i.e. in the X-direction.



Enter the longitudinal antenna offset position from the front left corner of the vehicle, i.e. in the Y-direction.



Enter the vertical antenna offset position from the road surface, i.e. in the Z-direction.



After the configuration of the system is completed, the system should be rebooted.

Roadside Based Subsystem Parameters Configuration

In order to program the RCVW RBS, more preparatory work is required. This system will sit at the HRI so it must know the position and geometry of the crossing. At this point, the RBS Computing Platform should be pre-loaded with the location's map (MAP). See section *Upload a MAP file to the Roadside Computing Platform* for instructions on how to load a new MAP to the RBS CPU. Steps to create a location MAP can be found in the *RCVW Standard Operating Procedures – SPAT, MAP and RTCM messaging* (Baumgardner, 2021). Follow the procedure presented in the Connect to the RCVW CPU section before proceeding through this section.

The following will be programmed and configured into the RBS:

- IP of the rcvw-roadside DSRC radio.
- Interface to receive Train Preemption Data.
- MAP to be used.
- Longitude, Latitude and Elevation of the location where the antenna of the GNSS RTK base station will be positioned.

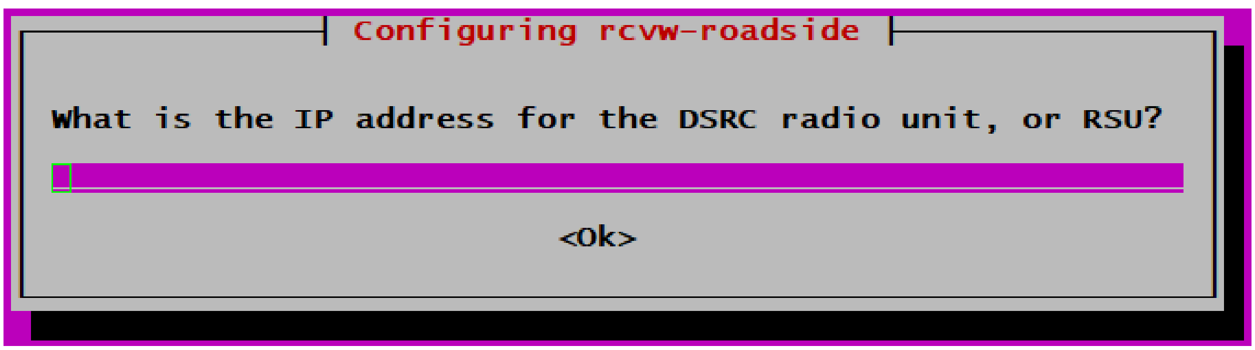
A set of installation scripts, complete with prompts for specific deployment details, have been provided to configure the device up to the standard setup. These, and other troubleshooting commands, are only available within a Linux shell. Open up a terminal program on the desktop or laptop computer (Windows PowerShell or PuTTY, for example) and connect to the RCVW Computing Platform through SSH (use the IP labeled on the VBS CPU). When prompted, logon to the device as **user** with the password **RCVW@pplication**. This should bring up a command prompt like the following:

```
user@user-POC-351VTC:~$
```

To access the programming scripts run the following command :

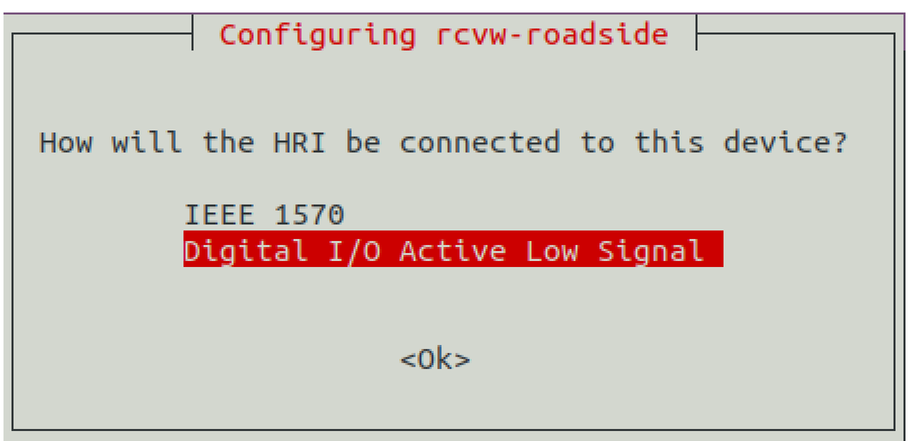
```
user@user-POC-351VTC:~$ sudo dpkg-reconfigure rcvw-roadside
```

The first window that will be presented will ask for the IP address of the rcvw-roadside DSRC radio. Enter the IP address of the DRSC radio (See the label on the radio) and click enter.

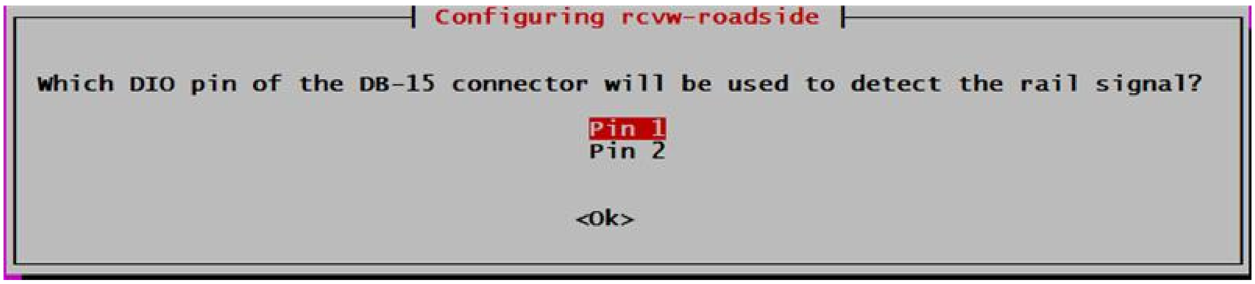


Select how the RBS will interface with the preemption signal (i.e. Digital I/O Active Low Signal, or IEEE 1570 Interface or)

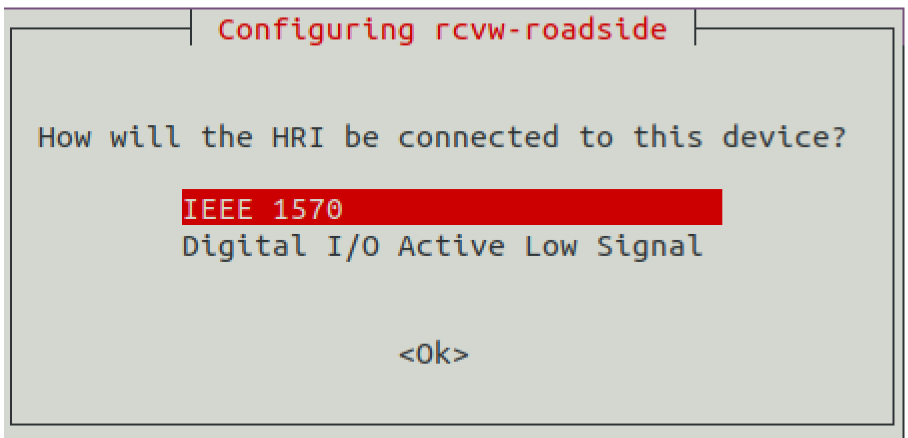
If Digital I/O Active Low Signal is selected.



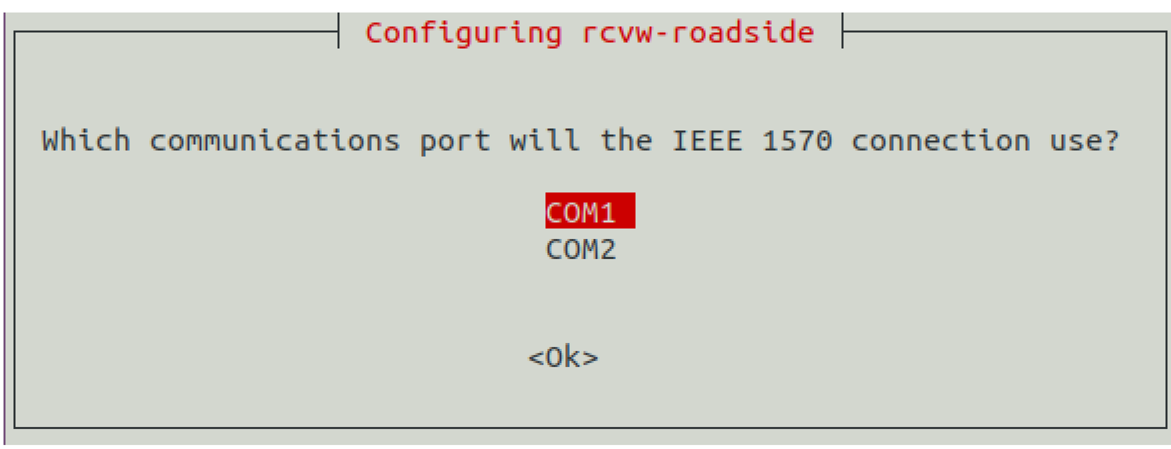
The next step is to select the DIO pin of the DB-15 connector that will be used to detect the preemption signal. The Neousys Intel CPU only accepts pins 1 and 2 as input and pin 3 and 9 as ground. The RCVW prototype system cable was wired for the input signal on pin 1 and ground on pin 9.



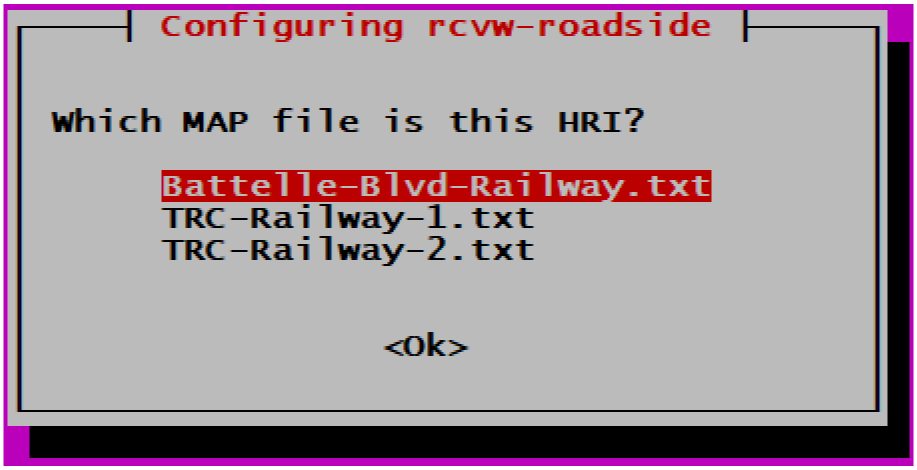
If IEEE 1570 is selected



The next step is to select a communication port.

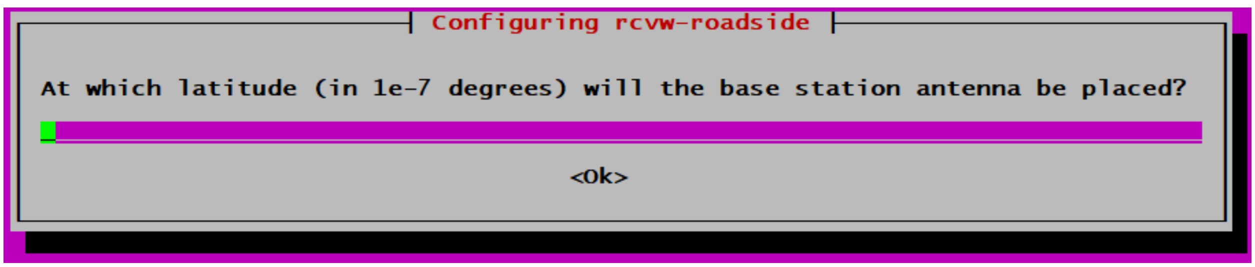


Next, select which MAP is to be used at this HRI. The current list is determined by the available MAPs for RCVW deployments but can be later overridden for new deployments.

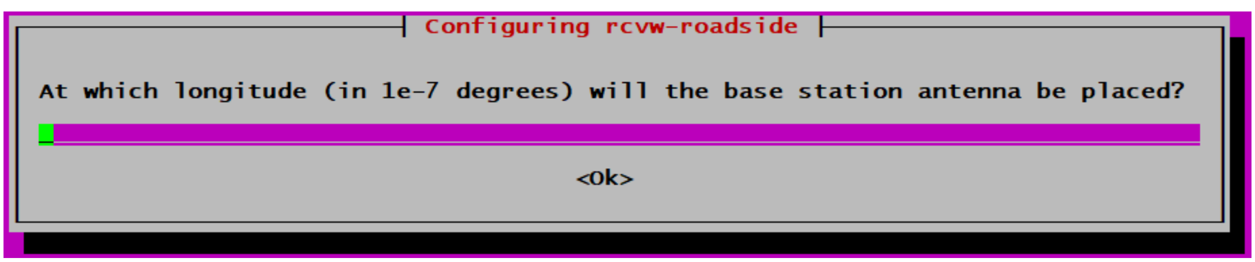


The remaining questions refer to the position of the RBS GPS antenna which is used to build the RTCM corrections.

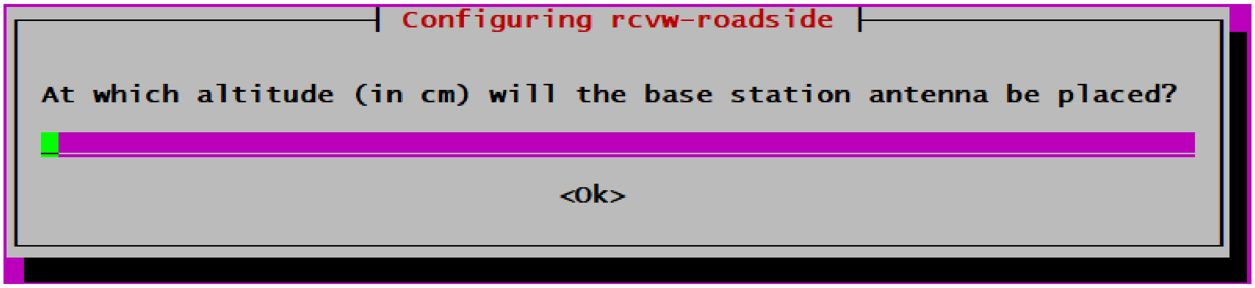
Enter the absolute latitude (with a precision up to 0.0000001 degrees), without decimals for the antenna placements.



Enter the absolute longitude (with a precision up to 0.0000001 degrees), without decimals for the antenna placements.



Enter the absolute altitude (elevation from the survey grade system plus antenna height) in centimeters, without decimals for the antenna placements.

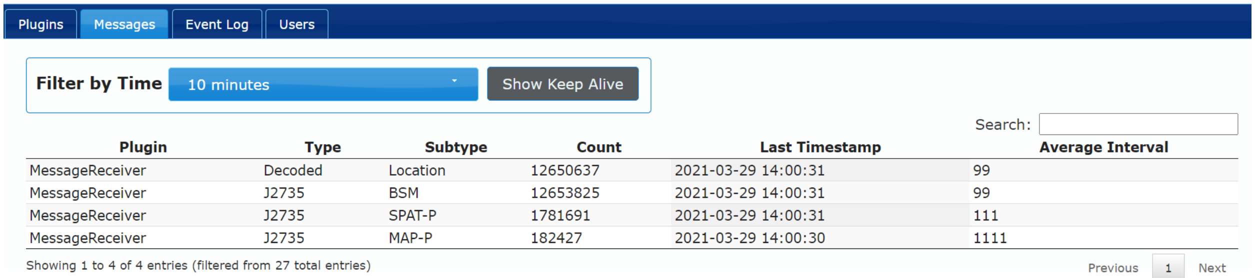


After the configuration of the system is completed, the system should be rebooted.

Troubleshooting

Missing DSRC

If the in-vehicle display presents a *System Fault* message, it is possible that the DSRC messages are not being received properly. This can be confirmed using the administrative portal by noting if J2735 message types are being received as shown in the Messages tab.



Plugin	Type	Subtype	Count	Last Timestamp	Average Interval
MessageReceiver	Decoded	Location	12650637	2021-03-29 14:00:31	99
MessageReceiver	J2735	BSM	12653825	2021-03-29 14:00:31	99
MessageReceiver	J2735	SPAT-P	1781691	2021-03-29 14:00:31	111
MessageReceiver	J2735	MAP-P	182427	2021-03-29 14:00:30	1111

The SPaT-P type should be received at an interval near or below 100. and the MAP at near or below 1000. There are also other incoming messages, like RTCM. If there are missing messages or the rate is too low, the DSRC link may be intermittent. The trouble may be at the RBS. For example, if the DSRC radio fails to receive a good GPS signal for a period of time, the messages are not broadcast. To resolve this issue, the RSU should be rebooted, or power cycled by reseating the PoE cable.

The DSRC trouble may be with the VBS OBU, there may be a communication problem between the OBU and the RCVW. Check the Ethernet connectivity and verify the connectivity from the OBU by connecting to the VBS Computing Platform as shown in the *Connect to the RCVW CPU* section and Ping the radio. If there is no response, the OBU should be rebooted.

Setting the System Parameters to Default values

The RCVW software comes pre-configured and optimized for use. However, it is possible to change and update settings using the administration portals of the RBS and the VBS. To verify the current configuration state against the default optimal settings, run this command on the RCVW in-vehicle:

```
user@user-POC-351VTC:~$ auditConfig.py /usr/local/share/tmx/rcvw/config/*
```

Because this command evaluates every difference, there are generally going to be some WARNING messages indicating that certain parameter or keys are not expected for plugins (see example below). This is because those specific keys, such as the RBS antenna locations and the vehicle information, are meant to vary from instance to instance. Therefore, the WARNINGs can be ignored. However, any messages beginning with the word “tmxctl” are specific misconfigurations, according to the default configurations. To reset these parameters, copy the commands and paste then directly onto the RCVW system. For example:

```
user@user-POC-351VTC:~$ auditConfig.py /usr/local/share/tmx/rcvw/config/*
WARNING: key MessageManagerThreads not expected for plugin "MessageReceiver"
```

```
WARNING: key MessageManagerStrategy not expected for plugin "MessageReceiver"
WARNING: key UDP_Address not expected for plugin "DecodeandForward"
tmxctl --set --key "V2 Check RTK" --value "true" --defaultValue "true" --description
"If enabled check location message for RTK fix while in range of HRI." "RCVW"
tmxctl --set --key "Distance To HRI" --value "480.0" --defaultValue "480.0" --
description "Distance to a known HRI for warning a driver that communications with the
RBS are down." "RCVW"
WARNING: key MessageManagerThreads not expected for plugin "RCVW"
WARNING: key V2 Antenna Placement Y not expected for plugin "RCVW"
WARNING: key V2 Antenna Placement X not expected for plugin "RCVW"
WARNING: key V2 Vehicle Type not expected for plugin "RCVW"
WARNING: key MessageManagerStrategy not expected for plugin "RCVW"
WARNING: key V2 Vehicle Length not expected for plugin "RCVW"
WARNING: key V2 Antenna Height not expected for plugin "RCVW"
WARNING: key Inputs not expected for plugin "VehicleInterface"
WARNING: key Year not expected for plugin "VehicleInterface"
WARNING: key Model not expected for plugin "VehicleInterface"
WARNING: key Make not expected for plugin "VehicleInterface"
```

The tmxctl issues above can be remedied by running:

```
tmxctl –set –key “V2 Check RTK” –value “true” –defaultValue “true” –description “If
enabled check location message for RTK fix while in range of HRI.” “RCVW”
tmxctl –set –key “Distance To HRI” –value “480.0” –defaultValue “480.0” –description
“Distance to a known HRI for warning a driver that communications with the RBS are
down.” “RCVW”
```

This will reset the values of V2 Check RTK and Distance to HRI to the default values.

Bibliography

Baumgardner, G. (2021). *Rail-Crossing Violation Warning (RCVW) Standard Operating Procedures - SPAT, MAP and RTCM Messaging* . Federal Railroad Administration.

Appendix A. List of Acronyms and Abbreviations

CAN	Controller Area Network
DC	Direct Current
CPU	CPU
DIO	Digital Input/Output
DSRC	Dedicated Short-Range Communication
DVI	Driver-Vehicle Interface
GNSS	Global Navigation Satellite Systems
GPS	Global Positioning System
HDMI	High-Definition Multimedia Interface
HRI	Highway-Rail Intersection
IEEE	Institute of Electrical and Electronics Engineers
IP	Internet Protocol
JSON	Java Script Object Notation
LAN	Local Area Network
MAP	Intersection Map
NEMA	National Electrical Manufacturers Association
OBD	On-Board Diagnostics
OBU	On-board Unit
OEM	Original Equipment Manufacturer
PoE	Power Over Ethernet
RBS	Roadside-based Subsystem
RCVW	Rail Crossing Violation Warning
RSU	Roadside Unit
RTCM	Radio Technical Commission for Maritime Services
RTK	Real-Time Kinematic
SMA	SubMiniature version A
USB	Universal Serial Bus
VAC	Volts of Alternating Current
VBS	Vehicle-based Subsystem
VGA	Video Graphics Array

Appendix B. RAM Pod HD Installation

Written installation instructions for the RAM Pod HD Vehicle mount can be seen in the document embedded below.

RAM Mount
Installation Instructior

An instructional video can be seen in the following link.

Appendix C. CAN Configuration

Connect the CAN cable to the Neousys CAN port. See red rectangle on Figure 26. Connect the far-end of the CAN cable to the vehicle's OBD-II port. The RCVW system uses data from the vehicle's OBD-II port to retrieve vehicle speed data. If for any reason the CAN cable is not connected to the OBD-II port, the system will rely on the vehicle speed provided by the GNSS module.

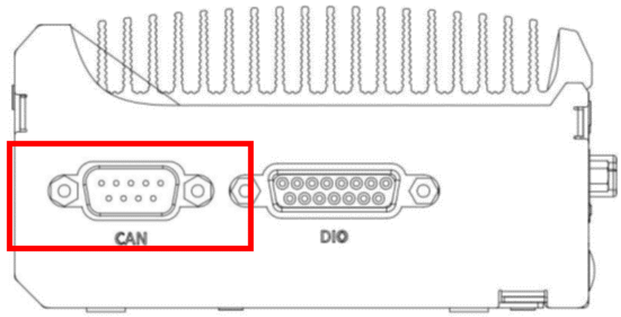


Figure 25. Neousys CAN/DIO ports

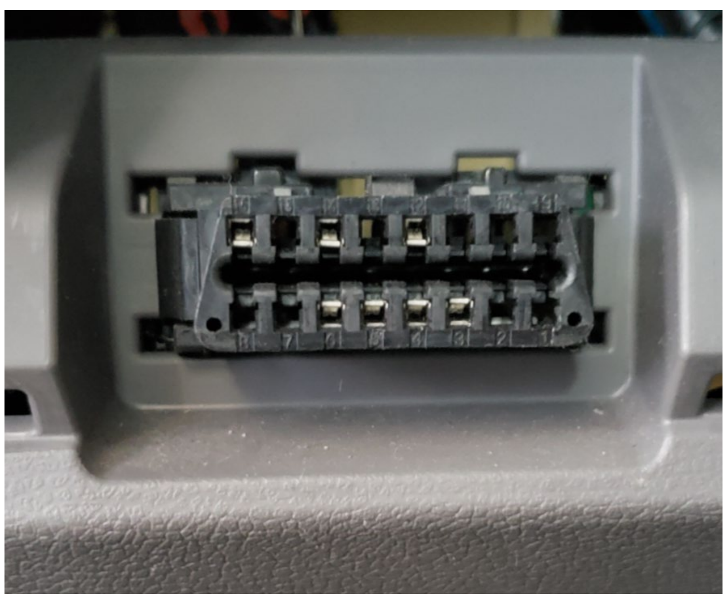


Figure 26. Vehicle OBD-II Port

In order for the plugin to understand what message to read and how to convert the data into a speed value, a JSON configuration file must be created. The file can be called anything, but it must have a .json extension. For example, we will create a file called APPX.json. This is the example CAN configuration file:

```
{
```

```
  "name": "Appendix-X",
  "revision": "20210518",
  "comment": "Example input file for the CarX Fantasy CAN.",
  "types": [ "Car" ],
  "makes": [ "CarX" ],
  "models": [ "Fantasy" ],
  "can": [
             {
               "name": "get-speed",
               "comment": "Determine the vehicle speed",
               "id": "0x218",
               "mask": "EFF",
                          "elements": [
                                   {
                                           "name": "Speed",
                                           "comment": "The speed of the vehicle",
                                           "datatype": "double",
                                           "unit": "kph",
                                           "byte": 4,
                                           "len": -2,
                                           "scale": 0.01
                                   }
                          ]
                 }
         ]
}
```

The following table describes the values

Table 2. Configuration File Parameter Description

Level	Parameter Name	Description
Top	name	The name of this file. Must be unique amongst all input files.
Top	revision	The revision of this file. Typical usage is just the date last edited.
top	comment	A comment for this file, ignored by the system.

Level	Parameter Name	Description
top	types	An array of vehicle types to use if this file is selected. The possible values are “Car”, “Light Duty Truck”, or “Heavy Duty Truck”.
top	makes	An array of vehicle makes, such as Ford or Honda. This example is a made-up vehicle manufacturer to emphasize that this file is not intended for actual use.
top	models	An array of vehicle models for the specified make, such as Explorer or Civic. This example is a made-up vehicle model to emphasize that this file is not intended for actual use.
top	can	This is the type of connection to use for this configuration file. Currently, the only valid value is *can*. The value supplied for this parameter must be an array of JSON objects, each of which will map to a separate connection within a separate thread.
can	name	The name of this CAN connection. Must be unique amongst all other CAN connections.
can	comment	A comment for the CAN connection, ignored by the system.
can	id	The CAN message identifier to match for this connection. Only one identifier can be matched in each CAN connection.
can	mask	The bit-mask to use for this CAN data, given by name. Valid values are “SFF” for the standard frame format (0x000007FF) and “EFF” for the extended frame format (0x1FFFFFFF). See <linux/can.h>.
can	elements	An array of data elements to extract from the CAN message. There can be multiple entries for each CAN message.
elements	name	The name of the Vehicle Basic Message (VBM) parameter to populate from this CAN data element. The only one that matters for RCVW is “Speed”, although others may exist.
elements	comment	A comment to describe this CAN data element, ignored by the system.
elements	datatype	The data type to use for populating the VBM. Valid values are “enum” for enumerated values, “int” for integer values, and “double” for decimal values.
elements	signedval	If the value needs to be signed for integer or double types. Note that the number of bytes used in the data element is key if this parameter is set.
elements	mask	A bit-mask to apply to data element value byte(s).
elements	unit	The unit for the conversion, for example “kph”. These values are dependent on the VBM parameter.

Level	Parameter Name	Description
elements	byte	The byte of the CAN message (beginning at byte 0) in which to extract the CAN data element from. For example, byte 4 is the 5th byte in the message. Note that most CAN messages are 8 bytes long.
elements	len	The number of bytes to extract for this CAN data element. A negative value means the bytes are in reverse order. For example, using a -2 from byte 4 means that the 5th byte in the message is the most significant byte, while the 4th byte is the least significant. If, however, a 2 is used, then the 5th byte in the message is the most significant but the 6th byte is the least significant.
elements	scale	A multiplier used to scale the CAN data element. The default is 1.0.
elements	adjust	A minimum value to use after scaling. The default is 0.0
elements	states	A JSON list of name-value pairs that map the data element value to a specific enumerated value. For example, { “ON”: 0, “OFF”: 1, “NA”: * } would indicate that the value of this VBM parameter should be “ON” if the data element is found to be the value 0, or “OFF” for the value of 1, or “NA” for any other result, as indicated by the asterisk.

Once the file is created, it should be stored under the **/usr/local/share/tmx/config** directory on the VBS Computing Platform. After the system is re-configured (see section X), make certain to enter the correct make and model of the vehicle, and this new file should automatically be setup as the default for the CAN interface. You can confirm receipt of correct messages by monitoring the state information of the VehicleInterface plugin within the V2I Hub Admin portal while driving the vehicle. The JSON file can be edited in place to correct errors in the configuration, but this plugin must be restarted after each modification.

Appendix D. RCVW System Requirements

RCVW Requirement No	System /Subsystem	Requirement
RCVW-1	RCVW System	The system shall include a vehicle-based subsystem component and a roadside-based subsystem component.
RCVW-3	RCVW System	The system shall be modular and sufficiently extensible to address all design objectives defined in this SRS.
RCVW-5	RCVW System	The only point(s) of connection between the RCVW system and the train detection system shall be the preemption signal available through a track-circuit or IEEE 1570-compliant serial interface.
RCVW-7	RCVW System	The vehicle-based subsystem OBU and roadside-based subsystem RSU shall communicate in compliance with SAE J2735-2016, IEEE 1609, SAE J2739, and SAE J2450 (ITIS) Standards.
RCVW-8	RCVW System	All "over-the-road" licensed vehicles (i.e., vehicles of all vehicle classes) are included.
RCVW-11	RCVW System	The system shall be compliant with Connected Vehicle Personally Identifiable Information (PII) standards and guidelines.
VBS-1	Vehicle-Based Subsystem (VBS)	The vehicle-based subsystem DVI shall have the capability to produce alerts suitable for all licensed drivers.
VBS-2	Vehicle-Based Subsystem (VBS)	The vehicle-based subsystem DVI shall have a human-machine interface (HMI) that is configurable to be audible, visual, both, or neither by the driver
VBS-3a	Vehicle-Based Subsystem (VBS)	The vehicle-based subsystem will present alerts that conform to In-Vehicle Display Icons and Other Information Elements, Volume 1: Guidelines and Human Factors Design Guidance for Driver-Vehicle Interfaces.
VBS-3b	Vehicle-Based Subsystem (VBS)	The system shall provide two-stage alert messaging consisting of an informational, and, if applicable, a warning alert. Note: An Approach Inform Alert is non-obtrusive and serves to inform the driver of an active HRI ahead. This alert primes the vehicle operator for the potential need to stop at the HRI. A warn alert is obtrusive and occurs if it is predicted that the vehicle will not stop prior to the HRI using non-emergency braking. This alert serves to notify the

RCVW Requirement No	System /Subsystem	Requirement
		vehicle operator that remains unaware of the active HRI ahead or who has decided to exercise poor judgement.
VBS-3c	Vehicle-Based Subsystem (VBS)	The inform and warn alerts shall be multimodal in nature. Note: Multimodal alerts may be visual, auditory or haptic.
VBS-4	Vehicle-Based Subsystem (VBS)	The vehicle-based subsystem shall produce alerts that can be implemented in all vehicle classes and types equipped with appropriate connected vehicle technologies. Note: vehicle-specific installation procedures may be required.
VBS-5	Vehicle-Based Subsystem (VBS)	The vehicle-based subsystem shall receive and process RTK corrections using the RTCM messaging protocol broadcasted from the roadside-based subsystem to achieve a R95 probability of horizontal position accuracy of less than or equal to 1.5 meters..
VBS-6	Vehicle-Based Subsystem (VBS)	The vehicle-based subsystem shall process HRI configuration (GID) data that describes the geographic composition of the intersection
VBS-7	Vehicle-Based Subsystem (VBS)	The vehicle-based subsystem shall be able to provide direction specific alerts. Note: For clarity, the application shall be able to provide alerts to vehicles approaching the HRI and not alert vehicles departing the HRI.
VBS-8	Vehicle-Based Subsystem (VBS)	The system shall provide a driver-vehicle interface (DVI) and, alternately, support display to OEM displays through standardized physical and electrical outputs.
VBS-9a	Vehicle-Based Subsystem (VBS)	The vehicle-based subsystem shall not interfere with any of the onboard safety systems, especially automotive industry automated safety systems.
VBS-9b	Vehicle-Based Subsystem (VBS)	The vehicle-based subsystem shall not interfere with any existing infrastructure subsystems (traffic control and HRI warning systems).
VBS-10	Vehicle-Based Subsystem (VBS)	The vehicle-based subsystem shall determine if the vehicle is within the HRI Hazard Zone and/or the HRI Approach Zone.
VBS-11a	Vehicle-Based Subsystem (VBS)	The vehicle-based subsystem shall issue a unique warn alert that directs users to take evasive action to clear the HRI by any means when the vehicle is stopped within the HRI Hazard Zone. Note: In the future, when SAE J2735 has been modified to better support rail applications and the intersection zone (HRI Hazard Zone) or when an alternative approach is found to be viable, it is anticipated that the RCVW tool will be capable of distinguishing whether the crossing is active when the vehicle is within the HRI Hazard

RCVW Requirement No	System /Subsystem	Requirement
		Zone. At that time, it is desired that this requirement will be transformed into two requirements – one for when the crossing is active where a warn alert such as the one described here is issued, and one when the crossing is not active where a new Approach Inform Alert will instead be presented.
VBS-11b	Vehicle-Based Subsystem (VBS)	The vehicle-based subsystem shall issue warnings while the HRI is active when the vehicle is in the HRI Approach Zone if the vehicle is not decelerating sufficiently to stop safely before the HRI using non-emergency braking.
VBS-11c	Vehicle-Based Subsystem (VBS)	The warning alert shall use a dynamic visual icon(s) and invasive auditory alert(s) in accordance with Campbell et al. (2016). Human Factors Design Guidance for Driver-Vehicle Interfaces
VBS-12	Vehicle-Based Subsystem (VBS)	The vehicle-based subsystem shall issue an Approach Inform Alert to the vehicle operator when the crossing ahead is active and rail crossing signage for an active crossing is within visual range according to the Guidelines for Advance Placement of Warning Signs in Table 2C-4 of the 2009 Manual on Uniform Traffic Control Devices (MUTCD), Revision 2, June 13, 2012. Note: These guidelines identify where to place a warning sign (i.e. stop sign) in advance of a location with a potential stop condition according to the speed of the vehicle. The presentation of an Approach Inform Alert is limited to approaches toward active rail grade crossings to avoid nuisance alerting.
VBS-13	Vehicle-Based Subsystem (VBS)	The Approach Inform Alert shall use static visual icons and non-invasive audible alert(s) in accordance with Campbell et al. (2016). Human Factors Design Guidance for Driver-Vehicle Interfaces.
VBS-14	Vehicle-Based Subsystem (VBS)	The vehicle-based subsystem shall process the HRI Active message in the context of its position with respect to the HRI, its instantaneous speed, acceleration, and other vehicle parameters to determine if an RCVW should be issued.
VBS-15	Vehicle-Based Subsystem (VBS)	An RCVW warning shall be presented to the vehicle operator based on: 85th percentile driver response time, vehicle characteristics (i.e., vehicle class), and vehicle telematics (i.e. velocity, acceleration).
VBS-16	Vehicle-Based Subsystem (VBS)	The vehicle-based subsystem shall not provide warnings when it is not inside the HRI Hazard Zone or HRI Approach Zone.
VBS-17	Vehicle-Based Subsystem (VBS)	Once issued, the graphical component of an Approach Inform Alert will persist while the vehicle is within the approach zone, except when superseded by a warning or fault alert, or when the crossing becomes inactive.

RCVW Requirement No	System /Subsystem	Requirement
VBS-18	Vehicle-Based Subsystem (VBS)	The vehicle-based subsystem shall issue a fault alert to the vehicle operator when the RCVW system is not functioning in "normal" operations mode. A fault alert will be triggered when the VBS does not receive critical information, including: 1) position information, a) GNSS information being received at a rate lower than 10 Hz b) GNSS solution not reaching and RTK fix, either floating or fixed integer 2) MAP, 3) SPaT (which includes loss of the IEEE 1570 interface communication heartbeat from the HRI warning system, when this interface is used), or 4) DSRC communications (MAP and SPaT) when expected and needed
VBS-19	Vehicle-Based Subsystem (VBS)	Fault alerts shall supersede all other annunciations.
VBS-20	Vehicle-Based Subsystem (VBS)	Warn alerts shall supersede Approach Inform Alerts.
VBS-22	Vehicle-Based Subsystem (VBS)	The vehicle-based subsystem shall be capable of receiving messages sent by the roadside-based subsystem within 50 ms.
VBS-23	Vehicle-Based Subsystem (VBS)	The vehicle-based subsystem shall be capable of processing received data within 85 ms.
VBS-24	Vehicle-Based Subsystem (VBS)	The vehicle-based subsystem shall know the position of the GNSS antenna relative to the front of the vehicle and the rear of the vehicle.
RBS-1	Roadside-Based Subsystem (RBS)	The roadside-based subsystem shall interoperate with current infrastructure safety systems (e.g. traffic control and Train Approaching warning devices) in accordance with NEMA TS 2-2016 v03.07.
RBS-2	Roadside-Based Subsystem (RBS)	The roadside-based subsystem shall operate using 60 Hz 115VAC power as the primary power source.
RBS-2b	Roadside-Based Subsystem (RBS)	The roadside-based subsystem shall determine HRI crossing status using preemption signal information from a IEEE 1570-compliant serial interface or from a voltage-based interconnection circuit.

RCVW Requirement No	System /Subsystem	Requirement
RBS-3	Roadside-Based Subsystem (RBS)	The infrastructure-based communication equipment shall be compliant with the V2I Hub Reference Implementation platform.
RBS-4	Roadside-Based Subsystem (RBS)	The roadside-based subsystem shall broadcast the HRI Active message 10 times per second when an associated HRIC activates a preemption signal.
RBS-5	Roadside-Based Subsystem (RBS)	The roadside-based subsystem shall stop broadcasting the HRI Active message when the HRIC deactivates the preemption signal(s).
RBS-7	Roadside-Based Subsystem (RBS)	The roadside-based subsystem shall broadcast the HRI Configuration Data Format (HCDF) once per second.
RBS-10	Roadside-Based Subsystem (RBS)	The roadside-based subsystem shall execute periodic BIST, which includes a default mode that, if possible - depending on the nature of the failure, informs the driver via the vehicle-based subsystem when critical components are offline.
RBS-11	Roadside-Based Subsystem (RBS)	The roadside-based subsystem shall employ methods to prevent unauthorized physical and cyber access.
RBS-12	Roadside-Based Subsystem (RBS)	The V2I communication shall implement security as defined by IEEE 1609 Standards for Wireless Access in the Vehicular Environment (WAVE). For clarity, a unique security solution will not be developed for this project, but the available security solution provided by U.S. DOT for V2I communications will be exercised.
RBS-13	Roadside-Based Subsystem (RBS)	Secure-communication protocols shall not adversely impact the performance of the safety application with respect to the ability to provide alerts in a timely manner.
RBS-16	Roadside-Based Subsystem (RBS)	The roadside-based subsystem shall identify and log system failures to the extent that it is practicable.
RBS-18	Roadside-Based Subsystem (RBS)	The roadside-based subsystem shall incorporate self-recovering routines in order to recover from a major system failure associated with firmware/software systems.
RBS-20	Roadside-Based Subsystem (RBS)	The roadside-based subsystem shall not interfere with any HRI infrastructure subsystems.
RBS-21	Roadside-Based Subsystem (RBS)	The roadside-based subsystem shall be capable of receiving HRI message packets across the IEEE 1570 serial interface in less than 250 ms conforming to the IEEE1570 standard.

RCVW Requirement No	System /Subsystem	Requirement
RBS-22	Roadside-Based Subsystem (RBS)	The roadside-based subsystem shall be capable of generate and broadcast RTK corrections using the RTCM messaging protocol.