

Connected Commercial Vehicles—Retrofit Safety Device Kit Project Final Report

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		16. Abstract Connected vehicle wireless data communications can enable safety applications that may reduce injuries and fatalities. Cooperative vehicle-to-vehicle (V2V) safety applications will be effective only if a high fraction of vehicles are equipped. Deployment of V2V technology will be enabled if it is available not only for manufacturing in new vehicles but also for retrofit to existing vehicles. The objective of the Connected Commercial Vehicles—Retrofit Safety Device (CCV-RSD) Kit Project was to develop complete hardware and software that can be used in various brands and models of heavy trucks. The RSD kits provide the functionality needed for cooperative V2V and vehicle-to-infrastructure (V2I) safety applications to support the Model Deployment and other USDOT connected vehicle projects. This project included testing and documentation needed for installation, operation, enhancement, and maintenance of the units. These retrofit kits were built so they could be installed in existing class 6, 7, or 8 trucks. The RSD kits achieved a V2V and V2I functionality similar to that of the Connected Commercial Vehicles—Integrated Truck vehicles, where onboard equipment was integrated with newly manufactured truck tractors. This final report summarizes all of the activities and accomplishments of this project. Hardware and software were developed to adapt safety applications to commercial vehicles. Carefully planned testing on a benchtop and test track provided successful operation in the Safety Pilot Model Deployment.	
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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS				
SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
LENGTH				
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
AREA				
in ²	square inches	645.2	square millimeters	mm ²
ft ²	square feet	0.093	square meters	m ²
yd ²	square yard	0.836	square meters	m ²
ac	acres	0.405	hectares	ha
mi ²	square miles	2.59	square kilometers	km ²
VOLUME				
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft ³	cubic feet	0.028	cubic meters	m ³
yd ³	cubic yards	0.765	cubic meters	m ³
NOTE: volumes greater than 1000 L shall be shown in m ³				
MASS				
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
TEMPERATURE (exact degrees)				
°F	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	°C
ILLUMINATION				
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m ²	cd/m ²
FORCE and PRESSURE or STRESS				
lbf	poundforce	4.45	newtons	N
lbf/in ²	poundforce per square inch	6.89	kilopascals	kPa
APPROXIMATE CONVERSIONS FROM SI UNITS				
SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
LENGTH				
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
AREA				
mm ²	square millimeters	0.0016	square inches	in ²
m ²	square meters	10.764	square feet	ft ²
m ²	square meters	1.195	square yards	yd ²
ha	hectares	2.47	acres	ac
km ²	square kilometers	0.386	square miles	mi ²
VOLUME				
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m ³	cubic meters	35.314	cubic feet	ft ³
m ³	cubic meters	1.307	cubic yards	yd ³
MASS				
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
TEMPERATURE (exact degrees)				
°C	Celsius	1.8C+32	Fahrenheit	°F
ILLUMINATION				
lx	lux	0.0929	foot-candles	fc
cd/m ²	candela/m ²	0.2919	foot-Lamberts	fl
FORCE and PRESSURE or STRESS				
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in ²

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ACRONYMS AND ABBREVIATIONS

API	Application Programming Interface.
Application	A use of the connected vehicle technology to avoid a certain kind of crash, such as Blind Spot Warning (BSW) or IMA (Intersection Movement Assist).
ASD	Aftermarket Safety Device. Not as well integrated with a vehicle as an OBE, but with greater capability than a Vehicle Awareness Device.
BSM	Basic Safety Message. The package of information about a vehicle's position and status that is broadcast to surrounding vehicles by the OBE, ASD, or Vehicle Awareness Device.
BSW + LCW	Blind Spot Warning, Lane Change Warning. A safety application.
CAMP	Crash Avoidance Metrics Partnership. Originally was GM and Ford; now includes Mercedes-Benz, Toyota, Honda, Volkswagen, Nissan and Hyundai-Kia.
CAN	Controller Area Network. Just about all cars and trucks have one nowadays. Lots of parts of the vehicle broadcast their status and receive their instructions from the bus.
CCV	Connected Commercial Vehicle.
CCV-IT	Connected Commercial Vehicles—Integrated Truck.
CCV-RSD	Connected Commercial Vehicles—Retrofit Safety Device.
CSW	Curve Speed Warning. An application developed by MBRDNA for commercial vehicles.
CVSCA	Commercial Vehicle Safety Communications Application.
DAS	Data Acquisition System. Records data for the engineers to examine after the experiment.
DSRC	Dedicated Short-Range Communication. Think of it as Wi-Fi for the road.
DVI	Driver-Vehicle Interface. A lighted symbol on the dash, possibly a beep, and maybe a seat vibration.

EEBL	Emergency Electronic Brake Light. A safety application.
FCW	Forward Collision Warning. A safety application.
FHWA	Federal Highway Administration (part of USDOT).
GPS	Global Positioning System.
HIA	“Here I Am.” Old name for a Vehicle Awareness Device (which see).
HV	Host Vehicle. The vehicle in which the safety application resides.
IMA	Intersection Movement Assist. A safety application.
ITS JPO	Intelligent Transportation Systems Joint Program Office (part of USDOT).
MBRDNA	Mercedes-Benz Research & Development North America, Inc.
MD	Model Deployment. A parallel but separate project.
miniWSU	The particular model of DENSO’s Wireless Safety Unit that was used in the CCV-RSD kits.
MITRP	Michigan Technical Research Park.
NHTSA	National Highway Traffic Safety Administration (part of USDOT).
NMEA	National Marine Electronics Association.
OBE	On-Board Equipment. A device on the vehicle that supports the connectivity.
OTA	Over-the-Air.
RF	Radio Frequency.
RSD	Retrofit Safety Device. A device with functionality similar to an OBE that is installed in a vehicle as an aftermarket retrofit. May have slightly less integration than an OBE but is better integrated with the vehicle and has more capability than a Vehicle Awareness Device.
RV	Remove Vehicle. A vehicle in a scenario other than the HV.

Scenario	An arrangement of vehicles and a plan for their motion intended to demonstrate an application.
SP	Safety Pilot. A parallel but separate project.
SR	Scenario Replicator.
SSID	Service Set Identifier.
TIM	Traveler Information Message.
UMTRI	University of Michigan Transportation Research Institute.
USDOT	United States Department of Transportation.
Vehicle Awareness Device	(not to be shortened) A device in a vehicle that broadcasts announcing its position to neighboring vehicles. The BSM from a Vehicle Awareness Device contains only location information, no information about the vehicle condition. An OBE does include vehicle status in the BSM.
VRTC	Vehicle Research and Test Center. A laboratory of NHTSA in Ohio.
V2V	Vehicle-to-vehicle (communication).
V2I	Vehicle-to-infrastructure (communication).
WSU	Wireless Safety Unit.

EXECUTIVE SUMMARY

Connected vehicle telecommunications can transform travel in North America, enabling major reductions in crashes, injuries, and fatalities on our highways, as well as enabling reductions in traffic congestion and effects on the environment. This project demonstrated the technical viability of equipping an in-service truck tractor with connected vehicle safety applications. Furthermore, this “retrofit safety device” or RSD can be manufactured as a kit that can be installed by technicians and is not limited to a particular make of tractor. By equipping not only newly manufactured tractors but also previously manufactured tractors, it is possible to accelerate capturing the benefits of connected commercial vehicle safety applications. The project provided information and data needed to assess the applications’ safety benefits and support regulatory decision processes.

The miniaturized electronics package that implements the safety applications, the “miniWSU,” was small enough to be mounted in a housing external to the cab and robust enough to perform for an entire year. The external mounting simplified installation and minimized the number of connections required to the cab interior. The RSD kits implemented four vehicle-to-vehicle (V2V) safety applications:

- Intersection Movement Assist (IMA).
- Forward Collision Warning (FCW).
- Emergency Electronic Brake Light (EEBL).
- Blind Spot Warning (BSW).

The RSD kits also implemented one vehicle-to-infrastructure (V2I) safety application:

- CurveSpeed Warning (CSW).

In support of the research, each tractor was outfitted with a Data Acquisition System (DAS) to record the truck’s motion as well as all messages transmitted and received by the RSD kit.

Ten kits were delivered. The first was installed by staff at the National Highway Traffic Safety Administration (NHTSA) Vehicle Research and Test Center (VRTC). This demonstrated that technicians not affiliated with the project team with written directions can install the kit. A second was installed in a tractor for closed-course testing by the project team. This tractor successfully executed 25 scenarios that verified the functioning of the V2V safety applications. The remaining eight kits were installed in tractors that were operated by a fleet during the year-long model deployment in Ann Arbor, Michigan. These tractors exchanged Basic Safety Messages (BSMs) with the other light and commercial vehicles in the model deployment and gave alerts to their drivers. The success in the model deployment demonstrated the interoperability of the RSD kits with light vehicles in a real-world setting.

CHAPTER 1. INTRODUCTION

The purpose of the project was to take technology that has been developed for light passenger vehicles and package it in a way that it can be retrofit to commercial motor vehicles, specifically a truck tractor for pulling a semitrailer. Vehicles equipped with this technology broadcast radio signals indicating their position and other information to surrounding vehicles. This information is intended to help drivers avoid crashes. The project deployed technology on commercial vehicles and supported those vehicles in research and testing that provided information to assess their safety benefits and support regulatory decision processes.

DESCRIPTION OF THE OVERALL PROJECT

Connected vehicle telecommunication systems for vehicle data have the potential to transform vehicle travel in North America, enabling major reductions in injuries and fatalities suffered on our roads and highways, as well as enabling reductions in traffic congestion and effects on the environment. As a critical part of achieving these goals, the USDOT wishes to apply the successful experience with connected vehicle technology implementation on light vehicles to commercial vehicles; and to demonstrate the performance, interoperability, and safety benefits of the technology in mixed light and commercial vehicle environments. This project applied connected vehicle technology to commercial vehicles. The equipment in this project was developed as a kit that could be retrofit to an existing truck tractor. Thus, the name of the project was Connected Commercial Vehicles—Retrofit Safety Device (CCV-RSD) Kit.

The team adapted safety applications that had been developed for light vehicles. While maintaining the basic functionality of the applications, parameters were adapted to the particular needs of large commercial vehicles. A new generation of the hardware was used to enhance integration with the commercial vehicle. Two Dedicated Short-Range Communication (DSRC) antennas, one each on the left and right side mirrors on the cab, proved to be sufficient for transmitting and receiving around the tractor and trailer. Icons to depict the hazards in each safety application were developed specifically for commercial vehicles. They were displayed on a screen above the parking brake controls.

Components of the equipment were subjected to rigorous testing before integration with the rest of the system. The first RSD kits and installation instructions was delivered to the National Highway Traffic Safety Administration's (NHTSA's) Vehicle Research and Test Center (VRTC), where VRTC staff installed it in a tractor already owned by NHTSA. Project staff installed a kit on another tractor, and the functioning of the safety applications was tested on a closed course in Michigan. Finally, kits were installed on eight tractors belonging to a commercial fleet for testing in revenue service during the model deployment where they performed as intended.

DESCRIPTION OF THE TECHNOLOGIES

The heart of the technology is a radio and computer on a vehicle. It determines the vehicle's location using Global Positioning System (GPS) and broadcasts its location to surrounding vehicles ten times a second. The technology has matured to the point that these functions are performed in a compact,

field hardened wireless safety unit (WSU). The particular model employed in the RSD kits was the miniWSU manufactured by DENSO. A special radio protocol called Dedicated Short-Range Communication (DSRC) uses the 5.9 GHz band to transmit signals, either from a vehicle to a vehicle (V2V) or between vehicles and the infrastructure (V2I).

The Basic Safety Message (BSM) that is transmitted to surrounding vehicles includes not only the position of the vehicle, but also its speed, heading, size, whether the brake lights are on, and more. Other vehicles nearby can use this information to determine whether they are on a possible collision course and advise their drivers. A “safety application” is the name of the computer logic on the receiving vehicle that determines whether to inform the driver of a potential hazard (for example, a vehicle in a blind spot) or to warn the driver of an imminent hazard (for example, of a stopped vehicle ahead).

INTEGRATED TRUCK AND TRANSIT PROJECTS

A separate contract, conducted in parallel with this one, developed safety applications for integration with a newly manufactured truck tractor. The Connected Commercial Vehicles—Integrated Truck (CCV-IT) project developed a set of safety applications that were essentially identical to those in this RSD Kit project. The integrated trucks went through similar testing: bench-top checkouts, functional tests in carefully planned scenarios on a closed track, and participation in the model deployment in Ann Arbor, Michigan. The CCV-IT project also included driver acceptance clinics and a demonstration at the ITS World Congress in 2011. The CCV-IT project is documented in a separate report.⁽⁴⁾

Another Battelle-led team prepared transit buses that participated in the model deployment. Battelle build retrofit packages for the buses and developed, demonstrated, and deployed transit-specific applications.

CHAPTER 2. COMPONENTS OF THE SYSTEM

The retrofit safety device kit is literally a kit, delivered as separate parts intended to be installed on a tractor that had previously been manufactured without regard to V2V communications. The only requirement of the tractor is that it use the SAE standard J1939 bus for communications (as is now universal among tractors in North America). Instructions for installing the kit are in appendix A.

The kit consists of the retrofit Onboard Equipment (OBE), which had hardware and software patterned after the light vehicle counterpart, antennas and wiring, a tablet and mounting bracket for the driver display, and a bracket to mount the equipment atop the cab.

The architecture of the RSD is illustrated in figure 1. The central piece of equipment is the miniWSU. A pair of DSRC antennas broadcast and receive BSMs. Communication with the host vehicle is through its J1939 data bus. Messages to be displayed by the Driver Vehicle Interface (DVI) are transmitted via Wi-Fi. A Data Acquisition System (DAS) was not part of the RSD but was part of the project to support testing and analysis.

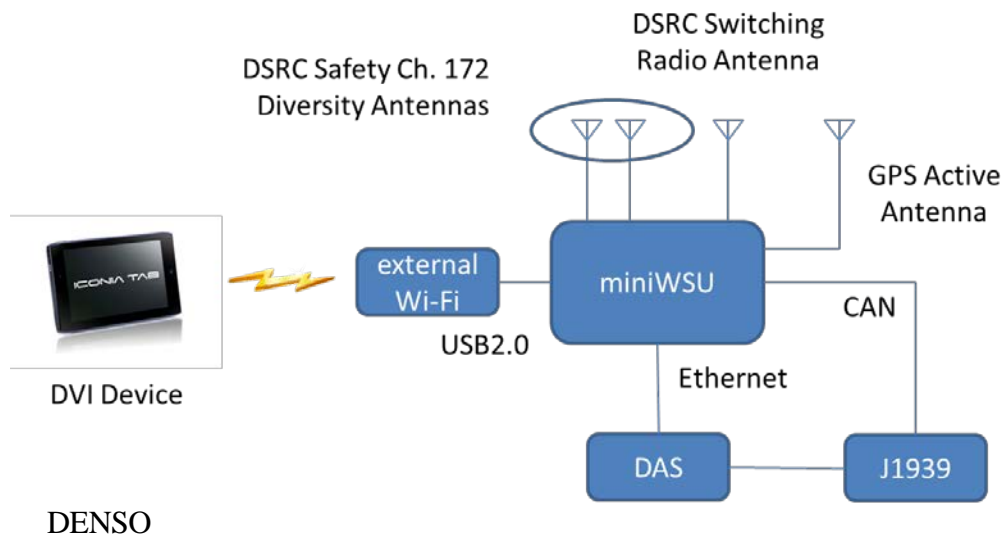


Figure 1. Diagram. Architecture of the RSD, including its interfaces to the vehicle, DVI, and DAS.

RSD EQUIPMENT

The platform development portion of the CCV Safety Applications Development project was adapted from the system developed over multiple projects for light vehicles. The RSD safety applications have much in common with those of the CCV-IT, but nearly every part of the hardware is different between the two projects.

Electronics Hardware

A DENSO product called the Wireless Safety Unit (WSU) functioned as the heart of the OBE in this project. The particular version used for the CCV-RSD project was the miniWSU (figure 2), which was designed specifically for retrofit applications. Its size is 106 x 72 x 25 mm. The software to support all of the communications and safety applications runs on electronics in this package.



DENSO

Figure 2. Photo. The miniWSU performed most of the functions of the safety applications.

The miniWSU includes an internal GPS receiver that provides National Maritime Electronic Association (NMEA) messages and a 1 pulse-per-second (PPS) signal. The internal miniWSU configuration file includes an element for entering the three-dimensional physical offset between the location of the GPS antenna and the geometrical center of the vehicle. The receiver device also provides a GPS system timing pulse to the WSU GPS interface with the 1- μ s accuracy necessary to accommodate the Wireless Access in Vehicular Environments (WAVE) P1609.4 channel coordination specification.

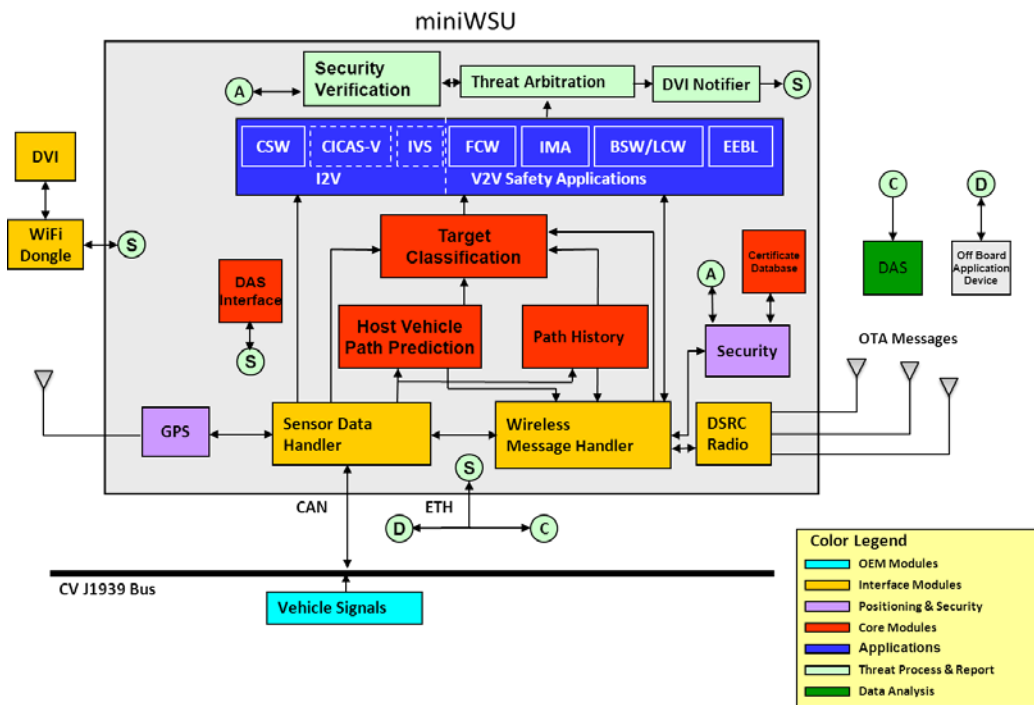
Software

Linux is the general purpose operating system for the miniWSU services and application functions. The miniWSU software includes device drivers for CAN, Ethernet, USB, and all other interfaces and provides an application programming interface (API) used by the safety applications.

The miniWSU Software Service provides an API to enable applications to obtain data from the GPS receiver and the CAN Bus. The API also enables an application to configure the DSRC radio parameters and to transmit and receive data. The Time/Position Service interfaces to the internal

GPS receiver to obtain time and position updates and Radio Technical Commission for Maritime Service (RTCM) messages, and provides this data to requesting applications. Similarly, the Vehicle Interface Service interfaces to the CAN bus to obtain vehicle status updates, and provides this data to requesting applications. The vehicle interface service also accepts data from applications for output to the CAN buses. Applications may access other WSU hardware interfaces by using the corresponding device drivers provided by Linux.

The software structure of the primary WSU is illustrated in figure 3. It is similar to the OBE installations used for light vehicle V2V crash avoidance and the CCV-IT architecture. The Commercial Vehicle Safety Communications Application (CVSCA) modules consist of system framework modules and application modules. The system framework modules interface to external equipment, calculate data to support the CVSCA application modules, and support the User Interface. The application modules evaluate potential safety threats based on inputs from the system framework modules. The application modules consist of four V2V applications and one V2I application developed or modified under the CCV-IT project. The architecture and design provides the ability to add applications in the future.



DENSO

Figure 3. Diagram. System architecture of the miniWSU.

Vehicle Interface

Vehicle data from tractor's J1939 CAN interface was obtained by tapping into the J1939 backbone through commercial plugs and connectors.

Driver-Vehicle Interface (DVI)

The driver-vehicle interface (DVI) was an Acer A100 Tablet PC. The miniWSU communicated to the tablet through an external USB Wi-Fi unit that served as an access point.

Figure 4 shows where the display for the driver was located in the tractors in the Model Deployment. The display may be in a different location and mounted in a different manner in a cab with a different layout.



UMTRI

Figure 4. Photo. Messages for the safety applications were displayed on the tablet in the red circle.

Retrofit Mounting Hardware

The retrofit kit includes not only the miniWSU to execute the safety applications but also the hardware and cables necessary to mount the device to a tractor. Much of the hardware is attached to the telescoping bar mount shown in figure 5. The bar fastens to the back of the cab. The miniWSU is in an enclosure near the center of the bar. The enclosure provided necessary protection from the weather. It included a “shark fin” antenna for DSRC security signals and for GPS. The two main DSRC antennas are mounted at the two ends of the bar, so they extend beyond the cab as shown in figure 6. Cables run along the bar between the antennas and the enclosure, and from the enclosure down to the tractor itself for power, communication with the tractor’s J1939 bus, and for the driver display. Mounting the enclosure on the bar with the DSRC antennas enabled the RF cables to be fixed length regardless of the installation details. Cutting the cables to length and connectorizing them at the factory is advantageous because doing so requires specialized tooling and training. Mounting the electronics external to the cab also minimized the number of wires that needed to pass through the cab.

The kit is shown installed on a tractor for the Model Deployment in figure 7. The cameras shown in the photograph were for data collection in the DAS during the Model Deployment; they are not part of the RSD kit.

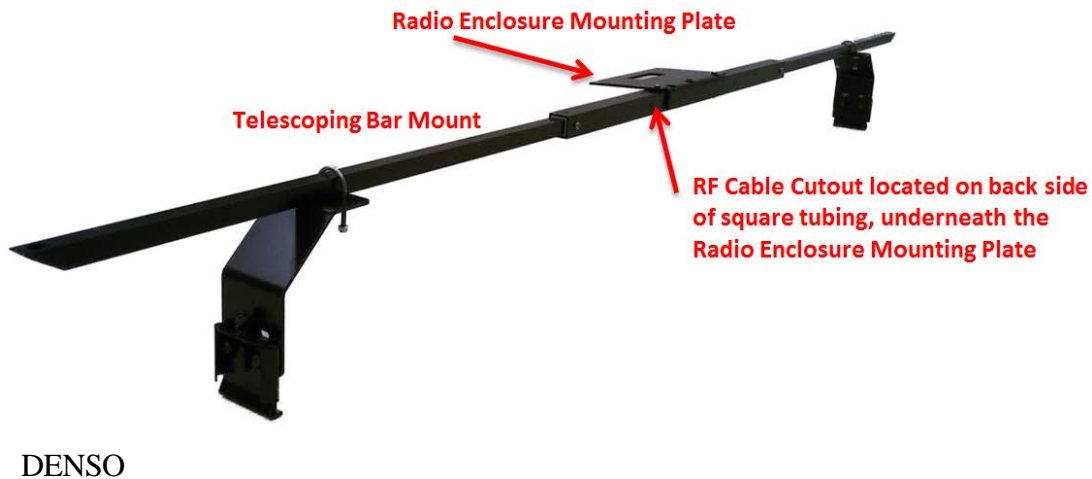
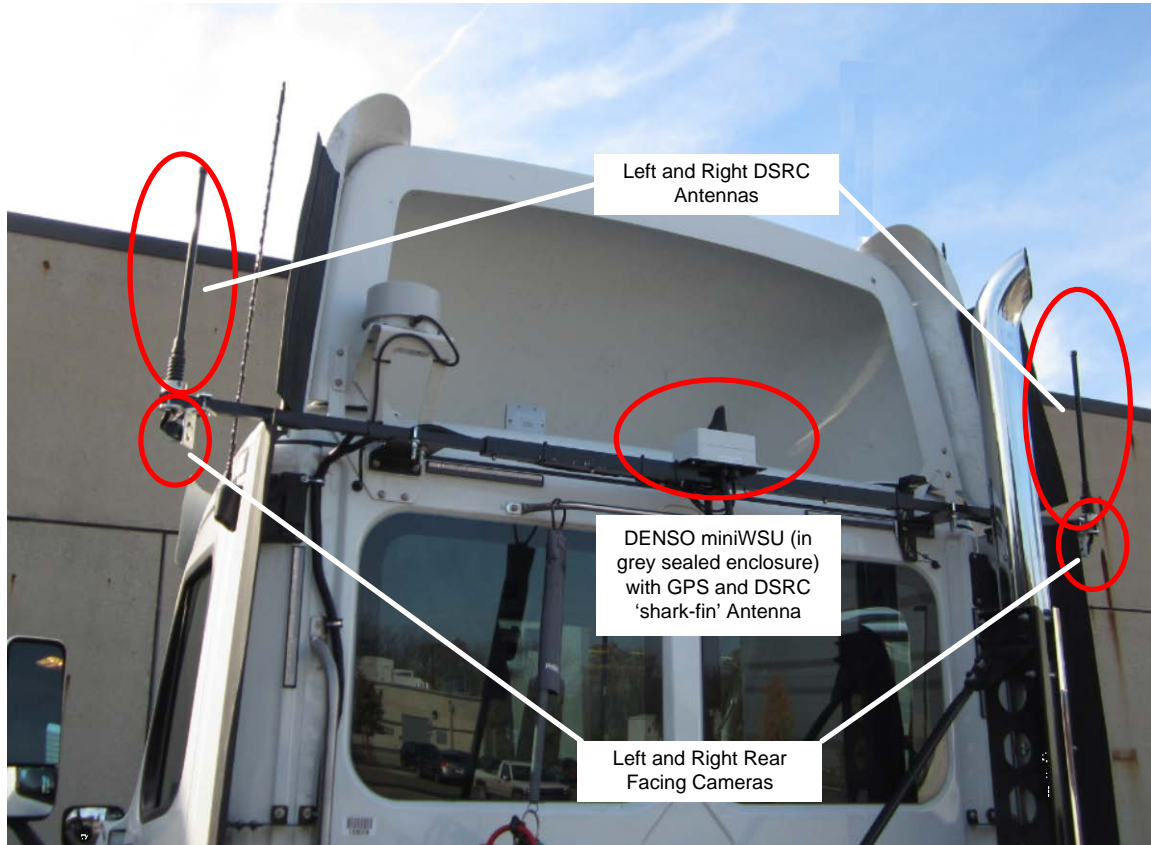


Figure 5. Photo. RSD bar mount assembly.



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Figure 6. Photo. Front view of a tractor with the RSD kit installed. The arrow points to the right-side DSRC antenna. This tractor was outfitted for the Model Deployment.



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Figure 7. Photo. Rear view of a tractor with the RSD kit installed.

DESCRIPTION OF THE SAFETY APPLICATIONS

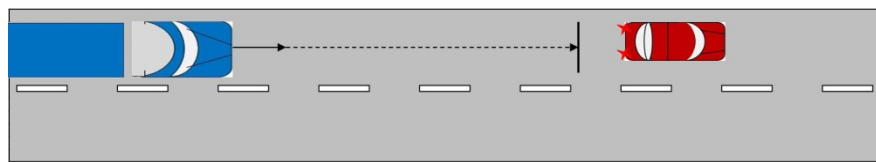
The connected vehicle safety applications are intended to inform the driver of developing situations around the vehicle. Each application warns of a particular type of hazard. The RSD vehicles implemented four V2V safety applications, which warn the driver of other vehicles that may be a threat, and one V2I safety application, which warns the driver of a fixed hazard, in this case, an upcoming curve.

All of the applications except BSW have two levels of alert. The lower level “inform” alert displays a yellow triangle along with a simple sketch of the situation, as in the figures that follow. The more urgent “warn” alerts look similar but have a red triangle and include a sound. Fuller descriptions of the safety applications and the display images are in appendix D, and complete definitions of the safety applications are in the Safety Applications Development Plan.⁽⁵⁾

Forward Collision Warning (FCW)

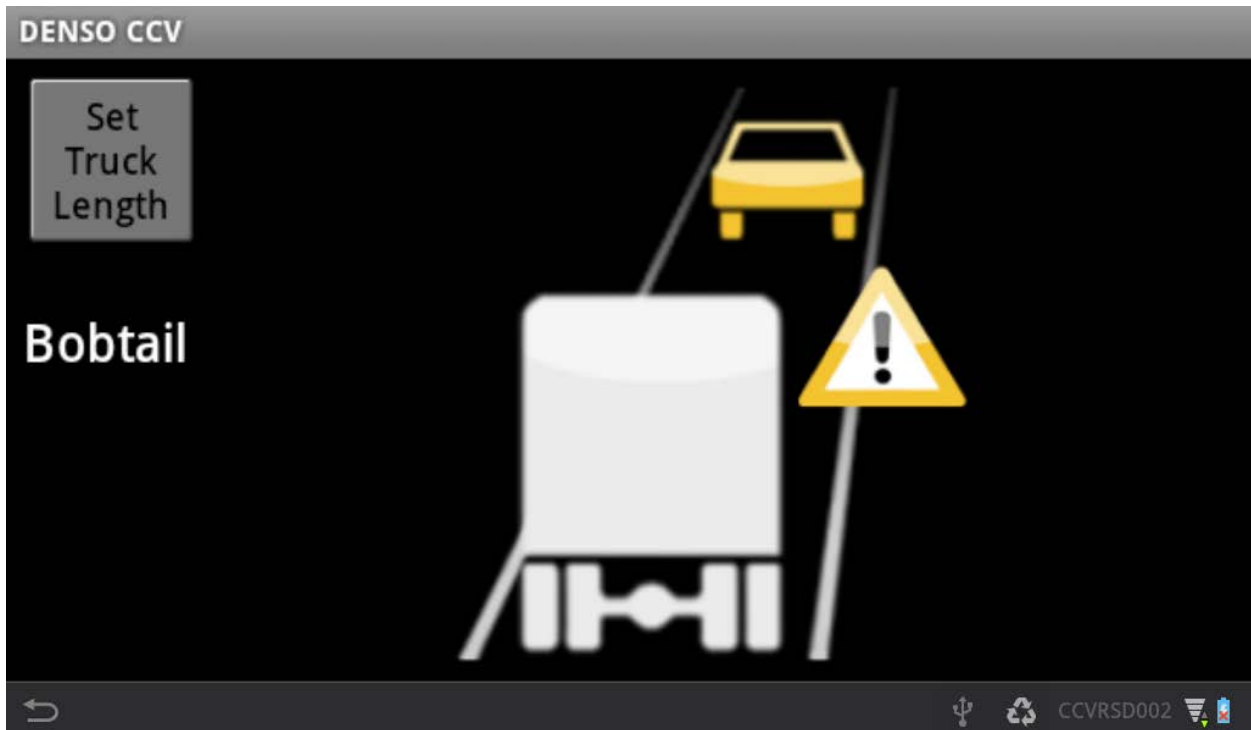
The FCW application alerts the driver of an impending front-end collision with a remote vehicle that is ahead and in the same lane, as illustrated in figure 8. The application considers the current position and relative speed of the host and remote vehicles to determine if a collision is imminent. The display given to the driver by the FCW application is in figure 9.

Even under the best conditions, commercial vehicles cannot brake as well as light vehicles. Therefore, the FCW implementation on a commercial vehicle monitors farther ahead for stopped vehicles. The parameter for the truck's deceleration is lowered, and increased driver response time is allowed. The application delivers alerts to a truck driver earlier than it would to a light vehicle driver.



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Figure 8. Illustration. The FCW message might be given if a lead vehicle is stopped in the same lane as the truck's travel.

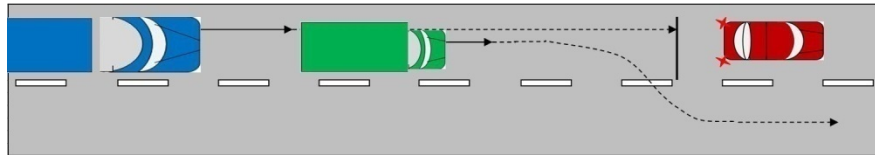


DENSO

Figure 9. Illustration. This image was displayed to the driver for the FCW inform-level alert.

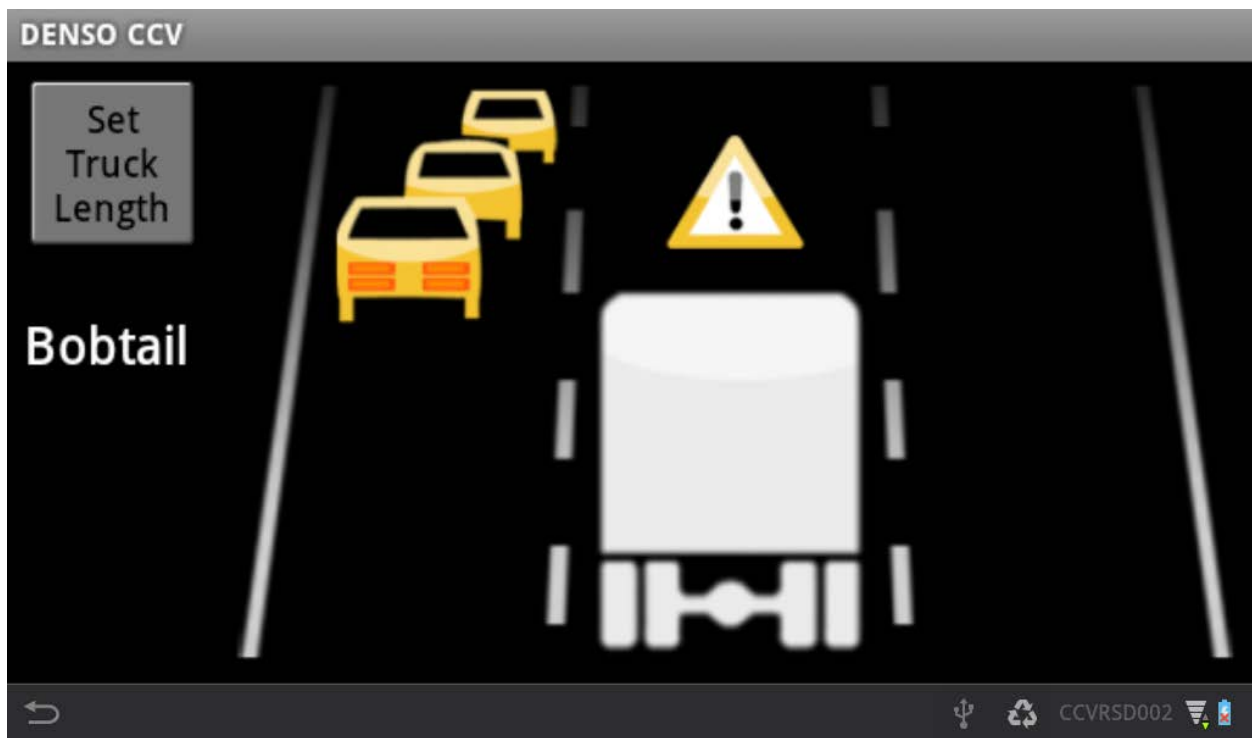
Emergency Electronic Brake Light (EEBL)

The EEBL application alerts the driver to a hard braking by a vehicle that is ahead and in the same lane or adjacent lane. It is intended to be especially beneficial in the case where a third vehicle blocks the truck driver's view of the braking vehicle, as illustrated in figure 10. The application monitors the hard braking event indications in BSMs received from other vehicles. Upon receiving a braking indication, it determines whether the remote vehicle is in close proximity ahead and in the same or an adjacent lane. If so, and the driver has not yet applied the truck's brakes, the image in figure 11 will be displayed.



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Figure 10. Illustration. The EEBL application advises the truck driver of the braking lead vehicle, even if the view is blocked by a third vehicle in between.



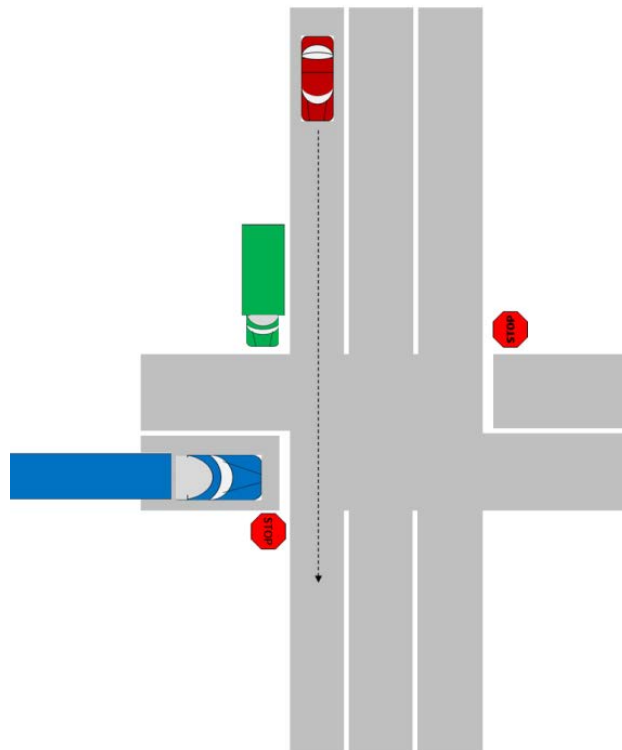
DENSO

Figure 11. Illustration. This image was displayed to the driver for the EEBL inform-level alert.

Intersection Movement Assist (IMA)

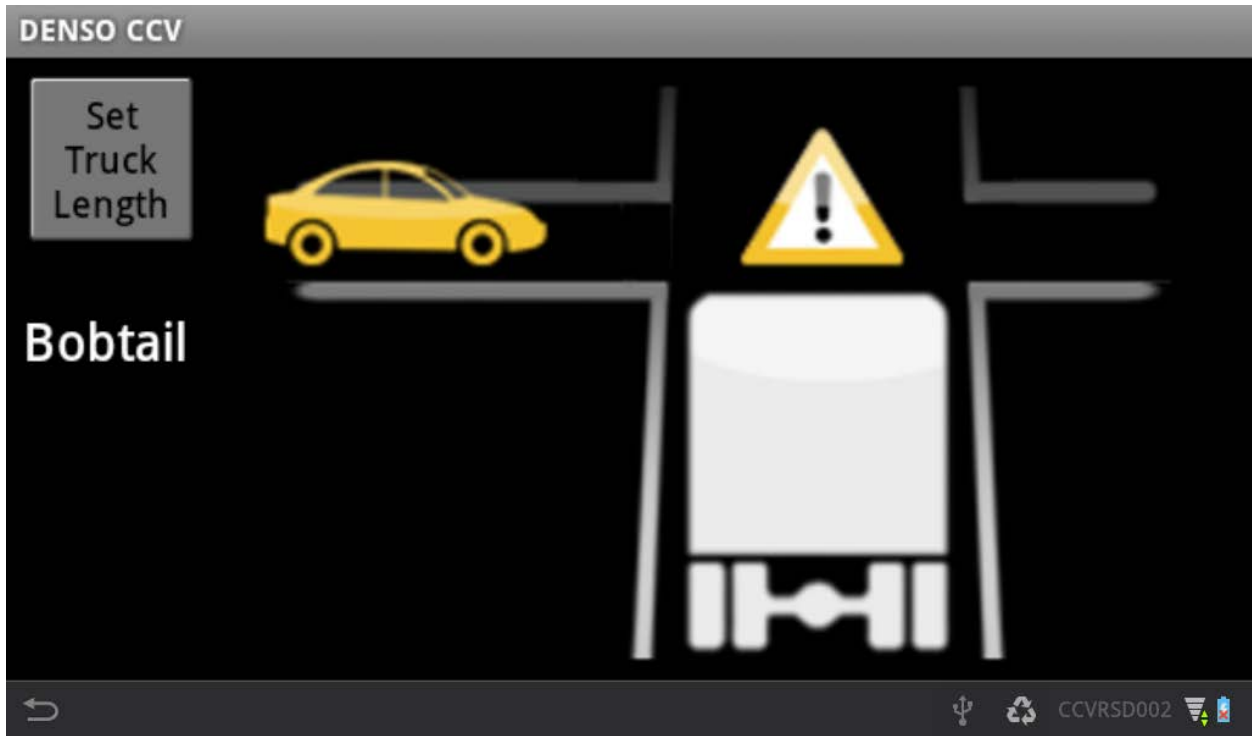
A typical scenario served by this application is a truck waiting at a stop sign. As shown in figure 12, another vehicle may obstruct the truck driver's view of a light vehicle approaching from the left. If the truck starts to move forward, the IMA application will issue an alert to the truck driver. The inform-level image that was displayed for the IMA application is shown in figure 13.

This application on a light vehicle begins to warn as soon as the driver's foot is removed from the brake pedal because an automatic transmission vehicle can begin to move when the brake is released. In contrast, the application on a commercial vehicle warns only when the accelerator is pushed and the vehicle speed begins to increase. In addition, the estimate of the commercial vehicle's acceleration capability is less than a light vehicle's, and the commercial vehicle parameters allow a greater driver response time. These two changes provide the commercial vehicle a larger gap in cross traffic.



Battelle

Figure 12. Illustration. The IMA message might be given if the host truck is stopped at an intersection and begins to pull forward when another vehicle is approaching.



DENSO

Figure 13. Illustration. This image (or its reflection) was displayed to the driver for the IMA inform-level alert.

Blind-Spot Warning (BSW)

The BSW application informs the driver whenever a vehicle traveling in the same direction as the truck is positioned alongside the HV, as illustrated in figure 14. The display, figure 15, indicates the side of the blind spot that is occupied. The BSW application has only an inform-level alert, and, as in other inform-level alerts, no sound is issued.

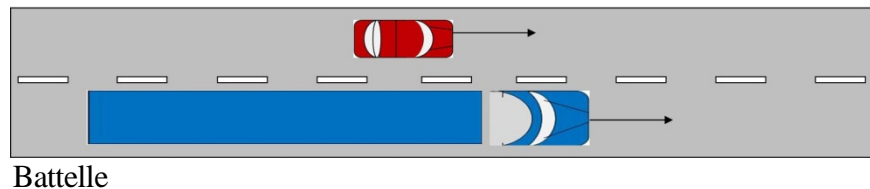


Figure 14. Illustration. The BSW application alerts the driver to the presence of a vehicle in its blind spot in the adjacent lane.

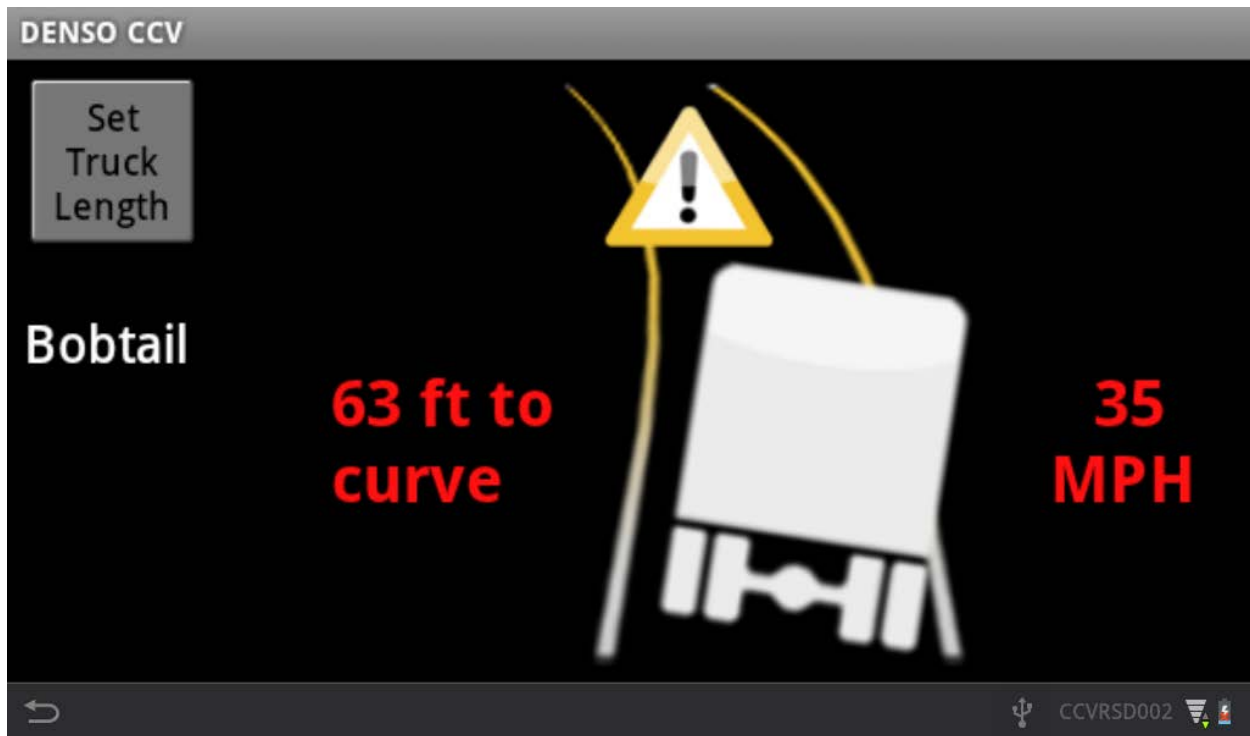


DENSO

Figure 15. Illustration. This image (or its reflection) was displayed to the driver for the BSW inform-level alert.

Curve Speed Warning (CSW)

The CSW application alerts the driver to a curve when the truck is moving too fast. This V2I application receives messages from fixed Roadside Equipment (RSE). The messages include the position of the curve entry and its advisory speed. The application will alert a driver approaching or in an instrumented curve if the truck is traveling more than 10 mph over the advisory speed and not slowing. The display for the CSW application is in figure 16.



DENSO

Figure 16. Illustration. Inform-level display for the CSW application.

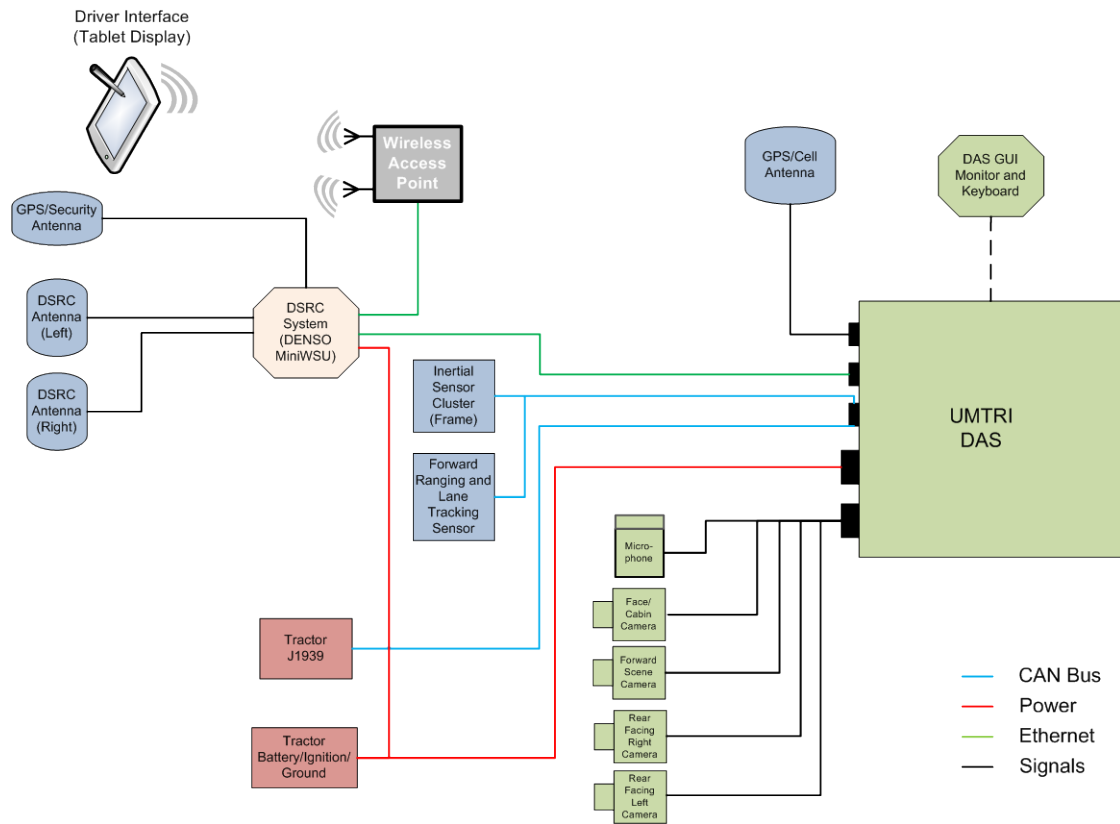
DATA ACQUISITION SYSTEM (DAS)

The activity of the OBE and the vehicle was recorded by a Data Acquisition System (DAS). Figure 17 shows the face of the DAS with the connectors, and figure 18 is a block diagram of the DAS and its connections. The design of the DAS, as well as documentation of testing it and instructions for operating it are in appendix C.



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Figure 17. Photo. The DAS recorded the signals from the RSD to support testing and analysis.



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Figure 18. Diagram. The DAS recorded data from the OBE and from sensors of the vehicle's motion, including video cameras.

CHAPTER 3. TESTING

A significant portion of this equipment development project was testing. Beginning with bench-top tests and culminating in the Safety Pilot Model Deployment, the OBE and DAS went through many stages of testing and refinement. In addition to these tests conducted by the CCV-RSD team itself, team members supported testing by NHTSA's Vehicle Research and Test Center (VRTC) and the safety pilot conductor.

ELECTRONICS TESTS

The miniWSU was subjected to a series of tests by an independent laboratory. Tests included power supply range, conformance to communication standards, message processing, and security. Because the nature of some aspects of testing is proprietary, the test plan and full results were not published. With minor exceptions, the miniWSU passed the tests.

APPLICATIONS DEMONSTRATION

The initial tractor with the RSD kit installed was taken to a closed course to test the safety applications in coordination with a remote vehicle. This was the purpose of the Applications Performance and Functional Test.⁽¹⁾

These tests consisted of a comprehensive series of 25 test scenarios shown below:

- Four to test the EEBL application.
- Eight to test the FCW application.
- Seven to test the BSW application.
- Two (with variations) to test the IMA application.

Most of these tests were intended to demonstrate that an alert was presented to the driver in the appropriate conditions. A small number of tests were to demonstrate that the safety application did not alert when the vehicles were in a situation that was close to, but not in, a warning condition.

Testing was conducted at the Michigan Technical Research Park (MITRP) in Ottawa Lake, Michigan. MITRP includes an oval test track and associated proving grounds. Most of the tests were on the three-lane oval track; the IMA applications were at a mocked up intersection. The host vehicle (the one on which the applications were being tested) was in combination with a 40-foot container on a chassis for the BSW scenarios. The tractor ran bobtail (without a trailer) for the other three scenarios. Figure 19 shows what the driver of the host vehicle saw during one of the FCW tests.



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Figure 19. Photo. The nearer light vehicle blocked the host vehicle driver’s view of the slow-moving light vehicle before changing lanes in this test of the FCW application.

Results of the functional tests are summarized in table 1. Each of the four applications was tested with a number of scenarios. Each scenario was repeated several times, and a pre-determined number of successful repetitions was required to pass the test. In some of the tests for false positive alarms, the vehicles were required to maintain a certain proximity for a period of time.

Table 1. Summary of results of the application performance tests.

Application	Number of Scenarios Run	Number of Scenarios Passed	Comments
EEBL	4	4	Scenarios included the remote vehicle in hard braking and mild braking.
FCW	8	8	The host vehicle approached the remote vehicle that was slowing or completely stopped in straights and in curves.
BSW	7	7	The light vehicle passed the host vehicle on the left and right on straights and on a curve. In the “false positive” tests, the light vehicle maintained a position immediately behind the host vehicle or abreast of the host vehicle two lanes away.
IMA	6	6	Scenarios were run with the host vehicle stopped and approaching the intersection at two speeds.
TOTAL	25	25	

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SAFETY PILOT MODEL DEPLOYMENT

The Safety Pilot Model Deployment studied connected vehicle technology in naturalistic driving for a year in and around Ann Arbor, Michigan. More than 2800 equipped vehicles were on the road, including the eight CCV-RSD tractors. The tractors exchanged BSMs with the light vehicles in the study, and V2V safety messages in the tractors were generated. The previous steps of testing included only the four V2V applications; those safety applications and CSW were active during the Model Deployment.

The eight tractors on which RSD kits had been installed were operated by a commercial fleet in revenue service as part of the study. They accumulated a total of 147,839 miles in 5,164 hours of driving over the year of operation between November 2012 and November 2013. Table 2 shows a summary comparing exposure, V2V interactions, and safety application event count. A total of 71,050 interactions with other vehicles was recorded. The cumulative duration of these interactions was 671 hours. Additionally, 1,008 inform level and 464 imminent level safety events were issued by the system.

Trips for maintenance and with known failures are excluded from the table. An “interaction” occurs when the tractor received BSMs from a remote vehicle for more than 0.5 s and a maximum gap of missed messages no more than 5.0 s. V2V safety events exclude the V2I events for the CSW application.

Table 2. Summary of the exposure, interactions, and safety application events for the CCV-IT vehicles in the Model Deployment.

Driver	Exposure			Interactions		V2V Safety Events	
	Trips	Time, hr	Distance, mi	Events	Time, hr	Inform	Imminent
1	4,027	732.3	22,478	16,508	159.7	103	31
2	4,466	725.8	18,060	9,780	66.9	186	83
3	3,829	690.0	19,076	2,773	36.0	240	113
4	4,328	685.3	22,360	16,662	113.9	74	31
5	3,609	645.8	21,933	6,189	69.8	73	31
6	2,854	617.1	14,959	9,898	99.8	76	34
7	3,192	601.4	14,495	4,161	47.3	222	119
8	2,817	466.1	14,477	5,079	77.9	34	22
Total	29,122	5,163.8	147,839	71,050	671.3	1,008	464

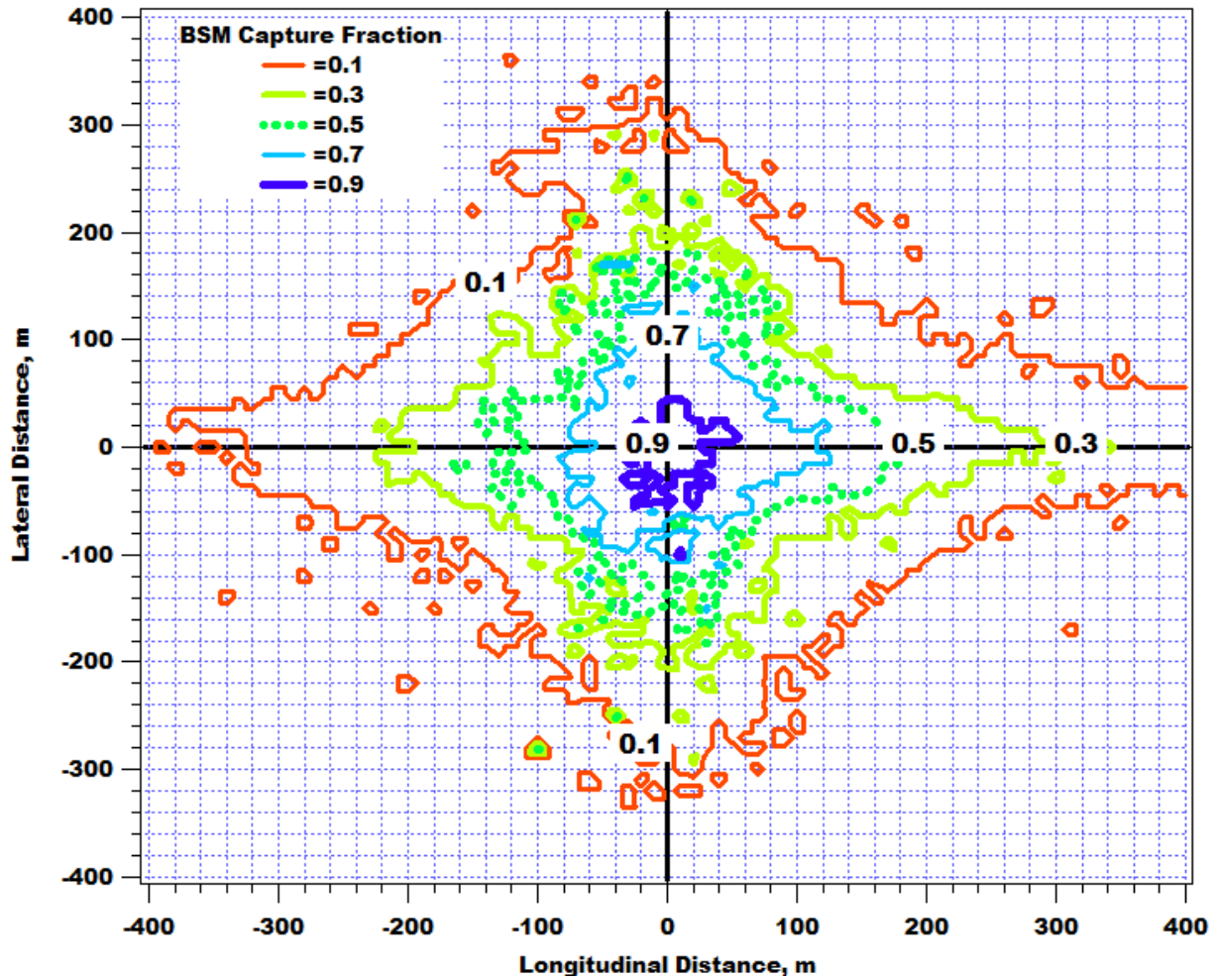
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One measure of the performance of the equipment during the Model Deployment is the fraction of BSMs that were captured and recorded. The BSMs from all vehicles in the Model Deployment are in a single database, so it is possible to compute the fraction of BSMs that were broadcast by other vehicles and recorded by the CCV-RSD tractors. BSMs are more relevant to the tractor if they come from a vehicle nearby, so the capture fraction was computed as a function of both the remote vehicle's distance from the tractor and its direction from the tractor. The contours in figure 20 show the fraction of BSMs that were captured from vehicles at various distances and directions from the tractors.

The outer red contour shows that the tractors were capturing ten percent of the BSMs from remote vehicles several hundred meters away. The inner dark blue contour shows that more than 90 percent of the BSMs were captured from vehicles up to 40 m in front of the tractor. Other observations from the figure:

- The general shape of the contours shows that the reliability of reception is better ahead of the tractor and to its sides than behind it. The trailer evidently reduces the ability of the antennas to receive BSMs from immediately behind the vehicle.
- The RSD kit captured better than 90 percent of the BSMs from vehicles approximately 40 m in front of the vehicle. This is the important region for the FCW safety application.
- The dotted green contour represents the 50 percent capture fraction. Half of the BSMs broadcast by remote vehicles on the line were recorded by the CCV-RSD tractors. The contour line extends from 120 m behind to 180 m ahead of the tractor and approximately 150 m to each side. Reliability to the sides affects the IMA application. For example, a vehicle approaching at 20 m/s (slightly more than 40 mph) is 5 s away at a range of 100 m.
- In the case of EEBL, only a single remote vehicle's hard braking event flags need to reach the host tractor. This safety application had an effective range of approximately 300 to 400 m or about 0.25 mile.
- This installation and antenna location provide better remote vehicle detection in the forward direction than behind the CCV-RSD tractor. This effect is present on all contours.

Complete results of the CCV-RSD vehicles in the Model Deployment are in a separate report.⁽³⁾



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Figure 20. Graph. The fraction of BSMs captured by the CCV-IT tractors depended on the distance and direction to the vehicle sending the BSM.

CHAPTER 4. CONCLUSIONS

This project proved the technical viability of equipping an in-service truck tractor with V2V safety applications using a retrofit safety device. By deploying safety applications on both newly manufactured and existing commercial vehicles, realizing the benefits of connected vehicles can be accelerated.

ACCOMPLISHMENTS

Ten RSD kits were manufactured and delivered as part of this project. The installation of the first kit by staff at NHTSA's VRTC demonstrated that written instructions are sufficient to enable technicians unaffiliated with the project to install the kits. The staff provided feedback on the instructions, and the revised instructions are in appendix A of this report.

Tractors on which RSDs had been installed performed well in both closed-course tests and in revenue service during the model deployment. A series of 25 scenarios involving one or two remote vehicles demonstrated the four V2V safety applications. "True positive" scenarios tested whether the safety applications would issue alerts at appropriate times, and "false positive" scenarios tested whether the applications would withhold alerts when they were not warranted. The equipment passed the tests in all 25 scenarios. The functional performance tests are summarized in chapter 3 of this report and documented fully in a separate report.⁽¹⁾ A commercial fleet operated eight RSD-equipped tractors in revenue service during the model deployment. They accumulated a total of 147,839 miles in 5,164 hours for a year of operation. They logged 71,050 interactions with other vehicles, leading to 1,008 inform level and 464 imminent level safety alerts. The performance of the RSDs in the model deployment is summarized in chapter 3 of this report and documented fully in a separate report.⁽³⁾

FINDINGS

The compact miniWSU was key to enabling the RSD to be mounted exterior to the cab of the truck. That eliminated the need to have any knowledge of the cab's interior structure or equipment. The only components inside the cab were related to the driver display. The telescoping bar with mounting wings was readily adapted to different cab styles.

The innovative approach to routing the radio frequency (RF) cables proved workable. The cables leading from the miniWSU to the DSRC antennas are thick and do not bend easily. They need to be as short as possible, but they have to be included in the kit as finished cables because applying the connectors requires specialized tooling and training.

The electronics was mounted in an enclosure exterior to the cab, where it was exposed to the elements. The enclosure was sealed for protection from rain, and a small amount of internal air flow was sufficient to prevent critical components from overheating. While the enclosure was adequate for this project; further improvements are needed for long-term deployment.

The miniWSU communicated driver alert messages to the display through Wi-Fi. Although the freedom of positioning was attractive, a wired connection would be preferable for reliability.

APPENDIX A. RSD INSTALLATION, TROUBLESHOOTING, AND INITIALIZATION GUIDE

Step 1 – Assemble Telescoping Bar Mount. (Refer to figure 21.)

Parts List:

- 1 ½” Square Tubing – 1 piece.
- 1” Square Tubing – 2 pieces.
- 1 ¼” Plastic C-Channel – 2 pieces.
- RF Cable – 2 pieces.
- RF Antenna – 2 pieces.
- RSD Mounting Plate – 1 piece.
- ¼-20 x 2 ¼” Hex Head Cap Screws – 4 pieces.
- ¼” Flat Washers – 8 pieces.
- ¼-20 Nylon-Insert Hex Locknuts – 4 pieces.
- 10-32 x 1” Hex Head Machine Screws – 2 pieces.
- 10-32 x 2 ½” Hex Head Machine Screws – 2 pieces.
- #10 Flat Washers – 8 pieces.
- 10-32 Nylon-Insert Hex Locknuts – 4 pieces.

Assembly Instructions:

1. Identify all pieces needed to assemble the Bar Mount. (See figure 22.)
2. Slide one piece of plastic C-channel (figure 23) on each 1” square bar, aligning the two ¼” holes in the c-channel with the two ¼” holes in the top of the 1” square bar. (figure 24) **(NOTE: The top of the 1” square bar has two ¼” holes and one 5/8” hole. The slit in the C-Channel should be on the bottom of the 1” square bar.)**
3. Locate the SMA connector on the end of an RF cable. (figure 25)
4. Slide the SMA connector into the 1” square bar, starting at the end with the 5/8” “D” antenna mounting hole (figure 27.) Continue to feed the RF cable through the 1” square bar until the SMA connector and approx. 12” of cable extend out the end of the bar with the C-Channel. **NOTE: Installer shall ensure all RF cables are appropriately protected to prevent damaging the RF cable jacket.**
5. Remove the nut and lock-washer from the N-Type connector (figure 26) located at the end of the RF cable opposite the SMA connector.
6. Create a loop in the RF cable near the N-Type connector; using care to ensure the RF cable is never bent at a radius of less than ¾”.
7. Align the N-Type connector on the RF cable with the “D” antenna mounting hole through the 1” square tubing and push the N-Type connector through this mounting

hole until the rubber O-ring at the base of the connector comes in contact with the 1" square tubing. (See figure 28.)

8. Re-install the lock washer and nut on the N-Type RF connector and tighten securely. Use care to ensure the nut is not over-tightened or stripped. **(NOTE: ThreadLocker may be needed to keep these thin nuts from vibrating loose after installation.)**
9. Pull the RF cable from the SMA end until the loop near the N-Type connector measures approx. 2" in diameter, (figure 29.) **Ensure the RF cable is not kinked at any time.**
10. Repeat steps 3-9 for the other RF cable and 1" square bar.
11. Locate the 1 ½" square bar and orient it with one set of holes facing up, and the 4" slot cutout (figure 30) facing the assembler.
12. Insert the SMA connector and 1" square bar into one end of the 1 ½" square bar until the SMA connector reaches the cutout in the center of the 1 ½" square bar. **(NOTE: Ensure the N-Type connector on the 1" square bar is facing up and the RF cable loop is facing down.)**
13. Reach into the cutout and gently pull the SMA connector and RF cable out of the cutout.
14. Continue feeding the 1" square bar into the 1 ½" square bar until the two ¼" holes at the ends of the bars align and approx. 12" of RF cable extends out of the cutout.
15. Repeat steps 12-14 for the other RF cable/1" square bar.
16. Ensure the ¼" holes in the 1½" square bar and the 1" square bars are properly aligned, and install ¼"-20 x 2 ¼" hex head cap screws, washers and locknuts through the holes at the ends of the 1 ½" square bar to secure the sections together. **(NOTE: Use care when installing the bolts through the Bar Mount holes to avoid damaging the RF cable running through the square bars.)**
17. Torque the ¼" locknuts to 40 in-lbs.

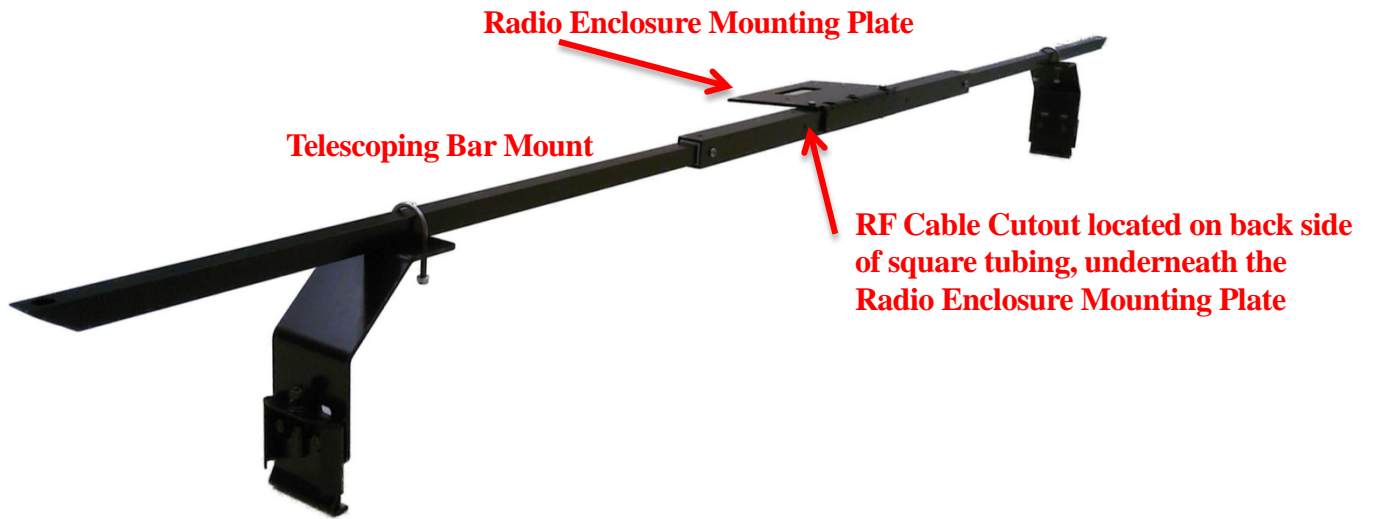


Figure 21. Photo. RSD bar mount assembly.

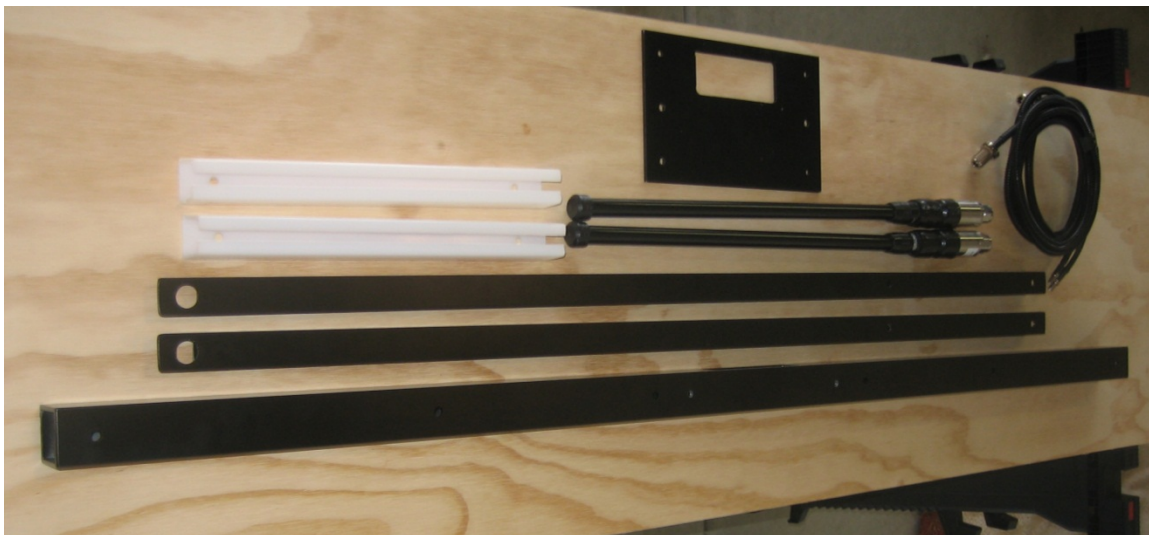


Figure 22. Photo. Bar mount parts.



Figure 23. Photo. Plastic C-channel pieces.



Figure 24. Photo. Plastic C-channel on 1" square bar.



Figure 25. Photo. RF cable SMA connector.



Figure 26. Photo. N-type RF connector.



Figure 27. Photo. 5/8" "D" antenna mounting hole.



Figure 28. Photo. Properly installed N-type connector.



Figure 29. Photo. RF cable loop.



Figure 30. Photo. 4" slot cutout.



Figure 31. Photo. Radio enclosure mounting plate.

Step 2 – Mount the RSD Radio Enclosure to the Radio Enclosure Mounting Plate (figure 31) using two 10-32 x 1" hex head machine screws, four washers and two locknuts. When properly aligned on the Mounting Plate, the RF, data and power cables exiting the bottom of Radio Enclosure will pass through the cutout in the Mounting Plate. Insert the 10-32 x 1" hex head machine screws through the holes located at the edge of the mounting plate nearest the cutout. Do not fully tighten the 10-32 locknuts at this time, to allow the RSD Radio Enclosure to be aligned for mounting on the Bar Mount.

Step 3 – Position the Radio Enclosure Mounting Plate on the top, center of the 1 1/2" square bar, with the cutout in the Mounting Plate extending over the RF cables protruding from the 1 1/2" square bar. Mount the RSD Radio Enclosure and Radio Enclosure Mounting Plate to the Bar Mount using two 10-32 x 2 1/2" hex head machine screws, and locknuts. When properly aligned and positioned on the Bar Mount, the Mounting Plate is located in the center of the Bar Mount, with the RF cables exiting the cutout in the 1 1/2" square tubing cutout directly under the Mounting Plate. Torque all four 10-32 locknuts to 20 in-lbs.

Step 4 – Attach the RF antenna cables extending out of the mounting bar (figure 32) to the RF cables exiting the Radio Enclosure. Slip one section of 3/8" heat-shrink tubing (supplied) over each antenna RF cable exiting the Radio Enclosure prior to securing the SMA connectors to the RF cables that lead to the antennas. Ensure the SMA connectors are properly torqued. Position each section of 3/8" heat-shrink tubing over the SMA connections and use a heat gun to shrink the tubing and weatherproof the connections. Excess heat may damage the RF cable integrity.

NOTE – Installer shall ensure appropriate weatherproofing is provided at all external RF

cable terminations. Installer shall ensure all bends in RF cables do not result in a bend radius that is less than $\frac{3}{4}$ ".



Figure 32. Photo. RF cables extending out of cutout.



Figure 33. Photo. Mounted RF antenna.

Step 5 – Mount the RF antennas to the Bar Mount. Mount the RF antennas to the N-Type connectors located at the ends of the Telescoping Bar Mount. (See figure 33.)

Step 6 – (a) (Optional for Angle-Iron Mount – Used when mounting the Bar Mount to structural members on the tractor cab or a wind fairing):

1. Identify an appropriate location and structural member(s) for attaching the Bar Mount. The 2" x 3" x 6" long Angle-Iron Mounts must be spaced accurately at either 27" or 47" (center-to-center) if mounting directly to the $\frac{1}{4}$ -20 x 2 $\frac{1}{4}$ " Cap Screws on the 1 $\frac{1}{2}$ " Bar Mount.
2. Locate the Angle-Iron Mounts so that the Bar Mount will be centered with the cab of the tractor and aligned with the $\frac{1}{4}$ -20 x 2 $\frac{1}{4}$ " Cap Screws on the 1 $\frac{1}{2}$ " Bar Mount.

3. Mark and drill holes (as needed) in the wind fairing structural member for bolting the Angle-Iron Mounts to the structural member. (U-bolts may be used to secure the Angle-Iron Mounts to round structural members.)
4. Mount the Angle-Iron Mounts to the structural member using 1/4-20 bolts, (or U-bolts) washers and locknuts.
5. Remove the locknuts and washers from the 1/4-20 x 2 1/4" Cap Screws on the 1 1/2" Bar Mount that align with the holes in the Angle-Iron Mounts.
6. Place the Bar Mount on the Angle-Iron Mounts and align the 1/4-20 x 2 1/4" Cap Screws on the 1 1/2" Bar Mount with the holes in the Angle-Iron Mounts.
7. Re-install the 1/4" washers and locknuts on the 1/4-20 x 2 1/4" Cap Screws.
8. Torque the 1/4" locknuts to 40 in-lbs.

Step 6 – (b) (Optional for Rain Gutter Mount)

Mount the Rain Gutter Brackets to the truck body. (Reference figure 34 and figure 35):

1. Identify an appropriate location to mount the RSD Bar Mount Assembly (assembled in Steps 1-5 above) across the roof of the truck cab. Note – it is generally preferable to mount the bar near the rear of the cab to allow easier routing of the RF, data and power cables to the interior of the cab.
2. Assemble the bracket assemblies and place on each side of factory rails per figure 35. Do not fully tighten the hardware until the Telescoping Bar Mount is positioned and attached as described in Step 7.

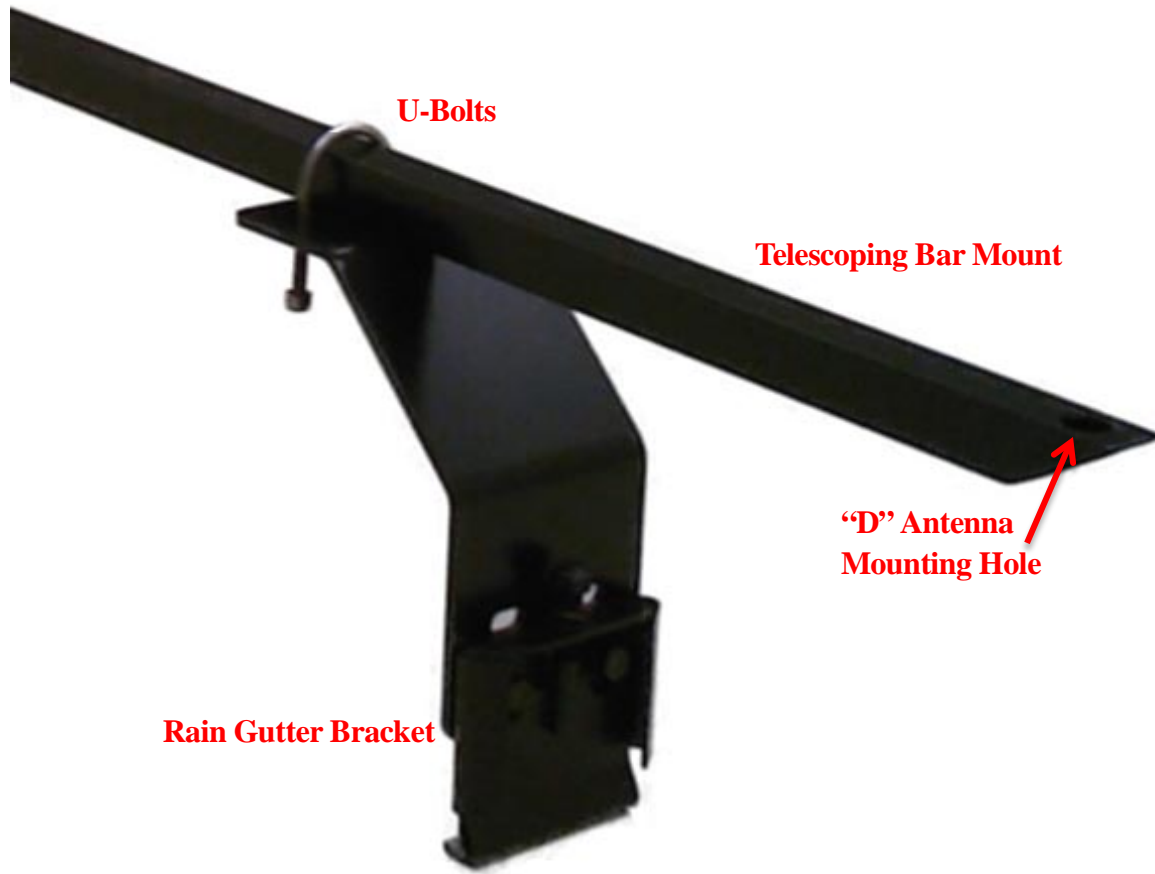
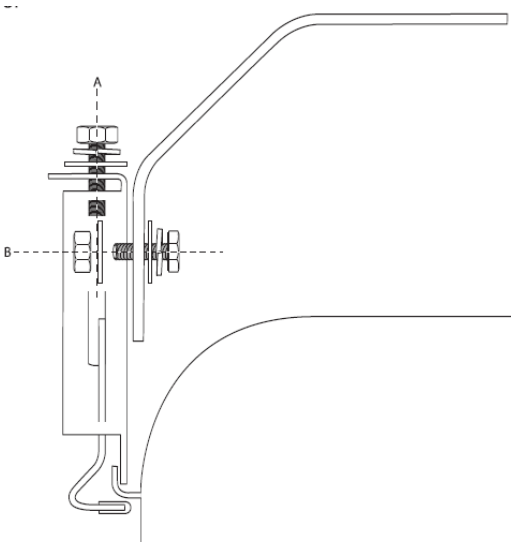


Figure 34. Photo. Rain gutter bracket assembly.



Grade 8 nut torque specifications

	STANDARD		METRIC	
5/16" nuts	20 ft. lbs.	M6	9 ft. lbs.	
3/8" nuts	35 ft. lbs.	M8	23 ft. lbs.	
7/16" nuts	60 ft. lbs.	M10	45 ft. lbs.	
1/2" nuts	90 ft. lbs.	M12	75 ft. lbs.	
9/16" nuts	160 ft. lbs.	M14	120 ft. lbs.	
5/8" nuts	175 ft. lbs.	M16	165 ft. lbs.	

Figure 35. Diagram. Rain gutter mounting.

Step 7 – (Optional for Rain Gutter Mount)

Mount the RSD Bar Mount Assembly to the Rain Gutter Brackets using the supplied ¼”-20 SS U-Bolts, washers, nuts and locknuts. Ensure the RSD Bar Mount Assembly is centered with the truck cab prior to tightening the nuts on the U-Bolts. (See figure 34.) Torque the ¼” nuts on the U-Bolts to 40 in-lbs. prior to installing the locknuts. Tighten the locknuts against the nuts (double-nut) and torque to 40 in-lbs. Tighten all Rain Gutter Bracket hardware per the torque specifications listed in figure 35.

Step 8 – Attach the data and power extension cables to the cables exiting the Radio Enclosure. Note – the CAT6 data cable includes connections for Ethernet, J1939 and IMU data per the wiring information below.

RSD Data Interface

Refer to the data cable wiring information below for connecting the Power, Ethernet, J1939 and IMU data interfaces.

Power Cable:

- Red 1 = Battery (numbered on red wire insulation jacket).
- Red 2 = Ignition sense (numbered on red wire insulation jacket – See figure 36.)
- Yellow/Green = Ground.

CAT6 Data Cable:

- **Ethernet**
 - Pin 1 = White/Orange = Transmit +.
 - Pin 2 = Orange = Transmit -.
 - Pin 3 = White/Green = Receive +.
 - Pin 6 = Green = Receive -.
- **CAN1:**
 - Pin 4 = Blue = CAN1 Low.
 - Pin 5 = Blue/White = CAN1 High.
- **CAN0:**
 - Pin 7 = Brown/White = CAN0 High.
 - Pin 8 Brown = CAN0 Low.

Use the supplied Add-A Circuit connectors (figure 37) for connecting the Access Point, DVI Tablet, and RSD Radio to the truck’s 12V power source. The Add-A-Circuit connector with the three splices attached is intended for connecting the Access Point, DVI Tablet, and RSD Radio ignition sense (Red #2 wire) to a 12V power connection that has 12V applied only when the ignition is in the ACC or RUN position. The Add-A-Circuit connector with the single splice attached is intended for connecting the RSD Radio (Red #1 wire) to a 12V power connection that has 12V applied at all times.

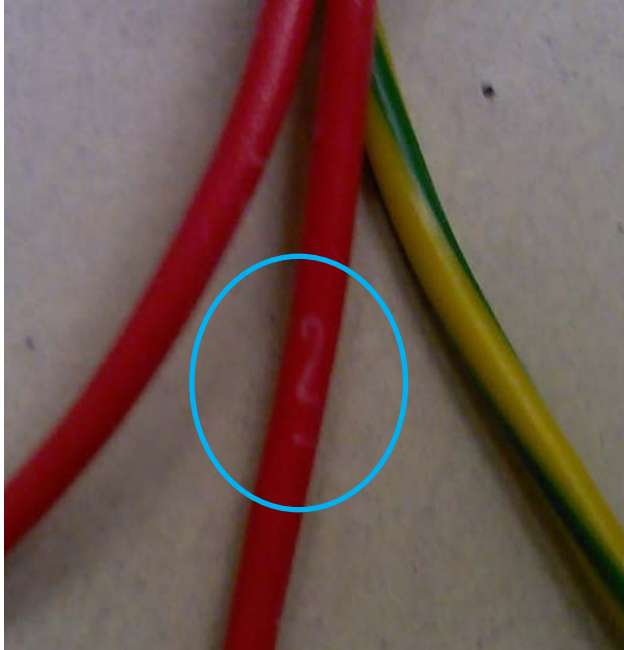


Figure 36. Photo. Power wire numbering.



Figure 37. Photo. Add-a-circuit connector.

Step 9 – Data and power cable routing and cable management:

- Installer shall determine appropriate routing and management method for the data and power cables between the RSD Enclosure mounting location and the cable termination locations.

Step 10 – Mount the WiFi Access Point inside the truck cab. (Refer to figure 38 and figure 39):

- Installer shall determine an appropriate location and method for mounting the WiFi Access Point inside the truck cab. Note – the Access Point includes hardware that may be used for surface-mounting the device.
- Installer shall determine appropriate routing and management for the power connection to the WiFi Access Point. Connect the power cable to a 12V power connection that has 12V applied only when the ignition is in the ACC or RUN position.



Figure 38. Photo. WiFi access point.



Figure 39. Photo. Access point power cable.

Step 11 – Connect the J1939 CAN interface to the RSD Radio:

- Installer shall select the preferred method for connecting the RSD J1939 interface wires to the truck’s J1939 CAN data interface. Hardware is provided to enable attaching to the truck’s J1939 interface the supplied 2-pin Deutsch connectors and “Y” adapter. (See figure 40.)



Figure 40. Photo. J1939 2-pin Deutsch connectors.

Step 12 – Connect the Ethernet interface between the RSD Radio and the WiFi Access Point:

- Installer shall determine appropriate routing and management for the Ethernet wires between the Radio Assembly and the WiFi Access Point.

Step 13 – (Optional) Connect the IMU CAN interface between the RSD Radio and the IMU:

- Installer shall determine appropriate routing and management for the wiring between the Radio Assembly and the IMU.

Step 14 – Mount the DVI Tablet:

- Installer shall determine an appropriate location and method for mounting the DVI Tablet. Two different mounting pedestals are provided to enable multiple options for tablet mounting locations. Mount the tablet securely in the custom fit holder after the holder has been mounted to the selected pedestal using the dual “T” slots in the holder and the “Ts” on the pedestal. (Refer to figure 41, figure 42, and figure 43.)

- Installer shall determine appropriate routing for the tablet power cable (the cable with the tablet-specific connection on one end) from the tablet to a 12V power connection that has 12V applied only when the ignition is in the ACC or RUN position. (See figure 44.)



Figure 41. Photo. DVI tablet and custom fit holder.



Figure 42. Photo. 10" aluminum mounting pedestal.



Figure 43. Photo. Adhesive or screw mount pedestal.



Figure 44. Photo. Tablet power cable.

Step 15 – Connect the power wires from the RSD Enclosure to the 12V truck’s power:

- Connect the Yellow/Green wire in the power cable from the RSD Enclosure to Chassis Ground.
- Connect the Red #1 wire (numbered on one red wire insulation jacket) to a 12V power connection that has 12V applied at all times.
- Connect the Red #2 wire (numbered on one red wire insulation jacket) to a 12V power connection that has 12V applied only when the ignition is in the ACC or RUN position.

If the RSD Radio does not boot properly following installation and within 60 seconds of supplying ACC power, (as determined by the DVI screen in figure 45), reset the RSD radio by following the steps below:

1. Disconnect the Red #2 wire from its 12V power source.
2. Disconnect the Red #1 wire from its 12V power source.
3. Keep all power disconnected for ~10 seconds.
4. Reconnect the Red #1 wire to its 12V power source.
5. Reconnect the Red #2 wire to its 12V power source.



Figure 45. Photo. Active RSD DVI screen.

Step 16 – Set the vehicle parameters in the USDOT Model Deployment configuration file.
 (NOTE: The RSD miniWSU includes the VI editor, which should be used for viewing and modifying any files stored on the RSD miniWSU):

- With the RSD powered up and properly booted, connect a laptop to the RSD using the Ethernet connection provided in the RSD Data Interface Cable using the wiring information provided in Step 8 – above.
- Initiate an SSH session with the RSD miniWSU. (NOTE: PuTTY is commonly used to manage the SSH session between a Windows laptop and the RSD miniWSU.) When prompted, enter userid **root** and password **rootroot**.
- Verify the V2VIUSDOTMDConfigFileDir configuration parameter in the /rwflash/configs/denso-v2vi.conf file is set to /mnt/cflash/ModelDeploymentConfigurationItems.
- Edit the /mnt/cflash/ModelDeploymentConfigurationItems/ModelDeploymentRemovable.conf file as described below: (NOTE: All measurements must be in cm.)
 - Set the ModelDeploymentDeviceID to the desired “TempID” for the RSD.
 - Set the VehicleLength to the overall length of the vehicle **without any trailers connected**, (i.e., bobtail).

- Set the antOffsetX value based on the following equation:
$$\text{antOffsetX} = (\text{VehicleLength}/2) - (\text{longitudinal distance from the front bumper to the center of the RSD Radio Enclosure}).$$

(NOTE: This value must be negative if the RSD Radio Enclosure is installed behind the longitudinal center of the vehicle.)
- Set the antOffsetZ value to the distance from the ground to the base of the RSD Radio Enclosure.
- Set the VehicleType value to 7 if the bobtail tractor has 2 axles, or set the VehicleType value to 8 if the bobtail tractor has three axles.
- Ensure the VehicleWidth value is set to 259. (259cm = 102”).

APPENDIX B. PRE-DELIVERY TEST PLAN FOR RSD KITS

This appendix describes the steps in the pre-delivery tests for RSD kits. The specified tests include steps to bench-test the OTA interface and interfaces to the DVI and DAS. Test utilities developed by DENSO for execution on the miniWSU or on a PC platform are used for many of these tests.

The tests described in this document are intended to verify that the software and hardware included in each RSD Kit has been confirmed to work as a system when subjected to a known set of inputs in a lab environment.

Part 1 Hardware Test Procedure:

- Calibrate and test miniWSU hardware.
(To be performed on each miniWSU)
 - Verify RF performance.
 - Power up the miniWSU with a PC attached to the miniWSU through the serial connector.
 - Monitor the boot-up sequence as displayed on a serial console window on the PC to verify the radio card drivers successfully initialized both radios.
 - Use DENSO wsm_send utility and an RF power meter to verify transmitter output levels for all antenna ports on both radios.
 - Use DENSO wsm_rcv utility and a known-good transmitter to verify the receive sensitivity for all antenna ports on both radios.
 - Verify GPS operation.
 - Use DENSO tpstestapp to verify GPS data is received and properly parsed.
- Configure and test WiFi Access Point.
(To be completed on each Access Point)
 - Power on the Access Point and load the appropriate configuration file for the RSD Kit being provisioned.
 - Verify a known-good DVI tablet can successfully connect to the Access Point using the SSID for the RSD Kit being provisioned.
 - Connect an Ethernet cable from a known-good miniWSU to the Access Point and launch the DENSO safety application on the miniWSU.
 - Launch the DVI application on the tablet and verify it is receiving DVI packets from the miniWSU.

Part 2 Software Test Procedure:

- Safety application verification.
(To be completed on each miniWSU)
 - Load the firmware image onto the miniWSU and verify the configuration file settings.
 - Launch the DENSO safety application and use the DENSO v2vmonitor utility and a known-good WSU to verify BSM transmit and receive operations.

- Safety application and DVI testing.
(To be completed for each firmware release)
 - Load the firmware image on a known-good miniWSU.
 - Use DENSO Scenario Replicator (SR) utility to playback SR recordings of the BSW+LCW, CSW, EEBL, FCW, and IMA safety applications. Verify alerts are received at the appropriate time during the playback and that these alerts are displayed on the DVI.
 - Load the firmware image on a second known- good miniWSU and install RSD Kits (i.e., miniWSU, Access Point and DVI tablet) running this firmware in two test vehicles.
 - Perform live drive testing to verify the BSW+LCW, CSW, EEBL, FCW, and IMA safety applications perform as expected per the configuration settings.
 - Using CAMP equipment and DENSO ASD equipment installed in one test vehicle, and the latest RSD firmware in the other test vehicle, perform live drive testing to confirm interoperability with the latest CAMP and ASD firmware releases.

- DAS Logging testing.
(To be completed for each firmware release)
 - Use the DENSO dasif_rcv utility running on a PC to verify the format and content of the packets that are sent to the DAS. (This utility will receive, parse, and log data sent from the miniWSU destined for the DAS. Each firmware release is tested using this utility.

APPENDIX C. PRE-DELIVERY TEST PLAN AND TEST REPORT FOR DAS

This appendix presents testing activities for verifying the performance of the data acquisition systems (DASs) that were installed on connected commercial vehicles with RSD devices. These vehicles include a prototype tractor owned by UMTRI and eight tractors that are part of a fleet owned and operated in the Safety Pilot Model Deployment by Sysco Foods Detroit LLC. The testing activities are broken down into three classes and several subclasses, and include testing on the bench, in the vehicle during and following integration, with static and dynamic (moving on public roads) situations. The testing also includes analysis of data captured and loaded into relational databases and sent over cellular networks.

CHAPTER C-1. INTRODUCTION

The Connected Commercial Vehicles—Retrofit Safety Device Kit (RSD) Kit Project is one of several inter-related research projects addressing the use of vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) wireless technologies for highway safety. This project is being conducted for the U.S. Department of Transportation (USDOT) by a team lead by the Battelle Memorial Institute. The team includes DENSO International North America Research Laboratory (NARL), the University of Michigan Transportation Institute (UMTRI), Daimler Trucks North America (DTNA), and Meritor WABCO. The Battelle RSD project involves developing a set of driver assistance functions for commercial vehicles, then field-testing them in active service to assess the technical performance, driver acceptance, and fleet perspectives for these connected-vehicle functions. The RSD device hosts the following crash warning applications: forward crash warning (FCW), electronic emergency brake lamps (EEBL), intersection movement assist (IMA), blind spot indication (BSD), and curve speed warning (CSW). The wireless technology being used is dedicated short-range communications (DSRC), which operates at 5.9 GHz. The RSD application is now operating on a full-time basis on a set of eight Class-8 tractors operated by Sysco Foods Detroit, LLC, based in Canton Township, Michigan. The eight tractors were selected because they are associated with routes that included the Safety Pilot Model Deployment geographic area in Ann Arbor, Michigan.

This document presents the pre-delivery test plan for the data acquisition systems (DAS) that are installed on tractors hosting RSD devices. The test plan ensures:

- Proper operation of the DAS module.
- Proper operation of the dedicated DAS sensors.
- Integrity of the data connectivity and DAS power inputs within the vehicle.
- Ability of the DAS to collect data from a previously-tested RSD device in order to assess the connected vehicles safety applications.

Several documents provide supplementary background to this report. These includes a description of the RSD safety applications [4], the RSD device test plan [5], and a description of the DAS along with its input signals, its installation within the vehicle, the database it enables, and instructions for the use of the DAS by research partners [2].

CHAPTER C-2. THE DAS WITHIN THE SYSTEM ARCHITECTURE

Figure 46 shows the DAS as well as RSD and vehicle elements that interface with the DAS. The main interfaces are shown in the figure and include:

- Tractor SAE J1939 CAN bus.
- Ethernet connection to the Denso DSRC platform (called the mini Wireless Safety Unit or miniWSU).
- DAS-dedicated integrated GPS and cellular antenna.
- Four DAS-dedicated cameras for analysis of the experimental field operational data.
- Vehicle ignition and power.
- Keyboard, video, and monitor interfaces for use in testing.
- DAS sensor cluster with yaw rate and acceleration information.
- Forward-looking vision sensor for vehicle lane position and position and motion information for multiple vehicle targets ahead of the vehicle.

Details of the modules and interfaces can be found in [2]. The DAS and RSD hardware can be installed at various locations within the vehicle. The document describes an installation done for the Safety Pilot Model Deployment on tractors from the Sysco Foods Detroit, LLC, fleet.

Note that the DAS does not have direct access to the driver display (shown in the upper left of figure 46); the presentation of alerts is captured from the miniWSU.

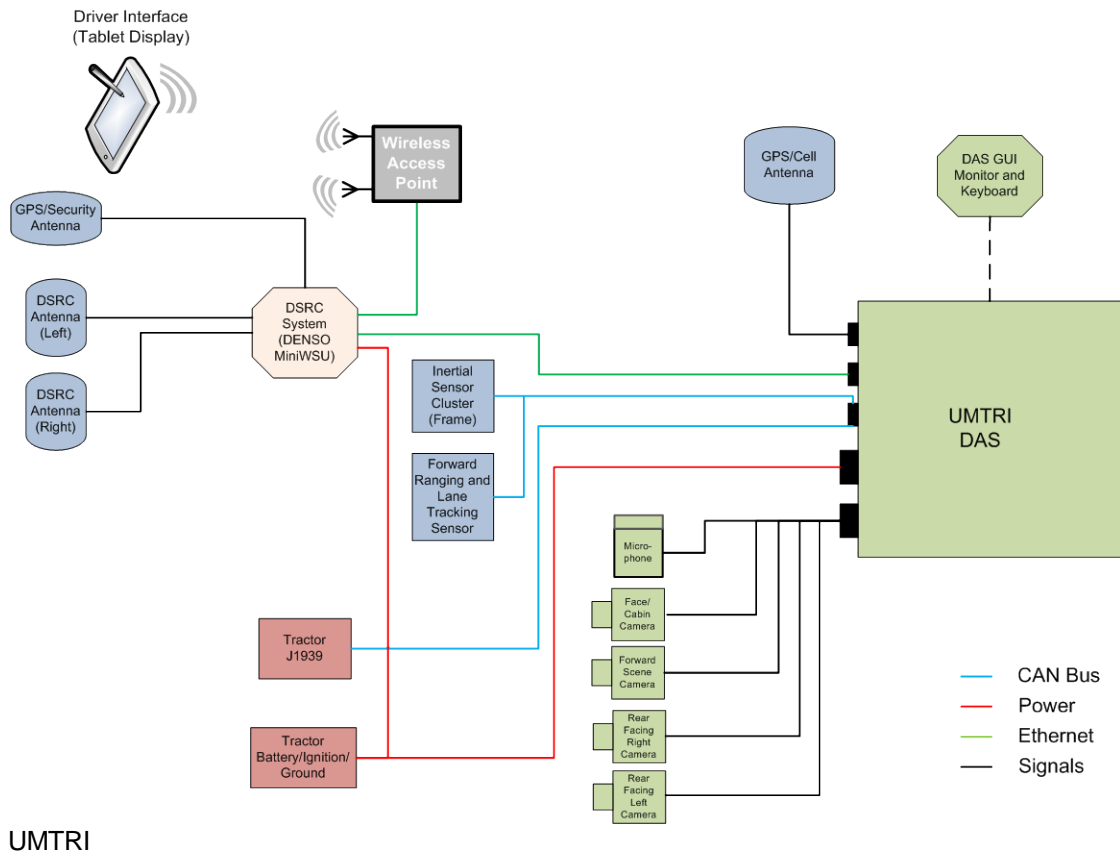


Figure 46. Diagram. Schematic of the DAS within the RSD architecture.

CHAPTER C-3. TESTING PROCESS OVERVIEW

Testing of the DAS addresses the following sets of capabilities, as shown in figure 47:

- Proper operation of the DAS module and DAS-dedicated sensors.
- Integrity of the DAS's connectivity to vehicle, sensor, and miniWSU signals.
- Ability of the DAS to collect data from a previously-tested RSD device.
- Integrity of the DAS data and the uploading processes.

As figure 47 shows, some of this testing occurs on the bench, some within the vehicle in the parking lot with the integration ongoing or completed (static testing), some while the vehicle is being driven (dynamic testing), and some involves exercising and validating the data upload processes. Chapters 4, 5, and 6 addressing the left, middle, and right blocks in figure 47.

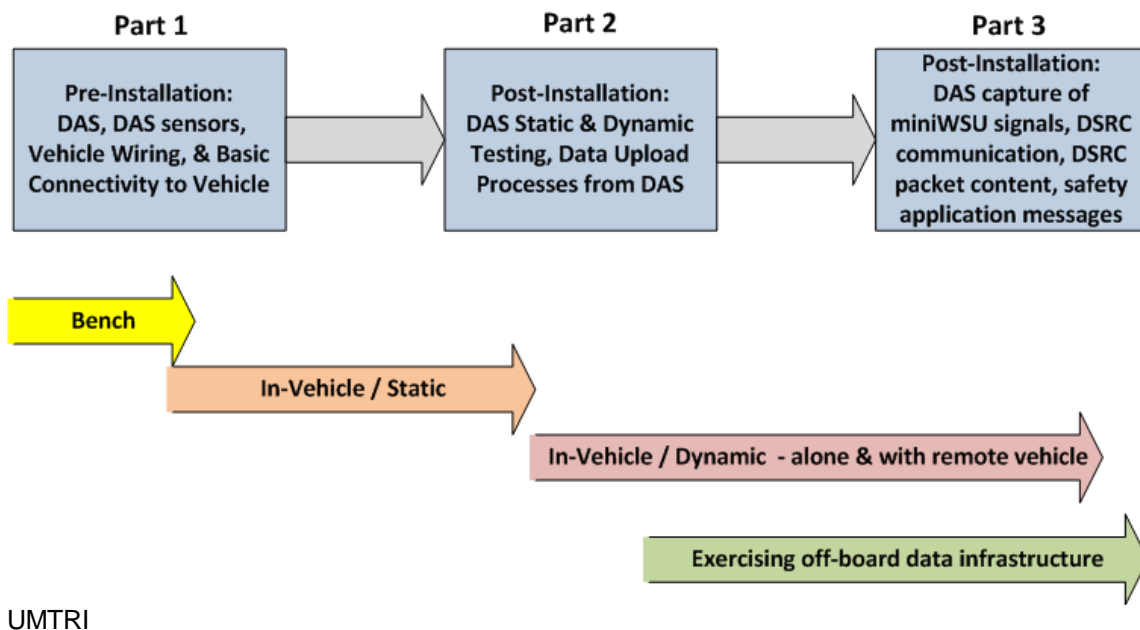


Figure 47. Chart. Vehicle build and testing process.

CHAPTER C-4. PRE-INSTALLATION TESTS

The test activities in this chapter focus on installation and fabrication related issues. These tests are conducted by engineers and technicians before and during the early stages of the integration of the DAS and RSD into the tractor. These tests are important for the long term robustness of the installation and help reduce both permanent and intermittent failures that can occur in a real-world vehicle environment.

The test fall into three categories, each addressed in a separate section as follows:

- Section 4.1: pre-installation DAS tests to verify that the software and hardware components are working as specified.
- Section 4.2: tests to ensure that cabling and modules have been properly fabricated and installed on the vehicle.
- Section 4.3: tests demonstrating that the DAS captures the appropriate J1939 CAN signals.

Table 3 summarizes the individual activities; these activities will be described in the following sections.

Table 3. Pre-installation tests: basic connectivity and capture test results.

Pre-Installation Tests
<p>DAS functionality on the bench</p> <ul style="list-style-type: none"> • Unique DAS Identification Setup • Verify the Operation of Audio • Verify DAS GPS Configuration and Operation • Verify DAS Video Frame Grabber Card • Verify DAS CAN card operation • Modem Configuration and Operation • Prepare Database for Use • Update and verify DAS software • Final inspection and labeling
<p>In-vehicle installation; wiring/voltage integrity</p> <ul style="list-style-type: none"> • Pre-installation wire harness fabrication • Install DAS-to-truck cable set • Install Mobileye ranging sensor (calibrate with laptop) • Install Truck-to-Terminal-block power • Install wires & check voltages • Install DAS; check connectors and power-up
<p>Capture of CAN bus signals by DAS</p> <ul style="list-style-type: none"> • Verify DAS/CAN interface • Verify and check CAN BUS data load • Check for Zero Error Frames on all buses • Verify messages on update rates on J1939 bus • Verify messages and update rates on UMTRI bus

Source: UMTRI

DAS Pre-installation Functionality Verification

Following the fabrication of a DAS, images of an UMTRI standard embedded operating system are loaded onto the DAS hard drives. The DAS is then connected to a pre-wired and customized bench testing site which allows technicians to exercise, through a series of tests, the function and verification of all the hardware and software on the DAS. The following are to be verified, among other activities:

- IP address and DAS software are installed and configured properly.
- Video and audio interfaces are functioning and capturing images and audio.
- DAS GPS is configured properly and is capturing messages.
- CAN interface and cellular modem function properly.

Wiring Continuity and Power Verification

Prior to installing the DAS and DSRC onboard equipment (OBE) hardware, cabling is routed and installed in the vehicle to provide power, ignition, and connectivity between hardware modules. This requires the removal and disassembly of the vehicle instrumentation cluster and trim components on the interior of the vehicle. Cable routing length measurements are made and wiring harnesses are fabricated on the bench and connectors are installed when possible. (Often the constraints of the installation require running cabling through small spaces, which calls for installing connectors after running the cables.) These activities are shown in figure 48.

Direct battery and switch ignition power terminals are installed on the vehicle, with multiple nodes to allow for the multiple components and multiple fusing requirements. The power terminal also provides proper and common ground for the installation. During or following the routing and installation of the wiring harnesses the technician performs continuity and power verification tests using a checklist, which includes:

- In-vehicle power distribution to the DAS is checked.
- Wiring from the DAS to its sensors, including connectors, is tested.
- Wiring from the DAS to the miniWSU, and wiring within the OBE components, is tested.
- Signals are received at the DAS connectors from powered-up sensors and CAN buses, and are reasonable.
- OBE signals appear at the input connectors for the miniWSU and are reasonable.

A detailed wiring harness checklist is typically created and used by a technician for this activity.

DAS Capture of CAN Bus Signals

The next set of test activities in figure 48 involves the capture and verification of CAN bus signals from both the vehicle bus (SAE J1939 standard) and a project CAN bus used for a subset of the DAS sensors. The DAS is not fully installed for this test, but must be connected to the various wire bundles including the cameras, CAN buses, power, sensor cluster, modem antenna, GPS antenna, and the DAS mode switch. The DAS mode switch is used to start the DAS in a “maintenance” mode which allows full control over the launch of all software residing on the DAS operating system. To facilitate this test, an external USB mouse, keyboard, and VGA monitor are connected to the DAS. Figure 48 shows the interface panel of the DAS used for this project.

Once the DAS is fully booted, a graphical user interface (GUI) interface program is launched on the DAS. Next the vehicle ignition is turned on and a GUI dialog box is opened that reports the status of the defined CAN messages on each CAN bus. Using the mouse the engineer can update the counts of the individual CAN messages and verify that they are on the bus, are being read by the CAN card on the DAS and that the rate of the message is consistent with their specification.



UMTRI

Figure 48. Photo. DAS interface panel.

CHAPTER C-5. POST-INSTALLATION DAS TESTS

Following the tests in Chapter 4, the DAS is installed in the tractor. These sets of tests are performed with the engine running—sometimes in a static mode (while parked) and sometimes in a dynamic mode (driving on the road). This section’s tests are designed to look at the quality of the signals directly measured by the DAS.

Post-installation testing activities are summarized in table 4 and are described in subsections:

Section 5.1: Verification of DAS signals while parked.

Section 5.2: Verification of DAS signals while driving.

Section 5.3: Validation of processes to upload DAS data and loading into database.

Section 5.4: Validating the transfer of selected DAS data over cellular networks.

Chapter C-6 will address signals sent from the miniWSU to the DAS.

Table 4. Vehicle build post-installation tests: DAS signals and data integrity test results.

Post-Installation Tests
<p>Signals in the vehicle while parked (static tests)</p> <ul style="list-style-type: none"> • Verify Video Signal Updates and Capture Rates • Verify Audio Signal Capture and Volume Level • Verify IMU Signal Updates • Verify Instrument Cluster Signals (wiper, turn, etc.) • Verify Engine Related Signals (accel pedal, RPM, etc.) • Verify GPS Signals
<p>Signals while driving (dynamic tests)</p> <ul style="list-style-type: none"> • Verify IMU Signal Polarity • Verify Mobileye Lane Tracking Signals • Verify Mobileye Forward Target Signals • Verify Speed and Cruise Control Signals • Verify Traction Control and ABS Signals (if possible) • Verify Engine Status Signal
<p>The transfer of data from the onboard DAS to off board servers</p> <ul style="list-style-type: none"> • Check Authentication between UMTRI Servers and DAS • Verify Connectivity between Server and DAS Catalogs • Verify Updates to DAS and Server Catalogs upon File Copy • Run and Verify Database FastLoad Routines • Reconcile Table Record Counts with Catalog Counts • Verify All Video Image Cropping • Verify Objective Data and Video Synchronization
<p>DAS cellular data transfers for monitoring purposes</p> <ul style="list-style-type: none"> • Check Authentication between UMTRI Phone Server and DAS • Verify Connectivity between Server and DAS Catalogs • Verify Updates to DAS and Server Catalogs upon File Copy • Run and Verify Database FastLoad Routines • Reconcile Table Record Counts with Catalog Counts

Source: UMTRI

Static Verification of DAS Signals (Real time)

Static tests are conducted with the DAS installed in the vehicle and the engine running. The DAS keyboard and monitor are used to confirm that the DAS GPS, inertial sensor cluster, microphone, and parsed CAN messages are correct and vary as expected over time, for example as turn signals or throttle are modulated. The DAS application can display limited amounts of data or data statistics from its inputs, such as video displays, inertial sensor cluster values, J1939 signal values, and the

bytes captured from the digitized audio. These static tests demonstrate confidence of DAS connectivity. The types of signals that can be examined in the static mode include:

- Basic engine, throttle, and brake information.
- Camera and inertial sensor cluster signals.
- Steering.
- Wipers and turn signals.

Dynamic Verification of DAS Signals (Real Time)

Following the static verification of signals being logged by the DAS, the next step is to capture and inspect signals while the vehicle is being driven to verify reasonable values for dynamic signals. The signals that are most suitably addressed with dynamic testing includes measures of speed, GPS heading, GPS satellite count, lane tracking confidence, target tracking by the forward ranging sensor, and more. The engineer instructs the driver to perform benign driving tasks while watching the measured signals change on the screen and noting any anomalous values using a checklist. Post-drive analysis is also performed.

Data Normalization and Consistency

As part of the dynamic verification tests, data are logged by the DAS in a manual mode by the test conductor using the GUI interface to initiate and terminate multiple data collection sessions during the public road drives with and without a DSRC equipped remote vehicle. The files generated during this exercise were used to verify the data transfer methodology between the DAS and UMTRI servers, along with the protocols and software developed to map the DAS generalized binary signals into a database on the UMTRI project servers.

Since the creation and loading of the database tables leverage the same metadata that is used to configure the DAS software, this process of database loading serves as another test to find inconsistencies in the installed hardware and software on the equipped vehicle. The steps involved in this test are:

- Retrieve or compute characteristics of data files on the DAS.
- Execute scripts to move binary data from the DAS over Ethernet to UMTRI file servers, and compare the moved data's characteristics to the DAS's self-auditing characteristics.
- Load the binary data from file servers into relational databases, using databases with carefully selected primary keys and database design. Compare the database characteristics (e.g., number of records, number of non-null values) to the previous characterizations of the data.

The results of these tests ensure that data collected by the DAS meet a level of quality necessary for scalability and query efficiency required for the analysis and processing of large scale data collections, generally measured in millions of records and terabytes in size.

After the transfer of data between the DAS and SQL database, high-level reconciliation software compares the number of rows in each database table with the logged number of records recorded by the DAS. Other consistency checks are performed between the onboard data file sizes and characteristics and the database versions.

DAS Cell Data Transfer

At the conclusion of an ignition event, the DAS cell modem remotely connects with a dedicated UMTRI server to transfer a summary set of files from the DAS to UMTRI servers. This is useful to monitor system performance and health, vehicle travel, and important events and patterns. As part of testing, a packet data call from the DAS cell modem to UMTRI's servers is done to test modem capability in the installed DAS. Successful completion of the test indicates that the calls are received and deliver meaningful data to UMTRI's servers, and confirms that this process works on each of the tractors equipped with DAS. This test is done in both static tests at UMTRI as well as during driving trips around the Ann Arbor region.

CHAPTER C-6. POST-INSTALLATION OBE INSTALLATION AND INTEGRITY TESTS

The final set of vehicle build tests look at the integrity of the signals being generated by the DSRC OBE. These tests are designed to validate that the safety application software and hardware are installed correctly and working properly. The testing is intended to cover typical use aspects of the vehicle and how that use might affect the function of the installed components.

Table 5 shows the testing activities associated with the verification of OBE functions. These activities include three main topics which are presented in subsections that follow:

- Section 6.1: Capture of UDP packets from the miniWSU.
- Section 6.2: DSRC functionality static and dynamic situations.
- Section 6.3: OBE use and broadcast of vehicle bus and GPS data.

The tests are not intended to validate the accuracy of the OBE and its safety applications. Those performance tests were planned separately [5].

Table 5. Vehicle build post-installation tests: OBE signals and integrity test results.

Post-Installation: OBE Signals and Integrity
DAS capture of miniWSU data packets <ul style="list-style-type: none"> • Verify Host Vehicle Data Packets are logged by DAS • Verify Remote Vehicle Data Packets are logged by DAS • Verify Threat Arbitration Packets (a.k.a. OEM packets) • Verify Sent Wireless Messages Packets are logged by DAS • Verify Received Wireless Data Packets are logged by DAS
DSRC communication in static and dynamic tests <ul style="list-style-type: none"> • Verify Content of Host and Remote Packets • Verify Content of Received and Sent BSM Messages • Verify Warning Event Triggers by the DAS
OBE access to vehicle bus data and GPS <ul style="list-style-type: none"> • Verify Content of OBE Vehicle Bus Data • Verify Content of OBE GPS Measures
Safety Application Functionality <ul style="list-style-type: none"> • Verify EEBL Warning Functionality with Remote Vehicle • Verify FCW Functionality with Remote Vehicle • Verify CSW Functionality

Source: UMTRI

Capture of UDP Packets from miniWSU (Real Time)

Although all the testing described above applies to many vehicle instrumentation and installation efforts conducted by UMTRI, there were specific test protocols developed for the customized hardware installed specifically for the RSD project related to connected vehicle communications. In this case, as shown in figure 46, a Denso miniWSU unit was installed. The miniWSU transfers data to the DAS using an Ethernet and User Datagram Protocol (UDP). To verify these messages, the following are examined to ensure proper communication with the miniWSU and signal capture:

- miniWSU and GPS configurations and time stamps.
- GPS data from the miniWSU (separate from the DAS GPS).
- Basic vehicle signals used on the miniWSU, e.g., speed, yaw rate, throttle, etc.
- miniWSU estimates of remote connected vehicle locations and motions.
- miniWSU safety application alert flags.

Similar to the dynamic test outlined above for DAS data, but with the addition of a DSRC-equipped remote vehicle, the test was conducted driving on the public road network. Using cell phones or dedicated radios, the driver of the RSD vehicle and the remote vehicle are instructed by the test engineer to perform benign maneuvers while the engineer visually inspects signals that are processed by the miniWSU and piped to the DAS. Of particular significance in these tests are signals related to the remote vehicle position classification, the calculated range and range-rate of the remote vehicle. (Note: when the RSD vehicle is following the remote vehicle, multiple measures of the distance and relative distance between the vehicles can be compared to verify the signals being calculated by the miniWSU). In general, the level of validation of many of these measures is somewhat subjective with the test conductor comparing the reported value with what is visually present outside of the vehicle.

DSRC Functionality in Static and Dynamic Testing

These static tests ensure that both antennas are functional and successfully integrated with the miniWSU, and that the miniWSU can transmit and receive signals as expected. Denso's miniWSU wireless test application (WTA) was used for this testing. The WTA system consists of a miniWSU connected to a laptop running the test application. This set up allows easy movement from location to location. This testing includes a confirmation of successful performance with the transmission and reception of the DSRC basic safety message (BSM) for a remote vehicle at several locations around the host vehicle in order to confirm expected antenna coverage and performance.

Dynamic tests on the road were also conducted to ensure that the vehicle-to-vehicle communication with a remote OBE-equipped vehicle was successful in both directions (receive and transmit). This was done systematically, with the cooperating vehicle positioning itself at several designated locations around the tractor-trailer combination and included a test of all target classification zones, and a test of measured range values which is judged to be consistent with the observed range by the test conductor. This latter test involved the cooperating vehicle being both in front, and behind, the tractor, with the range allowed to grow continuously from about 10 meters to 350 meters. The success of these tests and a measure of the packet exchanges between the vehicles were quantified upon return to UMTRI using the data and video collected by the DAS and loaded into the database.

OBEs Use and Broadcast of J1939 and GPS Data

These tests ensured that the onboard equipment is consistently and accurately receiving its J1939 bus data and its GPS receiver data. This test was done by examining the DAS capture of BSM logs that are sent from the miniWSU to the DAS over Ethernet and was done concurrently with the DSRC functionality testing outlined above. Examination of these BSM data, after they have been parsed and loaded into a relational database, and compared with DAS data collected from other sources provides a very good indication that the miniWSU is successfully receiving reasonably-valued inputs from the J1939 bus and the OBE GPS receiver.

CHAPTER C-7. TEST RESULTS

The pre-installation tests were conducted for the prototype tractor and then eventually for the eight Sysco tractors. As with any testing and verification of prototype systems, there were several instances in which a subsystem did not perform as expected; problems were identified and fixed.

Results of the pre-installation tests are presented in table 6. The technicians and engineers followed detailed checklists to complete the testing.

Table 6. Pre-installation tests: basic connectivity and capture test results.

Items to Verify Pre-Installation Tests: Basic Connectivity and Capture	Tractors Completed	
	UMTRI (Prototype)	SYSCO (8 Units)
DAS functionality on the bench <ul style="list-style-type: none"> • Unique DAS Identification Setup • Verify the Operation of Audio • Verify DAS GPS Configuration and Operation • Verify DAS Video Frame Grabber Card • Verify DAS CAN card operation • Modem Configuration and Operation • Prepare Database for Use • Update and verify DAS software • Final inspection and labeling 	✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓	✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓
In-vehicle installation; wiring/voltage integrity <ul style="list-style-type: none"> • Pre-installation wire harness fabrication • Install DAS-to-truck cable set • Install Mobileye ranging sensor (calibrate w/laptop) • Install Truck-to-Terminal block power • Install wires & check voltages • Install DAS; check connectors and power-up 	✓ ✓ ✓ ✓ ✓ ✓	✓ ✓ ✓ ✓ ✓ ✓
Capture of CAN bus signals by DAS <ul style="list-style-type: none"> • Verify DAS/CAN interface • Verify and check CAN BUS data load • Check for zero Error Frames on all buses (ensure data bus is not overloaded) • Verify messages on update rates on J1939 bus • Verify messages and update rates on UMTRI bus 	✓ ✓ ✓ ✓ ✓	✓ ✓ ✓ ✓ ✓

Source: UMTRI

The post-installation tests were conducted for all tractors. The results of the post-installation DAS tests (Part 2 in figure 47) are presented in table 7. All systems passed the tests.

Table 7. Vehicle build post-installation tests: DAS signals and data integrity test results.

Items to Verify Post-installation Tests: DAS Signals and Integrity	Tractors Completed	
	UMTRI (Prototype)	SYSCO (8 Units)
Signals in the vehicle while parked (static tests) <ul style="list-style-type: none"> • Verify Video Signal Updates and Capture Rates • Verify Audio Signal Capture and Volume Level • Verify IMU Signal Updates • Verify Instrumentation Cluster Signals (wiper, turn, etc.) • Verify Engine Related Signals (accel pedal, RPM, etc.) • Verify GPS Signals 	✓ ✓ ✓ ✓ ✓ ✓	✓ ✓ ✓ ✓ ✓ ✓
Signals while driving (dynamic tests) <ul style="list-style-type: none"> • Verify IMU Signal Polarity • Verify Mobileye Lane Tracking Signals • Verify Mobileye Target Signals • Verify Speed and Cruise Control Signals • Verify Traction Control and ABS Signals (if possible) • Verify Engine Status Signal 	✓ ✓ ✓ ✓ ✓ ✓	✓ ✓ ✓ ✓ ✓ ✓
The transfer of data from the onboard DAS to off board servers <ul style="list-style-type: none"> • Check Authentication between UMTRI Servers and DAS • Verify Connectivity between Server and DAS Catalogs • Verify Updates to DAS and Server Catalogs upon File Copy • Run and Verify Database FastLoad Routines • Reconcile Table Record Counts with Catalog Counts • Verify All Video Image Cropping • Verify Objective Data and Video Synchronization 	✓ ✓ ✓ ✓ ✓ ✓ ✓	✓ ✓ ✓ ✓ ✓ ✓ ✓
DAS cellular data transfers for monitoring purposes <ul style="list-style-type: none"> • Check Authentication between UMTRI Phone Server and DAS • Verify Connectivity between Server and DAS Catalogs • Verify Updates to DAS and Server Catalogs upon File Copy • Run and Verify Database FastLoad Routines • Reconcile Table Record Counts with Catalog Counts 	✓ ✓ ✓ ✓ ✓	✓ ✓ ✓ ✓ ✓

Source: UMTRI

The post-installation OBE tests (Part 3 in figure 47) are were conducted for all tractors. The results are presented in table 8. All systems passed the tests.

Table 8. Vehicle build post-installation tests: OBE signals and integrity test results.

Items to Verify Post-installation: OBE Signals and Integrity	Tractors Completed	
	UMTRI (Prototype)	SYSCO (8 Units)
DAS capture of miniWSU data packets <ul style="list-style-type: none"> • Verify Host Vehicle Data Packets are logged by DAS • Verify Remote Vehicle Data Packets are logged by DAS • Verify Threat Arbitration Packets (a.k.a. OEM packets) • Verify Sent Wireless Messages Packets are logged by DAS • Verify Received Wireless Data Packets are logged by DAS 	✓ ✓ ✓ ✓ ✓	✓ ✓ ✓ ✓ ✓
DSRC communication in static and dynamic tests <ul style="list-style-type: none"> • Verify Content of Host and Remote Packets • Verify Content of Received and Sent BSM Messages • Verify Warning Event Triggers by the DAS 	✓ ✓ ✓ ✓	✓ ✓ ✓ ✓
OBE access to vehicle bus data and GPS <ul style="list-style-type: none"> • Verify Content of OBE Vehicle Bus Data • Verify Content of OBE GPS Measures 	✓ ✓ ✓	✓ ✓ ✓
Safety Application Functionality <ul style="list-style-type: none"> • Verify EEBL Warning Functionality with Remote Vehicle • Verify FCW Functionality with Remote Vehicle • Verify CSW Functionality 	✓ ✓ ✓ ✓	✓ ✓ ✓ ✓

Source: UMTRI

CHAPTER C-8. REFERENCES

- [1] Bogard, S. and LeBlanc, D. (October 31, 2013) “Connected Commercial Vehicles—Retrofit Safety Device Kit Project: Applications Performance and Functional Test Report.” (Report from the University of Michigan Transportation Research Institute to Battelle for ITS JPO) Battelle document 10005986-405. Contract No. DTFH61-11-D-00014/T11001.
- [2] Bogard, S., LeBlanc, D., and Gilbert, M. (September 13, 2013) “Connected Commercial Vehicles—Retrofit Safety Device Kit Project: Data Acquisition System (DAS) Documentation.” (Report from the University of Michigan Transportation Research Institute to Battelle for ITS JPO) Battelle document 10005986-502. Contract No. DTFH61-11-D-00014/T11001.
- [3] Bogard, S., LeBlanc, D., and Gilbert, M. (November 11, 2013) “Connected Commercial Vehicles—Retrofit Safety Device Kit Project: Data Acquisition System (DAS) Pre-Delivery Test Report.” (Report from the University of Michigan Transportation Research Institute to Battelle for ITS JPO) Battelle document 10005986-704. Contract No. DTFH61-11-D-00014/T11001.
- [4] Wells, B. and Berg, R. (January 31, 2012) “Connected Commercial Vehicles—Retrofit Safety Device Kit Project: Safety Applications and Development Plan Draft Technical Report.” (Report from the DENSO North American Research Laboratory to Battelle for ITS JPO) Battelle document 10005986-502. Contract No. DTFH61-11-D-00014/T11001.
- [5] Wells, B. and Berg, R. (November 2013) “Connected Commercial Vehicles—Retrofit Safety Device Kit Project: RSD Pre-Delivery Test Plan.” (Report from the DENSO North American Research Laboratory to Battelle for ITS JPO) Battelle document 10005986-701. Contract No. DTFH61-11-D-00014/T11001.

APPENDIX D. RSD USER'S GUIDE

The Retrofit Safety Device (RSD) User's Guide was written by DENSO. It has instructions on how to use the DENSO Retrofit Safety Devices (RSDs) for Model Deployment. The guide has sections on configuration, connecting a computer to the miniWSU to change the configuration, and the Driver Vehicle Interface. This version of the guide is dated July 12, 2013.

1 INTRODUCTION

1.1 Scope

This document provides instructions on how to use the DENSO Retrofit Safety Devices (RSDs) for Model Deployment. The RSD kits are being delivered to the University of Michigan Transportation Research Institute (UMTRI).

1.2 DENSO Contact information

Please use the following information to contact DENSO for any issues or questions.

Primary contact information:

Bryan Wells
Manager – Wireless Systems
bryan_wells@denso-diam.com
(760) 409-8874 (Cell)
(760) 597-7448 (Office)

Alternate contact information:

Sue Graham
Director of Wireless Systems
sue_graham@denso-diam.com
(760) 271-8810 (Cell)
(760) 597-7440 (Office)

Other alternate points of contact are:

- For hardware or installation issues, please contact Brian Gallagher at (760) 271-8836 (Cell) or brian_gallagher@denso-diam.com.

DENSO's address:

DENSO International America, Inc.
North America Research Laboratory
3252 Business Park Drive
Vista, CA. 92081

The web site for DENSO North America is www.densocorp-na.com.

1.3 Definitions, Acronyms, and Abbreviations

Acronym	Abbreviation
ASD	Aftermarket Safety Device
CCV	Commercial Connected Vehicle
CML	Communication Message Log
CSW	Curve Speed Warning
DHCP	Dynamic Host Configuration Protocol
DSRC	Dedicated Short Range Communications
DVI	Driver Vehicle Interface
EEBL	Emergency Electronic Brake Light
FCW	Forward Collision Warning
GPS	Global Positioning System
HD	Host Device
HV	Host Vehicle
IGN	Ignition
LED	Light Emitting Diode
MD	Model Deployment
miniWSU	Miniature Wireless Safety Unit
N/A	Not Applicable
PC	Personal Computer
PCAP	Packet Capture
RSD	Retrofit Safety Device
RV	Remote Vehicle
SCMS	Security Credential Management System
SCP	Secure Copy
SEL	System Event Log
SSH	Secure Shell
SSL	System Status Log
SSID	Service Set Identification
UMTRI	University of Michigan Transportation Research Institute
USB	Universal Serial Bus
USDOT	United States Department of Transportation
WPA	Wireless Protected Access

1.4 Applicable Documents

- [1] Wells, B. and Berg, R. (July 11, 2013) “Connected Commercial Vehicles—Retrofit Safety Device Kit Project: RSD Installation, Troubleshooting, and Initialization Guide.” (Report from the DENSO North American Research Laboratory to Battelle for ITS JPO) Battelle document 10005986-601. Contract No. DTFH61-11-D-00014/T11001.
- [2] FHWA RFTP 2011-16, Commercial Vehicle Retrofit SOW, dated June 2011.
- [3] FHWA RFTP 2011-16, Commercial Vehicle Retrofit SOW, dated June 2011.
- [4] ASD System Requirement Description, Version 3.0, dated 26Dec2011.
- [5] USDOT System Requirement Description 5.9 GHz DSRC Vehicle Awareness Device Specification, Version 3.6, dated 20120125.
- [6] CAMP Model Deployment Safety Device DSRC BSM Communication Minimum Performance Requirements, Revision 11.1, dated 1/24/2012.

1.5 Overview

This document provides instructions on how to use the DENSO RSD for Model Deployment. Refer to the CCV RSD Installation Instructions (Appendix A) for a complete parts list and assembly/installation instructions.

2 CONFIGURATION

Configure the GPS antenna offsets if needed by setting the antOffsetX, antOffsetY, and antOffsetZ parameters in the ModelDeploymentRemovable.conf file (see information on configuration file location below). The antenna offsets should be entered in centimeters using the SAE J670 Z-down coordinate system. A positive X value indicates the antenna is forward of the center of the vehicle. A positive Y value indicates the antenna is to the right of the center of the vehicle when looking forward. A positive Z value is the elevation of the vehicle above the road. Please refer to figure 49. The miniWSU supports the vi editor.

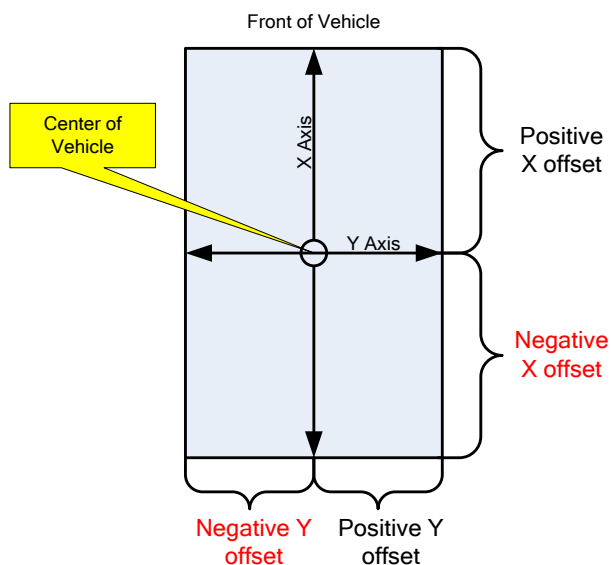


Figure 49. Diagram. Antenna offset coordinates.

3 USAGE INSTRUCTIONS

3.1 Power Up/Down

3.1.1 Power Up

When power is applied and the ignition input is sensed, the miniWSU inside the RSD Radio Enclosure initializes and starts the RSD application. The WiFi Access Point and DVI tablet will also power on/wake up when ignition power is sensed, and the RSD DVI application on the tablet will launch. The RSD DVI application includes LED indicators in the upper right-hand corner of the screen, and sets the colors to indicate the device and application status as shown in table 9:

Table 9. DVI LED indicator definitions.

LED	Color	Indication
Power	Off	Device powered off. (<i>Display device can't communicate with miniWSU.</i>)
	Amber	Communication (socket) errors between miniWSU and display device.
	Green	Device and software initialization complete.
Stat-1	Off	RSD application not running or halted.
	Green	RSD application running, and transmitting BSMs.
Stat-2	Off	RSD application is not receiving BSMs from remote any remote vehicles.
	Green	RSD application is receiving BSMs from one or more remote vehicles.

The normal time for the RSD application to start execution is approximately 35 seconds.

The RSD may not power up automatically when ignition is sensed if any of the following has occurred:

1. The miniWSU was powered off abruptly (i.e., battery power was removed before it completed the shutdown process).
2. The reset button was pressed when the miniWSU was powered off and disconnected.
3. Battery power has been removed for an extended period of time.

If the power LED is not illuminated amber after the ignition is turned on, turn off the ignition, disconnect vbatt, reconnect vbatt, and then turn on ignition again. The miniWSU should power up after this after this second sequence. If this does not occur, open the lid of the RSD Radio Enclosure and press the reset button on the miniWSU to initiate the power-up sequence.

3.1.2 Power Down

The RSD software automatically powers down upon detecting the loss of the ignition sense input. The software executes its shutdown process, and then powers off the RSD hardware after approximately 10 seconds. If the graceful software shutdown is not completed for some reason, the device automatically shuts down approximately 30 seconds after it detects the loss of ignition sense.

The shutdown process requires the RSD to continue operating from battery power until the unit is powered off. The User should avoid disconnecting the battery power until the shutdown process has completed. Disconnecting the battery power prior to shutdown completion may result in the loss of data in the file system and non-compliant “quiet” current draw on the battery.

3.2 Network Connection and Login

A User-supplied Host Device (HD) may be connected to the miniWSU via a network connection, by establishing an ssh connection to the miniWSU after it is powered up. The miniWSU supports a wired Ethernet connection.

Use the following procedure for setting up a wired Ethernet connection:

1. Connect an Ethernet cable between the HD and the miniWSU.
2. Configure the HD to use a static Ethernet IP address of 192.168.1.xxx, where xxx is a value other than 250. The miniWSU Ethernet IP address is 192.168.1.250, and the HD must have a different address.

After the miniWSU has been powered up, complete the login process as shown below:

1. Establish ssh connection from HD to miniWSU
 - a. From a linux HD, type “ssh root@192.168.1.250” at the command prompt.
 - b. From a Windows HD, use putty and establish an ssh connection to 192.168.1.250.
2. At the miniWSU login prompt, type "root" as the user name and “rootroot” as the password. If the password “rootroot” does not work, contact DENSO for the correct password for your device.

3.3 Configuration, Log, and Security Files

The RSD application reads four configuration files and generates two types of log files. It also uses pre-loaded security credentials. Table 10 shows the file locations. The subparagraphs referenced in the table provide additional information for each file type. Files located in the /mnt/cflash directory are accessible by the user either by logging into the device or extracting the microSD from the RSD device and modifying and/or copying the file as desired. Files located in the /rwflash/configs directory are only accessible by logging into the device.

Table 10. Configuration and log file location.

File Type	Directory	SubPara #
USDOT Model Deployment Configuration File	/mnt/cflash/ModemDeploymentConfigurationItems/ModelDeploymentRemovable.conf	3.3.1
Communication Message Logs (CMLs) (PCAP format)	/mnt/cflash/pktlogs	3.3.2
System Event Logs (SELs)	/mnt/cflash/V2V-I/systemeventlogs	3.3.3
DENSO Configuration Files	/rwflash/configs/v2vi_obe.conf /rwflash/configs/denso-v2vi.conf	3.3.1

3.3.1 Configuration Files

The RSD application uses the USDOT ModelDeploymentRemovable.conf file plus two additional DENSO configuration files: v2vi_obe.conf, and denso-v2vi.conf. The USDOT file is in the format specified in Appendix B of the Vehicle Awareness Device Specification [5]. The software does not support the MemoryDeviceMountTimeDate parameter.

The DENSO v2vi_obe.conf and denso-v2vi.conf files contain the current values for the configuration parameters, plus the minimum and maximum acceptable values for the parameters. The syntax of each line is “<parameter name> = <current value>;<min value>,<max value>”.

For example:

```
BSMPartITxInterval_ms = 100; 50, 1000
```

A “#” character indicates the remainder of the line is a comment

Table 11 identifies the configuration parameters referred to in the ASD specification [4] or VAD specification [5] that are located on the external microSD and modifiable by the customer without logging into the miniWSU.

Table 12 identifies the configuration parameters referred to in the ASD specification [4][1] or VAD specification [5] that are located in internal DENSO configuration files and not modifiable by the customer without logging into the miniWSU. The parameters shown are for reference only. These files also contain other parameters for DENSO use.

DENSO has set the default values to meet the specification requirements. Refer to comments in the configuration files for additional information. The miniWSU supports the vi editor for editing configuration files.

Table 11. Customer modifiable RSD configuration parameters.

Description	File	Parameter Name, Comments	Default Value
MD Device ID	ModelDeploymentRemovable.conf	ModelDeploymentDev iceID	13100
Temporary ID Randomization Control	ModelDeploymentRemovable.conf	TemporaryIDControl	0
Memory Device Mount Time	ModelDeploymentRemovable.conf	MemoryDeviceMount TimeDate (not currently supported)	0
GPS Antenna X Offset	ModelDeploymentRemovable.conf	antOffsetX	0 (cm)
GPS Antenna Y Offset	ModelDeploymentRemovable.conf	antOffsetY	0 (cm)
GPS Antenna Z Offset	ModelDeploymentRemovable.conf	antOffsetZ	305 (cm)
Vehicle Type	ModelDeploymentRemovable.conf	VehicleType	8
Vehicle Length	ModelDeploymentRemovable.conf	VehicleLength	808 (cm)
Vehicle Width	ModelDeploymentRemovable.conf	VehicleWidth	255 (cm)

Table 12. RSD configuration parameters – reference only.

Description	File	Parameter Name, Comments	Default Value
SSL time threshold	Not currently supported. One SSL will be generated per application execution		N/A
SSL size threshold	Not currently supported. One SSL will be generated per application execution. The maximum storage size for all SSL files can be configured in denso-v2vi.conf	SSLStorageSizeMB.	512 MB
WAAS enable/disable	Not currently supported. WAAS corrections are always enabled		N/A
CML separation by interface	denso-v2vi.conf	PCAPLogCombineRadioFiles	0=Different files
CML separation by direction	denso-v2vi.conf	PCAPLogEnableRadio1	4=Tx/Rx combined in a single file
		PCAPLogEnableRadio2	1=Tx only
CML time threshold	denso-v2vi.conf	PCAPLogTimeThresholdMin	0=No limit
CML file size threshold	denso-v2vi.conf	PCAPLogFileSizeThresholdMB	500 MB
CML total size threshold	denso-v2vi.conf	PCAPLogSizeThresholdMB	4000 MB
AIFS	v2vi_obe.conf	AC_BE_AIFSN	6
		AC_BK_AIFSN	9
		AC_VI_AIFSN	3
		AC_VO_AIFSN	2

Table 12. RSD configuration parameters – reference only. (Continued)

Description	File	Parameter Name, Comments	Default Value
EDCA	v2vi_obe.conf	AC_BE_CWminKVal	4
		AC_BE_CWmaxKVal	10
		AC_BK_CWminKVal	4
		AC_BK_CWmaxKVal	10
		AC_VI_CWminKVal	3
		AC_VI_CWmaxKVal	4
		AC_VO_CWminKVal	2
		AC_VO_CWmaxKVal	3
Certificate Minimum Attachment Interval	v2vi_obe.conf	CertAttachInterval_ms	500 ms
WSMP-S Control Field	v2vi_obe.conf	WSMPSafetySuppSupport,	1
		WSMPSafetySuppData	1
PSID and User Priority	v2vi_obe.conf	BSMRxSecurePSID	0x20
		BSMTxSecurePSID	0x20
		BSMUserPriority	2
WSMP Header Options	denso-v2vi.conf	DWMHWSMTxHdrDataRateEnable	1=Yes
		DWMHWSMTxHdrPwrEnable	1=Yes
Radio Operating Mode	v2vi_obe.conf	ChannelMode	0=Continuous mode (applies to first radio)
Radio Channel Usage	[See the following parameters]		
Continuous Channel	v2vi_obe.conf	ContinuousChanNum	172
Alternating Channel	N/A	BSMs will be sent on the control channel. Service channel numbers for other services will be obtained from WSAs.	N/A
Service Channel Interval	N/A	See comments for Alternating Channel	N/A

Table 12. RSD configuration parameters – reference only. (Continued)

Description	File	Parameter Name, Comments	Default Value
Continuous Mode – Default Configuration	N/A	The first radio will be configured according to Channel Mode. The default configured value is continuous mode.	N/A
Alternating Mode – Default Configuration	N/A	The second radio will default to alternating mode (RSD).	N/A
DSRC Radio Pair - Default Configuration	[See above]		N/A
Congestion Control	Not currently supported.		N/A
BSM Message Rate	v2vi_obe.conf	BSMPartITxInterval_ms	100 ms
BSM Radio	N/A	BSMs will be transmitted on the first radio, configured as described above.	N/A
BSM Part I Message Rate	v2vi_obe.conf	BSMPartITxInterval_ms	100 ms
BSM Part II Message Rate	denso-v2vi.conf	DWMHPartIITxObjectRate	1=Every message

3.3.2 *Communication Message Log (CML)*

The CML consists of PCAP formatted log files consisting of transmitted and received messages. The CML files are stored in /mnt/cflash/pktlogs and have the following naming convention:

DevID_YYYY_MM_DD_hh_mm_ss_<ifname>_<logtype>.pcap

Where

DevID = MD Device ID

YYYY = year

MM = month

DD = day

hh = hour

mm = minute

ss = second

ifname = the radio interface name (wlan0 or wlan1)

logtype = the type of logs (tx, rx, or tx_rx combined).

If the configuration file is set to limit the CML file size (via PCAPLogSizeThresholdKB setting), then a sequence number is also appended to the filename.

3.3.3 *System Event Log (SEL)*

The SEL files are stored in /mnt/cflash/V2V-I/systemeventlogs and have the following naming convention:

dddd_c_YYYY-MM_DDThh:mm:ssZ.csv

Where

dddd is the unique device ID,

c is the configuration number,

YYYY, MM, DD, hh, mm, ss are the same as the CML,

and the characters “T” and “Z” are delimiters surrounding the timestamp.

3.3.4 *Security Credentials*

Prior to delivery, DENSO will load at least 12 months of security certificates to support the complete Model Deployment period. Over-the-air (OTA) security certificate downloading is supported but disabled on the RSDs. Contact DENSO if the long-term security certificates must be restored on the RSD.

3.4 File Transfer

An HD can transfer configuration files, log files, or security credentials to/from the miniWSU using the Secure Copy (SCP) command with the following procedure. Note that this procedure requires entering the password of the miniWSU.

1. Setup the Host device and establish an Ethernet connection between the HD and miniWSU as described in Section 3.2 (without using the ssh command).
2. If the HD is a running Windows, the “winscp” program can be used on Windows to establish an scp connection between the HD and miniWSU. Once connected, files can be easily transferred between the HD and miniWSU by dragging them between the different screens.
3. If the HD is running Linux (or a version of Linux WMware), the following commands can be used. If prompted, enter “yes” to allow the security keys to be stored.
 - a. To copy from HD to miniWSU:
scp <filename> root@192.168.1.250:/<path on miniWSU>
 - b. To copy from the miniWSU to HD:
scp root@192.168.1.250:/<path on miniWSU>/<filename>.

3.5 MicroSD Formatting

If necessary, a microSD card may be formatted via the following steps on the miniWSU. Note that this procedure requires logging into the miniWSU. Equivalent steps can be performed on an external machine, but the appropriate files will need to be copied to their corresponding directories.

1. Power down the RSD. Insert the microSD card into the miniWSU and then power up the RSD. Login to the miniWSU device.
2. Enter the “mount” command and verify the microSD card is not already mounted. If it is, type the following command:
umount /mnt/cflash
unmount /media/mmcblk0p1
3. Format the microSD card with the ext2 filesystem using the following command:
mke2fs /dev/mmcblk0p1 (note that this is number “0” and number “1”).
4. Disable periodic file system checking using the following command:
sudo tune2fs -c 0 -i 0 /dev/mmcblk0p1
5. Power down the RSD and then power it up again. Enter the command “mount” and verify device is mounted on the /mnt/cflash directory as an “ext2” filesystem.

After formatting a new microSD, the following commands should be executed on the miniWSU:

```
# cp -rf
/rwflash/configs/ModelDeploymentConfigurationItems/ModelDeploymentConfigurationItem.conf.backup
/mnt/cflash/ModelDeploymentConfigurationItems/ModelDeploymentConfigurationItem.conf

# cp -rf /rwflash/configs/ModelDeploymentConfigurationItems/lcm.cfg.backup /mnt/cflash
ModelDeploymentConfigurationItems/lcm.cfg

# mkdir /mnt/cflash/ModelDeploymentConfigurationItems/1609Certificates (this step is not
needed when downloading certificates from SCMS)
```

The default parameters in the two files located in the /mnt/cflash/ModelDeploymentConfigurationItems directory will likely need to be modified for each unique device.

Lastly, the procedure to download new security certificates should be followed as described in Section 3.3.4.

If the microSD is being used as a backup to an existing microSD, all the files in the /mnt/cflash/ModemDeploymentConfigurationItems and /mnt/cflash/V2V-I/lcmfiles directories should be copied from the old to new microSD card.

3.6 Application Control

The RSD application automatically starts when the miniWSU is powered up. After login, the RSD application may be stopped and restarted with the commands “halt-asd” and “run-asd”. The RSD application currently incorporates five safety applications (refer to Section 0 for a description of each application):

1. Forward Collision Warning (FCW).
2. Emergency Electronic Brake Lights (EEBL).
3. Curve Speed Warning (CSW).
4. Intersection Movement Assist (IMA).
5. Blind-Spot/Lane Change Warning (BSWLCW).

By default, all five safety applications are enabled. They can be individually enabled or disabled using the following parameters in the denso-v2vi.conf file (see Section 0 for more information on configuration files):

- DVFCWAppEnableFlag.
- DVEEBLAppEnableFlag.
- DCSWAppEnableFlag.
- DVIMAAppEnableFlag.
- DVBSWLCWAppEnableFlag.

3.7 Firmware Update

Use the following procedure to upgrade the RSD firmware when using a pre-built bootable microSD card:

1. Power down the RSD by removing ignition sense and remove the currently installed microSD card from the miniWSU (which contains configuration files and security certificates).
2. Insert the microSD card with the new firmware image and power up the RSD by applying ignition sense.
3. Do not disturb the RSD for at least two minutes to allow the firmware upgrade to complete.
4. After two minutes, power down the RSD by removing ignition sense, and then disconnect the power connector from the miniWSU. Remove the microSD card with the firmware image, and reinsert the original microSD card with the configuration files and security certificates.
5. Reconnect the power connector and apply ignition sense. The RSD should reboot.

Use the following procedure to upgrade the RSD firmware over an Ethernet connection:

1. If the following files are not found on the miniWSU /home/root/upgrade directory, they should be copied there before starting:
 - a. `miniwsu-minimal-image-2065.tar.gz`.
 - b. `switch_to_ram_fs.sh`.
 - c. `upgrade_step0a.sh`.
 - d. `upgrade_step0b.sh`.
 - e. `upgrade_step1.sh`.
 - f. `upgrade_step2.sh`.
 - g. `wsu_apps0`.
 - h. `wsu_init0`.
2. Put the miniWSU in a known good state before attempting the software upgrade. This script will modify the startup scripts and reboot the miniWSU so minimal processes are executing. You will have to log back in after executing the following command:
 - a. `#!/upgrade_step0a.sh`.

3. Verify the microSD doesn't have any errors before copying the new software image to it. This script will unmount the file system and then do a file system check and attempt to automatically repair any problems found.
 - a. # ./upgrade_step0b.sh.
 - b. Sometimes the file system cannot be repaired automatically and the following commands have to be entered manually. Enter these commands if instructed to do so:
 - i. # umount /dev/mmcblk0p1.
 - ii. # umount /dev/mmcblk0p1 (need to unmount twice).
 - iii. # fsck.ext2 /dev/mmcblk0p1 (enter 'y' to any questions).
 - iv. # mount /dev/mmcblk0p1 /mnt/cflash.
4. Copy the following files that correspond to the new software to be loaded onto the miniWSU "/mnt/cflash" directory.
 - a. Image.
 - b. rfs-part.img.
5. Login to the miniWSU via ssh. Execute the following command:
 - a. # /home/root/upgrade/upgrade_step1.sh.
6. After the step1 script executes, the previous ssh terminal will be closed. Login to the miniWSU again using ssh and execute the following command:
 - a. # upgrade_step2.sh.
7. After the step2 script completes, the software upgrade is complete. Enter the command "reboot" because IGN line sensing won't be detected at this point. After the miniWSU completes rebooting, it is recommended to power down the miniWSU by removing and re-applying the IGN line.
8. If desired, modify any configuration settings on the onboard flash. The following files may need to be modified:
 - a. /etc/init.d/ws_u_apps – to start the RSD application automatically. To do this, remove the hash ("#") to uncomment out the following 2 lines:

```
/home/root/waitForGoodDate.  
run-asd.
```
 - b. The files on the microSD will not be affected by the firmware upgrade. However, if the previous release used different files for security or other configuration files, those may also need to be updated or merged to be compatible with the latest release.

4 DRIVER VEHICLE INTERFACE (DVI)

4.1 Overview

The RSD DVI consists of a driver-console mounted dedicated video display device providing graphical image and audible alerts. The safety applications support two threat levels (inform and warn) depending on the severity of the threat. Table 13 summarizes the criteria for the alert levels.

Table 13. Safety application alert levels.

Application	Inform Alert Criteria	Warning Alert Criteria
FCW	FCW threat detected, driver action required.	Imminent FCW threat, driver action required immediately.
EEBL	Remote Vehicle (RV) hard braking detected in adjacent lane.	RV hard braking detected in same lane.
CSW	Host Vehicle (HV) approaching curve and exceeding advisory speed.	HV in curve and exceeding advisory speed.
BSW	Remote Vehicle (RV) detected in the drivers Blind Spot region of right or left adjacent lane. No audio Alert.	none
IMA	Remote Vehicle (RV) detected approaching the Host Vehicle (HV) on an intersecting path from the left or right, while the HV is stopped with the brakes applied. No audio alert.	Remote Vehicle (RV) detected approaching the Host Vehicle (HV) on an intersecting path from the left or right, while the HV is moving.

An RSD alert consists of the display of a graphical image on the video display, and the output of an audible alert.

4.1.1 Audible Alerts

The RSD DVI display device outputs an audible alert consisting of 3 short beeps for an inform alert, and a longer series of beeps for a warning alert; except where stated otherwise in the table above. The RSD will only output an audible alert at most once every 10 seconds if any of the conditions continue to persist.

4.1.2 Graphical Interface

The RSD DVI display is an Android device that is 100% dedicated to running a DENSO-developed DVI application for the RSD. DENSO is supplying Samsung Galaxy Tab 7" tablets that are configured to run the DENSO RSD DVI application whenever external power is applied. The RSD DVI display device communicates with the miniWSU using a WiFi link. An Aaxeon APN-200-T Access Point is connected to the miniWSU to support this link.

In addition to the DVI application that supports RSD operation, DENSO has also developed a demonstration application that enables the user to preview the graphical alert screens and audible alerts. The sections below describe how to use both of the applications.

4.1.3 DVI Display Device Power

After installation, the RSD display device must be turned on by pressing and holding the power button near the upper left corner of the device. External power should be applied to the device during operation and then removed if immediate use is not planned, in order to allow the device to enter sleep mode. The RSD display device will now automatically wake up / run the DVI application whenever the vehicle is turned on; and shutdown the DVI application / go to sleep whenever the vehicle is turned off. If the vehicle is not used for more than one week, the DVI display device internal battery may completely discharge, and the above procedure may need to be repeated.

The RSD DVI application is always running when the vehicle ignition is on.

The RSD display device is configured to dim the display about 10 seconds after power is removed, and turn off the display and enter sleep mode about 5 seconds after that. During device configuration, software update, or while running the RSD demo application, a dimmed video display can be reactivated by touching the display. If the video display has completely turned off, it can be reactivated by a quick tap of the power button in the upper left corner of the RSD DVI display device.

4.2 DVI Application

When the vehicle is turned on, the RSD display device should automatically wake up and start running the RSD DVI application.

- 1) When the RSD DVI application starts, the application displays a Startup screen (figure 50) for a few seconds.
- 2) If the RSD display device has not established communication with a fully operational RSD miniWSU, the RSD DVI application will display one of three status screens indicating the state of the RSD. The RSD display device can also transition to these status screens at any time when the conditions described below occur.
 - a. Figure 51 is displayed if the RSD display device does not have a WiFi connection to the RSD access point. WiFi communication to the miniWSU must be established before the DVI application will continue. Verify the miniWSU and Aaxeon APN-200-T access point are powered. Also verify the RSD display device shows the correct name (RSD miniWSU SSID) in the lower right-hand corner of the display.

- b. Figure 52 is displayed if the RSD display device has a WiFi connection to the RSD access point (Aaxeon APN-200-T), but is not in communication with the RSD application on the miniWSU. The RSD display device must establish communication with the RSD application on the miniWSU before the RSD DVI application will continue. Verify the miniWSU is powered up and the RSD software is running. Also verify the RSD display device shows the correct name (RSD miniWSU SSID) in the lower right-hand corner of the display.
 - c. Figure 53 is displayed if the RSD display device is connected to the RSD application on the miniWSU, but the RSD application is not transmitting BSMs. Verify that the miniWSU is receiving GPS and that valid security credentials are loaded.
- 3) When the RSD display device has established communication with a fully operational RSD access point and miniWSU, the display will transition to the Truck Length selection screen (figure 54). The driver should select the truck length based on the trailer that is connected to the tractor. If the driver does not select a truck length within 20 seconds, the truck length is automatically set to the most recent truck length entered. If a truck length has never been entered, the truck length will default to bobtail. The driver can return to this screen to change the truck length at any time by pressing the Set Truck Length Button on the main screen.
- 4) After the truck length has been selected, the DVI application will display the default “active” screen (figure 55). This indicates the RSD display device is connected to a fully operational RSD access point and miniWSU. The curved lines on each side of the antenna indicate the RSD miniWSU is currently transmitting BSMs. This is the default operational state.

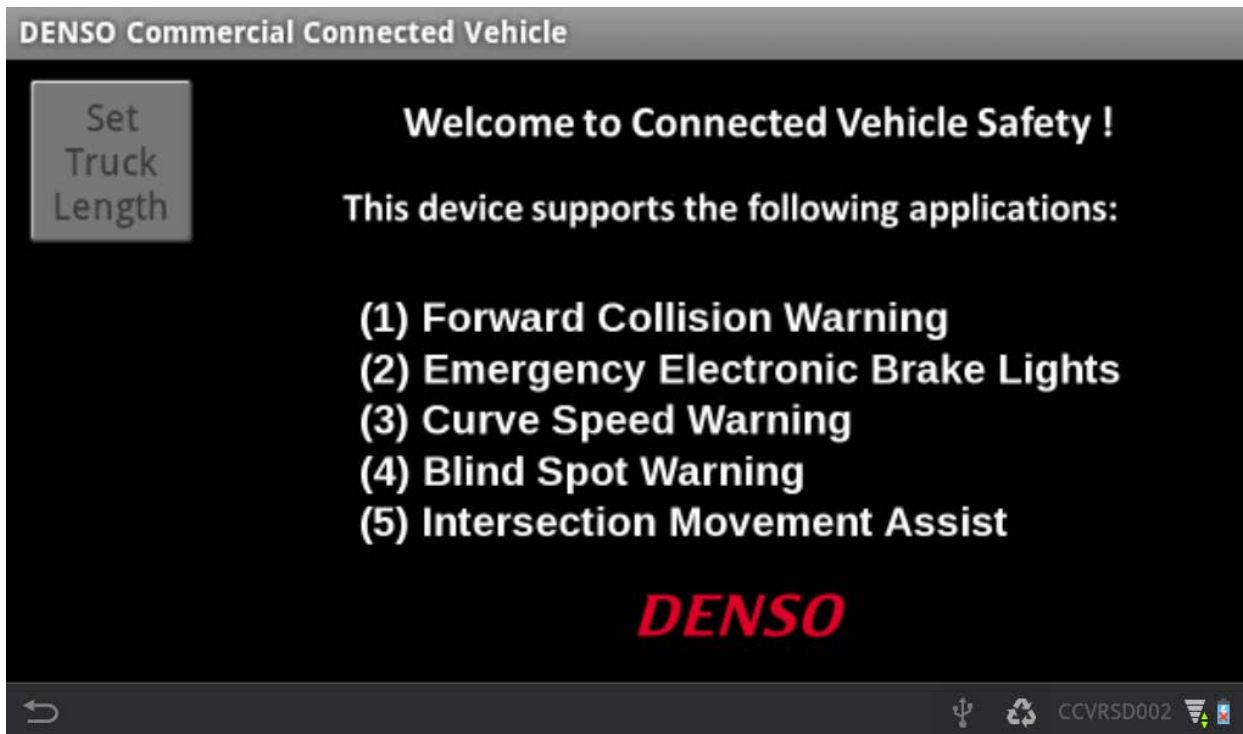


Figure 50. Illustration. DENSO RSD startup.



Figure 51. Illustration. Default screen – display not connected to RSD (no WiFi).

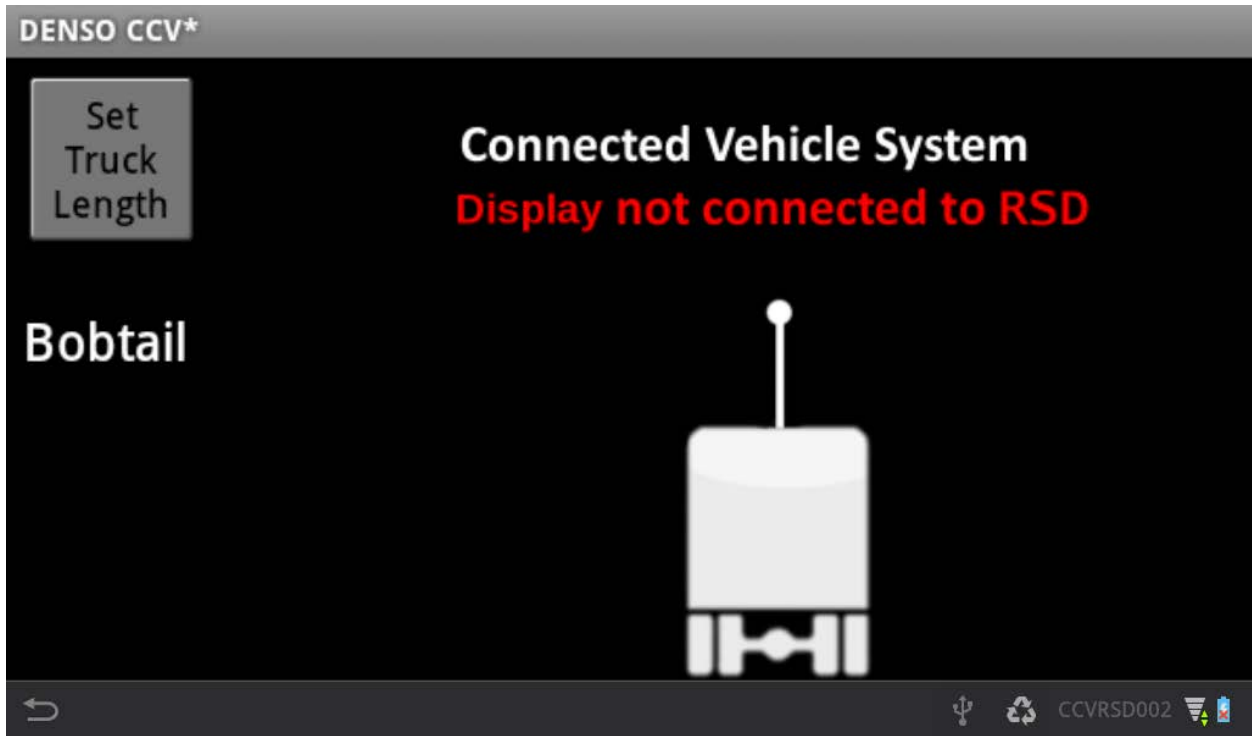


Figure 52. Illustration. Default screen – display not connected to RSD (WiFi connected).

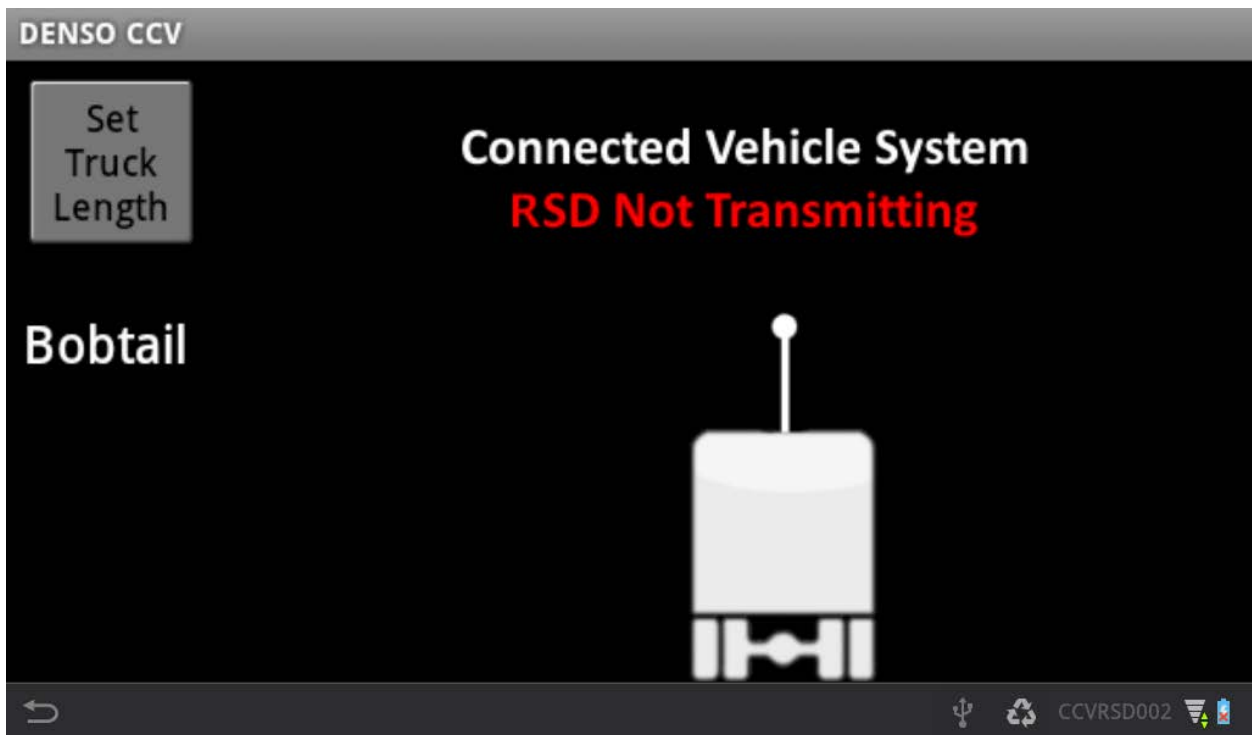


Figure 53. Illustration. Default screen – display connected but RSD not transmitting.

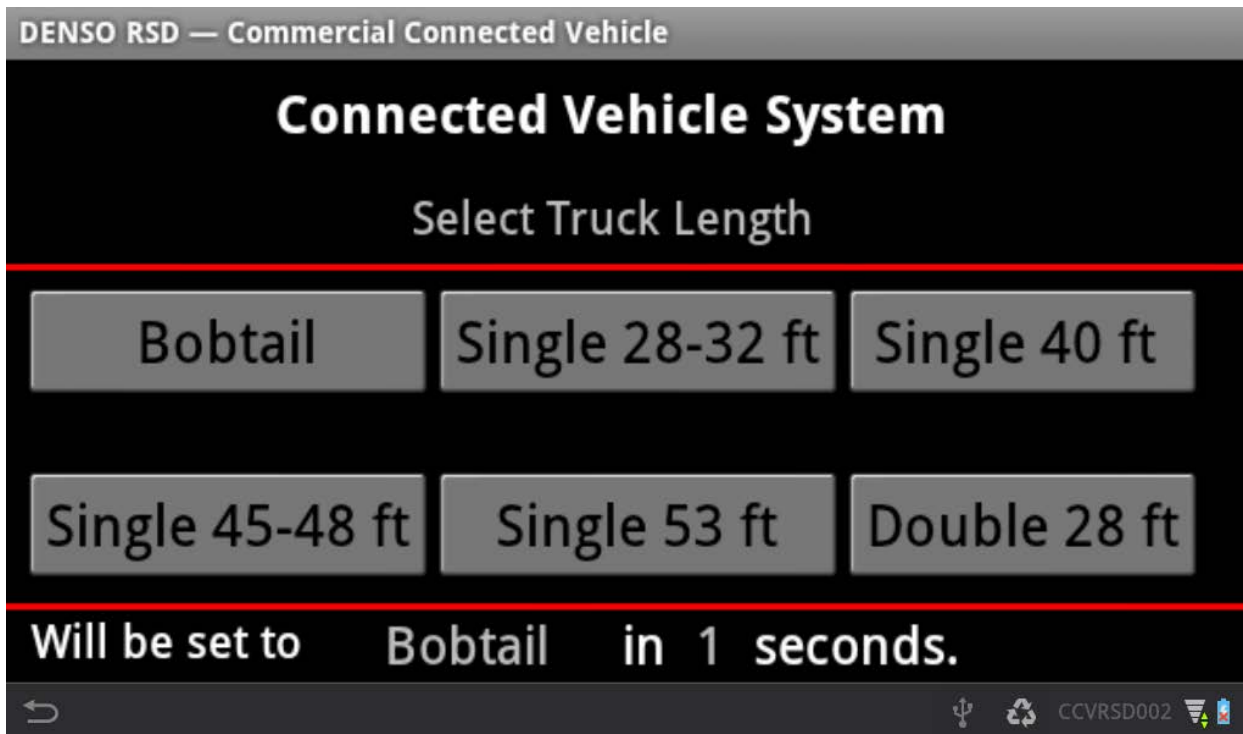


Figure 54. Illustration. DENSO RSD truck selection screen.



Figure 55. Illustration. Default screen – display connected and RSD transmitting.

When the RSD application on the miniWSU detects a safety threat, the RSD display device will display a graphical image corresponding to the alert detected by the RSD application. Figure 56 through figure 66 provide examples of the RSD DVI application alert displays described in table 13.

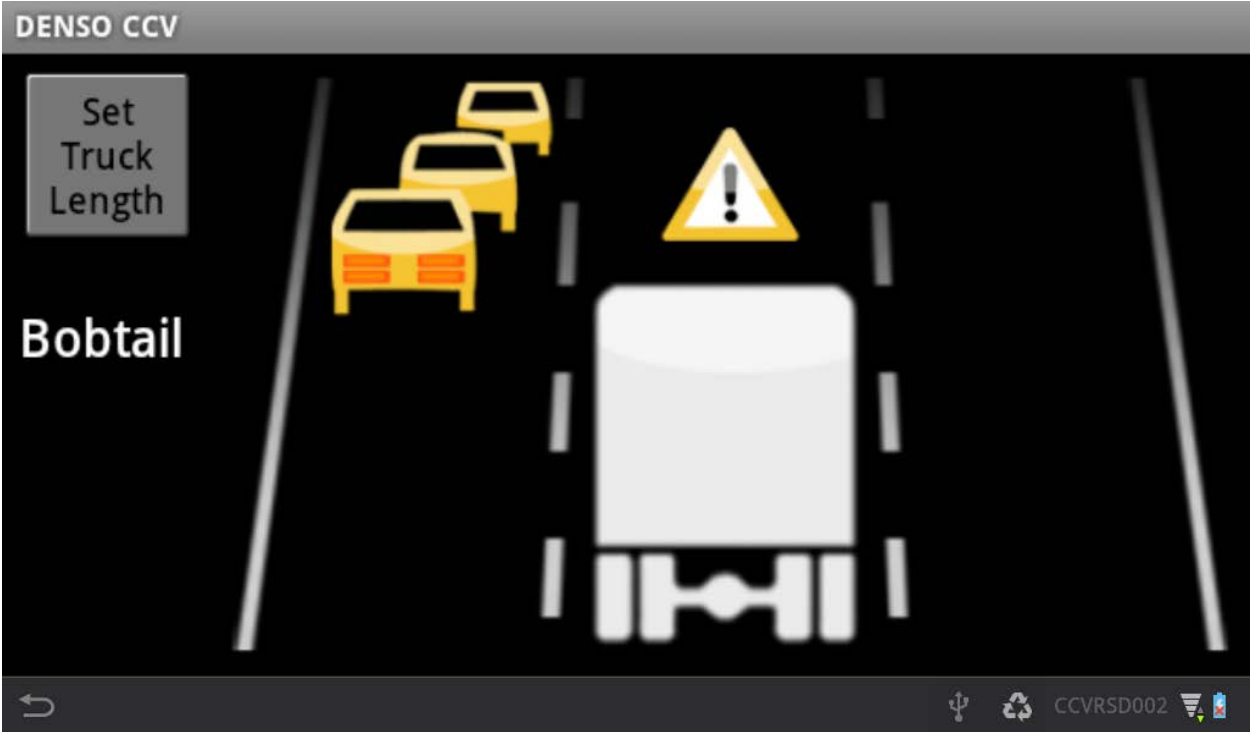


Figure 56. Illustration. EEBL inform.

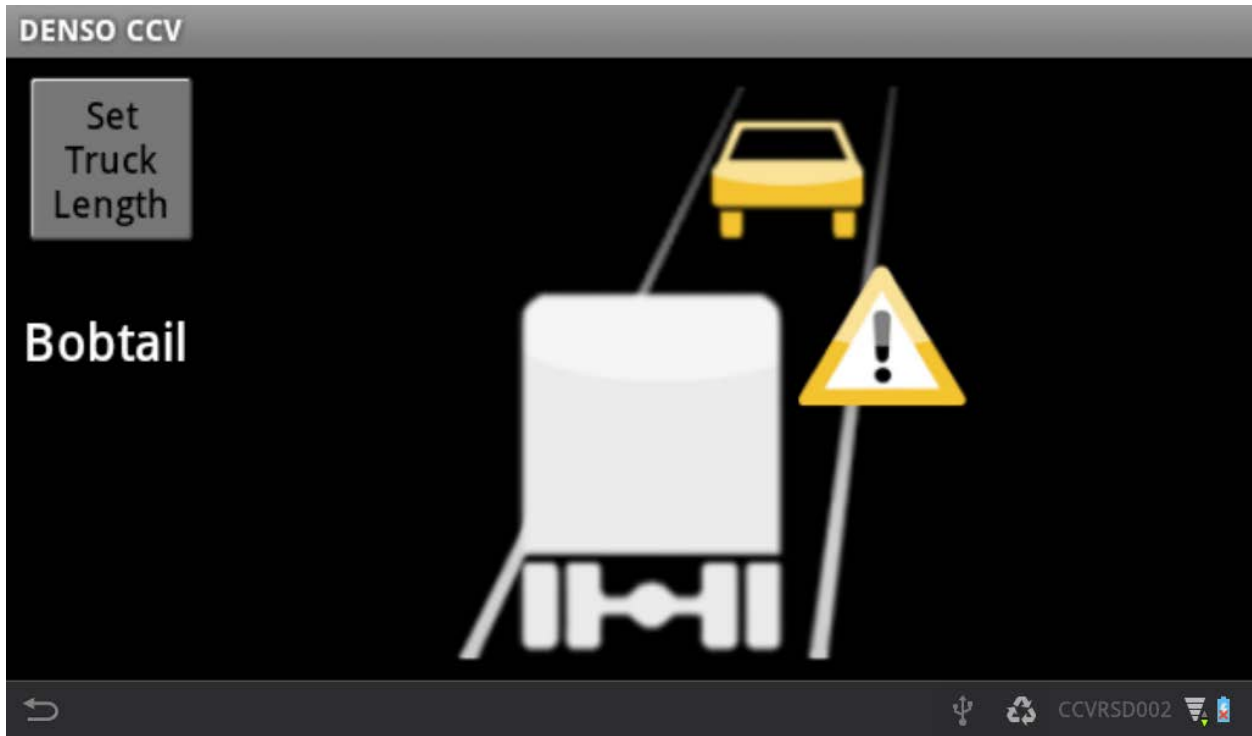


Figure 57. Illustration. FCW inform.



Figure 58. Illustration. FCW warning.

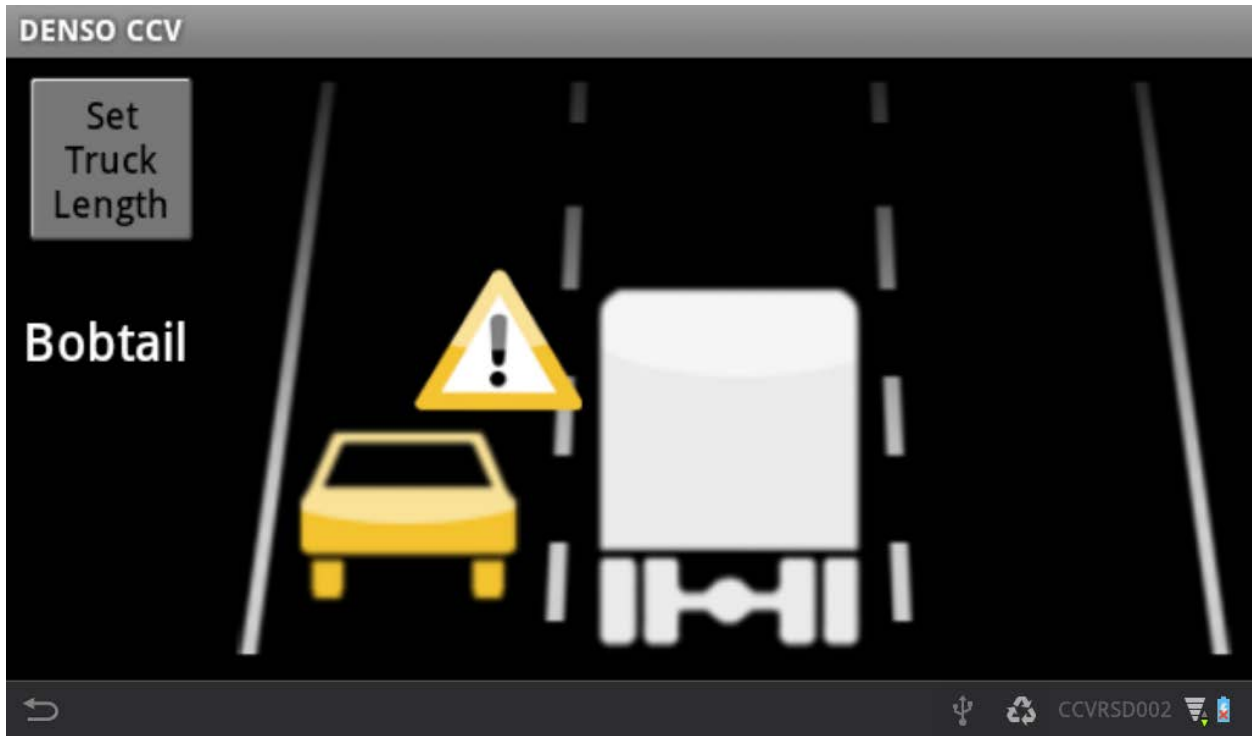


Figure 59. Illustration. Left-side blind spot warning (BSW) inform.

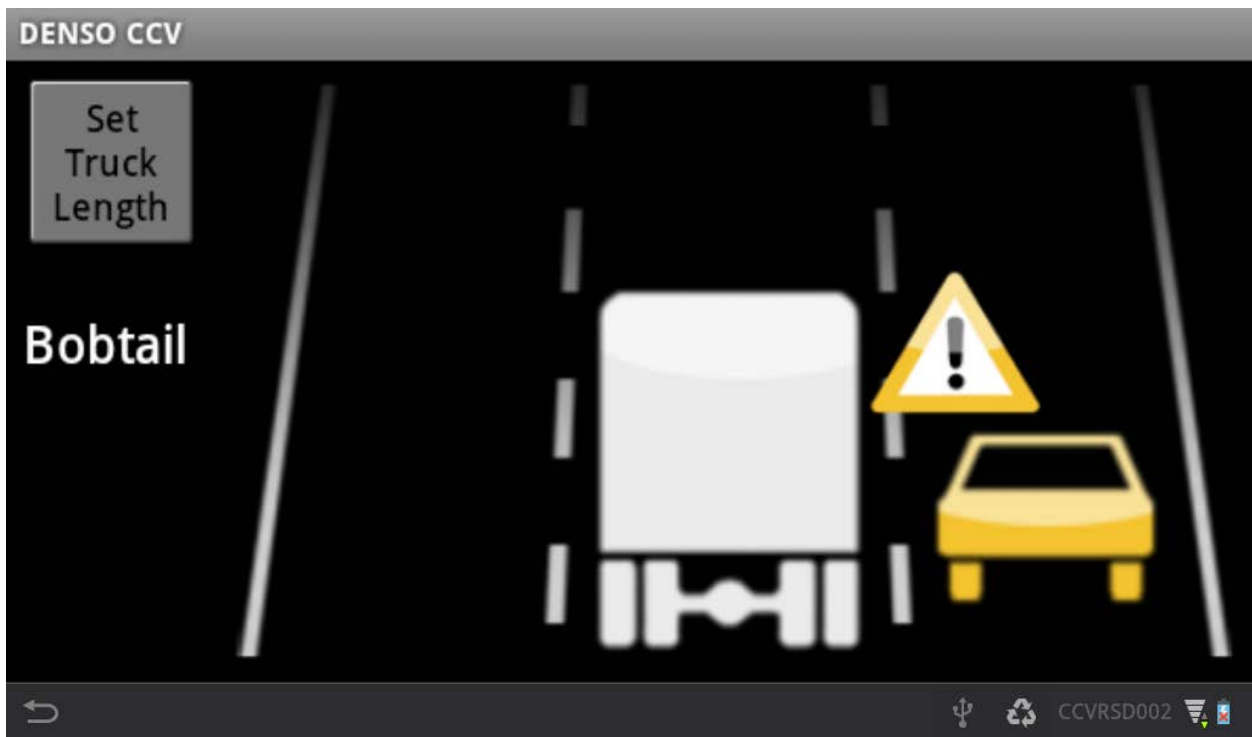


Figure 60. Illustration. Right-side blind spot warning (BSW) inform.

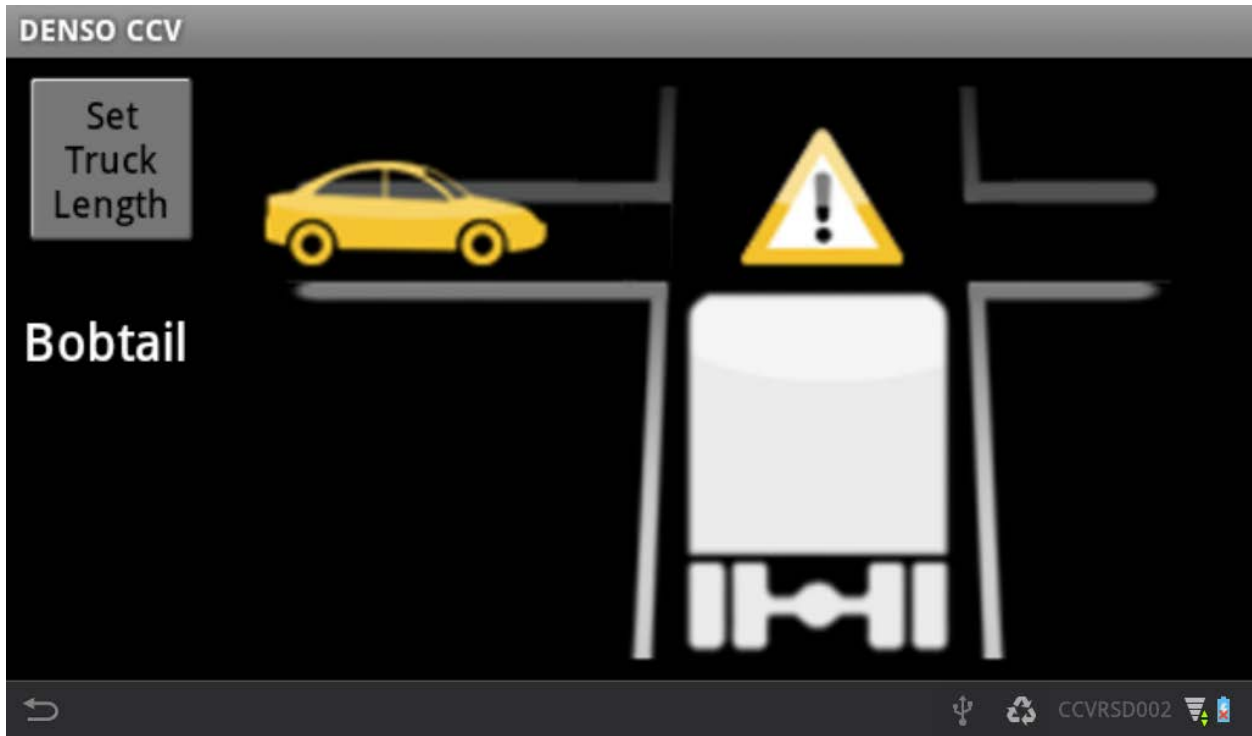


Figure 61. Illustration. Left-side intersection movement assist (IMA) inform.



Figure 62. Illustration. Left-side intersection movement assist (IMA) warn.

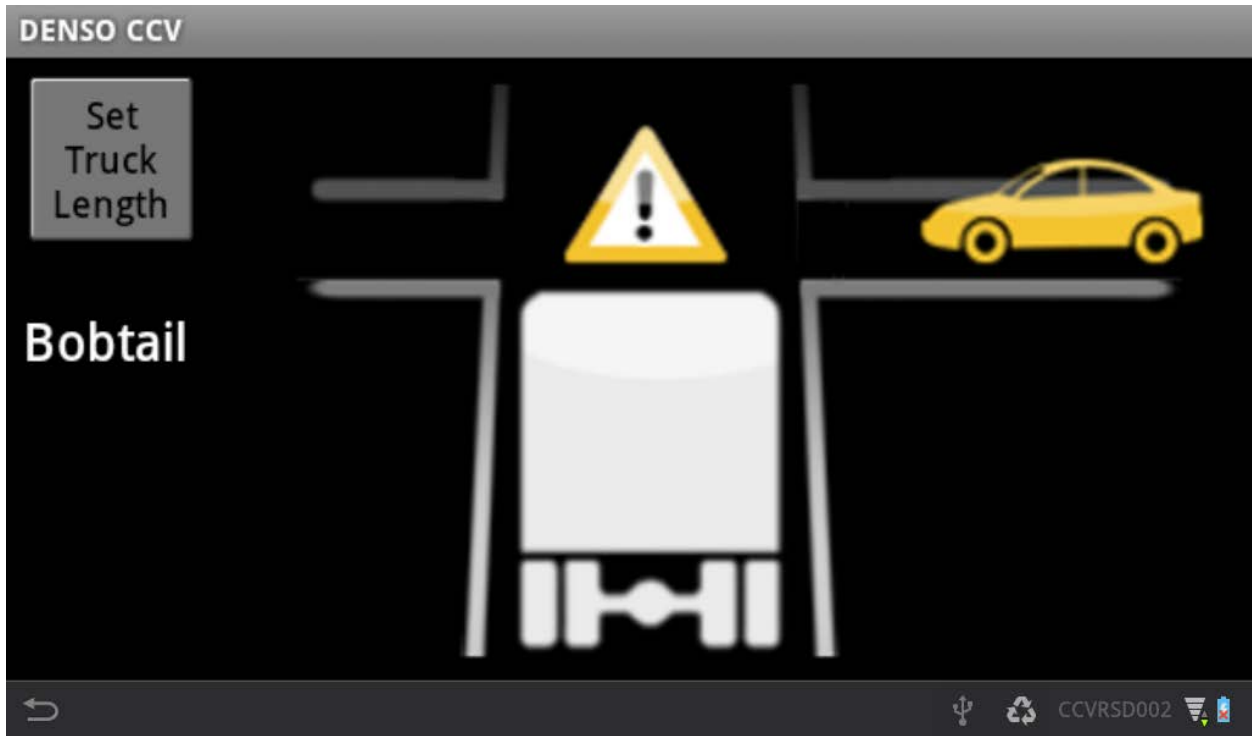


Figure 63. Illustration. Right-side intersection movement assist (IMA) inform.



Figure 64. Illustration. Right-side intersection movement assist (IMA) warn.

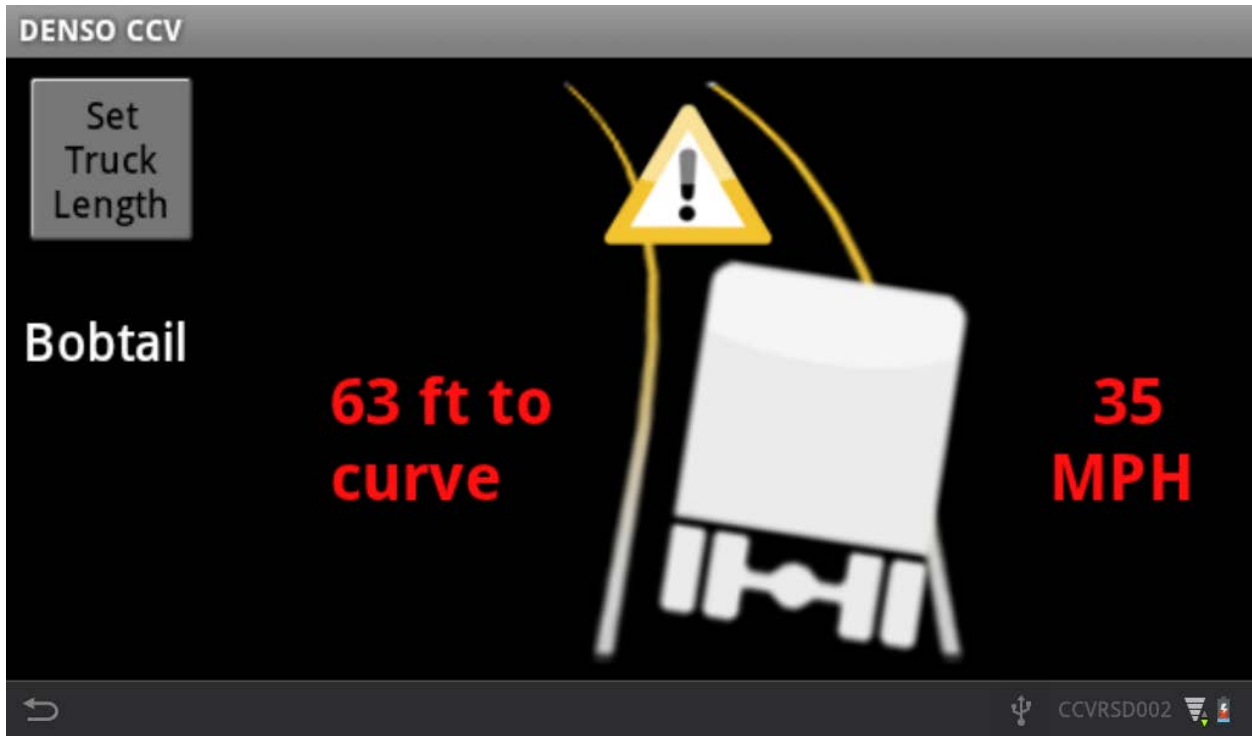


Figure 65. Illustration. Before-curve curve speed (CSW) inform.

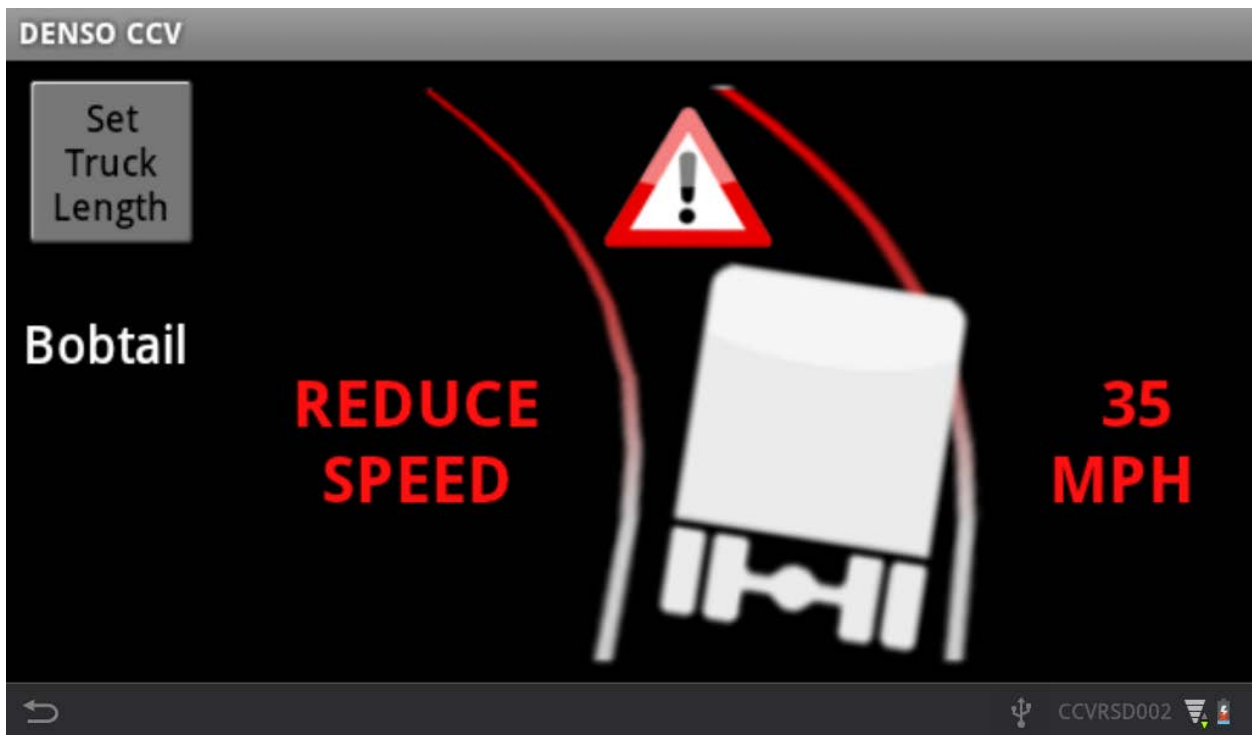


Figure 66. Illustration. In-curve curve speed (CSW) warning.

- 5) The RSD DVI application cannot be exited and will continue to display one of the above screens as long as the vehicle is on (external power applied to the RSD display device).
- 6) When the vehicle is turned off (external power removed from the RSD display device), the RSD DVI application will exit and the RSD Idle display (figure 67) will be visible for about 12 sec, at which time the screen will dim, and 5 seconds later the screen will turn off when the RSD display device enters a suspend (sleep) state. If the RSD display device screen is touched while the RSD Idle screen is active, it will delay suspend state by 15 seconds.



Figure 67. Illustration. RSD idle screen (preparing to enter suspend state).

- 7) The icons visible on the RSD Idle screen are password protected and are not used when the RSD is in operational mode. They are only used for by RSD installers to configure and/or update the RSD display device.
- 8) If the tablet PC settings must be changed, contact DENSO for instructions on navigating the security protections installed on the RSD DVI tablet.

4.3 Safety Application Description

4.3.1 Forward Collision Warning (FCW)

The FCW application alerts the driver of an impending front-end collision with an RV that is ahead and in the same lane. The application performs calculations based in part on the current position and relative speed of the HV and RV to determine if a collision is imminent. The

application issues alerts if an imminent threat exists, the HV is traveling at a speed greater than 11.4 kph (25 mph), and the driver has not pressed the brakes.

4.3.2 *Emergency Electronic Brake Light (EEBL)*

The EEBL application alerts the driver of a hard braking by an RV that is ahead and in the same lane or adjacent lane. The application monitors the hard braking event indications in the received over-the-air messages. Upon receiving a braking indication, it determines if the RV is in close proximity and is ahead in the same or adjacent lane. If so, it alerts the driver if the HV is traveling at a speed greater than 11.4 kph (25 mph) and the driver has not pressed the brakes.

4.3.3 *Curve Speed Warning (CSW)*

The CSW application alerts the driver when he/she is approaching a curve or in a curve and driving at a higher speed than is safe. The application receives over-the-air messages from Roadside Equipment (RSE) containing curve descriptions and advisory speed limits. When the vehicle is approaching or in a curve for which the application has information from an RSE, the application will alert the driver if the HV is traveling at a speed that is more than 10 mph over the advisory speed and the HV speed is not decreasing.

4.3.4 *Intersection Movement Assist (IMA)*

The IMA application alerts the driver of a potential collision with an RV that is on an intersecting path with the HV from the left or right. The application performs calculations based in part on the current position, heading, and speed of the HV and RV to determine if the two vehicles may collide. The application issues an Inform alert if the HV and RV are on intersecting paths but the HV is stationary or braking. The application issues a Warning alert if the HV and RV are on intersecting paths and the HV is moving.

4.3.5 *Blind-Spot/Lane Change Warning (BSWLCW)*

The BSWLCW application provides an indication to the driver whenever an RV traveling in the same direction as the HV and is positioned alongside the HV. Alert tones are not issued with the BSWLCW indications.

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