# Connected Commercial Vehicles—Integrated Truck Project

## Vehicle Build and Build Test Plan Final Technical Report

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**FHWA-JPO-13-103**

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**16. Abstract**


Connected vehicle wireless data communications can enable safety applications that may reduce injuries and fatalities suffered on our roads and highways, as well as enabling reductions in traffic congestion and impacts on the environment. As a critical part of achieving these goals, the U.S. DOT contracted with a Team led by Battelle to integrate and validate connected vehicle on-board equipment (OBE) and safety applications on selected Class 8 commercial vehicles and to support those vehicles in research and testing activities that provide information and data needed to assess their safety benefits and support regulatory decision processes. Driver Clinics are being conducted as a part of this project to evaluate acceptance of the connected vehicle technology and safety applications by drivers who are previously unfamiliar with the technology.

This document describes the hardware to be installed in Integrated Trucks, how it will be installed, and how this installation will be tested.


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# Chapter 1 Introduction

As part of the U.S. Department of Transportation's (USDOT) connected vehicle program, the Connected Commercial Vehicles—Integrated Truck Project will install DSRC-enabled equipment to provide vehicle-to-vehicle and vehicle-to-infrastructure safety applications on heavy trucks. This document describes the hardware to be installed, how it will be installed, and how this installation will be tested. Subsequent project documents will describe the applications themselves, functional requirements, evaluation procedures at the application level, and more.

# Chapter 2 CCV Equipment and Platform

The vehicle build, vehicle integration, and testing of the CCV hardware will be done on a total of four (4) class 8 semi tractors and three different platforms. All tractors will be newly purchased from Freightliner Trucks and be year 2011 Cascadia models with SmartWay Level II fuel efficiency features. The three platforms (and associated number of units) consist of the following:

- One (1) Cascadia day cab as shown in left of Figure 2-1
- One (1) Cascadia Sleeper Cab as shown in the middle of the figure, and
- Two (2) Cascadia Raised Roof Sleeper Cab shown on the right of Figure 2-1.




**Figure 2-1. Build platforms: day cab, mid-roof sleeper and raised-roof sleeper.**

## CCV System Architecture and Components

The CCV Platform Architecture and Designs Specifications document describes the overall architecture of the CCV system. Figure 2-2 below shows the likely set of hardware components and connections that will realize that architecture.

The principle system components that comprise both the DSRC-enabled onboard equipment (OBE) and data acquisition systems (DASs) are given in Table 2-1 below. The table also shows which components will need to be secured to the vehicle with either off-the-shelf or custom made brackets that are designed for the noise and vibration effects of a heavy-duty environment. In some cases, components may need to be shrouded or enclosed for functional, environmental, and aesthetic reasons. Also given in the table are component power requirements along with signal connection type and connection destination component.

**Table 2-1. Principal components of the DAS and OBE equipment.**

| | Mount/ Bracket | Shroud/ Encl | Direct Battery Power | Ign. Signal | Switch Bat. Power | J1939 Bus | Connected To: | Connection Type |
|---|---|---|---|---|---|---|---|---|
| ***Data Acquisition System (DAS)*** | | | | | | | | |
| DAS Computer | x | X | X | x | | x | AP/Sw | Ethernet |
| IMU | x | X | | | | | DAS | USB |
| Camera 1 Forward | x | X | | | | | DAS | Sig/Pwr |
| Camera 2 Face/Cabin | x | X | | | | | DAS | Sig/Pwr |
| Camera 3 Left | x | X | | | | | DAS | Sig/Pwr |
| Camera 4 Right | x | X | | | | | DAS | Sig/Pwr |
| DGPS/Cell Antenna | x | | | | | | DAS | Ant wire |
| GUI (Monitor/Kybrd) | x | | | | | | DAS | USB |
| | | | | | | | | |
| ***On-board Equipment*** | | | | | | | | |
| Access Point/Switch (AP/Sw) | x | x | | | X | | WSUs/DAS | Ethernet |
| Driver-Vehicle Interface (DVI) | x | | X | x | | | AP/Sw | Wireless |
| WSU Primary | x | x | X | x | | | AP/Sw | Ethernet |
| WSU Secondary | x | x | X | x | | | AP/Sw | Ethernet |
| Netway72 Gateway | x | x | | | X | x | WSU Pri | CAN |
| DGPS Receiver | x | x | | | | | WSUs | Serial |
| DGPS Antenna | x | | | | | | DGPS | Ant wire |
| DSRC Antenna 1 | x | | | | | | WSU Pri | Ant wire |
| DSRC Antenna 2 | x | | | | | | WSU Pri | Ant wire |
| DSRC Antenna 3 | x | | | | | | WSU Sec | Ant wire |

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# On-board Equipment Components

The components below will be supplied for each tractor platform by MBRDNA. See the CCV *Architecture and Design Specification* for detailed specifications of each component. A high-level OBE System Architecture is shown in Figure 2-2 which shows the major components and their interface with the DAS and truck J1939 bus.

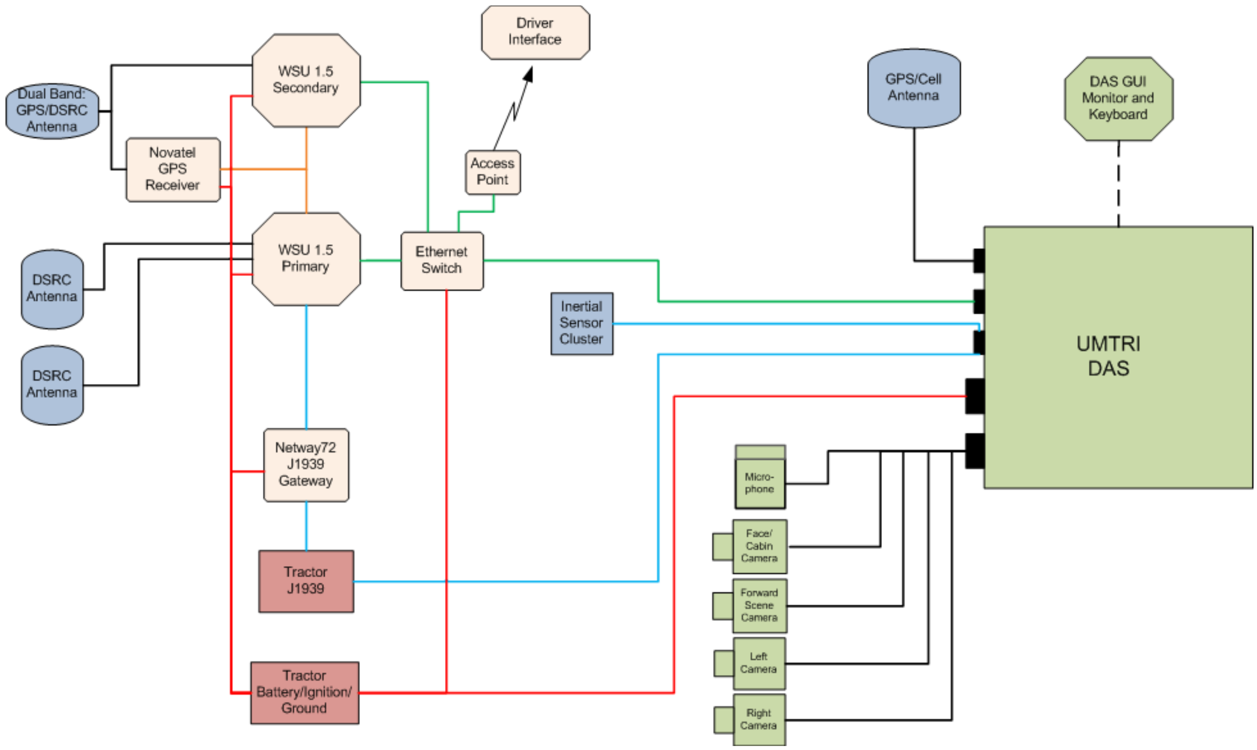


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**Figure 2-2. CCV System Architecture.**

### *Wireless Safety Unit (WSU)*

The main component of the OBE is a pair of DENSO WSU1.5 model electronic control units. These units are referred to as the primary and secondary WSU units. Figure 2-3 shows two images of the device, the left details the electrical interface for the unit, the right shows a bottom view of a prototype unit with a ruler for scale.


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**Figure 2-3. DENSO WSU1.5 with automotive-grade and style connectors.**

### *DGPS Receiver*

The OBE DGPS receiver is a Novatel model OEMV FLEXG2-V1-L1.  The receiver is shown in Figure 2-4.


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**Figure 2-4.  OBE DGPS receiver.**

### *J1939 Interface Device*

Interface to the truck J1939 bus will be done using a Netway 72 device from Smart Engineering Tools, Inc.  This unit is shown in Figure 2-5, below.


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**Figure 2-5.  Interface device for the truck J1939 bus.**

***Driver-Vehicle Interface***

Safety application and system status messages and audio warnings will be delivered to the driver using an Apple iPad2 device as shown in Figure 2-6. The WSU controls the DVI output using a User Datagram Protocol (UDP) via a wireless connection with the OBE switch and access point as shown in Figure 2-2.


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**Figure 2-6. Driver-vehicle Interface.**

**DSRC Antenna Set**

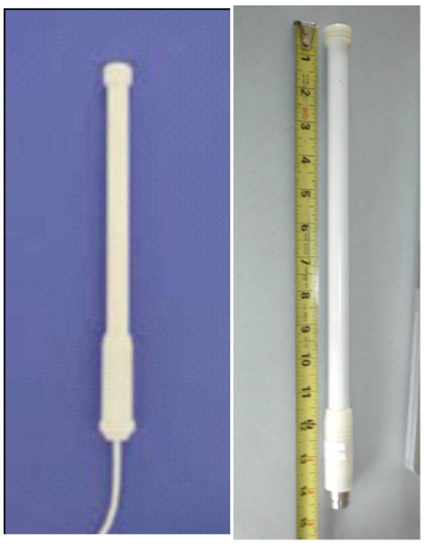

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**Figure 2-7. DSRC antenna for the primary WSU.**

The primary WSU will broadcast and receive messages for the safety applications using a pair of DSRC antennas as shown in Figure 2-7. These antennas will be mounted on each side of the tractor cab for coverage of the area surrounding the tractor and trailer. To handle security and additional applications a single antenna will interface with the secondary WSU. This antenna is shown in Figure 2-8.

## DAS Components

To capture data from the OBE and other onboard sensors, an existing UMTRI DAS from the Integrated Vehicle-Based Safety System (IVBSS) program will be installed on each tractor. The DAS is approximately cube-shaped, nine inches on each side. In addition to an interface with the WSU via Ethernet switch, the DAS will also interface with the J1939 CAN bus, a suite of four cameras to capture video of the area around the tractor and inside the cab, a microphone, an external GPS and cell modem antenna, and an independent inertial measurement unit (IMU) to capture the vehicle motion state measures of each tractor.

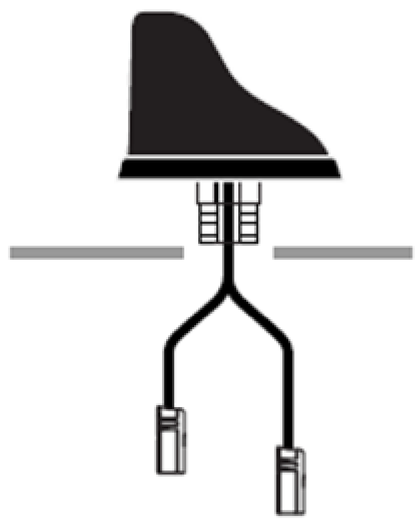

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**Figure 2-8. Dual band DSRC/GPS antenna for security and additional applications.**

## Main DAS CPU and Interface

The main computer consists of an EBX form-factor single-board computer (including display, and Ethernet controllers), two PC104-plus CAN cards, a PC104 analog and digital interface card, and an automotive hard disk.  All of these components operate over a –30C to +85C temperature range.  The video computer runs on an EBX form-factor single-board computer (including display, audio, and Ethernet controllers), has two PC104-plus MPEG4 encoder cards, a digital interface card, and an automotive hard disk.  The temperature range of this system also operates from –30C to +85C.

The computers are configured to permit automatic operation while in unaccompanied, turnkey mode.  During other testing, the DAS has a hot-pluggable keyboard, mouse, and video operation for maintenance and troubleshooting activities.  Figure 2-9 shows the location of the connectors for use in data upload and maintenance.  The two computers are internally connected to each other via a crossover cable, leaving an Ethernet port on each computer to connect to the WSU.  During upload this cable is removed and the two computers are plugged into a building (or laptop) Ethernet switch.  A battery charger, on-off switch, and mode select switch plug into the mode connector, allowing remote control of the DAS micro-controller and program execution sequence and DAS utility mode.

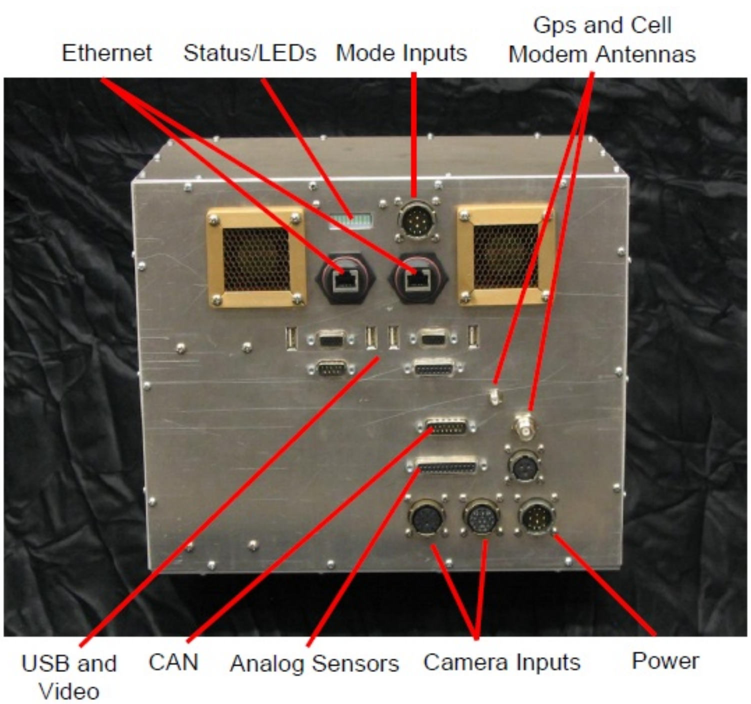


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**Figure 2-9.  UMTRI IVBSS DAS.**

## IMU Sensor

The DAS IMU sensor will record yaw rate and longitudinal and lateral accelerations. These units will be automotive grade and mounted in an enclosed weather-proof box located at the lateral center of the vehicle between the frame rails (approximately, at the center-of-gravity height of the vehicle to reduce roll and pitch effects on measured accelerations). A picture of the enclosure, mounted on an IVBSS tractor, is shown in Figure 2-10.

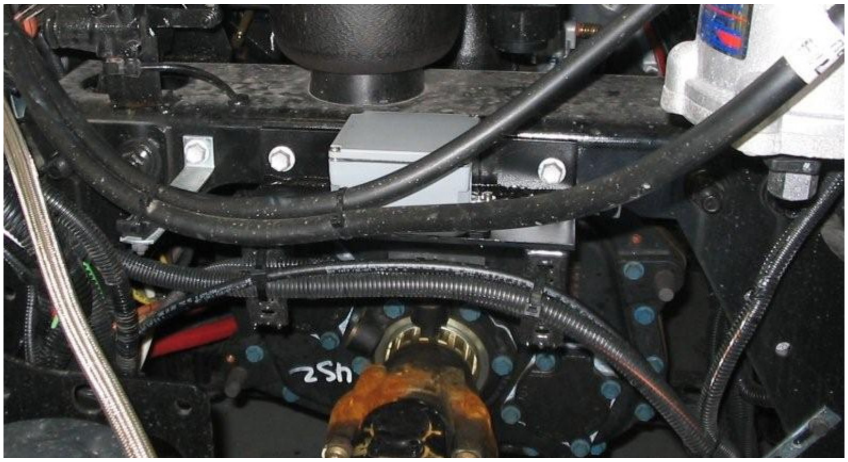

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**Figure 2-10. DAS IMU in sample location between frame rails behind cab on unsprung mass.**

## DGPS/Cell Antenna

For independent position and the transfer of diagnostic and summary data for remote fleet/unit monitoring, a combination cell modem and DGPS antenna will be used. The exact model antenna has not been specified but will be similar to the antenna shown in Figure 2-11.

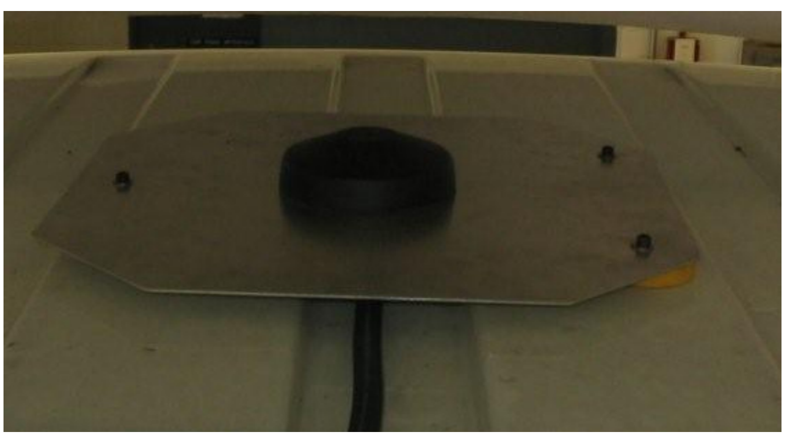

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**Figure 2-11. DAS combined DGPS and cell modem antenna.**

## Component Testing

Upon receipt of the OBE hardware kits, UMTRI will perform a basic function test of major components on the bench to ensure that the proper software and configuration files have been installed. UMTRI will work with MBRDNA to establish procedures necessary to update software on the WSU, Netway and Novatel components as needed to support any future software changes to these units.[1] The DAS and other UMTRI equipment will undergo a series of bench testing which is described in the Vehicle Build Testing section of this plan.

[1] UMTRI will be able to receive data from the WSUs via the defined interface. Only MBRDNA and DENSO personnel will have access to the WSU internal workings, configuration file, firmware, etc. Likewise, the Netway settings and programming will be accessible only to MBRDNA personnel. MBRDNA will bench test their equipment before installation.

# Chapter 3 Vehicle Integration Design

First and foremost, the OBE and DAS equipment will be integrated into the tractors in such a way that their presence has a minimal effect on normal vehicle operation during the unaccompanied testing in the Safety Pilot model deployment phase. Equipment must be out of the driver's way, robustly mounted, and have no significant impact on vehicle electrical system function or crashworthiness. Secondly, wiring assembly and electrical integration must be done to high standards to ensure system reliability. Lastly, where vehicle disassembly is necessary, industry standard procedures will be followed (e.g., torque wrench used on wheel lug nuts). To the extent that documentation is available, factory service manual procedures will be consulted.

The next set of figures show the current likely position where major hardware components would be mounted in the CCV host vehicles. Shaded circles are shown on the figures to indicate the location where the hardware would be installed. These figures show a high-rise roof sleeper version of the Freightliner Cascadia tractor.

Location of the OBE hardware will be platform specific. Every effort will made to maintain similar mounting locations and common wiring harness design across platforms to the extent possible. The primary constraint on mounting location is the requirement of short, relatively straight cable runs for the DSRC antennas connecting to the primary and secondary WSU. To accommodate this, both WSU units are likely to be mounted in the storage compartment above the windshield with the antenna wires routed above the headliner to the side of the cab where access holes allow an external connection to the antenna on each side of the cab. Figure 3-7 shows the available storage compartments above the windshield of a Cascadia day cab tractor. The primary DSRC antenna location is shown in Figure 3-6. Likewise, the secondary WSU antenna cable will be routed through a hole in the cab roof and then forward to the dual band antenna mounted in the center of the roof toward the front of the cab. The other OBE components (GPS receiver, Netway 72, Ethernet switch, etc.) will be mounted in the same area as the WSUs, provided space is available.

The UMTRI DAS will be mounted under the bunk in the high-roof sleeper. For platforms that are not high-roof sleepers, the DAS location will be selected for accessibility and protection of the components. For example, the DAS will be installed under a shroud between the seats in the day cab, and in the bottom compartment of a storage cabinet behind the passenger seat in the mid-roof sleeper. All wiring will be routed behind trim or in an enclosure. Access to hardware inside the cab (other than the DVI) will be restricted and not readily accessible to the driver.

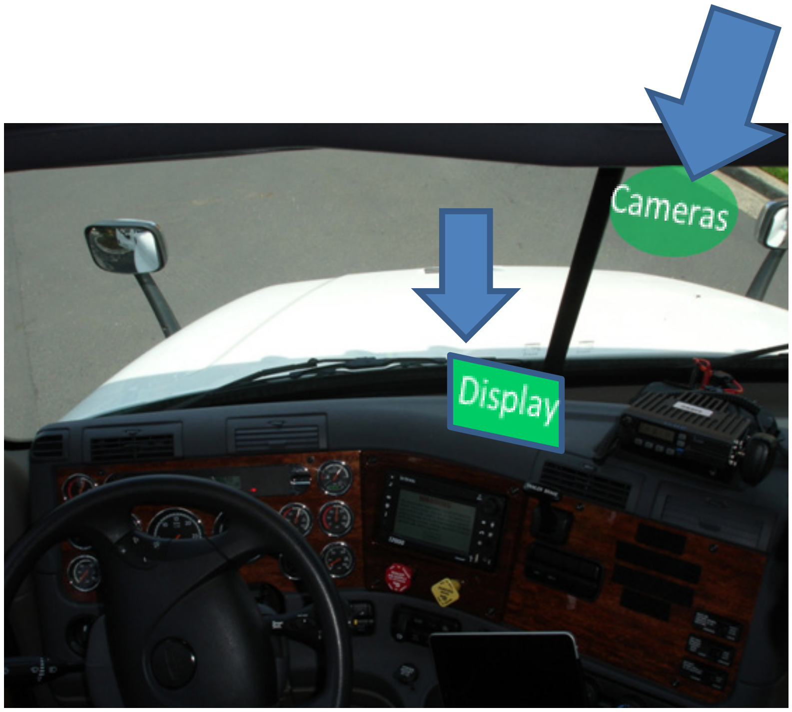


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**Figure 3-1. Locations for driver display and forward and face/cabin cameras mounting location.**

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**Figure 3-2. Example image of the face/cabin camera.**

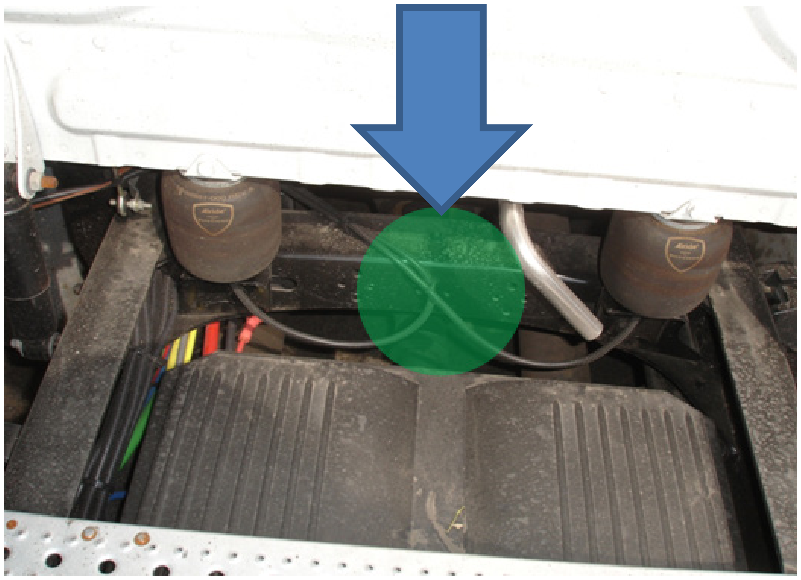

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**Figure 3-3. Inertial sensor cluster mounting location.**

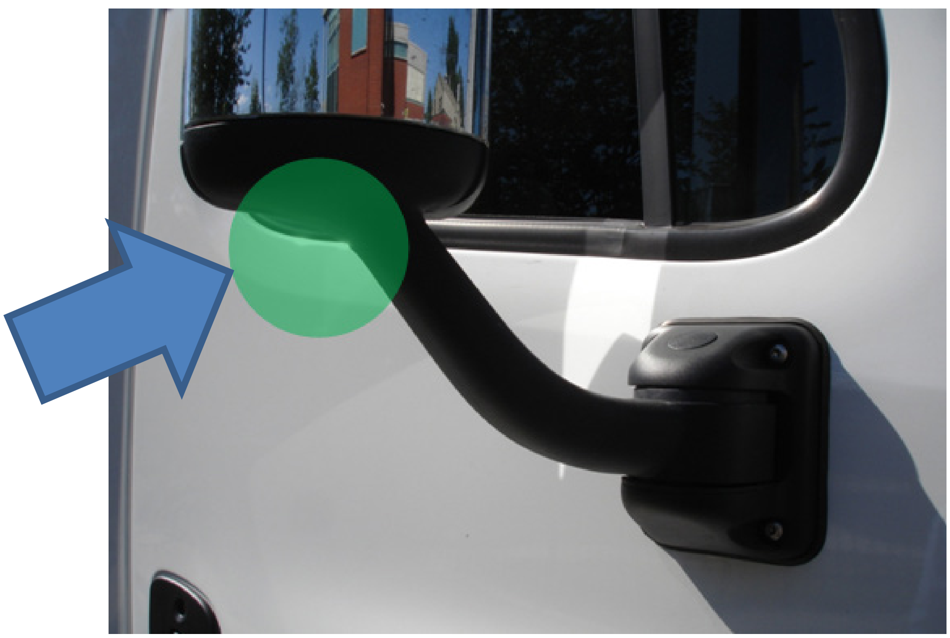

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**Figure 3-4. Camera mounting location for rear/side/forward view.**

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**Figure 3-5. UMTRI DAS GPS/Cell Modem (at the top of the cab, viewed from behind the cab).**

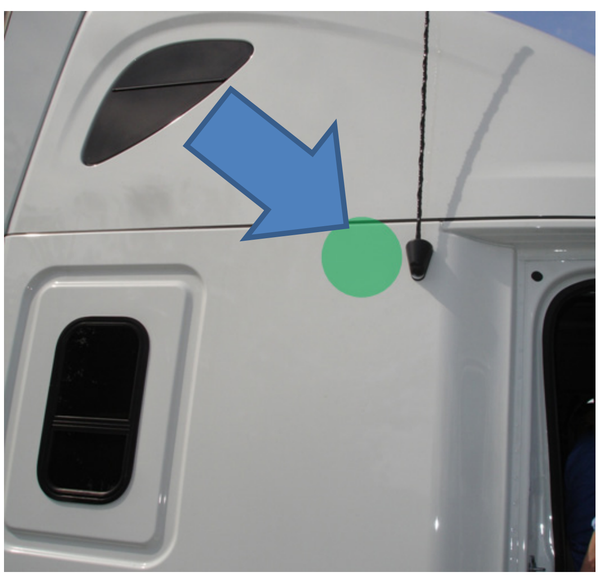

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**Figure 3-6. Primary DSRC antenna mounting location (passenger side shown here).**

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**Figure 3-7. Headliner storage compartments above the windshield of a Cascadia Day Cab.**

# Chapter 4 Vehicle Build and Testing Process

Figure 4-1 shows the overall process of vehicle build and testing. The first step is acquiring the components described in earlier sections. These components are first tested on the bench to validate basic operating functions and, in some cases, system interactions. Next, the components are installed in a tractor. A set of static tests are performed on the installed components and systems, followed by dynamic (on-road or parking lot) tests. These steps are each described in the sections that follow. After this process is complete, the CCV system and the DAS are considered operational and ready for the introduction of the safety application software upgrades.

At the time of vehicle build, the WSUs will be capable of generating and receiving BSMs, and using data from the J1939 data bus and the OBE GPS receiver and the DSRC receivers. Furthermore, MBRDNA is providing a simple tool to allow the exercise and validation testing of the WSU and DVI's ability to communicate wireless with each other via the Ethernet switch and access point. At this point, the WSUs will also be streaming data via Ethernet for capture by the DAS.

Thus the data exchange that is validated is not the full set of DAS data that will eventually be exchanged, but is still a sufficient set of data to demonstrate a high confidence that the hardware and the installation is successful and will support the final software load. Testing of the safety application performance is performed later in the project, during Task 4, and will be described in the Applications Performance and Functional Test Plan & Procedures document.

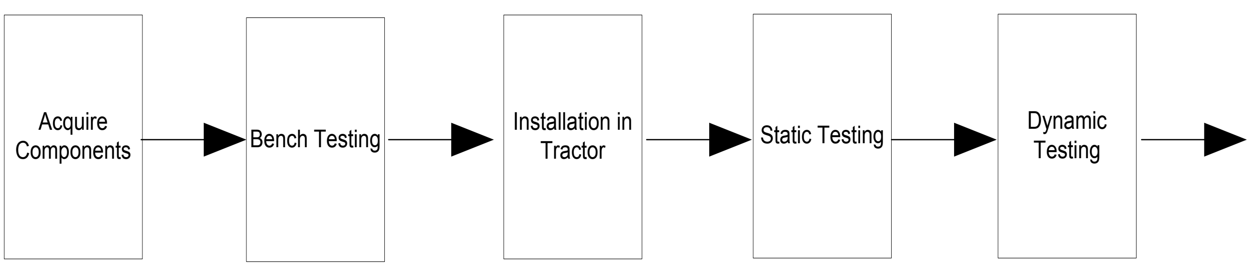


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**Figure 4-1. Vehicle build and testing process.**

# Chapter 5 Bench Testing and Harness Fabrication

Bench testing provides a controlled environment for efficient testing of many basic operating functions of components, subsystems, and system-level functions. The goal is to detect and remediate as many issues as possible before moving hardware into the tractor. Diagnosis in the tractor is often more difficult due to the uncertainty of whether a problem is related to the elements being installed, or the installation itself.

## Build Wiring Harnesses

A custom made, platform specific, master wiring harness will be designed by MBRDNA and UMTRI, and fabricated by MBRDNA for the OBE equipment, and by UMTRI for DAS-specific harnesses. This harness will be routed from the rear component cluster along the tractor door sill, into the dash and up the A-pillar to access the space above the windshield where cameras, microphone and OBE components are located. Access to J1939 will be at an available splice point located in the dash of the each vehicle or using the existing diagnostic connector with pass through connector that leaves the diagnostic port available for normal use.

The wiring harnesses for the OBE and the DAS and their associated components will be built on a bench where layout, lacing, and connector assembly is performed in a controlled, clean environment. All connector terminals will either be soldered or assembled using production style crimp tools. Where production tooling is not readily available (e.g., for the OBE's DSRC antenna FAKRA connectors), then cable subassemblies will be outsourced to vendors with the appropriate equipment.

## Inspect Wiring Harness

After completion and before installation, each wiring harness will receive an end-to-end test for continuity and shorts between conductors. It will also be inspected for cuts on cable insulation, proper strain relief, and cold solder joints where assembly techniques allow.

## Bench Test and Setup of Cameras and DAS Sensors

All cameras will be bench tested individually for focus and function. The microphones and the IMUs will be bench tested and the IMUs will be calibrated before installation. DAS GPS antennas and receivers will be configured and tested on the bench for their ability to provide appropriate data to the DAS. The cellular modems are being updated from the IVBSS hardware, and the individual units will be tested on the bench to ensure that they support the calls from the DAS to UMTRI servers (via a VPN through the cellular data service provider's servers). Where appropriate, sensor modules will have the correct firmware and settings loaded, and will be functionally tested to make sure they power up and communicate.

## Bench Test DAS

All DAS units will be configured with the appropriate databases and application software. Then, they will undergo an extensive bench test using known good cameras and other sensors. This test will include power cycling and functional checks of all inputs and systems (e.g., GPS receiver, frame-grabber, I/O card). It will also include a brief data collection, including a packet data connection via the DAS modem to UMTRI's servers and file transfers across that link.

## OBE Compliance Testing

Under other contracts, the USDOT DSRC compliance team is verifying the WSUs' compliance with the standards 802.11p, 1609.x, and SAE J2735.

## Bench Test on OBE Hardware

The major OBE hardware elements include WSU units, a GPS receiver, three DSRC antennas, an Ethernet switch and access point, and the DVI hardware. To the degree possible on the bench, these components will be tested separately and in combination with each other and the DAS. This includes the ability to power up, receive GPS signals, communicate with another bench DSRC unit that is known to be functioning properly, and to communicate with the DVI through the wireless access point. The ability of the DAS to collect data via Ethernet from the primary WSU can be demonstrated on the bench as well. Once the DAS and OBE components are bench tested, they are ready to be installed.

# Chapter 6 Installation Process

This section describes the steps that will be taken to equip the tractors with the OBE and DAS hardware. This hardware integration will be done at the Freightliner facility in Portland for the first tractor and at UMTRI's facility in Ann Arbor for the remaining three tractors.

## Fabricate Equipment Mounts

Mounts for all equipment such as antennas, modules, sensors, and cameras will be designed to be robust and as unobtrusive as possible. Where necessary, mechanisms for adjustment will be incorporated (such as for leveling the IMU). Shrouds will be provided for components such as cameras, or IMU sensors, if those are required to protect them from stone impingement or environmental exposure.

## Inspect and Prepare Tractor

Upon factory delivery to the dealer, a long checklist from Battelle will be used to ensure that each vehicle has the appropriate features installed and operational, with an acceptable quality level. In addition, each tractor will be driven by one of UMTRI's staff holding a CDL to confirm the truck is operating correctly and has no assembly issues (noises, drivability issues, diagnostic faults, etc.) and will be inspected mechanically and electrically (e.g., to confirm all the necessary J1939 messages are populated). Trim and other components, such as mirrors, that need to be removed from the tractor to allow for wire routing will be stored until final assembly.

## Install Wiring Harness

The wiring harness will be laid out in the tractor and routed so as not to disturb factory wiring and components. Where appropriate, split loom or conduit will be used to protect the harness from pinch points and damage during vehicle operation. All wiring will be secured behind trim and out of reach of the driver or passenger. Where the harness interfaces with production wiring, appropriately sized fuses will be used so that vehicle operation is not affected in the event of an electrical problem in the instrumentation wiring harness. Modifications to production wiring will be kept to an absolute minimum, with consideration for the eventual decommissioning of the tractor.

## Install DAS Components

Cameras and other DAS-specific sensors and antennas will be mounted on the tractor. Once installed on the tractor and wired to the DAS, the cameras will be aligned and again checked for focus and function in order to detect any loss of focus resulting from bumps, or loss of signal due to cabling or connector issues. The microphone and infrared illuminator for night-time video in the cab will be installed. The IMU will be mounted on the frame rails, as shown earlier. The combined GPS/cell modem antenna will be installed. The DAS itself will be mounted in the locations described earlier. The DAS will be mounted securely in the locations described earlier; it is possible that ventilation may be required in one or more of the cab types. The day cab installation is between the seats and may require fabricating a custom shroud to cover the DAS and protect it during daily use of the vehicle. This approach was used successfully in the IVBSS project. The DAS connects to the OBE equipment via the Ethernet switch, and this connection will be made.

# Install OBE Components

All DSRC system components will be installed and connected to the wiring harness, with the exception of power connections. These include the components depicted in Figure 2-2 and discussed throughout this report. During installation, special care is required for the handling of the DSRC cables which are thick with a wide required bending radius to prevent cable damage and loss of signal. The DVI will be mounted on the dash just to the right of the steering wheel for easy viewing. The connection of the gateway to the J1939 bus will also be made.

# Chapter 7 In-Vehicle Build Testing

The purpose of in-vehicle build testing is to ensure that hardware components have been integrated into the tractors properly, that the systems power up, have electrical and data connectivity, and that the individual elements are operating as expected and data is being exchanged successfully. The objectives of this stage of testing are to:

- confirm that all inputs are available to the appropriate modules,
- confirm that basic operational elements of the modules perform, while installed in the vehicle,
- confirm that there is appropriate communication between the driver display and the primary WSU, and
- confirm that critical information is captured by the data acquisition system (DAS).

This stage of testing occurs before the safety application software load is completed.

As with other testing in this document, the vehicle build testing will make use of one or more hardcopy checklists. Each checklist records the tractor, date, time of day, test engineer, and DAS number. The test engineer fills in the checklist during testing and, when completed successfully, the checklist becomes part of a binder that contains the history and outcomes of the vehicle build testing. The testing described below will be translated into one or more checklists, which will ensure that each vehicle passes all important tests before being declared to be a fully integrated CCV system.

## Test Wiring and Power Availability

Power fuses will be installed and all component power connectors tested for proper voltage and polarity before connections are made. Upon completion of voltage and polarity testing, power will be connected to each component and power up confirmed.

## Test the Capture of DAS Component Input Signals

The DAS parses most of its input signals in real time in order to extract and properly scale signals into engineering units. This helps in confirming during static testing that the DAS-specific components are functioning properly and are being recorded on the DAS. With DAS components powered, the DAS keyboard and monitor will be used to confirm that the DAS GPS, IMU, microphone, and J1939 inputs are reasonable and, when appropriate, vary as expected over time. The DAS has applications that can display limited amounts of data or data statistics from its inputs, such as video displays, IMU values, J1939 signal values, and microphone byte counts. These static tests demonstrate confidence of DAS connectivity.

The tractor will also be driven on public roads with the DAS capturing these data. Upon return to UMTRI, the DAS data will be uploaded into a relational database and inspected to ensure that the captured data from all the DAS input elements are within expected values. This includes the GPS, IMU, microphone, all cameras, and the DAS-specific J1939 connection.

# Test the DAS Cell Data Transfer

Recall that UMTRI uses cell data transfers upon key-off to send a small summary set of data to UMTRI servers. This is useful to monitor system performance and health, vehicle travel, and important events and patterns. A packet data call from the DAS cell modem to UMTRI's servers will be placed to test modem capability in the installed DAS. Successful completion of the test will be when calls are received and deliver meaningful data to UMTRI's servers, and this will be confirmed on each of the tractors equipped with DAS's. This will be done in both static tests at UMTRI as well as during driving trips around the Ann Arbor region.

# Test DSRC Functionality in Static Testing

These static tests ensure that both antennas are functional and successfully integrated with the WSUs, and that the WSUs can transmit and receive signals as expected. DENSO's WSU wireless test application (WTA) will be used for this testing. The WTA system will consist of a WSU 1.5 connected to a laptop running the test application, set up to allow easy movement from location to location. This testing will include confirmation of successful performance with the BSM transmit and receive modes, and for post-installation testing, will be performed at several locations around the vehicle to confirm expected antenna coverage. For the primary WSU, this will be done with the left antenna, then the right, then both. The secondary WSU only has one DSRC antenna (the dual-band, shown earlier).

Dynamic tests on the road will also be conducted to ensure that the vehicle-to-vehicle communication with a cooperating OBE-equipped vehicle is successful in both directions (receive and transmit). This will be done systematically, with the cooperating vehicle positioning itself at several designated locations around the tractor-trailer combination. This will include all target classification zones, and will also include testing the domain of ranges within which consistent communication is observed. This latter test involves 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 packet exchanges will be quantified upon return to UMTRI and examination of the DAS data.

# Test the OBEs use and Broadcast of J1939 and GPS Data

Testing will ensure that the onboard equipment is consistently and accurately receiving its J1939 bus data and its GPS receiver data. This will be done by examining the DAS capture of BSM logs that are sent from the primary WSU to the DAS over Ethernet. This will be done both statically and while driving on public roads. Examination of these BSM data, parsed and loaded into a relational database, and compared with DAS data collected from other sources, provides a very good indication that the primary WSU is successfully receiving reasonably-valued inputs from the J1939 bus and the OBE GPS receiver.

# Test Driver Inputs and Displays

The WSU communicates wirelessly to the driver display and input device (DVI), via an Ethernet switch and access point, as shown earlier. Vehicle build testing serves to show that the WSU and the DVI communicate successfully. The DVI runs an application which can be tested on the bench. In the vehicle, a script from MBRDNA exists, and can be executed on the WSU in the tractor to validate that the DVI receives the wireless signal and responds by displaying visual and audio information. Likewise, this allows testing that driver inputs at the DVI are received and understood at the WSU. It is important to demonstrate robust operation of the wireless DVI arrangement within the vehicle environment, so research engineers will monitor the displays during on-road driving to detect any interruption in the WSU-to-DVI communication.

# APPENDIX A. Acronyms

| | |
|---|---|
| **AP/Sw** | Access Point/Switch |
| **BSM** | Basic Safety Message |
| **BSW** | Blind Spot Warning |
| **CAMP** | Crash Avoidance Metrics Partnership |
| **CAN** | Controller Area Network |
| **CCV** | Connected Commercial Vehicle |
| **CICAS-V** | Cooperative Intersection Collision Avoidance System - Violation |
| **DAS** | Data Acquisition System |
| **DSRC** | Dedicated Short Range Communications |
| **DVI** | Driver-Vehicle Interface |
| **GPS** | Global Positioning System |
| **GUI** | Graphical User Interface |
| **I/O** | Input/Output |
| **IVBSS** | Integrated Vehicle-Based Safety System |
| **MBRDNA** | Mercedes Benz Research & Development, N. America |
| **OBE** | On-Board Equipment |
| **OEM** | Original Equipment Manufacturers |
| **PCS & CM** | Pre-Crash Sensing and Collision Mitigation |
| **RSE** | Road-side Equipment |
| **UMTRI** | University of Michigan Transportation Research Institute |
| **USDOT** | United States Department of Transportation |
| **VSC-A** | Vehicle Safety Communications – Applications |
| **V2I** | Vehicle-to-Infrastructure |
| **V-V or V2V** | Vehicle-to-Vehicle |
| **WSU** | Wireless Safety Unit |
| **WTA** | Wireless Test Application |

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