Connected Commercial Vehicles—Integrated Truck Project

Vehicle Build Test Report

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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 effects on the environment. As a critical part of achieving these goals, the USDOT 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.

This document describes the testing that was conducted to ensure that the prototype safety application hardware and software components were integrated into the four tractors properly: that the systems power up, have electrical and data connectivity, and that the individual elements operate as expected and data is exchanged and collected successfully. The outcome of this activity is that the vehicle build process and basic functionality of four tractors was confirmed.

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Chapter 1 Introduction

The U.S. Department of Transportation (USDOT) contracted with a team led by Battelle to conduct the Connected Commercial Vehicle (CCV) Integrated Truck Project, or the Connected Commercial Vehicle Safety Applications Project. A key part of this project was to install DSRC-enabled equipment to provide vehicle-to-vehicle and vehicle-to-infrastructure safety applications on heavy trucks.

The installation was conducted according to the *Vehicle Build and Build Test Plan* [1] and the *Data Acquisition System (DAS) Documentation* [2]. Following installation, the systems were subjected to a number of tests by government and contractor organizations for a variety of purposes. This document describes the very first of those tests, in-vehicle build testing to ensure that hardware components had been integrated into the tractors properly. Tests ensured that the systems powered up, had electrical and data connectivity, that the individual elements operated as expected, and that data was being exchanged successfully.

Subsequent testing included

- Tests of the safety applications on a closed course [3]
- Interoperability testing with light vehicles (conducted by the National Highway Traffic Safety Administration's Vehicle Research and Test Center)
- Driver acceptance clinics with naïve drivers on a closed course [4]
- Performance tests over a variety of terrain and geography [4]
- Model deployment in the vicinity of Ann Arbor, Michigan [5].

The Connected Commercial Vehicle Team is led and managed by Battelle and includes Mercedes-Benz Research and Development North America, Inc. (MBRDNA), DENSO International North America Research Laboratory (NARL), the University of Michigan Transportation Institute (UMTRI), Daimler Trucks North America (DTNA), and Meritor WABCO.

Chapter 2 Overview

The installation consisted of both the on-board equipment (OBE) that performs the safety applications, and a Data Acquisition System (DAS) that monitors and records the performance for research. This equipment was integrated with four truck tractors purchased specifically for this purpose. The installation was verified before the tractors proceeded to subsequent testing of the applications.

Connected Commercial Vehicle Integrated Trucks

The four CCV integrated trucks were 2012 Freightliner Cascadias outfitted with a set of prototype hardware and software to provide the connected vehicle safety application functions. These applications warn the driver to help prevent specific types of vehicle crashes. No vehicle control functions are affected by the CCV system. The vehicle configurations are shown in Figure 2-1:

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

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

The CCV Platform Architecture and Designs Specifications document describes the overall architecture of the CCV system. A brief overview of this architecture is useful for explaining the vehicle build testing approach that was used. That approach leverages the DAS because it receives signals from all relevant modules (except the driver interface) and therefore is a convenient window to verify proper operation – and therefore installation – of the CCV systems.

Figure 2-2 shows the hardware components and connections for the CCV system. On the right side of the figure, the DAS can be seen to be well connected to the other elements of the system. The DAS has a number of its own sensors, including cameras, a microphone, an inertial sensor cluster to measure vehicle yaw rate and accelerations, and a connection to both the vehicle CAN bus (the tractor's J1939) and one of the wireless safety units (WSU).

Toward the left of the figure, the safety application OBE set features two WSUs. The WSUs each integrate DSRC radio capabilities with several functions that include the application layer, security, and transmission and reception of DSRC packets. The WSU that is responsible for the safety application functions has a direct Ethernet connection to the DAS and therefore provides a way to verify proper OBE operations. The other WSU handles transmission of certain security information with the roadside.

Summary of the Build Tests

The objectives of this stage of testing were to

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

Other project documents define and validate the safety application functions themselves, including a test report from test-track validation activities [3].

The vehicle build testing approach included several types of tests. Table 2-1 summarizes the verification test activities and serves as an outline of the remainder of this document. These will be addressed in detail in Chapters 3, 4, and 5.

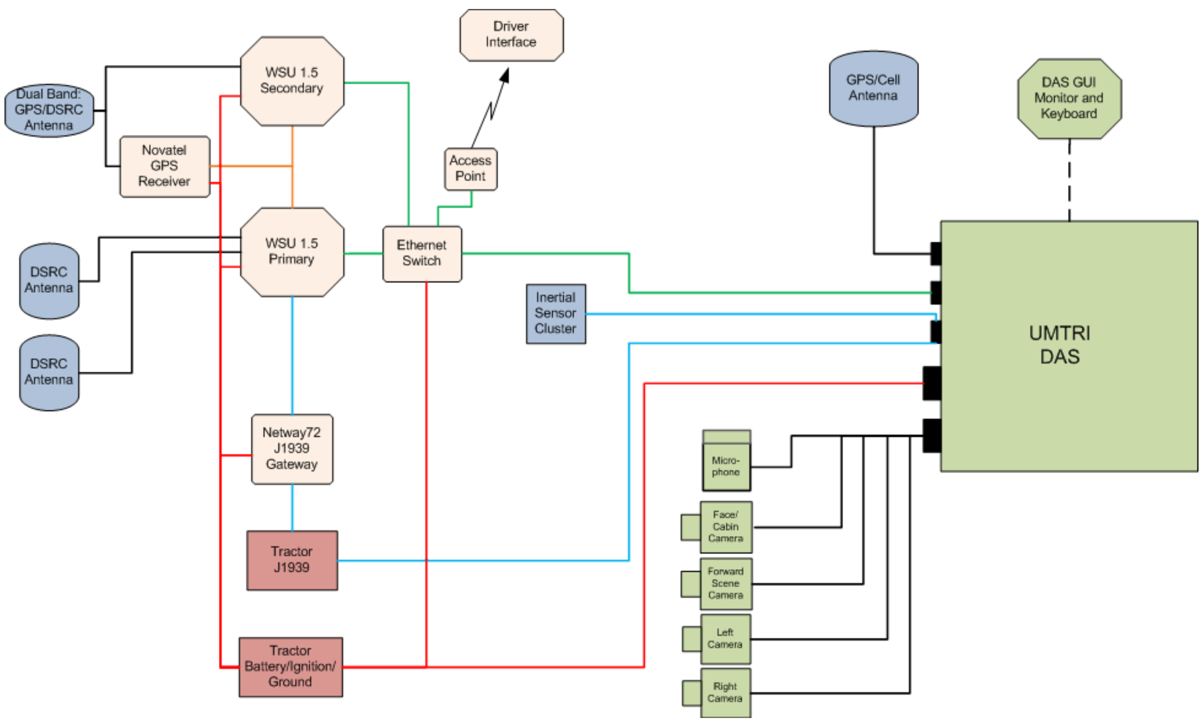

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Figure 2-2. CCV system architecture.

Table 2-1. Vehicle build verification tests.

Type of Test	Items to Verify
Pre-installation tests: Basic connectivity and capture	DAS functionality on the bench In-vehicle power availability and wiring integrity Capture of CAN bus signals by DAS
Post-installation tests: DAS signals and integrity	Signals in the vehicle while parked (static tests) Signals while driving (dynamic tests) The transfer of data from the onboard DAS to off board servers DAS cellular data transfers for monitoring
Post-installation tests: OBE signals and integrity	DAS capture of WSU data packets DSRC communication in static and dynamic tests OBE access to vehicle bus data and GPS

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Chapter 3 Pre-Installation Tests

The first series of tests focused on installation and fabrication. Generally, these tests were conducted by technicians as the vehicle was being up-fit with the DAS and the OBE hardware. These tests were important for the long term survivability of the installation (particularly in a heavy-truck environment) and help to reduce both permanent and intermittent failures that can occur in the real-world vehicle environment. The tests fall into three categories: a) the pre-install DAS tests to checked that the software and hardware components were working as specified, b) continuity tests ensured that all cabling and their associated elements had been fabricated and installed on the vehicle properly, and c) signal capture tests showed that the DAS could capture the appropriate J1939 CAN signals. Each of these processes is given under the three headings that follow.

DAS Pre-installation Functionality Verification

Following the fabrication of a DAS, images of an UMTRI standard operating system were loaded onto the DAS hard drives. The DAS was then connected to a customized bench testing site which allowed technicians to exercise, through a series of tests, the function and verification of all the hardware and software resident on the DAS. A checklist was used to verify

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

Figure B-1 in Appendix B is the DAS pre-installation checklist.

Wiring Continuity and Power Verification

Prior to installing the DAS and OBE hardware, conductors and power sources were routed and installed in the vehicle. Generally, this required the removal and disassembly of the vehicle instrumentation cluster and trim components on the interior of the vehicle. Cable routing length measurements were made, and wiring harness were fabricated on the bench with connectors installed to the extent possible given the constraints of the installation and the path of the conductors (which often pass through small spaces requiring the installation of connectors at one end of the harness to be completed on the vehicle).

Also, installed on the vehicle were power terminals (both direct battery and switch ignition power) with multiple nodes. This allows multiple component power wires to be fused according to their installation 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 verifies:

- In-vehicle power distribution to CCV components was checked
- Wiring from the DAS to its sensors, including connectors, was tested
- Wiring from the DAS to the WSU, and wiring within the OBE components was checked
- Signals were received at the DAS connectors from powered-up sensors and CAN buses, and were reasonable
- OBE signals appeared at the input connectors for the WSUs and were reasonable.

The wiring harness checklist is in Appendix B, Figure B-2.

DAS Capture of CAN Bus Signals

The next test was the capture and verification of CAN bus signals from both the vehicle bus (SAE J1939 standard) and a project CAN bus used for some DAS sensors. The DAS was not fully installed for this test; it was connected to the various wire bundles including the cameras, CAN buses, power, inertial cluster, modem antenna, GPS antenna, and the DAS mode switch. The DAS mode switch was 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 was connected to the DAS. Figure 3-1 shows the interface panel of the DAS being used on this project.

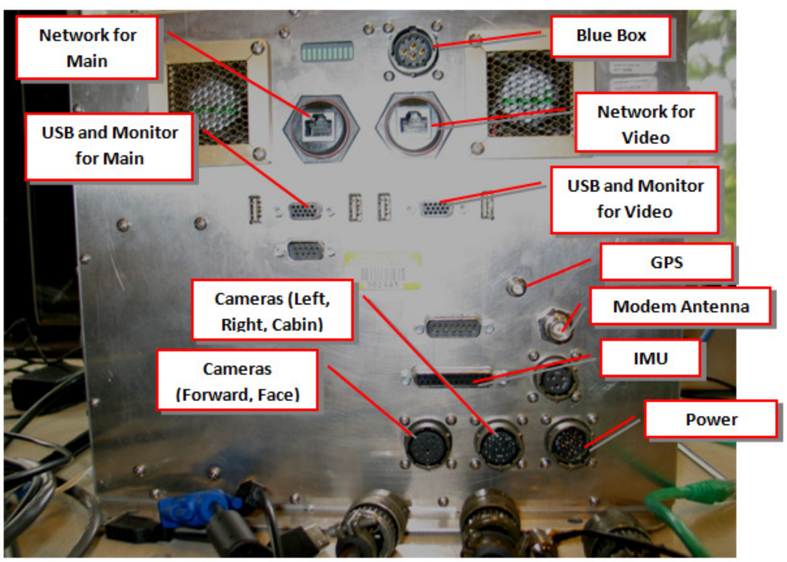

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Figure 3-1. DAS interface panel.

After the DAS was fully booted, a graphical user interface (GUI) interface program launched on the DAS. Next, the vehicle ignition was turned on and a GUI dialog box opened to report the status of the defined CAN messages on each CAN bus. Using the mouse the engineer could update the counts of the individual CAN messages and verify that they were on the bus, were being read by the CAN card on the DAS and that the rate of the message was consistent with their specification. A checklist for this procedure is in Figure B-3.

Chapter 4 Post-Installation DAS Tests

Following the tests in Chapter 3, the DAS was installed in the tractor. These tests were performed with the engine running. The was parked for the static tests, and it drove on a public road for the dynamic tests. This chapter's tests were designed to look at the quality of the signals directly measured by the DAS, and the OBE signals will be treated in Chapter 5.

Static Verification of DAS Signals (Real Time)

Static tests were conducted with the DAS installed in the vehicle and the engine running. The DAS keyboard and monitor were used to confirm that the DAS GPS, inertial sensor cluster, microphone, and parsed CAN messages were correct and vary as expected over time, for example as turn signals or throttle were 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.

The static signal verification checklist is in Figure B-4.

Dynamic Verification of DAS Signals (Real Time)

Following the static verification of signals being logged by the DAS, the next step was to capture and inspect signals while the vehicle was driven to verify reasonable values for dynamic signals. The signals most suitably addressed with dynamic testing are measures of speed, GPS heading, GPS satellite count, lane tracking confidence, target tracking by the forward ranging sensor, and more. The engineer instructed the driver to perform benign driving tasks while watching the measured signals change on the screen and noting any anomalous values using the checklist in Figure B-5. Post-drive analysis was also performed.

Dynamic Verification and Transfer to Servers

After verifying in real time that the measurements were reasonable, the next step was to document that the measurements were properly recorded and transmitted from the truck to the UMTRI servers. The test conducted used the DAS manual mode to initiate and terminate multiple data collection sessions as the test vehicle drove on public roads This was done with and without a DSRC-equipped remote vehicle. The files generated during this exercise were transferred from the DAS to UMTRI servers. This verified the transfer itself and protocols and software developed to map the DAS generalized binary signals into a database on the UMTRI project servers.

The creation and loading of the database tables used the same metadata that was used to configure the DAS software. This enabled the process of database loading serves to be another test to find inconsistencies in the installed hardware and software on the CCV vehicle. The steps in this test were

- Retrieve or compute characteristics of data files on the DAS
- Execute scripts to move binary data from the DAS over Ethernet to UMTRI fileservers, and compare the moved data's characteristics to the DAS's self-auditing characteristics.
- Load the binary data from fileservers 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 ensured that data collected by the DAS met a level of quality necessary for scalability and query efficiency required for the analysis and processing of large scale data collections. The size of the database was expected to be millions to billons of records and terabytes of data.

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

DAS Data Transfer via Cell Modem

When the vehicle's engine was turned off, the DAS cell modem remotely connected with a dedicated UMTRI server to transfer a summary set of files from the DAS to UMTRI servers. This was 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 was done to test modem capability in the installed DAS. Successful completion of the test indicated that the calls were received and delivered meaningful data to UMTRI's servers, and confirmed that this process worked on each of the tractors equipped with DAS. This test was done in both static tests at UMTRI as well as during driving trips around the Ann Arbor region.

Chapter 5 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 were designed to convince engineers that the safety application software and hardware were installed correctly. That is, the test was designed to cover typical use aspects of the vehicle and how that use might affect the function of the installed components. The tests were not designed to validate the accuracy of the OBE and its safety applications. That was the purpose of separate performance and validation tests [3].

Capture of UDP Packets from WSU (Real Time)

Although all the testing described above applied to many vehicle instrumentation and installation efforts conducted by UMTRI, specific test protocols were developed for the customized hardware installed specifically for the CCV project related to connected vehicle communications. In this case, as shown in Figure 2-2, a pair of DENSO WSU1.5 units was installed. The primary WSU transferred data to the DAS using an Ethernet and User Datagram Protocol (UDP). To verify these messages, another checklist was used to examine WSU signals, including

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

The complete WSU signal checklist is in Figure B-6.

Similar to the dynamic test outlined for DAS data, but with the addition of a DSRC-equipped remote vehicle, the test was conducted driving on public roads. Using cell phones or dedicated radios, the driver of the CCV and remote vehicle were instructed by the test engineer to perform benign maneuvers while the engineer visually inspects signals that were processed by the WSU and piped to the DAS. Of particular significance in these tests were signals related to the remote vehicle position classification, the calculated range and range-rate of the remote vehicle. (Note: when the CCV vehicle was 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 WSU). The validation of many of these measures was somewhat subjective with the test conductor comparing the reported value with what was visually present outside the vehicle.

DSRC Functionality in Static and Dynamic Testing

These static tests ensure that both antennas were 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) was used for this testing. The WTA system consists of a WSU1.5 connected to a laptop running the test application, this set up allows easy movement from location to location. This testing includes confirmation of successful performance with the DSRC basic safety message (BSM) transmit and receive modes, and for post-installation testing, and was performed at several locations around the vehicle to confirm expected antenna coverage.

Dynamic tests on the road were conducted to ensure that the vehicle-to-vehicle communication with a remote OBE-equipped vehicle was successful in both 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 was 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 was 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 were sent from the primary WSU to the DAS over Ethernet and was done concurrently with the DSRC functionality testing outlined above. Examination of these BSM data, after they had been parsed and loaded into a relational database, and compared with DAS data collected from other sources provides a good indication that the primary WSU was successfully receiving reasonably valued inputs from the J1939 bus and the OBE GPS receiver.

Chapter 6 Vehicle Build Test Results

The tests described above were performed for the four CCV tractors. There were instances in which the tests revealed an issue, which led to troubleshooting and remediation, e.g., a faulty solder joint or a CAN message header that needed correction. Finally all tests were successfully completed, as illustrated below. After the application development engineers took a final set of rides in the tractors to ensure that operations did not exhibit unexpected behavior, the tractors were determined to have properly integrated CCV systems onboard.

Table 6-1. Vehicle build verification test results.

Type of Test	Items to Verify	Tractors Completed			
		Red	White	Blue	Silver
Pre-Installation tests: Basic connectivity and capture	DAS functionality on the bench	✓	✓	✓	✓
	In-vehicle power availability and wiring integrity	✓	✓	✓	✓
	Capture of CAN bus signals by DAS	✓	✓	✓	✓
Post-installation tests: DAS signals and integrity	Signals in the vehicle while parked (static tests)	✓	✓	✓	✓
	Signals while driving (dynamic tests)	✓	✓	✓	✓
	The transfer of data from the onboard DAS to off board servers	✓	✓	✓	✓
	DAS cellular data transfers for monitoring	✓	✓	✓	✓
Post-installation tests: OBE signals and integrity	DAS capture of WSU data packets	✓	✓	✓	✓
	DSRC communication in static and dynamic tests	✓	✓	✓	✓
	OBE access to vehicle bus data and GPS	✓	✓	✓	✓

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Chapter 7 References

[1] LeBlanc, D., Bogard, S., and Gilbert, M. (UMTRI) (January 31, 2014) "Connected Commercial Vehicle—Integrated Truck Project: Vehicle Build and Build Test Plan Final Technical Report." (Report from the University of Michigan Transportation Research Institute to Battelle for ITS JPO) Battelle document 10003838-202. Contract No. DTFH61-06-D-0007, Task Order No. BA07-095. Publication Number FHWA-JPO-13-103.

[2] Bogard, S., LeBlanc, D., and Gilbert, M. (UMTRI) (January 31, 2014) "Connected Commercial Vehicles—Integrated Truck Project: Data Acquisition System (DAS) Documentation." (Report from the University of Michigan Transportation Research Institute to Battelle for ITS JPO) Battelle document 10003838-302. Contract No. DTFH61-06-D0007/ORDER T11004/WO BA07-092. Publication Number FHWA-JPO-13-105.

[3] Bogard, S. (UMTRI) and Peredo, G., (MBRDNA) (January 31, 2014) "Connected Commercial Vehicle—Integrated Truck Project: Applications Performance and Functional Test Report." (Report from the University of Michigan Transportation Research Institute to Battelle for ITS JPO) Battelle document 10003838-404. Contract No. DTFH61-06-D0007/ORDER T11004/WO BA07-092. Publication Number FHWA-JPO-13-108.

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[5] LeBlanc, D., Bogard, S., and Gilbert, M. (UMTRI) (January 31, 2014) "Connected Commercial Vehicle—Integrated Truck Project: Model Deployment Operational Analysis Report." (Report from the University of Michigan Transportation Research Institute to Battelle for ITS JPO) Battelle document 10003838-803. Contract No. DTFH61-06-D-0007, Task Order No. BA07-095. Publication Number FHWA-JPO-13-111.

APPENDIX A. Glossary of Terms and Abbreviations

BSM	Basic Safety Message
CAN	Controller Area Network
CCV	Connected Commercial Vehicle
DAS	Data Acquisition System
DSRC	Dedicated Short Range Communications
GPS	Global Positioning System
GUI	Graphical User Interface
MBRDNA	Mercedes Benz Research & Development North America, Inc.
OBE	On-Board Equipment
RSE	Road-Side Equipment
SQL	Structured Query Language
UDP	User Datagram Protocol
UMTRI	University of Michigan Transportation Research Institute
USDOT	United States Department of Transportation
WSU	Wireless Safety Unit
WTA	Wireless Test Application

APPENDIX B. Checklists for Vehicle Build Tests

The following pages the following checklists that support Chapters 3, 4 and 5 in the main body of the report.

- Figure B-1. DAS Pre-install Function Verification Checklist
- Figure B-2. Wire Harness Continuity and Power Verification Checklist
- Figure B-3. Checklist for CAN message Verification
- Figure B-4. Static Signal Verification Checklist
- Figure B-5. Dynamic Signal Verification Checklist
- Figure B-6. WSU Signal Verification Checklist

Figure B-1 is the checklist to perform the pre-install DAS functionality verification tests.

DAS pre-install checklist

Name: ______________________________

Date: ______________________________

SP DAS ID: ______________________________

DAS IP address: ______________________________

I/O Card S/N: ______________________

Frame Grabber S/N: ______________________

CAN Card S/N: ______________________

CPU S/N: ______________________

HD S/N: ______________________

GPS S/N: ______________________

Cell ESN: ______________________

Connector Board S/N: ______________________

Controller/Power Board S/N: ______________________

Windows XP Embedded: ______________________

	Quality of Measure		
	Reasonable/Correct	*Zero/Fixed*	*Saturated/Fixed*
Unique DAS Identification Setup			
Set the IP address of the 'Download' port according to the I			
Set the IP address of the 'Device' port (192.168.1.3)			
Change the "Computer Name" to TRI-SPxxx			
....			
Verify the Operation of Audio Recording			
Using the "Sound Recorder" program verify operation of th			
....			
Verify GPS Configuration and Operation			
Ensure baud rate is set to 57600 & Com3			
Verify the correct messages are active			
....			
Verify Frame Grabber Card			
Scroll through the camera inputs			
Verify Quad campture function			
....			
Verify CAN card operation			
Verify High-speed messages to CAN 1			
Verify High-speed messages to CAN 2			
....			
Modem Configuration and Verify Operation			
Connect to modem and provision			
Reset modem and verify connection to cell network			
Verify connection to VPN over cell network			
Record MDN:			
....			
Prepare Database for Use			
Set the device number to 10000 + DAS number			
Set trip number to zero			
Set the driver number to 10000 + DAS number			
Set the DAS to be the number of the DAS			
Set the vehicle number to zero			
Set vehicle type to 3			
Delete any existing catalog entries			
....			
Update and verify DAS software			
Update the DAS with the latest versions from the network			
Configure shortcuts to run the DAS specific versions			
Perform a sample FOT for full system verification			
....			
Final inspection and labeling			
Place the Windows XP Embedded license on the DAS			
Place the Serial bar code and other ID labels on the DAS			

DAS pre-install CheckList.xlsx 9/27/2013

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Figure B-1. DAS pre-install function verification checklist.

Figure B-2 is the wiring harness checklist.

Wire Harness Verification checklist

Name: ____

Date: ____

Vehicle ID: _______________________________________

Focus Foward camera	
Focus Left camera	
Focus Right camera	
Wire right Camera 17 ft wire, test image	
Wire Left Camera 17 ft wire, test image	
Wire Microphone 17ft test sound level	
Wire IR lights 17ft, test light with digital camera	

DAS to truck cable set	**Connection points**		**Ohm out conn**
DAS Pwr	Term block	DAS conn 14,15	
DAS GNDS	Term block	DAS conn 1,2	
DAS TRK CAN	Trk CAN	DAS conn 3,4,16,17	
DAS ING	term strip	DAS conn 20	
MIC	Mic	DAS conn 8,9,22	
Fwd Camera pwr	Fwd Camera	DAS conn 10,23	
Face Camera pwr	Face Camera	DAS conn 11,24	
IR pwr	IR	DAS conn 9,22	
Left CAM jumper	molex conn	DAS conn 12,25	
Right CAM jumper	molex conn	DAS conn 13,26	
Face camera	molex conn	Coax J2	
Fwd camera	molex conn	Coax J3	
Left camera	molex conn	Coax J4	
Right camera	molex conn	Coax J5	
Denso Pwr cable	Term block	Denso conn	
Access Point cable	Term block	Access point conn	
IMU Cable	USB conn	splice IMU stock cable	
Mobileye pwr cable	Term block	splice Mobileye stock cable	
Ground Wire			
Install Mobileye (calibrate w/lapt	**C2-270 instructions**		
Truck to Terminal block power			**Check Voltage**
12V main power (Trk fuse box)	12V Fused	Term block 1,2	
12V ING line (Trk fuse box)	ING Fused	Term block 3,4	
Ground point Trk frame at Batt box	Gnd	Term block 5,6	
DENSO power cable	12V ING Fused	GND	
Access Point cable	12V ING Fused	GND	
Install wires check voltages		**Check Voltage**	
Ground	DAS 1,2		
12V batt pwr	DAS 14,15		
CAN 1 signal w/laptop	DAS 3,4		
CAN 2 signal w/laptop	DAS 17,18		
ING 12v			
DAS Install	**completed**		
Run Framegrabber program			
CK Face image			
CK FWD image			
CK Left image			
CK Right image			
Run Data collection GUI program			
CK CAN bus signals			
CK IMU signals			
CK ING switch signal			
CK GPS signal			
CK communication with DENSO			
CK communication with AccessPoint			
CK communication with Mobileye			

Drive truck on 10 min trip, download data	
CK cell data call	
CK GPS data	
CK Face Video	
CK FWD Video	
CK Left Video	
CK Right Video	
CK CAN bus signals	
CK IMU signals	
CK ING switch signal	
CK Mobileye data	
CK DENSO Data	

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Figure B-2. Wire harness continuity and power verification checklist.

Figure B-3 is the checklist for verifying CAN message capture on the DAS.

CAN Messge Verification Check List

Name: ______________________________

Date: ______________________________

Vehicle Id: ______________________________

DAS Id: ______________________________

Channel Name	*BUS*	*Present*	*Rate*
Acc1Msg0x10FE6F2A	Vehicle		
AmbientMsg0x18FEF500	Vehicle		
AmbientMsg0x18FEF521	Vehicle		
BrakesMsg0x18FEFA21	Vehicle		
EBC1Msg0x18F0010B	Vehicle		
EEC1Msg0x0CF00400	Vehicle		
EEC2Msg0x0CF00300	Vehicle		
EngTempMsg0x18FEEE00	Vehicle		
ExhaustMsg0x18FEF600	Vehicle		
FuelMsg0x18FEF200	Vehicle		
HeadLampMsg0x10FF2121	Vehicle		
OdoMsg0x18FEC100	Vehicle		
TurnWiperMsg0x14FF3131	Vehicle		
VDC2Msg0x18F0093E	Vehicle		
VehPowerMsg0x18FEF700	Vehicle		
VSC1Msg0x18FEF100	Vehicle		
TargetStatusMsg0x738	Umtri		
LaneLeftAMsg0x766	Umtri		
LaneMsg0x737	Umtri		
LaneRightAMsg0x768	Umtri		
NumBndryMsg0x76B	Umtri		
TSRMsg0x727	Umtri		
Target10Raw0x754	Umtri		
Target1Raw0x739	Umtri		
Target2Raw0x73C	Umtri		
Target3Raw0x73F	Umtri		
Target4Raw0x743	Umtri		
Target5Raw0x745	Umtri		
Target6Raw0x748	Umtri		
Target7Raw0x74B	Umtri		
Target8Raw0x74E	Umtri		
Target9Raw0x751	Umtri		

CAN Messge CheckList.xlsx

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Figure B-3. Checklist for CAN message verification.

Figure B-4 is the checklist for verifying DAS signals while the vehicle is parked.

Static Signal Verification Check List

Name: ____________________________________

Date: ____________________________________

Vehicle Id: ________________________________

DAS Id: __________________________________

Channel Name	*Reasonable/Correct*	*Quality of Measure* *Zero/Fixed*	*Saturated/Fixed*
AccelPedal			
Altitude			
AudioCount			
Ax			
AxVehicle			
Ay			
AyVehicle			
Az			
BoostPressure			
CabinCount			
CabinKey			
CabinSize			
CoolantTemp			
CurvatureAcc			
Differential			
EngineSpeed			
EngineStatus			
EngineTorque			
FixMode			
ForwardCount			
ForwardKey			
ForwardSize			
....			
....			
Steer			
SyncCount			
SyncCountOut			
SyncMilliseconds			
SyncSubMilliseconds			
SyncTime			
SyncTimeValid			
SyncWeek			
TargetDetectedAcc			
Time			
TurnSignal			
UtcTime			
UtcWeek			
Wiper			
YawRate			
....			
....			

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Figure B-4. Static signal verification checklist.

Figure B-5 is the checklist for verifying signals on the DAS in dynamic testing while the vehicle driving.

Dynamic Signal Verification Check List

Name: ____

Date: ____

Vehicle Id: ____

DAS Id: ____

	Quality of Measure		
Channel Name	*Reasonable/Correct*	*Zero/Fixed*	*Saturated/Fixed*
AbsActive			
Age			
Altitude			
AngleRate			
AvailableLeft			
AvailableRight			
Ax			
Ay			
Blinker			
BoundaryLeft			
BoundaryRight			
Brake			
BrakeLights			
CIPV			
CloseCar			
ConstructionArea			
CruiseEnabled			
CruiseEngaged			
CruiseStatus			
....			
....			
LaneDistanceLeft			
LaneDistanceRight			
LaneHeading			
LaneQualityLeft			
LaneQualityRight			
LineWidthLeft			
LineWidthRight			
NumBoundary			
NumTargets			
ObstacleAx			
ObstacleType			
Range			
Range			
RangeRate			
Rangerate			
ScaleChange			
Speed			
Status			
Transversal			
TurnSignal			
Valid			
Width			

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Figure B-5. Dynamic signal verification checklist.

Figure B-6 is the checklist for verifying signals are sent by the WSU to the DAS.

WSU Signal Verification Check List

Name: ______________________________

Date: ______________________________

Vehicle Id: ______________________________

DAS Id: ______________________________

	Quality of Measure		
Channel Name	*Reasonable/Correct*	*Zero/Fixed*	*Saturated/Fixed*
GpsValidWsu			
GpsTimeWsu			
LatitudeWsu			
LongitudeWsu			
AltitudeWsu			
GpsHeadingWsu			
GpsSpeedWsu			
HdopWsu			
PdopWsu			
FixQualityWsu			
GpsCoastingWsu			
ValidCanWsu			
YawRateWsu			
SpeedWsu			
TurnSngRWsu			
TurnSngLWsu			
BrakeAbsTcsWsu			
AxWsu			
PrndlWsu			
VsaActiveWsu			
HeadlampWsu			
WiperWsu			
ThrottleWsu			
SteerWsu			
TimeCs			
TaUdpPacket			
....			
....			
InformRvLocation			
InformRvAx			
InformRvBrake			
InformRvHeading			
InformRvRandomId			
InformRvLatitude			
InformRvLongitude			
InformRvLatOffset			
InformRvLongOffset			
InformRvSpeed			
InformTcRange			
InformTcRangeRate			
WarningRvLocation			
WarningRvAx			
....			

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Figure B-6. WSU signal verification checklist.

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