TECHNICAL REPORT DOCUMENTATION PAGE

1. REPORT NUMBER T8080-160062 MSSC Deliverable No. 4	2. REPORT DATE March 31, 2018	3. PUBLISHED DATE May 11, 2018
4. TITLE Transport Canada Commercial Bus HVEDR Feasibility Study Deliverable No. 4		5. DELIVERABLE Summary Report of All Devices developed by original equipment manufacturers and after-market suppliers, including equipment requirements, operational requirements and technical specifications
6. AUTHOR(S) Christopher Armstrong, Bradley Higgins, Krystina M. Engleman, John Grindey, Kristina Lombardi, Jacobo Pardo, Henry Ramirez, Henry Schmoker and John Steiner		7. SUPPLEMENTARY NOTES There are 5 individual reports that make up the full report for this Feasibility Study (Deliverable No. 3 thru Deliverable No. 7)
8. PERFORMING ORGANIZATION NAME AND ADDRESS Mecanica Scientific Services Corp 3051 Sturgis Road Oxnard, California, 93030		9. CONTRACT NUMBER T8080-160062
10. SPONSORING AGENCY NAME AND ADDRESS Transport Canada Motor Vehicle Safety 330 Sparks Street Ottawa, ON, Canada, K1A 0N5		11. SPONSORING AGENCY ROUTING SYMBOL ASFCA Collision Investigations and Research

12. ABSTRACT

Event data recorder (EDR) and heavy vehicle event data recorder (HVEDR) devices are capable of recording vehicle data as a result of a crash or other programmed event and can be classified as either original equipment manufacturer (OEM) electronic devices or aftermarket add-on devices. Research has identified limitations in the data recorded by both types of devices but has concluded the data are generally accurate and useful in crash analysis. This summary report of all HVEDR devices begins with a brief history of telematics devices, such as global positioning system (GPS), electronic logging devices (ELDs), and in-vehicle dash cams. What follows is an overview of the current HVEDR functionality of major OEM electronic control units (ECUs), including data elements, trigger thresholds, reporting duration and frequencies, and data formatting and retrieval. The report then turns to aftermarket devices, with a history of ELD regulation for commercial motor vehicles, an overview of today's major ELDs with EDR functionality, and an examination of one major accident data recorder on the market. It will be shown that, although not always easily accessible, significant event data are collected by OEM ECUs and increasingly by aftermarket add-on devices in the industry today.

13. ACKNOWLEDGEMENTS

The Mecanica team would like to acknowledge Mr. Timothy Cheek, P.E. (Charlotte, NC), Mr. David Plant, P.E. (Washington, D.C.) and Mr. Timothy Austin (Appleton, WI) for their contributions, expertise and guidance in this project. The team would like to acknowledge Sr. Abraham Pardo (Cuidad de Mexico, Mexico) for his expertise, guidance, and input on the Mexican national bus industry. We would also like to acknowledge the Mecanica Scientific Services Team for their contribution in releasing this document.

14. KEY WORDS

EDR, HVEDR, Event Data Recorder, bus, school bus, motorcoach

15. SECURITY CLASSIFICATION Unclassified	16. NUMBER OF PAGES 58

Transport Canada Commercial Bus HVEDR Feasibility Study (File No. T8080-160062) Deliverable No. 4:

All Devices Summary Report

4. Submission of a summary report of all commercial vehicle-based systems, engine-based systems as well as global positioning systems developed both by original equipment manufacturers and after-market suppliers. This should include equipment requirements, operational requirements and technical specifications.
Deadline: Within 14 weeks of deliverable # 3

Mecanica Scientific Services Corporation

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1.0 INTRODUCTION

Despite any North American state or federal regulations in Canada, the United States or Mexico, a vast majority of NAFTA commercial medium- and heavy-duty vehicles are equipped with some form of **event data recorder (EDR**) device as defined by SAE J1698 or **heavy vehicle event data recorder (HVEDR)** as defined by SAE J2728.

Devices with capability of recording driver input and vehicle data as a result of a crash, a hard brake event, a stop event or other programmed event can be classified into one of two general categories:

1. Original equipment manufacturer (OEM) electronic devices installed in the vehicle by the manufacturer of the vehicle such as the engine electronic control unit (ECU), airbag control module (ACM) or the anti-lock brakes (ABS)/electronic stability control (ESC) ECU.
2. Aftermarket add-on devices added to a vehicle by the vehicle owner, such as a telematics device, automatic on-board recording device (AOBRD), electronic logging device (ELD) or dash cam device, that capture vehicle data, GPS data as well as video.

As discussed in this series of research (Deliverable No. 3), extensive research, testing and validation have been conducted on both OEM device-based EDR or HVEDR functions as well as the aftermarket device-based EDR or HVEDR data accuracy and reliability. The sum of the research has identified limitations in the data recorded by OEM EDR/HVEDR but has concluded OEM EDR/HVEDR data are generally accurate and useful in crash analysis. Similar findings have been found for aftermarket EDR/HVEDR devices.

The most significant positive attribute of OEM-based EDR/HVEDR devices is that the EDR/HVEDR is a software function added to a pre-existing ECU that is original to the vehicle and required for its operation. The OEM EDR/HVEDR function leverages sensors and data already on the vehicle and required for vehicle operation to meet federal regulations, such as emissions requirements. The OEM EDR/HVEDR function could be analogized to adding an “app” to a smartphone.

However, the Mecanica research team recognizes the potential engineering and design time, expense and complication of adding processor power and memory capability to ECUs that do not feature HVEDR functionality.

A considerable downside for OEM-based EDR/HVEDR devices is that there tend to be more data limitations and potential for reduced data accuracy when the vehicle’s OEM data network and sensors are leveraged as opposed to a purpose-built, independent data recorder essentially serving as a data-acquisition system.

Although an add-on device that serves as EDR/HVEDR for a vehicle may feature improved data reliability, accuracy, and recording and reporting resolution, the improved data quality comes at a significant per-vehicle cost for the device and for the labor to install, configure and calibrate it.

2.0 EXECUTIVE SUMMARY

2.1 History of HVEDR

HVEDR-type functionality originally grew in response to U.S. Environmental Protection Agency (EPA) requirements for lower diesel nitrous oxide (NOX) emissions. To meet EPA emissions requirements and refine engine controls, medium- and heavy-duty truck engine manufacturers moved away from traditional mechanical or electro-mechanical engine controls to solid-state, electronic engine controls. HVEDR is not a stand-alone data recorder with its own network of sensors but an algorithm added to pre-existing OEM ECUs that leverages already-existing and standardized communication networks, sensors and closed-loop ECUs with processors and memory for data storage. The HVEDR function typically found as an add-on algorithm within OEM ECUs can also be found in OEM optional equipment. The history of EDR/HVEDR development and technical research has been explored extensively *in T8080-160062 Transport Canada Commercial Bus HVEDR Feasibility Study*, Deliverable No. 3, “Summary Report of Facts.”

In 2000, a vast majority of NAFTA-market, over-the-road truck-tractors were equipped with these OEM-based HVEDR-type functions. As of 2018, NAFTA-market, over-the-road truck-tractors and buses are increasingly equipped with two or more independent OEM-based HVEDR functions. In addition to the OEM HVEDR functions found in current model-year (MY2018) commercial trucks and buses, additional EDR-type recorders are found in the aftermarket systems that are installed by commercial vehicle operators, such as telematics, ELDs or video event data recorders (VEDRs).

2.2 History of GPS Telematics

“Telematics” is derived from the French word *télématique*, which was first defined by Simon Nora and Alain Minc in a 1978 report to the French government. Télématique was the result of combining the French words *télécommunications* ("telecommunications") and *informatique* ("computing science") and thus referred to the transfer of information over telecommunications. Telematics continues to be used in academic fields, but in commerce, it now generally refers to vehicle telematics.[1]

The purpose of telematics is to be able to obtain specific information on vehicles in motion. The original version of a telematic system was the tachograph. In the mid-1950s, early tachographs automatically recorded vehicle information, such as driving speed versus time and distance. In the 1990s, telematics converged with the Global System for Mobile communications (GSM),

[1]Ewing, T., “What Is Telematics?”, accessed Aug. 2017.

internet and Global Positioning System (GPS). The U.S. Department of Defense designed and developed GPS for navigation and positioning. Today, GPS has revolutionized the environmental impact of vehicles. With dozens of GPS satellites orbiting the globe, GPS receivers allow the pinpointing of approximate vehicle location on Earth. Although GPS was originally used for military applications, its civilian applications have expanded while still under U.S. military control. GPS provides accurate navigational data that, along with other collected vehicle data, is used by telematics to communicate with parties external to the vehicle. This convergence has expanded the range of services offered through telematics and significantly improved fleet operations and fuel burn efficiencies.

Several community-based research programs have focused on finding ways of using telematics for road safety, improving efficiency levels and reducing environmental impact. In the late 1990s and early 2000s, the European Union heavily promoted telematics research as a way to improve traffic management and harmonize traffic throughout E.U. member states. Telematic technologies have since continued to evolve and have allowed for improving vehicle safety while striving toward a more efficient global transportation system. Table 2.2 below outlines some technological innovations in telematics in more recent years.

Table 2.2. Recent Telematic Technological Innovations

Year	Telematic Innovation
1998	The first hands- free car gateways were introduced
2000	The first GSM & GPS systems were brought to market
2002	Bluetooth hands-free voice gateways with advanced voice integration features
2003	Integrated GSM phone with Bluetooth
2007	Multimedia handset integration is introduced
2009	Fully integrated mobile navigation using a car GSM system
2010	3G multimedia car entertainment system
2011	Telematics and Infotainment systems introduced based on Linux

2.3 History of ELD

An ELD is a newer technology designed to monitor truck drivers' hours of service (HOS). Federal Motor Carrier Safety Administration (FMCSA) requirements for limiting how many hours a truck driver may operate a commercial vehicle have changed over the years, but the fundamental motivation for monitoring HOS is to improve roadway safety. To assess HOS, ELD monitors the commercial vehicle to determine vehicle speed, engine idle status, length of time the engine has been running, and how many miles were driven; these are then compared with and serve to double-check the driver's indicated status (driving, sleeper berth, on duty - not driving, off duty).

Foundations for FMCSA's ELD mandate stretch back to the mid- to late 1980s when motor carriers first used electronic logging devices referred to as "automatic on-board recording devices" to monitor driver HOS. These AOBRDs were simple but set the basis for the technology present in today's commercial vehicles. Prior to the ELD mandate, the most popular method for logging driver HOS was via paper logbooks that included carbon copies for the driver, fleet and law enforcement each. As most fleets and owner-operators used these paper logbooks through the 1980s, cellular networks and satellite communication platforms had only just been introduced; transmitting data wirelessly between carriers was therefore not feasible.

After lobbying from the Insurance Institute for Highway Safety (IIHS), the U.S. Department of Transportation (DOT) took the first regulatory action regarding devices for electronic logging when requiring all carriers to equip their trucks with ELDs in 1986. Shortly after in 1988, AOBRDs were introduced, and regulations standardized the means of their incorporation into the industry. AOBRDs are similar to ELDs although technical specifications separate the two, such that ELDs are required by law to connect to the engine of the truck whereas AOBRDs are not. FMCSA first attempted to reform HOS regulations to mandate the use of ELD in the year 2000. Although this attempt to mandate HOS tracking with ELD was initiated for compliance and safety benefits, it was struck down by a court order in 2004.

In April 2010, a second attempt was made at mandating ELD. DOT established a rule in the *Federal Register* allowing FMCSA to mandate ELD for carriers holding the worst track records of non-compliance with HOS legislation. Two years later, the Moving Ahead for Progress in the 21st Century (MAP-21) Act was passed by the United States Congress. This Act required FMCSA to develop a rule requiring ELD as well as research for how to implement ELD use to push driver HOS compliance as close to 100% as possible. Finally, after public comment periods and approval from the executive branch, the final version of the ELD mandate was published near the end of 2015. This mandate included guidelines on which features were required to build compliant ELDs. In addition, the mandate covered HOS tracking methods as well as means of preventing motor carriers from harassing drivers with ELDs.

The ELD mandate currently in effect was not inaugurated until February 16th, 2016. Since the official release of the mandate, FMCSA has established a precise compliance schedule that allows motor carriers enough time to adapt their current systems to the new laws. The initial phase focused mainly on awareness and transitioning into complete compliance. This phase was intended to last until the end of 2017 and would allow all methods of HOS logging.

More complexity is anticipated in the second phase, which is set to last from the end of the first phase to the end of 2019. During this phase, carriers are required to start taking compliance measures, and manual paper logging or logging software will no longer be permitted. Only compliant ELDs or AOBRDs installed before the end of phase one will be accepted HOS logging devices.

The final and strictest phase begins after December 16, 2019 and demands full compliance from carriers. Once in effect, this phase will enforce HOS tracking by using only registered FMCSA-compliant ELDs on all drivers and carriers operating in the U.S. On their website, FMCSA has published a list[2] of ELDs that meet all federally mandated requirements as certified by third-party industry experts, who include companies such as PeopleNet, Spireon, Fleetmatics, Zonar, EROAD, Teletrac Navman, Rand McNally and several others.

2.4 History of In-Vehicle (Dash) Cams

The first videotape recording systems became available in the early 1960s. Video technology in this decade was not conducive to mounting cameras in police vehicles. In 1980, Mothers Against Drunk Drivers (MADD) formed and brought heightened awareness to the national problem of driving under the influence. Police began installing cameras in police vehicles to document the infractions leading up to the initial stop and eventual field sobriety test. These recordings came to be viewed as the most effective method of providing necessary evidence to support conviction.[3]

In the late 1980s, dashboard cameras, or “dash cams,” were first introduced in police cars in the Lone Star State of Texas. Early versions of dash cams incorporated VHS cassettes and were typically mounted on tripods. Dash cams were initially created to ensure safety for police officers in remote rural areas and were bulky and expensive.

In the 1990s, America’s war on drugs further advanced the use of in-car cameras by documenting interdiction stops. The camera increasingly documented consented searches that were later used to gain convictions.[4] By 1999, however, lawsuits alleging racial profiling in traffic stops were increasingly filed against state police and highway patrol agencies throughout the United States. At the same time, assaults on officers were on the rise. Responding to these concerns, state and federal legislative bodies began enacting laws requiring all police agencies within their jurisdiction to document details of every traffic stop. The Department of Justice Office of Community Oriented Policing Services recognized the value of the in-vehicle camera in addressing officer safety issues and allegations of racial profiling while enhancing public trust.[5]

The program provided financial aid to state police and highway patrol agencies for the sole purpose of implementing in-car camera systems. The first federal awards were dispersed in 2000, and by the end of 2003, 47 states and the District of Columbia had received a total of more than $21 million in federal assistance for the purchase of dash cams. During the incentive program, the number of dash cam-equipped vehicles in the United States grew from approximately 3,000 to 17,500, representing 72% of total state patrol vehicles, with 4,500 stemming from program’s financial aid alone.

[2] https://csa.fmcsa.dot.gov/ELD/List
[3] Rosenblatt, D. N., Cromartie, E. R., and Forman, J., “The Impact of Video Evidence on Modern Policing,” 2003.
[4] Ibid.
[5] Ibid.

Miniaturization and advances in technology have made the use of dash cams practical and affordable, allowing for their widespread adoption. Dash cams saw yet another steep increase in sales in the late 2000s due to insurance fraud in Russia in which claimants threw themselves at moving vehicles to allege injury.

Dash cams have been shown to enhance the ability to capture and convict true violators, improve insurance claim settlements and provide valuable data for accurate accident reconstruction. Major dash cam producers include Lytx, Garmin, DriveCam, Falcon Zero, SmartDrive and numerous others.

3.0 SUMMARY OF FINDINGS

3.1 OEM-Based HVEDR

As described in Deliverable No. 3: “Summary Report of Facts,” a majority of NAFTA market medium- and heavy-duty vehicles model-year 2000 and newer are equipped with some form of HVEDR. This vehicle class includes truck-tractors, straight trucks, buses, motorcoaches, school buses and vocation-specific trucks, such as sanitation trucks, dump trucks and fire apparatuses. HVEDR is typically located in the vehicle’s engine ECU or cab/chassis ECU. The exact configuration depends on the engine OEM. The current HVEDR functions built into commercial vehicle OEM ECUs have significant recording capabilities, including the capture of a large number of data elements, longer than previously recorded time durations and high data resolutions. Retrieval of this data is accomplished through communication with the in-cab diagnostic link connector (DLC) equipped on all vehicles.

HVEDR was originally based on the older serial communications network defined by SAE J1708 and J1587. As electronic controls advanced to meet more stringent emissions requirements, the industry moved toward higher-speed Controller Area Network (CAN) and ISO networks as defined by SAE J1939 and ISO 15765: “2011 Road Vehicles – Diagnostic Communication over Controller Area Network (DoCAN).” The standardized physical connection port to access and image data from a medium- or heavy- duty truck is defined by SAE J1939/13 and is known as a Deutsch® 6- or 9-pin DLC. Some model-year 2016 and newer heavy-duty vehicles have switched to using the passenger vehicle On-Board Diagnostics (OBD)-II-style connector since the Deutsch 9-pin DLC did not have enough pins. Refer to Figures 3.1-1, 3.1-2 and 3.1-3 below for examples of a J1939/13 9-pin connector, 6-pin connector and new OBD-II connector.

Figure 3.1-1. Late model 6/9-pin-style DLC

Figure 3.1-2. Late model 9-pin DLC port

Figure 3.1-3. Late model Mack truck-tractor with OBD-II style DLC

While the data elements captured and stored on HVEDR are generally similar across OEM ECUs, the manner in which the data are presented varies. The data-retrieval method is essentially the same and consists of connecting the vehicle to a laptop equipped with the appropriate software and thereby imaging available data. The following is a summary outline of HVEDR capabilities among various engine and ABS OEMs.

3.1.1 Detroit Diesel & Mercedes Benz

3.1.1.1 Detroit Diesel

Detroit Diesel first introduced integrated electronic controls in their heavy-duty engines with the Series 92 engine in 1985. Their electronics system is called Detroit Diesel Electronic Controls (DDEC) and began with DDEC I. A couple of years later in 1987, the Series 60 engine was introduced as the first engine ever designed exclusively for electronics controls. This same year saw the introduction of DDEC II, the next iteration of Detroit Diesel's electronics system. Not until 1997 and 1998, however, were the data from these electronics systems made available with the DDEC III system. DDEC III was actually introduced in 1994, but the option to have DDEC Data Pages was not made available until 1997/98. Continuing with the iterative naming process, Detroit Diesel released the DDEC IV system in 1998 that ran until 2003, followed by DDEC V in 2004 and DDEC VI in 2007. The naming convention then changed to relate to the year in which the electronics system was produced in compliance with EPA emissions requirements; thus, in 2010, the DDEC 10 system was introduced, followed by DDEC 13 in 2013 and so on, up to the current DDEC 16 system introduced in 2016.

Only when DDEC III was introduced in 1997 were data made accessible; however, this system was limited in that it only provided a trip activity report, configuration data, periodic maintenance, histograms, a profile and life-of-vehicle data. At the time, incident-specific data, such as hard brake events, were not recorded. Not until the 1998 introduction of the DDEC IV system, specifically Release 21.0 and later, was incident-specific event recording available. DDEC IV data included the previously mentioned DDEC III features, with the addition of monthly activity data, a daily engine usage report, additional histograms, Diagnostic Records, a last stop record and two hard brake events. In addition, an internal battery was added for the real-time clock whereas the DDEC III system had no internal battery-maintained clock.

The DDEC IV's newly added Diagnostic Records, two hard brake events and last stop event are incident-specific records. Diagnostic Records allow the recording and storing of the three most recently triggered events. These events are triggered when certain fault codes are activated under certain operating conditions. The system then records 1 minute of activity prior to the fault becoming active and reports this activity in 5-second intervals. Recorded data includes vehicle and engine speeds, boost pressure, oil pressure and fuel pressure. The fault code is also listed, as are the date and time at which the fault became active.

In addition, the two most recent hard brake events and one last stop event are also recorded. Each hard brake event records 1 minute of activity prior to the trigger and 15 seconds after the trigger. Recorded values include vehicle and engine speed, brake application, clutch application, engine load, throttle percentage, cruise control and diagnostic code activity. These values are reported in 1-second intervals. The triggering threshold for a hard brake event is set to 7 mph/sec by default, but it can be changed by the owner. Additionally, the vehicle speed must be above 10 mph and will not trigger if preceded or followed by an acceleration of more than 4 mph/sec. The last stop event records 1 minute and 44 seconds of data prior to stopping and 15 seconds after. It records the same values as the hard brake event and also reports in 1-second intervals. The last stop event is triggered when the vehicle speed changes from drive state to stop state and remains stopped for 15 seconds. Drive state is defined as having vehicle speed greater than or equal to 1.5 mph and engine speed greater than zero for 2 seconds. Stop state is defined as having vehicle speed less than 1.5 mph or the ignition off. Both the hard brake events and the last stop event are stamped with the date and time of the trigger as well as the odometer value at the time of recording.

Over the various DDEC iterations, these incident-specific events have largely remained the same. The only exception was the DDEC VI system, which had no Diagnostic Records available but instead provided extended fault code data for a single instant in time at the occurrence of the fault.

As the DDEC system evolved and grew in complexity, additional modules were added to trucks to compensate. The DDEC III, IV and V systems had only one ECU that physically contained the data and was mounted on the driver's side of the engine. The DDEC VI system introduced a second module called the common powertrain controller (CPC-2) and renamed the engine-mounted module the motor control mount (MCM). The CPC-2 is mounted inside the cab, usually under the dash or behind the B-pillar. From this point forward, DDEC data was stored on the CPC while the other modules stored their own fault codes and configuration parameters. The DDEC 10 system kept the CPC and MCM but introduced the Aftertreatment Control Module (ACM) mounted under the cab. DDEC 13 introduced a fourth (optional) ECU, the TCM01T, which controls the *optional* Detroit Diesel DT12 automatic transmission. This transmission control module (TCM) is only included on trucks *optioned* with this transmission, however.

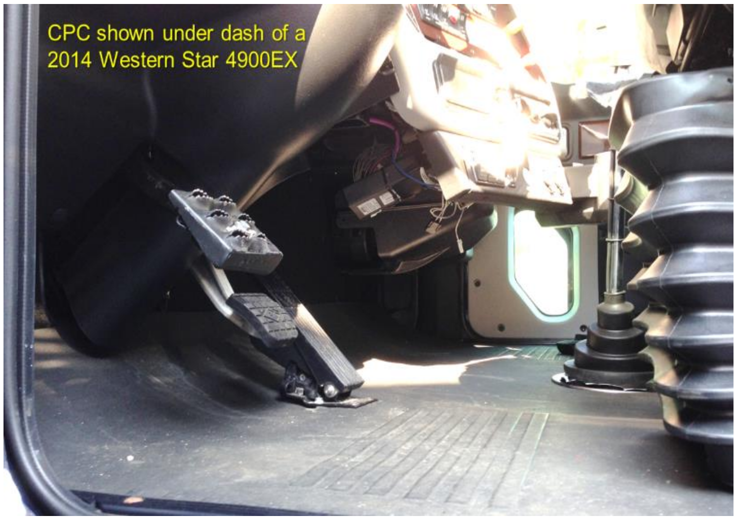

Figure 3.1.1.1-1. Daimler CPC ECU, 2014 Western Star

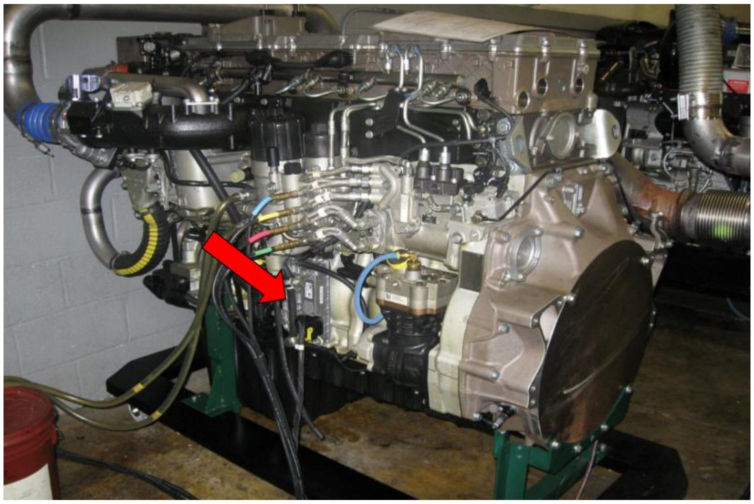

Figure 3.1.1.1-2. Typical DDEC VI/10/13/16 MCM location

Beyond these ECUs, there also exists the optional Detroit Diesel ProDriver system. Very few Detroit Diesel powered trucks have ProDriver, but the system does have the capability of storing additional data separate from the DDEC ECU(s) that include a trip activity report, an alerts report, up to five hard brake events and a last stop event. Most importantly, the hard brake events can be manually stored by the driver. These events capture 2 minutes of data values, including vehicle and engine speed, percent throttle, engine load, cruise control status, active alerts, and service brake and clutch status. These events are automatically captured in the case of hard braking and record 90 seconds pre-trigger and 30 seconds post-trigger. If the driver manually triggers an event capture, 120 seconds of pre-trigger data are recorded.

Figure 3.1.1.1-3. Typical ProDriver installation

Imaging the data from Detroit Diesel engines requires two software applications, the Detroit Diesel Diagnostic Link (DDDL) and Detroit Diesel Electronic Controls Reports (DDEC Reports). DDDL retrieves the calibration data, audit trail, real-time clock and additional fault code data while DDEC

Reports retrieve incident-related and engine operation data, such as hard brake records, a last stop record, trip information and daily engine usage.

Over the course of these DDEC iterations, issues have been documented, such as the aforementioned DDEC III system lacking an internal battery to maintain the real-time clock. Power interruptions are known to have adverse effects on data storage. For instance, DDEC IV and V require 20 to 25 seconds after initiating a hard brake to store a complete hard brake event.[6] Conversely, DDEC VI requires a key-off signal to store a hard brake event, so a power interruption before key-off may result in no hard brake event record. As for the last stop record, DDEC IV and V store the record upon key-off. Fortunately, DDEC VI and newer systems store the last stop record to non-volatile memory immediately after the event.

Concerning Diagnostic Records, the most prevalent issue is their complete absence from the DDEC VI system. On other DDEC systems, the Diagnostic records can be imaged through the cab diagnostic connector without issue. Through the benchtop data-imaging method, however, a suitable surrogate vehicle or a chassis simulator harness is required, otherwise the Diagnostic records can be overwritten. For benchtop data imaging of DDEC 10 and 13, the CPC must be connected in order to image data from other ECUs, such as the MCM.

3.1.1.2 Mercedes-Benz

As a result of the Daimler Trucks North America (DTNA) acquisition of Detroit Diesel Corporation in 2000, Mercedes Benz medium- and heavy-duty engines (MBE) share a common electronics system. The engines include the MBE 4000 heavy-duty engine, which may be equipped in Freightliner and Western Star tractors, and the MBE 900 medium-duty engine, found in Freightliner Business Class M2, Freightliner Custom Chassis and Thomas Bus vehicles. Much like the DDEC VI system on Detroit Diesel engines, the MBE engines featured a two-module system using the vehicle control unit (VCU) and the *Pumpe Liene Dusse* (PLD) or engine-resident control unit. Much like the CPC, the VCU is typically mounted under the dash in the cab or on the B-pillar while the PLD is mounted on the driver's side of the engine, like the MCM.

[6] Messerschmidt, W., Austin, T., Smith, B., Cheek, T. et al., "Simulating the Effect of Collision-Related Power Loss on the Event Data Recorders of Heavy Trucks," SAE Technical Paper 2010-01-1004, 2010.

Figure 3.1.1.2-1. Typical MBE PLD location

Figure 3.1.1.2-2. Typical MBE VCU location

From 2000 until pre-EPA07,[7] MBE engines utilized a system that recorded the same data as the DDEC IV and V systems, including capability of storing incident-specific data, such as hard brake and last stop events. However, these engines only recorded this data if the VCU ran on software version 12.09 or higher. EPA07 MBE engines used DDEC VI ECUs. The data available from DDEC VI-equipped MBE engines were the same as that available from Detroit Diesel engines, with a few minor exceptions. Across all MBE engines equipped with DDEC, the only absent piece of data is the audit trail. DDEC Reports data are also stored within the VCU while clock and configuration data are stored in the PLD.

Many of the same data-recording issues experienced with Detroit Diesel DDEC systems also affect MBE engines. For pre-EPA07 (DDEC IV and V) MBE engines, the VCU requires power for 15 seconds after initiating a hard brake to record and store the event in memory. Additionally,

[7]EPA07 refers to an era of more stringent emissions requirements issued by EPA in 2007 that significantly increased complexity in emissions systems and sensors to meet compliance, thus resulting a greater number of and more complex ECUs.

testing has shown that a last stop event is triggered when the engine speed is at 0 rpm regardless of vehicle speed and still requires approximately 15 seconds of power after reaching 0 rpm to record the event.

Concerning Diagnostic Records on pre-EPA07 MBE engines, testing has shown that if active faults are present, then Diagnostic Records will be overwritten. This occurs even if data imaging is completed through the diagnostic connector on the truck. The number of Diagnostic Records overwritten depends on the number of active faults present at the time of power application and the number of key cycles since the records were written. Key cycles factor when there are inactive faults present on the PLD. Testing has revealed that when the PLD has inactive faults, the Diagnostic Records will be overwritten every time the ignition key is turned on even if no active faults are present.

In order to avoid overwriting Diagnostic Records, an appropriate engine simulator can be used. A surrogate PLD, with all inactive faults cleared, can be connected with the subject VCU and the engine simulator to image the Diagnostic Records without overwriting them. The subject PLD and VCU can then be connected with the engine simulator to retrieve the rest of the data from the PLD. However, this will overwrite the Diagnostic Records should there be any inactive faults on the subject PLD. For DDEC VI-equipped MBE engines with CPC software 5.0 and below, a key-off signal is required to record a hard brake event. Concerning the last stop event, testing has shown that if power interruption occurs prior to key-off, the last stop event will not be recorded. However, if the CPC software is 5.03 and above, a key-off signal is not required to record the hard brake event, and the last stop event is written to memory immediately after the event.[8] [9] [10]

3.1.2 Cummins

Cummins manufactures engines for heavy-duty and medium-duty commercial vehicles. The family of heavy-duty engines include ISX, ISM and ISX-G, a natural gas-burning engine. Medium-duty engines include ISB, ISC, ISL and the natural gas-burning ISL-G. The “IS” designation has been dropped as of 2017 to become X15, X12 and so on.

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[8] Messerschmidt, W., Austin, T., Smith, B., Cheek, T, et al., “Simulating the Effect of Collision-Related Power Loss.”

[9] Plant, D., Austin, T., and Smith, B., “Data Extraction Methods and their Effects on the Retention of Event Data Contained in the Electronic Control Modules of Detroit Diesel and Mercedes-Benz Engines,” *SAE Int. J. Passeng. Cars – Mech. Syst. 4*(1):636-647, 2011.

[10] Austin, T., Cheek, T., Plant, D., Steiner, J., and Lackey, L., “SAE C1022: Accessing and Interpreting Heavy Vehicle Event Data Recorders,” Module 4, 2016.

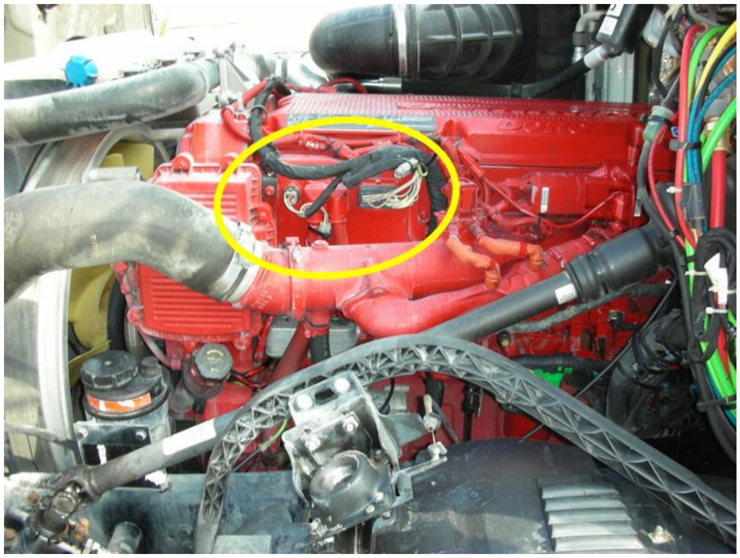

Figure 3.1.2-1. Typical Cummins Engine ECU location

Sudden Deceleration Data (SDD) recording was enabled in ISX engines in November 2004. Previously, incident information was only recorded by an optional, dash-mounted trip computer called the RoadRelay system or if the 2002-2005 vintage engines were re-flashed with updated electronic control module (ECM) software. The Cummins RoadRelay trip computer is a device similar to the previously discussed Detroit Diesel ProDriver.

Data recorded on Cummins ECMs includes Sudden Deceleration Data records, Fault Code Snapshots, trip information, data plate information, feature settings, maintenance monitor, data monitor, audit trail, J1939 (powertrain) control history, engine protection, engine abuse history and histograms (duty cycle monitoring).

The Cummins ECM can store three incident-specific SDD records. Recording is triggered when a preprogrammed acceleration is detected. The default trigger is 9 mph/sec but may be reprogrammed to a user-defined value. SDD records data 59 seconds prior to the trigger and 15 seconds after the trigger and may be overwritten by subsequent events, with the oldest replaced by the newest in the first in, first out (FIFO) format. The designation of event one, two or three does not indicate order of recording. SDD are time-stamped with ECM time and odometer at occurrence. SDD may be disabled on 2010 and 2013 ISB engines and is typically disabled on the natural gas engines.

Fault Code Snapshots may also provide incident-specific data if the fault was triggered at the time of the subject incident. The fault code will be time-stamped with the ECM runtime (electronic hour meter) and records data like engine speed and vehicle speed for the moment the fault code became active. It is important to note that the moment the fault code becomes active may not be the moment that the actual fault occurred.

Two software applications, Cummins PowerSpec and Cummins Insite, are used to image Cummins ECM data. Insite images fault code data, programming parameters, detailed trip data, historical data, and audit trails whereas PowerSpec is required to image SDD, engine parameters and trip information. In addition to this software, a RP1210A-compatible data link must be used to interface the engine ECM with the computer. The data link connector facilitates communication with the ECM. If the commercial vehicle is seriously damaged and the data link connector cannot establish communication, the ECM may be accessed by installing it on a surrogate vehicle or by imaging data on the benchtop through a simulation or programming harness.

Known data errors may exist on certain vintage engines. For instance, a calibration error may interfere with the data reporting rate on Sudden Deceleration Data reports of all engine ECMs built for the 2007 EPA certification. In this case, data points are recorded at 5 Hz instead of 1 Hz, providing only 15 seconds of pre-trigger data instead of the standard 59 seconds and 11.8 seconds of post-trigger data instead of the published 15. This data reporting error has been analyzed, and a fix was proposed to correct the data.[11] Results showed recorded parameter values to be correct and only the clock incorrect. It was therefore recommended to divide the time values by 5 to correct the data.

SDD records are written to the electrically erasable programmable read-only memory (EEPROM) at key-off. If power is interrupted for reasons such as a catastrophic collision, SDD will not save to non-volatile memory and be lost. Fault Code Snapshots are written "on-the-fly" and therefore retained even with a power interruption.

RoadRelay was an optional trip computer offered in conjunction with Cummins-powered commercial vehicles. Versions include RoadRelay 3, RoadRelay 4 and RoadRelay 5, and these dash-mounted trip computers record *additional* trip data to that found in the Cummins ECMs, such as trip reports, fault codes and SDD records.

Figure 3.1.2-2. Cummins RoadRelay trip computer

[11]Bortolin, R., van Nooten, S., Scodeller, M., Alvar, D. et al., "Validating Speed Data from Cummins Engine Sudden Deceleration Data Reports," *SAE Int. J. Passeng. Cars – Mech. Syst. 2*(1):970-982, 2009.

3.1.3 Caterpillar

Caterpillar, also widely known in the industry as CAT, introduced its first programmable electronic engine control (PEEC) unit in 1987. Caterpillar heavy- and medium-duty engines manufactured since 1994 feature accessible data although most of the data from these ECUs are limited to configuration data and general parameters. Caterpillar ECUs have had the ability to record Snapshots since November 1995. Beginning in model year 2010, Caterpillar no longer manufactured on-highway engines.

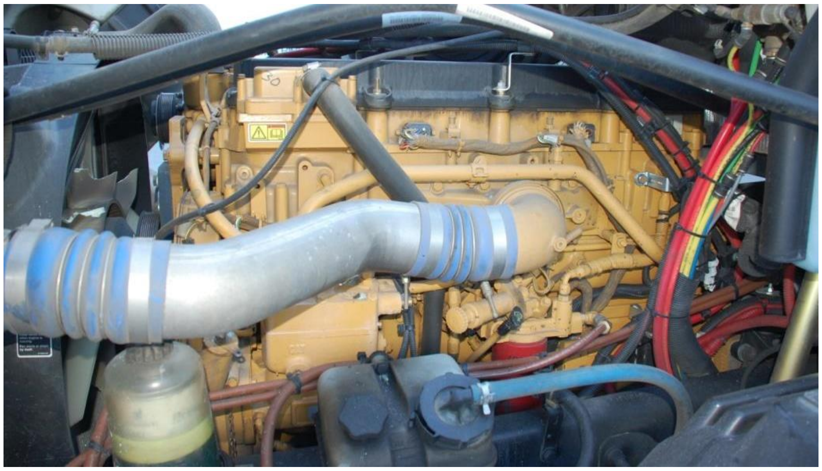

Figure 3.1.3-1. Typical Caterpillar engine ECU location

Caterpillar's modern engine controls are called Advanced Digital Engine Management (ADEM). A snapshot file is created when a user-specified acceleration trigger, the "Quick Stop rate," is sensed. CAT ECUs did not originally have the Quick Stop data recording function enabled from the factory by default until January 2007, after which EPA07 engines left the factory with this feature enabled. It was still possible for a truck owner to enable (or disable) the Quick Stop feature by setting the Quick Stop rate to something other than 0 mph/sec. Caterpillar recommends that the Quick Stop trigger rate be set at 7 mph/sec. Quick Stops record 44 seconds of pre-trigger data and 15 seconds of post-trigger data at a rate of 1 Hz (1 sample per second); such recorded data includes vehicle speed, engine speed, service brake position and acceleration pedal position, clutch pedal position, cruise control status and other data channels.

Diagnostic Snapshots are similar to Quick Stop Snapshots and are created when an engine fault code is generated. In a Diagnostic Snapshot, 19 pre-trigger data points and 7 post-trigger data points are generated at 0.48-second intervals (approximately 2 Hz sampling rate). Fault Snapshots include vehicle speed and service brake position.

Caterpillar engines also have the ability to record externally triggered events, which are created when the driver toggles the cruise control set/resume switch or when technicians trigger events using the CAT Electronic Technician (CAT ET) diagnostic software. Recorded data are similar to that generated by a Diagnostic Snapshot or a Quick Stop Snapshot. This software application also images Caterpillar engine data, including all Snapshots.

As with other OEMs, there are some known data anomalies with CAT engines, including time-stamping all snapshots 24 hours ahead of real time, as well as dating snapshots recorded on the 31st of a given month with the date of December 31, 1969 instead. These anomalies have been documented on ADEM 2000 and ADEM III-equipped engines. Some ADEM 2000, ADEM III Bridge, ADEM IV MXS/NXS and ADEM IV-controlled engines have encountered a different timing anomaly in which the time step between data entries is approximately double the actual duration.[12]

3.1.4 Mack

Mack's electronic engine control system is called Vehicle Management and Control (V-MAC). The system has gone through a few iterations since inception. Beginning in 1998 with the V-MAC III electronic controls, Mack ECUs have had the ability to record incident-specific event data. The V-MAC III system utilized two modules (Figure 3.1.4-1), the engine electronic control unit (EECU) to control engine functions and the vehicle electronic control unit (VECU) to control vehicle functions. Use of this two-module system continued up to 2007.

Figure 3.1.4-1. V-MAC III EECU (left) and VECU (right)

In addition to incident-specific event data, the ECUs recorded trip information, maintenance tracking logs, configuration parameters and fault codes. The V-MAC III VECU also maintained a system clock that was used to time-stamp incident-specific data records. Incident-specific event records varied with the V-MAC III system as different versions of the VECU were implemented. These versions were referred to as "Steps." Step 5 was the first implementation of incident-specific event data recording called DataMax Incident Logging, which captured two acceleration triggered events. Beginning with Step 8 was the capability of recording fault code snapshots, known as Fault Reporter. The last change occurred in the final version of the VECU, Step 12, in which the incident logs changed from recording two acceleration triggered events to one acceleration triggered event and one last stop event. The bulk of this data was stored in the VECU while the EECU mainly housed module-specific fault codes and programming parameters.

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[12] Austin, T. and Farrell, M., "An Examination of Snapshot Data in Caterpillar Electronic Control Modules," *SAE Int. J. Passeng. Cars – Mech. Syst. 4*(1):611-635, 2011

Acceleration-triggered events recorded 15.8 seconds of data pre-trigger and 16 seconds post-trigger and recorded in 0.2-second intervals (5 Hz recording). Data entries included vehicle speed, engine speed, service brake, park brake and clutch application, cruise control switch position, key on/off position, and engine brake high and low switch status. The default triggering threshold is a +/-10 mph/sec change in vehicle speed accompanied by a +/-50 rpm/sec change in engine speed though this is also a programmable parameter.

The last stop event records 15.8 seconds of data before the vehicle comes to a stop and 16 seconds after, also in 0.2 second intervals (5 Hz recording). Last stop records feature the same data entries as acceleration triggered events but also require the park brake application prior to key-off to trigger recording the event.

Both incident-specific events are date- and time-stamped and include the date and time when the data was imaged as well as the date and time of the incident trigger. There is also a mileage stamp reporting the mileage at the time of data imaging and not specific to the incident.

The Fault Reporter feature has the capability of recording and storing the four most recent fault code snapshot events. These events record certain parameters such as vehicle and engine speed for a single moment, or snapshot, of time. They also record the date and time, odometer value, accelerator pedal position, and service and park brake application.

The next iteration of Mack electronic controls, V-MAC IV, was introduced in 2006 and ran until 2013. This system added a third module called the Instrument Panel Electronic Control Unit (IPECU). The VECU and EECU were also present but underwent redesigns as pictured below.

Figure 3.1.4-2. V-MAC IV IPECU (left), EECU (middle) and VECU (right)

V-MAC IV and the current iteration, V-MAC IV+, share nearly the same characteristics but are different from the V-MAC III system. Most notably, incident-specific event logs were updated. For V-MAC IV and V-MAC IV+, the acceleration triggered event and the last stop event both record 90 seconds of data. The acceleration triggered event records 60 seconds of pre-trigger data and 30 seconds of post-trigger data while the last stop event records 90 seconds of pre-trigger data and is triggered when the truck comes to a complete stop. Both events also record and report data in 0.25 second increments (4 Hz). The acceleration-trigger threshold remains the same from V-MAC III, which is set at +/-10 mph/sec change in vehicle speed accompanied by a +/-50 rpm/sec change in engine speed.

These incident logs have timestamps much like the previous iteration of V-MAC III. The only difference is that the mileage stamp is directly related to the mileage at the incident trigger as opposed to the mileage at data imaging.

In addition to these incident logs, V-MAC IV also retained the Fault Reporter feature from V-MAC III. For V-MAC IV, the Fault Reporter snapshots record detailed information around the time of a specific fault occurrence. Up to four snapshots can be logged as well, with one reserved for EECU faults and one reserved for VECU faults. The other two snapshot files log faults from any controller. V-MAC IV+ unfortunately does not support the Fault Reporter feature though it is possible to view expanded fault code data via the Diagnostic Trouble Code readout.

The rest of the data available to be imaged on V-MAC IV is as follows:

- vehicle life and trip reports
- vehicle histograms
- fault codes
- configuration and programmable parameters
- exhaust aftertreatment system logged data
- engine protection data
- sensor values history
- system date and time

V-MAC IV+ features this same data except for the sensor values history.

Each of these Mack systems experience their own data errors as well. The system clock of the V-MAC III, for instance, does not have internal battery backup, so if power is interrupted, the clock may return a random value or revert to a previous value upon imaging. Clock accuracy also degrades over time because there is no an internal battery. The incident-specific event logs also experience data errors. On late version V-MAC III systems, the hard brake event can lock due to the factory testing procedure and cannot be overwritten.[13]

On early V-MAC IV trucks, the VECU would only write incident log files to memory at ignition key-off rather than at the trigger.[14]

3.1.5 Volvo

Volvo trucks have also produced a few iterations of electrical systems and share several similarities with Mack trucks due to Volvo's acquisition of Mack in 2001. Volvo's electrical systems, as they pertain to HVEDR, can be separated into three categories classified by year. From 2002-2011, the Volvo electrical system is referred to as the Legacy Version 2 electronic controls system. This system utilized three ECUs, namely the IPECU, EECU and VECU (pictured below). The

[13]Steiner, J., Cheek, T., and Hinkson, S., "Data Sources and Analysis of a Heavy Vehicle Event Data Recorder – V-MAC III," *SAE Int. J. Commer. Veh. 2*(1):49-57, 2009.
[14]Austin, T., Cheek, T., Plant, D., Steiner, J., and Lackey, L., "SAE C1022," Module 7.

Legacy Version 2 system was capable of supporting the DataMax Incident Logging function with the acceleration triggered and last stop events, but this capability did not come factory-enabled until October 2010 for the 2011 model year.

Fault code-related Freeze Frame data records are specific to Volvo products although somewhat similar to Mack Fault Reporter records.

Figure 3.1.5. Ver. 2/Ver. 3 IPECU (left), EECU (middle) and VECU (right)

Volvo Version 2 was the first iteration to feature DataMax Incident Logging function (acceleration triggered event and last stop event incident logs) enabled from the factory. The Version 2 controls first enabled the DataMax Incident Logging function in Volvo trucks manufactured in late October 2010 and continued until 2013. The Volvo Incident Logs functioned the same as those found in Mack V-MAC IV and V-MAC IV+ and consisted of two recorded events, the acceleration triggered event and the last stop event. Both event logs record 90 seconds of data at 4 Hz and include values for vehicle speed, engine speed, service brake, park brake, clutch application, engine brake low and high, cruise control switch status and key on/off status. The acceleration triggered event records 60 seconds of pre-trigger data and 30 seconds of post-trigger data while the last stop event records 90 seconds of pre-trigger data. The acceleration triggered event threshold is also the same as Mack, set at +/-10 mph/sec change in vehicle speed accompanied by a +/-50 rpm/sec change in engine speed, and the last stop event is triggered when the vehicle comes to a 0-mph stop.

These two incident logs are also time-stamped the same way that Mack V-MAC IV and V-MAC IV+ incident logs are stamped; each incident log is stamped with the date and time of the data imaging and the incident trigger, though the mileage is stamped with the mileage at the time of the incident trigger.

As aforementioned, the other incident-specific data are called Freeze Frames. A Freeze Frame is captured and stored when certain fault codes are activated. When this occurs, the system records five separate frames of data: two frames are recorded prior to fault code activation, one is recorded at the time of activation, and two are recorded after activation. These data frames are captured at 30 second intervals, so the two frames captured prior to fault code activation span anywhere from 0 and 30 seconds prior to 30 and 60 seconds prior, depending on when the fault occurred. This is due to the nature of the circular buffer on which the data is captured. The data stored in each frame include vehicle and engine speed, accelerator pedal position and total distance in miles. In addition, these Freeze Frame events are stamped with engine hours at occurrence as well as the vehicle's total engine hours.

Volvo trucks are additionally equipped with a Supplemental Restraint System (SRS) ECU. This is an airbag system exclusive to Volvo trucks (in the NAFTA market) that has the capability of storing occupant restraint system performance data, such as restraint system readiness, diagnostics status and an acceleration time history record limited to 150 ms.[15]

3.1.6 International/NAVISTAR

International manufactures engines for heavy-duty and medium-duty commercial vehicles. MaxxForce 7 engines are used in Class 4 and 5 medium-duty vehicles while MaxxForce DT 9 and 10 engines are used in Class 6 and 7 medium-duty vehicles. MaxxForce 11, 12 and 13 engines are used in Class 7 and 8 heavy-duty vehicles. Current offerings from International/Navistar include MaxxForce N9, N10 and N13 engines. For model year 2018, Navistar has introduced a Class 8 heavy-duty turbo-diesel engine, the A26 with a displacement of 12.4 liters.

International engines have had the ability to record and report fault code data since 2007 but have not recorded incident-specific data since the 2010 and later MaxxForce 11, 13 and 15 engines. Such data include the two most recent acceleration triggered records and two most recent last stop records. Newer event data overwrite acceleration triggered and last stop records in the FIFO format.

Acceleration-triggered events are recorded when the programmable event trigger is defeated. The acceleration triggered event contains 105 seconds of pre-trigger data, a snapshot at the time the trigger occurred and 15 seconds of post-trigger data—all recorded in 1-second increments (1 Hz). In addition to reaching the trigger threshold for recording, testing has found that, with the trigger set at 5.5 mph/sec, the vehicle must travel at greater than 14.29 mph to record event data. With the trigger set at 9.5 mph, the vehicle must travel at greater than 28.58 mph.

Last stop event data are recorded when the vehicle comes to a stop and the engine is shut down (ignition off), or the vehicle comes to a stop and the engine remains at idle for more than 2 minutes. Time stamps at occurrence include real-time clock value, ECM total distance and trip distance, and engine hours. The last stop record is also stored at 1 Hz and includes 105 seconds of pre-event data, a snapshot at the time of stop and 15 seconds of post-event data.

Freeze Frame data provide another type of event-specific data, and recording is triggered when a fault is detected. Freeze frames record data for a single point in time and include such parameters as vehicle speed, engine speed, accelerator pedal percent, brake switch and clutch switch. Freeze Frames are stamped with the odometer and engine hours at occurrence.

[15] Ibid., Module 8.

No formal research has explored the implications of sudden power loss for International engines. However, preliminary findings[16] suggest that for the last stop record to be written, the ECM requires up to 2 minutes of power to write a new last stop record without an “elegant shutdown.” In the case of a key-off, the ECM requires approximately 20 seconds of power to write the new file. The hard brake record appears to require approximately 15 seconds of power following the hard brake incident to record the file.

ServiceMaxx is the software required to image data from International/Navistar engines. Some versions of the ServiceMaxx software, such as version 39.64 released in May 2014, have been unable to access the data. The fix for this issue was released in August 2014 in version 40.1.119. In cases where data are not retrievable, checking the software version in use is advised.

3.1.7 PACCAR

PACCAR is an international truck and engine manufacturer. PACCAR’s North American brands include Kenworth, Kenmex (Kenworth Mexicana) and Peterbilt; European brands include Leyland and DAF; and Australian brands include Kenworth and DAF. North American brands may use PACCAR, Cummins or Caterpillar (prior to MY2010) engines.

PACCAR turbo-diesel engines consist of medium-duty and heavy-duty engines. Medium-duty engines include the PX-7 and PX-9 turbo-diesel engines. It is important to note that the PX series of PACCAR engines are rebadged Cummins ISB (PX-7) and ISC (PX-9) engines with Cummins electronic controls. The PX-7 and PX-9 engines have the capability to record and report the previously discussed Cummins Sudden Deceleration data records. Additionally, Cummins software and protocols are followed for imaging data from PACCAR PX-7 and PX-9 engines.

Heavy-duty PACCAR turbo-diesel engines include the MX-11 and MX-13 engines and are native PACCAR engines with PACCAR electronic controls. The PACCAR electronic controls may be equipped with a HVEDR function referred to as the Fast Stop Recorder. The Fast Stop Recorder is enabled by factory default, but the customer has the option to disable it.

Fast Stop event data are imaged by using the DAVIE4 diagnostic software. Additional data including Diagnostic Trouble Codes (DTCs) for the PACCAR Multi-Controlled Injection (PMCI) and Emissions After-Treatment System (EAS), Freeze Frames, Fast Stop Recorder, Life and Trip data, Snapshot Recorder and Programming Parameters are also available. In order to image event data with DAVIE4, a live internet connection is required.

The Fast Stop Recorder (a hard brake event record) stores the last three events. Events span 10 total seconds, with 5 seconds of pre-trigger data and 5 seconds of post-trigger data recorded at 4 Hz. Events are time-stamped with the engine ECU serial number, total engine hours and total vehicle distance. The default Fast Stop trigger is 8.95 mph/sec, and unpublished testing has shown that the minimum vehicle speed needed to record a Fast Stop event is approximately 30 mph.

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[16]Ibid.

PACCAR's Snapshot Recorder captures data from a specific instant in time. Up to three snapshots may be stored and are replaced by new snapshots in FIFO format. Snapshots record data for 15 seconds that include 10 seconds of pre-trigger data and 5 seconds of post-trigger data at a recording rate of 2 Hz. Snapshots are triggered by certain DTCs but may also be manually triggered by pressing the Cruise Control "Resume" switch then the "Set" switch in immediate succession.

DAVIE4 software allows viewing of active, inactive and pending DTCs. The interface displays the number of DTC occurrences along with snapshots of the first and last occurrences. Some DTCs contain Freeze Frames with extended Snapshot data. Certain "critical" DTCs are associated with Freeze Frames with multiple frames; this type of Freeze Frame will store five frames before the trigger and four frames after. Freeze Frames record multiple parameters, including vehicle speed.

3.1.8 Bendix

Bendix is a supplier of commercial vehicle components including various safety and stability systems for medium- and heavy-duty trucks, tractors, trailers, buses and other commercial vehicles in North America. These systems include ABS, electronic stability control (ESC) and collision mitigation technology. Bendix systems are commonly found on Mack, Volvo, Peterbilt, Kenworth and International truck tractors. Over the years, Bendix has developed these and other safety systems capable of recording incident-specific data. Since approximately the 2013 model year, a vehicle equipped with some versions of the EC-60 generation of ABS/ESC ECU and the newer EC-80 ECU may be equipped with the Bendix Data Recorder.

Bendix has developed variations in their ABS systems dependent on the size and configuration of the truck (or bus) to ensure that the vehicle meets FMVSS 121. Some examples of these variations are ABS with automatic traction control and added stability control systems, such as roll stability program/control (RSP/RSC) and "full stability" or electronic stability program/control (ESP/ESC). Depending on the system, the vehicle is equipped with different sensors that can measure wheel speed, lateral and longitudinal acceleration, steering angle, brake pressure and yaw rate.

Bendix's main collision mitigation system is referred to as the Wingman Collision Avoidance System. The Wingman Collision Avoidance System is built on the foundational ABS and ESC system and adds Forward-Looking Radar (FLR) and a windshield-mounted camera for detecting other vehicles and objects in front of the Wingman-equipped vehicle. There are three versions of the Wingman system: Wingman ACB, Wingman Advanced and the latest model, called Wingman Fusion. Wingman Fusion is the most comprehensive safety system of the three and provides the most features, including overspeed alerts, stationary vehicle braking and advanced collision mitigation.

Bendix's lane departure warning (LDW) system called AutoVue can be added to the ABS/ESC and Wingman safety systems. The AutoVue LDW system utilizes a windshield-mounted camera to detect the painted lane markings and provide visual, audio and haptic feedback to the driver if the vehicle starts to depart from its lane of travel.

SafetyDirect is another Bendix safety system. It pairs with an existing telematics system and allows the collection and transmission of safety data and video. SafetyDirect may be streamed to a server and/or captured in an on-board data logger. Data include:

- video of severe events as captured through AutoVue camera
- 10 seconds pre- and post-trigger for onboard
- 5 seconds pre- and post-trigger for transmit
- lane changes without turn signal
- excessive curve speed
- excessive braking (measured through internal accelerometer)
- following distances
- ABS and stability control events
- speeding (if equipped with AutoVue)
- hard brake events that include speed, timestamp and location

The Bendix Fusion system combines advanced safety technologies such as a forward radar, camera, brakes, event recorder and SafetyDirect into an integrated, comprehensive driver assistance system.

The AutoVue and SafetyDirect systems can be paired together and utilize one ECU. The AutoVue/SafetyDirect ECU is connected to the AutoVue camera. It may therefore serve a dual function as both a controller for Bendix AutoVue LDW and a processor/recorder for SafetyDirect telematics (if enabled). The AutoVue system only records data/video if SafetyDirect is enabled when initially ordered or configured to "on" at a later time. SafetyDirect has 16 different triggers that are configurable, but only certain triggers are configurable for video. Video continuously records for 10 seconds to two alternating RAM (volatile) buffers. When triggered, video records for an additional 10 seconds post-trigger, and this video then transfers to flash (non-volatile) memory. It is important to note that power interruption may result in loss of video or data that has not completed this transfer. Available data include event type, time and date, vehicle speed, odometer value, GPS latitude/longitude, accelerator pedal position and brake application.

Aside from the aforementioned systems, newer Bendix ABS provide the possibility of data in the form of the Bendix Data Reporter (BDR). The Bendix ACOM diagnostics software can be used to image diagnostics and configuration data from the ABS/ESC ECU. However, the Bendix ABS ECU has to be removed from the vehicle and sent in to Bendix for imaging and reporting the BDR data. Data availability depends on both the ECU type and software configuration. The software configuration of the Bendix ABS ECU can be found on the ACOM Event Report. The ECU types with data potentially available are the EC-60 and EC-80 ECUs. These ECUs can store four or more events and are time-stamped using "engine hours." Each event records 20 seconds of data split into 10 seconds of pre-trigger data and 10 seconds of post-trigger data at 2 Hz intervals. The Bendix EC-60/EC-80 systems that are built in 2013 and later feature the following event triggers:

- when the magnitude of lateral and/or longitudinal acceleration exceeds 0.5g in any direction. (acceleration > 0.5g)
- when vehicle speed is reduced by 6.9 mph or greater in one second (hard brake)
- when there is a Wingman Advanced system brake intervention
- when Active Cruise with Braking (ACB) is set and either the takeover alert (or impact alert) or the driver overrides the system.

The ECUs follow the FIFO process for the overwriting of event logs for new events. Severe events, such as acceleration change greater than 0.85g or vehicle speed change greater than 9 mph/sec, can be "locked". These locked events will not be overwritten until after the next 50 events are recorded. Only two events are lockable at a time and, if a third event deemed to be lockable occurs, the oldest event is overwritten.

Available data elements that can be imaged from an EC-60/EC-80 include vehicle speed, steering wheel angle, accelerator pedal position percent, CCVS (J1939 Cruise Control/Vehicle Speed) brake light request, driver service brake application pressure, park brake status, cruise control status, brake lamp request status from Bendix ECU, FLR audible alert type issued, FLR intervention status, ABS activity (on any controlled axle), ESP intervention, and HSA (Hill Start Assist) intervention. If a data element is not present at the time of recording, it is indicated with "N/A," blank or a specific code.

Most of the data available on the above-mentioned Bendix systems are obtained via the Bendix ACOM Diagnostics software with the exception of the BDR data. At present, the only manner of BDR data retrieval is by sending the EC-60/EC-80 ECU to Bendix.

3.1.9 Meritor WABCO

Meritor WABCO is another available ABS system and a direct competitor to Bendix. Meritor offers basic information on the ABS ECU, such as configuration, part/serial numbers and software version. Additional information that can be taken from the Meritor ABS module includes fault codes (active and stored-inactive), programmed tire size and a function to report and save all EEPROM data in hexadecimal format.

Meritor WABCO offers a collision mitigation system marketed as Meritor OnGuard®, which provides audible and visual stationary-object warnings that alert drivers to possible lane obstructions. In addition, OnGuard features haptic warnings, which provide short brake pulses that can aid in drivers to respond faster to imminent rear-end collisions. OnGuard consistently operates while the vehicle is traveling at speeds above 15 mph when cruise control is not set and applies up to 50% of the vehicle's braking power to help avoid or mitigate an impending collision.

There are two generations of OnGuard currently on the road. Meritor WABCO launched the first model in 2007; referred to as Gen. 1, this OnGuard system provided a maximum deceleration rate of up to 0.35g without any driver intervention and was not designed to react to stationary objects. The following Gen. 2 system was released in early 2013 and eventually allows up to 0.6g of deceleration when the target is a moving vehicle and up to 0.3g in response to a stationary object.

The Meritor WABCO Toolbox software can image the data, which include DTCs (which may include snapshot data) and parameters. Parameters must be submitted to Meritor WABCO if retrieved from a Gen. 1 model, but Gen. 2 models have the capability to decode the parameters through the Toolbox software.

OnGuard systems contain certain stored and active data. “Active” data stored in the OnGuard system are overwritten by the next mitigation event. It is recommended that the truck or radar be taken out of service until this data can be imaged. The “parameters” file contains event data that can be decoded by Meritor WABCO. Toolbox (Ver. 11.3 or higher) makes decoding the parameters file possible; alternatively, the radar unit can be removed and sent to Meritor WABCO for imaging.

WABCO also provides OnLane LDW to aid in preventing unintentional lane departures that can lead to commercial vehicle accidents. This is accomplished through a system that incorporates a windshield-mounted camera to detect roadway lane markings. During normal driving, the system:

- Detects lane marks and helps keep the vehicle in the lane.
- Monitors the road ahead and areas on either side of the vehicle’s lane via a camera mounted at the top or bottom of the vehicle’s windshield.

The system also assists in preventing unwanted lane departures by:

- Detecting unintentional lane departures when the vehicle crosses lane marks without an activated turn signal.
- Providing the driver with a visual, acoustic or seat-vibration warning to indicate unwanted lane departures on either side of the vehicle.
- Warning the driver about unintentional lane departures when the vehicle’s speed is 60 kph (38 mph) or more.

The same Toolbox software is used to view and image OnLane video files. Video records about 10 seconds before and 5 seconds after trigger, and up to 20 video clips can be stored in the FIFO method.

3.2 ELDs

Numerous companies have manufactured ELDs as well as AOBRDs. These two devices differ in their technical specifications as outlined in each Code of Federal Regulations (CFR) and the ELD mandate proposed by FMSCA. The “Electronic Logging Devices and Hours of Service Supporting Documents” final rule (80 FR 78292), otherwise known as the ELD mandate, is a rule designed to improve commercial motor vehicle (CMV) safety and reduce the overall paperwork burden for both drivers and motor carriers. Increasing the use of ELD within the motor carrier industry is intended to improve compliance with applicable HOS rules. This mandate largely stipulates new technological specifications for ELD that address statutory requirements, require ELDs for drivers that currently use Record of Duty Status (RODS), clarify supporting-document requirements so motor carriers and drivers comply efficiently with HOS regulations, and adopt both procedural and technical provisions for ensuring ELDs are not used to harass CMV operators. Several statutes have established the foundation for this rulemaking, including:

- Motor Carrier Act of 1935
- Motor Carrier Safety Act of 1984
- Reform Act of 1988
- Hazardous Materials Transportation Authorization Act of 1994
- MAP-21 (Moving Ahead for Progress in the 21st Century Act)

The final version of the mandate was published on December 16, 2015 and implemented changes to document requirements, technical specifications, exemptions and ELD certification for potential third-party ELD contributors. Under the current rule (80 FR 78292), FMCSA estimates 1,844 crashes could potentially be avoided, which would in turn save around 26 lives annually.

In the 2011 Notice of Proposed Rulemaking (NPRM; 76 FR 5537), FMCSA proposed that drivers using RODS more than two out of seven days must use an ELD, and drivers using RODS for two or fewer days out of seven could continue to use paper. However, this idea accumulated rejection, and FMCSA proposed an eight in 30-day threshold for ELD use. While the 8/30-day threshold preserves nearly the same ratio as the proposed 2/7 threshold, the extended time provides drivers and motor carriers more flexibility. Additionally, the eight-day period is the standard timeframe for current HOS recordkeeping requirements. ELD use would be required only if a driver operates outside the short-haul exception to the paper RODS provision for more than eight days of any 30-day period. FMCSA declined to limit the regulation to CMVs over 26,000 pounds or exempt small passenger vehicles.

The ELD mandate's main modification to document requirements has been in lowering the previous Supplemental Notice of Proposed Rulemaking (SNPRM; 79 FR 17656) proposal for 10 minimum documents to eight. FMCSA maintained that only two or three documents obtained through the normal course of the day's business is an insufficient number for verifying accuracy of driver RODS in compliance with the 60/70 rule, which stipulates how many on-duty hours a driver may perform in a given period of days.

Modifications to these stipulations required that drivers submit supporting documents to motor carriers no later than 13 days after receiving them—an extension from the original eight-day period allowed by the SNPRM—while motor carriers must retain RODS and supporting documentation for six months.

FMCSA's proposed supporting-document requirements clarify ELD certification. FMCSA stated the changes to supporting-documents requirements were to improve quality and utility of retained documentation and to increase efficiency of FMCSA's review process of motor carriers HOS records and detection of HOS violations. The Agency highlighted that ELDs provided the most robust form of HOS documentation to that end. Although FMCSA noted that ELDs are highly effective at monitoring compliance with HOS rules during driving periods, supporting documents are still needed to verify on-duty, not driving (ODND) time.

To meet the supporting-documentation requirements, documents must feature certain criteria, including driver name or carrier-assigned identification number, location, date and time. Examples providing such data include bills of lading, itineraries and schedules; dispatch or trip records; expense receipts reflecting ODND time; payroll and settlement records; and electronic mobile communication records transmitted through fleet management systems (FMS) during the driver's duty day.

ELD provides such pertinent HOS compliance data as driver identification, location, date and time, timestamp for CMV engine power-up or -down, engine hours, vehicle miles, duty status, vehicle information, motor carrier identification and authenticated user data. FMCSA outlined specifications for data recording that are compliant with the new mandate. These data elements are automatically recorded when the driver changes duty status or another special driving category. ELD records all data in the case of a driver logging in or out of the ELD or a malfunction of data diagnostic event, except for geographic location. For purposes of HOS enforcement, FMCSA requires all ELDs to record location in a way that provides an accuracy of approximately a 1-mile radius during on-duty driving periods. When the engine powers up or down, or the CMV is in motion without a driver triggering recording within the previous hour, ELD records all required elements. However, during a period of driver-indicated authorized use, a record may leave some elements blank, and location information records at single decimal point resolution, or a 10-mile radius.

The ELD rule stipulated internal synchronization interfacing with the CMV engine ECM, to capture engine power status, vehicle motion status, miles driven, and engine hours automatically. The time associated with ELD must be synchronized to UTC, and absolute deviation was not to exceed 10 minutes at any point. ELDs must also have the capability to monitor compliance (engine connectivity, timing, positioning, etc.) for detectable malfunctions and data inconsistencies and be able to record such occurrences.

The following table from the FMCSA document outlines the malfunction coding required by the mandate, including engine synchronization compliance malfunctions. Such malfunctions can be captured as illustrated. For example, a record can capture when the ECM or its connectivity remains unresponsive for more than 5 seconds or the ELD is unable to capture the data until fully operational again. FMCSA has clearly indicated that they expect all compliant ELDs to adhere to consistent connectivity standards.

Table 4

Standard Coding for Required Compliance Malfunction and Data Diagnostic Event Detection

Malfunction/Diagnostic Code	Malfunction Description
P	"Power compliance" malfunction
E	"Engine synchronization compliance" malfunction
T	"Timing compliance" malfunction
L	"Positioning compliance" malfunction
R	"Data recording compliance" malfunction
S	"Data transfer compliance" malfunction
O	"Other" ELD detected malfunction

Malfunction/Diagnostic Code	Data Diagnostic Event
1	"Power data diagnostic" event
2	"Engine synchronization data diagnostic" event
3	"Missing required data elements data diagnostic" event
4	"Data transfer data diagnostic" event
5	"Unidentified driving records data diagnostic" event
6	"Other" ELD identified diagnostic event

Figure 3.2. FMCSA ELD coding for compliance malfunctions[17]

This mandate requires interstate motor carriers to use only FMCSA-compliant and registered ELDs, a list of which FMCSA has published on its website.[18] FMCSA has also published compliance-test procedures to assist providers in determining whether their products meet the requirements.

Problems anticipated with the mandate included the failure to improve HOS compliance or highway safety, imposition of excessive costs, invasion of privacy and inadequate protection of drivers from harassment. FMCSA addressed some of these concerns in the 2014 SNPRM (79 FR 17656) while justifying the mandate with the ease of logging, paperwork reduction and accurate records.

A stipulation was presented that ELDs should be limited to only carriers with severe HOS violations. FMCSA ultimately rejected the suggestion to exempt experienced drivers with strong safety records from the requirement due to the difficulty in crafting criteria for identifying eligible drivers. FMCSA further ruled that Congress did not stipulate the safe-driver thresholds when enacting the MAP-21 provision requiring FMCSA to mandate ELD.

The rule also advanced industry standards for handling data and access requirements, ensuring only authenticated individuals could access an ELD system. An ELD record reflecting a driver's RODS is considered the driver's record although motor carriers are responsible for maintaining these for six months under Federal Motor Carrier Safety Regulations (FMCSRs). Motor carriers and drivers therefore share responsibility for record integrity. Motor carriers are responsible for maintenance of these records for a 6-month period. Limited editing rights and shared ability of the

[17]Source: FMCSA, *Electronic Logging Device (ELD) Test Plan and Procedures*, p. 9, 2016.

[18]https://csa.fmcsa.dot.gov/ELD/List

driver and motor carrier to annotate records was expected to ensure accurate records without an unreasonable number of edits or complicated data for enforcement.

FMCSA also outlined changes to technical specifications, including ELD data-transfer options. One option allows telematics-style ELD data transfer over web services and email while the second uses local connectivity methods of Bluetooth and USB 2.0. However transferred, the ELD must provide data via display or printout to a safety authority on demand. Two exemptions from ELD use are permitted; the first is in the case of driveaway-towaway operations in which the driven vehicle is part of the shipment, and the second is for CMVs older than model year 2000. Drivers using paper RODS for no more than eight days in a 30-day period are allowed to continue to use paper logs instead of ELD in addition to the previous two exemptions.

The 2014 SNPRM (79 FR 17656) evaluated four options during proposal drafting. The second option was agreed upon and mandated ELDs for all CMV operations in which the driver is required to complete RODS under 49 CFR Part 395.8. This was objected to on the grounds of government imposition of device installation in private property as well as the possibility of drivers bending rules while still tampering with RODS to portray compliance.

Exemptions were therefore advanced for some CMV operations, but these were limited given the mandate's purpose for reducing fatigue-related collisions. The National Limousine Association argued that the mandate should focus on long-haul operators, who are more subject to fatigue-related incidents, as opposed to short-haul operators with greater compliance and safety records. It was decided the mandate applied to all CMV operations in which drivers are required to maintain RODS. FMCSA declined to provide industry-specific exceptions, given the lack of safety performance data for specific industry segments and the fact that industry segments often overlap. FMCSA established that its safety requirements generally do not vary for fleet size or small businesses. FMCSA anticipated that most of the industry segments seeking relief from the ELD-mandate are addressed, in part, under the short-haul exemption under 49 CFR Part 395.

U.S. Department of Transportation regulations govern the release of private information, including requests for purposes of civil litigation. In addition to other statutory privacy protections, under 49 U.S.C. 31137 (e)(1) and (3), MAP-21 limited the way FMCSA may use ELD data and required that law enforcement personnel use information collected from ELDs to determine HOS compliance only. These measures were to be included in the ELD implementation and training protocol currently under development within FMCSA. Thus, drivers and carriers share responsibility for the record's integrity, and FMCSA did not plan to retain ELD data during investigations. Regarding privacy, FMCSA stated that the rule "includes industry standards for protecting electronic data, regulates access to such data and requires motor carriers to protect drivers' personal data in a manner consistent with sound business practices. FMCSA has limited authority to ensure total protection of information in the custody of third parties."[19] FMCSA furthermore acknowledged a potential market for additional security features.

[19] FMCSA, 49 CFR Parts 385, 386, 390 and 395, "Electronic Logging Devices and Hours of Service Supporting Documents."

The National Transportation Safety Board (NTSB) asked FMCSA to consider adding crash survivability for ELD and ELD data; however, FMCSA had not yet required crash survivability standards for ELDs due to costs involved. Crash survivability would require the ELD withstand high-impact or crash forces, be water resistant and withstand extended exposure to open flame—an expensive and complicated requirement. Furthermore, FMCSA has not required full interoperability between all ELDs for similar concerns of complication and cost.

FMCSA highlighted their intentionality in setting standards that can be met by reprogramming currently existing devices with low additional cost to carriers. FMCSA clarified that the ELD in the CMV only need retain data for a current 24-hour period and the previous seven consecutive days. The requirement for carriers to retain data records for six months was estimated to require only 10 MB of storage.

As of the date of this report, there are currently 211 ELDs self-certified by the manufacturers and registered with FMCSA's published list online. The following provides information on four of the many self-certified and registered ELDs recognized by the FMCSA as compliant with upcoming ELD regulations.

Although ELD is outside of the scope of this HVEDR feasibility study, ELDs are discussed here as most of these devices feature EDR/HVEDR functionality. The following sections highlight providers that have cornered the largest share of the ELD manufacturing market.

3.2.1 Omnitracs

Omnitracs, LLC reports to have pioneered the use of commercial vehicle telematics for over 25 years and provided the transportation industry with "solutions for compliance, safety and security, productivity, telematics and tracking, transportation management (TMS), planning and delivery [and] data and analytics."[20] The Omnitracs Intelligent Vehicle Gateway (IVG), pictured in Figure 3.2.1, is an ELD mandate-compliant telematics device that supports electronic logging capabilities for trucking fleets and other companies. The IVG can be installed in 30 minutes or less, and the system is hardwired to the ECM. The advantages of this device are its flexible network connection, future scalabilities, integration options and hands-free access to key information.

[20] Omnitracs LLC, "Omnitracs Strengthens Partnership with C.H. Robinson, Providing Virtual Load View Tracking Solutions," Oct. 17, 2017.

Figure 3.2.1 Omnitracs IVG[21]

3.2.1.1 Operational Requirements

Fleet operators are able to comply with the recent government regulations, cross-border controls and local rules imposed on them using the Omnitracs system. Omnitracs offers fleet drivers comprehensive compliance with HOS regulations, the International Fuel Tax Agreement (IFTA), the ELD mandate, as well as FMCSA and DOT compliance. This device may appeal to fleet managers, who especially understand the need for selecting compliance solutions that stay ahead of changing regulations to ensure continuity for their business.

3.2.1.2 Equipment Requirements

As depicted in Figure 3.2.1.2-1,[22] Omnitracs has developed the Routing, Dispatching and Compliance (RDC) system, which combines routing, trip management, and HOS and DVIR compliance functions in a single application with a backend for fleet drivers to view all data on one mobile device. Alternatively, the spectrum of software products is available on mobile phones, tablets and computers. The Omnitracs Relay Telematics device is easy to install and allows reception of real-time GPS data points to generate a variety of driver performance and vehicle performance reports.

Figure 3.2.1.2-1 Omnitracs RDC System

Figure 3.2.1.2-2 below displays the interconnection between the Omnitracs system and a fleet vehicle.

[21]Source: https://www.omnitracs.com/products/omnitracs-ivg

[22]Source: Omnitracs LLC, “Omnitracs Routing + Dispatching + Compliance (RDC),” 2017.

Figure 3.2.1.2-2. Omnitracs IVG interconnecting hardware[23]

3.2.1.3 Technical Specifications

FMCSA's ongoing development of technical specifications for compliant ELDs has specific goals that must be met regarding interoperability, cost reduction, technology evolution, and driver harassment prevention and privacy. Omnitracs has addressed such ELD specifications through features such as making ELDs "tamper resistant" to unauthorized changes to the hardware, software and stored data. Collected data must be easily transmitted to authorized enforcement officials, protecting driver privacy.

3.2.2 PeopleNet

PeopleNet (a Trimble Company) is a provider of web-based solutions for carrier fleet management. The PeopleNet Fleet Manager system provides secure online control of both communications and fleet management functions, including online mapping, messaging, driver-based and vehicle-based reporting, interactive dashboards, online billing usage, alarm notifications and security fleet settings and preferences, user management and group management. Fleet Manager also allows comparative key performance indicator (KPI) reporting, including viewing various reports in real-time, performing historical trend analysis and obtaining reports via e-mail. Regarding performance, the PeopleNet system can generate driver information reports as well as engine-related performance metrics reports such as speed, rpm, fuel efficiency and idle time.

[23] Source: Omnitracs LLC, "Intelligent Vehicle Gateway: Getting Started," 2016.

3.2.2.1 Operational Requirements

The PeopleNet eDriver Logs are compliant with both the ELD mandate and U.S. Regulation 395.15, which includes state regulations for Texas, California, Florida, Alaska, and Canadian regulations below the 60th parallel, regarding AOBRDs. PeopleNet's Electronic Driver Vehicle Inspection Report (eDVIR) solution meets all FMCSA requirements for electronic vehicle inspection records and simplifies the DVIR process by eliminating issues associated with paper records and paperwork maintenance.

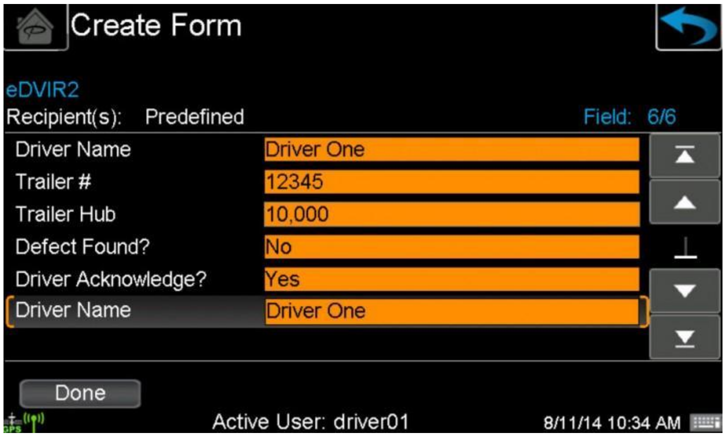

Figure 3.2.2.1. PeopleNet eDVIR[24]

Another PeopleNet product, Drivewyze™ PreClear, helps maximize opportunities of weigh station bypasses—especially for fleets with solid safety and compliance records. This device features hands-free operation in compliance with federal and state distracted-driving regulations. It further ensures data privacy protection, given that no personal or proprietary data are stored on in-cab devices or transmitted during operations.

3.2.2.2 Equipment Requirements

PeopleNet's manufacturing partners allow fleet owners to view truck diagnostics remotely and in in real-time. In a pre-wired truck, owners need only mount the PeopleNet onboard computer and display for their trucks to be on the way to increased safety and compliance, reducing operating cost and improving customer service.

With pre-wired vehicles, only a PeopleNet in-cab display need be added to utilize the additional features this device offers, such as remote diagnostics and the PeopleNet Fleet Management system. Currently, a number of new tractors are pre-wired for the PeopleNet System, which features the following:

- **Power.** The PeopleNet Main Cable, using dedicated circuits, is directly connected to the vehicle's power system, which eliminates the need for standard fuse holders. The

[24]Source: https://www.peoplenetonline.com/products/safety-compliance/compliance-solutions

Main Cable connector is typically located under the sleepers or at the back wall (day cab), allowing the installer to easily connect the PeopleNet system.

- **Antennas.** As a convenience, PeopleNet has made available the fully-assembled GPS & Cellular Antennas mounted on the vehicle.
- **Engine Diagnostic & Fault Code Access.** A direct connection into the vehicle's J1708/1939 bus enables comprehensive vehicle data collection through the PeopleNet Vehicle Management application, which allows access to vehicle data, enhanced reporting, scorecards and dashboards, PTO data collection and easier integration with third-party systems. Collected engine data includes average, max, over and excess speeds; over RPM; various idle durations and frequencies; ambient temperature; and headlight and seatbelt use. More pertinently, PeopleNet's Onboard Event Recording (OER) collects such event data as sudden acceleration (SA), sudden deceleration (SD), manual trigger (MT) and stability control (SC).[25]

3.2.2.3 Technical Specifications

PeopleNet Display.4 is shown in Figure 3.2.2.3-1 and its technical specifications in Figure 3.2.2.3-2.

Figure 3.2.2.3-1. PeopleNet Display.4[26]

[25] Source: PeopleNet, "PeopleNet Display.4 & TABLET: Quick Reference Guide," 2014.

[26] Source: https://www.peoplenetonline.com/technology/hardware/android-tablets

Technical Specifications

Processor
- i.MX535 – ARM Cortex – A8 Core @ 1 GHz

RAM Memory
- 512MB DDR3

Storage Memory
- 16 GB iNAND flash memory + SD Card expansion

Operating Temperature
- -20° to +70°C

Operating System
- Windows Embedded Compact 7 operating system

Connectors
- Two high-speed USB 2.0 ports (1 on the unit and 1 on the cable)
- Audio jack for external speaker
- Microphone Jack

Networking
- WiFi 802.11 b/g/n and Bluetooth v4.0 + EDR standard

Figure 3.2.2.3-2. PeopleNet Display.4 Technical Specifications[27]

3.2.3 Geotab

Geotab has been in the telematics industry for more than 15 years and is ranked among the top leaders in technology innovation. Geotab Cloud ELD is a user-friendly and reliable fleet platform for tracking, managing, and sharing RODS. In general, the Cloud ELD is reliable and robust when compared to other types of ELD solutions that are hard-wired, use Bluetooth pairing to work, or require records be downloaded to USB. Carriers can use Cloud ELD to ensure their HOS data are kept safe and secure. Geotab's ELD is effective with keeping carriers in line with regulations and avoiding compliance violations, fines and potential harm to their Compliance, Safety, and Accountability (CSA) score.

3.2.3.1 Operational Requirements

The individual components of the Cloud ELD system ensure a reliable, accurate and stable flow of data in a concerted manner. The Engine and GPS Data from the GO device is sent to the MyGeotab server. Duty Status logs are created on the server, then pushed down to the Geotab Drive App together with engine and location information.

As the vehicle is driven, the Geotab system follows a cyclical process:
1. The Geotab GO device sends engine and location data to MyGeotab.
2. The Drive App sends the driver's duty status to MyGeotab.
3. MyGeotab combines data from the Drive App and the GO device to create an accurate RODS.
4. MyGeotab sends the updated information back to the Drive App.

3.2.3.2 Equipment Requirements

The main interface is the OBD-II port connector, into which the Geotab GO7 vehicle tracking device plugs directly.

[27] Source: PeopleNet, "PeopleNet Display.4," 2015.

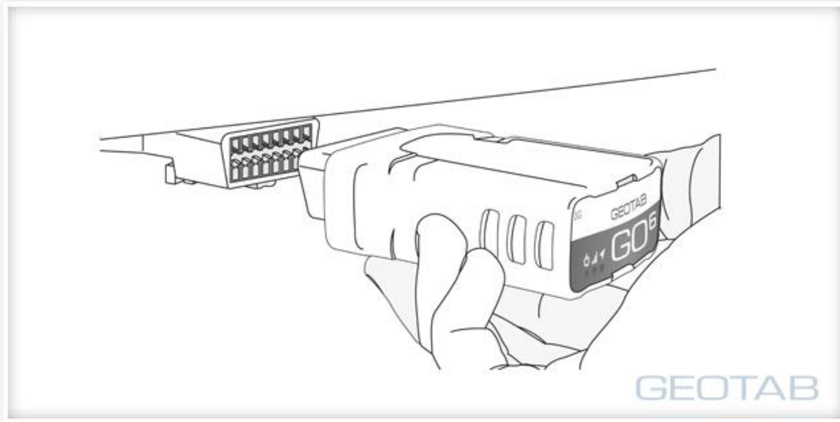

Figure 3.2.3.2-1. Geotab OBD-II plug-in[28]

Geotab's online fleet management platform and IOX Expansion technology can be extended for integration with third-party providers and add-ons that include satellite tracking, driver ID, HOS and camera systems.

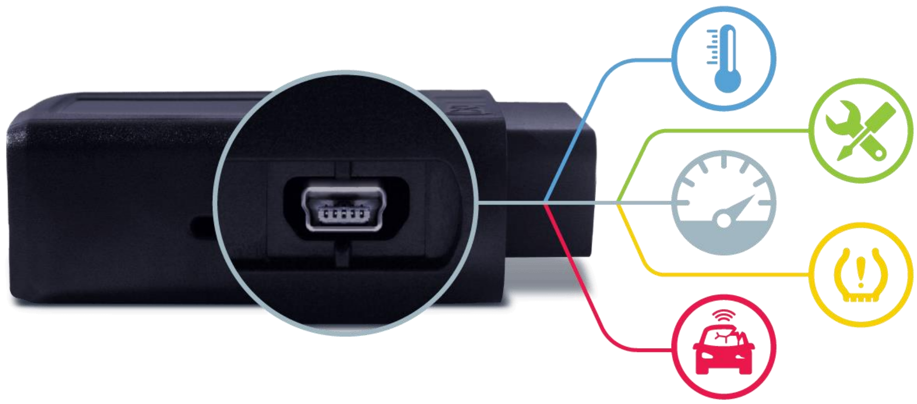

Figure 3.2.3.2-2. IOX Expansion input/output interface[29]

GO7's internal networks capture data from multiple sources, including the engine, drivetrain, instrument cluster and other subsystems. Geotab's various reports for accidents and log data, accelerometer graphs, speed profiles, RPM graphs, and exceptions reports facilitate accident reconstruction and the determination of what happened before, during, and after collision; for example, accident detection logs and accelerometer logs can be used to determine accident severity.[30] GO7 has capability of detecting in-vehicle reverse collisions as well.

If an accident is detected, an email or desktop alert can be set up that provides the manager with first notice.

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[28]Source: Geotab, "Differences in OBD Plug-In Fleet Management Devices," 2012.

[29]Source: Khan, T., "Guide to Geotab IOX Add-Ons," 2018.

[30]Ahmed, S., "Fleet Manager's Guide to Accident Reconstruction with Telematics Data," 2016.

Geotab use authentication, encryption and message integrity verification for Geotab vehicle tracking devices and network interfaces. Each Geotab tracking device uses a unique ID and non-static security key that is difficult to circumvent the device's identity. Over-the-air updates use digitally-signed firmware to verify that updates come from a trusted source.

3.2.3.3 Technical Specifications

The Geotab platform can be extended for additional functionality; Geotab GO7 includes an expansion port, the IOX. Multiple IOXs can be connected together to add new peripherals as needed, including the following Geotab features:

Figure 3.2.3.2-3. Geotab GO8[31]

- **IOX-NFC.** Driver Identification using RFID
- **IOX-AUX.** Auxiliary connections and digital inputs to identify various fleet activity
- **IOX-Garmin.** Garmin for HOS and messaging; connecting Garmin to Geotab GO7 allows messages between carriers and drivers, provides directions or manages compliance Garmin HOS. Geotab supports PNDs with and without traffic in both Europe and North America.
- **IOX-CAN.** Private CAN interface allows data transmission from a third-party device external to the vehicle network. Possible partner integrations include Mobileye for Driver Distraction Systems and Valor for Reefer Monitoring (temperature monitoring) and TPMS (tire pressure monitoring systems).
- **IOX-RS232.** Serial interface similar to the IOX-CAN, this IOX allows partners to push data from external devices through the GO7 to MyGeotab using proprietary serial protocol.
- **IOX-DICKEY-john.** Salt & Sand Spreader Monitoring Ideal for municipality fleets, this monitoring enables managers to better understand material and liquid distribution: how much, where, and when in real time.

Figure 3.2.3.2.3. Geotab IOX expansion ports[32]

[31] Source: https://www.geotab.com/vehicle-tracking-device

[32] Ibid.

3.2.4 Zonar

Zonar has been in the industry for over 16 years and is a strategic partner to Daimler Trucks of North America as well as a member of Continental AG. Together, Zonar has produced more technologically efficient ELD for fleet transportation drivers and owners. Zonar offers a smart fleet-management suite of solutions along with their patented EVIR technology for both pre- and post-trip inspections. Zonar's expanded set of inspections, diagnostics, student visibilities and GPS solutions help fleet managers and drivers increase safety and security, optimize bus routes, ensure inspection compliance and make data-driven decisions using stored data.

3.2.4.1 Operational Requirements & Technical Specifications

Zonar offers vehicle tracking, asset utilization and more. Tablets with software applications are offered to assist with every aspect of a driver's job responsibilities. Zonar capabilities include the Zonar V3 GPS technology, which provides high-definition GPS tracking, keeps vehicles on the road using remote diagnostics, tracks fuel consumption cost data and supports the advanced UDS protocol that meets or surpasses OEM specification.

Figure 3.2.4.1. Zonar V3 telematics platform[33]

Zonar's Ground Traffic Control uses a Web-Based Fleet Management Application. This allows access to real-time fleet operations data through a secure internet connection. It also allows the automation of automate tasks once a burden on drivers, dispatchers and back-office staff.

Zonar's patented RFID technology makes it possible to combine their Connect Next Generation Tablet and its Electronic Verified Inspection Reporting (EVIR) System for verifying pre- and post-trip maintenance inspections that promote safety, compliance and accountability. Additionally, Zonar's Forms-Based Messaging system allows them to replace paper forms between drivers and dispatch staff. These forms hold all data using pre-defined fields that are auto-populated. Messages are sent electronically and contain electronic signatures that further alleviate the burden on drivers and staff. Zonar's Advanced Navigation System provides drivers with mapped directions, real-time traffic information and driver feedback.

[33]Source: https://www.constructionequipment.com/zonar-v3-telematics-platform

Zonar’s API Integration allows them to work with software solution companies and deliver complete integrated solutions that would deliver considerable business results ranging from maintenance, diagnostics, planning and telematics providers to the solution integrator.

3.2.4.2 Equipment Requirements

Zonar’s systems are scalable and can be configured to address the requirements for the ELD mandate that support fleet management for drivers, including telematic data collections. Core required equipment includes a GPS system, ELD hardware, Zonar’s supporting Integrated Software applications, compatible displays, portable devices, corresponding cables and interface connectors.

Zonar Connect Tablet is ELD-ready and an AOBRD self-certified smart fleet tablet software platform that allows fleets to customize and upgrade. Zonar 2020 mobile communications tablet is a mobile telematics device that works inside and outside the cab and is applicable to fleets of all vehicle types. The Zonar Ground Traffic Control Captures data that are utilized by ZFuel and include frequency of cruise control usage, engine idle time, speed, and current truck gear. ZFuel uses telematics data collected by the Zonar's V3 connected directly to the engine ECU and analyzes it for various factors.

Zonar’s EVIR system uses small and durable RFID tags strategically placed inside and outside of a vehicle, usually within 2 inches from the point of inspection. This ensures a manual inspection is performed by the driver as the data from each inspection are electronically transmitted to the administrative staff in real time.

3.3 VEDRs

Video event data recorders have grown in popularity over the past years and have become more prevalent in commercial vehicles. VEDRs implement accelerometers, gyroscopes and GPS equipment, allowing them to function as event recorders. These recorders typically function so long as vehicle ignition is on and many often record data continuously. When an event is triggered, the recording system can capture minutes prior to the event and several minutes after though many VEDR suppliers offer extended video services and storage.

These video recorders also monitor the actions of the driver, useful as a training and safety maintenance tool for larger fleets. Implementing “drive cams” in large fleets has reduced the frequency of unsafe driving behaviors with drivers. Drive cams typically incorporate a two-camera system; one looking forward and the other looking inward. Forward-looking camera captures the roadway while the inward camera simultaneously captures driver input. These cameras trigger events when instances such as distracted driving, late responses and unsafe following distances occur. VEDRs therefore aid in opportunities for improving driver behavior through feedback and analytics tracking drivers at greater safety risk, which in turn produces a lower mileage death rate.

3.3.1 SmartDrive

SmartDrive Systems specializes in VEDR and performance analytics for a variety of transportation segments, including private fleets, commercial trucks, transit rail systems, transit buses, construction and concrete vehicles, as well as government fleets that include utilities and fire trucks. SmartDrive's VEDR technology offers 360-degree video on up to four cameras, which can alternatively be set to facing only the road or to an off-duty privacy mode in compliance with ELD mandate data-privacy standards. Video and data recording are triggered to capture drive operations from aggressive speeding or braking, maneuvers such as U-turns and unsafe following, to drowsy or distracted driving (texting, inattentiveness, eyes off the road) via their SmartSense for Distracted Driving technology while also monitoring HOS for compliance.

SmartDrive offers fleet managers the SmartChoice Program, a package that combines managers' video and safety preferences with management software. This software generates KPI reports, allows immediate offloading of real-time driver performance data via web and mobile devices, and tracks other analytics that work to improve fuel savings up to an average 2%, maintenance savings, and claims cost reduction among other financial costs that SmartDrive has estimated amount to $4,900 savings per vehicle. SmartDrive also offers coaching services, which research has consistently shown to improve driver safety when maintained, and which contribute to their touted average CSA safety score improvement of 60% and overall collision frequency reduction of 50%.

Figure 3.3.1-1 below demonstrates monitoring systems and event triggers detected by SmartIQ Transportation Intelligence systems.

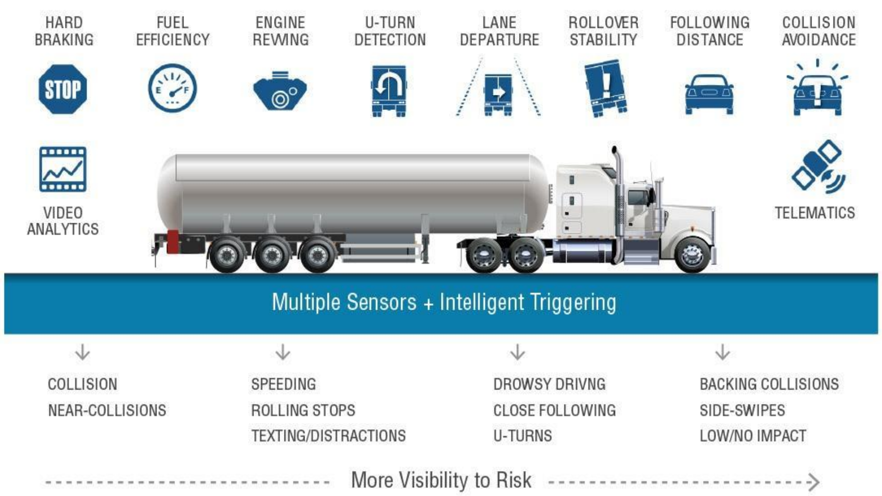

Figure 3.3.1-1. Monitoring by SmartDrive's SmartIQ[34]

[34]Source: https://www.smartdrive.net/technology

Figure 3.3.1-2 displays the two to four-camera customizable configurations available with SmartDrive VEDR.

Figure 3.3.1-2. SmartDrive camera configuration[35]

SmartDrive also offers extended recording to provide additional video context for collision investigators, researchers, and fleet managers; as well as SmartDrive Tracking, which improves vehicle use and real-time tracking via trip mapping and geo-fencing.

3.3.2 Lytx

Lytx is a VEDR provider that offers comprehensive video and data recording services for fleet managers in the construction, distribution, waste, trucking and transit transportation segments. Lytx reports to have aided over 650,000 drivers and 2,200 companies since 1988. In addition to their many safety programs, Lytx's division RAIR has partnered with Instructional Technologies, Inc. (ITI) as of 2011 to offer ITI's online driver safety training for DOT-regulated fleets to improve CSA safety scores, HOS logs, and other safety compliance measures.

Lytx's ActiveVision data recording technology detects distracted and drowsy driving events that trigger in-vehicle alerts. DriveCam, their VEDR safety program, offers side, rear and cargo-area recording services such as on-demand continual video transmitted at regular intervals as well as livestreaming road views over cellular networks. Extended recording aids in detecting low-g-force collisions while their live-streaming services allow collaboration between drivers and managers to improve response time and productivity. Uniquely, Lytx offers video recording through their own cameras or cameras already equipped on fleets as their services are NTSC or PAL camera-compatible, offering cost-effective options for their comprehensive VEDR service.

Captured data can be transmitted across a number of mobile platforms, including mobile phones, tablets and laptops. The data are saved for 100 hours and analyzed by both algorithms and human reviewers to produce predictive models and insights for fleet managers as needed.

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[35] Ibid.

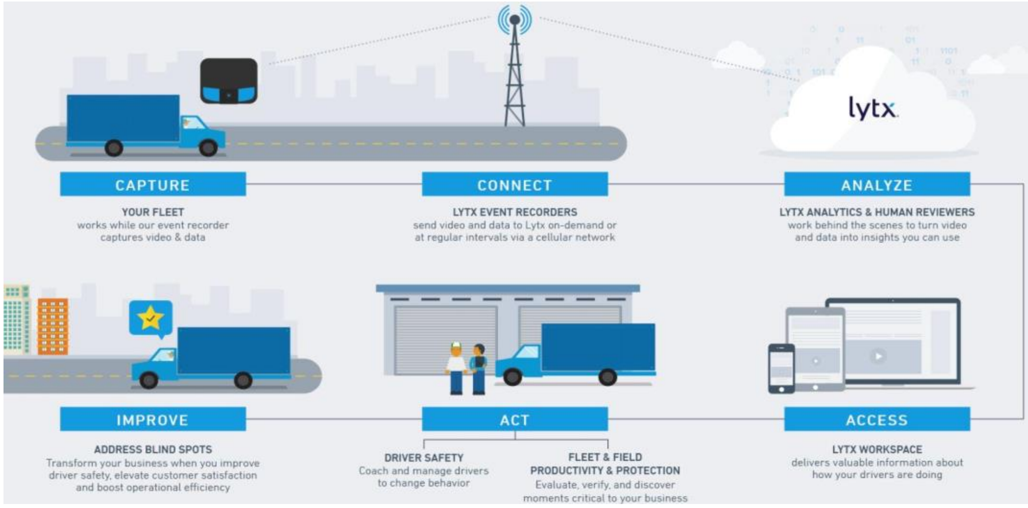

Figure 3.3.2-1. Lytx DriveCam safety program[36]

Lytx offers fleet managers the Fuel Reporting program to track inefficient drivers or vehicles so as to reduce fuel consumption and annual costs. Fleet tracking uses GPS, engine status, accelerometer data and video to aggregate and analyze data on real-time vehicle locations, vehicle speeds, stop times and locations, idle duration, driving distance, estimated arrival and departure times, mileage and trip history; this in turn enables fleet managers and drivers to improve routing efficiency, re-route drivers on real-time traffic and road conditions, recover stolen vehicles, locate nearest available drivers, as well as monitor compliance with driving speeds and HOS. Their services further aim to reduce costs of collisions, vehicle maintenance and repairs, claims and insurance. A user-friendly interface accessible on a number of mobile devices via the web pinpoints areas for productivity optimization and generates needed reports.

In October 2017, Lytx's RAIR division released additional functionality specifically in response to the DOT ELD mandate. Such functionality has added capability for verifying electronic and paper event logs and supporting documentation against driver HOS. Their "log falsification checks" use data from multiple sources, including GPS tracking, EZPass, fuel cards, and inspections. Their auditing makes compliances effortless for fleet managers by identifying documentation gaps from incomplete or inaccurate logs. Additionally, this software automatically updates its compliance currency by accessing FMCSA and MCMIS violations databases on a monthly basis. For further convenience and cost-efficiency, their analytics software integrates with a number of major ELDs already on the market or equipped in fleets.

3.3.3 Waylens

Recently founded in 2014, Waylens launched its flagship device, the Waylens Horizon, in 2015. This device was designed for car enthusiasts to capture the thrill of racing and adventure driving in high-resolution, road-facing video that is overlaid with a driver performance metrics interface. The camera is mounted on the windshield while the device collects data through a Bluetooth-equipped OBD-II transmitter and is controlled via remote attached to the wheel. Performance data

[36]Source: https://www.lytx.com/en-us/fleet-services/programs/lytx-video-services

recorded by the Horizon includes mph, GPS, g-force, pitch and roll, date and timestamps. GPS pinpoints location at a rate of 10 Hz GPS while 3-axis gyro, 3-axis accelerometer and 3-axis magnetometer determine orientation no matter how extreme the vehicle's maneuver. Video and data can be accessed through the mobile and desktop Horizon applications.

At the time of this report, the Waylens team of car enthusiasts, designers and engineers claim to be expanding their video services and developing the Waylens Secure 360, a 360 degree-view dash cam recording device. Among the device's intended purposes are the use of GPS to locate lost or stolen vehicles and provide evidence of collisions or other accidents to the vehicle in the owner's absence. The dash cam features sensor-fusion event detection, GPS, automatic event uploading, access to event data via the cloud, and real-time event notifications and location data as well as night vision viewable from Waylens Secure 360 smartphone and desktop applications. By smartphone, users can view 360-degree livestream of their vehicle over a high-speed 4G LTE connection.

3.3.4 FalconEye

An example of another video-only recording system is the mobile digital video recorder (MDVR) by Falcon Electronics LLC. Falcon Electronics LLC has designed a spectrum of video data recording products, most notably their trucker dash cams, a 9-inch LCD quad screen wireless dash cam system, and a MDVR three-camera system featuring a 7-inch LCD and GPS integration, marketed as their "vehicle black box."

Systems such as the Falcon Electronics LLC MDVR is strictly a mobile closed-circuit video surveillance system that does not have capability for capturing vehicle data.

3.3.5 BlackVue

Established in 2007, BlackVue offers one and two-channel, front-facing HD dash cams that reduce motion blur by recording 60 frames per second. BlackVue dash cams use Sony STARVIS image sensors that allow high-definition video recording. The camera sensors detect motion, and parking mode is activated when the driver steps away from the vehicle. When switched to parking mode, the dash cam triggers night vision. The company reports that even without night vision, the dash cams record with clarity that outperforms other sensors and competitors. Alternatively, the dash cam can be configured to record upon an impact event trigger. In driving mode, some BlackVue dash cam models feature a LDW system that emits a sound alert when sensors detect the vehicle's proximity to crossing a road line or to some other calibrated threshold. Like other data recorders, BlackVue dash cams record in a FIFO loop format.

In addition to user-friendly LCD touch screen menus, six main interactive features are available via the BlackVue Over the Cloud service. These include real-time, remote live viewing, as well as GPS location and two-way voice communications via smartphone. The Over the Cloud service also offers the ability to transfer files and data from the camera to cloud storage or to a mobile device, such as a smartphone or tablet. This option avoids the overwriting of important data on the dash cam's memory while additionally allowing video playback on mobile devices. From the

Cloud, users can access video playback of files on a mobile device, and of additional interest are live notifications for preprogrammed events.

BlackVue has also designed dash cams specifically for heavy vehicle and large commercial trucks while offering tracking services for fleets of up to 100 vehicles. BlackVue Fleet Tracking offers expanded vehicle management, including remote live-streaming of up to four dash cams at a rate of 600kbps, GPS tracking, a 90-day GPS history exportable to spreadsheets, 10 GB of cloud video backup options per dash cam, and geo-fencing with real-time smartphone alerts. All features are accessible in the BlackVue Viewer Pro interface, though this application operates only on Microsoft Windows while the BlackVue App is accessible on iOS or Android smartphones.

3.3.6 SmartWitness

Since 2007, SmartWitness has specialized in high-definition, in-vehicle CCTV cameras for both private and commercial vehicles and pioneered integration of telematics hardware into dash cams, or “video telematics.” SmartWitness has delivered over five generations of products utilizing components from Sony, Bosch, Telit, U-Blox and others, and which have been equipped in more than 250,000 vehicles to date.

SmartWitness video recorders feature options similar to other VEDR providers, including GPS to monitor vehicle location, vehicle speed, direction and driving routes, and accurate date and time; microphones for in-vehicle audio recording, which can also be deactivated; and 3G LTE or wireless video and data transfer within minutes of a road event or collision. Up to four cameras can be installed on a vehicle, with camera lenses capturing 170-degree fields of front and peripheral views each. SmartWitness cameras also feature three-axis g-force sensors that auto-calibrate and provide detailed data on collision events and driver operational behavior. They also have compatibility for third-party telematics software integration to live-stream video remotely. Device power-up, operation and shutdown are automatic, and security systems include dual SD card redundancy, automatic SD formatting and tamper resistance to driver interference.

SmartWitness offers solutions specially designed for the trucking industry. Hardware systems may fit up to five cameras on a large commercial truck, including a video data recorder and dash camera, and left and right side-view camera, rear-facing camera, and a driver/cargo facing camera. Camera lenses also offer HD 170-degree wide angle views, while recording options may be set to continuous or event. Recording resolution and frame rate are configurable, and the g-shock sensor sensitivity is likewise adjustable. An optional panic button allows drivers to trigger emergency event recording remotely. Software and cloud storage features complement the video recording systems, allowing an AVI conversion tool retaining a data watermark, Google Maps integration for route monitoring, SmartWitness’s Google Earth Export Tool, and generation of event reports through an integrated desktop interface.

3.4 Specific Add-On Data Recorders

3.4.1 Kienzle Argo *Unfalldatenspeicher*

Some add-on (aftermarket) data recorder devices are also available. One such device is the Kienzle Argo GmbH (Berlin, Germany) *Unfalldatenspeicher* (UDS), or accident data recorder.

As previously discussed in this feasibility study (Deliverable No. 3), UDS has been the foundational data recorder of several published highway safety and commercial fleet safety studies in Europe. Most of these studies were conducted with a (now) older generation of UDS, the UDS 2.0 device. The UDS-AT is a new generation of accident data recorder recently introduced by Kienzle Argo to replace the previous accident data recorder, UDS 2.0.

The primary function of Kienzle Argo's UDS-AT is to measure, record and report data from vehicle critical events like collisions. The "AT" in UDS-AT stands for "advanced technology."

The UDS-AT and older UDS can be found in European taxi fleets, commercial vehicle fleets and "blue light vehicles" such as police, fire and paramedics or rescue vehicles. The UDS-AT is unique when compared to other recording devices as it does not rely solely on vehicle CAN-bus data, such as J1939 data sources. The UDS-AT uses CAN-bus signals from the vehicle as well as its own internal sensors.

The main internal sensor for the UDS-AT device is a tri-axial accelerometer with a range of +/-70 g, a magnetic field sensor and gyroscope for yaw measurements. The previous UDS device had a two-axis accelerometer with a range of +/-50 g, a magnetic field sensor and no capabilities to measure yaw.

UDS-AT (and older generation devices) are classified as journey recorders due to continuously recording data while the vehicle is in use. The UDS-AT has a low-resolution recording/reporting rate of 512 Hz but can be triggered into high-resolution mode of 1 kHz should the sensor detect a critical event, like collision. The UDS-AT stores data automatically or manually, and automatic triggers can be customized.

The UDS-AT also has eight discrete signal inputs that can be logged. A typical setup is shown in Figure 3.4.1 below.

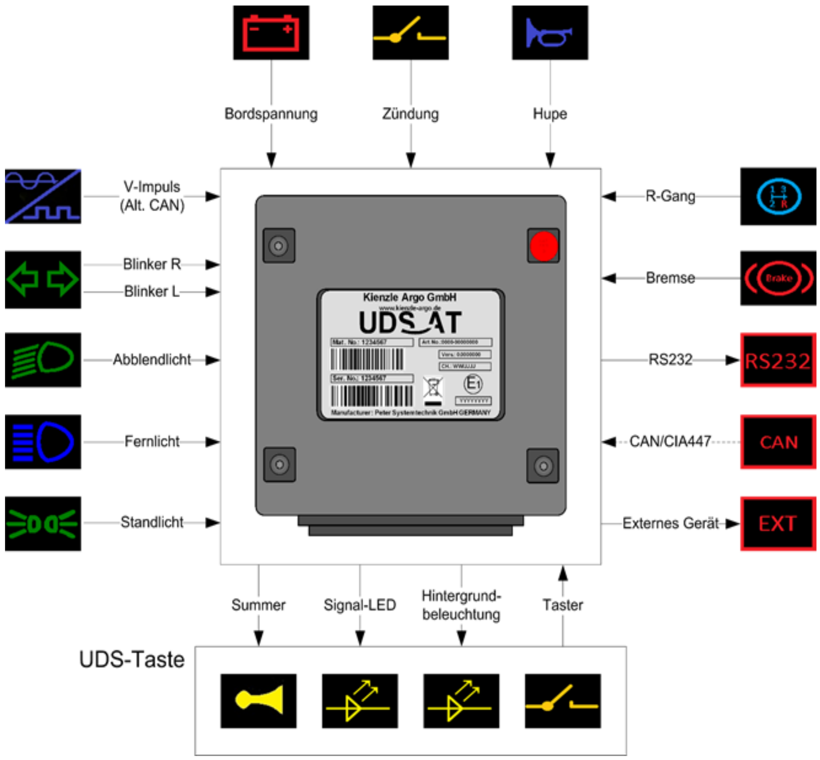

Figure 3.4.1. UDS-AT signal inputs and outputs[37]

3.4.2 NFPA 1901 Vehicle Data Recorder

A second, vocation-specific accident data recorder that exists in U.S. fire apparatus is the National Fire Protection Association (NFPA) 1901 vehicle data recorder (VDR). In 2009, NFPA amalgamated the 1901 “Standard for Fire Apparatus” to include a VDR to “capture data that can be used to promote safe driving and riding practices.”[38] [39]

The NFPA 1901 VDR is defined as a journey recorder that is not triggered to record incident-specific data. Rather, the 1901 VDR records data continuously at a 1 Hz (once every second) frequency within a 48-hour recording loop. The recorded data are sourced from the J1939 CAN bus equipped on the fire apparatus. An example of a Pierce NFPA 1901-compliant VDR is shown in Figures 3.4.2-1 and 3.4.2-2 below.

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[37]Gerlach, W., “Training for UDS-AT,” Slide 11, 2017 (used with permission).

[38]NFPA Standard 1901, “Standard for Automotive Fire Apparatus,” Rev. 2009

[39]Austin, T., Plant, D., and LeFevre, J., "Using NFPA Compliant Fire Apparatus Vehicle Data Recorders for Collision Investigation - Weldon Type 6444," SAE Technical Paper 2015-01-1446, 2015.

Figure 3.4.2-1. Pierce 1901 VDR installed in cab

Figure 3.4.2-2. Pierce 1901 VDR

The 1901 VDR data logs are accessible via a standard USB type-A physical connector.

Figure 3.4.2-3. NFPA 1901 USB type-A connection port

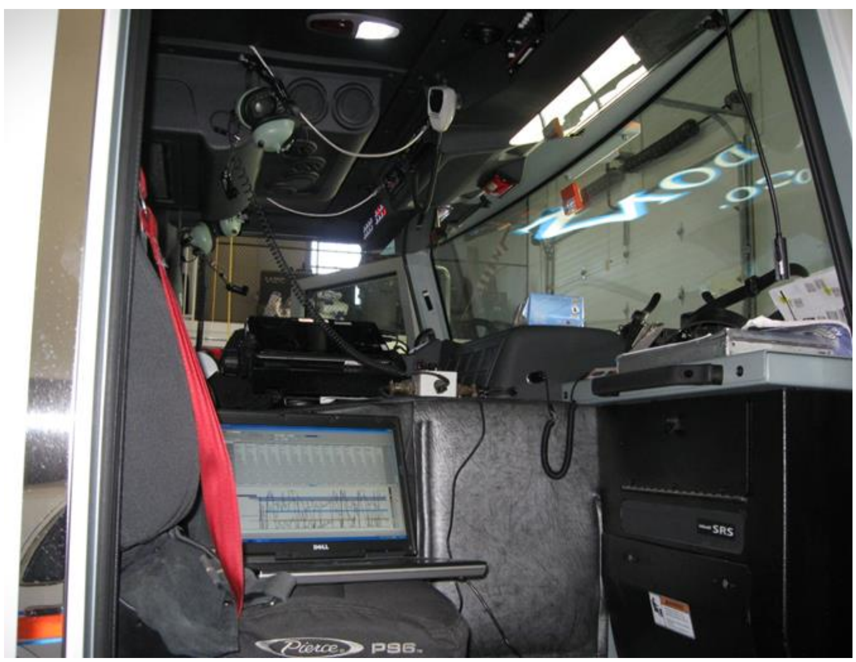

Figure 3.4.2-4. Typical access to NFPA 1901 VDR

4.0 CONCLUSION

This review of telematics devices concludes *T8080-160062 Transport Canada Commercial Bus HVEDR Feasibility Study,* Deliverable No. 4: “All Devices Summary Report.” As of 2018, NAFTA-market over-the-road truck-tractors and buses are increasingly equipped with two or more independent OEM-based HVEDR functions. The number of registered commercial trucks and buses in Canada, the United States and Mexico (MY2000 and newer) already equipped with some form of OEM-based EDR/HVEDR function is significant.

The most significant positive attribute of OEM-based EDR/HVEDR is that it is a software function. As shown, considerable event data are already recorded on various heavy vehicle OEM devices. However, such data are not always easily accessible due to inconsistencies across manufacturers, such as the number of and different modules that record and store the data, varying data record formats, and the numerous software applications required to access OEM device data. Further complications to data preservation include the spoliation of data due to power loss, failure to meet a trigger threshold to record data, or logistical complications, such as overwriting event data when relocating a vehicle. These challenges to the preservation of heavy vehicle event data are in stark contrast to the standardized preservation of passenger vehicle event data established by U.S. 49 CFR 563.

In addition to the OEM HVEDR functions found in MY2018 commercial trucks and buses, additional EDR-type recording is found in the aftermarket systems that are installed by commercial vehicle operators, such as telematics, ELDs or VEDRs. Although an add-on device that serves as EDR/HVEDR for a vehicle may feature improved data reliability, accuracy, and recording and reporting resolution, the improved data quality comes at a significant per-vehicle cost for the device and for the labor to install it.

While ELD is beyond the scope of this HVEDR feasibility study, ELDs were discussed as most of these devices feature EDR/HVEDR functionality, and the ELD device may be considered a “host” for an EDR function on commercial trucks and buses. In devising the ELD mandate, FMCSA highlighted their intentionality in setting standards that can be met by reprogramming currently existing devices with low additional cost to carriers, which is beneficial to this end.

Like Part 563, FMCSA’s development of an ELD mandate has modeled a pre-existing regulatory infrastructure for HVEDR standardization. Further discussion regarding the use of OEM HVEDR devices as well as the use of U.S. federally mandated ELD as a host for an HVEDR function can be found in Deliverable No. 6, “Commercial Bus HVEDR Feasibility Report.”

APPENDIX A - ACRONYMS

ABS	Anti-Lock Brakes System
ACB	Active Cruise with Braking
ACCTYPE	Accident Type
ACM	Aftertreatment Control Module
ACM	Air Bag Control Module
ACN	Automatic Crash Notification
ACRS	Air Cushion Restraint System
ADAS	Advanced Driver Assistance Systems
ADEM	Advanced Diesel Engine Management (Caterpillar)
ADL	Alexander Dennis Limited
ADR	Accident Data Recorder
AEB	Automatic Emergency Braking
AOBRD	Automatic On-Board Recording Device
APTA	American Public Transportation Association
ATA	American Trucking Association
Ax, Ay	Longitudinal, Lateral Acceleration Change (g)
BAGDEPLY	airBag System Deployment
BDR	Bendix Data Reporter
CADaS	Common Accident Data Set
CAN	Controller Area Network
CARE	Community Road Accident Database
CAT ET	Caterpillar Electronic Technician
CCTV	Closed-Circuit Television Camera
CCVS	Cruise Control/Vehicle Speed (Defined by SAE J1939)
CDC	Collision Deformation Classification
CDR	Crash Data Retrieval
CDS	Crashworthiness Data System
CECU	Cab Electronic Control Unit (PACCAR specific)
CFR	Code of Federal Regulations
CIREN	Crash Injury Research and Engineering Network
CPC	Common Powertrain Controller
CSA	Compliance, Safety and Accountability
D	Deployment (event)
D/DL	Deployment and Deployment-Level (event)
D/N	Deployment and Non-Deployment (event)
DARR	Digital Accident Research Recorder (Volvo)
DDDL	Detroit Diesel Diagnostic Link
DDEC	Detroit Diesel Electronic Controls
Delta V (ΔV)	Change in Velocity (mph)
DERM	Diagnostic & Energy Reserve Module (General Motors specific)
DL	Deployment-Level (event)
DLC	Diagnostic Link Connector
DoCAN	Diagnostic Communication Over Controller Area Network
DOT	Department of Transportation
DTC	Diagnostic Trouble Code

DTNA	Daimler Trucks North America
DVIR	Driver Vehicle Inspection Report
DVLAT	Lateral component of delta V
DVLONG	Longitudinal component of delta V
EAS	Emissions After-treatment System (PACCAR specific)
ECBOS	Enhanced Coach and Bus Occupant Safety
ECM	Engine Control Module
ECU	Electronic Control Unit
EDR	Event Data Recorder
EDS	Electronic Data System
eDVIR	Electronic Driver Vehicle Inspection Report
EECU	Engine Electronic Control Unit
EEPROM	Electrically Erasable Programmable Read-Only Memory
ELD	Electronic Logging Device
EPA	Environmental Protection Agency
ERSO	European Road Safety Observatory
ESC	Electronic Stability Control
ESP	Electronic Stability Program (Knorr-Bremse specific)
EVIR	Electronic Vehicle Inspection Reporting
FARS	Fatality Analysis Reporting System
FCW	Forward Collision Warning
FHWA	Federal Highway Administration
FIFO	First In, First Out
FLR	Forward-Looking Radar
FMCSA	Federal Motor Carrier Safety Administration
FMCSR	Federal Motor Carrier Safety Regulations
FMS	Fleet Management System
FMVSS	Federal Motor Vehicle Safety Standard
GES	General Estimates System
GIT	Global Information Technology
GM	General Motors
GPS	Global Positioning System
GSM	Global System for Mobile Communications
GVWR	Gross Vehicle Weight Rating
HCV	Heavy Commercial Vehicle
HOS	Hours of Service
HVEDR	Heavy Vehicle Event Data Recorder
IFTA	International Fuel Tax Agreement
IIHS	Insurance Institute for Highway safety
IPECU	Instrument Panel Electronic Unit
ITS	Intelligent Transportation System
IVG	Intelligent Vehicle Gateway (Omnitracs)
JDR	Journey Data Recorder
kph	kilometers per hour
KPI	Key Performance Indicator
LCV	Light Commercial Vehicles
LDW	Lane Departure Warning
LER	Locomotive Event Recorder
LTCCS	Large Truck Crash Causation Study

MADD	Mothers Against Drunk Drivers
MANEUVER	Attempted Avoidance Maneuver
MANUSE	Manual (Active) Belt System Use
MBE	Mercedes Benz medium- and heavy-duty Engines
MCM	Motor Control Mount
MCMIS	Motor Carrier Management Information System
MDVR	Mobile Digital Video Recorder
MMUCC	Model Minimum Uniform Crash Criteria
MOU	Memorandum of Understanding
mph	miles per hour
ms	milliseconds
MVEDR	Motor Vehicle Event Data Recorder
MVEDRCLA	Motor Vehicle Event Data Recorder Connector Lockout Apparatus
MVSRAC	Motor Vehicle Safety Research Advisory Committee
MY	Model Year
N	Non-Deployment (event)
NAFTA	North American Free Trade Agreement
NASA	National Aeronautics and Space Administration
NASS	National Automotive Sampling System
NASS-CDS	National Automotive Sampling System's Crashworthiness Data System
NCHRP	National Cooperative Highway Research Program
NCSA	National Center for Statistics and Analysis
NFPA	National Fire Protection Association
NHTSA	National Highway Traffic Safety Administration
No.	Number
NOX	Nitrous Oxide
NPRM	Notice of Proposed Rulemaking
NTSB	National Transportation Safety Board
OBD	On-Board Diagnostic
ODND	On-Duty, Not Driving
OEM	Original Equipment Manufacturer
PACCAR	Pacific Car and Foundry Company
PDOF	Principal Direction of Force (1st)
PDOF1	Clock Direction for PDOF in Degrees (Highest CDC)
PEEC	Programmable Electronic Engine Control
PLD	*Pumpe Liene Dusse* (Mercedes-Benz)
PMCI	PACCAR Multi-Controlled Injection (PACCAR specific)
RAM	Random Access Memory
RCM	Restraint Control Module
RDC	Routing, Dispatching and Compliance
RF	Right-Front
RFID	Radio Frequency Identification
RODS	Record of Duty Status
RODS	Records of Duty Status
rpm	revolutions per minute
RSC	Roll Stability Control (WABCO specific)
RSP	Roll Stability Program (Knorr-Bremse specific)
SAE	Society of Automotive Engineers
SCI	Special Crash Investigations

SDD	Sudden Deceleration Data (Cummins)
SDM	Sensing and Diagnostic Module (General Motors)
sec	seconds
SNPRM	Supplemental Notice of Proposed Rulemaking
SRS	Supplemental Restraint System
t	time (seconds)
TCM	Transmission Control Module
TIFA	Trucks Involved in Fatal Accidents
TMC	Truck Maintenance Council
TMS	Transportation Management
TPS	Throttle Position Sensor
TRB	Transportation Research Board
TSB	Transportation Safety Board of Canada
UDS	Universal Documentation Service
US DOT	United States Department of Transportation
V2I	Vehicle-to-Infrastructure
V2V	Vehicle-to-Vehicle
VCU	Vehicle Control Unit
VDO	Vereinigte DEUTA - OTA (Company Name)
VDR	Vehicle Data Recorders
VECU	Vehicle Electronic Control Unit
VEDR	Video Event Data Recorder
VERONICA	Vehicle Event Recording based on Intelligent Crash Assessment
VIN	Vehicle Identification Number
VRU	Vulnerable Road Users
VSS	Vehicle Speed Sensor
Vx (ΔVx)	Longitudinal delta V (mph)
Vy (ΔVy)	Lateral delta V (mph)
XML	Extensible Markup Language

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