Transport Canada Commercial Bus HVEDR Feasibility Study (File No. T8080-160062) Deliverable No. 7:

Final Report

Mecanica Scientific Services Corporation

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12. ABSTRACT

The following report is the submission for Transport Canada, *T8080-160062 Feasibility Study of Event Data Recorder for Commercial Buses*, Deliverable No. 7, “Final Report.” This summary report discusses the implications for developing a commercial passenger bus event data recorder (EDR) standard, focusing on the feasibility of equipping heavy vehicle event data recorders (HVEDRs) in motorcoaches, buses and school buses. A review of international studies suggests that the use of EDR/HVEDRs in commercial fleets can improve accident rates, driver safety and training, and crash analysis while the data made available to transportation safety authorities can help identify highway/infrastructure design issues and vehicle or system issues, as well as refine national crash and emergency response databases. This report also presents a history of international regulatory frameworks for heavy vehicle data recording and explores the current status and challenges to HVEDR regulation. What follows is a discussion of the technical feasibility of a commercial bus EDR standard through two prevalent engineering and design methods: an original equipment manufacturer (OEM) device solution and an aftermarket add-on device solution. Because standardization must account for variations in current HVEDR industry implementations, this report concludes with technical recommendations for data elements and formatting, recording and reporting rates, preservation and retrieval.

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1.0 INTRODUCTION

On September 18, 2013 at approximately 08:48 AM, a collision occurred between a westward VIA Rail Canada (VIA) commuter train and an OC Transpo model-year 2012 Alexander Dennis Enviro500 42-foot-long double-decker bus, equipped with a Cummins turbo-diesel engine with electronic controls with HVEDR functionality. VIA was operating the daily westward VIA 51 from Montréal, Quebec, to Toronto, Ontario, via Ottawa. The VIA 51 train was comprised of one General Electric Genesis (Model EPa42) locomotive at the head of the train, equipped with a locomotive event recorder (LER).

The collision resulted in six fatalities, nine serious injuries and approximately 25 minor injuries among the occupants of the double-decker bus. The final investigation report authored by Transportation Safety Board of Canada (TSB) contained numerous safety recommendations, with one of those recommendations focused on commercial and passenger bus **event data recorders (EDRs)**. TSB investigators identified eight "electronic units" (electronic control units) on the AD double-decker bus, including the "ECM" (Cummins Engine "electronic control module") data recorder. As a result of this investigation, TSB published Recommendation R15-03, which suggested the "Department of Transport require commercial passenger buses to be equipped with dedicated, crashworthy, event data recorders."[1]

TSB Recommendation R15-03 is the triggering event for Transport Canada to request this research for the *Feasibility Study of Event Data Recorders (EDRs) for Commercial Buses (T8080-160062)*. Mecanica Scientific Services Corporation (MSSC) was awarded a contract to submit to Transport Canada a feasibility study for developing a commercial passenger bus EDR standard for Canada.

The following report is the submission for Transport Canada, *T8080-160062 Feasibility Study of Event Data Recorders for Commercial Buses*, Deliverable No. 7, "Final Report," which summarizes the discussion and implications for developing this commercial passenger bus EDR standard, focusing on the feasibility of equipping **heavy vehicle event data recorders (HVEDRs)** for commercial passenger buses and the advantages and challenges of implementing this standard.

2.0 EXECUTIVE SUMMARY

Multiple studies worldwide have shown that the use of EDR in commercial fleets has resulted in reduced accident rates after drivers are educated and understand the presence of the EDR as well as its purpose and function. This reduction of accident rates is typically temporary, however, unless EDR data is used proactively to mentor drivers continuously. Additionally, multiple studies

[1]TSB, *Crossing Collision, Via Rail Canada Inc. Passenger Train No. 51, OC Transpo Double-Decker Bus No. 8017, Mile 3.30, Smiths Falls Subdivision, Ottawa, Ontario, 18 September 2013*, Railway Investigation Report No. R13T0192, Dec. 2015.

have also shown that if EDR data is consistently used to mentor or coach drivers, the reduction of the fleets accident rate can be sustained.

As automated driver systems (ADS) and autonomous driver assistance systems (ADAS) enter major transportation systems, stakeholders such as regulatory agencies and OEMs will require the ability to test and validate these advanced systems. In the unfortunate event of an accident, there will be a need for the ability to evaluate the readiness of the ADS or ADAS function and to what level the ADS or ADAS was in control versus the actions (or inactions) of the driver.

A finite list of data elements for an accident reconstructionist (private, government agency crash investigator, or law enforcement investigator) will be needed to determine how a driver's actions (or inactions) contributed to a crash and to what level the ADS or ADAS technology was engaged or intervening.

In addition to EDR/HVEDR's role in analyzing driver behavior and improving motor-vehicle operator safety, federal transportation safety agencies such as Transport Canada, National Highway Traffic Safety Administration (NHTSA) and NHTSA's Special Crash Investigations (SCI) research team can leverage EDR/HVEDR data to improve highway safety by identifying highway or infrastructure design issues and vehicle or system issues, in addition to coordinating national emergency response, transportation and crash database systems.

In Mecanica's extensive research, the only arguments found to complicate EDR/HVEDR standardization concern drivers' privacy rights. Although this policy issue is beyond the scope of this study, it must be recognized that U.S. Supreme Courts have found that, in the United States, individuals' expectations for privacy is greatly diminished on public roads as one's actions can have profound and unexpected outcomes on other road users against their will.[2] It is also important to note that, where privacy has been a concern, research and safety organizations have recognized that the EDR/HVEDR benefits to highway safety are too significant to forego incorporating EDR/HVEDR altogether.

3.0 HVEDR PROJECT SUMMARY

A brief outline of the *T8080-160062 Feasibility Study of Event Data Recorders for Commercial Buses* project is as follows.

A list of technical and scientific reports/papers and validation studies on the accuracy, reliability and limitations of commercial vehicle EDR was compiled and submitted in spreadsheet format (Deliverable No. 1) to Transport Canada. Mecanica submitted a second listing (Deliverable No. 2), which included additional references and available abstract summaries for each reference. This submittal included further supplemental references in support of the summary report (Deliverable No. 3, "Summary of Facts"), which outlines a history of research and relevant

[2] NHTSA Event Data Recorders Working Group, *Event Data Recorders: Summary of Findings, Final Report,* Aug. 2001.

literature pertaining to the functionality of HVEDR devices and the reliability of data imaged from them.

This project also reviewed the history of and current market of telematics devices (Deliverable No. 4, “Summary of All Devices”), including data-recording capabilities for major OEM ECUs and a sample of manufacturers cornering the largest share of the electronic logging device (ELD) market. A summarized history of standards activities related to EDR/HVEDRs that have taken place or are currently in progress (Deliverable No. 5, “Summary Report of International Commercial Vehicle EDR Industry Standards and Recommended Practices”) were found to have occurred largely within the United States. Several members of the Mecanica research team have been active members and served in leadership roles for some of the following standards committees on EDR and HVEDR functionality. The Mecanica research team was additionally tasked with reaching out to organize meetings with key government stakeholders focused on highway safety research or regulatory work on EDR/HVEDR.

The project culminates in a final discussion of the implications for feasibility of developing a commercial passenger bus EDR standard for Canada (Deliverable No. 6, “Commercial Bus HVEDR Feasibility Report”) and a final summary of all findings (Deliverable No. 7, “Final Report”).

3.1 Results of Literature Review

The review of literature and research on EDRs and HVEDRs produced the following:

- 106 reports on data recorders and data-recorder impacts on highway safety
- 12 technical reports on the accuracy of passenger-vehicle EDR
- 3 technical reports on the accuracy of HVEDR
- 5 legislative acts mandating data recorders
    - Japan (1 mandate)
    - United States (4 mandates)
- 14 technical standards on passenger-vehicle (light-duty) EDR
- 19 technical standards on HVEDR
- 10 recommendations for data recorders

A considerable number of these presented clear data and findings on reducing accident rates and improving driver safety and training. Of the research summarized, all independent research groups worldwide concluded that EDR/HVEDR has significant impact on highway safety.

3.1.1 Accident Reduction through Data Recording of Driver Behavior

Internationally, multiple studies have found that the use of EDR/HVEDR in commercial fleets effects a reduction in accident rates when drivers are made aware of the presence of EDR. By the mid- to late 1990s, it was understood that a major factor of collisions and therefore highway safety was driver operational behavior, and therefore, a means of monitoring operational behaviors for understanding and training driver behavior increasingly underscored the objective of highway safety research.

As early as 1995, the Commission of the European Communities 1992-1995 DRIVE-II research program developed the Safety Assessment Monitoring On-Vehicle with Automatic Recording (SAMOVAR) framework,[3] and a major premise underlying the study was the positive effect EDR monitoring could have on driver behavior influence, as explored by Wouters and Bos.[4]

By the time of the 1992-1995 study, prior indications for the effect of behavior monitoring on driver behavior had already been established. Such evidence included a German study in which installing "accident reconstruction recorders" into a fleet of vehicles allegedly resulted in a 30% reduction in accidents.[5] An unnamed British insurance company was said to have offered fleets a 15% reduction in premiums if "trip recorders" were installed in their vehicles.[6] Finally, the United Kingdom's Royal Mail produced data showing accident reduction rates of 17% from the use of 500 data recorders in their fleet.[7] A research gap remained, however, formally identifying what accident reduction effects were possible, which factors brought about such effects, or if positive effects would be produced in all circumstances of installing data recorders to influence driver behavior and safety.

The 1997 SAMOVAR study's main subject of study was driver response to data recorder feedback, which was found to reduce accident rates by 20% in particular fleets and, in one cluster, to attenuate accident severity and damage. A margin of ±15% was partly dependent on the fleet's pre-test accident history. The results could only be given within wide confidence intervals with the divergence stemming from a small sample size. It was thus recommended that such a project be implemented on a larger scale, with attention paid to the content of feedback given to drivers when confronted and how feedback implementation (via incentive schemes or the basis of recurrence, for example) influenced the large variation in accident reduction effects. The difference in fleet owners' attitudes of safety were also proposed as a factor contributing to the variation in accident rates among fleets of similar vehicle types.

Not long after, the Kienzle Automotive *UDS Accident Data Recorder - A Contribution to Road Safety* study, published by VDO in 1998, also discussed the positive outcome of equipping fleet vehicles with accident data recorders. The authors argued that, at least in Germany, "about 90% of the recorded accidents are caused by human failure of the involved parties, [and] only about 10% by technical defects or the condition of the roads." The researchers discovered that several E.U. fleets including police vehicles, buses, security vehicles and taxis fitted with *Unfalldatenspeicher* (UDS), or "accident data recorder" (ADR), showed a reduction in accidents anywhere from 15% for buses to 66% for taxis.

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[3]Wouters, P.I.J., and Bos, J.M.J, *The Impact of Driver Monitoring with Vehicle Data Recorders on Accident Occurrence; Methodology and Results of a Field Trial in Belgium and The Netherlands,* 1997.

[4]Wouters and Bos, "Traffic Accident Reduction by Monitoring Driver Behavior with In-Car Data Recorders," *Accident Analysis and Prevention, 32*:643-650, 2000.

[5]Wouters and Bos, *The Impact of Driver Monitoring*.

[6]Ibid.

[7]Ibid.

Regarding buses specifically, a pilot test sponsored by the German Ministry of Transport using buses from the Association of Baden-Württemberg Bus Companies examined 123 buses fitted with UDS and discovered that "accidents were reduced by 15 to 20%," depending on the company. The Wouters and Bos SAMOVAR study found that variations in fleet accident rates could result from different implementations of feedback, such as incentive or rewards programs. Consistency and frequency of feedback as well as fleet managers' varying safety priorities were also suggested by Wouters and Bos as contributing to variance in accident reduction.[8]

An equally significant proposition from the SAMOVAR study was that accident reduction rates and driver safety would persist only if drivers were not only aware of the presence of in-vehicle EDR but were consistently given feedback in order to maintain accident reduction. Because of this, Wouters and Bos recommended that *journey data recorders* (JDRs), which log data continuously, were preferable for providing consistent feedback and maintaining driver safety as opposed to ADRs (now commonly EDRs), which write data upon pre-programmed event triggers.

The need for feedback to be consistent in order to maintain driver safety was confirmed by Toledo and Lotan at the Technion-Israel Institute. Their 2006 publication "In-Vehicle Data Recorder for Evaluation of Driving Behavior and Safety" detailed a prototype IVDR that would monitor vehicle motions and driver inputs to study driver behavior and vehicle collisions for improved safety. The study implemented IVDR not only to monitor driver behavior during crash-relevant events but to monitor normal, non-collision driving behavior as well. The researchers found a "significant positive impact" on driver safety during the initial exposure to IVDR feedback but discovered the influence on driver behavior diminished after five months. The researchers' conclusions that IVDR can affect driver behavior and therefore highway safety if drivers are exposed to consistent feedback from data recorders aligned with contemporaneous findings from the European SAMOVAR Drive II Project of 1992-1995.

Mechanical and—contemporary to the SAMOVAR study—electronic tachographs are one model of data loggers that can be considered a journey recorder satisfying the purpose of monitoring driver behavior continuously and providing feedback consistently, as recommended by Wouters and Bos. It is electronic tachographs that, for 32 years as of the writing of this report, have been and are currently mandated in the United Kingdom and European. In the United States, a similar journey recorder (or logging) device, the ELD, has also been mandated by the Department of Transportation (DOT) Federal Motor Carrier Safety Administration (FMCSA) as of 2015 under what is known as the ELD mandate (49 CFR, Part 385, 386, 390, 395) with a schedule for stages of implementation to reach maximum compliance by 2019.

Years after Toledo and Lotan's 2006 publication, the U.S. DOT published the *Motorcoach Safety Action Plan* in 2009. This publication featured a data analysis recognizing that driver fatigue, vehicle rollover, occupant ejection and operator maintenance issues contribute to the majority of motorcoach crashes, fatalities and injuries. Seven priority action items were outlined to improve motorcoach safety. The first action item was a call to "initiate rulemaking to require electronic on-

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[8]Wouters and Bos, *The Impact of Driver Monitoring* and "Traffic Accident Reduction."

board recording devices on all motorcoaches to better monitor drivers' duty hours and manage fatigue." The DOT's 2009 *Action Plan* echoes earlier calls for consistent monitoring of driver behavior as a priority for highway safety. Here, the concerns are voiced around drivers' hours of service (HOS) and fatigue. Again, tachographs and ELDs, among whose primary functions are the recording of HOS, are set up for future standardization as a device for ensuring compliance with regulations to improve overall highway safety.

More recently, research has continued to find positive results of driver-behavior monitoring on accident reduction for large commercial vehicles. The U.K.'s Transport Research Laboratory, Ltd. 2014 study[9] determined that the fitment of EDRs to large commercial vehicles (N2/N3) and buses and coaches (M2/M3) varies in terms of the way the system is organized and the types of data recorded. In these studies, a range of reduction in accidents was shown when in-vehicle data recorders (including EDRs) were installed; the EDR affected the driver's behavior, resulting in fewer operational accidents.

The above study noted that the findings in accident reduction rates for commercial fleets with EDR was limited as commercial fleet vehicles (N2/N3 and M2/M3) were already engaged in monitoring with EDR technologies to support the driver; it was therefore estimated that more than 30% of the fleets had already realized the benefits of fewer accidents. Another finding was that behavioral change in drivers was strongly linked to information feedback provided by installed EDRs; this aligns with the positive results EDR feedback has on driver behavior and therefore accident reduction found by the 1992-1995 SAMOVAR DRIVE-II Project study published by Wouters and Bos in 1997 and 2000, VDO's 1998 Kienzle Automotive UDS study, and Toledo and Lotan's 2006 study.

As TRL conducted their EDR study, the benefits of data recording on driver behavior were already widely accepted by 2014 enough for several agency recommendations and regulation activity to set standardization into legislation as explored in Deliverables No. 3, 4, 5 and later in this report.

3.1.2 Crash Analysis Accuracy through EDR/HVEDR Data

EDR/HVEDR has been found to improve highway safety not only by influencing or modifying driver behavior but for more effective crash analysis and driver training. The complexity of today's vehicles can make it difficult to analyze pre-collision physical evidence for crash investigation. A prime example of this is seen in the 1999 Canon City, Colorado passenger motorcoach accident investigated by the U.S. National Transportation Safety Board (NTSB).

The 1999 Setra 59-passenger motorcoach traveled eastbound on State Highway 50 down a 7-mile grade just west of Canon City. The weather was 20°F, with a light snowfall and snow and ice on the roadway. As the motorcoach descended the grade at approximately 63 mph, the motorcoach began to fishtail.[10] For approximately the next 36 seconds, the driver was in and out of control of the motorcoach as he attempted to negotiate the various curves on the downgrade.

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[9]Hynd, D., and McCarthy, M., *Study on the Benefits Resulting from the Installation of Event Data Recorders, Final Report*, 2014.
[10]A vehicle dynamic event in which the rear axle(s) of the vehicle slides out to one side or the other.

The accident event was captured by the Detroit Diesel DDEC IV engine ECU. The accident resulted in three fatalities, 36 serious injuries and 24 minor injuries.

Figure 3.1.2. 1999 Setra at final rest position[11]

Because of the data obtained from the Detroit Diesel DDEC IV ECU, NTSB investigators were able to determine and conclude that one of the main contributing factors to this accident was the improper use of the engine retarder. With snow and ice on the roadway, the driver's attempt to downshift the Allison automatic transmission and put the transmission in neutral took away any of the natural engine braking to help maintain control and speed as the truck descended the grade. The driver received little to no training on the transmission retarder device. Without an HVEDR, it would not have been possible to determine at what points during the event the driver used the retarder or put the automatic transmission in neutral. HVEDR allowed for the determination of these contributing factors and took investigators back to a driver and driver-training problem that could then be corrected.

Because of the nature and complexity of commercial truck and bus driving and the need for commercial drivers to know proper grade descension—starting down the grade in the proper gear, as well as knowing when and when not to use other driver assistance or vehicle control devices like engine brakes (Jake Brakes) and driveline retarders (transmission retarders, Telma retarders, etc.)—HVEDR devices are valuable technologies when investigating accidents to determine whether these controls are properly used or not.

[11]Source: NTSB Report No. NTSB/HAB-02/19; Accident No. HWY-00-FH011; Accident Location: Eastbound State Highway 50 near milepost 273, Canon City, Colorado

As discussed in Section 3.1 on accident reconstruction, monitoring driver behavior not only improves driver safety behaviors but can better understand them for improving training protocols, as concluded with the Canon City event. In this case, the data was recorded by HVEDR-type functionality already installed in the OEM ECU.

A few years later in 2002, NTSB published Recommendation H-02-35, calling for IEEE and Society of Automotive Engineers (SAE) International to collaborate "as part of [their] initiative to establish on-board vehicle recorder standards, to develop standards for brake and transmission electronic control units that require those units to store a full history of electronic fault codes that are time-stamped using a recognized clock synchronized with other on-board event data recording devices."

The 1999 Canon City, CO accident illustrates a stark contrast to the 2013 Ottawa, ONT accident that triggered the need for research into EDR standardization in passenger, commercial vehicles. Similar to TSB's calls for research into EDR standardization, NTSB has highlighted the urgency for devices monitoring and recording operational behavior as early as their 2002 Safety Recommendation H-02-35. As of 2013, NTSB has endorsed SAE's work in producing a comprehensive list of data elements and data requirements for accident reconstruction and standards with the publication of SAE Recommended Practice (RP) J2728; as discussed later in this report, however, NTSB has also acknowledged that some crash data standards are still unmet and H-02-35 remains reopened.

As of 2015 and currently in implementation stages, the only data-recording device standards mandated in North America are those for tachographs in Mexico and ELDs in the United States. In December 2017, the Canadian Transport Minister announced a law that would require ELDs also be used in Canada by 2020. ELD is FMCSA-mandated in the U.S. for monitoring records of duty service (RODS) and driver HhowOS safety compliance, however, and these devices monitor parameters typically include location data, date and time, engine hours, vehicle miles, duty status, driver identification information, vehicle information, motor carrier identification data, and engine power-on and -off timestamps. These parameters do not provide data comparable to that provided by OEM ECUs, like the parameters that were found helpful in the 1999 Canon City, CO incident or sought after in the 2013 Ottawa, ONT accident. Data-logging regulation must further account for the plethora of factors contributing to driver safety beyond exceeded HOS and driver fatigue.

Furthermore, as vehicles become more advanced, especially with the advent of ADAS, such as automatic emergency braking (AEB), it will be important to analyze EDR data to determine whether driver inputs or ADAS systems effectively intervene in the moments leading up to a crash.

3.1.3 Highway Infrastructure Design & National Emergency Databases

The collection of EDR data made available to transportation safety authorities can be leveraged to improve highway safety by identifying highway/infrastructure design issues, vehicle or system issues, and improving national crash and emergency response databases.

The aforementioned 1998 VDO study discovered improvements not only in accident reduction but suggested the use of UDS and its system extension, Emergency Management, could improve safety by sending alarm signals when accidents occurs, providing accident location via GPS and establishing communication with emergency services, resulting in reduced response times.

In August 2003, the European Commission, under the Competitive and Sustainable Growth Programme of the Fifth Framework, published the *ECBOS - Enhanced Coach and Bus Occupant Safety Final Report*. This project was jointly conducted by research centers of six EU-member nations and motivated by approximately 20,000 European buses and coaches that were involved in crashes, resulting in 30,000 injuries and 150 deaths. The study's findings led to various recommendations on bus crashworthiness, addressing compatibility of large truck and bus structures with lower and smaller passenger vehicles, occupant restraints, better crash protection for drivers, rollover mitigation and prevention of occupant ejections (or partial ejections). Also discussed were recommendations for a harmonized bus accident database and guidelines for use of numerical techniques.

Regarding data elements for improving highway safety research databases and analysis, Gabler et al. concluded in a 2004 study[12] that EDRs can contribute significant improvements to accident databases. Regarding heavy truck and bus accident databases specifically, Gabler et al. identified database data elements that can be attributed to the Trucks Involved in Fatal Accidents (TIFA) and the Motor Carrier Management Information System (MCMIS) Crash File databases. The TIFA database consists of accidents specifically involving medium- and heavy-duty vehicles with GVWR of 10,000 lbs. or more. At the time of the study, TIFA consisted of 250 data elements, 15 of which Gabler et al. suggested could be provided by the then-current EDR technology and 37 of which could be provided by future EDR technology. The MCMIS database is operated and maintained by FMCSA and contains data from state police reports for crashes involving drivers and vehicles of motor carriers. It was suggested that for state accident databases to meet the Model Minimum Uniform Crash Criteria (MMUCC) format requirements, EDR could provide one-third (24 of 75) of the recommended data elements.

Similarly, the 2006 VERONICA I *Final Report*[13] addressed the technical, administrative, legal, safety and environmental issues with the implementation of EDR in Europe; evaluated available and necessary standards, solutions and requirements; and recommended a legal framework, in particular to collect accident data into the European Accident Databases. The VERONICA report pointed out that member states have been collecting individual road accident data details on a voluntary basis since 1991 using the national collection system, the CARE database (i.e. Community Road Accident Database). This hindered their potential and limited their data analysis and comparisons at the E.U.-level, however. This led to the recommendation for and development of the Common Accident Data Set (CADaS) to help standardize a minimum set of data allowing recipients to obtain comparable road accident data, eliminating the limits restricting CARE. This

[12]Gabler, H. C., Gabauer, D. J., Newell, H. L., and O'Neill, M. E., *Use of Event Data Recorder (EDR) Technology for Highway Crash Data Analysis, Final Report*, Dec. 2004.

[13] Schmidt-Cotta, R., Steffan, H., Kast, A., Labbett, S., and Brenner, M., *Vehicle Event Recording based on Intelligent Crash Assessment (VERONICA) Final Report,* Nov. 2006.

would allow the CADaS system to accept increasingly more national data for aggregation within the CARE database.

In the 2006 document, “Intelligent Transportation Systems [ITS] in Israel,” MOT’s Chief Scientist Zeev Shadmi identified ITS highway safety initiatives of interest. At the time of the presentation, an ongoing eSafety research and development program hosted by the Ministry of Science and Technology was cited and said to focus on such developments involving Mobileye, Roadeye, and the “Aider” (eCall) E.U. FP5 project technologies, with a commercial market for the eCall service. These initiatives were identified as contributing to an Israeli national ITS policy and framework architecture adapting the European ITS FRAME or U.S. DOT architectures. ITS standards were to be developed by the Israel Institute of Standards expert committee with a view towards cooperation with the European Union in ITS e-Safety.

The benefits of an EDR/HVEDR database for national highway design and safety systems were also acknowledged in China. In the 2011 presentation, “National Road Safety Action Plan in China,” Wang identified a 2008 cooperative agreement signed among China’s Ministry of Science and Technology, Ministry of Transport and Ministry of Public Security. This agreement inaugurated a national highway safety action plan for preventing and decreasing accidents, mass injuries and fatalities and improving pre-warning, control and emergency rescue operations. Technology was cited as the means to achieve four main objectives in support of such goals, namely intervening in traffic participants’ behavior, organizing transportation vehicle safety, managing and enforcing road traffic and safety and enhancing road infrastructure safety.

Wang indicated that a research phase from 2009 to 2011 funded by local and central governments sought to implement large-scale demonstration projects across a 5000-kilometer road network to establish a series of road-safety technology specifications into a sustainable action plan. Five provinces participated in commercial vehicle safety inspections and remote traffic safety education and training. An integrated traffic accident database belonging to police and highway agencies as well as vehicle operation-monitoring technologies were developed. The presentation proposed its objectives for the next phase of research. Major targets for the new safety infrastructure were expressways, rural and low-volume roads, and commercial vehicles, with a vision for implementing this infrastructure in the internet of things, Beidou Navigation System, and driver behavior interventions.

As aforementioned, no technical obstacles to EDR/HVEDR standardization have been discovered. Rather, obstacles related to EDR/HVEDR implementation have manifested sometimes as objections to government overreach in industry manufacturing design choices[14] or mandating device installation on fleet owners’ private property,[15] with constitutional privacy rights

[14]Williams, J., *Delivering a Compliance Framework for Heavy Vehicle Telematics, Final Policy Paper*, June 2014.
[15]FMCSA, *Electronic Logging Device (ELD) Test Plan and Procedures*, Apr. 2016.

problematized specifically in light-vehicle EDR.[16] [17] [18] [19]

3.2 Foundations for Commercial Bus & Motorcoach EDR Standardization

As early as 1999, when researchers first acknowledged the positive role EDR/HVEDR has played in driver safety and crash investigation, various federal safety agencies have called for HVEDR in buses and motorcoaches. The following is a brief overview of prior recommendations for an EDR compliance framework in heavy vehicles generally and motorcoaches and buses specifically.

In 1999, NTSB issued Recommendations H-99-53 and H-99-54 to NHTSA to require EDRs in motorcoaches and school buses. On November 2, 1999, NTSB issued a recommendation concerning school bus and motorcoach safety. NTSB Safety Recommendations H-99-45 through -54 pointed to numerous studies that prompted several safety recommendations. At the time, on-board recorders had been in use by school bus fleets in over 100 U.S. jurisdictions.

After NTSB was able to determine the root causes of the triple-fatality motorcoach accident outside of Canon City, Colorado in December 1999, the agency published Safety Recommendation H-02-35 in December 2002 and called for the industry to collaborate in establishing on-board vehicle recorder standards.

The recommendation regarding on-board recorders pointed to a study by Laidlaw, Inc., that took place in Bridgeport, Connecticut from December 1, 1996 through May 30, 1997. Nearly half of the fleet's 150 buses were equipped with an on-board recorder. The study found that 72% of the accidents happened on buses not equipped with EDR. The results prompted changes to Laidlaw's training program. In this and other similar studies, the on-board recorder did not record data such as crash pulse but was able to determine speed. Regarding on-board recording devices on school buses and motorcoaches, NTSB recommended,

> *All motorcoaches and busses manufactured after January 1, 2003 be equipped with on-board recording systems that will record a minimum of 18 parameters including acceleration, braking, speed, etc…Other things to consider are the sampling rate, data preservation in the event of an accident or power loss and the location of the on-board recording system. Additionally, in cooperation with government agencies, develop and implement standards for bus crash data using on-board recording devices. Minimal parameters to be recorded should be data sampling rates, duration of recording, interface configurations, data storage format, incorporation of*

[16] NHTSA EDR Working Group, *Event Data Recorders: Summary of Findings*, Aug. 2001.
[17] Schmidt-Cotta, et al., *Vehicle Event Recording based on Intelligent Crash Assessment (VERONICA)*.
[18] U.S. Congress, H.R. 22, Subtitle C, "Part I - Driver Privacy Act 2015."
[19] Williams, *Delivering a Compliance Framework for Heavy Vehicle Telematics*.

fleet management tools, fluid immersion survivability, impact shock survivability, crush and penetration survivability, fire survivability, independent power supply, and ability to accommodate future requirements and technological advances.

In 2004, NHTSA published a Notice for Proposed Rulemaking (NPRM; 69 FR 32932) for voluntarily installed EDRs to record a minimum set of specified data elements useful for crash investigations, analysis of safety equipment performance and CAN systems. The NPRM explicitly stated it did not mandate EDR and applied only to voluntarily installed EDRs in vehicles with GVWR of 8,500 lbs. and an unloaded vehicle weight of <5,500. This NPRM set the foundation for Part 563. In 2006, NHTSA published the Part 563 rule in CFR Title 49 (71 FR 50998). The original Part 563 rule published in 2006 was revised and reissued in 2009. Part 563 outlined specifications for uniform, national requirements for equipping EDR. The rule remained voluntary and applicable only to light-duty vehicles of GVWR 3,855 kg (8,500 lbs.) or less. In the 2006 *Final Report*, the VERONICA research team noted that the proportion of new U.S. light-vehicle fleets that were equipped with a portion of the Part 563-compliant EDR had grown to over 90%. This indicated that Part 563 specification compliance was well underway.

NHTSA published an "Approach to Motorcoach Safety" memorandum to Docket No. 2007-28793 in 2007. Within the context of NTSB Safety Recommendations H-99-53 and H-99-54, the memorandum discussed how specifications for crash characteristics and other measurements would differ for motorcoaches compared to the requirements for light passenger vehicles established in Part 563. NHTSA indicated they were collaborating with the SAE Truck & Bus Committee to co-develop a standard for recording crash parameters relevant to heavy trucks. NHTSA referred to the then in-progress SAE J2728 standard developing functional requirements for HVEDRs and indicated NHTSA would consider an appropriate requirement for HVEDR installation in motorcoaches once J2728 development completed.

Later in 2009, the U.S. DOT published the *Motorcoach Safety Action Plan*, which identified opportunities for enhancing motorcoach safety. The Plan presented the Department's analysis of safety data and assessment of causes and contributing factors for motorcoach crashes, fatalities and injuries. In addition to requiring what are now called ELDs, the Department outlined action items for NHTSA and FMCSA to improve data collection and analysis and called for these organizations to "[m]ake agency decision on installation and performance characteristics of heavy vehicle event data recorders (HVEDRs) on motorcoaches - Q2 2010 (NHTSA)."

The report highlighted the collaborative work between NHTSA and the SAE Truck & Bus Committee's J2728 "Heavy Vehicle Event Data Recorder (HVEDR) Recommended Practice, Tier 1." The report also stipulated a deadline outlining the first quarter of 2010 as the SAE J2728 Committee's estimated release date for the J2728 document. NHTSA was to make a decision on "installation and performance characteristics of HVEDRs on motorcoaches" by the second quarter of 2010; however, no regulatory activity concerning motorcoach or passenger bus EDR followed.

In 2011, however, NHTSA published the “NHTSA Vehicle Safety and Fuel Economy Rulemaking and Research Priority Plan 2011-2013,” stating a priority for developing HVEDR performance requirements. The “Priority Plan” indicated that the agency would decide by 2011 whether to initiate rulemaking for EDR requirements for newly manufactured heavy vehicles.

A Preliminary Regulatory Evaluation (PRE) from the Office of Regulatory Analysis and Evaluation followed in November 2012 and analyzed potential impacts of a NHTSA-proposed FMVSS 405, “Event Data Recorders,” which would require all light vehicles to be equipped with EDRs that meet the standardized data elements, capture, format, retrieval and crash survivability requirements outlined in Part 563. The 2012 PRE on FMVSS 405, however did not discuss medium- and heavy-duty vehicles, likely due to already widespread in-vehicle recording for these classes as well as differing requirements.

In 2014, the TRL research team discussed the SAE J2728 “Heavy Vehicle Event Data Recorder Committee, Tier 1” standard published in June 2010. The TRL team explicitly recommended that EDR data be stored separately from digital tachograph data.

Also in 2014, the Australian NTC’s *Final Report*[20] addressed a compliance framework for mass standardization of EDR/HVEDR. This policy report highlighted that Australian freight and bus industries had already been equipped with telematics devices to improve on-road safety and efficiency. To illustrate, in 2011, NTC made recommendations for developing an enforcement policy that would support industry uptake of telematics, followed by a 2012 proposal for ensuring that ITS in each jurisdiction was compatible and a set of agreed compliance and enforcement principles was established.

As of the writing of this report, no current regulations requiring HVEDR are in place in the NAFTA zone. NHTSA’s last discussion of HVEDRs was published in the U.S. DOT *Motorcoach Safety Action Plan* (DOT HS 811 177) in November 2009 and was still outlined as a priority in the “NHTSA Vehicle Safety and Fuel Economy Rulemaking and Research Priority Plan 2011-2013” of 2011. See Appendix B for a complete history of NTSB Safety Recommendations pertaining to EDR/HVEDR.

3.3 Current Status of Heavy Vehicle Data Recorders in Commercial Passenger Buses

Active and inactive EDR/HVEDR standards activities have largely taken place in the United States and been organized within the internationally recognized standards organization, SAE International. SAE RP J2728 is the document addressing and defining the protocols for heavy vehicle network communication and ECU system management. Heavy vehicles, as defined by J2728, are heavy-duty ground-wheeled vehicles over 4,545 kg (10,000 lbs.), commonly referred to as Classes 3-8. In early 2017, the SAE J2728 committee reconvened, is once again active and, similar to the SAE J1698 Committee (for passenger-vehicle EDR), currently looks to address new

[20]Williams, *Delivering a Compliance Framework for Heavy Vehicle Telematics.*

challenges and update HVEDR recommended practices to keep up with new vehicle technologies, especially ADAS.

Even without federal regulations, however, the industry has increasingly headed in the direction of standardizing HVEDR functionality according to J2728. This industry standardization has been largely driven by manufacturers' needs to examine warranty claims and product performance in the field, as well as commercial carriers' general demand for data to improve fleet performance and driver safety.

The heavy-vehicle data recorders whose standardization have been regulated internationally are tachographs and ELDs. In 1990, then-president of Mexico Carlos Salinas de Gortari founded the initial First Class Differentiated Service Enlaces Terrestres Nacionales (ETN), who used the first Brazilian Mercedes-Benz motorcoaches (Model OM-371 RS and RSD) that included the tachograph as standard equipment.

Mechanical and electronic tachographs have been mandated recording devices in heavy vehicles in the U.K. and E.U. for 32 years, and European tachograph regulations are defined by Commission Regulation No. 1360/2002, issued June 13, 2002.

Comparable to tachographs, which are continuously recording journey recorders (or loggers), are ELDs. The ELD mandate currently in effect in the United States was inaugurated on February 16th, 2016. Since the official release of the mandate, FMCSA has established a precise compliance schedule that allows motor carriers sufficient 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. The second phase is set to last from the end of the first phase to the end of 2019. The final and strictest phase begins after December 16, 2019 and demands full compliance from carriers. Once in effect, this phase enforces HOS tracking by using only registered FMCSA-compliant ELDs on all drivers and carriers operating in the U.S. On their website,[21] FMCSA has published a list 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.

FMCSA's development of an ELD mandate models a pre-existing regulatory infrastructure for EDR standardization for heavy commercial vehicles. Among the most important compliance factors the ELD mandate addressed were data standardization, integrity, transferability and privacy. The ELD mandate also offered a cost-benefit analysis that considered the lowest costs to manufacturers and CMV carriers for the compliance transition.

Objections and comment periods to the ELD mandate also provide insight into anticipated complications of HVEDR standardization. Aside from overwhelming concerns addressed in a number of international studies regarding data privacy, the ELD mandate rulemaking period

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

acknowledged standardization challenges like costliness of crash survivability of data recorders. NTSB asked FMCSA to consider adding crash survivability for ELDs 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.[22]

Additionally, motor carriers expressed concerns of government overreach into private vehicle manufacturing. Concerns of government overreach were also echoed by the Australian NTC's 2014 *Final Report*, which concluded that more specific regulatory purposes must be defined to justify the cost of a mass EDR compliance framework.

It should be noted, however, that these concerns were primarily raised by specialty, small-volume and light-vehicle manufacturers, and that crash survivability is already addressed by OEM ECUs that feature HVEDR functionality to some degree.

The ELD mandate advanced industry standards for handling data and access requirements, ensuring only authenticated individuals could access an ELD system to protect data privacy. 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." FMCSA therefore acknowledged a potential market for additional security features.

ELDs are significant here given that many of these devices feature EDR functionality, and the ELD device may be considered a potential "host" for an expanded EDR functions 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.[23]

3.4 Commercial Bus HVEDR Feasibility Summary

Technical reasons against EDR/HVEDR implementation and standardization have not been discovered. This study considers OEM-based HVEDR and aftermarket add-on devices as the two most feasible HVEDR standardization implementation methods.

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[22] FMCSA, *Electronic Logging Device (ELD) Test Plan and Procedures*, 2016.
[23] Ibid.

In accordance with SAE J2728, the industry has moved in the direction of HVEDR standardization largely without regulation. Since model year 2000, a vast majority of commercial vehicle trucks and buses have been equipped with OEM HVEDR functions that have the capability of recording extensive data when triggered by aggressive braking ("hard brake") events or collision events with or without braking. OEM-supplied HVEDR functions by utilizing the vehicle's factory-equipped ECU, communications network and sensor; no additional equipment is purchased or installed on the vehicle.

Within the NAFTA market, there are commercial fleet aftermarket tracking/dispatch devices and ELDs that can record incident-specific data. These aftermarket devices include both non-mandated (such as video data recorders [VDRs] and telematics systems) and mandated systems, such as ELDs. These systems do not use their own sensors but rather tap into the vehicle's CAN bus and are configured to monitor these channels for data.

The 2015 ELD mandate enforces FMCSA standards for RODS and driver HOS to improve driver safety specifically and highway safety generally. In addition to recording on- and off-duty status, ELDs are required to store pertinent HOS compliance data like driver identification, GPS 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.

In addition to continuous monitoring, many ELD manufacturers have expanded the number of incident-specific data elements these devices report. Many ELDs are now equipped with additional capabilities for recording data pertinent to collision events, such as event triggers like hard braking, detailed data on collision events and driver operational behavior, in addition to some ADAS capabilities, such as lane departure warnings, following-distance monitoring and collision avoidance.

Of particular interest with these add-on devices is how ELDs have already been mandated in the U.S. with a schedule for compliance to reach full effect by 2019. The ELD mandate models a mandatory compliance framework and policy infrastructure for data standardization and transferability in addition to data privacy protection, which are shared priorities for HVEDR standardization and can be maximized for its implementation.

The immediate downside to leveraging the ELD device as a "host" for an HVEDR function, however, is that not all bus, motorcoach or school bus operations would be required to operate with an ELD.

Furthermore, although an add-on device, such an ELD with HVEDR programmed functionality, 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.

It must also be noted that for those CMVs required to meet ELD compliance, FMCSA does not require crash survivability for these devices nor their data despite NTSB recommendations. Adding HVEDR software to existing ELDs would change requirements for sustaining high-impact and crash forces and significantly increase costs for ELD manufacturers as well as commercial purchasers of these devices, which would result in significant CMV carrier pushback.

A standalone data recorder designed specifically to meet crash survivability and analysis requirements, such as Kienzle Argo GmbH *Unfalldatenspeicher* (UDS), or "accident data recorder," provides an alternative to using ELD devices as a "host" for HVEDR software. A significant advantage to this device is its reporting rate of 1,000 samples a second at 1-10 samples/sec or 1-10 Hz for 30 seconds. However, this advantage comes at an 800-1000€ (1200-1600 CAD, 1000-1250 USD) per-vehicle cost of installation. Such costs would require significant substantiation from regulatory accounting offices and, again, would result in heavy fleet pushback regardless of regulatory justification.

The more feasible alternative to aftermarket, stand-alone data recorders is maximizing OEM data-recording devices, such as the OEM chassis/engine/drivetrain safety ECUs already installed in all heavy-duty vehicles, the vast majority of which are equipped with some HVEDR functionality. Leveraging current OEM ECUs for HVEDR purposes is a less costly option for OEMs to phase into compliance over time and would receive the least pushback of all alternatives.

When examining OEM-based HVEDR feasibility, however, it must be noted that a considerable downside for these 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 like the Kienzle Argo UDS essentially serving as a data-acquisition system.

Standardization of HVEDR through an OEM-based solution must account for the variations in HVEDR functionality across OEM ECUs (as explored extensive detail in Deliverable No. 4). While beneficial that OEM ECUs essentially record the same data, many physically record in different modules. Standardizing HVEDR recording units need not control in which ECUs manufacturers choose to store the data but reducing HVEDR recording and storage to one unit is optimal. It would be preferable to avoid dispersing all the data that would constitute an HVEDR report across different ECUs and, instead, record all data to a single ECU that can be accessed either via the preferred connection method (the diagnostic link connector [DLC], as defined by J1939/13 on a heavy truck) or direct to that single ECU if the vehicle sustains too much damage to connect via the DLC.

Reporting duration and frequency as well as trigger thresholds vary even more significantly across OEM ECUs than the number of recording units and complicates data aggregation into a common database such as an ACN system for crash analysis research. Most OEM HVEDRs record at 1 Hz, a considerably low resolution and the most glaring departure from SAE RP J2728, which recommends a record rate of 10 Hz.

Nonetheless, current OEM HVEDR capabilities are actually on track to be standardized because of SAE RP J2728. Most heavy vehicles on the road today are already equipped with data recorders that write more than 30 seconds of data. SAE J2728 also recommends several additional data elements and header recorded values that current OEM HVEDRs do not report. An OEM-based HVEDR standardization must effectively address the currently wide variation in HVEDR functionality across OEM ECUs as well as variation in data elements and reporting frequency, duration and thresholds.

Of additional note is significant inconsistency in date and timestamps across OEM data records, which reinforces the need for the common clock first recommended by NTSB's 2002 Safety Recommendation H-02-35. In 2013, NTSB endorsed SAE's work in producing a comprehensive list of data elements and data requirements for accident reconstruction and standards with the publication of SAE Recommended Practice J2728; however, NTSB lamented that SAE J2728 fell short of a common clock and reopened Safety Recommendation H-02-35.[24] HVEDR standardization must include a common clock, and the accuracy and universality of GPS provides an easily available solution.

Finally, crash survivability has been emphasized as a significant objective for data-recorder standardization as early as 2002. As discussed in *Volume II: Supplemental Findings for Trucks, Motorcoaches, and School Buses* of their *Final Report*, the NHTSA EDR Working Group raised particular concerns for school buses and whether this industry has sufficient funds to outfit crash survivable EDR modules in their fleets. Indeed, the costs and complication of fitting EDR units with crash survivability that sustains impact shock, temperature, fluid immersion, penetration and especially fire were the reasons the FMCSA ruled out NTSB-requested requirements for crash survivability of ELDS when drafting of the 2015 ELD mandate.

The 2010 SAE RP J2728, however, addressed HVEDR crash survivability and established only minimal requirements that HVEDR units survive collisions while still maintaining HVEDR compliance. Further research is needed on HVEDR units' ability to withstand crash severity and the costs for HVEDR data preservation as NTSB hopes to achieve protection of these modules with little financial impact and significant safety returns.

4.0 CONCLUSION

This study's findings point to the importance of an HVEDR standardization entailing a common reporting format that includes standardized data elements and reporting frequency, as well as a common clock dated and timestamped by GPS. Events outside of crashes, such as hard brake events and aggressive driving events, should be included in this HVEDR technology to help coach commercial drivers and achieve lower accident rates, as numerous U.S. and international research studies have found. These data can also be archived in a common format as recording and archiving data in an unconventional format makes it difficult to capture data into a tabular format with accurate results for meaningful crash analysis.

[24] NTSB, "Safety Recommendation H-02-35," accessed Feb. 2018

A common data-retrieval tool compatible with any commercial bus regardless of the commercial vehicle (or engine) manufacturer, as modeled by the universal Bosch CDR Tool for light vehicles, can be developed. By standardizing a common data imaging tool for HVEDR, training can be greatly simplified and government agencies, researchers, fleet managers, law enforcement agencies and independent consultants will not need to purchase and train on multiple tools for imaging data from commercial trucks and buses.

APPENDIX A - ACRONYMS

ACCTYPE	Accident Type
ACM	Air Bag Control Module
ACN	Automatic Crash Notification
ADAS	Autonomous Driver Assistance Systems
ADR	Accident Data Recorder
AEB	Automatic Emergency Braking
Ax, Ay	Longitudinal, Lateral Acceleration Change (g)
BAGDEPLY	airbag System Deployment
CADaS	Common Accident Data Set
CAN	Controller Area Network
CARE	Community Road Accident Database
CDC	Collision Deformation Classification
CDR	Crash Data Retrieval
CDS	Crashworthiness Data System
CFR	Code of Federal Regulations
CIREN	Crash Injury Research and Engineering Network
CMV	Commercial Motor Vehicle
D	Deployment (event)
D/DL	Deployment and Deployment-Level (event)
D/N	Deployment and Non-Deployment (event)
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
DOT	Department of Transportation
DVLAT	Lateral component of delta V
DVLONG	Longitudinal component of delta V
ECBOS	Enhanced Coach and Bus Occupant Safety
ECM	Engine Control Module
ECU	Electronic Control Unit
EDR	Event Data Recorder
EDS	Electronic Data System
ELD	Electronic Logging Device
ESC	Electronic Stability Control
ETN	Enlaces Terrestres Nacionales (Mexico)
FHWA	Federal Highway Administration
FMVSS	Federal Motor Vehicle Safety Standard
GM	General Motors
GVWR	Gross Vehicle Weight Rating
HOS	Hours of Service
HVEDR	Heavy Vehicle Event Data Recorder
IEEE	Institute of Electrical and Electronics Engineers
ITS	Intelligent Transportation System
IVDR	In-Vehicle Data Recorder

JDR	Journey Data Recorder
kph	kilometers per hour
LER	Locomotive Event Recorder
MANEUVER	Attempted Avoidance Maneuver
MANUSE	Manual (Active) Belt System Use
MCMIS	Motor Carrier Management Information System
MMUCC	Model Minimum Uniform Crash Criteria
MOT	Ministry of Transport
MOU	Memorandum of Understanding
mph	miles per hour
ms	milliseconds
MSSC	Mecanica Scientific Services Corporation
MY	Model Year
N	Non-Deployment (event)
NAFTA	North American Free Trade Agreement
NAS	National Academy of Sciences
NASS	National Automotive Sampling System
NCSA	National Center for Statistics and Analysis
NHTSA	National Highway Traffic Safety Administration
No.	Number
NPRM	Notice of Proposed Rulemaking
NTC	National Transport Commission (Australia)
NTSB	National Transportation Safety Board
OEM	Original Equipment Manufacturer
PDOF	Principal Direction of Force (1st)
PDOF1	Clock Direction for PDOF in Degrees (Highest CDC)
PRE	Preliminary Regulatory Evaluation
RCM	Restraint Control Module
RODS	Record of Duty Status
rpm	revolutions per minute
SAE	Society of Automotive Engineers
SCI	Special Crash Investigations
SDM	Sensing and Diagnostic Module (General Motors)
sec	seconds
t	time (seconds)
TIFA	Trucks Involved in Fatal Accidents
TRB	Transportation Research Board
TRL	Transport Research Laboratory
TSB	Transportation Safety Board of Canada
UDS	Universal Documentation Service
VDO	Vereinigte DEUTA - OTA (Company Name)
VDR	Vehicle Data Recorders
VERONICA	Vehicle Event Recording based on Intelligent Crash Assessment
VIN	Vehicle Identification Number
Vx (ΔVx)	Longitudinal delta V (mph)
Vy (ΔVy)	Lateral delta V (mph)

APPENDIX B – HISTORY OF EDR/HVEDR SAFETY RECOMMENDATIONS & STANDARDS

The following timeline includes U.S. National Transportation Safety Board (NTSB) and Transportation Safety Board of Canada (TSB) Recommendations, as well as National Highway Traffic Safety Administration (NHTSA) and Federal Motor Carrier Safety Administration (FMCSA) rulemaking as they pertain to the development of event data recorder (EDR) and heavy vehicle event data recorder (HVEDR) standards. This history also features significant international developments and Society of Automotive Engineers International (SAE) J1698 "Event Data Recorder" and J2728 "Heavy Vehicle Event Data Recorder (HVEDR) Standard – Tier 1" Committee organizations and Recommended Practices to demonstrate how technical specifications for EDR and HVEDR developed alongside policymaking.

1997 NTSB ISSUED.
Safety Recommendation H-97-018
Recommended NHTSA and vehicle manufacturers collaborate on the development and implementation of a plan for improved crash data collection through current or augmented sensing and recording devices.

SWOV Institute for Road Safety Research, "SAMOVAR and Traffic Accident Reduction through Monitoring Driver Behavior with Data Records."
The Commission of European Communities 1992-1995 DRIVE-II Research Program findings are published.

1998 Jet Propulsion Laboratory (JPL), California Institute of Technology: *Advanced Air Bag Technology Assessment, Final Report*
Included a recommendation to "study the feasibility of installing and obtaining crash data for safety analysis from crash recorders on vehicles."

1999 NTSB ISSUED.
Safety Recommendation H-99-53
Recommended the requirement that all school buses and motorcoaches manufactured after January 1, 2003 be equipped with on-board recording systems and specified elements and reporting rates.
Safety Recommendation H-99-54.
Recommended government agencies and industry collaborate on the development and implementation of standards for on-board recording of bus crash data elements, sampling rates, storage format, survivability and power supply.

2001 NHTSA R&D Working Group: *Event Data Recorders: Summary of Findings, Final Report,* No. NHTSA-1999-5218-9
Findings published by EDR Working Group formed and hosted by NHTSA in response to the 1998 NASA/JPL-issued recommendations for EDR.

2002 NHTSA R&D EDR Working Group: *Event Data Recorders: Summary of Findings, Final Report, Volume II Supplemental Findings for Trucks, Motorcoaches, and School Buses*, No. DOT HS 809 432
Supplemented the NHTSA EDR Working Group 2001 *Final Report* by researching truck and bus EDR and proposing recommendations for data elements, survivability and event descriptions.

NTSB ISSUED.
Safety Recommendation H-02-35
Called for IEEE and SAE collaboration in establishing standards for recording full history of electronic fault codes with a common timestamp.

2003 SAE J1698 "Vehicle Event Data Interface" (VEDI) Committee organized.

SAE ISSUED.
J1698 "Vehicle Event Data Interface – Vehicular Output Data Definition"
Established common format for displaying and presenting light-duty vehicle post-downloaded data.

2004 SAE ISSUED.
J1698-2 "Vehicle Data Interface – Vehicular Data Extraction"
Defined a common method for extracting event data; aimed to utilize existing industry standards by using the SAE J1962 physical interface and designating industry-standard diagnostic protocols for communications.

NHTSA ISSUED.
"Event Data Recorders," Notice of Proposed Rulemaking (69 FR 32932)
Specified a minimum set of data elements for voluntarily installed EDRs to record and initiated 49 CFR Part 563.

NTSB CLOSED – Exceeds Recommended Action.
Safety Recommendation H-97-018
Issued statement endorsing NHTSA's NPRM "Event Data Recorders" as a step toward establishing light-vehicle EDR in response to NTSB recommendations for both light-vehicle and heavy-vehicle applications.

NTSB ISSUED.
Safety Recommendation H-04-026
Recommended that EDRs be installed in all newly manufactured light-duty vehicles once light-vehicle EDR standards were developed.

2005 SAE REVISED.
J1698 "Vehicle Event Data Interface – Vehicular Output Data Definition"

SAE ISSUED.
J1968-1 "Vehicle Event Data Interface – Output Data Definition"
Defined data items related to events.

2006 NHTSA ISSUED.
"Event Data Recorders," Final Rule (71 FR 20998)
Published the Part 563 final rule specifying requirements for light-vehicle EDR data "accuracy, collection, storage, survivability and retrievability."

European Commission, Directorate-General for Energy & Transport, Vehicle *Event Recording based on Intelligent Crash Assessment (VERONICA),* Agreement No. TREN-04-ST-S07.39597
Related to "exploring the possibilities of implementing Vehicle Event Data Recorders (EDRs) for enhanced understanding of collisions but also recognizing the potential benefits for prevention, road safety and legal fairness."

2007 NHTSA, "NHTSA's Approach to Motorcoach Safety," Memorandum to Docket No. 2007-28793

Discussed within the context of NTSB Safety Recommendations H-99-53 and -54 how specifications for crash characteristics and other measurements would differ for motorcoaches and indicated a standard (the contemporaneously in-progress SAE J2728) was under co-development with the SAE Truck and Bus Committee, after which NHTSA was to consider appropriate HVEDR installation requirements in motorcoaches.

2008 NTSB CLOSED – Acceptable Alternate Action.
Safety Recommendation H-04-026

Issued statement acknowledging NHTSA's 2006 final rule for voluntary compliance with light-vehicle EDR installation but made clear NTSB sought mandatory compliance.

NTSB CLOSED – Unacceptable Action.
Safety Recommendation H-02-035

Issued statement of dissatisfaction that IEEE's work on on-board vehicle recording common timestamps ceased without developing the recommended standards.

NTSB OPEN – Acceptable Response.
Safety Recommendations H-99-53 and -4

Recognized progress in light-vehicle EDR standards but reiterated the need for EDR performance standards for buses, urging an active push for completing the development of standards for large motorcoaches and requirement for EDRs in all new motorcoaches.

2009 European Commission, Directorate-General for Energy & Transport, *Vehicle Event Recording based on Intelligent Crash Assessment, VERONICA-II*, Agreement No. TREN-07-ST-S07.70764

Studied European EDRs and concluded EDR's purpose is to reduce the number of fatalities, provide opportunities for in-depth research using actual crash data from EDR and improve vulnerable road-user safety, among other EDR benefits.

NHTSA, "Vehicle Safety Rulemaking and Research Priority Plan 2009-2011," Docket No. NHTSA-2009-0108

Included a priority to develop performance requirements for "heavy-vehicle EDRs" with the next agency decision deadline set for 2010.

U.S. Department of Transportation (DOT), *Motorcoach Safety Action Plan*, Publication No. DOT HS 811 177

Listed plans to augment the data currently collected on motorcoach drivers and operators by having the FMCSA explore other passenger carrier data sources. Also refers to NHTSA's work with the SAE Truck and Bus Committee regarding the development of SAE Recommended Practice J2728 "Heavy Vehicle Event Data Recorder (HVEDR) - Base Standard."

2010 SAE J1698 "Vehicle Event Data Interface" Committee reconvened as the "Event Data Recorder" Committee

Addressed recently proposed legislation responding to a series of reported unattended acceleration claims and featuring some degree of an EDR requirement; conducted a five-year review of 2005 J1698 Recommended Practice to update it according to in-progress and changing technologies; restructured J1698 "Event Data Recorder" base document into a series of three documents: "J1698-1 Event Data Recorder – Output Data Definition," "J1698-2 Event Data Recorder – Retrieval Tool Protocol," and "J1698-3 Event Data Recorder – Compliance Assessment." Committee remains active to date.

SAE ISSUED.
J2728 "Heavy Vehicle Event Data Recorder (HVEDR) Standard – Tier 1"
Applied to HVEDRs for heavy-duty, ground-wheeled vehicles over 4,545 kg/10,000 lbs. (Class 3-8), equipped with one or both of the SAE J1587/1708 or SAE 1939 vehicle communication networks; attempted to standardize HVEDR by categorizing data into Tiers 1-3 and setting minimum perform specifications.

NTSB CLOSED – Unacceptable Action/Superseded.
Safety Recommendation H-99-53.
Recommendation was closed and superseded by H-10-07.

NTSB ISSUED.
Safety Recommendation H-10-007
Superseded H-99-53 and reiterated the need for requiring all medium and heavy buses be equipped with EDR.
Safety Recommendation H-10-015
Recommended the development of performance standards for EDRs for medium and heavy trucks and the subsequent requirement for truck EDRs.

2011 NHTSA, "Vehicle Safety and Fuel Economy Rulemaking and Research Priority Plan 2011-2013," Docket No. NHTSA-2009-0108
Included a priority for developing "heavy-vehicle EDRs" performance requirements and whether the agency would initiate rulemaking on EDR requirements for newly manufactured heavy vehicles by 2011.

NTSB OPEN – Unacceptable Response.
Safety Recommendation H-10-007
Issued statement recognizing NHTSA's progress in rulemaking for voluntary passenger-vehicle EDR requirements but urged EDR requirements for medium and heavy buses.

NTSB ISSUED.
Safety Recommendation H-10-010
Recommended FMCSA require all heavy commercial vehicles be equipped with video event recorders capturing data about the driver, external environment and roadway in the event of a crash or sudden deceleration event.

2012 NHTSA ISSUED.
"Event Data Recorders," Final Rule (77 FR 47552)
Amended the final Part 563 rule after receipt of petitions regarding light-vehicle EDR specifications.

NHTSA ISSUED.
"Federal Motor Vehicle Safety Standards; Event Data Recorders," Notice of Proposed Rulemaking (77 FR 74144)
Advanced FMVSS 405 "Event Data Recorders" and proposed FMVSS 405 Part 571 to require compliance with EDR crash test performance and survivability requirements.

2013 SAE REVISED.
J1698-2 "Event Data Recorder – Retrieval Tool Protocol."
Previously "Vehicle Event Data Interface – Vehicular Data Extraction"
Identified common physical interface for intended development of EDR Retrieval Tools connecting to light-duty vehicles; specified how to image, translate and report EDR records through use of existing industry standards.

J1698-1 “Event Data Recorder – Output Data Definition”

Previously “Vehicle Event Data Interface – Output Data Definition”

Provided common data output formats for a variety of data elements (in light-duty vehicle OEM applications) useful for analyzing vehicle crash and crash-like events that meet specified trigger criteria.

SAE ISSUED.

J1698-3 “Event Data Recorder – Compliance Assessment”

Defined procedures to be used for validating relevant EDR output records in compliance with reporting requirements outlined in Part 563, Table 1 during FMVSS-208, FMVSS-214 and other vehicle-level crash testing.

2014 SAE REVISED.

J1698 “Event Data Recorder”

Previously “Vehicle Event Data Interface” and structured into the J1698-1, -2, and -3 document series.

NHTSA ISSUED.

“Request for Comment on Automotive Electronic Control Systems Safety and Security” (79 FR 60574)

Acknowledged the National Academy of Sciences (NAS) 2012 Transportation Research Board (TRB) Special Report No. 308 recommendations that NHTSA ensure commonplace EDR implementation in new vehicles.

NTSB OPEN – Unacceptable Response.

Safety Recommendation H-10-007

Issued statement recognizing NHTSA research on EDRs but expressed disappointment at continued lack of EDR requirement for buses.

2015 SAE REVISED.

J1698-3 “Event Data Recorder – Compliance Assessment,” CURRENT.

NHTSA ISSUED.

“Guidelines for the Safe Deployment and Operation of Automated Vehicle [AV] Safety Technologies,” Extension of Comment Period for Proposed Guidelines (81 FR 31296)

Outlined the need to consider data-recording capabilities and which triggers are appropriate for determining correct operation, operational status and possible malfunctions in AV systems.

Transportation Safety Board of Canada (TSB), *Crossing Collision - VIA Rail Canada Inc. Passenger Train No. 51, OC Transpo Double-Decker Bus No. 8017, Mile 3.30, Smiths Falls Subdivision, Ottawa, Ontario, 18 September 2013*, Railway Investigation Report No. R13T0192

Major commercial bus collision resulting in TSB R15-03.

TSB ISSUED.

Safety Recommendation R15-03

Proposed the Department of Transport require commercial passenger buses to be equipped with dedicated and crashworthy event data recorders.

NTSB OPEN – Unacceptable Response.

Safety Recommendations H-99-54 and H-10-007, -014, -015

Issued statement recognizing continued lack of standards and requirements for EDRs in medium and heavy trucks and buses; reiterated recommendations.

2016 SAE ISSUED.

J1698-1A "Pedestrian Protection EDR output Data Definition Appendix," CURRENT.

Appendix to J1698-1 containing EDR record parameters and definitions related to pedestrian protection systems in light-duty vehicles.

TSB OPEN – Satisfactory in Part.

Safety Recommendation R15-03

Issued statement recognizing Transport Canada's initiation of research on EDR technologies and feasibility of developing an EDR standard for commercial passenger buses in Canada.

NHTSA and FMCSA ISSUED.

"Federal Motor Vehicle Safety Standards; Federal Motor Carrier Safety Regulations; Parts and Accessories Necessary for Safe Operation; Speed Limiting Devices," Notice of Proposed Rulemaking (81 FR 61942)

Proposed regulation applicable to commercial motor vehicles (CMVs) in the heavy-vehicle class and called for equipping a speed limiter and devices that read records of speed-setting changes to limit vehicle speed.

NTSB OPEN – Acceptable Alternate Response

Safety Recommendation H-10-010

Acknowledged FMCSA's NPRM for requiring CMVs to mount video event recorders; indicated the recommendation would be satisfied when the final rule featured incentives for early adoption of video event-recording technologies by majority of motor carriers.

FMCSA ISSUED.

"Federal Motor Vehicle Safety Standards Federal Motor Carrier Safety Regulations; Parts and Accessories Necessary for Safe Operation; Windshield-Mounted Technologies," Final Rule (81 FR 65568)

Amended 49 CFR 393 in accordance with the FAST Act; did not mandate installation or use of devices but permitted their use; requested NTSB close recommendation.

2017 SAE J2728 "Heavy Vehicle Event Data Recorders" Committee reconvened

Currently looks to update HVEDR Recommended Practices in accordance with new vehicle technologies, such as ADAS.

SAE REVISED.

J1698-1 "Event Data Recorder – Output Data Definition"

Listed relevant data elements for vehicle-specific sensors and/or the vehicle system and the system status received by the EDR via the vehicle communication bus, classified data elements into Classifications I-III and specified a minimum reporting frequency of 100 Hz (100 samples/second).

J1698 "Event Data Recorder," CURRENT.

NTSB OPEN – Unacceptable Response.

Safety Recommendation H-99-54

Issued statement of disappointment that performance standards for heavy-vehicle EDRs have not been developed 18 years after first issuance of this recommendation; reiterated recommendation.

2018 SAE REAFFIRMED.

J1698-2 "Event Data Recorder – Retrieval Tool Protocol," CURRENT.

TSB OPEN – Satisfactory in Part.
Safety Recommendation R15-03

Issued statement recognizing Transport Canada's start of research and the SAE Truck and Bus Event Data Recorder Committee's reactivation.

SAE REVISED.
J1698-1 "Event Data Recorder – Output Data Definition," CURRENT.

NTSB OPEN – Unacceptable Response.
Safety Recommendations H-99-54 and H-10-007

Issued statement recognizing continued lack of standards requiring the use of HVEDRs for school buses, transit buses and motorcoaches and indicated the safety expectations of bus passengers should parallel those of other commercial passenger transportation; given that crash-protected recorders have been required for years and even decades in some instances, reiterated H-99-54 and H-10-007 to NHTSA.

SAE Standards Status Definitions[25]

ISSUED Initially published technical report; subject to a five-year review.

REVISED Updated and re-published active technical report; subject to a five-year review.

CURRENT Active version of technical report.

REAFFIRMED Technical report reviewed by technical committee and determined current; subject to five-year review.

[25]Source: https://www.sae.org/standards/development/definitions

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