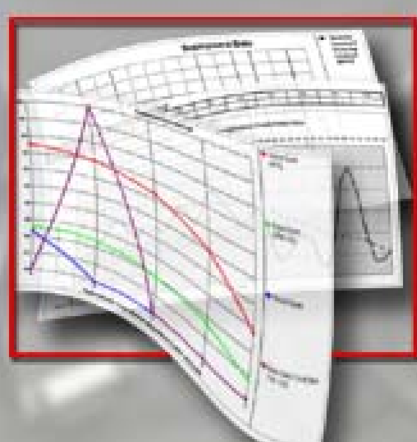
Summary of Findings by the NHTSA EDR Working Group

Event Data Recorders

May 2002



Volume II

Supplemental Findings for Trucks, Motorcoaches, and School Buses

Final Report
DOT HS 809432

EVENT DATA RECORDERS

SUMMARY OF FINDINGS
by the
NHTSA EDR Working Group

Volume II
Supplemental Findings for
Trucks, Motorcoaches, and School Buses

May 2002

FINAL REPORT

DOT HS 809 432

Technical Report Documentation Page

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16. Abstract

Event Data Recorders (EDR) are devices that record information related to highway vehicle crash. EDRs could have a major impact on highway safety, ranging from assisting in real-world data collection, to better defining the auto safety problem, to aiding law enforcement in understanding the specific aspects of a crash. This report summarizes the activities and findings of the NHTSA sponsored Truck and Bus Event Data Recorder Working Group (T&B EDR WG). The T&B EDR WG focused its findings in 3 areas: data elements, survivability of the EDR data, and discussion on when data should be collected. Twenty-eight data elements were highlighted for inclusion in EDRs. These were subdivided as follows: 13-Priority 1 elements, 13-Priority 2 elements, and 2- optional elements. Based on input from the WG members, manufacturers should focus on collecting the Priority 1 data elements and include Priority 2 data elements only as sensors to measure these characteristics become more commonplace, or as technology develops that would make them more feasible for large vehicles. The T&B EDR WG felt that technology was now sufficiently developed for the two optional data elements, but chose not to include them at this time. The T&B EDR WG assessed the needs for EDR data survivability and event description. They found that typical highway-vehicle crash characteristics were different than other modes, such as airplanes and trains, and as such, found that a unique set of survivability requirements were needed. Generally, the T&B EDR WG found that EDR data should be collected when a substantial crash occurs, and thus advised that triggering the EDR should occur when the vehicle's deceleration exceeded 2-4 g. In the process of developing the data elements, survivability, and event description findings, the T&B EDR WG felt the need for some research effort in certain areas. These areas have been identified. In the current fleet of large vehicles, very few employ EDR technology. Summary findings include: 1) EDRs have the potential to greatly improve truck, motorcoach and school bus vehicle safety, 2) Many manufacturers of engines for use in large vehicles have included memory modules in the engine's electronic control unit (ECU) that collect vehicle data, and 3) Manufacturers of aftermarket EDRs have had limited success in deploying EDR technology into large vehicle fleets.

17. Key Words Event Data Recorders; Crash Data Collection, Black Boxes, Survivability of Crash Data	**18. Distribution Statement** Document is available to the public through the National Technical Information Service, Springfield, VA 22161 http//:www.ntis.gov

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Executive Summary

Event Data Recorders (EDR) are devices that record information related to an event. In the context of this report, an event is defined as a highway vehicle crash. EDRs could have a major impact on highway safety, ranging from assisting in real-world data collection, to better defining the auto safety problem, to aiding law enforcement in understanding the specific aspects of a crash.

There has been increased activity in the area of highway-based EDRs over the past decade. In the early 1990s, General Motors (GM) began installing limited-capability EDRs on their new airbag-equipped vehicles. Shortly thereafter, the National Highway Traffic Safety Administration (NHTSA) started utilizing EDR data in its crash investigation process. Around the mid 1990s, there was an increased interest in aftermarket EDRs for fleet application, especially in Europe. By the late 1990s, GM and Ford had developed a third generation of EDRs and were installing these devices on their newly designed vehicles. Today, there are many companies offering original equipment and aftermarket systems, ranging in complexity from simple compact standalone devices that measure crash pulses, to complex devices that are integrated into the vehicle, to devices that can automatically capture video.

Since the early 1990s, highway-based EDRs have been a focus activity within the Federal Government. In 1997, the National Transportation Safety Board (NTSB) issued recommendations to NHTSA to pursue crash information collection using EDRs. The National Aeronautics and Space Administration (NASA) Jet Propulsion Laboratory (JPL), in April of the same year, recommended that NHTSA "study the feasibility of installing and obtaining crash data for safety analyses from crash recorders on vehicles." In November 1999, the NTSB issued recommendations for NHTSA to mandate installation of EDRs on motorcoaches and school buses and gave specific requirements for the data collection and survivability of the devices.

NHTSA's interest in EDRs sprang from its crash investigation program, where early EDRs were used to better understand crashes. This interest has grown over the years from EDRs being used to enhance a few crash investigations to their widespread use in all NHTSA's crash investigation programs – Special Crash Investigation (SCI) program, National Automotive Sampling System's, Crashworthiness Data System (NASS-CDS), and Crash Injury Research and Engineering Network (CIREN). To further the understanding of highway-based EDRs, in 2001, NHTSA launched an EDR research web page. The site provides lists of highway-related EDR reports, articles, news stories, patents, and other material. (http://www-nrd.nhtsa.dot.gov/edr-site/)

This report summarizes the activities and findings of the NHTSA sponsored Truck and Bus Event Data Recorder Working Group (T&B EDR WG). The report supplements the findings of the first EDR report, published in August 2001. That report, which included 29 detailed findings, was the final product of a 1998 NHTSA effort which utilized the collective efforts industry, academia, and other Government organizations to study EDRs. This group was called the EDR WG. The EDR WG's objective was: *To facilitate the collection and utilization of collision avoidance and crashworthiness data from on-board EDRs*.

The T&B EDR WG focused its findings in 3 areas: data elements, survivability of the EDR data, and discussion on when data should be collected. Twenty-eight data elements were highlighted for inclusion in EDRs. These were subdivided as follows: 13-Priority 1 elements, 13- Priority 2 elements, and 2- optional elements. Based on input from the WG members, manufacturers should focus on collecting the Priority 1 data elements and include Priority 2 data elements only as sensors to measure these characteristics become more commonplace, or as technology develops that would make them more feasible for large vehicles. The T&B EDR WG felt that technology was now sufficiently developed for the two optional data elements, but chose not to include them at this time. Several companies are actively pursuing incorporation of event video technologies into EDRs.

The T&B EDR WG met with NTSB experts, EDR manufacturers, and other experts to assess the needs for EDR data survivability and event description. They found that typical highway-vehicle crash characteristics were different than other modes, such as airplanes and trains, and as such, found that a unique set of survivability requirements were needed. Generally, the T&B EDR WG found that EDR data should be collected when a substantial crash occurs, and thus advised that triggering the EDR should occur when the vehicle's deceleration exceeded 2-4 g.

In the process of developing the data elements, survivability, and event description findings, the T&B EDR WG felt the need for some research effort in certain areas. These areas have been identified.

The findings were divided into several categories. The following presents the findings of the working group:

- In the current fleet of large vehicles, very few employ EDR technology.
- Manufacturers of aftermarket EDRs have had limited success in deploying EDR technology into large vehicle fleets.
- Many manufacturers of engines for use in large vehicles have included memory modules in the engine's electronic control unit (ECU). To date, the data recorded are primarily for fleet management use.
- The NTSB has used engine ECM data to support crash investigations.
- The Working Group defined 28 data variables for inclusion in large vehicle EDRs.
- Thirteen data variables were defined as Priority 1.
- The Working Group established a set of survivability guidelines specifically tailored for large vehicle application.
- The Working Group established some guidelines for defining when data should be recorded in a crash event.
- The Working Group identified several areas that require additional research. Funding for R&D of emerging EDR technologies is required.
- EDRs have the potential to greatly improve truck, motorcoach and school bus vehicle safety.

1.0 Introduction

1.1 Background

This report is a summary of the activities and findings of the National Highway Traffic Safety Administration (NHTSA) sponsored Truck and Bus Event Data Recorder Working Group. EDRs are devices that record information related to an event. In the context of this report the event is defined as a highway vehicle crash. EDRs have the potential to have a major impact on highway safety, ranging from assisting in real-world data collection, to better defining the auto safety problem, to aiding law enforcement in understanding the specific aspects of a crash.

In 1997, the National Transportation Safety Board (NTSB) issued recommendations to "pursue crash information gathering using EDRs." The National Aeronautics and Space Administration (NASA) Jet Propulsion Laboratory (JPL), in April of the same year, recommended that NHTSA "study the feasibility of installing and obtaining crash data for safety analyses from crash recorders on vehicles."

In early 1998, the National Highway Traffic Safety Administration's (NHTSA) Office of Research and Development (R&D) launched a new effort to form a Working Group (WG) comprised of members from industry, academia, Government, and other organizations to study EDRs. This group was called the EDR WG. The WG's objective was: *To facilitate the collection and utilization of collision avoidance and crashworthiness data from on-board EDRs*. The WG published a report with 29 findings that presented an overview from users, manufacturers, Government, and academia.

In November 1999, the NTSB issued Safety Recommendations H-99-53 and 54 to NHTSA. These recommendations indicated that NHTSA should mandate installation of EDRs on motorcoaches and school buses and gave specific requirements for the data collection and survivability of the devices.

NHTSA has been using EDRs to support its crash investigation program for several years. In the early 1990s, NHTSA Special Crash Investigation (SCI) program collected EDR data on a case-by-case basis. Toward the end of the 1990s, the SCI program was routinely collecting EDR data. With the availability of the Vetronix EDR download tool, NHTSA has equipped all its National Automotive Sampling System – Crashworthiness Data System (NASS-CDS), Crash Injury and Engineering Research Network (CIREN), and SCI investigators with this tool and has modified the data collection files to store EDR data.

In 2000, NHTSA sponsored a second WG looking into EDRs specifically associated with trucks, school buses, and motorcoaches. This working group was called the Truck and Bus Event Data Recorder Working Group (T&B EDR WG). This report presents the findings of the group.

In 2001, NHTSA launched an EDR web based research tool. The site provides lists of highway-related EDR reports, articles, news stories, patents, and other material. (http://www-nrd.nhtsa.dot.gov/edr-site/)

1.2 Objectives of the Working Group

Many of the participants that worked on the EDR WG Findings[1] Report, also participated in this effort. This WG believed that since that report was so recent and comprehensive, this report should be considered an update to the original report. Thus, these findings are published as supplemental information to the original report. The reader is encouraged to refer to the original report for the basis of this continuing fact-finding effort. Additionally, a select bibliography of 300 citations is listed in the original report.

This WG considered data elements, survivability, and event description as the core objectives of this fact-finding effort.

1.2.1 Data Elements

Data elements were identified and ranked as Priority 1 and Priority 2 to meet specific vehicle types. Two optional priority elements were also identified.

1.2.2 Survivability

The WG identified EDR survivability benchmarks but also found that additional research may be required to verify survivability needs specific to vehicle types.

1.2.3 Event Description

The working group found that the event definition should be acceleration based, should account for frontal and side crashes, and may require different thresholds for forward, side, and vertical accelerations.

1.3 Participants

The participants of the breakout sessions[2] are marked with an asterisk next to their name.

Organization	Name
Accident Research & Analysis	Richard Reed
American Bus Association	William Mahorney*
American Transportation Corporation	Bob Douglas*
American Trucking Associations	Larry Strawhorn*
Biocentrics Solutions	Barry Hatfield
Biocentrics Solutions	Tom Yager
Blue Bird Body Company	Tom Turner*
Broward County Fire-Rescue	Julie Shockley
Click, Inc.	Tom Kowalick
Collins Industries	Rod Nash
Cummins	Allen Muellenbach
Drive Cam	Gary Rayner
Evicam. International	Jeffery Scaman
Federal Highway Administration	Carl Hayden

[1] "Summary of Findings by the NHTSA EDR Working Group," August 2001, Final Report, DOT-HS-043 334 (http://www-nrd.nhtsa.dot.gov/pdf/nrd-10/EDR/WkGrp0801.pdf)

[2] See Section 1.5 for further details on breakout sessions

Florida Atlantic University ....John Harlin
Florida Atlantic University ....Mary Russell
Florida Atlantic University ....Tom Kelly
Florida Department of Transportation ....Selma Sauls
Federal Motor Carrier Safety Administration..............Douglas McKelvey
Federal Motor Carrier Safety Administration..............Gary Woodford*
Federal Motor Carrier Safety Administration..............Kate Hartman
Ford ....Joe Marsh
Forensic Accident Investigations.................................Bob McElroy*
Freightliner...Gary Rossow
Freightliner...Herbert Mehnert
Georgia Technological University...............................Jennifer Ogle*
Insurance Institute for Highway Safety ....Raul Arbelaez
Independent Witness, Inc...Dave Clark
Independent Witness, Inc...Scott McClellan
Insurance Services Office ....Ed Quinones
International Truck & Engine ....Gary VanderMolen
Kanouse & Walker..Susan Walker
National Association of State Directors of Pupil
Transportation Services ....Charles Gauthier
New World Tours ....David Bolen
National Highway Traffic Safety Administration.........Charles Hott
National Highway Traffic Safety Administration.........Alrik Svenson*
National Highway Traffic Safety Administration.........Duane Perrin
National Highway Traffic Safety Administration.........John Hinch*
National Transportation Safety Board ....Kris Bolte
National Transportation Safety Board ....Sarah McComb*
National Transportation Safety Board ....Vernon Roberts
Society of Automotive Engineers ....Dan D'Angelo
Society of Automotive Engineers ....Doug Read
Society of Automotive Engineers ....Steve Ezar
Safety Intelligence Systems, Corp. ....Andy Mackevicus*
Safety Intelligence Systems, Corp. ....Anthony Geller
Safety Intelligence Systems, Corp. ....John Mackey
Safety Intelligence Systems, Corp.. ....Ricardo Martinez
Safety Intelligence Systems, Corp. ....Rich Pandolfi
Smiths Aerospace...Barry Cassey
Smiths Aerospace...Jim Elliot
Smiths Aerospace...Theresa Dekkinga
Thomas Built Buses ....Jim Freiburger
Thomas Built Buses ....Ken Dodson
Transport Canada ....Alan German
Transportation Research Board...................................Chuck Niessner
Truck Manufacturers Association................................Will Schaefer*
United Motorcoach Association ....Norm Littler*
United Motorcoach Association ....Steve Sprague

VDO North America...Dan May
VDO North America...Tony Reynolds

1.4 Fact Finding Effort

The purpose of the NHTSA sponsored T&B EDR WG was to gather factual information as opposed to developing consensus recommendations for NHTSA or any other Federal agency. As such, there is no "Recommendations" section to this report. Rather, the findings of this fact gathering effort are summarized in the "Findings" Section.

1.5 Meetings

The NHTSA T&B EDR WG held four meetings and three breakout sessions: A summary of each is presented below. For each WG meeting, a set of minutes was developed and placed in the DOT Docket system. See section 1.6, below, for further details on docket access.

1.5.1 Meeting #1 - June 8, 2000

In June 2000, the initial meeting of the NHTSA T&B EDR WG was held in Linthicum, Maryland. The meeting included an explanation of the objectives, limitations of the NHTSA's role, emphasis on a fact-finding mission, and awareness that the WG could not make recommendations to a regulatory agency. The WG felt it could compile information to provide input for future decisions.

The WG formulated a preliminary set of questions for the fact-finding effort. They were:

1. What data elements need to be recorded?
2. What is to be gained by putting recorders on a bus, given the low numbers of bus passenger deaths each year?
3. What are the benefits of event recorders?
4. What are some of the drawbacks to event recorders?
5. What is the goal of the EDR we are talking about? Is it to record what the driver does or is it for finding mechanics of a crash, change in velocity, acceleration, etc.? Is it to find culpability or causes of injuries?
6. Will EDRs be mandated?
7. What constitutes an event? Does the crash event occur when an air bag is deployed, or is it something else?
8. Can current recording devices accept analog inputs as well as digital inputs?

SAE discussed the SAE Strategic Alliance (SSA)[3], a partnership of mobility market leaders to collaboratively address corporate and industry needs of the mobility community. SSA's intent is to foster the alignment of SAE's strengths and resources with the Partners' business and technical goals.

Additional materials circulated included the agenda, a draft Recommended Practice from the Technical and Maintenance Council (TMC), a paper on Crash Survivable Modules from Smiths Industries, and a system schematic from Loss Management Services, Inc (LMS).

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[3] For additional information on SSA see: http://www.sae.org/technicalcommittees/ssa.htm

1.5.2 Meeting #2 - October 25, 2000

On October 25, 2000, the second NHTSA T&B EDR WG meeting was held in Washington, DC. Several presentations were made.

The National Transportation Safety Board presented an analysis from a fatal crash of a tour bus. The overview showed the benefits as well as the shortcomings of analyzing data from the engine's electronic control unit (ECU). The data analysis allowed the NTSB to draw some conclusions that could not have been drawn otherwise and it raised some questions regarding the specific crash that might not have been otherwise considered.

VDO North America, which manufacturers an Accident Data Recorder for the automotive industry, presented an overview of VDO's product including some of the data storage parameters and accident reconstruction features.

Tom Kowalick of Click Incorporated presented highway crash fatality and injury statistics to show a need for more crash reduction efforts.

The WG reviewed the NTSB recommendations (see section 2.0 of this report), and conducted an assessment of the data element requirements in those recommendations.

1.5.3 Meeting #3 - February 15 and 16, 2001

On February 15-16, 2001, the third NHTSA T&B EDR WG meeting was held at Florida Atlantic University in Boca Raton, Florida. This 2-day meeting commenced with an EDR showcase sponsored by the host (See section 3 of this report for details on the Showcase) followed by a WG meeting.

Bob McElroy, Forensic Accident Investigations, Inc., gave an overview of technologies involved in accident reconstruction. He discussed some of the history of recording information in vehicles as well as the contrasts between the European market and the American market with regards to data recording. He discussed tachographs, crash recording, and onboard recording.

Tony Reynolds presented information regarding recording products available from VDO and discussed some examples of EDR applications. One example demonstrated that the presence of these devices reduced the number of crashes in a Berlin, Germany police car population by 27 percent. Mr. Reynolds suggested the importance of standardization of the data parameters collected in recorders, either in accident causation or driver behavior recording.

Dr. Ricardo Martinez, of Safety Intelligence Systems[4] (SIS), discussed the role of EDR data collection and storage, including the MACBOX™, an EDR which collects vehicle-based and "driver's view" video-based data, and other facets of EDR data including collection, wireless encrypted transmission, storage, and managing EDR data.

Ed Quinones, of Insurance Services Office (ISO), discussed their role in collecting and storing insurance data. Mr. Quinones reported that ISO and SIS have created a separate entity, Global

[4] Formerly Loss Management Services, Inc

Safety Data Corporation, for the sole and exclusive purpose of providing a secure, private data vault to store and manage all vehicular crash data[5].

Jim Elliott & Barry Casey, of Smiths Group, discussed a proposal they had developed for testing the crash hardening characteristics of an EDR system, which included a set of physical tests and associated requirements that could be used to evaluate EDR systems. These concepts formed the bases for the WG's recommendations in this area (see section 7.0 of this report).

Several other smaller presentations/updates on EDR-related activities were made by WG participants. The WG spent some time discussing data elements and possible definitions for events that could trigger recording. The WG agreed that a breakout group should be formed to develop a data element lists, survivability requirements, and other EDR related items.

1.5.4 Breakout Session #1 - June 27, 2001

The breakout session was formed with representation from a diverse group, including: school bus manufacturers, truck manufacturers, truck users, motorcoach industry, EDR manufacturers, EDR users, academia, and Government. The main focus for the first meeting included:

1. Review current standards for data collection
2. Review EDR report recommendations for data variables
3. Review NTSB recommendations
4. Draft preliminary list of data elements

During the meeting, the breakout group identified 26 data elements[6]. They were subdivided into two groups, Priority 1 and Priority 2. Each member was assigned several elements for development of a fact sheet to document key areas concerning that element.

1.5.5 Breakout Session #2 - August 14, 2001

Before the second breakout session, each member submitted the fact sheet for the 26 data elements. These were combined into a set of requirements and distributed to the breakout session members for review prior to the August meeting. During the review process, two additional elements were added. Since these represented fairly new technologies, they were put into an optional category.

The second meeting focused on refinement of the data element fact sheets and development of the first set of survivability requirements. NTSB staff, specializing in survivability of EDR data, assisted the breakout group with the effort. The group also started working on the definition of event as it applied to the vehicle mix of trucks, motorcoaches, and school buses.

1.5.6 Breakout Session #3 - September 24, 2001

This meeting was a teleconference. Its main purpose was to finalize the activities of the previous two sessions and develop a presentation for the full WG meeting planned for Atlanta.

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[5] In 2002, IBM partnered with SIS Corp. and ISO to assist in the build out of the Global Safety Data Vault for EDR database information.
[6] See Section 1.5.7 for complete list

1.5.7 Meeting #4 - October 26, 2001

On October 26, 2001, the fourth NHTSA T&B EDR WG meeting was held at Georgia Institute of Technology in Atlanta, Georgia. There were several presentations, including the findings from the breakout sessions.

John Hinch presented information on a study conducted by Aloke Prasad of NHTSA's Vehicle Research and Test Center (VRTC) evaluating the performance of several aftermarket EDRs. This included 2 MACBOX™ EDRs made by SIS, Corp. and being used in a Georgia Institute of Technology (GaTech)-NHTSA study, two models of the DriveCam video EDR, and two models of the IWI EDR. Most of the EDRs were installed on a large flat plate bolted to the bed of a 2001 Ford F150 extended cab pickup, with a couple of the DriveCam video EDRs being installed on the windshield with their video cameras pointed forward. The test conditions consisted of a 30 mph impact into a flat barrier. At the time of the presentation, the results were not finalized.

John Hinch presented a summary of the three breakout sessions held June-September 2001. He reviewed the lists of data elements that were proposed by the breakout group.

The Priority 1 data elements include:

1. Acceleration, X (Longitudinal)
2. Acceleration, Y (Lateral)
3. Acceleration, Z (Vertical)
4. Accelerator Pedal Position
5. Antilock Brake System Status (ABS)
6. Automatic Transmission Gear Selection
7. Belt Status (driver)
8. Brake Status (Service Pedal, Emergency, Trailer)
9. Engine RPM
10. Identification
11. Time/Date
12. Vehicle Speed
13. Wheel Speeds

The Priority 2 data elements include:

1. Air bag deploy time
2. Air Bag Lamp Status
3. Air Bag Status
4. Battery voltage
5. Cruise Control (and Auto Distance)
6. Heading
7. Lamp Status
8. Retarder System Status
9. School Bus Warning Lamp Status
10. Steering Wheel Angle
11. Traction Control
12. Turn Signal/Hazard Operation
13. Windshield Wiper Status

The optional data elements include:

1. Digital Imaging
2. Vehicle Load

John Hinch presented two additional reports, survivability and event definition.

Jim Elliott, of Smiths Aerospace, made a presentation regarding EDR data survivability. Randall Guensler, of Georgia Institute of Technology, presented "Onboard Diagnostic System Data and Vehicle Emissions Modeling," a review of other electronic storage capability currently used in vehicle systems. Tom Kowalick discussed an upcoming effort by the IEEE Vehicular Technology Society to develop a standard for Motor Vehicle Event Data Recorders (MVEDRs).

The WG felt it had accomplished its major fact-finding goals and decided not to have any future meetings. John Hinch agreed to develop a final report outline and draft the final report, which would be circulated for review via e-mail.

1.6 T&B EDR Docket NHTSA-2000-7699

All materials provided to the working group were placed in the Department of Transportation's Document Management System (DMS). This included the final meeting minutes and attachments to the minutes. Final minutes are those that were approved by the working group. The docketed information for the EDR working group can be found in docket NHTSA-2000-7699. These dockets are viewable and printable from the DMS and are located by searching for docket 7699 at http://dms.dot.gov.

Table 1 presents a summary of the docket.

Table 1. Summary of Docket NHTSA-2000-7699

Item 1, September 5, 2000	Handouts from June 2000 meeting.
Item 2, December 5, 2000	Minutes from June 2000 meeting and handouts from October 2000 meeting.
Item 3, April 11, 2001	Minutes from October 2000 meeting, handouts from the FAU EDR Showcase on EDRs, and handouts from the February 2001 meeting.
Item 4, November 7, 2001	Minutes from February 2001 meeting and handouts from October 2001 meeting.
Item 5	Minutes from October 2001meeting.

2.0 NTSB Actions and Recommendations Related to Highway-Based EDRs

The National Transportation Safety Board (NTSB) is an independent Federal agency charged by Congress with investigating every civil aviation accident in the United States and significant accidents in the other modes of transportation – railroad, highway, marine, and pipeline – and issuing safety recommendations aimed at preventing future accidents. The rules of the Board are located in Chapter VIII, Title 49 of the Code of Federal Regulations. During the past few years, the NTSB has held two symposiums and issued 3 recommendations to NHTSA related to EDRs. This section reviews these activities.

2.1 NTSB EDR-Related Symposiums

2.1.1 Transportation Safety and the Law

The National Transportation Safety Board hosted a symposium, held on April 25-26, 2000, to discuss the conflicts between the growing need for data to improve transportation safety and the industry's concern about the use of those data in regulatory actions, lawsuits, and criminal prosecutions. The symposium brought together knowledgeable participants from Government, industry (all transportation modes) and the legal community to examine the problems regarding the collection of data for crash prevention, including data collected during crash investigations, and the privacy concerns of those being investigated. Ideas were exchanged to help create a context in which safety data can be gathered while the legitimate rights of all concerned are protected. Although no specific recommendations were identified, many suggestions were presented. There was general agreement about the need to collect additional information to advance safety.

The proceedings from the symposium can be viewed in their entirety at:
http://www.ntsb.gov/events/2000/symp_legal/default.htm

2.1.2 International Symposium on Transportation Recorders

The National Transportation Safety Board held (on May 3-5, 1999) a symposium on issues related to the use of recorded information to improve safety in all modes of transportation. Topics included the use of recorded information for crash investigations and routine performance monitoring, the privacy, proprietary, and union issues associated with recorded information, and the future recording requirements and capabilities. The following papers and posters are applicable to EDRs in general:

PAPERS

- Smiths Industries Flight Data/Cockpit Voice Recorders, Jeffrey L. Brooks
- An Autonomous Data Recorder for Field Testing, Joseph A. Carroll, Michael D. Fennell
- Reducing Highway Deaths and Disabilities with Automatic Wireless Transmission of Serious Injury Probability Ratings from Crash Recorders to Emergency Medical Services Providers, Howard Champion, J.S. Augenstein, B. Cushing, K.H. Digges, R. Hunt, R. Larkin, A.C. Malliaris, W.J. Sacco, J.H. Siegel
- Recording Automotive Crash Event Data, Augustus Chidester, John Hinch, Thomas C. Mercer, Keith S. Schultz
- Proactive Use of Recorded Data for Accident Prevention, Ed Dobranetski, Dave Case

- On-Board Recorders: The "Black Boxes" of the Trucking Industry, Les Dole
- Digital Audio Recorders Life Savers, Educators, and Vindicators, Matthew Durkin
- Transportation Event Recorder Data: Balancing Federal Public Policy and Privacy Right, Gregory L. Evans
- Security of Recorded Information, Lindsay Fenwick
- Future Video Accident Recorder, Mike Horne
- Proactive Use of Highway Recorded Data Via an Event Data Recorder (EDR) to Achieve Nationwide Seat Belt Usage in the 90th Percentile by 2002, Thomas Michael Kowalick
- The Contribution of Onboard Recording Systems to Road Safety and Accident Analysis, Dr. Gerhard Lehmann, Tony Reynolds
- Transportation Recorders on Commercial Vehicles, Paul Menig and Cary Coverdill
- The Benefits of Vehicle-Mounted Video Recording Systems, R. Jeffrey Scaman
- On-Board Recording for Commercial Motor Vehicles and Drivers: Microscopic and Macroscopic Approaches, Neill L. Thomas, Deborah M. Freund
- A Vision of Future Crash Survivable Recording Systems, Michael H. Thompson

POSTERS

- Accident Reconstruction/Simulation with Event Recorders, Kristin Bolte, Lawrence Jackson, Vernon Roberts, Sarah McComb
- Seat Belt Event Data Recorder (SB-EDR), Thomas Michael Kowalick
- Mobile Accident Camera, John J. Mackey, Christopher J. Brogan, Edward Bates, Stephen Ingalls, Jack Howlett
- The Benefits of Vehicle-Mounted Video Recording Systems, R. Jeffrey Scaman

The proceedings from the symposium can be viewed in their entirety at: http://www.ntsb.gov/events/symp_rec/symp_rec.htm

2.2 NTSB EDR-Related Recommendations to NHTSA

2.2.1 H-97-18 – Crash Information from EDRs for Light Motor Vehicles

In 1997, the NTSB issued recommendations to NHTSA, based partly on a public hearing held on March 17-20, 1997, Public Forum on Air Bags and Child Passenger Safety, indicating that NHTSA should pursue crash information gathering using EDRs. The NTSB safety recommendation H-97-18 stated:

> "Develop and implement, in conjunction with the domestic and international manufacturers, a plan to gather better information on crash pulses and other crash parameters in actual crashes, utilizing current or augmented sensing and recording devices."

2.2.2 H-99-53 – EDR Data Elements for School Buses and Motorcoaches

With H-99-53, NTSB recommended that NHTSA require all school buses and motorcoaches manufactured after January 1, 2003, be equipped with on-board recording systems. NTSB proposed that these systems record the following vehicle parameters: lateral acceleration, longitudinal acceleration, vertical acceleration, heading, vehicle speed, engine speed, driver's seat belt status, braking input, steering input, gear selection, turn signal status, brake light status, head/tail light status, passenger door status, emergency door status, hazard light status, brake system status, and school bus flashing red light status. For those buses so equipped, the following should also be recorded: status of additional seat belts, airbag deployment criteria, airbag deployment time, and airbag deployment energy. The on-board recording system should record data at a sampling rate that is sufficient to define vehicle dynamics and should be capable of preserving data in the event of a vehicle crash or an electrical power loss. In addition, the on-board recording system should be mounted to the bus body, not the chassis, to ensure that the data necessary for defining bus body motion are recorded.

2.2.3 H-99-54 – Standards for EDRs in School Buses and Motorcoaches

With H-99-54, NTSB recommended that NHTSA develop and implement, in cooperation with other Government agencies and industry, standards for on-board recording. The following items were specified for consideration: parameters to be recorded, data sampling rates, duration of recording, interface configurations, data storage format, incorporation of fleet management tools, fluid immersion survivability, impact shock survivability, crush and penetration survivability, fire survivability, power supply independence, and the ability to accommodate future requirements and technological advances.

2.3 NTSB Crash Investigation Utilizing an EDR

The National Transportation Safety Board supports the use of Event Data Recorders as a means of helping determine the factors leading up to a crash and also the determination of the magnitude and direction of forces sustained during the crash. The Safety Board has long been a proponent of recorders in aviation, rail, and marine, as well as highway vehicles.

A Safety Board investigation of a December 1999 motorcoach crash in Colorado illustrates the type of information currently obtainable from a diesel engine electronic control module. Although not a dedicated crash recorder, such a control module can serve as a surrogate Event Data Recorder.

In this crash the recorder indicated the motorcoach had been on the verge of losing control for almost a mile before the final crash occurred.

- At :47 seconds prior going off the roadway, the drive wheels slipped on the slick roadway due to transmission retarder forces.
- At :44 seconds the transmission went into neutral and at :41 seconds the engine speed goes to idle.
- Between :35 and :15 seconds prior to the crash several brake applications were made in an attempt to arrest the speed of the bus.
- At :15 seconds a throttle application sent the engine RPM to its governed speed.
- At :05 seconds the vehicle began rotating, prior to exiting the roadway and overturning.

An Event Data Recorder output certainly needs analysis and interpretation to aid in understanding a crash. While recorders may never answer every question regarding a crash, they certainly provide valuable information never before available. At the time of this report, this investigation was not complete, thus NTSB had not published their findings.

Figure 1 presents a pictorial of the actual readout downloaded from the engine control module. Figure 2 presents another pictorial derived from overlaying highway design plans showing roadway grade and curvature with the vehicle speed and brake applications.

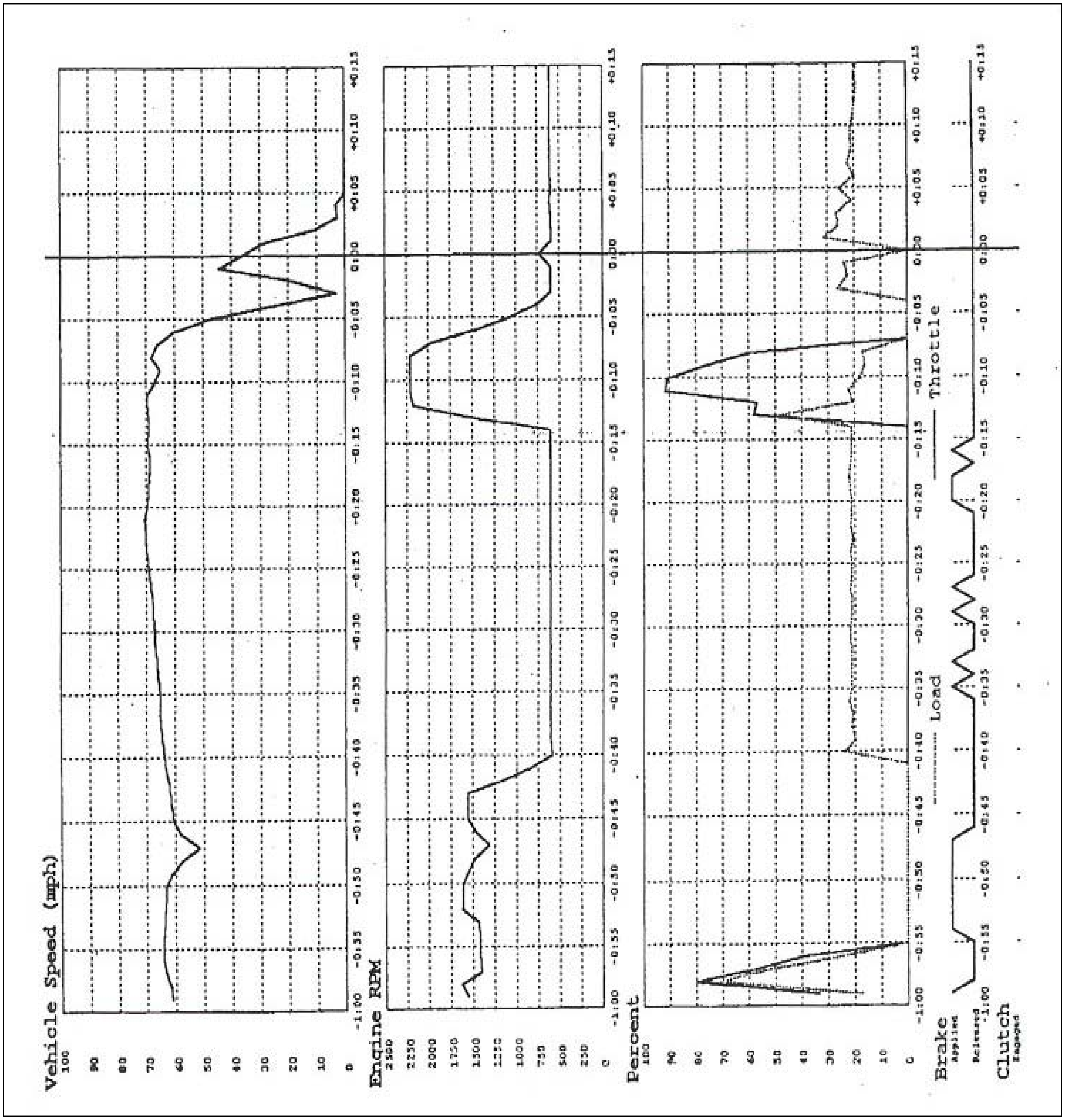

Figure 1. ECM Readout.

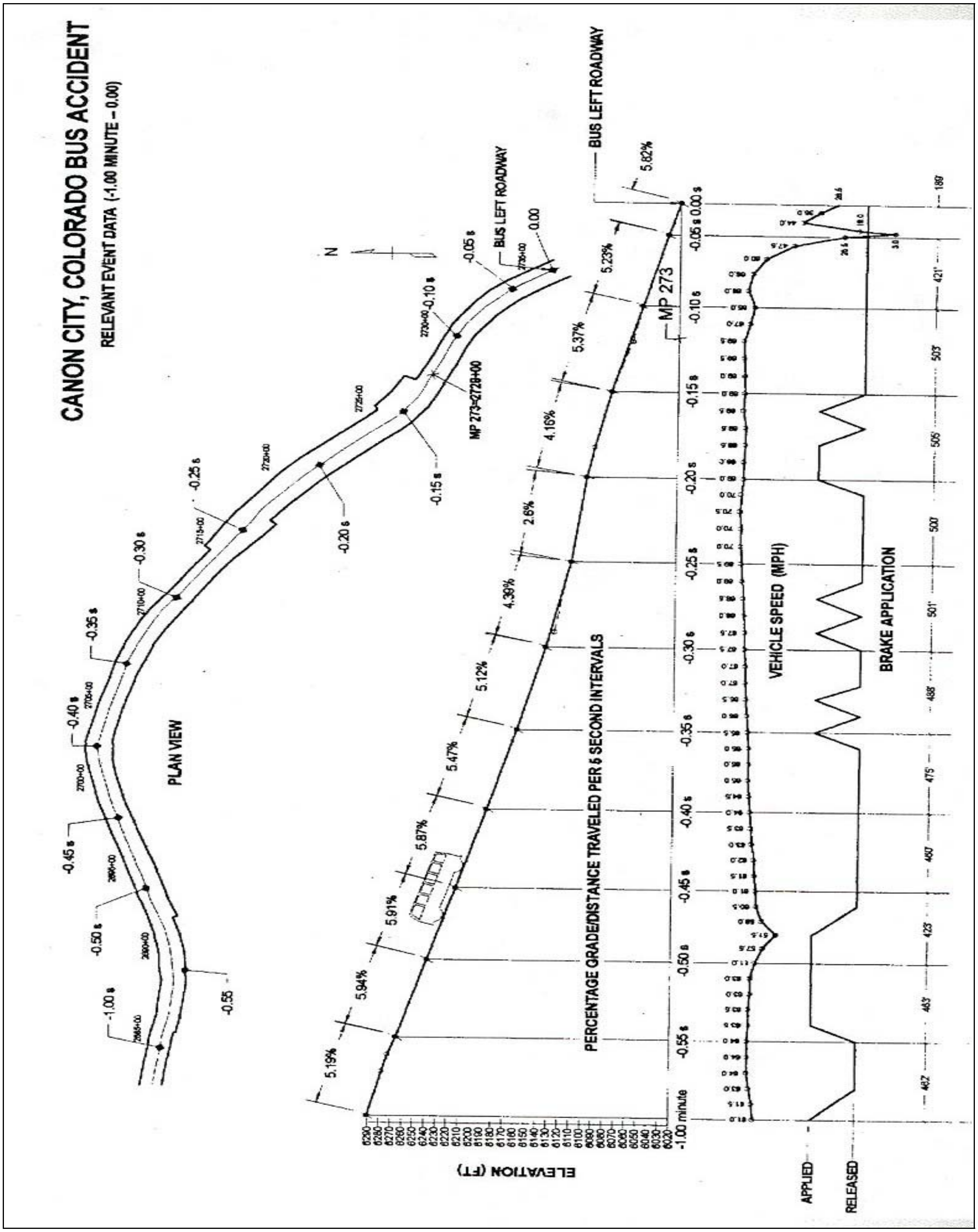

Figure 2. Overlay of Highway with Vehicle Speed and Brake Application.

3.0 EDR Showcase at Florida Atlantic University

3.1 Showcase Overview

The showcase, titled "*Showcase of Collision Analysis &Vehicle Data Systems for Private Passenger Vehicles, Fleet Vehicles, Trucks, and Buses*," allowed guests to view state-of-the-art technologies related to EDRs. The showcase also gave the opportunity to meet members of the Florida Atlantic University's Event Data Recorder Project. The showcase was designed to allow guests to move freely about the center to listen to presentations, see displays, interact with technologies, ask questions, and network with colleagues. The WG believes this was the first showcase dedicated to highway-based EDR technology. The WG would like to express its gratitude to Dr. Mary Russell – sponsor of the showcase and member of the WG. The program for the showcase is given in Table 2.

Table 2. Florida Atlantic EDR Program.

Display/Topic	Representative/Presenter
Wrecked County Bus with Cummins Engine	Howie Subbert- Palm Tran Jack Chavarria - Cummins Steve Ottoway - Cummins Sam Glickson - Cummins
New Peterbilt Tractor Trailer Cab Powered by Detroit Diesel	Detroit Diesel
Wrecked Chevrolet	Donald Felicella - Crash Airbag Module Reconstructionist Downloads
UDS 2.0	Tony Reynolds - VDO
i3000	Joe Dandy - Cosworth
I-Witness Drive-Cam	Jay Vitagliano
Tow Truck with Caterpillar Engine	Jim Sturko- Caterpillar
GIS	John Harlin / Brian Kelly
Driving Simulations and Traffic Models	Tom Kelly
Remote Data Transmission	Wayne Bullock
Loomy Driverless Vehicle	Dani Raviv
Legal Issues	Susan Walker
Human Aspect of Driving	Wendy Stav
Driver Assessments	Desiree Lanford / Wendy Stav

3.2 Showcase Highlights

The following sections present highlights from the EDR-related items in the showcase. For additional details on these and other items, a complete set of handouts was placed in the public docket. See section 1.6 for details on the docket location.

3.2.1 Caterpillar Engine Data Report

A copy of the Caterpillar "Engine Data Report" was distributed at the showcase. This document outlines Caterpillar electronic engine features. Caterpillar claims that "It is now possible to program fleet truck engines, and sit back and let the electronics take over." The engine control unit (ECU) can collect various data and generate reports, such as a histogram of vehicle speed or engine RPM. A sample of a speed histogram from a Caterpillar ECU, showing the number of hours cumulated in each speed range, is presented in Figure 3.

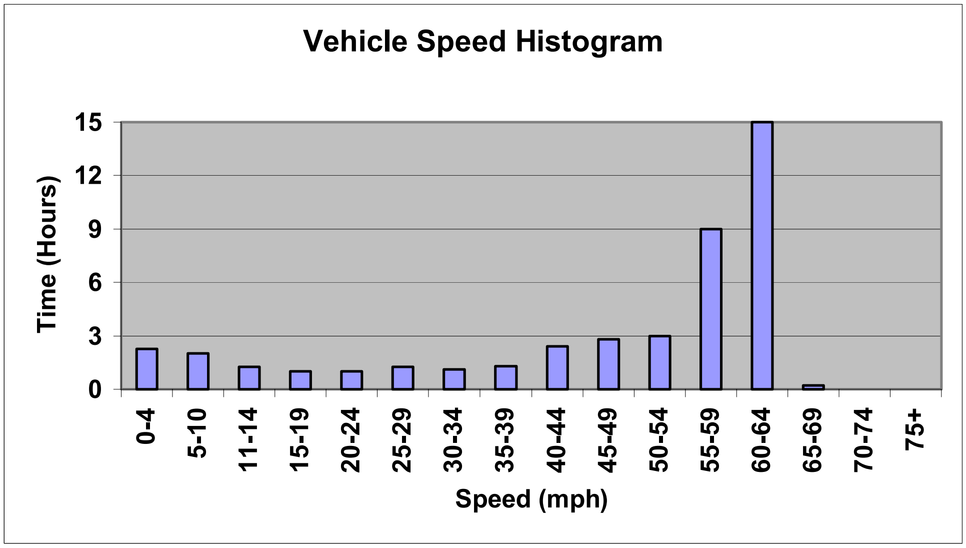

Figure 3. Caterpillar ECU Speed Histogram

3.2.2 Cummins Engine Data Report

A copy of a Cummins "Engine Data Report" was distributed at the showcase. It showed the data from an ECU, printed in a report format. Several pages of the report show the vehicle and engine setup for the specific vehicle for which the report was generated. Most of the information in this report is related to fleet needs.

3.2.3 Detroit Diesel Engine Data Report

A copy of a Detroit Diesel "Engine Data Report" was distributed at the showcase. It presents information regarding the Detroit Diesel Electronic Controls (DDEC) and Diagnostic Link. The report indicates that the "DDEC Data is dedicated memory in the DDEC IV ECM that records operating information about the engine and the vehicle." It continues to report that the "DDEC Data stores three monthly records and a trip file that may be reset after it is extracted from the Electronic Control Module (ECM). An internal clock/calendar, with an internal battery, is used for timekeeping. Data on daily engine use, periodic maintenance intervals, hard brake incidents, last stop records, and ECM diagnostics is also stored." It appears that the system can produce histograms, similar to those shown in Figure 1.

3.2.4 International Engine Data Report

A copy of an International "Engine Data Report" was distributed at the showcase. This report presented data from NAVPAK[7] Engine Control Programmable Parameters. Generally, these data are related to fleet operations.

[7] NAVPAK™ is a single unit electronic control module for International® engines

3.2.5 The Benefits of Vehicle Mounted Video Recording Systems

R. Jeffery Scaman, CEO of Evicam International, Inc. presented a two-page discussion on EDRs. Evicam was formed to develop advanced Video Event Data Recorders for the transportation and insurance industries.

3.2.6 Vetronix's Crash Data Retrieval System

Don J. Felicella of Felicella Consulting Engineers, Inc. presented a 7-page discussion regarding the use of Vetronix Crash Data Retrieval (CDR) tool to read GM-based EDRs to support crash reconstruction. He presented some background material, a description of the Vetronix tool, and two case studies, documenting the use of EDRs in crash reconstruction. A picture of the Vtronix CDR (right) and its software (on computer screen) is presented in Figure 4.

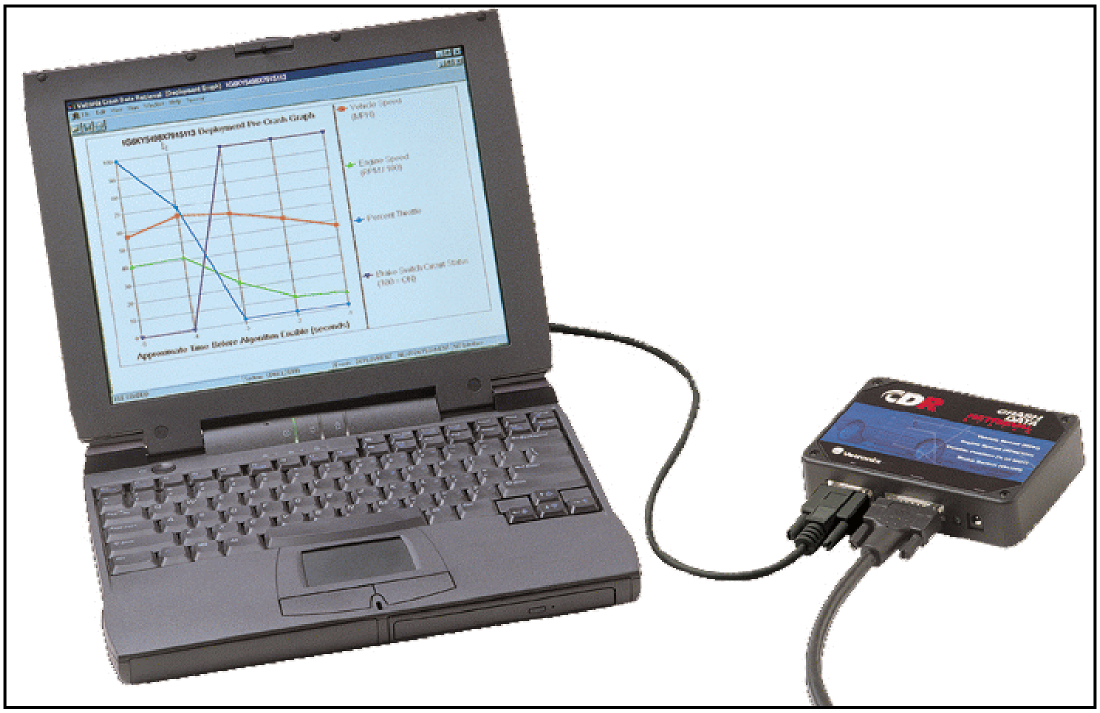

Figure 4. Vetronix EDR Data Retrieval System.

3.2.7 UDS EDR system

VDO Kienzle provided a set of slides describing the VDO EDR system. This 9-page document provided technical details on the unit along with several sample out plots and analyses. This system is shown in Figure 5 with a sample of the crash data analysis used for reconstruction shown in Figure 6.

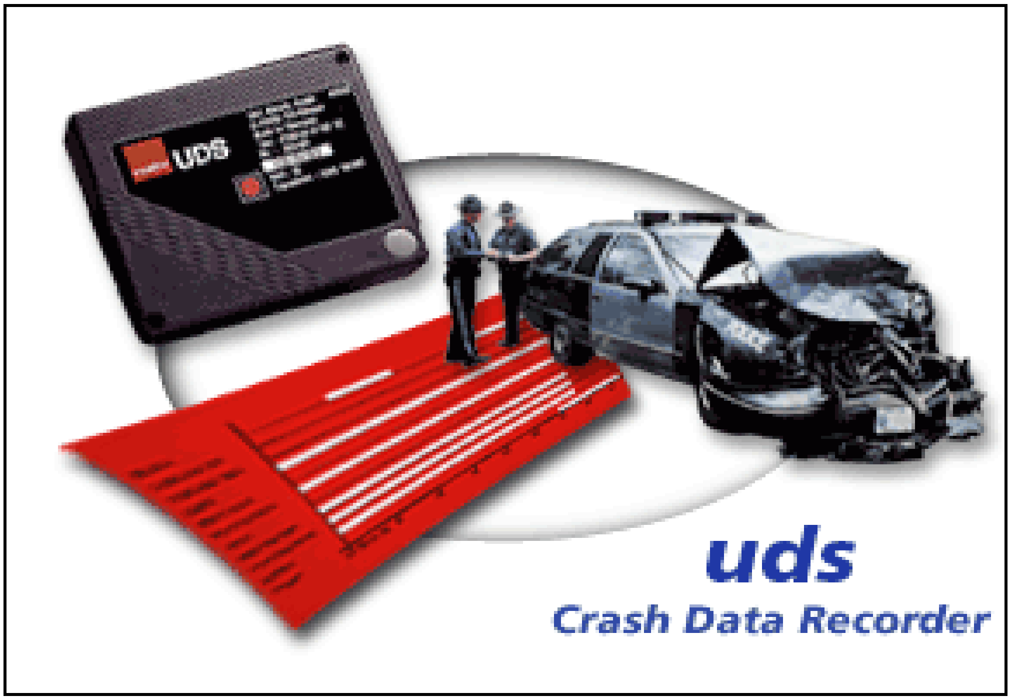

Figure 5. VDO UDS EDR System.

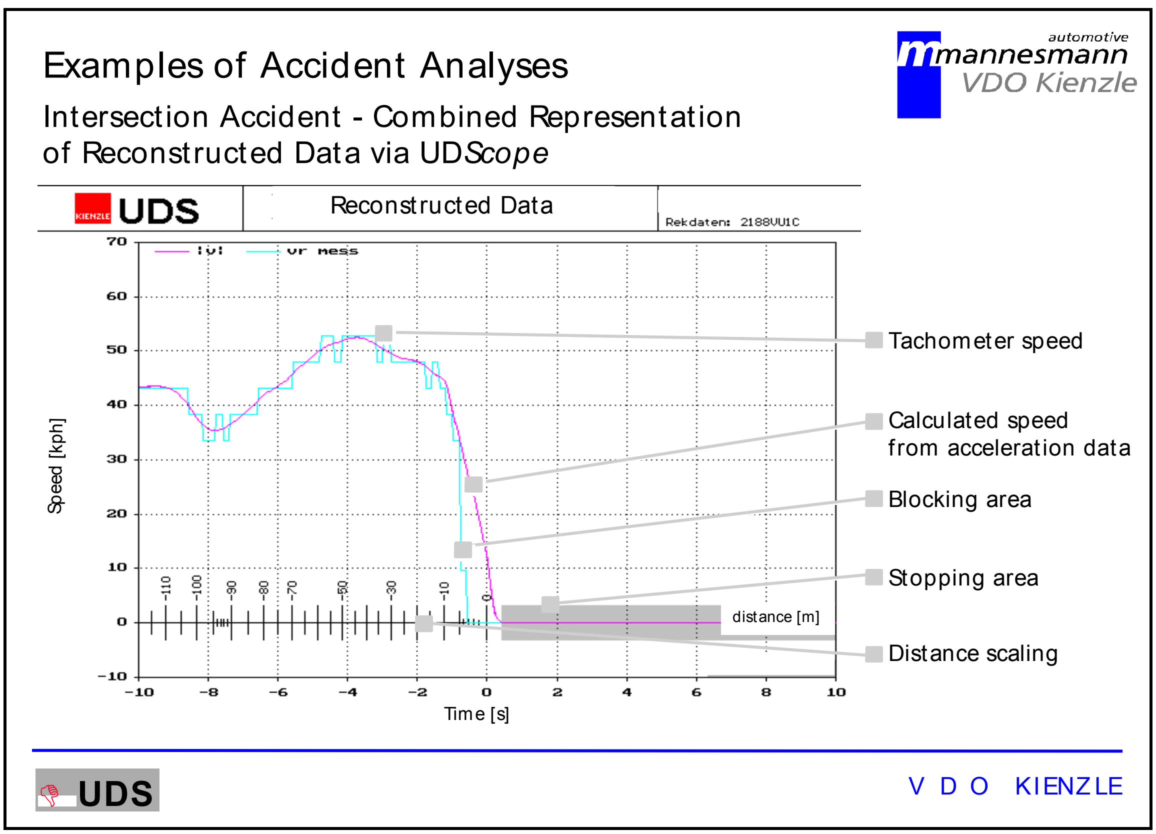

Figure 6. Sample Output from UDS EDR System.

3.2.8 Drive Cam

DriveCam presented a 9-page document titled "Who's looking out for you," which described the DriveCam event data recorder that is designed to collect video, audio, and vehicle acceleration. The DriveCam system starts collecting data 20 seconds prior to the event. A photograph of one of the DriveCam models is shown in Figure 7.

Figure 7. Drive Cam EDR Unit.

3.2.9 Legal Models for Using EDR Data

Susan Walker of Kanouse & Walker, presented two models for utilizing EDR data – "We are a people of Choices" and "Legal Framework for the Implementation of EDR Technology." Her multi-point model includes owner involvement, secure EDR data transmission and storage, traceable ID of the data to the vehicle, and release of aggregate data for use by outside parties.

4.0 Data Elements

4.1 Priority 1 Data Elements

Based on the findings of the WG, priority 1 data elements are those that could become the core of all EDRs for these classes of vehicles. Working Group members also felt that suppliers should be allowed to offer minimum configurations (for example, all priority one data elements) plus additional features such as multiple event storage, on-board trend analysis for maintenance, etc.

4.1.1 Acceleration, X, Longitudinal

- **Acronym**: Ax
- **Other Name**: Forward Acceleration, X Acceleration
- **Definition**: Longitudinal acceleration indicates acceleration of the frame or body in the direction of the travel X axis (longitudinal) of the orthogonal reference system (SAE J182[8]) of the vehicle during an incident as indicated by an on-board accelerometer.
- **Operation**: Longitudinal acceleration requires accelerometers to be located on-board the vehicle. The device should be sampled continually with data stored in a FIFO buffer, and would rely on crash/event detection algorithms to prompt data storage.
- **Unit of Measure**: g
- **Range**: +/- 100g (maybe more – passenger car systems typically include +/- 50g, sometimes up to +/- 100g)
- **Accuracy**: The error should be less than 5 percent of the channel amplitude class. The channel amplitude class is equal to the upper limit of the measurement range (in this case 5% of 100g or 5g)
- **Sampling Rate**: The necessary sampling rate is directly related to the sophistication of the reconstruction process. Minimum sampling rate should be 10 times that of the Channel Frequency Class (CFC) or Frequency in Hertz. For simple reconstruction, CFC of 60 is minimum requirement, so the corresponding sampling rate would be 600 samples per second. A sampling rate of 1800 samples per second should be the target.
- **Filter Class**: As a minimum, CFC should be no less than 60, but a CFC of 180 should be the target. The channel frequency class (CFC) for measurements of vehicle structural accelerations are as follows:
    - Total vehicle comparison 60
    - Collision simulation input 60
    - Component Analysis 600
    - Integration for Velocity 180
- **Discussion**: This data element would record the deceleration of the vehicle upon impact. Currently, limited if any accelerometers are located on heavy trucks and buses. Crash data (X, Y, and Z axis accelerations), considered one of the most important data elements by the WG, is currently not collected and would require additional sensors to be placed on the vehicle. Specifications for this element have been adapted from those of the SAE J211 specification.

[8] SAE J182 AUG 97, "Motor Vehicle Fiducial Marks and Three-dimensional Reference System," Figure 1.

4.1.2 Acceleration, Y, Lateral

- **Acronym**: Ay
- **Other Name**: Side-to-Side Acceleration, Y Acceleration
- **Definition**: Lateral acceleration indicates acceleration of the frame or body in the direction of the Y axis (lateral) of the orthogonal reference system (SAE J182) of the vehicle during an incident as indicated by an on-board accelerometer.
- **Operation**: Lateral acceleration requires accelerometers to be located on-board the vehicle. The device should be sampled continually with data stored in a FIFO buffer, and would rely on crash/event detection algorithms to prompt data storage.
- **Unit of Measure**: g
- **Range**: +/- 100g (maybe more – passenger car systems typically include +/- 50g, sometimes up to +/- 100g)
- **Accuracy**: The error shall be less than 5 percent of the channel amplitude class. The channel amplitude class is equal to the upper limit of the measurement range (in this case 5% of 100g or 5g)
- **Sampling Rate**: The necessary sampling rate is directly related to the sophistication of the reconstruction process. Minimum sampling rate should be 10 times that of the CFC or Frequency in Hertz. For simple reconstruction, CFC of 60 is minimum requirement, so the corresponding sampling rate would be 600 samples per second. A sampling rate of 1800 samples per second should be the goal.
- **Filter Class**: As a minimum, CFC should be no less than 60, but a CFC of 180 should be the goal. The channel frequency class (CFC) for measurements of vehicle structural accelerations are as follows:
  - Total vehicle comparison 60
  - Collision simulation input 60
  - Component Analysis 600
  - Integration for Velocity 180
- **Discussion**: This data element would record the deceleration of the vehicle upon impact. Currently, limited if any accelerometers are located on heavy trucks and buses. Specifications for this element have been adapted from those of the SAE J211 specification.

4.1.3 Acceleration, Z, Vertical

- **Acronym:** Az (suggested – no formal reference found)
- **Other Name:** Z Acceleration
- **Definition**: Vertical acceleration indicates acceleration of the frame or body in the direction of the Z axis (vertical) of the orthogonal reference system (SAE J182) of the vehicle during an incident as indicated by an on-board accelerometer.
- **Operation**: Vertical acceleration requires accelerometers to be located on-board the vehicle. The device should be sampled continually with data stored in a FIFO buffer, and would rely on crash/event detection algorithms to prompt data storage.
- **Unit of Measure**: g
- **Range:** +/- 50g (The vertical accelerations are typically less severe than that of longitudinal and lateral and may require a lesser range.)

- **Accuracy:** The error shall be less than 5 percent of the channel amplitude class. The channel amplitude class is equal to the upper limit of the measurement range (in this case 5% of 50g or 2.5g)
- **Sampling Rate**: The necessary sampling rate is directly related to the sophistication of the reconstruction process. Minimum sampling rate should be 10 times that of the CFC or Frequency in Hertz. For simple reconstruction, CFC of 60 is minimum requirement, so the corresponding sampling rate would be 600 samples per second. A sampling rate of 1800 samples per second should be the target.
- **Filter Class**: As a minimum, CFC should be no less than 60, but a CFC of 180 should be the target. The channel frequency class (CFC) for measurements of vehicle structural accelerations are as follows:
  - Total vehicle comparison 60
  - Collision simulation input 60
  - Component Analysis 600
  - Integration for Velocity 180
- **Discussion**: This data element would record the upward or downward acceleration of the vehicle upon impact. This data element is typically utilized to determine rollover events. This may be less of an issue with trucks and buses, as they do not tend to roll multiple times. Currently, limited if any accelerometers are located on heavy trucks and buses. Specifications for this element have been adapted from those of the SAE J211 specification.

4.1.4 Accelerator Pedal Position

- **Acronym:** APP
- **Other Names**: SAE Name: Accelerator Pedal Position; SAE: APP
- **Definition**: The setting of a foot-operated device, which, directly or indirectly, controls the flow of fuel and/or air to the engine, controlling engine speed.
- **Operation**: This data element will utilize the engine data link to obtain pedal position.
- **Unit of Measure**: The data element should indicate the accelerator pedal position in percent of travel or opening.
- **Range**: The range of the accelerator pedal position should be from 0 percent to 100 percent, and could utilize the engine high-speed data link (SAE J 1939).
- **Resolution**: The accelerator pedal position should be measured at 1(one) percent resolution.
- **Accuracy**: +/- 2 percent
- **Sampling Rate**: 2 times per second, starting 10 seconds prior to the event
- **Filter Class**: Not Applicable
- **Discussion**: The above data was based on one engine supplier only. Other engine manufacturers must be consulted prior to finalizing the above data. The accelerator pedal position only senses the position of the accelerator and does not necessarily reflect engine speed.

4.1.5 **Antilock Brake System Status (ABS)**

- **Acronym**: ABS
- **Other Names**: SAE Name: Antilock Brake System; SAE: ABS

- **Definition**: This data element indicates when ABS is activated.
- **Operation**: Activation of ABS may be defined as the time period when the foundation brake system is releasing brake torque to prevent incipient wheel lockup. This data element could utilize the time when brake torque is released to indicate ABS activation.
- **Unit of Measure**: The data element should indicate the status of the ABS, as: On and Off
- **Range**: On and Off
- **Resolution**: The data element requires on/off resolution.
- **Accuracy**: Not Applicable
- **Sampling Rate**: 2 times per second, starting 10 seconds prior to the event
- **Filter Class**: Not Applicable
- **Discussion**: There may be other means for determining if the ABS system is cycling, such as wheel speed sensors. The WG sees this signal as the control function, and the wheel speed as the outcome from the control signal. Thus the WG felt both should be recorded.

4.1.6 Automatic Transmission Gear Selection

- **Acronym**: ATGS
- **Other Names**: SAE Name: Transmission Range; SAE: TR
- **Definition**: This data element indicates the transmission gear position (PRNDL) that has been selected on automatic transmissions with electronic shifters.
- **Operation**: A substantial number of medium and heavy-duty vehicles use automatic transmissions and of these, on newer vehicles, most will be controlled with electronic shifting mechanisms. This data element will utilize the signals from the gear selector to record the gear position the operator has selected
- **Unit of Measure**: The data element should indicate the status of the automatic transmission gear selector, as follows:
    - P= Park
    - R= Reverse
    - N= Neutral
    - D= Drive
    - L= Low
- **Range**: The range of the data element is five states.
- **Resolution**: The data element required on/off resolution for each of the five states.
- **Accuracy**: Not Applicable
- **Sampling Rate**: 2 times per second, starting 10 seconds prior to the event
- **Filter Class**: Not Applicable
- **Discussion**: A substantial number of medium and heavy-duty vehicles will continue to use manual transmissions and some automatic transmissions may continue to have manually activated shifters. Although recording of transmission gear position may be desirable on these vehicles, it is more difficult and may not be cost effective to obtain. Some automatic transmissions may have more than five (5) gear selector positions. The WG may want to consider if it is necessary to provide for recording of any available gear selector position.

4.1.7 Belt Status (Driver Only)

- **Acronym:** No apparent common acronym.
- **Definition:** This element shows whether the driver was wearing a seat belt. SAE J1803 Sect.3.40 for Seat Belt Use Indicator defines this function as a means to indicate whether forces greater than or equal to a predetermined level were applied to the belt during a collision to indicate whether the belt was in use.
- **Operation:** The buckling of the seat belt by the seat occupant deactivates the seat belt warning lamp and/or buzzer. This data element could utilize the seat belt warning lamp/buzzer switch to indicate when the seat belt is utilized.
- **Unit of Measure:** This data element should indicate the status of the seat belt as: On and off.
- **Range:** On and off.
- **Resolution:** This data element requires On/Off resolution.
- **Accuracy:** Not applicable.
- **Sampling Rate:** 1 time per second, starting 10 seconds prior to the event.
- **Filter Class**: Not Applicable
- **Discussion:** The working group members were generally of the opinion that we would restrict this data collection to driver seat only, in view of logistics problems inherent with bus (motorcoach and school bus) seating. Since we only envision monitoring the driver seat, we probably do not need an indicator as to whether the occupants' seats were occupied. Electronic monitoring would eliminate reliance on police crash reports to determine seat belt use. Police reports are sometimes inaccurate on this point as emergency personnel often move the occupant, or the occupant exits the vehicle, before this information is noted. In addition, physical study of the subject belt (ex. stretch indicators) would no longer have to be relied on. As seat belt usage is a necessary predicate for airbag safety, the two systems are inter-related. This data is critical to understanding injury outcome.

4.1.8 Brake Pedal (Service Pedal, Emergency, Trailer)

- **Acronym**: BP, **Other Names**: SAE Name: Brake Pedal Position; SAE: BPP
- **Definition**: This data element indicates three different brake statuses: when the service brake pedal is pressed, if the emergency brake is activated, and if the trailer brake in activated.
- **Operation**: Activation of the service brake (by pressing on the pedal) also turns on the brake lamps. This data element could utilize the brake lamp switch to record when the vehicle operator presses the service brake pedal. Emergency brakes operate the spring brakes on the vehicle and trailer (if attached), and trailer brakes activate only the brakes on the trailer without operating the brakes on the truck-tractor.
- **Unit of Measure**: The data element should indicate the status of the function as: On and Off
- **Range**: On and Off
- **Resolution**: The data element requires on/off resolution
- **Accuracy**: Not Applicable
- **Sampling Rate**: 2 times per second, starting 10 seconds prior to the event
- **Filter Class**: Not Applicable

- **Discussion**: The brake lamp switch is not a direct measurement of the brake operation. The WG discussed how to make a direct measurement, such as measuring brake pipe pressure (hydraulic or air), but felt this may be too difficult. The brake lamp switch is regulated by NHTSA in FMVSS 108, thus all vehicles have such a switch. Section S5.5.4 of FMVSS 108 requires the stop lamps be activated upon application of the service brakes. This standard is applicable to all trucks, buses, and motorcoaches. Furthermore, section S5.1.7 of FMVSS 121 requires the stop lamps to be switched when the service brake pedal is pressed sufficiently to generate 6 PSI in the brake line. This standard is applicable to trucks, buses, and motorcoaches equipped with air brakes. Because the brake lamp switch is required by regulation, manufacturers probably make it quite robust. Integration of other brake operations will need to be considered.

4.1.9 Engine RPM

- **Acronym**: RPM
- **Other Names**: SAE Name: Revolutions per Minute; SAE: RPM
- **Definition**: This data element indicates the engine speed.
- **Operation**: This data element will utilize the engine data link to obtain engine speed.
- **Unit of Measure**: The data element should indicate the status of the engine speed in RPM.
- **Range**: 0 to 4,000
- **Resolution**: 10 RPM
- **Accuracy**: 10 RPM
- **Sampling Rate**: 2 times per second, starting 10 seconds prior to the event
- **Filter Class**: Not Applicable
- **Discussion**: The above data was based on one engine supplier only. Other engine manufacturers must be consulted prior to finalizing the above data. Typical diesel engines have maximum RPMs of 2200, while gas engines have maximum RPMs of 3,000. The engine speed only tells the RPM at the time of measurement and does not measure input data as it relates to throttle location, thus the WG sees the relationship between the accelerator control and engine RPM as important variables to understand events prior to a crash.

4.1.10 Identification

- **Acronym**: ID
- **Other Names**: Vehicle Identification Number (VIN), Engine Identification Number (EIN)
- **Definition**: This data element identifies the entity from which the recorder gathers data.
- **Operation**: This data element remains constant to identify the entity from which the recorder gathers data.
- **Unit of Measure**: Not Applicable
- **Range**: Possibly up to 20 characters, for example: VIN requires a 17-digit alpha/numeric character string.
- **Resolution**:
- **Accuracy**: Not Applicable
- **Sampling Rate**: Not Applicable

- **Filter Class**: Not Applicable

4.1.11 Time and Date

- **Acronym**: Time/Date
- **Other Names**: Time and Date, hour and day
- **Definition**: This data element indicates the time and date of an event.
- **Operation**: An internal clock continually records these data elements. The manufacturers set all clocks to a standard time. Those using the recorded time must convert it to the actual time at an event location.
- **Unit of Measure**: The data elements should indicate the time and date, as follows:
  - **Time**: The decimal hour per a 24-hour clock.
  - **Date**: The digital day of the year and the year.
- **Range**: The range of the data element is 24 hours and 366 days.
- **Resolution**: The data element requires constant resolution.
- **Accuracy**: ± .0014 hour (5 seconds)
- **Sampling Rate**: Since this records the time of the event, it will not be sampled.
- **Filter Class**: Not Applicable
- **Discussion**: The accuracy figure was taken from the Technical and Maintenance Council (TMC) EDR Task Force recommendation.

4.1.12 Vehicle Speed

- **Acronym**: V
- **Other Names**: SAE Name: Vehicle Speed Sensor; SAE: VSS
- **Definition**: The magnitude of velocity (regardless of direction)
- **SAE Definition**: A sensor that provides vehicle speed information.
- **Operation**: A speed sensor is a device that senses the average vehicle velocity over a specific unit of time, and converts that into an electrical signal. Vehicle speed can also be calculated through measurement of other parameters.
- **Unit of Measure**: mph
- **Range**: 0 to 100 mph
- **Resolution**: 1 mph.
- **Accuracy:** 1 mph (Since the vehicle manufacturer will most likely generate the data recorded, imposing an accuracy specification, which may be more restrictive than the manufacturer's accuracy, may require that a new speed signal be developed. The WG suggested that this variable accept the accuracy determined by the manufacturer.)
- **Sampling Rate**: 2 times per second, starting 10 seconds prior to the event.
- **Filter Class**: Not Applicable
- **Discussion**: Based on the draft TMC Recommended Practice, *Guidelines For Event Data Collection, Storage And Retrieval*, vehicle speed is calculated from other parameters (rpm/gears/tires) on large trucks currently equipped with EDRs. Thus, if this method is used, there should be no cost to the manufacturers. Use of a separate vehicle speed sensor would impose an additional cost.

4.1.13 Wheel Speeds

- **Acronym**: WS (*); where * is the location of the wheel.

- **Definition**: These data elements indicate the speeds of the individual wheels on the vehicle.
- **Operation**: Many new vehicles are equipped with ABS systems, including all new motorcoaches, school buses and heavy trucks. Fundamental within any ABS system is the requirement that the system continuously measure the speed of each wheel end (or combination of wheel ends such as a whole axle). Wheel speed measurements are monitored by the ABS system, and during a brake application the system looks for a wheel speed that departs from the vehicle speed. When this happens, the ABS system releases the brake at that wheel end and monitors the resulting wheel speed, reapplying the brake torque after the wheel speed approaches the vehicle speed.
- **Unit of Measure**: These data elements should indicate the speed of each wheel end. The WG does not know the units that are used to measure wheel speed on various vehicles, but suspects that many manufacturers use different systems, such as RPM, road speed, counts from the tone wheel, etc. The WG would prefer that the wheel speed be reported to the EDR in engineering units, such as feet per second or miles per hour.
- **Range**: 0 to 100 mph (or equivalent RPM).
- **Resolution**: 2 mph
- **Accuracy**: +/- 2 mph
- **Sampling Rate**: 100 times per second, starting 10 seconds prior to the event
- **Filter Class**: Not Applicable
- **Discussion**: Wheel speed is a very important variable; mainly because the tires and wheels are the only way a vehicle can apply forces to the roadway. Spinning wheels and sliding wheels act very differently in fulfilling this function. While a spinning wheel can provide both braking and turning forces simultaneously, a skidding (sliding) wheel can only generate stopping forces. Recording the individual wheel speeds will provide valuable information regarding vehicle dynamics just prior to the event. This metric is related to other metrics, such as brake application and traction control function, since they all affect wheel speed.

4.2 Priority 2 Data Elements

The WG felt that priority 2 data elements should be considered very carefully for inclusion when designing an EDR. The inclusion of these elements would allow better event reconstruction, leading to safer highways and, possibly, fewer deaths and injuries on the highway system.

4.2.1 Airbag Deploy Time

- **Acronym**: none
- **Other Names**: Airbag Firing Time
- **Definition**: Time from the sensing of impact to initiation of airbag inflation.
- **Operation**: An airbag is signaled to inflate when the vehicle experiences sufficient deceleration to require an air bag deployment. There is a delay between the initiation of the impact of the vehicle with the outside object and the time the air bag is signaled to deploy.
- **Unit of Measure**: milliseconds
- **Range**: 0 to 3,000 milliseconds
- **Resolution**: 5 milliseconds

- **Accuracy**: +/- 2 milliseconds
- **Sampling Rate**: Since this is a measurement of an event, only a time will be output and hence no sampling is needed for this channel
- **Filter Class**: Not Applicable
- **Discussion**: Some important issues arise in discussing airbag deployment. There are major differences between passenger car airbags and air bags installed in this class of vehicles. For example, due to their higher mass, heavy trucks and buses have more energy to absorb and may incur more than one impact sufficient to injure the driver before the vehicle comes to rest. As a result, the airbags in trucks are of significantly different design. Comparing airbag-deploy time for passenger cars to that for heavy trucks and buses must be done with care since both the design of the airbag and the nature of the impacts for each is unique.

4.2.2 Airbag Lamp Status

- **Acronym**: none
- **Other Names**: Readiness Indicator status; Airbag Warning Light Status
- **Definition**: Airbag lamp status shows whether the air bag system in the vehicle has a possible fault and should be serviced. This is the same lamp as currently required in FMVSS 208.
- **Operation**: The Airbag Lamp or Readiness Indicator signals the driver that the air bag system has a fault due to any of a number of possible elements being monitored. The airbag may or may not deploy during a crash of sufficient deceleration that would normally deploy the airbag. This monitoring does not include the condition when the passenger side airbag is deactivated by a keyed switch.
- **Unit of Measure**: On and Off
- **Range**: On and Off
- **Resolution**: Not Applicable
- **Accuracy**: Not Applicable
- **Sampling Rate**: 1 time per second starting 10 seconds prior to event
- **Filter Class**: Not Applicable
- **Discussion**: The Airbag Lamp Status will show whether the airbag system has encountered a fault via a number of checks in the system. The specifics of these checks on the system may be furnished with the vehicle owner's manual.

4.2.3 Airbag Status

- **Acronym**: none
- **Other Names**: Airbag Manual Cut-off Switch Status
- **Definition**: The condition of the airbag at the time of a crash as determined by an optional deactivation switch (if present).
- **Operation**: The deactivation switch is operated by means of the vehicle ignition key. The switch can be turned off only using the key and will remain off until it is turned on using the key.
- **Unit of Measure**: On and Off
- **Range**: On and Off
- **Resolution**: Not Applicable

- **Accuracy**: Not Applicable
- **Sampling Rate**: 1 time per second starting 10 seconds prior to event
- **Filter Class**: Not Applicable
- **Discussion**: Airbag Status, where applicable, would be an important data point for the purposes of crash investigation. Airbag Status, however, won't likely clarify crash causation.

4.2.4 Battery Voltage

- **Acronym**: B+
- **Other Names**: Battery Positive Voltage
- **Definition**: The battery is an electrical storage device designed to produce a DC voltage by means of an electrochemical reaction. The metric provides the potential (voltage) of the battery.
- **Operation**: The engine driven alternator produces positive system voltage that is stored in battery.
- **Unit of Measure**: Volts
- **Range**: 10 volts to 16 volts for 12-volt systems (42-volt systems to be determined).
- **Resolution**: 1 volt
- **Accuracy**: 1 volt
- **Sampling Rate**: 1 time per second, 10 seconds prior to the event.
- **Filter Class**: Not Applicable
- **Discussion**: 12-volt systems typically specify an operational range of 10 to 16 volts for components in addition to reversed polarity and short-duration higher-voltage protection. It is expected that the device will not operate on reversed polarity or elevated voltage, but it must be able to withstand this condition without damage. Voltage functions as 1) the "communication language" of the vehicle and 2) provides electrical pressure for operation of electrical and electronic devices in the vehicle. Typical alternator operation produces a regulated 14.2 to 14.5 volts, which charges the battery to approximately 12.5 volts. Typical car, truck and bus batteries are of lead-acid construction. Nickel-cadmium batteries have been used in buses and other vehicles with large starting loads. SAE J1113 Electromagnetic Susceptibility Test Procedures for Vehicle Components defines and discusses circuits, procedures and equipment for checking and measuring transient voltages. When running from the battery alone it is not uncommon to encounter voltages in the 10 to 12 volt range. Under development are 42 volt systems which are much more complex, especially in the critical areas of voltage arcing across electrical contacts and induction of current(s) in adjacent wiring bundles, circuits and structures.

4.2.5 Cruise Control

- **Acronym**: CC
- **Other Names**: Automatic Vehicle Speed Control-Motor Vehicles; SAE J195: AVSC
- **Definition**: An automatic vehicle speed control (AVSC) is a device capable of maintaining selected vehicle speeds in the presence of changing road load conditions. The AVSC regulates the output power of the engine to provide a stable and essentially constant vehicle speed.

- **Operation**: Deliberate action by the vehicle operator causes the AVSC to activate and reactivate. The system is deactivated by either turning off the ignition or an AVSC system switch or by depression of either the brake or clutch pedal.
- **Unit of Measure**: The data element should indicate the status of the automatic vehicle speed control, as follows: On and Off
- **Range**: The range of the data element is two states.
- **Resolution**: The data element requires on/off resolution
- **Accuracy**: Not Applicable
- **Sampling Rate**: 2 times per second, starting 10 seconds prior to an event.
- **Filter Class**: Not Applicable
- **Discussion**: No discussion was offered for this data element.

4.2.6 Heading

- **Acronym**: HDG
- **Other Names**: Magnetic Heading
- **Definition**: This data element indicates the direction the vehicle is pointed in the horizontal plane.
- **Operation**: This data element would use the output of a heading sensor to record a vehicle's heading.
- **Unit of Measure**: Degrees
- **Range**: 0 - 359 degrees.
- **Resolution**: The data element requires a resolution of 2 degrees.
- **Accuracy**: The accuracy required is +/- 2 deg.
- **Sampling Rate**: 2 times per second, starting 10 seconds prior to the event
- **Filter Class**: Not Applicable
- **Discussion**: Concerns exist within the WG regarding the cost of a device that would accurately measure heading. Preliminary research was done and there are sensors that can measure heading. However, the individual cost appears to be prohibitive. For example, the sensor from one manufacturer would cost $35/sensor (bulk cost may be less). A possible means of obtaining heading and additional location information would be to use GPS data from the terminal, for those vehicles so equipped.

4.2.7 Lamp Status

- **Acronym**: LS
- **Definition**: This data element indicates when the headlamps and tail lamps are activated.
- **Operation**: Activation of the headlamps and tail lamps is controlled by either the ignition switch (in vehicles equipped with daytime running lamps (DRL)) or by the headlamp switch (in vehicles without DRL). This data element could utilize the respective switch on the vehicle to record when the headlamps and tail lamps are activated.
- **Unit of Measure**: The data element should indicate the status of the ignition or headlamp switch, as it applies to activating the headlamps and tail lamps, as follows: On and Off
- **Range**: On and Off
- **Resolution**: The data element requires on/off resolution

- **Accuracy**: On and Off
- **Sampling Rate**: 1 time per second, starting 10 seconds prior to the event
- **Filter Class**: Not Applicable
- **Discussion**: The ignition and headlamp switches are not a direct measurement of headlamp and tail lamp operation. Monitoring of the power supplied to each headlamp and tail lamp on the vehicle would have to be accomplished to determine if the lamps were actually working. Although this information may be desirable to certain disciplines in certain accidents, it is more difficult and costly to obtain, and may not be necessary for most crash information recording purposes.

4.2.8 Retarder System Status

- **Acronym**: None defined
- **Definition**: Retarder System Status indicates whether the retarder system is both turned on and activated at the time of a crash.
- **Operation**: Retarder systems are devices auxiliary to the foundation brake that aid to slow the vehicle. There are different types of retarders and they are common on heavy vehicles. Retarders are often activated when the accelerator pedal is released. They might also be activated by the driver with a separate control or by application of the brake pedal. Retarder System Status would record whether the retarder has activated.
- **Unit of Measure**: On, Off, and Engaged
- **Range**: On, off, and engaged
- **Resolution**: On/off resolution needed
- **Accuracy**: On/off accuracy needed
- **Sampling Rate**: 2 times per second, 10 seconds prior to the event
- **Filter Class**: Not applicable
- **Discussion**: Since there are several types of retarders, it will be necessary to carefully identify these data element characteristics with respect to each type of retarder. Designs include compression release, exhaust, electrical, and mechanical retarders systems. Some retarders function automatically to slow the vehicle when the accelerator pedal is released, but the driver can turn the retarder off manually as well. Also, in the case of compression release engine retarders, many municipalities have banned their use due to noise they can produce so they must be turned off.

4.2.9 School Bus Warning Lamps

- **Acronym**: SBWL
- **Other Names**: SAE Name: School Bus Red Signal Lamps (SAE J887, July 1964 ref. by FMVSS 108)
- **Definition**: These data elements indicate when the school bus warning lamps are activated and if it is the amber or red school bus warning lamps that are activated.
- **Operation**: A manual switch typically activates amber school bus warning lamps when the bus is approaching a pick-up or drop-off stop. The amber school bus warning lamps are deactivated and the red school bus warning lamps are activated when the school bus entrance door is opened. Once activated the amber or red warning lamps flash alternately side to side.

- **Unit of Measure**: The data element should indicate the operation of the school bus warning lamps as one of the following: Off, Amber warning lamps activated, and Red warning lamps activated
- **Range**: The range of the warning lamp data is three states – Off, Amber, or Red
- **Resolution**: The data element requires on/off resolution for the amber and red lamps
- **Accuracy**: On/off accuracy needed
- **Sampling Rate**: 2 times per second, starting 10 seconds prior to the event
- **Filter Class**: Not Applicable
- **Discussion**: School bus warning lamps are regulated by NHTSA in FMVSS 108 and are required only for school buses. FMVSS 108 requires, as a minimum, red warning lights only, however, all states except Wisconsin and some Canadian Provinces require 8 lamp systems (amber and red). When 8-lamp systems are used, FMVSS 108 requires that the amber signal lamps are activated only by manual or foot operation, and if activated, are automatically deactivated and the red signal lamps automatically activated when the bus entrance door is opened. It is the intent of this data channel to measure the presence of a signal to the lamps, not whether the lamps are actually operating. The WG understands direct measurement of lamp light output or current load on the turn signal system would increase the difficulty of implementing these data elements without necessarily improving the quality of the data by an equivalent amount.

4.2.10 Steering Wheel Angle

- **Acronym:** SWA
- **Definition:** The angle and direction, clockwise (CW) or counterclockwise (CCW), to which the steering wheel is turned, when measured from the steering wheel's neutral position, which is the position that causes the vehicle to move straight ahead.
- **Operation:** Steering wheel rotation, CW or CCW, causes the vehicle front wheels to turn right or left. The steering wheel is mechanically connected to the front wheels through the steering shaft, steering gear, and the steering linkage. The steering gear ratio and linkage reduce the steering angle at the front wheels. This varies by vehicle make and model. Typically, in this class of vehicles, 270 degrees steering wheel angle would turn the front wheels approximately 45 degrees.
- **Unit of Measure:** Degrees CW or CCW.
- **Range:** 0 to 720 degrees CW and 0 to 720 degrees CCW.
- **Resolution:** 10 deg
- **Accuracy:** **+/-** 10 deg
- **Sampling Rate:** 2 times per second, starting 10 seconds prior to the event.
- **Filter Class:** Not Applicable
- **Discussion:** Measurement would be made using a sensor device that would convert steering column rotational distance into an electrical signal. Costs are unknown. This parameter is not measured on all large trucks today, based on TMC Recommended Practice 1214. There was some discussion regarding steering wheel angle vs. steer angle of the front wheels. Generally, it was thought that this variable was intended to see what the driver was doing, hence the steering wheel angle.

4.2.11 Traction Control On/Off/Functioning

- **Acronym**: TC & TC-FUNC
- **Definition**: These data elements indicate when the traction control system is switched on and when it is functioning.
- **Operation**: Some vehicles are equipped with traction control systems. These systems work automatically, if the switch is turned on, and pulse the vehicle's brakes on a wheel that is spinning in an effort to increase the wheel torque on that wheel end. This in turn will often allow the wheel(s) that are not turning to turn, thus increasing the overall traction of the vehicle.
- **Unit of Measure**: The data element should indicate the status of the traction control system, as follows: Control switch: On/Off; Traction control system controlling vehicle traction: Yes/No
- **Range**: The range of these data elements is two states each.
- **Resolution**: Each element requires on/off resolution
- **Accuracy**: Not Applicable
- **Sampling Rate**: 2 times per second, starting 10 seconds prior to the event
- **Filter Class**: Not Applicable
- **Discussion**: Vehicles equipped with traction control often have an indicator lamp that indicates whether the unit is switched on or off. The signal to this lamp would be sufficient to supply the EDR with the information of control switch status. Since traction control is an autonomous function, that is it works without driver action, it would be good to have an indication stored in the EDR when the system is actually controlling traction. It is not clear if a simple signal exists when the traction control system in functioning (that is, controlling the vehicle brakes). If no simple signal exists, development work will be needed.

4.2.12 Turn Signal/Hazard

- **Acronym**: TS & HAZ
- **Definition**: These data elements indicate when the turn signal is operating and if the hazard signal is operating.
- **Operation**: Activation of the turn signal lever causes the front and rear (and sometimes intermediate) directional indicator lamps to illuminate intermittently on the side of the vehicle associated with the position selected by the turn signal lever. The hazard lever (button) causes all directional signal lamps to illuminate simultaneously in an intermittent fashion.
- **Unit of Measure**: The data element should indicate the operation of the turn signal lamps, by side, and the status of the hazard system, as follows: Turn Signal: On right or On left; Hazard: On/Off
- **Range**: The range of these data elements indicate when the turn signal is operating and if the hazard signal is operating.
- **Resolution**: The data element requires on/off for hazard and left/right resolution for the turn signals
- **Accuracy**: Not Applicable
- **Sampling Rate**: 2 times per second, starting 10 seconds prior to the event
- **Filter Class**: Not Applicable

- **Discussion**: These devices are regulated by NHTSA in FMVSS 108, thus all vehicles have such devices. This standard is applicable to trucks, buses, and motorcoaches, among other vehicle classes. Because these devices are required by regulation, manufacturers probably make them quite robust. It is the intent of this data channel to measure the presence of a signal to the lamps, not whether the lamps are actually operating. The WG understands direct measurement of lamp light output or current load on the turn signal system would increase the difficulty of implementing these data elements without necessarily improving the quality of the data by an equivalent amount.

4.2.13 Windshield Wiper Status

- **Acronym**: No apparent common acronym.
- **Definition**: (per SAE J2349 Sect. 3.1): Electric Windshield Wiper Switch: Part of an electric or electro-pneumatic windshield wiper system by which the operator of a vehicle causes the windshield wipers to function by activating or interconnecting the electric circuit.
- **Operation**: Activation of switch by operator activates windshield wipers. This data element will utilize switch position to record when the operator activates windshield wipers.
- **Unit of Measure**: This data element should indicate the status of the windshield wiper switch as follows: On/Off.
- **Range**: The range of the data is in two states.
- **Resolution**: This data element requires On/Off resolution.
- **Accuracy**: Not applicable.
- **Sampling Rate**: 1 time per second, starting ten seconds prior to the event
- **Filter Class**: Not applicable.
- **Discussion**: The windshield wiper switch is not a direct measurement of windshield wiper operation as it only indicates the wipers are activated. Windshield wiper function is effective within 2-4 seconds after activation.

4.3 Optional Data Elements

4.3.1 Digital Imaging

- **Acronym**: No common acronym.
- **Other Names**: Onboard Video Recording
- **Definition**: An onboard device to capture digital video when an incident exceeds established algorithm standard. These units are usually coupled with other data collection devices to provide comprehensive crash data. There is no SAE definition at this time. SAE is considering establishing “Standards and Recommended Practice” for vehicular EDR which will include digital imaging.
- **Operation**: The digital image capture occurs when accelerometers residing within the device detect an incident which exceeds an established algorithm standard. One manufacturer’s comprehensive system, which includes wireless encryption transmission capabilities, captures compressed digital video imagery of the events in the seconds before, during, and immediately following a vehicular crash. This data is combined with

onboard diagnostic sensor data as well as global positioning system (GPS) location tracking.

- **Unit of Measure**: Video data, by its nature, is recorded and stored in its gross form.
- **Range**: Not defined at this time.
- **Resolution**: Not defined at this time.
- **Accuracy**: Not defined at this time.
- **Sampling Rate**: On one manufacturer's comprehensive system each accelerometer will sample 2,400 times per second with the result being decimated to 300 samples per second. With this system, the recording of video images is activated to allow for 15 seconds prior to incident and 10 seconds after. Timing could be adjusted to user preference. On another manufacturer's system 20 seconds in total is recorded prior, during and after the event.
- **Filter Class**: Not defined at this time.
- **Discussion**: The above data was based on information provided by a very small sample of digital imaging manufacturers.

4.3.2 Vehicle Load

- **Acronym**: None Defined
- **Other Names**: Vehicle Load Status, Trailer Status
- **Definition**: This element applies to trucks only. It would indicate whether the vehicle is carrying cargo and for a fifth-wheel tractor, whether there is a trailer present.
- **Operation**: Vehicle Load detection and trailer detection would both require development of sensing mechanisms.
- **Unit of Measure**: Load present- Yes/No; Trailer present- Yes/No
- **Range**: loaded/ no load; trailer present/absent
- **Resolution**: on/off
- **Accuracy**: on/off
- **Sampling Rate**: 1 time per second, 10 seconds prior to the event
- **Filter Class**: Not Applicable
- **Discussion**: This data element would record the status of the vehicle load. A possible means of determining load would be weight above a threshold for the vehicle, perhaps a percentage of the GVWR, within some accuracy. Current vehicles are not equipped to sense this so research would be required into the need for and means of sensing load.

5.0 Survivability

The survivability of EDRs was addressed by the working group. At issue is the ability of the EDR memory to survive crashes such that recorded data can still be retrieved. The working group was aided by recommendations from Smiths Group and discussions with the NTSB's National Resource Specialist for vehicle recorders. Smiths Group suggested requirements for various survivability factors based on the company's experience with manufacturing on-board recorders in other modes of transportation. The working group examined several factors in EDR survivability including location, impact shock, temperature, immersion, penetration, crush, fire, and independent power supply. Consideration was also given to cost and research issues.

5.1 Research

The working group found a lack of existing data to guide the group in evaluating each of the survivability factors for EDR use in heavy vehicles. While the working group was able to reach consensus on the survivability factors, additional research would need to be accomplished before any minimum requirements are set.

5.1.1 Cost

In discussing EDR survivability requirements, the working group recognized the need to balance any requirements with their associated costs. If requirements are set too high, EDR cost could become prohibitive, particularly for the school bus industry. Research into the cost of incorporating each survivability factor and the effect on total EDR cost needs to be accomplished.

5.1.2 NHTSA Large Truck Crash Causation Study

One source of data that may provide additional information about EDR crash environment is NHTSA's Large Truck Crash Causation Study. The data collected in the study may be used to help refine survivability requirements.

5.2 Location

The working group identified the location of an EDR within a vehicle as one of the most important survivability factors. This was based upon lessons learned in other modes of transportation and a discussion of known factors in the EDR crash environment. Proper placement of an EDR could minimize the likelihood that an EDR would be compromised by other survivability factors (impact shock, penetration, crush, fire). In discussing the various types of heavy vehicles and possible locations for EDRs, the WG found that the ideal location of an EDR may need to vary depending on the type of vehicle. More research is necessary to make this determination.

5.3 Impact shock

EDRs should be protected from impact damage. Based on a recommendation from Smiths Group and a discussion of heavy vehicle accidents, the WG found that EDRs should be capable of surviving an impact shock of 300 g for a duration of 50 milliseconds.

5.4 Temperature

Highway vehicles are operated in a wide range of temperatures. Experience with recorders in other modes of transportation has found that low operating temperatures may put the recording at risk. For EDR survivability, the working group focused on the minimum operating temperature as a constraint. The WG found that EDRs should be subjected to a temperature requirement of -40 degrees for 8 hours.

5.5 Immersion

The immersion of a vehicle in water was discussed by the working group. In other modes of transportation, requirements have been established for on-board recorders to survive the pressure of deep sea immersion for 30 days. However, for highway vehicles, shallow immersion for a relatively short period of time is the major concern. The WG found that no deep water immersion requirement is necessary for EDRs.

5.6 Fluid Immersion

In the course of a crash and subsequent rescue efforts, EDRs may be exposed to and possibly immersed in different fluids such as water, salt water, fuel, and oil. It is important to ensure that EDR data will not be compromised by exposure to these fluids for a short period of time. The WG found that EDR data should be able to withstand immersion in these fluids for at least 8 hours.

5.7 Penetration

In the event of a crash, protection of EDR data from penetration by metal or other materials is important. The WG found that EDRs should be capable of surviving 200 pounds dropped from 3 feet with a ½ -inch-diameter contact point.

5.8 Static Crush

EDRs may be subject to crush during the course of a crash sequence. To protect EDR memory, the WG found that EDRs should be capable of surviving a static crush of 500 pounds.

5.9 Fire

The working group examined NHTSA's highway crash data and found a very small percentage of fatal accidents involving fire. Although a relatively small percentage of crashes result in catastrophic fires, the recorded data in these types of crashes may be the most valuable data of all when it comes to reducing future crashes. While the consensus of the WG was that fire survivability requirements are not a high priority, future efforts to review EDR data survivability requirements may wish to reexamine these needs.

5.10 Independent Power

Independent power to help prevent the loss of crash data when main vehicle power ceases and results in loss of power to the recorder is desirable. Providing an independent power eliminates the need for the vehicle electrical system to remain intact during a crash. Independent power could be supplied from within the EDR device or from an external source. The WG felt an independent power should have sufficient reserve for the EDR to record data for at least one minute.

5.11 Survivability of Stored Data

In many instances, EDRs will not be accessed immediately after a crash has occurred. To ensure availability of recorded data, the WG found that storage of data should be such that data will be maintained without external power for 30 days.

5.12 NTSB Position on Survivability

The National Transportation Safety Board (NTSB) believes establishing clear requirements for fire survivability remains a critical component to the development of an industry standard. While NTSB recognizes the relatively small number of crashes in which fire may be a factor, experience in investigations in other transportation modes, as well as experience in highway investigations, has shown that the absence of any fire requirements may result in the loss of valuable information. In several NTSB highway investigations, investigators were unable to retrieve any information from ECMs due to fire damage. In particular, during a recent multi-vehicle crash investigation, four ECMs, the memory from an Eaton Vorad Collision Warning System, and two GPS processors were lost to fire.

If an industry standard does not include fire protection, it may result in a specific group of crashes for which no recorded data would be available, such as crashes involving trucks hauling flammable materials, or alternative fuel vehicles. The absence of any fire survivability requirement may limit the ability of government and industry to determine and implement necessary changes to improve highway safety.

NTSB also recognizes concerns regarding cost. Research into fire survivability will need to be performed to determine minimum requirements, as the minimum requirements used in other modes are likely too high. Research will also need to be performed to determine the cost of implementing the minimum requirements. It may be the case that protection of the recording medium against damage due to fire could be accomplished with little financial impact and significant safety benefits.

6.0 Event Description

The WG discussed the meaning of an event. Generally, there was agreement that the type of event we were concerned with was a crash, but some members indicated the need to collect data for different types of events, such as high brake force applications and aggressive driving and monitoring situations. The latter may apply more to video based EDR systems.

Crash-related events have been the typical triggering functions used by light vehicle OEM, such as GM and Ford. These manufacturers use the airbag crash sensor to make a determination to initiate the EDR function. With the GM EDR, which is incorporated into the Sensing and Diagnostic Module (SDM) – also known as the airbag sensor, the processor starts to collect data after the accelerometer reads about 2g deceleration for several samples. The initiation of data collection is often referred to as algorithm enable. After the event is over, the data are stored into the permanent memory modules. For events where the airbag does not deploy, the data are stored in the “near-deploy” file. These data can be overwritten by the next event if it has a total delta-V which exceeds that of the event in storage. If it is less, the file is not stored. For events that result in an airbag deployment, the data are stored in the “deployment” file. Thus GM vehicles will typically have a file stored in the “near-deploy” file and have a second file stored in the “deploy” file in the case when the crash resulted in an airbag deployment. The Ford system, which stores the EDR data in the Restraint Control Module (RCM), uses a similar threshold for algorithm enable. The RCM stores one file, which is updated when the delta-V exceeds the delta-V of the stored file. An airbag deployment will always be recorded, no matter what the delta-V.

Aftermarket systems use various trigger levels to define an event. The DriveCam system uses an acceleration threshold to automatically record data. There is also a button for recording files at the discretion of the driver. For example, if the driver was cut off by another vehicle (s)he could press the button to collect the data related to the event. In a similar manner, the VDO system can be triggered automatically, using predetermined acceleration thresholds or using other data channels and appropriate thresholds, or manually. The IWI system collects data automatically. The exact threshold is user specified, and can be set high (maybe around 2-3g) to limit the collection to crash-related events or lower (maybe around 1g) to collect both crash-related events and driving-related events, such as hard braking.

The WG also reviewed other organization’s efforts to define events. The American Trucking Associations’ Technical and Maintenance Council reviewed events and triggers. They developed several definitions that the WG felt were relevant to this fact-finding effort. They are:

- An EVENT is anything of interest that may occur during the operation of the vehicle.
- An INCIDENT is any event in which the safety of the vehicle or any person is threatened
- A TRIGGER is either any data parameter that exceeds a predefined threshold, or an external input. A trigger initiates the capture of data.
- CAPTURE is the process of saving recorded data.

There appears to be two prominent methods of determining an event – automatic and driver controlled. For automatic systems, thresholds are set to predetermined levels, which are dependent on two major considerations – the data parameter which is monitored (brake application, deceleration, etc.) and the class of events which are being recorded (crash, driver actions, etc.).

The WG focused on EDRs used for collecting data related to crashes. Thus the WG found that basing the trigger for the event on vehicle deceleration would be most appropriate. The WG also determined through discussions with its members, that these classes of vehicles[9] act differently than light vehicles. The WG found that a threshold in the range of 2-4g could be used to determine whether an event has occurred. Additional research would be needed to establish firm specifications.

The WG reviewed two crash tests of full-sized school buses – one full frontal into a rigid wall and the other a lateral hit near the front wheel by a large straight truck[10]. It would appear that in a frontal crash the acceleration profile (also called crash pulse) throughout a vehicle is fairly constant. This is seen in Figure 8, where the crash pulses, measured at 4 different locations, were nearly the same.

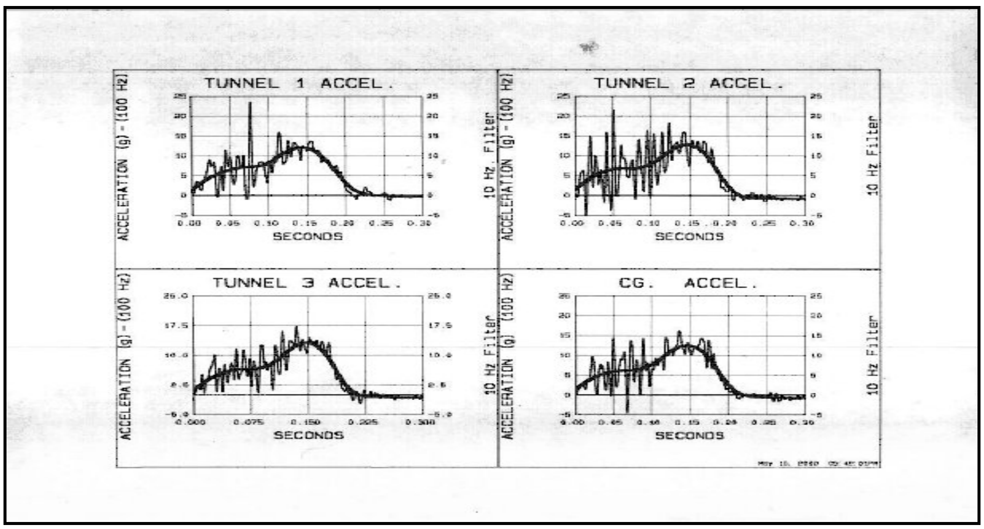

Figure 8. Longitudinal Deceleration Profiles at Different Locations on the Bus.

This was not true in a side crash, where the crash pulse varied significantly along the length of a bus. As seen in Figure 9, the highest acceleration measured was aligned with the impacting vehicle. At the furthest position from the impact (labeled “SID#2 (22 feet)”) the lateral acceleration is dramatically diminished. This occurs because the vehicle typically rotates significantly, where the rotational component of the acceleration confounds the crash pulse measured by the linear accelerometers.

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[9] Typically 10,000 pounds GVWR is consider the breakpoint between light vehicles and large vehicles, which would include most trucks, school buses and motorcoaches.

[10] More information regarding these two tests can be found in the DOT Docket Management System under docket NHTSA-98-4573, item 50.

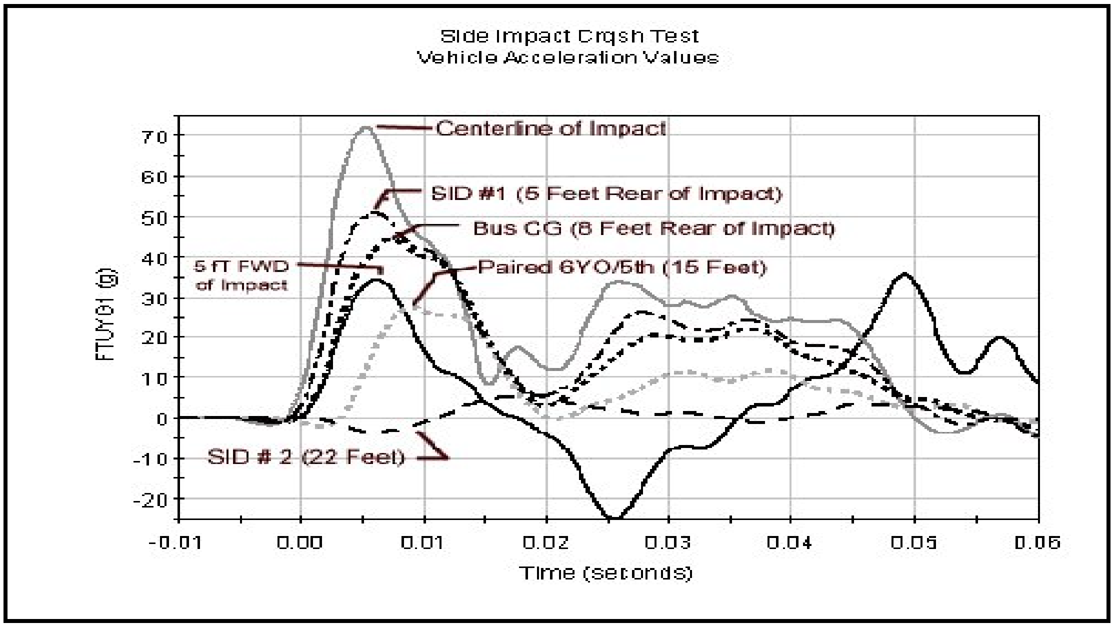

Figure 9. Lateral Crash Pulse Acceleration Profiles.

The WG found that the threshold of 2-4g would be good for longitudinal crashes but may not be good for lateral crashes. Further, the WG determined that research is needed to understand the threshold needs for frontal and side crashes. The location of the detection sensor (which will most likely be the same sensor to measure the crash pulse) can make a difference on which crashes are detected.

7.0 Summary of Research Needs

Research and development is required for emerging EDR technologies. The working group has identified 28 data elements for inclusion on trucks, motorcoaches, and school buses. During the development of these data elements, the WG quantified several general research topics and specific research areas related to the data elements. This section presents these research-related findings.

Other areas were also highlighted for research. These included the survivability needs for an EDR and further research associated to the definition of an event.

The WG encourages research in other areas. Field tests that involve EDRs installed in fleet vehicles may yield timely data. Industry standards and protocols such as those typically developed by IEEE and SAE for use by OEM and aftermarket vendors would increase acceptability of installing EDRs in vehicles and the eventual use of EDR data. Additionally, curriculum and teaching modules for law enforcement would aid in the proper collection and use of EDR data. Public awareness of the safety potential derived from using EDRs should be high priority.

7.1 General Research Needs

The WG identified several core areas for consideration for research. The following presents a discussion of these common areas.

7.1.1 Amount of Data and Sampling Rate

The WG discussed the pros and cons of the amount of time and the number of samples per second the data should be collected prior to, during and after the event. The WG believed there was a balance between the need to obtain good scientific-quality data and costs to obtain such data.

The WG reviewed several references related to the amount of data and digitizing rates. In a recent ESV paper published by NHTSA[11], NHTSA recommended that 10 seconds of data be collected prior to the crash. While this paper did not make a recommendation regarding the sample rate, it did mention using SAE J211 as a guide for data collection. General Motors (GM) is currently collecting pre-crash data on all its light vehicles equipped with airbags. On these vehicles, data collection starts 5 seconds prior to the event and uses a sample rate of 1 Hz. Aftermarket EDR manufacturers collect various amounts of pre crash data. VDO, a non-OEM supplier of EDRs, reported to the WG at the February meeting in Boca Raton, FL, that they recorded data starting from 45 seconds prior to a crash event and that they sampled those pre-crash data at ≥ 16Hz.

Crash events typically last for less than a second, and for light vehicles, the period of time during which the high crash forces exist (often referred to as the "crash pulse") typically lasts about 1/10 of a second. The WG believes that collecting crash pulse data is important in defining crash characteristics. For this reason sampling crash data once per second would miss the entire crash pulse, hence, much higher sampling rates are needed. Generally, two approaches have been

[11] Chidester et al, Real World Experience with Event Data Recorders, ESV paper 2001-247

taken – setting a fairly high sampling rate or using established data collection protocols, such as SAE J211.

Light vehicle OEM have taken different approaches for collecting crash pulse data. GM collects crash pulse data with a high sampling rate, about one sample per 312 microseconds (about 3,000 samples per second). The data are processed by the airbag computer and stored in the EDR every 10 milliseconds (100 times per second) in the form of change in velocity. Ford collects acceleration data in their EDRs for recording the crash pulse, and store it every 2 milliseconds (500 samples per second). Aftermarket systems also vary in their operation for collecting and storing crash pulse data. VDO systems use a high sample rate. A new system developed at Georgia Technical Institute samples crash data 2,400 times per second and stores sub-sampled data 300 times per second. Independent Witness Incorporated (IWI) uses SAE J211 protocols for collecting vehicle-based acceleration for recording crash pulse data.

As mentioned earlier, the WG tried to balance the need for scientific data and potential costs in establishing what the needs are for various data elements. For acceleration data, the WG found that relying on SAE J211 was most likely the best guideline. Thus, the data collection sampling rates are from this reference. For most other data variables, the WG found that collecting data 1 or 2 times per second would be sufficient. In all cases the WG found that collection of 10 seconds of data should be sufficient. But for both these cases, the WG found that it did not have the proper scientific foundation to make final findings, and hence believes additional research should be done to finalize the development of these characteristics.

7.1.2 Filtering

Filtering is a method of smoothing crash data. The purpose of collecting crash pulse data is to obtain data on the characteristic of the vehicle's acceleration profile during a crash event. This measurement is used to quantify the movement of the entire vehicle. For crash data, filtering is often needed to remove unwanted "ringing" of mechanical components, especially those to which the EDR's accelerometers are attached, which can be vibrating at different frequencies from that of the entire vehicle. Capturing component vibrations produced data that do not reflect the movement of the entire vehicle, hence it is desirable to smooth or "filter" them away.

For the accelerometer data, the WG found that SAE J211 protocols would produce proper filtering techniques for capturing the crash pulse data. For the other data elements, for example those that were sampled 1 or 2 times per second, filtering needs were not well understood by the working group. It might be possible to use no filtering, just report the state of the data variable at the exact time the data were sampled. As with amount of data and sampling rate, the WG found that additional research might be needed.

7.1.3 Metric/SAE

The WG stated its findings using SAE units. This was done for convenience. The WG believes that either unit system would be fine for EDRs and did not have a preference. The WG found that additional research might be required to express uncommon units, such as wheel speed measured as RPM or tone wheel frequency, into engineering units for input into an EDR.

Where accelerometers are calibrated and functioning in metric units, it would be preferable to store captured data in this format so as to avoid on-board computational overhead. Subsequent transformation to other desired units can easily be achieved through post-processing the data.

7.2 Data Element Specific Research Needs

This section presents some findings related to specific data elements.

7.2.1 Acceleration Measurement

- Maximum recorded accelerations for heavy trucks and buses are needed to define the upper limit for acceleration measurement. 100g has been suggested here as a starting point.
- Utilization of accelerometers for real-time crash acceleration data collection requires the development of algorithms to trigger recording. These algorithms can be as simple as a one value threshold (ex. 4g), or as complex as an algorithm that determines incident severity and triggers subsequent functions (e.g. Airbag systems). These vehicles will need algorithms that are tuned for front, side, rough roads etc. Rough roads may produce the same forces as those produced by a low severity passenger car/bus impact.
- For heavy trucks with trailers, there might be a need for EDR data, especially crash pulse data, from the trailer unit.
- For motorcoaches and school buses, the WG found that there might be a need to have multiple accelerometers in the front and rear of the bus. The WG reviewed crash test data from a lateral impact into a bus that showed the lateral crash pulse varied along the length of the vehicle.
- The WG felt that the location of the EDR unit was critical for survivability. But beyond that the location of the acceleration measurements is also critical for understanding the measurements. Body/chassis mounting location of the accelerometers and the actual EDR unit may not be the same for ideal data collection and survivability.
- The WG considered the need for an additional accelerometer in upper/roof portion of unit.
- The WG considered whether vertical accelerometers were needed. In the case of school bus crashes, where children being thrown vertically out of their seats can cause injuries, vertical acceleration could be an important variable.

7.2.2 Accelerator Pedal

- Research may be needed to determine the impact of this data element on a wider group of manufacturers. The WG believes that other engine manufacturers should be contacted to determine their ability to comply.
- Needs to be in concert with the SAE J1939 data bus speed.

7.2.3 ABS

- The recording of ABS fault codes is a consideration.
- Further sophistication of the recording system permitting, future possibilities could include recording the activation for each wheel, the pneumatic line pressure to the brakes at the time of ABS activation, and conceivably the cycling frequency of the ABS.

7.2.4 Automatic Transmission Gear Selection

- The WG found that recording the gear selected in a manual transmission vehicle could be difficult.
- For automatic transmission vehicles, the WG reviewed the need to determine the actual gear selected in the transmission versus the gear selected by the operator on the gear selection lever. Generally, the WG felt the easiest measurement would suffice for this measurement, but research might be considered to determine the best location for this measurement.

7.2.5 Belt Status

- The WG found that this could be measured using the FMVSS 208 switch in the seat belt system. However, this measurement does not monitor proper use, such as torso belt behind back. Research could be considered to determine if a more appropriate method of capturing proper seat belt use could be developed.

7.2.6 Brake Pedal

- The WG considered requiring the direct measurement brake line pressure. Generally, the WG felt this would be difficult and depending where in the line the pressure was measured, the results would vary, but found the additional research is necessary to finalize this finding.
- The WG found that measuring the truck-tractor would be sufficient for brake application, but also felt that additional research is needed to determine if trailer brake operation separate from tractor brakes in combination vehicles should be monitored.
- The WG felt that operation of the emergency brake and trailer brake control should be recorded in the EDR. Research may be needed to determine the best approach for accomplishing this requirement.

7.2.7 Engine RPM

- Research may be needed to determine the impact of this data element on a wider group of manufacturers. The WG believes that other engine manufacturers should be contacted to determine their ability to comply.
- The range of the engine high-speed data link (SAE J 1939) should be considered.

7.2.8 Identification

- The WG found that research would be needed on how this data will be entered into the EDR's memory, especially considering change out of EDR units.
- The WG identified several sources for identification, including: an EDR ID and the Vehicle's VIN.

7.2.9 Wheel Speeds

- The WG feels some research may be needed to fully understand the possibilities associated with measuring and recording wheel speeds.

- RPM may be a good substitute for wheel speeds. This will need to be studied.
- Sample rate for this element is quite high as compared to the others (except acceleration data needed to quantify the crash pulses). The WG found that 100 Hz sample rate should allow measurement of wheel speed during an ABS braking event, where the wheel speed is being cycled by the ABS computer. More research will be needed to accurately define the minimum requirement for this element.

7.2.10 Airbag Related Items

- Airbags are fairly rare in these classes of vehicles. Since very little is known, numerous research needs may exist with regard to these elements.
- Due to the significant costs associated with developing airbags and their deployment, much of the information pertaining to any particular airbag design is proprietary.
- Independent research would be necessary to determine general specifications for these elements, including: how many vehicles in the heavy truck and bus categories are fitted with airbags, how many have deactivation switches, etc.

7.2.11 Battery Voltage

- The WG found that 42-volt electrical technology is coming to these vehicles. Since EDRs are evolving, consideration of the effect of the 42-volt systems on EDRs should be evaluated.

7.2.12 Heading

- Assuming a low cost heading sensor can be found, additional research is needed to determine the feasibility and costs involved in mounting a heading sensor in a location to accurately detect heading and in sending the information to an EDR.
- Additional research is needed to determine if GPS systems could be used to provide these data. If so, research should consider the accuracy and resolution of GPS heading data systems.
- Response time of sensor needs to be studied. Sample rate may need to be modified if sensor speed exceeds the current findings.

7.2.13 Lamp Status

- With the deployment of DRL systems, the WG was unsure whether this element should monitor DRL or other lamp status, or possibly both.

7.2.14 Brake Retarders

- The WG felt that research into retarder types is essential.
- Different types of retarders have different levels of effectiveness in slowing vehicles so it would be important to note what type of retarder is in use.
- Different types of retarders would have to be addressed individually and could not be compared equivalently in crash reconstruction.

7.2.15 School Bus Warning Lamps

- Research is needed to determine how do we handle vehicles that do not have amber lamps.

7.2.16 Steering Wheel Angle

- There was some discussion as to whether we should be measuring steering wheel rotation rate instead of angle. Research is needed to determine which parameter is most useful.
- Research into the cost of such a sensor is needed.

7.2.17 Traction Control

- Some research may be needed to develop a method for detecting when the traction control system is functioning.

7.2.18. Turn Signal

- The WG determined that monitoring the switch should be sufficient to understand this metric, but felt that additional research should be considered in the area of sensing status.
- Possible methods of measuring signal - movement of lever, voltage going to bulb, bulb function, etc.
- The WG felt that research into use of OE bulb out function should be considered as an alternate method for this metric

7.2.19 Windshield Wipers

- Some vehicles may have pneumatic operated wipers that are manually turned on and off. Research into how these will be monitored may be needed.
- Some vehicles have two or more motors, such as dual front wipers and rear wipers. The WG felt it would be sufficient to monitor the driver's wiper, but additional consideration may be needed.

7.2.20 Imaging

- The unique ability of digital video to tie the other data elements recorded into a cohesive whole lends itself to a comprehensive EDR system which records multiple data elements.
- Data encryption needs to be reviewed
- Data transmission (over a digital wireless network to the secure data vault of an independent repository) needs to be studied.
- Other research needs include determining the availability of adequate economical transmission capabilities within the national wireless network.
- The WG also felt that input from other digital imaging manufacturers should be obtained and reviewed.
- The data available regarding video capturing was provided by one manufacturer. Other digital imaging manufacturers should be consulted before finalizing requirements. Possible topics include recommended number of cameras, video capture angulation, capture time, methods of data extraction, and cost factors.

7.2.21 Vehicle Load

- Load sensing systems would need to be researched, especially in light of the fact that many trailers are partially loaded.
- Trailer presence systems would need research.
- Future expansion to buses to determine the number of occupants.

- On site crash investigation may be sufficient to determine this data element.

7.3 Survivability Research Needs

The WG reviewed several survivability guidelines, including a set of guidelines developed expressly for large highway vehicles. Research is needed in this area to verify all of the findings that are specific to large highway vehicles, particularly impact shock, penetration, and static crush. In addition, research will be needed to develop performance requirements for each test condition. Further, additional costs associated with data survivability must be considered. There needs to be a better understanding of the types of crashes that an EDR can feasibly survive.

7.4 Event Definition Research Needs

While the WG found that a threshold of 2-4g would be good for determining if a significant crash occurs, it found, based on recent NHTSA crash test results, that this may only apply to longitudinal crashes. The WG found that further research is needed to understand the threshold needs of crashes, and in particular side crashes. The WG also found that the location of the detection sensor can make a difference on which crashes are detected, and believes this element should also be studied.

8.0 Findings

8.1 General

In the current fleet of large vehicles, very few employ EDR technology.

Manufacturers of aftermarket EDRs have had limited success in deploying EDR technology into large vehicle fleets.

Many manufacturers of engines for use in large vehicles have included memory modules in the engine's electronic control unit (ECU). To date, the data recorded are primarily for fleet management use.

The NTSB has used engine ECM data to support crash investigations.

8.2 Specific

The Working Group defined 28 data variables for inclusion in large vehicle EDRs.

Thirteen data variables were defined as Priority 1.

The Working Group established a set of survivability guidelines specifically tailored for large vehicle application.

The Working Group established some guidelines for defining when data should be recorded in a crash event.

The Working Group identified several areas that require additional research. Funding for R&D of emerging EDR technologies is required.

8.3 Safety

EDRs have the potential to greatly improve truck, motorcoach and school bus vehicle safety.