

1616™

IEEE Standard for Motor Vehicle Event Data Recorders (MVEDRs)

IEEE Vehicular Technology Society

Sponsored by the
Motor Vehicle Event Data Recorder (MVEDR) Committee



3 Park Avenue, New York, NY 10016-5997, USA

10 February 2005

Print: SH95281

PDF: 659-241



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IEEE Standard for Motor Vehicle Event Data Recorder (MVEDR)

Sponsor
**Motor Vehicle Event Data Recorder (MVEDR) Committee
of the
IEEE Vehicular Technology Society**

Approved 23 February 2005
American National Standards Institute

Reaffirmed 25 March 2010
Approved 3 September 2004
IEEE-SA Standards Board

Abstract: A performance standard for MVEDR data collection, storage, and retrieval, to ensure that comparable event data parameters are generated by all vehicles, is described.

Keywords: crash data, event data recorder, motor vehicle

The Institute of Electrical and Electronics Engineers, Inc.
3 Park Avenue, New York, NY 10016-5997, USA

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Second printing 23 February 2005.

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Print: ISBN 0-7381-4498-3 SH95281

PDF: ISBN 0-7381-4499-1 SS95281

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Introduction

[This introduction is not part of IEEE Std 1616-2004, IEEE Standard for Motor Vehicle Event Data Recorder (MVEDR).]

In 2000, over 16 million motor vehicle crashes occurred in the U.S., damaging over 27.6 million vehicles and injuring 5.3 million persons. With a crash occurring every two seconds, over 41,000 Americans die from fatal injuries annually. Motor vehicle crashes are the leading killers of Americans under the age of 34 and the leading cause of major brain and spinal injuries.

The impact of motor vehicle crashes on a society is enormous. For 2000, the National Highway Traffic Safety Administration (NHTSA) estimated the cost of crashes at well over 1/2 billion dollars a day, totaling \$230 billion annually. These costs include property damage, medical care, insurance administration, emergency services, legal and court costs, travel delay, productivity losses, and costs to employers.

According to the European Transport Safety Council, the numbers in EU countries are quite similar—43,000 die and over 3.5 million are injured annually, with motor vehicle injuries being the leading cause of death and hospital admission for citizens under 45. Globally, vehicle crashes are the single largest cause of death of men between the ages of 15 and 44 and the ninth disease burden worldwide. Currently, worldwide, one person dies every minute of the day in a motor vehicle crash. The World Health Organization projects that by the year 2020 road traffic injuries will be the third highest burden of disease in the world.

Crash information is critical to understanding causation leading up to the crash, occupant kinematics and vehicle performance during a crash, and post-crash events. Manufacturers, engineers, policy makers, researchers, and others rely on crash information to improve vehicle design, shape regulatory policy, develop injury criteria, detect vehicle defects, and resolve investigations and litigation.

Motor vehicles have markedly transitioned from mechanical machines with mechanical controls to highly technological vehicles with integrated electronic systems and sensors. Modern automobiles generate, utilize, and analyze electronic data to improve vehicle performance, safety, security, comfort and emissions. Surrounding a crash, capture of a subset of vehicle data on an MVEDR makes important information readily available for medical responders, crash investigators, and researchers. The degree of societal benefit from MVEDRs is directly related to the number of vehicles operating with an MVEDR and the ability to retrieve and utilize these data. Having standardized data definitions and formats allows the capture of vehicle crash information.

The P1616 Working Group of IEEE recognizes the value of improved crash information in improving the knowledge of what happens before, during, and after a motor vehicle crash. Such insights will provide major benefits to society and significantly improve the science of motor vehicle crashes. This standard defines a protocol for MVEDR output data compatibility and export protocols of MVEDR data elements

The impact of improved crash data goes beyond just understanding the dynamics of a crash; it affects a myriad of important societal and business functions. With that in mind, the Working Group solicited input from a range of end users to help identify important data element and critical uses of motor vehicle crash data. Both individual crash events and aggregate data have value for end users, depending on the application and data used.

Some users and uses include the following:

- *Automotive industry:* Data-driven design of vehicles, using larger numbers of crashes across a continuum of severity; early evaluation of system and vehicle design performance; and international harmonization of safety standards.

- *Insurance industry:* Help to identify fraudulent claim, costing more than \$20 billion annually; improve risk management; expedite claims and decrease administrative cost. Insurers require accurate crash data for subrogation of claims and recovery of expenses.
- *Government:* Promulgating and evaluating standards; identifying problem injuries and mechanisms; stipulating injury criteria and investigating of defects. State and local officials require crash information to identify problem intersections and road lengths, to determine hazard countermeasures, and to evaluate the effectiveness of safety interventions.
- *Researchers:* Human factors research, such as the man-machine interface; crash causation, the effects of aging and medical conditions, and fatigue; biomechanics research on human response to crashes, harmonized dummy development, and injury causation.
- *Medical providers:* On-scene field triage of motor vehicle crash victims; improved diagnostic and therapeutic decisions; automatic notification of emergency providers; better organization of trauma and EMS system resources.
- *The Public:* Better policies, vehicle design, emergency response, roadway design, and driving habits; lowered insurance costs, decreased possibility for fraud; fewer crashes and more efficient systems.

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Participants

The following is a list of corporate and individual participants in the motor vehicle event data recorder effort of the MVEDR Working Group. Voting members at the time of publication are marked with an asterisk (*).

Thomas M. Kowalick* and **James E. Hall***, *Co-Chairs*

Anthony A. Huffman*, *Secretary*

Robert C. McElroy*, *Treasurer*

<i>Actica Corporation</i>	Susan Ferguson	Christina Mullen
<i>American Public Transportation Association (APTA)*</i>	Dan Floyd	Ali Naqvi
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<i>Freightliner, LLC</i>	Deborah Freund*	Chuck Niessner*
<i>General Motors Corporation</i>	James R. Frysinger	Bob Norton
<i>Independent Witness</i>	Daniel P. Fuglewicz*	Eric Ogilvie*
<i>National Transportation Safety Board (NTSB)*</i>	Doug Gabauer	James Onder
<i>Nissan North America</i>	Clay Gabler*	Kim Oshinsky
<i>Ramtron International</i>	Ami Gadhia	Richard Pandolfi*
<i>Safety Intelligent Systems (SIS)*</i>	Liz Garthe*	Hare Patnaik
<i>Society of Automotive Engineers (SAE)</i>	Richard Geib	Rich Paulson
<i>Toyota North America</i>	Anthony Geller	Ruben Payen
<i>Veridian Engineering IT*</i>	Jack Gemender	Elana Pedrick
<i>William Lehman Injury Research Center & Ryder Trauma Center</i>	Kevin George	John A. Pierowicz
<i>Zepo Sales & Service, Inc.</i>	Steve Gerhing	Kathy Piersall
Michael Alwais	Alan German	Robert Pinto
Don F. Anderson	Alan Grau	David Phelps
Dan Angell	Sally Greenberg	Chuck Plaushin
Bob Arturi	Doughlas Gurin	Jack Pokrzywa
Jeffrey S. Augenstein	Hideka Hada	Doughlas Read
Janice Bachman	Jeff Hagarty	Adam Reardon
George Bahouth	Patrick Haley	Mary Rennie
Gabrielle Bayme	Tony Hanson	Jack Ribbon
Hal Beecraft	Barry Hare	Edward Ricci
Marcus Behrendt	Patrick Hare	Kevin Ro
Steve Belden	Martin Hargrave	Tom Roston
Tom Berringer	John A. Hinch	Louis Sanders
Rich Bishel	John Hus	Jeff Scanman*
Roger L. Boyell*	Klaus Hitzeroth	Scott Schmidt
Michael Bracki	Henry Jasny	Dan Selke
John Bradley	Steven Johnson	Richard Smolenski*
John Brophy	David Karmol	Dave Snyder
Jerry L. Cage	Jim Keller	Rick Snyder
Michael Cammisa*	Scott Kidd*	Mike Spitzley
Pascal Centomo	Paul Kostek	John C. Steiner
Chip Chidester	Dennis Kramer	Craig Taylor
David Clark	Miranjam Kulkarmi	Robert Thompson
Joan Claybrook	Thomas A. Kurihara*	Jerry Trotter*
Richard Cox	Ty A. Lasky	Hiroshi Tsuda
Tom Crofford	Joseph Lloyd*	Mary Ellen Tucker*
Deny Dayi	Patrick Lugan	Jack Volk
Ken Diggs	Laura MacCleery	Stephen Webb
Prabal Dutta	Joe Marsh*	Barbara E. Wendling
David Eiswerth	Ricardo Martinez*	Mike White
Brian Everest	Ed Maynard	Russ White
Thomas Eymann	Scott McClellan	Larry Williams*
Helen Fagerlind	Sarah McComb*	David Willis
	David McKendry	Mark Wood
	Paul Menig	Park Wu
	Mark Miller	Robert Yakushi
	Sandra Miller	Garold Yurko
	Jeff Morin	John Yurtin
		Guillermo Zepeda

The following members of the individual and entity balloting committee voted on this standard. Balloters may have voted for approval, disapproval, or abstention.

Dennis Bodson
Roger L. Boyell
Martin Caspe-Detzer
Liz Garthe

Kevin George
Fernando GenKuong
Anthony A. Huffman
Paul Kostek
Thomas M. Kowalick

Thomas M. Kurihara
Ty A. Lasky
Stephen Webb
Larry Williams

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IEEE Standards Project Editor

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IEEE Standard for Motor Vehicle Event Data Recorder (MVEDR)

1. Overview

1.1 Scope

MVEDRs collect, record, store, and export data related to motor vehicle predefined events. This standard defines a protocol for MVEDR output data compatibility and export protocols of MVEDR data elements. This standard does not prescribe which specific data elements shall be recorded, but instead provides a data dictionary of data attributes. It is applicable to event data recorders for all types of motor vehicles licensed to operate on public roadways, whether offered as original or aftermarket equipment, whether stand-alone or integrated into the vehicle.

1.2 Purpose

Many light-duty motor vehicles, and increasing numbers of heavy commercial vehicles, are equipped with some form of MVEDR. These systems, which are designed and produced by individual motor vehicle manufacturers and component suppliers, are diverse in function and proprietary in nature. The continuing implementation of MVEDR systems provides an opportunity to voluntarily standardize data output and retrieval protocols to facilitate analysis and promote compatibility of MVEDR data. Adoption of the standard will therefore make MVEDR data more accessible and useful to end users.

1.3 Data privacy and security recommendations¹

Privacy is a central element of consumer protection. In recent years, advances in technology have made it possible for detailed information about individuals to be compiled and shared. This has produced many benefits for society as a whole and individual consumers. At the same time, as personal information becomes more accessible, precautions must be taken to protect against the misuse of information.

MVEDR data aggregated across many events has significant scientific value. Occasional errors in data recording, communication, or retrieval will undoubtedly occur. However, uncontrolled release of any data, especially erroneous data for any specific event, has the potential to compromise the directly affected individual's need for confidentiality. Moreover, aggregate MVEDR data may contain an occasional

¹The recommendations contained in this subclause do not guarantee compliance with all state and local privacy requirements and are only intended to provide baseline recommendations. Individual parties collecting motor vehicle event data should consult local laws for specific privacy guidance.

statistical anomaly. While scientifically undesirable, minor errors are not catastrophic to the overall value of the data. However, individual or personal data containing statistically insignificant errors or omissions may wrongly attribute liability, falsely indicate fraud, or erroneously convict/exonerate a particular person.

The use of an MVEDR may make personal identification information available, which can potentially include one, or more of the following:

- 1) Driver or occupant name or the equivalent
- 2) Event place, date, and time
- 3) Precise Global Positioning System (GPS) coordinates
- 4) Wireless telephone number or electronic serial number (ESN)
- 5) Complete vehicle identification number (VIN)
- 6) Unique MVEDR serial number

MVEDR data shall not be compiled into a public database or released to third parties without due process of law unless done in accordance with local and Federal privacy regulations. Further, personally identifiable information similar to items a) through f) shall be recognized as requiring more stringent security precautions than data aggregated over multiple events. MVEDR data in the process of being recorded, retrieved, transmitted, preserved, and/or transmitted shall be subject to reasonable means of authentication and verification of its integrity. In particular, records shall be maintained of data recording, retrieval, transcription, preservation, or transmission, by which the “chain of custody” can be retraced to original sources.

All rights in retrieved MVEDR data shall be preserved, including the right of data owners and adversaries to dispute its accuracy. Any identified individual must be afforded notification that his personally identifiable information is contained in MVEDR data, and the individual must be given reasonable opportunity to legitimately challenge or correct possible erroneous or incomplete information.

1.4 Standard structure

This standard is portioned into clauses that serve several distinct purposes.

Clause 1, Overview, provides background for understanding the goals and objectives for this standard.

Clause 2, References, gives the references referred to in this standard.

Clause 3, Definitions, acronyms, and abbreviations, provides a glossary that defines the terms used by later clauses within the standard.

Clause 4, Applicability, provides information about the different constituencies who will benefit from this standard and also notes use-case perspectives and applications.

Clause 5, Event Description, defines the meaning of an *event* as it pertains to motor vehicle crashes.

Clause 6, Output, defines common interfaces that may be utilized to extract MVEDR data.

Clause 7, MVEDR data attributes, describes how the crash sequence is examined in circumstances surrounding the event prior to the crash occurring, the circumstances involved during the crash, and those involved after the crash.

Clause 8, MVEDR data dictionary, explains how the data dictionary is comprised as a collection of entries specifying the name, source, usage, and format of each data element used in a system or set of systems.

Clause 9, Conformance, specifies levels of conformance for the data formats defined by this standard.

Annex A, Test control program, identifies the requirements necessary to establish and implement a test control program.

Annex B, In-vehicle networks, explains Controller Area Network (CAN), a widely used vehicular network.

Annex C, Government databases, explains that for the purpose of accident causation analysis, a number of accident databases have been developed and used to identify effective countermeasures to improve the safety of the surface transportation system.

Annex D, MVEDRs and implementation of ACN systems, explains the connection between the two emerging technologies.

Annex E, Bibliography, lists background material for this standard.

1.5 Data dictionary

Historically, motor vehicles were basically mechanical systems. Mechanical systems, including early restraint systems, allowed a mechanical reconstruction of system performance and no MVEDR was needed, nor was there electronic data available to record. Modern motor vehicles now include a vast array of electronic systems. The past four decades have witnessed an exponential increase in the number and sophistication of electronic systems in vehicles. The growth of electronic systems has had implications for vehicle engineering. Today, electronic systems need to record critical system inputs and outputs to know if systems performed as intended in the field. A need exists to ascertain if motor vehicle safety-related components or systems performed properly in field events, to decide if a product improvement is necessary. This standard includes a data dictionary of data elements or data attributes. These data elements will be useful for effective crash investigations, analysis of the performance of safety equipment (e.g., advanced air bags), and automatic collision notification (ACN) systems. Several of these elements are associated with crash severity and usage of the restraint system while others are important to understanding the human response to avoiding a pending crash. The data dictionary is located in Clause 8.

2. References

This standard shall be used in conjunction with the following standards. When the following standards are superseded by an approved revision, the revision shall apply. In case of a conflict between this standard and the referenced document, this standard shall take precedence. Those provisions of the referenced documents that are not in conflict with this standard shall apply as referenced.

Canadian Motor Vehicle Safety Regulations, Standard 101-2003, Location and Identification of Controls and Displays.²

EIA 232D-1987, Interface between Data Terminal Equipment and Data.³

FMVSS 208, Occupant Crash Protection.⁴

FMVSS 214, Side Impact Protection.

²This publication is available from <http://www.tc.gc.ca/acts-regulations/GENERAL/M/mvsa/regulations/mvsrg/100/mvsr101.html>.

³EIA publications are available from Global Engineering Documents, 15 Inverness Way East, Englewood, CO 80112, USA (<http://global.ihs.com/>).

⁴FMVSS publications are available from <http://www.nhtsa.dot.gov/cars/rules/import/FMVSS/>.

FMVSS 301, Fuel System Integrity.

IEEE/ASTM SI 10TM-2002, American National Standard for Use of the International System of Units (SI): The Modern Metric System.⁵

ISO 2575:2004, Road Vehicles—Symbols for Controls, Indicators, and Telltales.⁶

ISO 4040:2001, Passenger Cars—Location of Hand Controls, Indicators, and Telltales.

ISO 11898-1:2003, Road Vehicles—Controller Area Network (CAN)—Part 1: Data Link Layer and Physical Signalling.

ISO 11898-2:2003, Road Vehicles—Controller Area Network (CAN)—Part 2: High-speed Medium Access Unit.

ISO 12353-2:2003, Road Vehicles—Traffic Accident Analysis—Part 2: Guidelines for the Use of Impact Severity Measures.

SAE J211/1-2003, Instrumentation for Impact Test—Part 1: Electronic Instrumentation. *See also* SAE Paper 2002-01-0796: Digital Filtering for J211 Requirements Using a Fast Fourier Transform-Based Filter.⁷

SAE J1455-1994, Joint SAE/TMC Recommended Environmental Practices For Electronic Equipment Design (Heavy-Duty Trucks).

Universal Serial Bus Revision 2.0 (USB 2.0) specification.⁸

U.S. Code of Federal Regulations (CFR) Title 49: Transportation; Part 571.101: Controls and displays (revised as of 2002).⁹

3. Definitions, acronyms, and abbreviations

3.1 Definitions

3.1.1 ABS activity: This indicates that the anti-lock brake system (ABS) is actively controlling the vehicle's brakes.

3.1.2 anti-lock brake system (ABS): A means to maintain directional stability and control during braking of a vehicle.

3.1.3 capture: The process of saving recorded data.

⁵IEEE publications are available from the Institute of Electrical and Electronics Engineers, Inc., 445 Hoes Lane, Piscataway, NJ 08854, USA (<http://standards.ieee.org/>).

⁶ISO publications are available from the ISO Central Secretariat, Case Postale 56, 1 rue de Varembe, CH-1211, Genève 20, Switzerland/Suisse (<http://www.iso.ch/>). ISO publications are also available in the United States from the Sales Department, American National Standards Institute, 25 West 43rd Street, 4th Floor, New York, NY 10036, USA (<http://www.ansi.org/>).

⁷SAE publications are available from the Society of Automotive Engineers, 400 Commonwealth Drive, Warrendale, PA 15096, USA (<http://www.sae.org/>).

⁸This publication is available from <http://www.usb.org/developers/docs/>.

⁹CFR publications are available from the Superintendent of Documents, U.S. Government Printing Office, P.O. Box 37082, Washington, DC 20013-7082, USA (<http://www.access.gpo.gov/>).

3.1.4 crash: An unusual or unstable event or an occurrence in a sequence of events that produces injury, death, and/or damage to one or more vehicles involving a motor vehicle in transport.

3.1.5 crash pulse: The acceleration-time history of the occupant compartment of a vehicle during a crash. This is represented typically in terms of acceleration as multiples of the standard calculational value for the acceleration due to gravity, g_n ($= 9.806\ 65\ \text{m/s}^2$, exactly), plotted against time in milliseconds ($1\ \text{ms} = 0.001\ \text{s}$). The crash pulse determines the test's severity of the crash: an occupant will undergo greater forces if the crash pulse accelerations are higher at the peak or if the duration of the crash pulse is shorter. Local values for the acceleration due to gravity, g , may differ from g_n significantly and vary from one locale to the next and in some areas with tidal conditions; hence g_n is the international standard calculational basis.

3.1.6 crash severity: The most severe injury sustained in the crash as recorded on the police accident report (PAR) and consists of: *property damage only* (no injuries); *minor or moderate* (evident, but not incapacitating; complaint of injury; or injured, severity unknown); *severe or fatal* (killed or incapacitating).

3.1.7 data definition: A description of the format, structure, and properties of a data element.

3.1.8 data dictionary: A collection of entries specifying the name, source, usage, and format of each data element used in a motor vehicle system or set of systems.

3.1.9 data element: A uniquely named and defined component of a data definition; a data “type” in which data items (actual values) can be placed.

3.1.10 delta-v (Δv): For vehicles with only longitudinal acceleration measurement capability, the change in velocity of the vehicle along the longitudinal axis, and for vehicles with both longitudinal and lateral acceleration measurement capability, the change in velocity of the resultant of the longitudinal and lateral vehicle velocity time histories, within the time interval starting from the time zero and ending 5000 ms after time zero.

3.1.11 deployment level: The highest level inflator ignited in an air bag deployment.

3.1.12 disposal: The deployment of the second (or higher, if present) stage of a frontal air bag for the purpose of disposing the propellant from the air bag device.

3.1.13 dual-stage event: An event that is a sequence of two single-stage events within a period of time.

3.1.14 engine RPM: For vehicles powered by internal combustion engines, the number of revolutions per minute of the main crankshaft of the vehicle's engine, and for vehicles not powered by internal combustion engines, the number of revolutions per minute of the motor shaft at the point at which it enters the vehicle transmission gearbox. The universal unit symbol for RPM is r/min.

3.1.15 engine throttle, percent full: For vehicles powered by internal combustion engines, the percent of the engine throttle opening compared to the full open position of the engine throttle opening, and for vehicles not powered by internal combustion engines, the percent of vehicle accelerator depression compared to the fully depressed position.

3.1.16 event: A change in the condition or performance of interest at a specific time that causes the trigger threshold to be met or exceeded after the end of the 500 ms period for recording data regarding the immediately previous event.

3.1.17 event data recorder (EDR): A device or function in a vehicle that records any vehicle or occupant-based data just prior to or during a crash, such that the data can be retrieved after the crash, including vehicle or occupant-based data included in any of the data elements of this standard, IEEE Std 1616-2004.

3.1.18 forward seat position: A seat position that is in the forward-most third of the measured distance between the full forward and the mid-track positions of the seat.

3.1.19 frontal air bag: The primary inflatable occupant restraint device that is designed to deploy in a frontal crash to protect the front seat occupants.

3.1.20 ignition cycle, crash: The number (count) of the ignition key applications sufficient to start the engine and/or the power vehicle accessories, from the date of manufacture to and including the time of the event.

3.1.21 ignition cycle download: The number (count) of the ignition key applications sufficient to start the engine and/or the power vehicle accessories, from the date of manufacture to and including the time when the data is downloaded from the MVEDR.

3.1.22 incident: An event in which the safety of the vehicle or any person is threatened.

3.1.23 lateral acceleration: The component of the acceleration vector of a point in the vehicle in the y-direction. The lateral acceleration is positive from left to right, from the perspective of the driver when seated in the vehicle facing the direction of forward vehicle travel.

3.1.24 longitudinal acceleration: The component of the acceleration vector of a point in the vehicle in the x-direction. The longitudinal acceleration is positive in the direction of forward vehicle travel.

3.1.25 motor vehicle event data recorder (MVEDR): A device that is installed in a motor vehicle to record technical vehicle- and occupant-based information for a period of time before, during, and after a crash. MVEDRs may record (1) pre-crash vehicle dynamics and system status, (2) driver inputs, (3) vehicle crash signature, (4) restraint usage/deployment status, and (5) certain post-crash data, such as the activation of an ACN system.

3.1.26 multi-event crash: The occurrence of two or more events, the first and last of which begin not more than 5 s apart.

3.1.27 normal acceleration: The component of the acceleration vector of a point in the vehicle in the z-direction. The normal acceleration is positive in a downward direction.

3.1.28 occupant size classification: The right front passenger, the classification of an occupant as an adult or a child occupant, and for the driver, the classification of the driver as being or not being a small female.

3.1.29 post-crash: Condition inside/outside a vehicle following a crash.

3.1.30 pre-crash: Condition inside/outside a vehicle prior to a crash.

3.1.31 pretensioner: A device that is activated by a vehicle's crash sensing system and removes slack from a vehicle belt system.

3.1.32 record: The process of storing data into volatile memory for later use.

3.1.33 recorder: A device or method to detail action and/or reaction. *See:* **motor vehicle event data recorder (MVEDR).**

3.1.34 safety belt status: This indicates if an occupant's safety belt is buckled or not buckled.

3.1.35 seat position: The position of a seat along the track for moving the seat in a forward or rearward direction.

3.1.36 side air bag: Any inflatable occupant restraint device that is mounted to the seat or side structure of the vehicle interior at or below the window sill, and that is designed to deploy and protect the occupants in a side impact crash.

3.1.37 side curtain/tube air bag: Any inflatable occupant restraint device that is mounted to the side structure of the vehicle interior above the window sill, and that is designed to deploy and protect the occupants in a side impact crash or rollover.

3.1.38 single-stage event: An event that is caused by a single trigger or the logical result of two or more triggers.

3.1.39 speed, vehicle indicated: The speed indicated on the vehicle's speedometer.

3.1.40 stability control: Any device that is not directly controlled by the operator (e.g., steering or brakes) and is intended to prevent loss of vehicle control by sensing, interpreting, and adjusting a vehicle's driving and handling characteristics.

3.1.41 steering wheel angle: The angular displacement of the steering wheel measured from the straight-ahead position (position corresponding to zero average steer angle of a pair of steered wheels).

3.1.42 suppression switch status: The status of the switch indicating whether an air bag suppression system is on or off.

3.1.43 telltale: A display that indicates the activation of a device, a correct or defective functioning or condition, or a failure to function. Telltales are considered visible when activated.

3.1.44 time to deploy: The elapsed time between time zero and the time when the inflator of a side air bag or side curtain/tube air bag is fired.

3.1.45 time to first stage: The status of the switch indicating whether an air bag suppression system is on or off.

3.1.46 time to n^{th} stage: The elapsed time between time zero and the time when the second stage of a frontal air bag is fired.

3.1.47 time zero: The beginning of the first 20 ms interval in which the trigger threshold is met during an event.

3.1.48 triage: At the time of a motor vehicle crash, the method or means of classification by which patients are directed to services by medical professionals based on the severity of their injuries.

3.1.49 trigger: This initiates the capture of data.

3.1.50 trigger threshold: A change in vehicle velocity, in the longitudinal direction for vehicles with only longitudinal acceleration measurements or in the horizontal plane for vehicles with both longitudinal and lateral measurements, that equals or exceeds 0.8 km/h with a 20 ms interval.

3.1.51 vehicle class: A term that includes sedans, station wagons, ambulances, buses and trucks, or different categories of vehicles such as light vehicles, medium vehicles, and heavy vehicles.

3.1.52 vehicle identification number (VIN): As defined in 49 CFR 567, a set of about 17 alphanumeric characters, assigned to a vehicle at the factory and inscribed on a small metal label attached to the dashboard and visible through the windshield. VIN is a unique identifier for the vehicle and therefore is often found on insurance cards, vehicle registrations, vehicle titles, safety or emission certificates, insurance policies, and

bills of sale. The coded information in the VIN describes characteristics of the vehicle, such as make, model, manufacturer, and other limited vehicle details.

3.1.53 vehicle roll angle: The angle between the vehicle y-axis and the ground plane.

3.1.54 x-direction: In the direction of the vehicle x-axis, which is horizontal and parallel to the vehicle's longitudinal centerline. The positive direction is forward.

3.1.55 y-direction: means in the direction of the y-axis, which is horizontal and perpendicular to its x- and z-axes. The positive direction is to the right, as seen from driver's perspective.

3.1.56 z-direction: In the direction of the vehicle z-axis, which is vertical and perpendicular to its x- and y-axes. The positive direction is down.

3.2 Acronyms and abbreviations

ABS	anti-lock braking system
ACN	automatic collision notification
APTA	American Public Transportation Association
ATA	American Trucking Association
AVL	automatic vehicle location
BI	bodily injury
CAN	controller area network
CDR	crash data retrieval tool
CFR	Code of Federal Regulations
CG	center of gravity
CMV	commercial motor vehicle
ComCARE	Communications for Coordinated Assistance and Response to Emergencies
CSS	child safety system
data BUS	electrical system installed in a vehicle that allows vehicle subsystems to communicate with each other
DC	direct current
delta-V	delta (change in) velocity, Δv
DGPS	Differential Global Positioning System
DOB	date of birth

DOT	Department of Transportation
DRL	daytime running lights
ESN	electronic serial number
EBV	equivalency barrier velocity
ECM	electronic control module
ECU	electronic control unit
EDR	event data recorder
EEPROM	electronically erasable programmable read-only memory
EIA	Electronic Industries Association
EMI	electromagnetic interference
EMS	emergency medical services
EPROM	electronically programmable read-only memory
FARS	Fatality Analysis Reporting System
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
FMVSS	Federal Motor Vehicle Safety Standard
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
GIS	Geographic Information System
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
IC	integrated circuit
ID	identifier
IEEE	Institute of Electrical and Electronics Engineers
I/O	input/output
IR	infrared electromagnetic spectrum
ISO	International Standards Organization

ITE	Institute of Transportation Engineers
ITS	intelligent transportation system
IVHS	Intelligent Vehicle Highway Systems
JPL	Jet Propulsion Laboratory, California Institute of Technology
MVEDR	motor vehicle event data recorder
NAT	Network Analysis Tool
NCHRP	National Cooperative Highway Research Program
NHTSA	National Highway Traffic Safety Administration
NTSB	National Transportation Safety Board
NTCIP	National Transportation Communications for ITS Protocols
OBD	on-board diagnostic
OEM	original equipment manufacturer
OSI	Open Systems Interconnection
PCMCIA	Personal Computer Memory Card Industry Association
PDOF	principal direction of force
PRNDL	transmission gear position (P = park, R = reverse, N = neutral, D = drive, L = low)
PIP	personal injury protection
R & D	research and development
RAM	random access memory
RCM	restraint control module
RF	radio frequency
RFCSS	rear-facing child safety system
RFI	radio frequency interference
ROM	read-only memory
RP	recommended practice
SAE	Society of Automotive Engineers
SSN	Social Security number

TCIP	Transit Communications Interface Profiles
TMC	The Maintenance Council of the American Trucking Association
TRB	Transportation Research Board
UIM	uninsured claim for the insured against a third party
UM	uninsured motorist
USB	universal serial bus
WGS	World Geodetic System
WSB	wheel speed based

4. Applicability

This standard shall benefit many different constituencies and applications including: automakers, automotive suppliers, academia, state and local department of transportation agencies, highway operations, transportation operators, vehicle safety regulators, accident investigators, law enforcement agencies, insurance companies, human factors researchers, emergency medical services, motorcycle manufacturers, school bus manufacturers, motor-coach manufacturers, transit agencies, fleet owners, and transit manufacturers.

4.1 Rationale for the development of this standard via use cases

The purpose of developing use-case scenarios is to establish a basis for making better, more informed decisions about the need for recording specific data elements and attributes, requirements for data accessibility, and overall (or high-level) design requirements. Essentially, the more that is known about how crash data can and will be used by various “users,” the more intelligently the recording requirements can be assembled. The use-case scenarios endeavor to provide the following:

- 1) Brief description of the user’s overall “business”
- 2) Description of the user’s “role” and objectives as related to automotive crashes/accidents
- 3) How does the user fulfill the role/objectives currently?
- 4) What are the current challenges, problems, and issues facing users as they try to fulfill their role and meet their objectives?

The use-case scenario provides examples of how an MVEDR might be used to address the current challenges and “problems” faced by the user, specifically:

- 1) The questions and/or decisions that the user hopes to address with information obtained from MVEDRs.
- 2) The analysis methodology needed to address the questions.
- 3) The specific data elements needed to support the analyses or to answer the questions confronting a particular end-user group.
- 4) How “accurate” does the data need to be?
- 5) What is the appropriate time period for recording the data?

The output of use-case scenarios are used to help identify and prioritize the data elements to be defined and included in this standard, as well as help to establish overall design requirements including data extraction standards.

4.2 International use of MVEDR data

Users of MVEDR data include, but are not limited to, the following:

- 1) Global development of treaties on roads and transport
- 2) Reports on international road safety
- 3) Government transport agencies
- 4) International road safety databases
- 5) Country specific road safety issues
- 6) Regional road issues
- 7) International organizations on road safety
- 8) United Nations road safety initiatives
- 9) European Union road safety initiatives
- 10) Organization for Economic Co-operation and Development (OECD)
- 11) International non-governmental organizations
- 12) World Health Organization (WHO) road safety initiatives

4.3 Summary of user group perspectives

This subclause presents use-case summaries for the following groups:

- 4.3.1 National Transportation Safety Board (NTSB)
- 4.3.2 General crash research and defect investigation community
- 4.3.3 Automotive industry
- 4.3.4 Emergency response community
- 4.3.5 Roadside/infrastructure design community
- 4.3.6 Insurance industry

4.3.1 National Transportation Safety Board (NTSB)

The NTSB is an independent Federal agency responsible for investigating every civil aviation accident in the U.S. and significant accidents in the other modes of transportation: railroad, highway, marine, and pipeline. The Safety Board determines the probable cause of these accidents and issues safety recommendations aimed at preventing future accidents. The Safety Board's work in this discussion is limited to its highway crash investigation activities, and specifically, to the collection of data by the Vehicle Factors/On-Board Recorder Group Chairman and the analysis of the data by its Office of Research and Engineering. Through its investigations, the Safety Board's objective is to obtain quantitative data of high quality and fidelity in order to improve transportation safety for the general public. The depth and breadth of the Safety Board's investigations are of the highest technical and analytical levels possible.

During the initial portion of a Safety Board highway crash investigation, the Vehicle Factors/On-Board Recorder Group Chairman identifies sources of recorded information [such as engine electronic control modules (ECMs)] on the vehicle(s) involved. Currently, data extraction is usually not performed by Safety Board personnel, but by a party to the investigation with the Safety Board's participation. The Vehicle Factors/On-Board Recorder Group Chairman prefers to have the data extracted while the device remains in

the vehicle and connected to its data sources. In the event that data from an ECM is extracted by the manufacturer, the ECM may be connected to a vehicle “simulator.”

The recovered data is then used to corroborate physical and other evidence with vehicle performance data, to diagnose and troubleshoot vehicle and systems defects, and as a data source when a driver is not available to be interviewed. The data is also supplied to performance engineers from the Office of Research and Engineering to use in software simulations of vehicle and, possibly, occupant kinematics during a crash sequence. The process of simulation consists of matching physical evidence from scene and vehicle recorder data, starting with known data, and then using engineering calculations and physics to determine other critical parameters. The simulation process begins by building a three-dimensional scene, including the roadway (which itself is surveyed and drawn with AutoCAD). The performance engineers build the vehicle next, starting with the physical dimensions [size, weight(s), center of gravity location, passenger or freight loading] and its engine (from design and performance curves as a function of engine speed in r/min). They assign stiffness parameters and solve equations of motion as a function of time. One of the products of the simulation is the crash pulse—the acceleration-time history of the vehicle.

The software can then be used to simulate the occupants. This begins with a definition of planar or ellipsoid contact surfaces defining the space surrounding the occupant. The occupant, defined as a fully jointed human model, must start at equilibrium within the vehicle. Interactions with contact surfaces are defined for each occupant. The crash pulse is used to “drive” the vehicle through the accident. As the vehicle accelerates or decelerates, the occupant has a speed differential with the vehicle that defines the impact forces and thus the predicted injury levels. Parametric analyses can then take place based on assumptions of differential stiffness of seats, occupant restraints, etc. Unfortunately, many assumptions are necessary for both the vehicle and occupant model. More specific information concerning the vehicle dynamics, accelerations, and motions would enable a more thorough evaluation of the occupant motion and, in the long run, enable designers to develop a safer vehicle. MVEDRs may provide much of this information.

The Safety Board has had success with the recovery of recorded data in a number of accidents. In one investigation, the data recorded in an air bag electronic control unit (ECU) was critical in understanding a crash involving a passenger car and commercial motor vehicle. In that case, the data indicated the truck underride device caused the passenger car to decelerate at a rate lower than that required to activate the air bag. The Safety Board also had success extracting data from multiple sources in the Canon City, Colorado, motor-coach accident. In this accident, the motor coach lost control on slippery pavement on a steep downgrade. Recorded data was recovered from the ECM as well as the ECU from the ABS. The recorded data highlighted factors related to the initial loss of control, that the motor coach was placed in neutral, braking was used infrequently, and the motor coach accelerated to about 70 mi/h before losing control in a curve. Nonetheless, more data on steering inputs, force of brake applications, and time stamping of fault codes would have further helped investigators and more focused safety recommendations may have resulted.

Despite the Safety Board’s successes, investigations such as the Bourbonnais, Illinois, railroad grade crossing accident illustrate accidents that would have greatly benefited from EDR data. In that particular case, steering data would have made a significant difference in determining whether a truck driver had gone around the gate at the grade crossing. Corroboration of other evidence would be a key advantage to the use of EDR data. Although recorded data is never used in isolation, information from an EDR could affect the focus of an investigation. Use of EDR data for diagnoses and troubleshooting is an emerging technology. As vehicle systems become more complex and interconnected, there is an increasing concern that unanticipated conditions or combinations of events could have unintended consequences. Examples include an ECM fault preventing the engine from being powered properly or a fuel pressure-related shutdown.

Further, analyses are time and resource intensive. Typically, simulation modeling usually takes 3 to 6 months, but some complex simulations can take more than a year. If additional data were recorded, the Safety Board would be able to perform more thorough and cost-effective investigations. The analyses would be more accurate and could be accomplished in a shorter period of time. As a result, safety improvements

could be identified and implemented sooner, thus benefiting the transportation community and the general public.

In general, the use of MVEDRs outweighs the cost of crashing \$500,000 motor coaches or other expensive vehicles to obtain crash information and product performance. Further, currently, much of the occupant protection system is designed based on the results of crash tests. Some research is being focused at determining real-world accident scenarios and resulting injury patterns, but the dynamics of the vehicle are often not fully known. Crash pulse data would allow designers and engineers to develop safety improvements based on the real-world crash environment rather than only on a laboratory setting.

For the purposes of heavy vehicle crash investigations, the Vehicle Factors/On-Board Recorder Group concurs with the recommendations of the National Highway Traffic Safety Administration (NHTSA) Truck and Bus Working Group report. However, in some instances, a lower resolution (i.e., fewer samples per second) could work for some data elements.

The Research and Engineering users provided a general list of data elements that would have to be tailored depending on vehicle type. For vehicle performance: steering in 20 to 30 degree increments (based upon the steering ratio for heavy vehicles), hard maneuvers, data on rear steerable axles on motor coaches; braking (time of application, pulses, pressure, temperature, ABS activity, and time stamped fault codes; stability control timing and force; retarder on/off and settings); transmission gear (from design and performance data as a function of speed in r/min, also fault codes and time stamps); throttle (from the driver's point of view); tire pressure, failure (pressure, time); crash pulse recording time at high sampling rates (passenger car: at least 100 ms; commercial motor vehicle: could be 100 ms to 300 ms; rollover: could last up to 4 s); linear and angular accelerations to determine how many times a vehicle rolled (Δv in x, y, z; the z-axis data is needed for rollover; and to obtain occupant position and protection information). Acceleration sensors should be measured at "known" positions, at a rigid location, and preferably at the vehicle's center of gravity. Aside from the vehicle data, Δv data is also useful when considering highway design issues [correct super-elevation, design vs. as-built, proper signs and appropriate posted speed limit (several recent accident sites have had speed limits raised above the initial design speeds)]. Additional useful data elements would be: location of impact (usually measured in field, Δv data would help); the direction of vehicle (with respect to magnetic north); and the geographic location (where the initiating event occurred).

The Research and Engineering users believe it would be desirable for data sampling rates to be targeted for the system (i.e., type of vehicle), and to be able to "bracket" the events of interest. The data collection rate should be at least 50 Hz, preferably >1000 Hz after crash initiated. The MVEDR should trigger "above what a vehicle is physically capable of on its own." It should also sample at rates higher than human input and provide for multiple events and time overlap. Finally, the recording period could vary according to various preset conditions: brake temperature could be saved (buffered), and the data would be saved for a longer period if a threshold were exceeded; brake application, nominally set at 1 s intervals within 1 to 2 min of hard braking, could be reset while the vehicle is traversing a severe downgrade to 30 s intervals over a 6 to 12 min period.

In terms of data accessibility and extraction, the Vehicle Factors/On-Board Recorder Group would like the ability to download through a database, using standard data collection, transmission, acquisition, and preservation protocols. Additional concerns of the Vehicle Factors/On-Board Recorder Group include MVEDR physical integrity. In particular, the current location of recording devices (i.e., ECMs) is generally acceptable, but the fire resistance qualities should be improved. Further, there are some limitations of the current sources of recorded data. For example, vehicle ECMs are not foolproof; they can be reprogrammed to alter basic data (VIN codes) and change operating parameters, and there can be differences between ECM data and what is on the vehicle.

4.3.2 General crash research and defect investigation community

The scope and level of detail of crash research and defect investigations vary considerably, depending upon the type of research or investigations being conducted. For example, manufacturers may conduct research to determine the performance of prototypes or new vehicles. On the other hand, crash investigators are more likely to focus on determining the sequence of events leading to a crash, possibly including the factors leading to the crash and an assignment of proximate cause. An organization investigating an allegation of a vehicle defect would be very detailed in its quest for information, but would typically only address the specific component or its relationship to a safety-impacting situation. The role of these users is to improve the safety of the motoring public through the continuous improvement of motor vehicles. This is accomplished by observing the safety performance of the vehicle when it is in operation. These users' responsibilities could involve assessing a new car's safety performance, investigating a crash, or investigating an alleged design or manufacturing defect.

MVEDR role in addressing needs: The role of the MVEDR is to capture and store data that cannot be determined readily or accurately using other means. For example, MVEDR data can/could be used to determine specific elements critical to an investigation, such as air bag deployment level, which cannot be assessed quantitatively from the crash evidence. It can/could also be used to improve analysts' ability to assess crash severity and the impacts on vehicle occupants, adding to the value of crash reconstruction software. MVEDR data could also be invaluable to determine information on the use and deployment of safety devices and other vehicle systems, such as safety belt status, information that is often lost due to immediate attendance to an individual's needs directly after the crash.

Specific data elements: Data needs vary by the type and purpose of the crash investigation. An investigator assessing an alleged vehicle defect would need data associated with the allegation. A researcher developing an improved air bag system would need data related to its operation. The list of potentially useful data elements is as long and varied as the uses for the data. In 2001, NHTSA's Special Crash Investigation office published an enhanced safety of vehicles (ESV) paper detailing MVEDR data it thought would be of interest for investigating vehicle crashes. A list of those recommendations, including data elements, is found in Table 1. In an effort to assess the needs of defect investigators, informal interviews were conducted. While these interviews are the opinions of the investigators and not the agencies they work for, they give some insight into the needs. Table 2 provides a list of data elements.

Table 1—Research recommendations for MVEDRs data collection [B6]

Data collection
• Lock the deployment record data in EEPROM such that the data cannot be erased, altered, or cleared by service or crash investigation personnel. • Use SAE J211 protocol for collecting data. • Locate the MVEDR in a crash survivable location while still providing post-crash inspection accessibility. • Ensure sufficient auxiliary power is available to record the entire crash sequence even when the vehicle's electrical system is damaged. • Employ a single universal crash data retrieval tool for downloading data. • The universal crash data retrieval tool should be able to be connected directly to the MVEDR for downloads. • Record data for at least two events.
Pre-crash data graph
• Record vehicle speed for 10 s before algorithm enable (km/h or m/min). • Record engine speed for 10 s before algorithm enable (r/min). • Record throttle position for 10 s before algorithm enable. • Record the brake switch circuit status for 10 s before algorithm enable (on/off). • Record the actuation of ABS for 10 s before algorithm enable (on/off).

Table 1—Research recommendations for MVEDRs data collection [B6] (*continued*)

At crash data
• Record the status of the warning lamp (on/off). • Record the driver and passenger belt switch status (buckled/unbuckled). The seat belt usage data should be recorded and stored in RAM at algorithm enable. • Record the driver and passenger air bag suppression switch status (on/off). • Record the ignition cycle at deployment. • Record the ignition cycle at investigation. • Record the air bag deployment level: first-stage or second-stage deployment. • Record the time from algorithm enable to air bag first-stage or single-stage deployment. • Record the time from algorithm enable to air bag second-stage deployment. • Record the time from algorithm enable to driver and passenger pretensioner deployment. • Record the time between the two event files if they are in the same ignition cycle. • Record the driver and passenger seat position. • Record the data from the passenger seat weight/position sensor.
Crash pulse graph
• Record at least 300 ms of crash pulse deceleration data recorded as multiples of g_n in 1 ms intervals for at least two events. • Record both the longitudinal and lateral axes data.

Table 2—Defect investigation data elements

<i>Speed:</i> Engine speed, vehicle speed from differential; final drive (ring and pinion—transfer case).
<i>Brake use:</i> Pedal (brake light switch—“circuit closed”) and ABS sensors (for wheel lock/slippage), also ABS operating threshold (ABS does not work at very low speeds, below about 8 km/h to 13 km/h (5 mi/h to 8 mi/h)).
<i>Engine data:</i> Engine temperature and manifold pressure data.
<i>Transmission gear:</i> Depends on the system whether to sense speed sensor or engine speed in r/min. Also want to see: clutch in/out (clutch switch), deceleration curve (deceleration values over time).
<i>Turn signals:</i> On-line diagnostic cable to OBD II; also ECM.

4.3.3 Automotive industry perspective

One way to assess the data needed by the auto industry is to review the data currently being collected by several automotive companies. During the NHTSA sponsored EDR Working Group, a list of automotive company data collection was developed. This data is presented in Table 3. There may be data collected by other automotive companies, which are not represented here.

Table 3—Summary of EDR systems, circa 1999, from NHTSA EDR WG Report

Category	GM	Ford	DCX	Honda	Toyota	Volkswagen
Application	Started MY99 w/ phases in	Internal fleet only for crash research	TBD	TBD	Started MY 01 w/ phases in	TBD
Air bag type deployed (dual-stage)	Y	Y	Y	Y	Y	Y
Ignition cycle counter	Y	Y	Y	Y	Y	Y
Seat belt	Y (driver only)	Y	Y	Y	Y	Y
Occupant sensing	No	Y	Y	Y	Y	Y
Air bag warning lamp	Y	Y	Y	Y	Y	Y
Engine r/min	Y (5 s pre-impact)	TBD	TBD	No	Some cars	Yes
Throttle position	Y (5 s pre-impact)	TBD	TBD	No	Some cars	Yes
Brake applied	Y (5 s pre-impact)	TBD	TBD	No	Some cars	Yes
Vehicle speed	Y (5 s pre-impact)	TBD	TBD	No	Some cars	Owners choice by dealer programming
Crash pulse information	Δv at 10 ms intervals	Actual deceleration pulse at 1 ms intervals	No	Partial Δv	Δv at 10 ms intervals	Deceleration, rate, and duration

Specialists with the proper training and equipment may now download and analyze the data on their own. Previously, the CDRs had to be downloaded by the CDR manufacturer. There have been several generations of MVEDR systems, each recording a unique set of data variables. Table 4 and Table 5 present a list of variables typically collected by these two manufacturers. Note that these lists may not include all data collected and outputted, nor do systems installed by these manufacturers record and store all these variables in every unit. These data represent a typical set of data elements.

Table 4—Data collected and downloadable by Ford Systems

Acceleration, x-axis
Acceleration, y-axis
Left (driver) side air bag
Right (pass) side air bag
Pass suppression switch
Air bag warning lamp
Time, wakeup to pretensioner
Time, wakeup to 1st stage, unbelted
Time, wakeup to 1st stage, belted
Time, wakeup to 2nd stage
Restraint, driver
Restraint, passenger
Driver seat forward
Pass seat weight sensor
Time, wakeup to pretensioner, driver
Time, wakeup to pretensioner, passenger
Time, wakeup to 1st stage, driver
Time, wakeup to 1st stage, passenger
Time, wakeup to 2nd stage, driver
Time, wakeup to 2nd stage, passenger

Table 5—Data collected and downloadable by GM systems

Speed
Brake
r/min
Throttle pos
Δv , long
Warning lamp
Driver belt
Ignition cycles
Ignition cycles, investigation
Max Δv , long
Time, enable to 1st stage, driver
Time, enable to 2nd stage, passenger
Time, enable to 1st stage, driver
Time, enable to 2nd stage, passenger
Time between near deploy and deploy events
Frontal deployment level event counter
Event recording complete
Multiple events associated with this record
Multiple events not recorded

4.3.4 Emergency response community

Although the WG devoted significant time and attention towards understanding the technical issues of standardizing a rapid download method specific to the needs of the real-time emergency medical services (EMS) community, many issues associated with the technical specifications remain unsettled despite the best efforts of the WG. This standard provides a comprehensive EMS use-case scenario, a recommended table of suggested EMS data elements (including ACN), technical specifications for a telltale, and an informative Annex D specific to EMS.

Emergency medical response users are the medical personnel who respond to the scene of a motor vehicle crash, assess crash victims for injuries, estimate the severity of the crash, begin treating the victims, and make decisions about how to transport victims to the “right hospital, in the right way, and in the right time frame.” The decision process they use is based on local, state, or national trauma triage guidelines. National and state trauma triage guidelines already use *guess-estimates* of mechanism of injury, such as crash severity, to guide EMS personnel. Crash severity data helps ensure that crash victims are transported and treated appropriately—there is evidence this reduces crash-related deaths.

The direct “customers” being served by the MVEDR data is: the EMS personnel, the hospitals and the victims of the crash. In many cases, the owner of the vehicle will be one of the victims of the crash. The victims of the crash benefit from better triage decisions that result in better outcomes. The hospitals treating the patients benefit by receiving better information about the severity of crashes so that it is less likely that “hidden” injuries will be overlooked. It is anticipated that insurers also will benefit by improvements in matching crash victims to the right type of transport and right level of hospital.

4.3.4.1 EMS’s role and objectives as related to automotive crashes

Presently, EMS personnel must guess-estimate the severity of crash from a visual assessment or “word of mouth” descriptions at the scene of a crash in order to triage patients. MVEDR data that more objectively describes the severity of the crash will help improve the triage decision process. Some serious injuries from car crashes are obvious and outwardly visible, and some are initially “hidden” (such as internal head or abdominal organ injuries). Using guess-estimates, EMS personnel are more likely to improperly estimate the severity of a crash than if they had more objective data. If the severity of a crash is underestimated, serious (e.g., internal or hidden) injuries may be overlooked at the scene of a crash, with life-threatening consequences.

Underestimates of the crash severity can lead to the “under-deployment” of the EMS system. For example, a ground ambulance may be called to transport a seriously injured patient to a community hospital instead of an air medical helicopter that would transport the patient to a Level I trauma center. If an injured person is taken to a hospital that does not have the staff or resources or operating room to treat their injuries, their risk of having complications or dying can increase. EMS may find it useful to have a flag indicating whether brake application had taken place before or after impact. Did the crash occur because the driver was unconscious (or unresponsive) or is the driver unconscious because of the crash? This can alert EMS to look for underlying medical problems as well as trauma problems during triage.

EMS response is time critical. There is a short time frame, the so-called *golden hour* in trauma care, to make triage decisions. A mistake in triage decisions can result in delays in key treatments and poorer outcomes, such as higher death rates. A delay in recognizing life-threatening injuries may result in the victim being transported to a hospital that does not have the resources or specialized staff to treat the injuries. How might MVEDRs address the current challenges and problems facing the EMS community? A priority download of key and objective MVEDR data that is obtained in a quick and easy manner at the scene of a crash will replace the current guess-estimates of crash severity by EMS personnel. This information will, in the short term, help answer the following questions at the scene of a crash:

- 1 How severely injured is each occupant of the vehicle? Risk of injury based on: severity of crash, vital signs, anatomic injuries.
- 2) Is a vehicle occupant with or without outward signs of injury still at high risk of a life-threatening internal injury, based on the severity of the crash, restraint use, etc.?
- 3) Given the risk of serious injury, what is the right way to transport the injured person to the hospital? Ground ambulance? Basic life support or advanced life support? Air medical helicopter?
- 4) What level of hospital does the injured person need? Community hospital; mid-level trauma center—Level II or III trauma center; highest level trauma center—Level I trauma center?

The EDR design community would provide the technical method for accessing key standardized data in a quick and easy manner at the scene of a crash. The EMS community would derive significant benefits from being able to rapidly access key items of data, in standardized formats, at the scene of a crash. This data would be output in a “raw” manner in standardized physical units. However, the clinical algorithms for the use of the data would reside outside the vehicle. The algorithms would translate the physical units into information that is understood by the medical community. The medical community would develop algorithms for proper triage based on the severity of the crash and the clinical assessments at the scene. The data would be incorporated into the EMS patient care report and ultimately the hospital medical record. As more data becomes available, it will be possible to refine the triage algorithms over time.

Table 6—Recommended data needs for EMS

Data element	Accuracy or sample rate	Time period	Justification
Time	Hours & minutes	At trigger	To assess EMS response time
Date	Calendar	At trigger	To assess EMS response time
VIN	17 character	Status prior to trigger	Matching of injured person with correct vehicle
Location (lat/long)	WGS1984 GPS high resolution	Status prior to trigger	Evaluate serious injury crash locations; for use by ACN systems to summon assistance.
3-axis acceleration	High resolution	During crash pulse	To determine impact direction and severity in order to assess probability of injury
Direction of force	High resolution	During crash pulse	To determine impact direction and severity in order to assess probability of injury
Restraint use, each occupied seat position	Yes/No	Status prior to trigger	Factor needed to assess possible severity of injury to each occupant
Air bag deployment(s), each occupied seat position	Yes/No/Disabled	Prior to and during crash pulse	Factor needed to assess possible severity of injury to each occupant
Number of occupants	Occupied seats	Prior to trigger	To determine number of persons in seat positions, allows a check for occupant ejection
Rollover	Flag	Prior to and during crash pulse	Might be determined from direction of force

4.3.4.2 Data accessibility and extraction

A dashboard or frontal area (i.e., rearview mirror location) mounted indicator shall be considered for a “check light” similar to those used by air bag systems, e.g., illuminating when the ignition key is turned to the ignition position. This light would indicate to the driver/owner that the system had passed its internal self-checks and that the MVEDR system is enabled for priority medical download use. It may be turned on and off by the driver if it is recognized that some vehicle owners will not want MVEDR features of any kind, including real-time medical use, activated. The system shall include a GPS circuit and offer continuous monitoring of seat belt usage, thereby providing the ability to record and store, for later retrieval and analysis, locations at which seat belt usage was detected. The visual telltale will provide a very quick and easy method that is needed for EMS personnel to access key data, such as seat belt usage, in a secure manner at the scene of a crash. This method should require minimal training. The access location should not require EMS personnel to use up valuable time hunting for it. The method should not require power from the vehicle. A priority download of the small number of data variables above is suggested for EMS personnel at the scene of a crash. For the data to be used to help treat victims of serious or fatal level crashes, the survivability of the MVEDR should be set at a level to cover a very high percent of these crashes. This requires survivability thresholds that exceed FMVSS 208 and 214.¹⁰ See Annex D for additional information.

¹⁰Information on references can be found in Clause 2.

4.3.5 Roadside/infrastructure design community

4.3.5.1 Description

This group includes researchers and engineers who focus on how the design of the roadway and roadside impacts the frequency and severity of automobile accidents. The effort to improve safety can be general and system-wide or specific to a particular site and/or design element. For instance, a system-wide effort would address the roadway and roadside rollover problem, while a more specific venture may focus on the effectiveness of a particular type of guardrail end treatment. Evolution of vehicle design and operating characteristics, changes in vehicular safety technology, and the development of additional roadside hardware prompt continual research by the roadside and infrastructure design community.

4.3.5.2 Role and objectives

The responsibility of this group is the enhancement of automotive safety through the improvement of the design of roadways and roadside safety hardware. Although the approach methodology can vary significantly depending upon the intended goals, most studies in this area include an identification and quantification of the problem, development of relationships, development and testing of possible solutions, solution implementation, and finally, field evaluation.

Currently, most problem identification and quantification is accomplished using national accident databases (e.g., FARS, NASS/GES [B56],¹¹ and NASS/CDS [B55]), several roadside/roadway focused databases (e.g., HSIS [B21], LBSS), and specialized objective studies (e.g., NCHRP Project 17-11 [B60], NCHRP Project 22-14(02) [B62]). The development of relationships between automotive accidents and roadway/roadside characteristics is typically facilitated using the same means as well as computer simulations to a more limited extent. For the development of possible solutions, finite element-based simulations are utilized in conjunction with full-scale crash tests to ensure that the proposed designs will perform as required. Then, in an ideal situation, the practicing design engineers will implement the solutions as they adhere to the suggested design guidelines. As it is impossible to predict or test all permutations of the solutions that may occur in the implementation phase, the field evaluation is used to ensure that the developed solutions are functioning as intended. Typically this is accomplished using roadside/roadway focused databases or specialized objective studies.

Problems in the roadside and infrastructure research area stem from a lack of complete understanding of the problem. Typically, this is a result of the data dichotomy: either there is a significant amount of data with a less than optimal level of detail or there is sufficient detail but not a significant quantity. Another noteworthy data challenge is the time frame for data collection. As current accident data collection is based on information gathered or estimated after the incidence of an automotive collision, researchers tend to lack confidence in the collected information.

4.3.5.3 Pertinence of MVEDR data

The success of roadside and infrastructure-related research is critically dependent upon the validity and consistency of collected crash data. To date, a majority of the data elements are collected or inferred after the occurrence of a vehicular crash and stored in state or nationally maintained databases. Analysis has historically been hindered by errors in the accuracy of the collected data as well as the lack of consistency between the information captured from database to database. MVEDR technology has the potential to augment the collection of these data elements as well as initiate the collection of elements previously not feasible to collect.

Although MVEDR technology will not replace all aspects of accident investigation, it has the potential to shift the accident data collection time frame closer to the interval in which the event occurs. Information

¹¹The numbers in brackets correspond to those of the bibliography in Annex E.

such as the initial vehicle speed, total change in velocity, and seat belt status may be obtained from these devices as it occurs during the event. This will aid researchers in obtaining a more accurate representation of the impact conditions and vehicular characteristics during an event. With a better understanding of the problem and the involved mechanisms, researchers will be better equipped to develop cost-effective solutions.

4.3.5.4 Data elements

An in-depth study regarding MVEDR data elements that could be utilized to support roadside safety research is being conducted under NCHRP Project 17-24 [B61]. By methodically examining existing accident database elements, conducting a literature review and consulting an expert advisory panel, the team assembled and prioritized a catalogue of candidate MVEDR data elements that could improve roadside safety research. The top 15 prioritized elements from this study are presented in Table 7, with an indication of whether the current state of the art supports collection.

Table 7—Roadside/infrastructure community prioritized potential MVEDR data elements

Priority	Variable description	Current technology	Technology does not exist now
1	Vehicle speed	X	
2	Vehicle yaw rate	X	
3	Location of the crash (GPS—includes latitude, longitude, state, county, and city or municipality)	X	
4	Longitudinal component of Δv	X	
5	Lateral component of Δv	X	
6	Vehicle roll rate	X	
7	Brake position		X
8	Crash pulse—lateral	X	
9	Crash pulse—longitudinal	X	
10	Acceleration—lateral (pre-crash)	X	
11	Acceleration—longitudinal (pre-crash)	X	
12	VIN	X	
13	Steering wheel angle		X
14	Manual belt status	X	
15	Compass heading	X	

4.3.6 Insurance Industry

4.3.6.1 Description

Insurance companies provide financial protection for their policyholders when an event occurs that damages property or injures people covered under the insurance policy. Policies may include payment of costs related to repairing the vehicle(s) in the subject accident, paying for injuries to the insured (personal injury

protection or PIP), to a third party (bodily injury or BI), or to cover costs related to an under insured (UM) or uninsured claim for the insured (UIM) against a third party. Some states have contributory negligence or comparative liability laws which can affect the ultimate financial settlement of the claim (e.g., the “amount” a party contributed to the accident’s occurrence affects their ability to recover for damages).

Insurance companies provide services to the businesses (commercial lines) and individuals (property and casualty or P&C). In general, the insurance companies want to understand what their legitimate financial exposure will be for the collision, and they want to quickly and efficiently resolve the claim for the parties involved. They want to provide good service to their insured at a reasonable cost and are contractually obligated to return the insured’s vehicle to its pre-accident condition.

The insurance companies may want to know some or all of the following related to an auto collision to manage and/or investigate the claim(s):

- 1) What is the condition of the vehicle occupant(s) and what is the condition of the vehicle(s), to determine what services to provide (e.g., tow truck, rental car, medical services, etc.) for the insured and others immediately or shortly after the accident?
- 2) How did the accident happen and which party (or parties) contributed to the accident’s occurrence?
- 3) Who was injured and what is the extent and prognosis of their injuries? Was the claimed injury likely to have been caused by the accident?
- 4) What is the level of damage to the vehicle(s) and can the vehicle(s) be repaired?
- 5) What other contributory factors were present, such as restraint usage, vehicle speeds prior to impact, driver visibility, distractions, etc.?

Insurance companies have claims professionals who handle claims. They will typically investigate, evaluate and negotiate the claim to its resolution. Often times, one person will review and resolve the property damage claims, and another person will evaluate and resolve any injury claims. As part of the claims resolution process, they may retain the services of other industry stakeholders, such as attorneys, engineering experts, etc., to help them review and resolve the claim. They historically have not had access to MVEDR data and are beginning to use the data as part of their claim investigation process.

4.3.6.2 Insurance company’s role

Insurance companies have historically relied on the training and experience of their claims professionals to evaluate the claims presented to them. The claims professionals frequently review repair estimates, photos, and a description of the impact (from police reports, statements of the parties involved, etc.) to evaluate property damage, liability, and/or injury issues. MVEDR data is relatively new to the insurance industry and has not been used on a wide scale to evaluate collision severity, accident causation, and/or injury causation. Technologies have become available which make the use of the MVEDR data more viable for the insurance industry, and companies are learning how to use the information to better investigate auto collisions.

The industry has used various technologies to help in the claims evaluation process, and the Insurance Institute for Highway Safety has done testing to understand vehicle performance in terms of property damage and factors contributing to injuries for select models each year. The use of outside expertise (e.g., accident reconstructionists, biomechanics, etc.) to help understand and evaluate claims is frequently made on financial considerations on a claim-by-claim basis. Such expertise is generally expensive, particularly in relationship to the cost of settling the claim, so it is not used on a widespread basis.

Some of the challenges facing the insurance industry include the following:

- 1) Evolving auto technology, which makes vehicles more robust in terms of their ability to withstand impact forces with reduced damage from low velocity impacts, “crumple zone” technology to improve occupant injury outcomes at higher velocities, new headrest designs to reduce “whiplash” injury, etc.

- 2) An increasing number of injury claims (33% increase) despite a decrease in the number of property damage claims (17% decrease) in auto insurance
- 3) An increased sophistication by those making injury and/or property damage claims
- 4) Pressure on financial results to manage claim costs and write better policies to manage their risks more effectively

MVEDR data can help the insurance companies to understand vehicle and occupant performance on a broader scale than is currently available today. On individual claims, MVEDR data can provide more information in understanding what happened to cause the accident and/or injury or if the injury was caused by a collision. Ultimately, MVEDR data can provide information to better understand and define collision events and allow the companies to have a better understanding of their risk in insuring a vehicle and/or driver.

4.3.6.3 Examples

The advent of availability of MVEDR data to the insurance companies allows them to address several issues by the use of the data. At the time of the crash, the insurance companies are one of the first to be notified of the accident. This early notification gives them the opportunity to better serve their insureds and provide cost-effective services quickly. For example, with a telematic MVEDR solution, the insurance companies could decide appropriate services to provide immediately post collision. From these data, the insurance company could understand the damage to the vehicle to determine if the vehicle needs to be towed, and possibly, the extent of repairs. From an occupant perspective, they could determine the possibility of injury and the need for medical services. A non-injured occupant with a damaged vehicle may need a rental car until their vehicle is repaired or declared a total loss.

The next questions that may need to be resolved in the evaluation of the claim are: Which party contributed to the occurrence of the accident? Could the accident have been avoided?

The insurance companies can use MVEDR data to understand how the accident happened. This is particularly important when there are issues of contributory negligence or comparative liability. They can combine the MVEDR data with the damage profile for the vehicle to determine the point and angle of impact, the pre-impact speeds of both vehicles, etc., to understand how the accident happened. Today, they rely on statements, vehicle damage, police reports, etc., which are often subjective and may be inaccurate, to make a determination of how the accident happened. MVEDR data allows a more accurate and consistent evaluation of accident causation by using the vehicle(s) to provide information about what happened.

They can also gain insight into the contributing factors to the accident. Understanding the braking and vehicle speed prior to the impact can determine how much time and/or distance the vehicle had to stop to avoid the collision. Was the turn signal on for the turn? Could the driver see or be seen with the vehicle's lights off/on? Were they steering to avoid the collision? All of these currently depend on scene and/or witness information that may be unreliable and/or biased.

The next question might be: Did the accident cause the injuries that are being claimed as a result of the impact? As with the accident causation, knowing information about the impact severity to one vehicle can lead to an understanding of the impact severity to the other vehicle when the MVEDR data is combined with the damage information. Direction of impact, restraint usage, and air bag deployment can provide insight into occupant(s) movement and stresses on their bodies, possible vehicle interior interactions, and the resulting injury potential.

4.3.6.4 Data elements

The data elements that would be helpful for insurance users are listed in Table 8. Most of the information is collected "forensically" and does not have to be "real-time" with the exception of possible crash notification

as discussed previously. Recording at least two events would be helpful. Standardized and fast collection of data is a positive although not an absolute requirement.

Table 8—Insurance industry prioritization of potential data elements

Data element	Units	Sample rate	Sample range	Data range	Rationale
Longitudinal change in velocity	km/h (mi/h)	10 Hz	300 s	0 to 97 km/h (0 to 60 mi/h)	Determine impact severity and estimate injury potential
Lateral change in velocity	km/h (mi/h)	10 Hz	300 s	0 to 97 km/h (0 to 60 mi/h)	Determine impact severity, principle direction of force, and estimate injury potential
Vehicle pre-crash speed	km/h (mi/h)	200 Hz	5 s	0 to 240 km/h (0 to 150 mi/h)	Determine accident causation
Braking activity	On/off	200 Hz	5 s	On/off	Determine accident causation
Driver restraint usage	On/off	At time of impact		On/off	Determine injury causation
Passenger restrain usage	On/off	At time of impact		On/off	Determine injury causation
Date	mm-dd-yy	At time of impact	—	—	Identify event and reduce opportunity of fraud
Time	hh-mm-ss	At time of impact	—	—	Identify event and reduce opportunity of fraud
VIN	17 characters	—	—	—	Identify vehicle and reduce opportunity of fraud
Front drivers air bag deployment	On/off	At time of impact	—	On/off	Determine injury causation
Front passengers air bag deployment	On/off	At time of impact	—	On/off	Determine injury causation
Side drivers air bag deployment	On/off	At time of impact	—	On/off	Determine injury causation
Side passengers air bag deployment	On/off	At time of impact	—	On/off	Determine injury causation
Steering input	—	200 Hz	5 s	—	Determine accident causation
Percent throttle	Percent	200 Hz	5 s	0% to 100%	Determine accident causation
Turn signal	On/off	200 Hz	5 s	On/off	Determine accident causation
Windshield wipers	On/off	At time of impact	—	On/off	Determine accident causation
Lights	On/off	At time of impact	—	On/off	Determine accident causation

Table 8—Insurance industry prioritization of potential data elements (continued)

Data element	Units	Sample rate	Sample range	Data range	Rationale
EDR warning lamp	On/off	At time of impact	—	On/off	Understand pre-crash vehicle status
Passenger air bag suppression	On/off	At time of impact	—	On/off	Understand pre-crash vehicle status
Number of occupants	Count	At time of impact	—	1 to 99	Determine occupants in vehicle during crash

4.4 Summary of recommended data elements from use-case scenarios

Table 9—Summary of data elements selected by case reports

Data element	Freq (Hz)	Current OEM	Defect investigation	EMS	NHTSA ESV	NTSB R & E	NTSB Rec	Insurance	Roadside
Acceleration, angular	1					X			
Acceleration, pre-crash, x-axis	1								X
Acceleration, pre-crash, y-axis	1								X
Acceleration, x-axis	5	X		X	X	X	X		
Acceleration, y-axis	5	X		X	X	X	X		
Acceleration, z-axis	3			X		X	X		
Air bag suppression, passenger air bag	4	X			X		X	X	
Air bag, deployment level, driver	2	X			X				
Air bag, deployment level, pass	2	X			X				
Air bag, driver deployment	4	X		X	X			X	
Air bag, driver's side air bag deployment	3	X		X				X	
Air bag, passenger deployment	4	X		X	X			X	
Air bag, passenger's side air bag deployment	3	X		X				X	
Air bag, time from enable to first/single-stage deploy, driver	3	X			X		X		
Air bag, time from enable to first/single-stage deploy, pass	3	X			X		X		
Air bag, time from enable to pretensioner fire, driver	2	X			X				

Table 9—Summary of data elements selected by case reports (continued)

Data element	Freq (Hz)	Current OEM	Defect investigation	EMS	NHTSA ESV	NTSB R & E	NTSB Rec	Insurance	Road-side
Air bag, time from enable to pretensioner fire, pass	2	X			X				
Air bag, time from enable to second-stage deploy, driver	3	X			X		X		
Air bag, time from enable to second-stage deploy, pass	3	X			X		X		
Battery voltage	1						X		
Braking activity, ABS	4		X		X	X	X		
Braking activity, service	1	X	X		X	X	X	X	X
Braking, fault codes	1					X			
Braking, line pressure	1					X			
Braking, pulses	1					X			
Braking, retarder	2					X	X		
Braking, stability control	1					X			
Braking, temperature	1					X			
Braking, timing	1					X			
Braking, traction control	1						X		
Braking, truck parking	1						X		
Braking, truck trailer	1						X		
Change in velocity, x-axis	4	X				X		X	X
Change in velocity, y-axis	3					X		X	X
Change in velocity, z-axis	1					X			
Clutch	1		X						
Cruise control	1						X		
Date	3			X			X	X	
Direction of force	1			X					
Engine data, manifold pressure	1		X						
Engine data, as a function of speed in r/min	4	X	X		X		X		
Engine data, temperature	1		X						
Engine data, throttle (percent open)	5	X			X	X	X	X	
Hazard	1						X		
Heading, direction of vehicle	3					X	X		X
Ignition cycle, crash	2	X			X				
Ignition cycle, investigation	2	X			X				

Table 9—Summary of data elements selected by case reports (continued)

Data element	Freq (Hz)	Current OEM	Defect investigation	EMS	NHTSA ESV	NTSB R & E	NTSB Rec	Insurance	Roadside
Load, truck	1						X		
Location of impact on vehicle	2					X			X
Location, lat/long	2			X		X			
MVEDR ID	2	X					X		
Number of occupants	2			X				X	
PRNDL	3		X			X	X		
PRNDL codes	1					X			
Restraint usage, driver	6	X		X	X		X	X	X
Restraint usage, other positions	1			X					
Restraint usage, pass	5	X		X	X			X	X
Roll rate	1								X
Rollover	1			X					
School bus warning lamps	1						X		
Seat position, driver	2	X			X				
Seat position, pass	2	X			X				
Seat, passenger, occupant classification	2	X			X				
Speed, vehicle pre-crash speed	6	X	X		X		X	X	X
Steering input	4					X	X	X	X
Steering input, rear axle	1					X			
Time between two events, if recorded	2	X			X				
Time of day	3			X			X	X	
Tire pressure	1					X			
Tire failure, time	1					X			
Turn signal	3		X				X	X	
Vehicle lighting	2						X	X	
Vehicle maneuver	1					X			
Video	1						X		
VIN	4			X			X	X	X
Warning lamp, air bag	2				X		X		
Warning lamp, MVEDR	1							X	
Wheel speeds (each wheel end)	1						X		
Windshield wipers	2						X	X	
Yaw rate	1								X

4.5 Additional use-case group perspectives

Additional use-case perspectives are deferred to the maintenance activity of this standard. IEEE P1616a permits follow-up standards activities to address motorcycles, school bus manufacturers, transit agencies, fleet owners, transit manufacturers of heavy commercial and public safety vehicles, and EMS first responders.

4.6 MVEDR operational requirements

4.6.1 Electronic equipment operating environment

As appropriate, either SAE J1211-1978 [B73] or SAE J1455-1994 shall be used to address the following environmental factors in the design of the MVEDR:

- 1) Electrical operational requirements
- 2) Temperature
- 3) Humidity
- 4) Salt spray atmosphere
- 5) Immersion and splash (water, chemicals, and oils)
- 6) Dust, sand, and gravel bombardment
- 7) Altitude
- 8) Mechanical vibration
- 9) Mechanical shock
- 10) Factors affecting the automotive or heavy-duty truck electrical environment
- 11) Steady-state electrical characteristics
- 12) Transient, noise, and electrostatic characteristics
- 13) Fungus (SAE J1455-1994)
- 14) Steam cleaning and pressure washing (SAE J1455-1994)
- 15) Electromagnetic compatibility/electromagnetic interference (SAE J1455-1994)

4.6.2 Battery/reserve power

The MVEDR shall have enough reserve power to complete all data acquisition after a trigger event has been detected and an indicator to provide notification if there is a battery disconnect.

4.7 Crashworthiness

The MVEDR memory shall be capable of meeting the crashworthiness requirements outlined in Table 10. Judicious placement of the MVEDR within the vehicle may also help to minimize the likelihood of damage as a result of a crash. Survivability requirements should be considered when selecting and installing connectors to the nonvolatile memory and other MVEDR components. Although protection of the MVEDR as a whole is important, the priority for crashworthiness is protection of the nonvolatile memory. The manufacturer should document, and make available to whomever requests it, the reliability, confidence level, and minimum lifetime information for a particular MVEDR. The MVEDR processor should continually operate when subjected to the vehicle environment where it is located. During a crash, at a minimum, the processor should operate long enough to attempt capturing the buffered memory within the nonvolatile memory. After an event, the processor should operate for at least the minimum duration specified by the data elements being recorded. The manufacturer shall specify what crashworthiness requirements were used for the following conditions: *impact shock*, *penetration*, *static crush*, *fire*, and *fluid immersion*. The requirements may be met by the design of the storage device within the vehicle body

envelope (e.g., to take advantage of the crashworthiness and fire-barriers properties of the vehicle body), or by a combination of these approaches. The MVEDRs of light vehicles are part of the air bag module that is located in the occupant compartment of vehicles, providing protection against crush in all but the most severe cases. Moreover, because MVEDRs are part of the air bag module, their electronics are designed to operate in a shock environment; however they lack protection from fire and immersion in water and motor vehicle fluids. MVEDRs shall meet the requirements for applicable data elements and format in crash tests specified in FMVSS 208, 214, and 301. To provide both a check on MVEDR performance and ensure a basic level of survivability, data shall be required to be retrievable by the method specified by the vehicle manufacturer after the crash test.

Table 10—Crashworthiness requirements

Condition	Requirement
Impact shock	Equal to or greater than that provided by an impulse of 50 ms duration, with a peak force of 1.5 N, and shaped like the first half of a sine curvature pulse, applied to the most damage-vulnerable axis in the most damage-vulnerable direction. ^a
Penetration	45 kg mass (100 lb) with a protruding 6 mm (0.25 in) diameter steel pin dropped from a height of 1.5 m (5 ft) onto the most damage-vulnerable face of the recorder at the most critical point. ^b
Static crush	2.3 kN (500 lbf) for 5 min, applied to at least four points on the crash protected module, irrespective of its shape and including, where applicable, each of the main diagonals and each of the main faces.
Fire	1000 °C for 10 min, followed by 260 °C for 30 min.
Fluid immersion	Immersion in any of the following individually for 6 hours: gasoline, diesel fuel, lubricating oil, regular water.

^aWhere necessary, tests shall be performed on a separate test specimen to determine the axis and direction that are most damage-vulnerable.

^bWhere necessary, tests shall be performed on a separate test specimen to determine the point that is the most damage-vulnerable.

5. Event description

This standard defines the meaning of an *event* as it pertains to motor vehicle crashes. Generally, there is agreement that the overall type of event is a crash, but MVEDRs may also collect data for different types of events, such as high brake force applications and large magnitude accelerations. An *event* may also be defined as a roadway departure.

Crash-related events have been the typical triggering functions used by light vehicle original equipment manufacturers (OEMs). Many OEMs use the air bag sensor to make a determination to initiate the MVEDR function. Some systems are incorporated into the sensing and diagnostic module (SDM), also known as the air bag sensor. In a typical scenario, the processor starts to collect data after the accelerometer reads a $2 g_n$ deceleration. The initiation of data collection is often referred to as *algorithm enable*. After the event is over, the data is stored into a permanent memory storage area. For events where the air bag does not deploy, the data is stored in the “near-deploy” file. These data can be overwritten by the next event if it has a total Δv which exceeds that of the event in storage. If it is less, the file is not stored. For events that result in air bag deployment, the data is stored in the “deployment” memory storage area. Thus several OEM vehicles will typically have a file stored in the “near-deploy” file and a second file stored in the “deploy” file, in the case when the crash resulted in an air bag deployment. Other OEMs store the data in the restraint control module (RCM) which uses a similar threshold for algorithm enable. The RCM stores one file, which is updated

when the Δv exceeds the Δv of the stored file. An air bag deployment will always be recorded, no matter what the Δv .

Aftermarket systems may use various trigger levels to determine an event. An acceleration threshold can be used to automatically record data. Aftermarket MVEDRs may be triggered automatically, using predetermined acceleration thresholds or using other data channels and appropriate thresholds, or manually. The exact threshold may be user specific, and can be set high to limit the collection to crash-related events or lower to collect both crash-related events and driving-related events, such as hard braking.

There are several characteristics of a collision that can be used to detect its occurrence. These include deceleration of the vehicle and chassis deformation.

Figure 1 illustrates the deceleration forces experienced during a crash test in which the vehicle struck a solid barrier at a speed of 50 km/h (30 mi/h). The deceleration peaks at $40 g_n$ and has a magnitude greater than $20 g_n$ for more than 50 ms. Since normal accelerations and decelerations of an automobile due to braking and poor road conditions rarely exceed $\pm g_n$ for more than a few milliseconds, it is expected that vehicle deceleration can be used to distinguish between a serious collision and normal driving. Furthermore, the magnitude of the crash test data implies that deceleration measurements do not have to be highly accurate; an accuracy of 5% to 10% would suffice. Other constraints associated with a deceleration measuring device include a $\pm 50 g_n$ operating range and an over-range protection ceiling that exceeds $100 g_n$. Frequency response should be adequate to completely characterize the deceleration over the entire collision, typically 100 ms to 200 ms in duration. This calls for a frequency response of 200 Hz or greater. An important advantage of measuring deceleration is that it can be directly linked to a standard measure of crash severity called equivalent barrier velocity (EBV). EBV is estimated by integrating the deceleration profile over a time period corresponding to the duration of a crash (e.g., 100 ms to 200 ms). It is possible to relate EBV to expected occupant injuries.

Chassis deformation occurs in almost every vehicle collision, and therefore could be used to detect the occurrence of a crash. However, it is also necessary to estimate the severity of that crash so that the processor can distinguish between a “fender bender” and a serious collision. This could be accomplished by measuring the amount of chassis deformation and correlating the deformation with expected occupant injury. It is also technically feasible to detect a crash by listening for a characteristic audible signature generated by chassis deformation and processing the required audio signal.

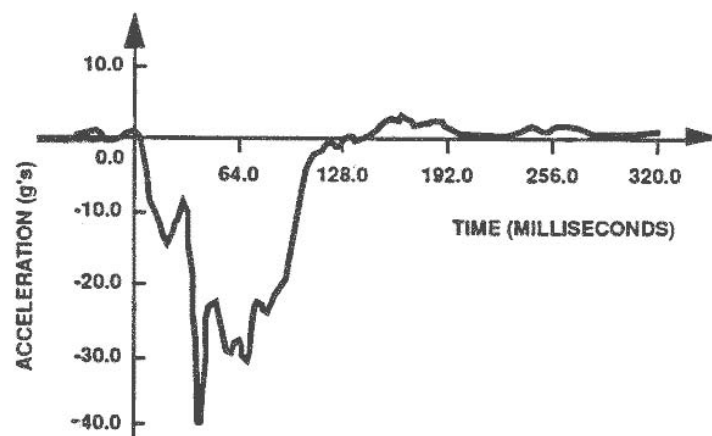


Figure 1—Acceleration data from crash test

5.1 Vehicle crash modes

This standard covers all international types and classes of motor vehicles involved in, but not limited to, any of the following types of crashes: *pole, underride, run-off road, swideswipe, frontal, offset angle, rollover, multiple, animal impact, human impact, side impact, and rear impact.*

5.2 Methods for determining an event

This standard covers methods of determining an event: automatic and driver controlled. Thresholds are set to predetermined levels, which are dependent on two major considerations: the data parameter that is being monitored (brake application, deceleration, etc.), and the class of events that are being recorded (crash, driver actions, etc.).

5.3 Crash mode and crash severity algorithms

This standard covers all crash modes and all crash severities cited in Table 11 by requiring that an MVEDR incorporate an algorithm that is capable of continuously determining the crash severity of collision events in real-time. The enabling of the algorithm and calculations performed in the processing module shall result in common data element parameters.

5.4 Crash timing and crash triggers

This device shall record crash timing from -8 s to $+5\text{ s}$ of a motor vehicle crash. This requirement would ensure that MVEDRs capture information about crashes of interest to crash investigators and researchers. The MVEDR operates in two modes. One is steady-state monitoring of pre-crash data. MVEDRs operate continually in this mode whenever the vehicle is operating. This process allows momentary recording of the pre-crash data. MVEDRs operate in the second mode when the vehicle is involved in a crash. In this mode, two decisions are made. The first is the determination of the occurrence of a crash and is accomplished by the use of a trigger threshold. The second is the decision to capture the recorded data and accomplished using a comparative process. Based on the outcome of the process, the recorded data associated with a crash are captured or deleted. In current light-duty vehicle applications, the trigger threshold is associated with the air bag crash severity analyzer. The circumstances that caused the threshold to be met are called an *event*. The beginning of the event that causes current MVEDRs to start capturing data in its permanent memory is sometimes defined as the vehicle's exceeding a specified deceleration threshold, typically around $2\text{ }g_n$. After the event is over and the air bags are deployed, the data is stored in the MVEDR, if appropriate. This standard requires that an MVEDR shall start recording data when the vehicle's change in velocity during any 20 ms time interval equals or exceeds 0.8 km/h. That is equivalent to slightly more than $1\text{ }g_n$ of steady-state deceleration. The vehicle's change in velocity is determined in one of two ways, depending on the data collected by the MVEDR. In the case of a vehicle that does not record and capture lateral acceleration, the Δv is based on the longitudinal acceleration only. In the more complex case of a vehicle whose MVEDR records and captures both longitudinal and lateral acceleration, the Δv is calculated based on both sets of data, or simply stated, change in velocity of the vehicle in the horizontal plane. Crash triggers may be determined by the manufacturer in order to capture the data element parameters in Clause 8. A trigger is one or more events that causes the MVEDR to start recording. Triggered data may be collected from a single source sensor or through a network. Network triggered-data may use protocol based on CAN (controller area network) data link layer as specified in ISO 11898-1:2003. Triggered data may use standardized CAN physical layers as specified in ISO 11898-2:2003 or ISO 11898-3:2000 [B40].

5.4.1 Single-stage event

A single-stage event is an event that is caused by a single trigger or the logical result of two or more triggers. Each event shall be described by an alphanumeric string used to identify the event. This event name must be a valid name and not contain any spaces. An event description is an optional description of the event.

5.4.2 Dual-stage event

A dual-stage event is an event that is a sequence of two single-stage events within a period of time. Either or both of the component events may capture data. The two single-stage events are logically entered over time.

5.4.3 Stage event sequence

A Stage 1 event is single-stage event that occurred first. A Stage 2 event is the event that occurred second. A crash may encompass several events. For example, a vehicle may swerveswipe a guardrail and then hit a car, or a vehicle may hit one vehicle, then another, and finally a tree. In fact, analysis of crash data from NHTSA's NASS/CDS database guide [B55] shows that while 54% of the crashes involve a single event, 28% involve 2 events, and 18% involve 3 or more events. Thus, if an MVEDR captures only a single event as the depiction of a multi-event crash, in nearly one-half of the cases, it could be difficult to determine the event of the crash with which the MVEDR was associated. Thus, MVEDRs shall be capable of capturing up to 3 events in a multi-event crash. For any given event that generates a change in velocity that equals or exceeds the trigger threshold, the MVEDR would be required to record and capture that event and any subsequent events, up to a total of three, that begin within a 5 s window from time zero of the first event. Subsequent events are events that meet the trigger threshold more than 500 ms after time zero of the immediately preceding event. To prevent unassociated events from being captured in the multi-event MVEDR, the maximum time from the beginning of the first event to the beginning of the third event shall be limited to 5 s. Furthermore, to understand the timing between the associated events, the number of associated events shall be included as a data element, and at the time from the first to the second event and the time from the first to the third event, also be included as a data element.

6. Output

This clause defines common interfaces that may be utilized to extract MVEDR data. These interfaces consist of hardware, communication protocol, data format, and security. The common interface will utilize standardized commercially available technologies. The purpose for one common standard interface is to allow multiple vendors or OEMs the ability to extract the desired information in the same manner with the least amount of complexity. Current MVEDR designs were developed independently by each automaker or aftermarket manufacturer to meet their own vehicle-specific needs. Consequently, the design of MVEDRs varies quite widely between automakers and units designed by the same automaker. This lack of standardization impedes common usage of MVEDR data.

6.1 Minimum outputs

An MVEDR shall have the following minimum outputs:

- a) Event recorder health status:
 - 1) A "go" or status "OK" green illuminated visual indication confirms that the recorder has passed a self-test. Faults detected during operation extinguish the green indicator and illuminate a red light. If the MVEDR is not readily accessible or viewable within the vehicle, the "go" or "OK" indication shall be displayed inside the vehicle in a location clearly visible to the operator of the driver's seating position (i.e., dash area, front windshield area, or rearview mirror area). The readiness indicator at the time of event is blue in color so as not to confuse it with colors

internationally designated for identification of controls, telltales, and indicators in accordance with ISO 2575:2004. A blue light indicates event data was captured (i.e., seat belt usage) at trigger.

- b) Data download:
 - 1) EIA 232D, USB, or Firewire portable test unit/laptop PC or desktop diagnostic tester
 - 2) Removable memory flashcard, RFID
 - 3) Remote extraction by wireless communication

6.2 Concept of operations (connectors) for common output

The output method and connections are directly related to the type of output provided. Output could be

- 1) A physical connection that could sustain major damage but is still “probe-able” after the event once the MVEDR is extracted from the vehicle.
- 2) A physical connection that could sustain major damage but is still capable of being “plugged to” by some diagnostic device while still connected to the vehicle.
- 3) A wireless device that could transmit data at the scene to first responders.
- 4) A wireless device that could transmit the data automatically at the time of the event.
- 5) An “IR port,” and/or a wireless device connected to the tamper-proof electronic storage.
- 6) A combination of communication and connection technology to permit the stored data to be accessed, including removal and taking to a shop for “reconstruction.”

6.3 Primary connections

The primary connections shall be

- 1) Between the MVEDR and the vehicle.
- 2) Between the MVEDR and data upload devices/components/systems.

6.4 Primary components—Concept of operations

The core components of an MVEDR vary according to the needs of manufacturers and end users. The basic operations of an MVEDR are a set of discrete tasks including collecting data with appropriate details and attributes, saving the data, and permitting later retrieval of this data. This subclause describes how an MVEDR is derived from relevant technology and the likely tangible components that make up an MVEDR either as a stand-alone device or a distributed system, or a hybrid thereof. While there are many technical ways to make an MVEDR, this standard does not determine specific technology; however, it is important to cite likely primary components, as follows:

- *Processor*, for managing or assisting data organization, retrieval, retention, or delivery of collected data
- *Nonvolatile memory*, for retaining key data that occurred immediately prior and after an event. This holds critical data relevant to an event, in a media that does not require a power source, to retain its contents
- *Memory buffer*, for collecting data just prior to an event, which can be refreshed, and to dump its content into a nonvolatile memory shortly after an “event” or “crash”
- *Internal or external clock*, for keeping relative or real-time when an event occurs and to determine when each data element occurred relative to the event
- *Rugged design*, for greater assurance that critical data will survive; at least one survivability container, or additional rugged design aspects, can be added to the nonvolatile memory, processor, or memory buffer.

6.5 Secondary components—Concept of operations

Secondary components of an MVEDR include wireless connections for data transfer, automatic alerting devices for emergency first responders, additional memory components to collect multiple events, and software or circuitry permitting collection of data sets beyond the scope of this standard, IEEE Std 1616-2004.

6.6 Ability to access nonvolatile memory

The main concern for addressing connectors is the interest in retrieving data after a severe event or crash and allowing for enough capability in the connector to collect the data. For example, if the connector or the overall MVEDR is damaged so much that normal downloading of data cannot occur, then the memory should be accessible to some extent and in turn read by special equipment or reconstructed at a lab.

6.7 Type of connectors

Connector(s) internal to the MVEDR for the nonvolatile memory shall be anything the manufacturer deems appropriate as being sufficient to comply with the other clauses within the standard. However, by using a connector with an existing standard, such as USB v 2.0, IEEE Std 1394-1995 [B35], EIA 232D-1987, and so on, the manufacturer shall meet its minimum standard.

6.8 Use of proprietary connectors

In the event the manufacturer uses a proprietary connector, the manufacturer must also make an MVEDR reader for it or universal adapter for it that would allow other MVEDR readers to connect, or it must provide a license or agreement for its manufacture by other companies. Also, if a manufacturer uses a propriety connector, there must be a well-documented way to access the nonvolatile memory in the event the connector or MVEDR is damaged, and this information shall be made available to anyone doing crisis/crash resolution on an MVEDR.

6.9 Data retrieval information

6.9.1 Information filing requirements

- a) Each manufacturer of a motor vehicle equipped with an MVEDR shall furnish non-proprietary technical specifications at a level of detail sufficient to permit companies that manufacture diagnostic tools to develop and build a device capable of the following:
 - 1) Accessing
 - 2) Retrieving
 - 3) Interpreting
 - 4) Convertingthe data stored in the MVEDR that are required by this part.
- b) The technical information provided under item a1) must identify the following:
 - 1) Make
 - 2) Model
 - 3) Model yearof each vehicle equipped with an MVEDR.
- c) Further, the technical information provided under item a1) must

- 1) Specify the interface locations
- 2) Permit the access, retrieval, interpretation, and conversion of the data in an identifiable manner,
- 3) Be consistent with the requirements of this part for each vehicle of every identified make, model, and model year.

If the information differs for different vehicles of same make, model, and model year, the information provided must explain how the VINs for the vehicles of that make, model, and model year can be used to determine which aspects of the information apply to a particular vehicle.

6.10 Distinguishing the recorded memory within the container

An MVEDR shall visually distinguish the recorded memory and provide a clear indication as to which side of the container has the connector by the following:

- 1) A distinguishing visual identification color or combination of colors different from other devices in the vehicle to assist those who are searching for the device
- 2) A diagram included within the documentation specifying the location of the installation and the exterior color of the device should be available in the vehicle
- 3) Clearly marking the port containing the nonvolatile memory

6.11 Location of an MVEDR within a vehicle

This standard does not prescribe the location of an MVEDR within a vehicle. Manufacturers of the vehicle and aftermarket installers will choose alternate locations. However, it is important that the location of the device and the operating health of the device are clearly and quickly determined by first alert responders. The operating health status of an MVEDR shall conform to 6.1 and 6.12.

6.12 MVEDR telltale

Many vehicle collisions result from drivers' distraction. One identifiable source of such distraction is the diversion of drivers' attention from the driving task by confusing information displayed in the drivers' field of vision and enigmatic identification of the controls necessary for a vehicle's operation. Travellers that use rental cars at their destinations are faced with drivers message systems on the vehicle dashboards and dissimilar identification of vehicle hand controls. The same applies to people purchasing new vehicles in countries allowing motor vehicles type-approved by, or certified in, different jurisdictions. The world travellers and new vehicle owners need time to learn their dashboard messages and to identify their vehicle controls. During this time, these vehicle operators have to divide their attention between the increasingly difficult task of driving and the task of identification of controls and comprehension of messages that the modern vehicles provide to their operators to "ease" their driving task. An MVEDR telltale located in a windshield mirror-borne display housing with a planar surface denotes the MVEDR is activated and operational, the location used for emergency medical download, and the occupant restraint status of front seat occupants at crash time in vehicles under 10 000 lb (4500 kg) gross vehicle weight rating (GVWR). This standard specifies requirements for the location, identification, color, and illumination of a an MVEDR telltale:

Location: Inside the vehicle, in a zone above and forward of the seating reference point (SGRP) H-point of the driver seat, when that seat is in its forward most position.

Tasks: Indicate MVEDR health status, faults, and data captured at trigger.

Colors: Green and red for health status, blue for data capture at trigger, in conformance with global harmonization of telltales (ISO 2575-2004).

Illumination: Multiple levels of illumination based on changes in the ambient light conditions.

6.13 Information in owner's manual

The owner's manual must contain the following statement: "This vehicle is equipped with a motor vehicle event data recorder. In the event of a crash, this device records data related to vehicle dynamics and safety systems for a short period of time, typically 30 seconds or less. These data can help provide a better understanding of the circumstances in which crashes and injuries occur and lead to the designing of safer vehicles. This device does not collect or store personal information."

7. MVEDR data attributes

7.1 Classification methodology

To understand the factors underlying injuries from motor vehicle crashes, the Haddon Matrix proposes that the elements of the epidemiology triad should be considered in unison with the crash sequence. The crash sequence can be examined in terms of three items: the circumstances surrounding the event prior to the crash occurring; the circumstances involved during the crash; and those involved after the crash. This standard uses a modified Haddon approach, as shown in Table 11. "Time-invariant" is added to the Haddon Matrix to illustrate items that do not have a time dependency. The use of this matrix illustrates how the crash sequence interacts with human, environment, and vehicular factors to define the frequency and severity of injury. In this approach, the environment includes entities outside the human-vehicle pairing that may have influenced either the actions leading to the crash or the outcome of the crash. Examples of environmental factors would be the weather, road curvature, or guardrail systems. Advantages of the Haddon Matrix are that it is relevant to all transportation modes, is well-known and widely applied in the injury field, and it can be expanded to accommodate various taxonomies related to motor vehicle crashes. It can be used to organize risk factors, exposure, circumstances of injury, and preventive measures.

Table 11—Modified Haddon Matrix

	Pre-crash	Crash	Post-crash	Time-invariant
Human				
Vehicle				
Environment				

7.2 Characteristic time durations

The event can be subdivided into three time phases: pre-crash, crash, and post-crash. Each event phase has a characteristic time duration. The characteristic duration of the pre-crash phase is generally measured in seconds to minutes. The duration of the crash is measured in milliseconds to seconds. The characteristic duration of the post-crash phase is measured in seconds to hours.

7.3 Division of data collected

MVEDR crash data shall be collected, stored, and transmitted as one or all of the following: *high-frequency data* shall have 1000 Hz sampling rate (1 ms intervals) or higher; *low-frequency data* shall have 1 Hz sampling rate (1 s intervals) or higher; *static data* is not connected to temporal resolution and shall be recorded once per event.

7.3.1 Amount of data and sampling rate

This standard determines the amount of time and the number of samples per second that data shall be collected prior to, during, and after the event.

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 last about 0.1 s. Collecting crash pulse data is important in determining crash characteristics.

7.4 Classification to determine collection of data elements

The objective of classification is to identify the location where data elements can be collected. The location where data elements could be measured include the occupant, the vehicle, or the environment. The time when a data element could be measured is the earliest time that a data element could be captured.

7.5 Time-based categories

Categorization by time or crash phase allows a lengthy list of data elements to be disaggregated by when the elements could be measured by an MVEDR.

7.5.1 Pre-crash variables

These variables are data elements pertaining to the time before the event (not including time-invariant variables).

7.5.2 Crash variables

These variables are descriptors of the crash event and the surrounding environment at the time of the crash.

7.5.3 Post-crash variables

These are characterization variables pertaining to the time after the incident.

7.5.4 Time-invariant variables

Time-invariant variables are fixed over the characteristic time of the event. Time-invariant variables would include: (a) fixed identifiers that are not time-dependent (e.g., VIN); (b) historical data (i.e., previous traffic violations); and (c) data elements unlikely to change over the course of the entire event sequence, (e.g., driver weight).

7.6 Location-based categories

7.6.1 Human variables

These variables are descriptive identifiers applying specifically to the human(s) involved in the incident. Typically, this includes the crash victim(s), vehicle occupants, and non-occupants, such as pedestrians. This may be a quantitative measure (i.e., driver weight) or be based on a legal system (i.e., license status, regulatory compliance). Human variables would also include the affect of the human(s) to the crash event (i.e., injury severity).

7.6.2 Vehicle variables

This category includes: (a) descriptive identifiers applying specifically to the vehicle(s) involved in the incident (i.e., vehicle body type); and (b) response of the vehicle(s) to the crash event (i.e., air bag deployment).

7.6.3 Environmental variables

These include descriptive identifiers applying specifically to the surroundings of the crash location, such as weather, road curvature, or guardrail systems.

7.7 Data capture

The MVEDR shall collect and store the data elements for events in accordance with the following conditions and circumstances:

- 1) The MVEDR collects data for an event, starting at time zero and not less than 500 ms later.
- 2) The MVEDR shall be capable of recording not less than three events in a multi-event crash.
- 3) The highest Δv of any of the events in a crash sequence is used to quantify the maximum Δv for a multi-event crash.
- 4) If an air bag, either side or frontal, deployment occurs in a single or multi-event crash, the data captured from any previous crash must be deleted, the data related to that deployment must be captured, and the memory must be locked to prevent any future overwriting of these data.
- 5) If an air bag deployment does not occur and if the absolute value of the maximum Δv recorded from a multi-event crash is greater than the absolute value of the maximum Δv currently stored in the MVEDR's memory, all previously captured data in the MVEDR's memory must be deleted and the current data must be captured.
- 6) If an air bag deployment does not occur and if the absolute value of the maximum Δv from a multi-event crash is less than or equal to the absolute value of the maximum Δv currently in the MVEDR's memory, the recorded data must not be captured.

7.7.1 Universal set of attributes format table

The "universal" set of attributes in Table 12 define the data elements for the MVEDR data dictionary catalogue.

Table 12—Format for MVEDR data element definitions

Data element name: Data element name recommended by IEEE P1616 Working Group.		Other names: Other names used for this data element in other documents, by other groups.		Abbreviations/acronyms: Common acronyms for this element.		Index number: Reference number for this standard, IEEE Std 1616-2004.																
Accident investigation uses: Use of data obtained from this data element.				Possible alternative/additional uses: Other uses of this data.																		
Agency recommendations	NHTSA top 10	NHTSA truck & bus	NHTSA general list	NTSB	TRB	FHWA-OMC	NASA JPL															
Modified Haddon Matrix <table border="1"> <tr> <td>Vehicle</td> <td></td> <td></td> <td></td> <td></td> </tr> <tr> <td>Driver</td> <td></td> <td></td> <td></td> <td></td> </tr> <tr> <td>Environment</td> <td></td> <td></td> <td></td> <td></td> </tr> </table>								Vehicle					Driver					Environment				
Vehicle																						
Driver																						
Environment																						
Definition/operation/filter class: Complete description of the data element, including its physical meaning, why it should be recorded, and any filtering requirements that should be used on the analog signal before it is sampled.																						
Range: Upper/lower, "special" values				Unit of measure: Physical data units																		
Resolution: Smallest data unit				Accuracy: Accuracy of data																		
Sampling rate: Rate at which data is recorded				Sampling timing: Data recording timing																		
Data format: Format of data when off-loaded				Discussion/references: General discussion, miscellaneous notes, and references used to define the data element.																		
NOTES 1—Data element name definition section: This section lists the formal name of the data element, other names that were used for the data element by the IEEE P1616 Working Group or other organizations, abbreviations or acronyms used for this data element, and a data element index number that is used to help organize the data element section of this standard, IEEE Std 1616-2004. 2—Uses section: This section defines the practical use of the data element—for both accident investigation and other uses. Other uses may include maintenance, back office, and other applications that are not necessarily related to vehicular/accident researcher purposes. 3—Agency recommendation section: This section documents which agencies have recommended the data element in the past. 4—Modified Haddon Matrix section: This section documents the data element's usefulness by illustrating what aspects of data are included in the modified Haddon Matrix. The difference between the "standard" and "modified" Haddon Matrix is that the modified matrix includes the "time-invariant" column. 5—Data element details section: This section includes all of the attributes required to completely define the data element. Using these attributes, designers can completely define the data acquisition, storage, and downloading tasks.																						