Recording Automotive Crash Event Data

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Introduction

The National Transportation Safety Board has recommended that automobile manufacturers and the National Highway Traffic Safety Administration work cooperatively to gather information on automotive crashes using on-board collision sensing and recording devices. Since 1974, General Motors' (GM) airbag equipped production vehicles have recorded airbag status and crash severity data for impacts that caused a deployment. Many of these systems also recorded data during “near-deployment” events, i.e., impacts that are not severe enough to deploy the airbag(s). GM design engineers have used this information to improve the performance of airbag sensing systems and NHTSA researchers have used it to help understand the field performance of alternative airbag system designs. Beginning with the 1999 model year, the capability to record pre-crash vehicle speed, engine RPM, throttle position, and brake switch on/off status has been added to some GM vehicles. This paper discusses the evolution and contents of the current GM event data recording capability, how other researchers working to develop a safer highway transportation system might acquire and utilize the information, and the status of the NHTSA Motor Vehicle Safety Research Advisory Committee’s Event Data Recorder Working Group effort to develop a uniform approach to recording such data.

Evolution of GM Event Data Recording

GM introduced the first regular production driver/passenger airbag systems as an option in selected 1974 production vehicles. They incorporated electromechanical g-level sensors, a diagnostic circuit that continually monitored the readiness of the airbag control circuits, and an instrument panel Readiness and Warning lamp that illuminated if a malfunction was detected. The data recording feature utilized fuses to indicate when a deployment command was given and stored the approximate time the vehicle had been operated with the warning lamp illuminated. In 1990, a more complex Diagnostic and Energy Reserve Module (DERM) was introduced with the added capability to record closure times for both the arming and discriminating sensors as well as any fault codes present at the time of deployment.

In 1992, GM installed sophisticated crash-data recorders on 70 Indy race cars. While impractical for high volume production, these recorders provided new information on human body tolerance to impact that can help improve both passenger vehicle occupant and race car driver safety. As an example, the data demonstrated that well restrained healthy, male race car drivers survive impacts involving a velocity change of more than 60 mph and producing more than 100 g's of vehicle deceleration. Such information will be helpful to biomechanics experts refining their understanding of human injury potential.

Changes in race car design have also been made using data obtained from the on-board recording capability. Specifically, it was observed that a substantial deceleration pulse occurred when the vehicle’s differential “bottomed out” during rear impact crashes. Knowing this, a simple, light weight impact attenuator was designed that, in combination with improved head padding, is believed to have substantially reduced the number of serious driver injuries during the 1998 racing season.

For the 1994 model year, the multiple electromechanical switches previously used for crash sensing were replaced by the combination of a single solid state analog accelerometer and a computer algorithm integrated in a Sensing & Diagnostic Module (SDM). The SDM also computed and stored the change in longitudinal vehicle velocity (ΔV) during the impact to provide an estimate of crash severity. This feature allowed GM engineers to obtain restraint system performance data when a vehicle was involved in a deployment event or experienced an impact related change in longitudinal velocity but did not command deployment (i.e. a near-deployment event). The SDM also added the capability to record the status of the driver's belt switch (buckled or unbuckled) for deployment and near-deployment events.

Certain 1999 model year GM vehicles have the added capability to record vehicle systems status data for a few seconds prior to an impact. Vehicle speed, engine RPM, throttle position, and brake switch on/off status are recorded for the five seconds preceding a deployment or near-deployment event. Almost all GM vehicles will add that capability over the next few years.

Table 1 contains an abbreviated summary of the data recording capability provided with various GM production airbag systems.

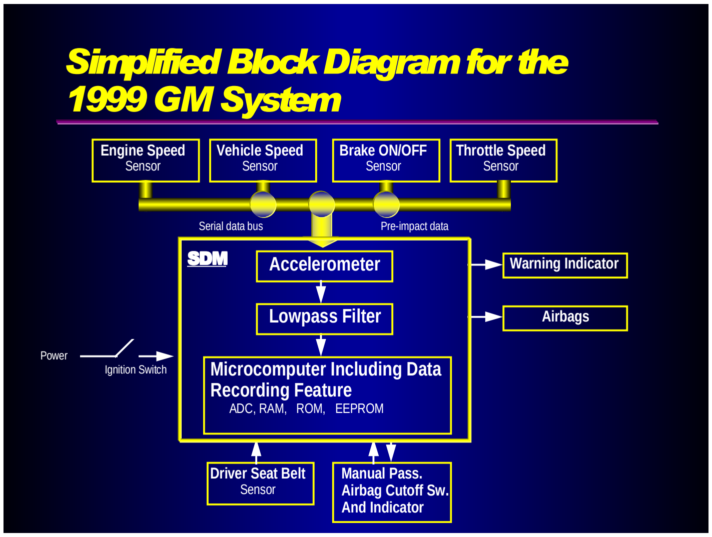
Parameter	**1990 DERM**	**1994 SDM**	**1999 SDM**
State of Warning Indicator when event occurred (ON/OFF)	X	X	X
Length of time the warning lamp was illuminated	X	X	X
Crash-sensing activation times or sensing criteria met	X	X	X
Time from vehicle impact to deployment	X	X	X
Diagnostic Trouble Codes present at the time of the event	X	X	X
Ignition cycle count at event time	X	X	X
Maximum ΔV for near-deployment event		X	X
ΔV vs. time for frontal airbag deployment event		X	X
Time from vehicle impact to time of maximum ΔV		X	X
State of driver's seat belt switch		X	X
Time between near-deploy and deploy event (if within 5 seconds)		X	X
Passenger's airbag enabled or disabled state			X
Engine speed (5 sec before impact)			X
Vehicle speed (5 sec before impact)			X
Brake status (5 sec before impact)			X
Throttle position (5 sec before impact)			X

Table 1: Data Stored by Selected GM Airbag Systems

Technical Description of the Event Data Recording Process

The crash sensing algorithm used in 1999 model year GM vehicles decides whether to deploy the airbags based on calibration values stored in the SDM reflecting that vehicle model's response to a variety of impact conditions. This predictive algorithm must make airbag deployment decisions typically within 15-50 msec (.015-.050 sec) after impact.

The SDM's longitudinal accelerometer is low-pass filtered at approximately 400 Hz. to protect against aliasing, before being input to the microcontroller (see Figure 1). The typical SDM contains 32k bytes of ROM for program code, 512 bytes of RAM, and 512 bytes of EEPROM. Every 312 µsec, the algorithm samples the accelerometer using an A/D converter (ADC) and when two successive samples exceed about 2 gs of deceleration, the algorithm is activated (algorithm enable).



Simplified Block Diagram for the
1999 GM System

Engine Speed Sensor
Vehicle Speed Sensor
Brake ON/OFF Sensor
Throttle Speed Sensor
Serial data bus
Pre-impact data
SDM
Accelerometer
Lowpass Filter
Microcomputer Including Data Recording Feature
ADC, RAM, ROM, EEPROM
Warning Indicator
Airbags
Power
Ignition Switch
Driver Seat Belt Sensor
Manual Pass. Airbag Cutoff Sw. And Indicator

Figure 1: Simplified Block Diagram for the 1999 System

Because of EEPROM space limitations, the SDM does not record the actual deceleration data. However, the frequency content of the crash pulse that is of interest to crash reconstructionists typically does not exceed 60 Hz and the crash pulse can therefore, be well-represented by low frequency velocity change data (ΔV). The SDM computes ΔV by integrating the average of four 312 µsec acceleration samples and stores them at 10 msec increments in RAM. Figure 2 shows the ΔV values for a representative moderately-high severity crash at each 10 msec point with a smooth curve drawn through them.

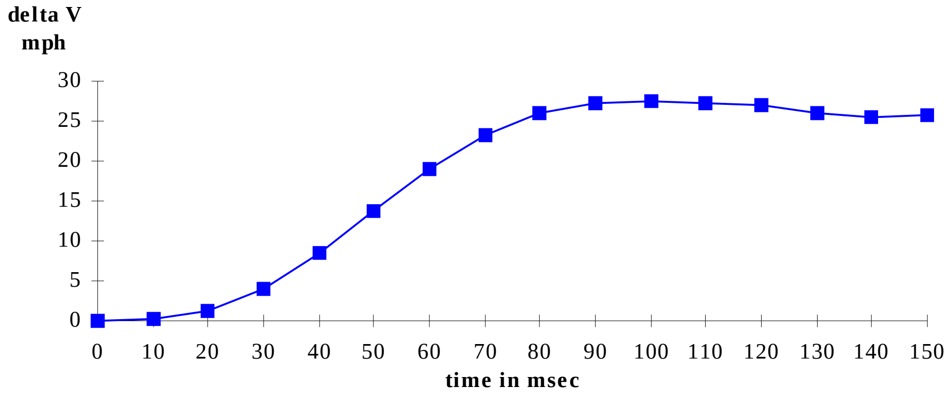


Figure 2: Post-impact ΔV vs. time

Several other sensors provide driver seat belt status, vehicle speed, engine RPM, brake on/off status, and throttle position. The driver seat belt switch signal is typically input into the SDM while the remaining sensors are monitored by one or more other electronic modules that broadcast their data onto the serial data bus. If there is an airbag deployment or a near-deployment crash, the last five seconds of data immediately preceding algorithm enable are stored in EEPROM. All stored data can later be recovered using a laptop PC equipped with appropriate software and interface hardware.

Figure 3 shows how the pre-impact sensor data would appear when downloaded. To understand this requires some knowledge of the serial data bus and the SDM's role. First, the serial data bus operates as a "contention" type of bus. Electronic modules transmit data based on a "send on change" design. For example, when engine speed changes by at least 32 RPM, the engine microcontroller broadcasts the new RPM value on the serial bus.

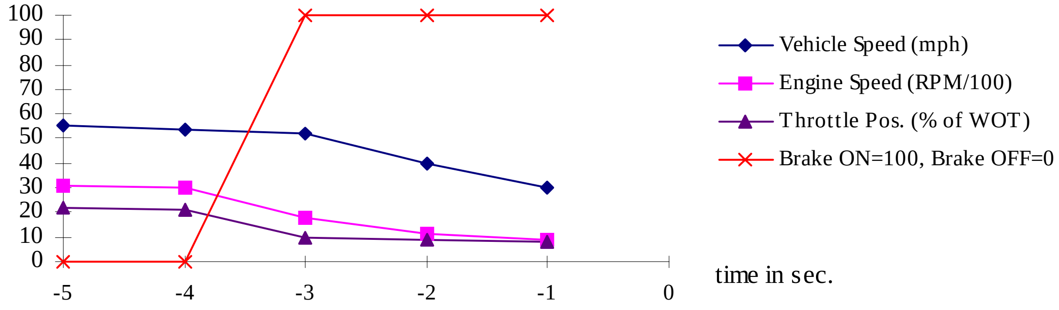


Figure 3: Pre-impact Vehicle Data vs. Time

Once each second, the SDM takes the most recent sensor data values and stores them in a recirculating buffer (RAM), one storage location for each parameter for a total of 5 seconds. When the airbag sensing system algorithm "enables" shortly after impact, buffer refreshing is suspended. Note that algorithm enable is asynchronous with the transmission of vehicle speed and other data. Hence, the data on the bus can be skewed in time from the crash by as much as one second.

The modules that broadcast the sensor data (engine RPM, brake status, etc.) also diagnose the sensors for faults and indicate the data's validity to the SDM. The bus is also constructed so failures of the serial link are detected by the SDM. At the time of deployment, the state of the driver's seat belt switch, the manual cutoff passenger airbag switch (if equipped), warning lamp state, and time to deployment are temporarily stored in RAM. The critical parameter values used to make the deployment decision are also captured in RAM.

When 150 msec have elapsed from algorithm enable, the data stored in RAM are transferred to the EEPROM. It requires about 0.7 sec to permanently record all information. Once a <u>deployment</u> record is written the data are frozen in EEPROM and cannot be erased, altered, or cleared by service or crash investigation personnel.

The recording of near-deployment data includes the pre-impact vehicle speed, engine RPM, etc. The criteria used to determine whether a near-deployment event is stored in EEPROM is based on the maximum ΔV observed during the event. If this maximum ΔV is larger than the previously recorded ΔV, the new near-deployment event is stored along with the corresponding pre-impact data. The near-deployment record is cleared after 250 ignition cycles. This is equivalent to an average of about 60 days of driving. Each time the algorithm is enabled and no deployment is commanded, the SDM compares the maximum ΔV previously stored with the maximum ΔV of this new event to decide whether to update the near-deployment event data.

Data Accuracy, Limitations, and Validation

Event information consists of discrete and variable data. Discrete data includes: brake switch status, manual passenger airbag cutoff switch position, and the driver seat belt switch status. Variable data includes: the analog acceleration information from which ΔV is computed, vehicle speed, engine RPM, and throttle position. Table 2 shows the accuracy and resolution for the variable-type parameters recorded for the 1999 SDM.

Parameter	Full Scale	Resolution	Accuracy	How Measured	When Updated
ΔV	± 55.9 mph	0.4 mph	~ ± 10%	integrated acceleration	recorded every 10 msec, calculated every 1.25 msec.
Vehicle speed	158.4 mph	0.6 mph	± 4 %	Magnetic pickup	vehicle speed changes by ≥ 0.1 mph
Engine Speed	16383 RPM	1/4 RPM	± 1 RPM	Magnetic pickup	RPM changes by ≥ 32 RPM.
Throttle Position	100% Wide open throttle	0.4 %	± 5%	Rotary potentiometer	Throttle position changes by ≥ 5%.

Table 2: Accuracy and Resolution of Data Recorded

There are three main sources of error in estimating ΔV. One error comes from the tolerance of the components in the SDM and the microcontroller. The hardware elements include the accelerometer, the analog-to-digital converter (ADC), low pass filter, and signal conditioning. The accelerometer and ADC contribute the largest portion of the total system error. Accelerometer accuracy is about 8% of full scale which equates to a ΔV error of ± 4.5 mph. ADC error is about 0.25 gs, not including quantization noise. Over a 150 msec recording period, the ADC contributes a maximum error of ± 0.8 mph.

The second ΔV error is due to integer-based arithmetic and representing ΔV using single data bytes. For a 56 mph full scale value, 7 bits (plus a sign bit) equates to a precision of 0.438 mph.

The third error source, which applies only to 1999 model vehicles, results from the crash sensing algorithm continuously applying a 1 g bias acceleration in the opposite direction to that seen in frontal impacts. This bias prevents inadvertent airbag deployments resulting from ΔV accumulation when driving on rough roads and contributes an underestimation error of 3.3 mph at the end of 150 msec. GM is in the process of updating its software to eliminate this error source. In the meantime, the downloading tool will utilize software to compensate for the bias.

In the worst case, the total error in ΔV is 5.7 mph (4.5 + 0.8 + 0.4) for a full scale reading of 56 mph. The RMS error, assuming independent error sources, is approximately 1.53 mph.

Another less predictable error comes from the potential for losing electrical power during the crash. While the SDM maintains the defacto industry standard energy reserve for airbag deployment, the reserve is insufficient to guarantee that all event data will be recorded in every crash. However, if it is not recorded, the SDM indicates this condition in the data record.

General Motors has historically verified proper SDM operation using component tests and laboratory simulations. Shock (thruster) tests have been run to verify crash recorder operation in deployment and near-deployment events. Crash tests have also been run and the event data verified when the vehicle was propelled by a tow system. Additionally, a crash test was conducted with the engine running at partial throttle before impact with a fixed barrier to further verify the pre-impact data recording capability. All data recorded prior to and during this crash were within defined error limits.

GM and the NHTSA have also cooperated in comparing event data and laboratory instrumentation for crashes conducted by NHTSA contractors for regulatory compliance and consumer information purposes. To date, the results have been satisfactory and will not be further discussed in this paper since the work is incomplete. Information from actual field events covering a variety of impact types are expected to confirm proper operation of the recording feature and offer insights about improvements that could aid crash investigators.

Uses of Event Data Recorder Information

Table 3 lists categories of uses for the data that can be obtained from an on-board data recording capability. Some of the major benefits relate to improving vehicle and roadway design so the following comments will focus on those objectives. Note, however, there are less direct but non-negligible benefits that can also be achieved over time.

Category	**Potential Examples**
Improve Vehicle Design/Highway Infrastructure	vehicle systems airbag sensing system deployment criteria highway systems roadside safety feature design standards
Provide a Basis for Regulatory & Consumer Information Initiatives	offset frontal impact severity average/extreme vehicle deceleration pulses
Provide Objective Data for Crash Reconstruction	alleged defects & litigation unintended vehicle acceleration crash & airbag deployment sequence
Develop an Objective Driver Behavior Database	pre-crash driver braking/steering belt use vehicle speed

Table 3: Categories of Uses for Event Data

Several examples of the general categories are now described.

1. Improving Airbag Sensing Systems

With some of the early airbag systems incorporating solid state accelerometers, rare instances of inadvertent deployments were reported for a particular vehicle type. Inspections revealed little or no vehicle damage other than what was judged to be normal wear and tear and the unanticipated deployments were not strongly correlated with seasonal weather patterns, geographic location, vehicle trim level, reported speed, or mileage. There was, however, a weak correlation with driving on gravel roads. Downloading the event data from a sample of the inadvertent deployment vehicles showed no fault codes present and that the SDM algorithm had commanded the airbags to deploy.

A typical vehicle ΔV vs. time history for a deployment event was illustrated in Figure 2. The typical ΔV increases smoothly until it levels off at approximately 70-120 msec and is usually at least 12 mph in magnitude. This confirms the design goal of deploying the airbags only if the change in longitudinal vehicle velocity is expected to exceed that observed in 9-14 mph fixed barrier impacts.

However, the history recorded for the inadvertent deployments was typically a short duration event (20 msec or less) with a total velocity change of less than 7 mph. This variation from the typical deployment event history suggested an unusual sensor deceleration environment. After extensive laboratory test and computer simulation work, the environment was found to be similar to that produced by small rocks or debris striking the underside of the vehicle with high impulsive energy. Ultimately a sensor calibration change was made to desensitize the SDM's response to these relatively rare events.

2. Improving Roadway Design

The Federal Highway Administration (FHWA) and the Transportation Research Board (TRB) through its Cooperative Research Programs with the states, are responsible for establishing most highway design standards. This work includes roadway design per se (e.g., side slopes, ditches, etc.) as well as the safety devices located along the roadside (e.g., guardrails, crash cushions, light poles, breakaway signs, etc.). To develop appropriate design tests and standards these groups need objective data about crashes that occur on the nation's highways. Typically local, state, and national databases are used that may not contain objective data about pre-crash vehicle speed, brake use, crash severity, etc. However, such data would be easily available if crash investigators could routinely download the event data as a normal part of their work.

3. Developing Meaningful Motor Vehicle Regulations

Recorded event data information can also help the NHTSA meet its responsibility for researching and issuing appropriate motor vehicle regulations in many ways. Not only will pre-crash data be useful for the Agency's crash avoidance research work, but the objective data recorded during a crash will be a major improvement for crashworthiness related activities.

We can consider the benefits on-board data recorders can provide using the Haddon matrix which divides the crash into three segments and looks at the human, vehicle, and environmental considerations of each. Table 4 shows the type of data that can be collected from a crash without on-board data recording. These data are primarily limited to post-crash observations.

	Human	**Vehicle**	**Environment**
Pre-Crash		Skid marks	
Crash		Calculated ΔV	
Post-Crash	Injury	Collision damage	Environment after collision

Table 4: Haddon Matrix Without Event Data Recording Capability

Table 5 shows the same matrix, this time populated with data which could be collected from vehicles equipped with enhanced on-board data recording capability. Here, there are numerous data from the pre-crash and crash portions of the event.

	Human	**Vehicle**	**Environment**
Pre-Crash	Belt Use Steering Braking	Speed ABS Other Controls	Conditions during Crash
Crash	Airbag Data Pre Tensioners	Crash Pulse Measured ΔV Yaw Airbag Activation Time	Location
Post-Crash	ACN (Automatic Collision Notification)	ACN	ACN

Table 5: Haddon Matrix With Enhanced Event Data Recording Capability

Technology allowing vehicle safety researchers to collect objective data on crashes would open the door to a new generation of understanding. The opportunities are immense since about 18,000 tow-away crashes occur each day.

Currently the primary metric used to represent crash severity is ΔV. NHTSA can use the output from on-board data recorders to supplement the ΔV crash severity estimate currently derived from post-crash vehicle inspections. NHTSA-sponsored National Automotive Sampling System (NASS), Special Crash Investigations (SCI), and Crash Injury Research and Engineering Network (CIREN) teams attempt to make such estimates for all crashes investigated. About 38 percent of the cases have ΔV information reported - typically for each vehicle when more than one vehicle is involved and for each impact in a multiple impact scenario.

However, the WINSMASH computer algorithm currently used to estimate ΔV, relies primarily on stiffness parameters derived from short duration 35 MPH rigid barrier impact tests. Longer duration real world crashes and less idealized crashes involving yielding fixed and narrow objects, underrides, or multiple impacts are beyond the capabilities of WINSMASH. On-board data recorders can provide crash severity data for most real world crashes (and confirm WINSMASH results for crashes against unyielding flat barriers) by directly measuring ΔV.

Figure 4 shows a field crash in NHTSA crash files involving a 1998 Chevrolet Malibu that struck a heavy, parked truck in a severe bumper underride impact. Such crashes typically generate long crash pulses. WINSMASH estimated a ΔV of 23 mph, while the investigator noted this ΔV estimate appeared to be low. The data from the on-board recorder indicated a ΔV of approximately 50 mph.

Figure 4: Chevrolet Malibu

Table 6 lists nine real world Special Crash Investigation cases involving GM vehicles with on-board recording capability. In four cases (44%), the on-board crash recording capability provided the primary or only source for ΔV information. In the remaining five cases, the ΔV measurements and the WINSMASH estimates differed. These differences may be due to constraints in the WINSMASH program. Thus on-board data recording capability can greatly enhance the quantity and quality of the crash severity data stored in government files.

#	Model Year/Make/Model	Driver Belted		ΔV(MPH)		Comments
		Field	EDR	SMASH	EDR	
1	1998 Chevrolet Malibu	Yes	No	23	50	Final seat belt determination was "not belted." Severe underride.
2	1995 Saturn SL	No	No	13	16	Very minor damage
3	1996 Geo Metro	Yes*	Yes	19	26	*Physical evidence indicated shoulder portion of the belt under the driver's arm
4	1995 Saturn	No	No	NR	11	Driver stated belt used, no physical evidence
5	1996 Oldsmobile 98	Yes	Yes	NR	17	Underride - visual of 14-18 mph
6	1995 Chevrolet Lumina	No	No	12	24	Underride, 24 mph @ 150 msec
7	1995 Geo Metro	Yes	Yes	14	9	The report writer specified the SDM ΔV data as more representative of this crash
8	1995 Geo Metro	No	No	NR	11	Undercarriage impact. Visual estimate of 9-14 mph
9	1998 Pont. Grand Prix	Yes	Yes	NR	2	Inadvertent deployment
NR = No Results						

Table 6: Special Crash Investigations Involving GM Event Data Recorder

Belt use data from on-board recorders will also enhance the NHTSA restraint use information files. The SCI, NASS, and CIREN restraint use data are determined from physical evidence that is not always definitive. On-board recorder data will be used as the primary indication of restraint use in cases where the physical evidence is not present or inconclusive.

On-board recorders will assist government and industry efforts to define appropriate test procedures for motor vehicle regulations and consumer information purposes. In the future, “electronic testing,” (i.e., using a computer to model the crash) is likely to be utilized. Objective crash pulse data will facilitate cooperative work to define the crash types and severities that should be modeled.

NHTSA has expanded its databases to allow event data to be stored. For the 1999 data collection year, variables were added to identify if a vehicle is equipped with an on-board recorder and was downloaded and an open format field was provided for recording the data collected. No universal format for storing such data has been developed because GM is currently the only manufacturer striving to make the data and data recovery tools available to researchers. NHTSA plans to equip its NASS, SCI, and CIREN crash investigation teams with the new GM downloading tools as soon as they are available. Since GM has been equipping most of its vehicles with some type of on-board recording capability for several years, NHTSA plans to routinely collect data from these vehicles.

In 1998, NHTSA requested that its Motor Vehicle Safety Research Advisory Committee (MVSRAC) approve a working group for Event Data Recorders under its Crashworthiness Subcommittee. The Working Group consists of representatives from the motor vehicle industry, academia, and federal and state governments. NHTSA’s MVSRAC Working Group meetings are closed to the public. Their mission is to collect facts and report them to the parent Subcommittee. The Subcommittee and full committee meetings are open to the public. The Working Group invites experts to assist in the fact finding mission and maintains the public file discussed below.

The technical objectives of the Working Group include: 1) defining functional and performance requirements for event data recorders, 2) understanding present technology, 3) developing a set of data definitions, 4) discussing various uses for the data, 5) considering related legal & privacy issues, and 6) standardization of publicly usable data.

Thus far, the Working Group has held two meetings in Washington, D.C. The meetings were attended by about 25 working group members and other NHTSA and FHWA interested parties. During these meetings, manufacturers have presented information on the current status of event recording technology at their respective companies. Government and other interested safety researchers have presented their needs for event data. The Working Group has started an effort to list the most desired data for inclusion in on-board recorders and is currently discussing privacy concerns, data ownership, and other policy and legal issues.

It is anticipated that the Working Group will continue its activities until the objectives are met. The group plans on writing a report which will include the fact finding results of the group, which should be completed by late 2000. The Working Group places its public material in the DOT Docket system. This information will be available by mid-1999 from the Docket Management System. Access can be gained on the Internet at: http://dms.dot.gov/ - click on “Search” about half-way down the page - click on “Docket Search Form” - fill in the docket ID with “5218" - select “NHTSA” for the agency - and “1999" for the calendar year and press search.

Retrieving Event Data from GM Vehicles

Currently GM uses a proprietary Event Data Retrieval Unit (EDRU) which interfaces with a standard Tech 1 scan tool to download data through the vehicle diagnostic connector. Data can be viewed on the Tech 1 or printed from the EDRU’s printer, and all data is displayed in a hexadecimal format. For vehicles that have sustained electrical system damage, interface cables are provided for powering the system and connecting the SDM directly to the EDRU (see Figure 5).

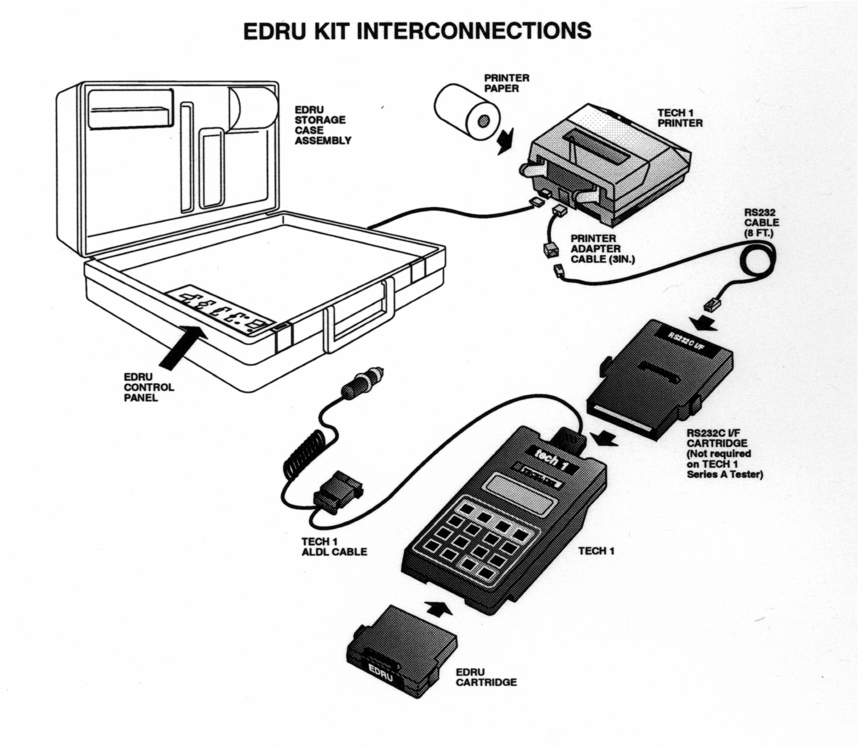


Figure 5: GM Event Data Retrieval Unit

To make EDR data available to all interested researchers, GM has selected Vetronix Corporation of Santa Barbara, California to develop software and interface cables allowing the data to be downloaded to commonly used laptop computers (see Figure 6). Data useful to such researchers (ΔV, belt use, pre-impact data, etc.) will be stored and displayed in a standard format using engineering units while data requiring expert knowledge to interpret will continue to be stored in hexadecimal format. The new tool will also allow the user to input other pertinent information (e.g., investigator's name) and export the data to a remote database. Like the current EDRU, interface cables will be provided for vehicles that cannot be powered up after a crash. These kits are expected to be commercially available during the summer of 1999 with the initial units going to GM and NHTSA crash investigators.

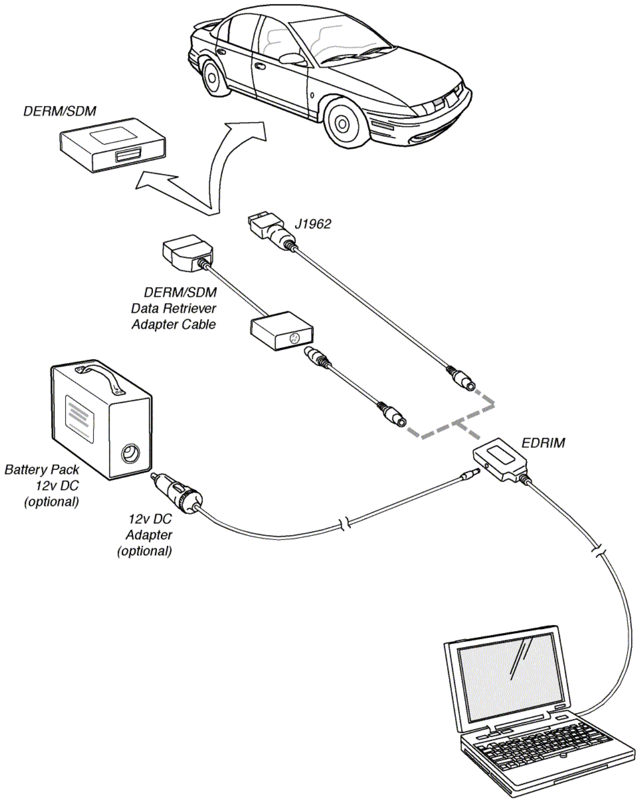


Figure 6: Vetronix Event Data Recovery System

Conclusions

- On-board vehicle recorders have the potential to greatly improve highway safety by providing regulators, vehicle manufacturers, and other researchers with objective data on vehicle crashes and pre-crash scenarios.

- Well-coordinated efforts by all parties sharing highway safety responsibility will be needed to achieve the results envisioned when the NTSB issued it's recommendation for cooperative efforts to utilize crash recording technology.

- The Motor Vehicle Safety Research Advisory Committee's Event Data Recorder Working Group will establish guidelines for future on-board data recording capability including prioritization of the data required to improve highway and traffic safety and recommendations on the need for all manufacturers to install such equipment.

- NHTSA is taking the necessary steps to collect and store data from on-board vehicle recording devices in its Motor Vehicle Research databases.

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Biographies

Augustus "Chip" Chidester is with the Special Crash Investigations program at NHTSA. He is responsible for the case selection, investigation, quality control, and distribution of in-depth crash data which are of special interest to the NHTSA. These in-depth crash investigations address a broad range of motor vehicle engineering and technical issues involving the safety and performance of the various occupant protection systems, potential safety defects, alternative fuel vehicles, and school buses.

Mr. Chidester has been involved in crash investigation since 1977. Prior to joining the NHTSA SCI Program, he was the National Automotive Sampling System's (NASS) Southern Zone Center Manager and an SCI Crash Investigator with the Calspan Corporation.

John Hinch works in NHTSA's Office of Research and Development as a staff engineer. He provides engineering guidance to many programs within R&D. Previously, Mr. Hinch worked in NHTSA's Office of Defect Investigations as a staff assistant and defects engineer. Prior to working for NHTSA, Mr. Hinch worked for a small research firm in the Washington, DC area where he was the Manager of its Highway Research Activities. During that ten-year, Mr. Hinch operated the company's full scale crash test facility and was the lead engineer for a Federal Highway Administration project to design and construct their FOIL, an outdoor impact laboratory capable of conducting crash tests at speeds up to 60 mph. Mr Hinch is a graduate of the College of Engineering at the University of Michigan and served 4 years in the USMC.

Thomas C. Mercer is with the Engineering Center at the General Motors Technical Center in Warren, Michigan. He is responsible for the development of electronics and sensing systems used in GM's airbag systems as well as establishing engineering requirements for the event data recording capability. Mr. Mercer has over 28 years of automotive electronics experience and has worked with airbag systems since 1987. He holds a Bachelors and Masters degree in Electrical Engineering from the University of Michigan.

Keith Schultz has been with General Motors Corporation for the past 14 years. Currently he is a Sr. Staff Engineer working in the North American Engineering Product Investigations Department. His responsibilities include coordinating investigations regarding information requests initiated by NHTSA-Office of Defects Investigation. Prior to joining Product Investigations, Mr. Schultz worked in the GM Safety Center - Product Analysis Department. He was responsible for supplying engineering technical support regarding alleged product defects in product liability litigation. During this period he performed accident reconstruction and evaluated the field performance of vehicle restraint systems. Mr. Schultz earned a Bachelor of Science Degree in Mechanical Engineering from the University of Cincinnati in 1983. He also earned a Master of Science Degree in Mechanical Engineering from the University of Michigan in 1984.