Event Data Recorder Summary and Comparison 11/27/2000								
Category/Data Item	**NHTSA EDR Working Group**	**Use of data. Why record data?**	**GM**	**Ford**	**DCX**	**Honda**	**Toyota**	**Volkswagen**
Application*	TBD-Final Fact Finding Report due in 2001	From NHTSA Working Group List- use data to improve: Crash Reconstruction, Emergency Response, Biomechanics Research, Highway Design, Threshold, Crash Causation	Started MY1999 with phase-in through MY2004. After MY2004 will add more data to record in response to NHTSA	Internal Fleet only-for Crash Research-Have not announced external plans	to be determined	to be determined	Started MY2001 with phase-in	to be determined
Activation of EDR Function	Not defined. Focus is on Frontal crash with some interest in Side crashes.	To be determined	Frontal - "Algorithm Enable" started by "Near Deployment" predetermined Delta-V.	Frontal Algorithm Activated - Events will be recorded when a minimum velocity change is achieved.	After any pyrotechnic deployment from a front, side, or rear impact	Frontal "Algorithm Enable" started by "Near Deployment"	trig: G >= 2.0 Hold: Deployment	Wake up of Airbag ECU Algorithm

Category/Data Item		NHTSA EDR Working Group	Use of data. Why record data?	GM	Ford	DCX	Honda	Toyota	Volkswagen
A	**1. Restraint System Usage (airbags, belts, other) (Internally called Occupant Restraint System Status)**								
A	Airbag Type Deployed (Dual Stage)	yes	Crash Reconstruction, Biomechanics Research	yes	yes	yes	yes	yes	yes
A	Ignition Cycle Counter		Crash Reconstruction	yes	yes	yes	yes	yes, during the warning lamp illumination	yes
A	Seat Belt status for front occupants (with buckle switch inputs)	yes	Crash Reconstruction, Biomechanics Research	yes (driver only)	yes	yes	yes	yes	yes
A	Occupant Sensing Status	yes	Crash Reconstruction, Biomechanics Research	no	yes	yes	yes, if applied	yes. if applied	yes
A	Airbag Disable switch status	yes	Crash Reconstruction	yes	yes	yes	yes, recorded in manual cut-off switch itself	yes, recorded in manual cut-off switch itself	yes
A	Airbag warning lamp status	yes	Crash Reconstruction	yes	yes	yes	yes	yes	yes
A	System Voltage		Crash Reconstruction	no	yes	to be determined	no	no	yes

Category/Data Item		NHTSA EDR Working Group	Use of data. Why record data?	GM	Ford	DCX	Honda	Toyota	Volkswagen
B	**Vehicle System Status**								
B	**2. VIN & EDR ID**	yes	Crash Reconstruction	no	EDR ID not vehicle VIN	yes	no	no	Yes
B	Vehicle Mileage		Crash Reconstruction	no	No	yes	no	no	?
B	Engine Lamp Status		Crash Reconstruction	no	No	to be determined	no	no	?

Category/Data Item		NHTSA EDR Working Group	Use of data. Why record data?	GM	Ford	DCX	Honda	Toyota	Volkswagen
C	**3. Driver Controls (Brakes, accelerator, etc.)**								
C	Cruise Control On/Off/Engaged Status	yes	Crash Reconstruction, Crash Causation	no	to be determined	to be determined	no	no	to be determined
C	Engine RPM	yes	Crash Reconstruction, Crash Causation	yes (5 sec before impact)	to be determined	to be determined	no	some cars	yes
C	**Throttle Position**	yes	Crash Reconstruction, Crash Causation	yes (5 sec prior to impact)	to be determined	to be determined	no	some cars	yes
C	**Brake Applied**	yes	Crash Reconstruction, Crash Causation	yes (5 sec prior to impact)	to be determined	to be determined	no	some cars	yes
C	**ABS Activated**	yes	Crash Reconstruction, Crash Causation	no	to be determined	to be determined	no	No	yes
C	**4. Vehicle Speed**	yes	Crash Reconstruction, Crash Causation	yes (5 sec prior to impact)	to be determined	to be determined	no	some cars	due to high impact on privacy issues recording would be owners choice at new car purchase or by dealer programming
C	Adaptive Cruise Control and other driver assistance systems	yes	Crash Reconstruction, Crash Causation	no	to be determined	to be determined	no	No	to be determined
C	ESP (stability control)	yes	Crash Reconstruction (verify ETC), Crash Causation	no	to be determined	to be determined	no	to be determined	to be determined

Category/Data Item		NHTSA EDR Working Group	Use of data. Why record data?	GM	Ford	DCX	Honda	Toyota	Volkswagen
D	**5. Crash Pulse Information**	delta V, deceleration, angular rates	Crash Reconstruction, Emergency Response, Biomechanics Research, Threshold	Calculated (from decel. Pulse) Delta Velocity at 10ms intervals	Actual deceleration pulse at 1ms intervals	no	Partial delta velocity	every 10ms delta V	deceleration; rate and duration depending on direction of pulse and available storage capacity
E	**6. Location, Time, Date-likely available from Telematics system, if equipped**	yes	Highway Design, Crash Reconstruction	no	no	no	no	no	no
E	**7. Automatic Collision Notification (ACN) Data Record sent to Telematics Provider-Time, Date, Location, Number of Occupants**	yes	Emergency Response	no	no	no	no	no	no
E	**8. Environmental Conditions**	yes	Emergency Response, Highway Design	no	no	no	no	no	no

* Numbered (1-8) and bold items are from the top ten data list. See section 4 for further details on WG findings related to data elements.

3.2.2 GM EDR Technology

The NTSB has recommended that automobile manufacturers and NHTSA work cooperatively to gather information on automotive crashes using on-board collision sensing and recording devices[9]. 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.

3.2.2.1 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 electro mechanical 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[10], 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 racecars. 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 biomechanic experts refining their understanding of human injury potential.

Certain 1999 and newer 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.

The following table contains an abbreviated summary of the data recording capability provided with various GM production airbag systems.

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9 This section is based on: "Recording Automotive Crash Event Data;" Augustus "Chip" Chidester, NHTSA, John Hinch, NHTSA, Thomas C. Mercer, GM, Keith S. Schultz, GM; 1999

10 SDMs were actually introduced in 1987 on a limited number of production vehicles. In 1990, they were used widely.

Data Stored by Selected GM 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 DV for near-deployment event		X	X
DV vs. time for frontal airbag deployment event		X	X
Time from vehicle impact to time of maximum DV		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

3.2.2.2 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. The typical SDM contains 32k bytes of ROM for program code, 512 bytes of RAM, and 512 bytes of EEPROM. Every 312 microseconds, the algorithm samples the accelerometer using an A/D converter (ADC) and when two successive samples exceed about two Gs of deceleration, the algorithm is activated (algorithm enable). (See Figure 3)

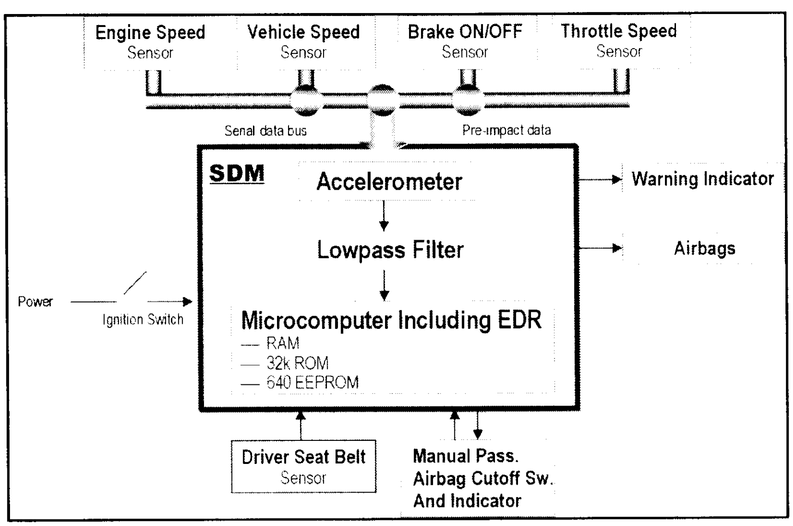


Figure 3. Block Diagram of 1999 SDM.

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 (DV). The SDM computes DV by integrating the average of four 312 microseconds acceleration samples and stores them at 10 msec increments in RAM. (See Figure 4)

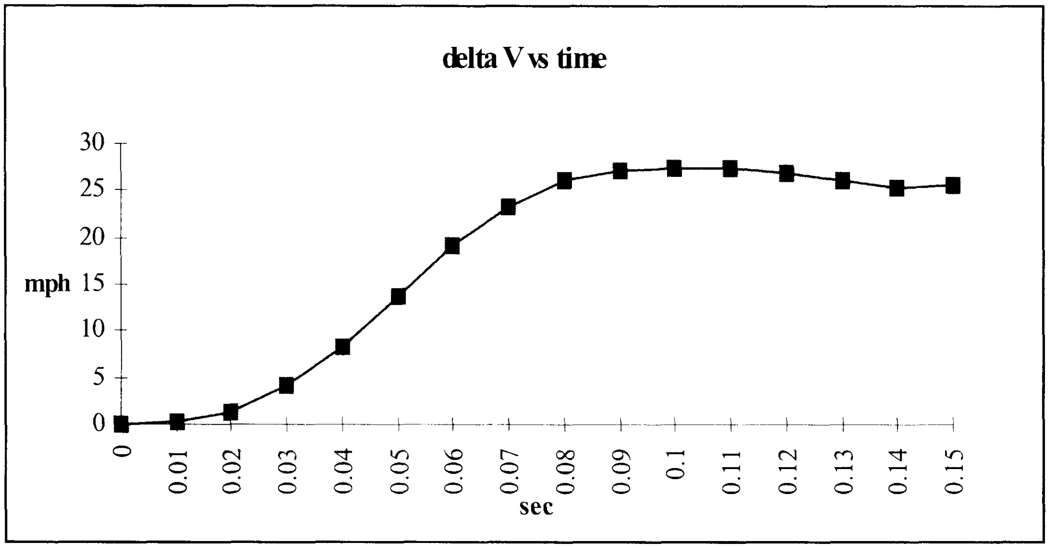


Figure 4. Delta-V Data Collection during Crash.

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. The SDM block diagram 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.

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 five 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. (See Figure 5)

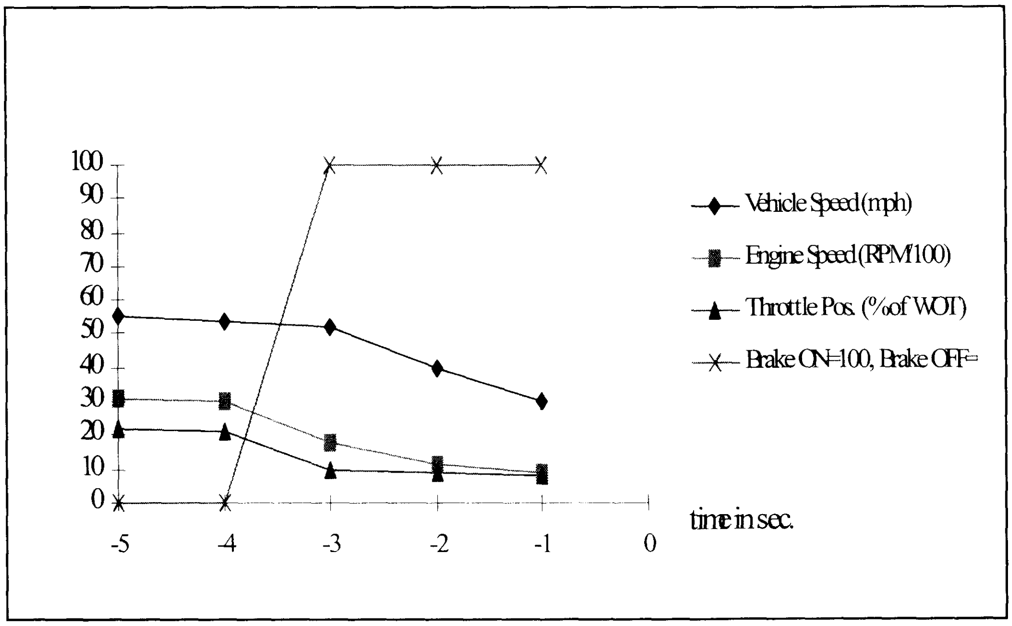


Figure 5. Example of Pre Crash Data Collection.

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 deployment 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 DV observed during the event. If this maximum DV is larger than the previously recorded DV, 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 DV previously stored with the maximum DV of this new event to decide whether to update the near-deployment event data.

3.2.3 Ford Motor Company

As of the time of this working group report, Ford did not have a technical description of their EDR system. Some Ford vehicles, especially those with advanced occupant restraint systems, are equipped with an EDR, which is an integral part of the airbag control system. The system records longitudinal and lateral acceleration, along with some data related to the driver and airbag deployment. Figure 6 depicts the longitudinal acceleration of a typical output chart from a Ford EDR.

Preliminary DRAFT

EDR Report – Summary Page [mock data]

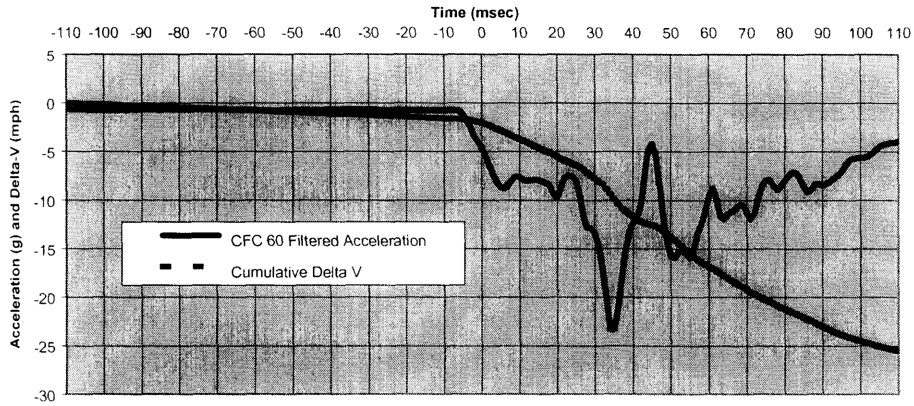
Investigator entered data:

Case No.	#1	Photos	No	Investigator	PG	Model Year	2000
VIN	195778			Invest. Date	4Jun99	Vehicle. Make/ Model	LM Sable 4dr

EDR Control module data:

		Data Validity Check	Valid	Deploy Attempt Made	YES
Read-Out Date	09-Jun-99	Time From Algorithm Wake-Up (0 msec) To Deploy Attempt (msec)			15
EDR Serial N	4107929028	Passenger Airbag Switch Position (On/ Off) During The Event			NA
Model-Version	ECS 2a				
Stored VIN	NA	Pretensioner		Side Air Bags Deployed	NA
Diagnostic Codes Active When Recorded Event Occurred:			None		

Longitudinal Crash Pulse Data



Cumulative Delta-V (mph) **Data Points**

Time (msec)	-100	-90	-80	-70	-60	-50	-40	-30	-20	-10	0	10	20	30	40	50	60	70	80	90	100	110
Delta-V (mph)	-0.2	-0.3	-0.5	-0.6	-0.8	-0.9	-1.1	-1.3	-1.4	-1.6	-2.0	-3.7	-5.5	-7.7	-12	-14	-17	-19	-21	-23	-24	-25

Notes: + Read-Out Date based on PC/ tool's internal calendar.
+ Features and data parameters that are 'Not Available' are noted as 'NA'
+ CFC 60 is Butterworth 4-Pole Phaseless Digital Filter, SAE J211/ Part 1 MAR95, Appendix C.
+ Total and maximum Delta-V results are not available from truncated/ incomplete crash pulses.
+ Algorithm Wake-up (0 msec) is not the first moment of vehicle contact or impact.

Figure 6. Mock up of Ford EDR Output.

3.3 Aftermarket Systems

3.3.1 Safety Intelligence Systems

Safety Intelligence Systems (SIS), formerly Loss Management Services, Inc. (LMS), has developed a state-of-the-art EDR as part of an end-to-end system solution for securely collecting, transmitting, storing, managing and reporting vehicular crash data. This EDR, called the MAC (Mobile Accident Camera) BOX system (See Figure 7), captures on-board diagnostic data and compressed digital video imagery of the events leading up to, during, and immediately following a vehicular crash. This provides an accurate, reliable, and unbiased "driver's eye view" of the entire incident. The MACBOX is a modular, all-digital, self-contained, and non-intrusive data center with flexibility for multiple applications. This technology is currently being refined through an ongoing collaboration with the Georgia Institute of Technology, partially funded by NHTSA.

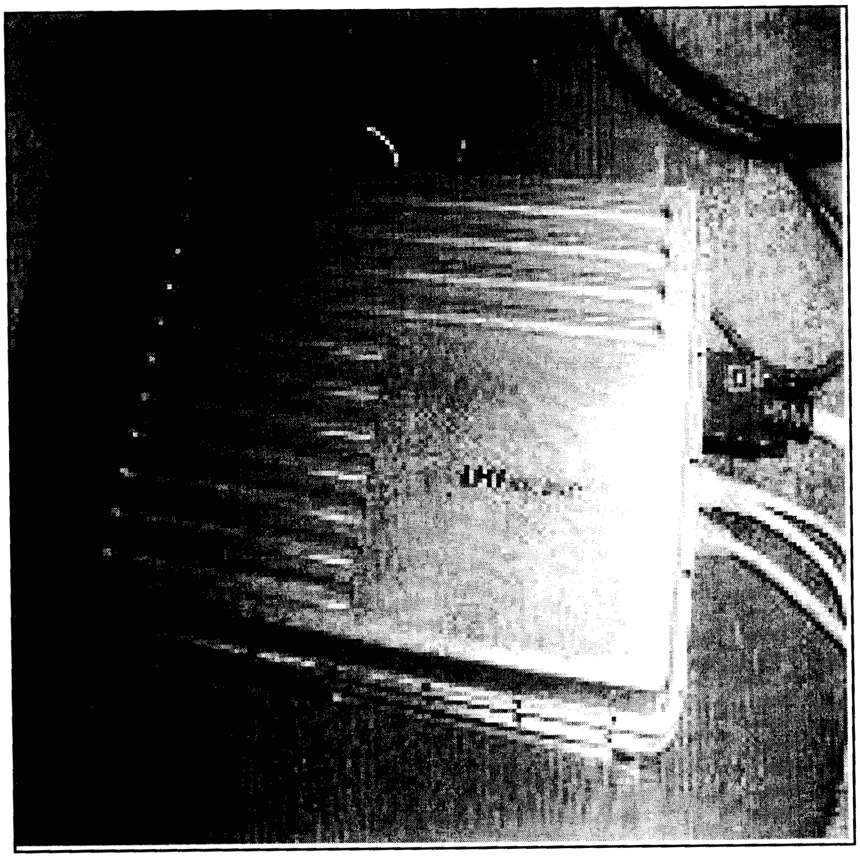


Figure 7. Safety Intelligence Systems EDR Unit.

Once collected, the crash data is encrypted (128-bit) and transmitted over a digital wireless network to a secure data vault. Safety Intelligence Systems has the U.S. and European exclusive patent on the wireless transmission of encrypted vehicular crash data, including video. Safety Intelligence Systems' solution will also include the ability to simultaneously notify the appropriate public safety answering points (PSAPs) and emergency medical services (EMS), as well as provide the necessary critical details of the crash and the likelihood of severe injury. The overall concept is shown in Figure 8.

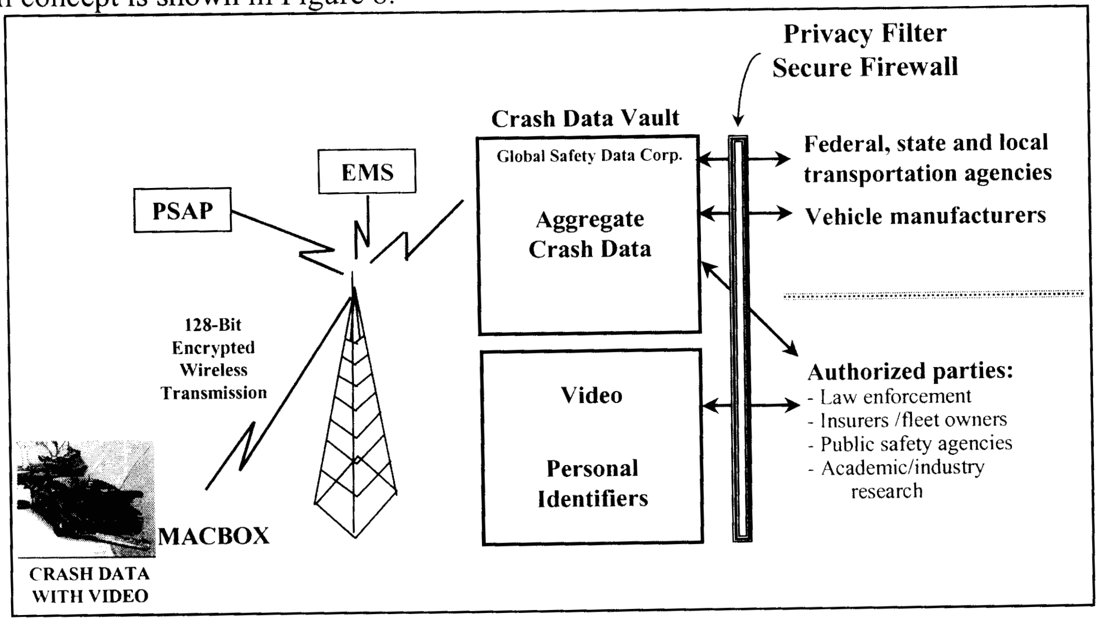


Figure 8. Safety Intelligence Systems Data Transmission, Collection, and Storage Concept.

To ensure all crash data is maintained in a private, secure and central location, Safety Intelligence System has formed a strategic partnership and joint venture with Insurance Services Office, Inc. (ISO), the trusted database of the property & casualty insurance industry and associated government agencies for over 100 years. This alliance created a separate entity, Global Safety Data Corporation, for the sole and exclusive purpose of providing a secure, private data vault to store and manage all vehicular crash data. This data vault will include the necessary privacy filters and security firewalls required to ensure that only authorized users have access to the crash data. The comprehensive Safety Intelligence Systems data vault complements the current data-gathering and analysis activities of existing federal and private databases.

Functional components of the system include the MACBOX with global positioning system (GPS) and digital video, wireless encryption and transmission systems, and a comprehensive, secure data vault to:

- Determine when and where a crash has occurred
- Capture, store, and lock crash data, including video images, after a crash
- Transmit encrypted crash data, including video images, to wireless networks
- Decode and download data to trusted, secure crash data vault

For additional details regarding products and services offered by Safety Intelligence Systems, please contact:

Safety Intelligence Systems, Inc; 790 Atlantic Drive, S-0355
Atlanta, GA 30332-0355
404-385-2551; rmartinez@safetyintelligence.com

3.3.2 VDO North America

The VDO UDS System registers the vehicle's speed, records transverse and longitudinal acceleration, and changes in direction at the rate of 500 times per second. In addition to recognizing the length of operation for ignition, brakes, indicators, and lights, the system can also record special functions such as the use of sirens and flashing lights on emergency vehicles. The UDS system is shown in Figure 9.

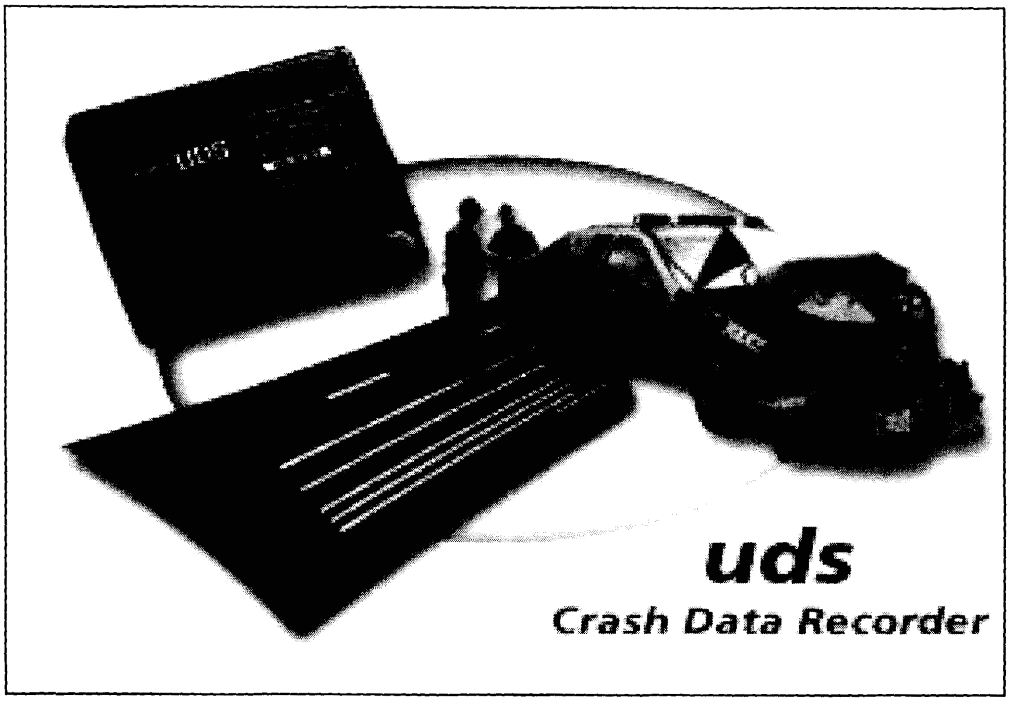


Figure 9. VDO UDS EDR System.

When the UDS is in operation, the data recording is continuous. In the event of a collision, the system automatically and permanently stores 45 seconds of data: 30 seconds before and 15 seconds after the crash. When a collision is recognized, the device emits a signal that can also be used in other applications such as signaling the vehicle's logistics system or incorporating in emergency signal management. See Figure 10 for UDS system layout.

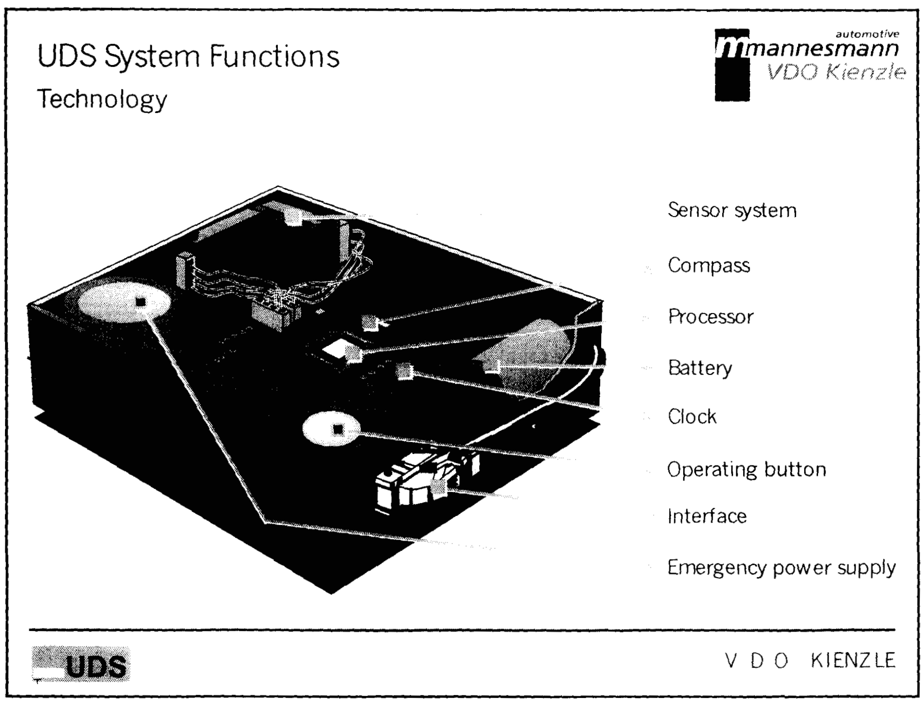


Figure 10. UDS System showing major Components.

Data storage can be manually activated in situations where the driver is not directly involved in a crash but wishes to record actions during or after the incident to counter any unjustified assertions of blame and questions of compensation. Manual storage can be triggered by switching on the hazard warnings or depressing a start button on the unit (24V version only). An external start unit is available if the UDS is not mounted in close proximity to the driver. Up to three separate 45-second events can be recorded.

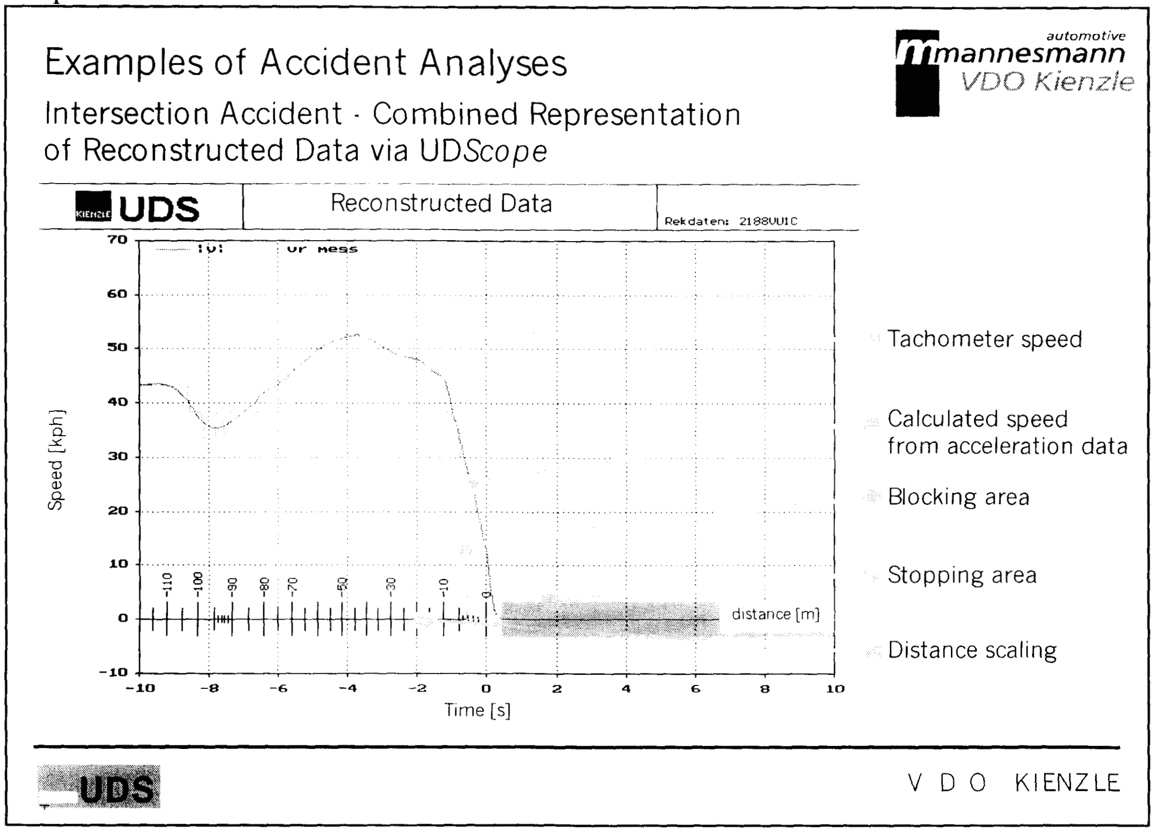


Figure 11. Sample Output from UDS EDR System.

UDS has three distinct operating modes: driving, parking, and sleep. When not in the "driving mode," the system goes into a "parking mode" a few seconds after the ignition has been turned off. It remains fully functional for a 24 hour period, after which, it automatically deactivates and goes into a "sleep mode" to protect the battery. The system becomes fully operational when the driver switches on the ignition. The unit signals the driver with an audible "beep" or dash-mounted lamp.

For additional details regarding this device, contact:
VDO North America; Fleet Systems; 188 Brooke Rd., Winchester, VA 22603(888) 373-4515; http://www.vdona.com/fleet/fleetudsframes.html

3.3.3 Drive Cam

DriveCam is designed to help fleet vehicle operators, researchers, and consumers improve safety and security by increasing the sophistication and effectiveness of identifying, diagnosing, apprehending, and reporting crash and road incidents. (see Figure 12)

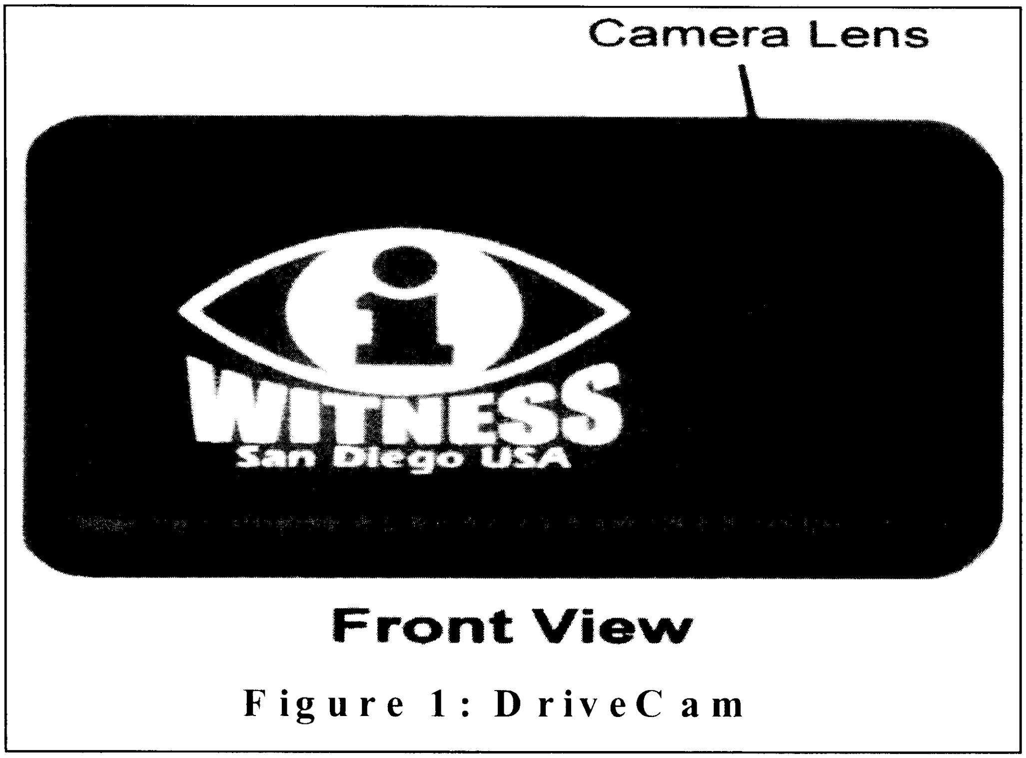


Figure 12. Drive Cam EDR Unit.

DriveCam was designed with the nontechnical person in mind. DriveCam puts the viewers in the driver's seat at the time of the crash or road rage event by recording everything the driver could see, hear, and feel in video, audio, and g-forces. The device is miniature (the size of a pager), inexpensive, very simple to install (less than 10 seconds), simple to operate, view and evaluate the data, tamper proof, and durable.

DriveCam continuously records exactly what the driver sees (in video), hears (in audio), and feels (in G-forces) in real time. When DriveCam is triggered, it records 10 seconds prior to, including, and 10 seconds after a crash. Being digital, the system has no moving parts, is maintenance free, and can be used repeatedly.

DriveCam has a very sensitive video camera that adjusts well in both daylight and at night. In addition, an internal lithium battery continues to provide power during recording if the main vehicle power is cut during the crash.

A green indicator light shows that the system is "armed" and operating correctly. After DriveCam has been triggered, the indicator light will turn red and begin blinking. Once DriveCam has recorded the event the light remains red. Manual triggering can be used to capture road rage, crashes involving other motorists, or car jacking by pressing the "panic button."

Installation is as simple as pressing DriveCam onto the windshield close to the rear view mirror. The plastic suction cups on DriveCam keep it firmly mounted. In fact, the complete unit can be installed or moved from car to car as easily as a radar-detector. For power, it plugs into the cigarette lighter power socket. Alternatively, the unit may also be wired directly into the vehicle's power.

The video, sound, and G-forces relating to the crash can then be replayed on a standard television or camcorder, which then can be recorded on videotape or a computer hard drive. Pressing the play, rewind, or forward buttons on DriveCam operates it like a VCR. An on screen display shows in real time the G-Force measurements experienced with audio and video in real time. (See Figure 13)

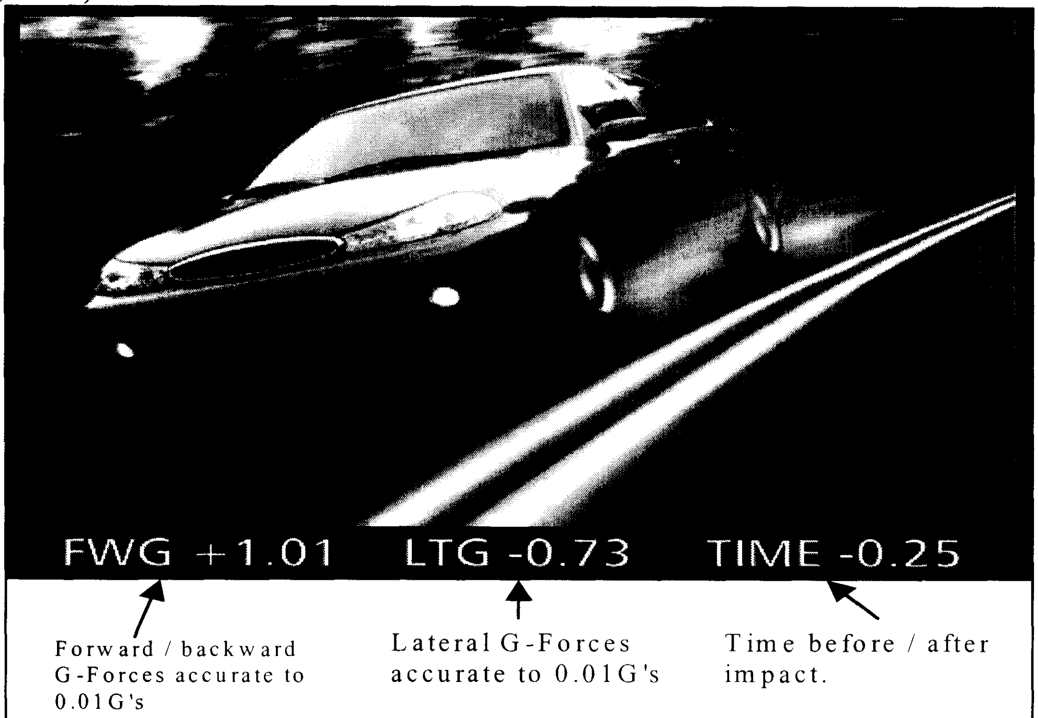


Figure 3: Onscreen Playback View of DriveCam Video EDR

Figure 13. Drive Cam EDR Output.

There are many benefits that EDR data will provide in the short and long term. These include: Researching collision data, providing more objective data for litigation, lower insurance premiums, promote and encourage conscientious driving, data to improve vehicle design internally and externally. DriveCam is currently developing a program that will be able to read EDR information from the several EDR software programs already in use and put them into a common readable format. This will greatly simplify databasing of crashes with a standard file format that will allow researchers around the world to download crash files over the Internet and view them with a familiar program. This software program is called Hindsight 20/20.

For more information:
DriveCam Video Systems; 9550-A Ridgehaven Court; San Diego CA 92123
Phone: 858-430-4000; Fax: 858-430-4001
www.drivecam.com

3.3.4 Independent Witness Incorporated

Independent Witness Incorporated (IWI) is a company dedicated to reducing the growing number of fraudulent and exaggerated insurance claims associated with low-impact collisions. IWI's proprietary technology monitors events that cause property damage to company vehicles, from rental cars to long haul semi-trucks and trailers. IWI's solution consists of two components: The Witness and the Accident Severity and Injury Potential Database (ASIP).

The Witness is a EDR specifically designed for cars, trucks, vans, buses, and trailers. The Witness monitors the vehicles motion and in the event of an impact it records the date, time, direction, impact severity (G-forces) and acceleration profiles. IWI has adopted SAE-J211 guidelines for collecting data. The data are stored in the Witness and can be accessed immediately for verification at the scene of a crash with a laptop computer or removed and downloaded at a desk. Upon extraction of the recorded data, the information is downloaded to IWI for cross-referencing in IWI's ASIP database. Once IWI's website is accessed, a full report can be immediately printed outlining the crash severity and injury potential details. (See Figure 14)

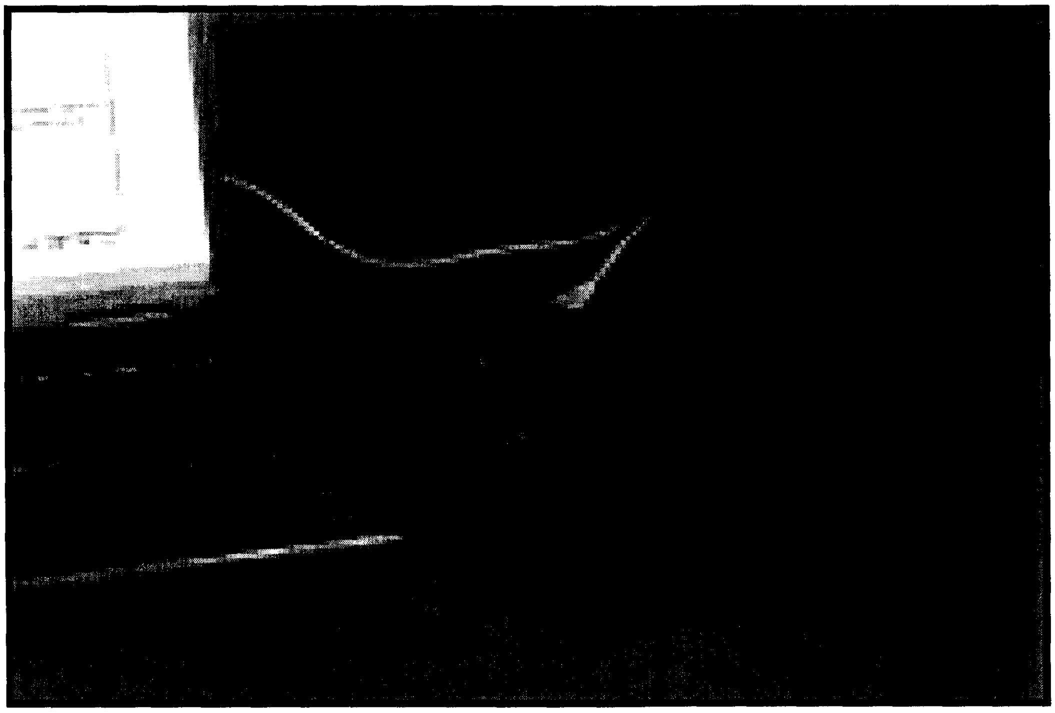


Figure 14. Independent Witness Incorporated 's EDR system

The ASIP database tracks EDR data from crashes recorded by the Witnesses installed in automobiles and trucks across the country. The information captured by The Witness is correlated with the injury claims, medical treatment, recovery time, pre-existing conditions, and other qualifiers (age, sex, occupation, hobbies, income, prior claims, etc.), creating a database capable of "objectively" predicting the probability of injury based on the forces involved in the crash. The database, based on real world data, will be used by claims adjusters, risk managers, and worker's compensation analysts to accurately and fairly assess the subjective injuries that result from a given crash. The ASIP will also correlate crash force with injury potential.

Contact information:
Independent Witness Incorporated; 1515 West 2200 South, Suite E; Salt Lake City, UT 84119(801) 983-0024; www.iwiwitness.com

3.3.5 Rowan University EDR/ACN System

Rowan University has developed and successfully demonstrated the Automated New Jersey Emergency Locator (ANJEL). Developed under the sponsorship of the New Jersey Department of Transportation, the system detects a crash, determines the location of the crash, and communicates the crash pulse and crash site location to an Emergency Response Base Station.

System Architecture. The system is composed of two major subsystems: (1) the Mobile Unit which is installed in the occupant compartment of the vehicle, and (2) the Base Station which is responsible for receiving distress calls from the Mobile Units and reporting their location to emergency response dispatch personnel. The Mobile unit, shown right, contains a two-axis silicon accelerometer, an embedded 8-channel GPS system, an embedded single chip microprocessor with an on-chip 10-bit ADC, and an embedded wireless modem. One axis of the twin silicon accelerometers is aligned to capture frontal-rear crashes while the second axis is aligned to detect side impacts. During operation, the onboard microprocessor continuously monitors the two accelerometers at a sampling frequency of 1 kHz. Upon detecting a collision, the microprocessor polls the GPS subsystem to determine the final resting position of the car. The microprocessor then uses its wireless modem to transmit both crash site location and the crash pulse to the Base Station. Ideally, the entire process, including linkup, will be completed within 30 seconds after the crash occurred – giving EMS personnel a crucial edge in rapidly reaching the crash victim. (See Figure 15)

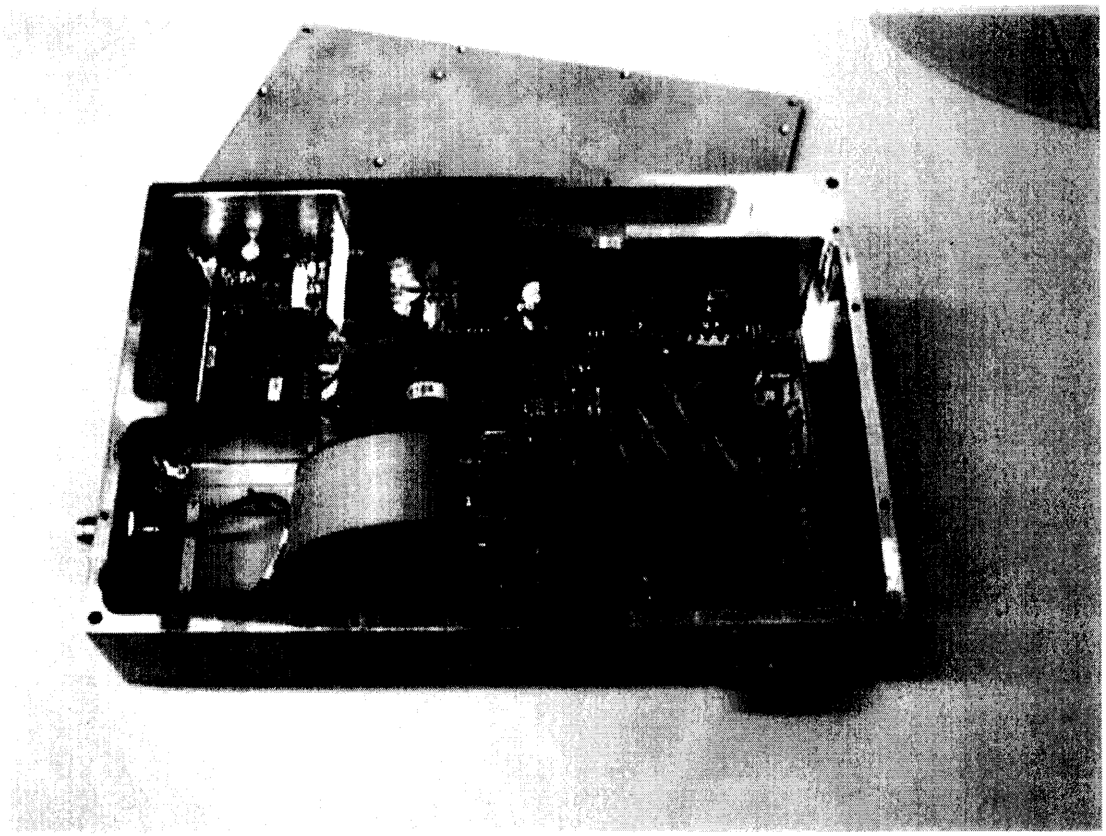


Figure 15. Rowan EDR

Crash Data Recording. A proprietary crash algorithm, a software module in the microprocessor, was developed to detect a crash while avoiding false alarms. Based upon analysis of NHTSA crash tests, coupled with crash test modeling, the algorithm is able to distinguish between actual crashes and low-severity crashes or non-crashes such as panic braking or backing into a shopping cart. The crash pulse along both axes is transmitted to the Base Station along with GPS coordinates. It should be noted that while inclusion of the crash pulse requires transmission of a longer message, the crash pulse can provide trauma teams with crucial early warning of the nature of the crash event. The crash pulse contains, for example, sufficient information to infer whether the car struck a tree or another car. Likewise, inclusion of crash severity for each axis also allows the Base Station to distinguish between frontal and potentially more serious side impacts.

Wireless Web Communication. The system uses Cellular Digital Packet Data (CDPD), sometimes referred to as a Wireless IP connection, to transmit data between the Mobile Unit and the Base Station. CDPD is a cutting edge wireless communications protocol that allows direct connection of remote devices to the Internet. The use of CDPD wireless web protocol avoids the dial-up delay and phone line contention issues inherent in circuit-switched ACN systems.

Power. Power for this system is provided by the car 12-volt electrical system. Note that this is the only interconnection between the Mobile Unit and the car. Power from the car battery is conditioned as necessary before input to the Mobile Unit electronics. In the event of power loss, backup power is provided by a small onboard battery.

Performance Testing. The Rowan research team has successfully demonstrated operation of ANJEL in on-road tracking tests and drop tower impact tests up to 10 Gs – with additional tests planned up to 30 G. The impact tests are designed to evaluate the survivability of the electronics to impact as well as testing the ability of the system to detect and report collisions of this magnitude.

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4.0 Data Elements

4.1 Overview

The working group developed a "top ten" list of data elements for storing in an EDR. This list was based on the input of many EDR users, not just the EDR manufacturer. The following provides the list along with some of the rationale for selecting each.

1. **Longitudinal and Lateral Acceleration and Principal Direction of Force (PDF)** - These data are used to define the crash pulse. They can be used to improve vehicle design and understand the interaction between the vehicle and what it's impacting. PDF can be derived from the two accelerometer signals and can be used to better assess the crash environment.

2. **Location of Crash** - This data is desired by the highway community to help understand the relationship between the roadside design and the vehicle crash outcome.

3. **Seat belt status by seating location** - These data will aid in understanding injury outcome, and generally improve the knowledge of seat belt performance.

4. **Number of occupants and location** - Because seat belts are often not worn, it is difficult to reconstruct where an occupant was seated prior to a crash, which may be instrumental to injury outcome. For ACN application, this could be used to improve emergency response.

5. **Pre-crash data** - Pre-crash data, such as steering wheel angle, brake use, vehicle speed, etc., will assist researchers to determine how drivers act just prior to a crash. This knowledge will can help manufacturers and the government establish intervention programs to eliminate crashes.

6. **Time of Crash** - The time of the crash is often unknown.

7. **Rollover sensor** - Many crashes involve rollover, and improved knowledge regarding how the vehicle rolled over (such as tripped vs. untripped) would be valuable in developing countermeasures.

8. **Yaw data** - Vehicle control is often related to the vehicle's yaw angle. Data relating crash outcome to yaw angle could be important in preventing single vehicle and other crashes.

9. **ABS, Traction control, Stability control information** - This information would help determine if these control devices were active during a crash. There is no method, other than EDR technology, to determine from a post crash investigation if these systems were active.

10. **Air Bag data, such as deactivation status, deployment time, stage of deployment, etc.** - These data can not be determined after a crash, and since they are critical safety systems, knowledge of their operation during a crash in critical, and EDR technology is the only method to obtain these data.

4.2 Data Element Lists

The WG developed a detailed list of data parameters which could be considered for recording in an EDR.

Data Element List	
#	Description
1	2 vs. 4 Wheel Drive
2	Active Suspension Measurements
3	Advanced Systems
4	Air Bag(s) Deploy Time (Time from Start of Crash to Start of Air Bag Inflation)
5	Air Bag(s) Status
6	Air Bag(s) Lamp Status
7	Air Bag(s) On/Off Switch Position (Suppression System Status)
8	Auto Distance Control
9	Auto Collision System
10	Automatic Collision Notification
11	Battery System Voltage
12	Belt Status - Each Passenger
13	Brake Effort - Service
14	Brake Pressure
15	Brake Status - ABS
16	Brake Stop Lamp Status
17	Clutch Status
18	Collision Avoidance, Braking, Steering, Etc.
19	Crash Pulse - Longitudinal
20	Crash Pulse - Lateral
21	Cruise Control Active
22	Child Safety Seat Presence Indicator
23	Delta-V - Longitudinal
24	Delta-V – Lateral
25	Digital Imaging
26	Door Ajar Switch On
27	Door Lock State
28	Electronic Compass Heading
29	Electric Steering Functional
30	Engine Throttle Status
31	Engine RPM
32	Environment - Ice
33	Environment - Wet
34	Environment - Inside Temperature
35	Environment - Outside Temperature
36	Environment - Lumination
37	Environment - Other
38	Exhaust Brake Status
39	Fuel Level
40	Ignition Cycle Counter
41	Lamp Status (Headlight and Tail Lamps On/Off)
42	Lateral Acceleration Just Prior to Crash Longitudinal Acceleration Just Prior to Crash
43	Location - GPS Data

44	Number of Occupants
45	Occupant Weight Sensor - Front Passenger
46	Pre-Tensioners
47	Phone Status
48	Principal Direction of Force
49	Roll Angle
50	Roll Rate
51	Rollover (# 1/4 turns)
52	Seat Position - Driver
53	Service Engine Soon Lamp On
54	Service Vehicle Soon Lamp On
55	Stability Control
56	Steering Wheel Angle
57	Steering Wheel Tilt Position
58	Steering Wheel Rate
59	Stop Lamps Status - School Bus
60	Trailer Status
61	Throttle Position
62	Throttle-by-Wire
63	Time/Date
64	Tire Pressure Warning Lamp On
65	Traction Control
66	Traction Coefficient (Estimated from ABS Computer)
67	Transmission Selection (PRNDL Position)
68	Turn Signal Operation
69	Vehicle Mileage
70	Vehicle Speed
71	VIN
72	Wheel Speeds
73	Windshield Wiper Status
74	Yaw Rate

During the process of reviewing the data elements and top ten list, the working group developed the following categories of data elements:

Data Element Categories
Restraint system usage (air bag, belts, other)
Crash Pulse (delta v, deceleration, angular rates)
Vehicle/EDR ID
Speed
Driver Controls (Brakes, accel. etc)
Location
ACN (time, date, location, number occupants)
Environmental Conditions

4.3 EDR Parameters Important to Highway Safety Research

4.3.1 Federal Highway Data Element List

- Vehicle Speed
- Brake Switch Status

- Throttle Opening (Percent)
- Steering Wheel Input
- Location of Crash (GPS Data)
- Longitudinal Velocity Change vs. Time
- Longitudinal Acceleration vs. Time
- Occupant and Driver Belt Status
- Occupant Seating Positions
- Time of Day

4.3.2 Transportation Research Board Data List

- Speed & Speed Profile
- Steering Inputs
- Braking Inputs
- Throttle Settings/Accelerator Inputs
- Location (GPS)
- Time
- Pavement Friction
- Wheel Rotation
- Seat Belt Usage
- Yaw/Pitch/Roll Measures
- Impact Velocity
- Occupant/Load Distribution
- Suspension Pulse History
- Crush Zone History
- Driver Condition
- Vehicle Id/Equipment Status

4.4 Haddon Matrix

NHTSA's first Administrator developed a 3x3 matrix which combined the crash and other related characteristics which affect the crash, namely the human, vehicle, and environment. This matrix can be used to demonstrate the effectiveness of an EDR in understanding a crash. The current understanding of a crash, without EDRs, is shown as follows:

	Human	**Vehicle**	**Environment**
Pre-Crash			
Crash			
Post-Crash	Injury	Crash	Environment after crash

As can be seen, all information related to the "pre-crash" and "crash" phases of a crash need to be determined by the crash investigator. Investigators utilize specific tools (from measuring crash scene evidence to crash reconstruction computer code) and rely on their experience as a professional investigator to determine these data. For vehicle crashes where the vehicle is equipped with a futuristic EDR, the Haddon Matrix would look as follows:

	Human	Vehicle	Environment
Pre-Crash	Belts Steering Braking	Speed ABS Other Controls	Conditions at the time of the Crash
Crash	Air Bag Data Pre-Tensioners	Actual Crash Pulse Actual Delta -V Vehicle Dynamics Air Bag Deployment time	Location
Post-Crash	Injury	Crash	Environment after crash

4.5 Potential Method for Classifying EDRs

A method for classifying EDRs was proposed that would categorize EDRs into two major types: Type II and I. Type I EDRs would use a minimal, but essential set of data elements. For example, Type I elements could include: time, location, direction of impact, velocity, occupants, seat belt usage, and crash pulse characteristics. Type II EDRs would evolve with emerging technologies and may include appropriate data elements that target specific vehicle types. In particular, the data gathered by Type II EDRs might provide additional information on crash, behavioral, demographic, vehicle safety, and roadway characteristics that would assist highway safety research and development efforts.