Crash Data Recorders:

The New Eyewitness in Vehicular Accidents

THOSE OF YOU WHO PRACTICE AUTOMOBILE LAW ARE ABOUT TO EXPERIENCE A PROFOUND shift in the way accident cases are litigated and settled. The field is on the verge of a technology driven paradigm shift that will have an immediate and lasting effect on the way crash related evidence is measured, recorded, collected and analyzed. The story of this change involves the vehicle airbag; more specifically, the sensors and control modules that monitor vehicle status and decide when the airbag should deploy. These modules are the aviation equivalent of "Black Box" data recorders that store and later provide vital information about the status of the airplane in the moments prior to disaster. We are now learning that airbag control modules have had the ability to provide similar data for vehicle crashes at least since the early 1990's. Methods for retrieval of these data are now commercially available and are currently being used as the equivalent of mechanical witnesses to tell crash investigators what happened in the moments prior to a vehicle crash.

By George C. Govatos

Overview of the Technology

Since the advent of airbag technology in the mid 1970s, engineers have had to develop and refine a method for sensing vehicle status so that airbag firing circuits could determine whether or not to deploy the airbag. Specifically, the control circuits had to be able to discriminate between normal driving conditions, and the initial stages of an impact that would require airbag deployment. To help increase their knowledge of the dynamic states of the vehicle, sensors, along with memory units, were designed to record and store some parameters associated with airbag deployment. These data could later be retrieved and analyzed to refine discriminatory conditions for sensing and firing the airbag.

In 1990, General Motors introduced a Diagnostic and Reserve Energy Module (DERM) that recorded airbag firing data and fault codes within the airbag firing system. In 1994, General Motors introduced a single point sensing system consisting of a solid state analog accelerometer and a computer algorithm integrated into a Sensing and Diagnostic Module (SDM). This system allowed recording and collection of data regarding maximum velocity change (delta V) of the vehicle for both deployment and near deployment events. Since historically, delta V has been used as a measure of crash severity, this allowed engineers to learn how the entire restraint system, including belts and airbags functioned with changing crash severity conditions.

In 1997, the National Transportation Safety Board (NTSB) made a recommendation that vehicle manufacturers and the National Highway Traffic Safety Administration (NHTSA) work together in collecting and using these crash data to increase highway and vehicle safety. In 1999, General Motors expanded the capabilities of the SDM allowing it to collect pre-crash parameters including vehicle speed, engine speed, throttle position and brake activation for a duration of 5 seconds prior to deployment or a near deployment event. A summary of the data collected and recorded by the 1990 DERM, the 1994 SDM, and the 1999 SDM is shown in Table 1.

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 illumninated	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_V for near-deployment event		X	X
_V vs. time for frontal airbag deployment event		X	X
Time from vehicle impact to time of maximum_V		X	X
State of driver's seat belt switch		X	X
Time between near-deployment and deployment event (if within 5 seconds)		X	X
Passenger's airbag enabled or disabled state			X
Engine speed (5 seconds before impact)			X
Vehicle speed (5 seconds before impact)			X
Brake status (5 seconds before impact)			X
Throttle position (5 seconds before impact)			X

Table 1

Although these data were recorded, they could only be retrieved and interpreted by General Motors technicians using specialized equipment. To make these crash records available to the general public, General Motors authorized Vetronix Corporation of Santa Barbara, California to develop the hardware, software, and connecting cables to download and analyze recorded data from the SDM. Last year, the Vetronix Crash Data Retrieval System became commercially available, and is now being used by police agencies and others engaged in accident reconstruction to assist in reconstruction of accident events.

The amount and type of data that can be downloaded varies according to the type of SDM in the vehicle. Not all 1999 models store the complete data set shown in Table 1. However, in succeeding years, 2000 and 2001, the number of General Motors cars offering the complete data set has increased. Vetronix has stated that subsequent versions of the Crash Data Retrieval System will be able to collect data for previous years through 1990 for all General Motors cars equipped with recordable modules. In addition, Vetronix has designed their Crash Data Retrieval System such that it can be used to retrieve data from other manufacturers by simply updating the software. Vetronix expects to begin to add models from Ford Motor Company by the end of 2001. Because of the recommendations from the NTSB and the NHTSA, it is expected that all manufacturers will soon be making recorded crash data available.

How the SDM Works

An outline of the SDM and its sensors is shown in Figure 1.

Vehicle speed, engine speed, and percent throttle are transmitted once a second by the Powertrain Control Module (PCM) through the vehicle datalink to the SDM. The brake switch circuit status is transmitted once per second through the PCM or the antilock brake module (ABM). The driver's seat belt switch is usually wired directly into the SDM. When the accelerometer detects a preset speed change, the processing unit initiates a computational procedure known as the "firing algorithm". The algorithm may compute secondary parameters such as deceleration, jerk (the rate of change of acceleration) and energy waveforms, and continually compares the results of these computations with preset firing criteria. The airbag may or may not deploy depending upon whether or not distinctive criteria are met.

Once each second, the memory unit stores 5 values for each of the precrash parameters;

Vehicle speed
Throttle position
Engine speed
Brake switch condition

In each successive second increments, the oldest value in memory is dropped, and a new value is added. This continues until the SDM firing algorithm initiates, at which time, the 5 values in memory are preserved. [1] [2]

Near Deployment Events

A near deployment event occurs when the firing algorithm is initiated, but the sensing criteria for airbag deployment is not subsequently met. Even so, the memory module collects all of the data as if the bag had deployed. This information remains in memory for approximately 60 days, or until the event is overridden by a more severe near deployment event. As will be discussed subsequently, near deployment events can be quite useful in cases involving minor impacts.

How the Vetronix Crash Data Retrieval (CDR) System Is Used

The Vetronix unit is normally used in conjunction with a laptop computer. It is lightweight and compact, and it and the computer can easily be taken to a car that is to be examined. If the electrical system of the car is intact, the unit can be plugged into the diagnostic link connector. This is the electrical port used by mechanics and technicians to communicate with the vehicle's onboard computer.

If vehicle power is unavailable, the Crash Data Retrieval System must be plugged directly into the SDM that is readily accessible under the passenger or driver front seat or under the center console. Once the connections are made, data download is almost immediate. Data is interpreted by the Vetronix software and available on the computer screen within a minute.

Verification and Standardization

Beginning in the Fall of 1998, an Event Data Recorder Working Group consisting of government and industry officials was appointed by the Motor Vehicle Safety Research Advisory Committee's Crashworthiness Subcommittee. The Working Group was later transferred to the National Highway Traffic Safety Administration's Research and Development Office. Since forming, the group has met seven times to discuss

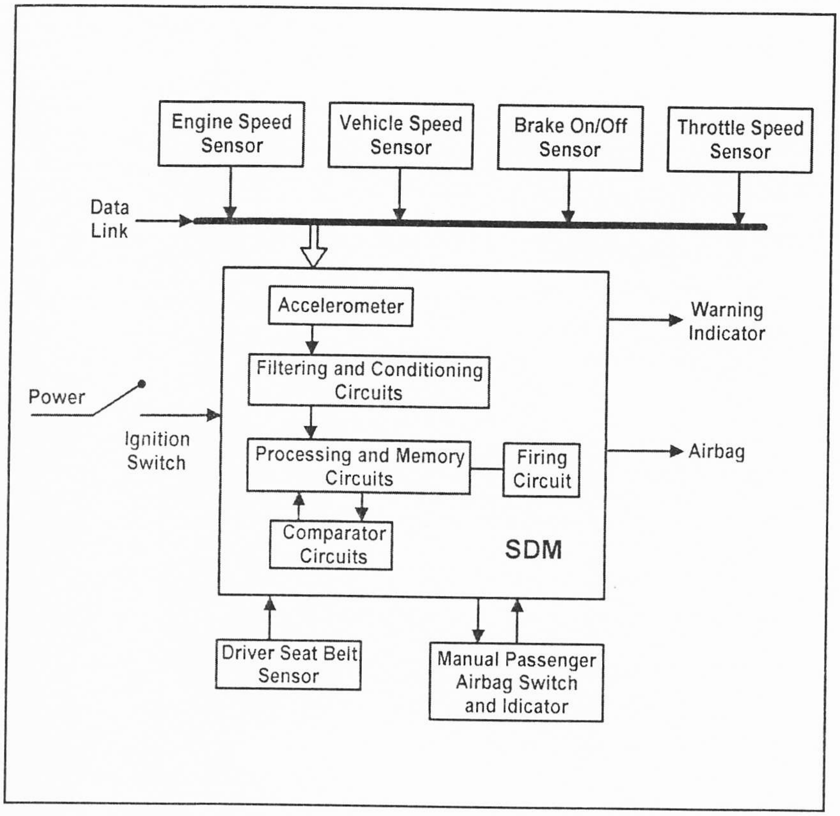


Figure 1

issues regarding standardization, verification, and dissemination of information regarding crash data recorders[3]. Generally, the objectives of the group are to:

- Act as a repository for event data recorder technology
- Select specific variables for data collection
- Develop methods for data collection, retrieval and consistency
- Determine who should be responsible for keeping the data
- Determine who owns the data

Eventually data collection procedures and protocol must be established to insure that accuracy of the data falls within specified ranges, and that stored data which becomes part of a national database will be uniform in format.

Example Reconstruction with a Deployment Event

One of my associates, James Mentzer, recently used the Vetronix Crash Data Retrieval System in the reconstruction of a fatal collision that occurred in the summer of 2000 [4]. This accident involved a 1997 Mercury Sable and a 2000 GMC Jimmy 4x4 that collided head on, on a two lane roadway. By examining roadway evidence, Mr. Mentzer determined that the GMC drifted off onto the shoulder and struck a mailbox. The driver attempted to steer to the left back onto the roadway, but over corrected and went into the lane of the oncoming Sable. As the GMC crossed the centerline, it began to slip sideways leaving yaw [5] marks on the pavement. The driver then steered back to the right to occupy his proper lane of travel, again leaving yaw marks. However, the driver of the GMC failed to regain his lane and hit the Sable head on, killing the driver.

Using the yaw marks, Mr. Mentzer was able to perform a speed analysis and determined that the GMC was traveling 53 mph in the first yaw when he skidded into the Sable's lane, and 47 mph in the second yaw just prior to striking the Sable. When possible, crash investigators seek to verify and cross check results with other evidence if it is available. It was important to do so in this case since there has been some contention that yaw analysis may not be applicable under certain conditions [6].

In this case, Mr. Mentzer discovered that the GMC was equipped with an SDM that supplied all of the data shown in Table 1. He therefore used a Vetronix Crash Data Retrieval System to download the stored information and check his yaw calculations. Figure 2 shows the precrash data as plotted by the Vetronix software. The recorded data confirmed that within 4-5 seconds prior to the collision, the GMC was traveling 54 mph, which is comparable to Mr. Mentzer's computation of 53 mph in the first yaw. It also shows that just prior to the collision, the GMC speed dropped to 47 mph comparable to the speed computed in the second yaw just before impact. Other comments on Figure 2 regarding additional data from the Vetronix output were supplied by Mr. Mentzer.

Example of Crash Data Recorder Use in a Low Speed Collision [7]

In this exemplar case, a 1994 Subaru was stopped at a traffic signal. The roads were wet, and a 1997 Chevrolet Cavalier approaching from the rear, failed to stop and struck the Subaru directly in the rear. There were no witnesses other than the drivers, and the police could not determine the point of impact nor how far each car moved after impact. The airbag in the striking car did not deploy and there was very little damage on either car. However, after the accident, the driver of the struck car began to experience neck pain that persisted long after the accident.

The company that insured the striking vehicle hired a crash investigator and a biomechanical expert to analyze the accident. The crash investigator concluded that the delta V of the Cavalier was about 5 mph, and based his opinion primarily on damage to the rear bumper of the Subaru. Using the speed calculation as a basis, the biomechanical expert concluded that impact forces should have been below injury threshold levels. She concluded that the driver of the Subaru should at most have experienced mild transitory discomfort. She based her opinion on studies that showed no injury to a class of volunteer subjects that had participated in staged low speed rear crash tests. Neither the crash investigator nor the biomechanical expert examined the vehicles. Their opinions were based on photos and published studies.

When I examined the Cavalier, I noted that it was equipped with an airbag, and that the SDM was of the type that recorded post crash delta V. Since no one really knew what I was looking for, I readily obtained permission to download the impact data from the SDM and found that the delta V for the Cavalier was 8.5 mph. By means of elementary physics, it directly followed that the delta V's of the vehicles were related simply in proportion to their weights. Specifically,

delta V (Subaru) = (weight of Cavalier / weight of Subaru) x delta V (Cavalier)

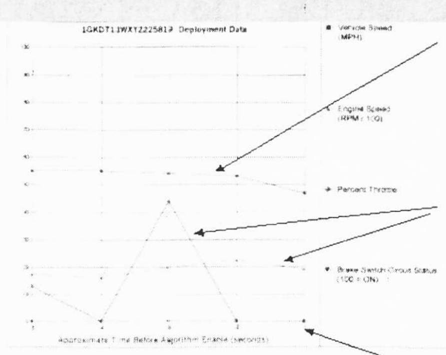
Weights of both vehicles were measured, and the delta V of the Cavalier was read directly from the air bag module, using the Crash Data Retrieval System. Using the output shown in Figure 3, the delta V was then easily computed as

delta V (Subaru) = (2578 lb / 2141lb) x 8.5 mph = 10.2 mph

This value is double that provided by the insurance crash investigator. The difference results from the fact that the insurance investigator had to infer the delta V of the Subaru based on scant and vague data. On the contrary, weights and measured delta V of the Cavalier were known to a high degree of certainty. Since the biomechanical expert based her conclusions on a delta V of 5 mph, her conclusions and opinions were meaningless for a 10 mph velocity change.

Data Recorder Information

The vehicle data recorder was removed from the Jimmy and its data was downloaded into a computer.



Note the "speed" line (red) drops from 54 mph to 47 mph within 5 seconds.

Also note the "engine rpm" (green) rising slightly then dropping, analogous to the engine speed rising slightly between two hard steering movements in response to throttle application (blue).

No brake application.

Figure 2

(continued on page 26)

Crash Data Recorders *(From Page 21)*

Use of the Crash Data Retrieval System In Establishing Better Crash Injury Databases

This low speed impact example highlights a basic problem in developing meaningful correlations between speed and injury. Historically, crash investigators and researchers were primarily interested in moderate to high speed collisions where damage was extensive. In searching for a relatively simple way to relate injury level to some aspect of the impact, they realized that standard mathematical techniques of reconstruction were based on velocity change only, and the high decelerations that occurred during the crush phase did not have to be considered in detail. Consequently they selected delta V as the correlating variable with injury. In the NASS database[8], vehicle crush was used to estimate delta V and hence injury level.

This simplistic approach has proven satisfactory at least for relatively large delta V's. However it sometimes escapes our attention that in principle, delta V cannot at all be related to injury unless there is an associated time over which the velocity change occurs. For example, when one accelerates normally from 0 mph to 60 mph, there is obviously no injury even though there is a 60 mph delta V. Conversely when one is in a crash and slows from 60 mph to 0 mph in approximately 200 milliseconds, injury levels can be drastic. The important variable then for injury correlation is deceleration (or acceleration) which is a measure of the change in velocity with respect to time.

In high to moderate impacts, the effects of deceleration may be secondary to the absolute velocity change. That is, regardless of deceleration levels, the magnitude of the crash will certainly produce injury. When low speed collisions became an important area of study, and litigation of these cases came to the fore, the delta V vs. injury approach came along with it. In my experience however, the correlation that held in high speed crashes fails to characterize low speed crash injury. I believe that absolute values of low speed velocity change may be insufficient to characterize and or predict injury. Instead the impact must be evaluated on a finer scale, which includes rather than disregards the duration of the impact. That is, injury must be correlated with the acceleration or the rate of change of velocity. On a deeper level, injury thresholds in low speed collisions may even be correlated to "jerk", defined as the rate of change of acceleration. Although a perfectly real and important physical quantity, this term is all but absent in the reconstruction and medical literature. The reason is clear. There has never been any way to measure acceleration, let alone jerk, in real world crashes. If one could correlate these concepts with reported injuries in low speed impacts, there may very well be a clear and decisive correlation, and the mystery and lack of consensus in the relationship of delta V and injury in low speed impacts may be removed.

This is the promise of making crash sensing technology and measurement available on a wide scale. New databases will be formed comprised of a large number of real world type crashes. No longer will investigators and juries have to rely on a potentially biased database of human crash test volunteers, not likely representative of the broad population of persons injured in the enormous number low speed crashes that occur each day in the United States.

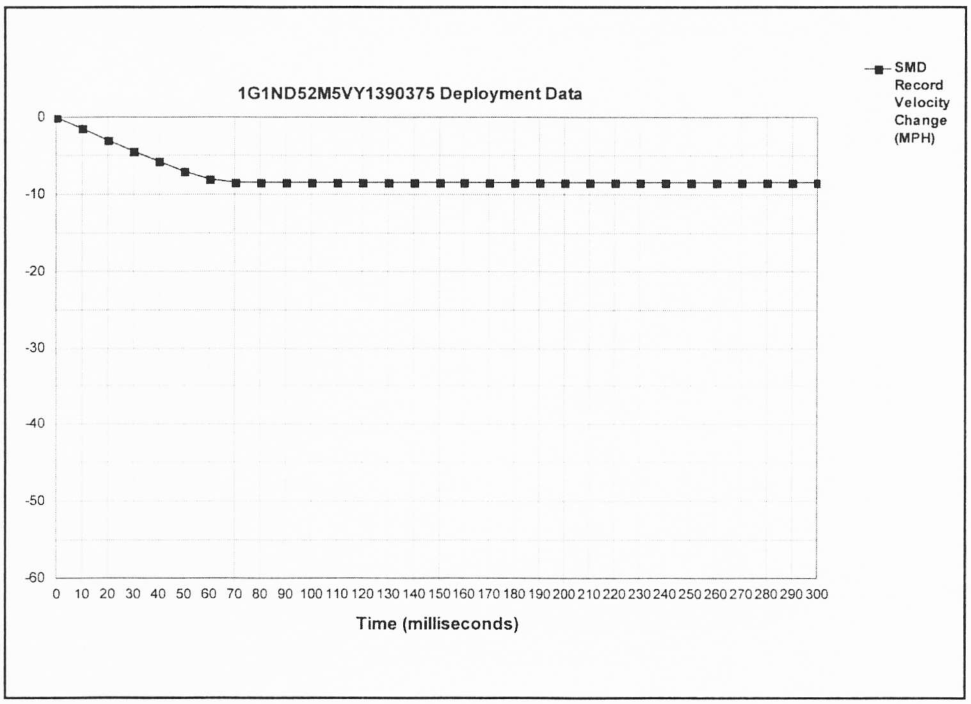


Figure 3

Further, as the NHTSA begins to include SDM crash data in its collision databases, medical, legal and crash investigators may find new and helpful information previously overlooked in the staged crashes into solid barriers that have historically been the mainstay of crash severity analysis. Only time and continued research will tell, and both favor the expansion of crash data recording.

What You Should Do Now

When initiating new cases, it is critical to determine whether your client's vehicle was equipped with a recording type SDM. The vehicle coverage list for the Vetronix Crash Data can be found at the Vetronix web site[9]. I will also post a continually updated list on my own web site[10]. However, just because a vehicle is not on the current Vetronix coverage list does not mean that the SDM might not yield important data at some future time. To insure that you are not discarding data that may be critical to your case, you must absolutely determine from the manufacturer whether or not the vehicle was equipped with a recording SDM. If it was, then either the vehicle or the module must be preserved. Although modules are normally immune to data corruption, one must follow manufacturer's recommendations for removal and preservation of the module.

Once you have established the data collection characteristics of your client's vehicle, the obvious next step is to do the same for any other vehicles involved in the accident. Be aware that there are alternate ways of crash sensing that may not involve airbag sensors. Be especially vigilant when dealing with fleet vehicles and trucks that may have special dedicated devices to monitor the speed and crash history of the vehicle. You should always include a broad question in your interrogatories related to the use of any recording devices that may have been in use at the time of the accident. These might include video and audio data as well as sensory impact values.

This short article can by no means address all of the technical issues associated with crash sensing and recording. I expect that based on the present level of technology, arguments will emerge to limit the use of crash sensor data in litigation. However I also believe that those arguments will eventually diminish, and that crash sensing will come to dominate the field. I therefore recommend that interested readers become acquainted with some of the basic literature on the subject starting with the citations referenced in this article. ❖

footnotes

[1] Govatos Professional Corporation, Wilmington, DE

[2] Chidester, Agustus; Hinch, John; Mercer, Thomas C.; Schultz, Keith S., "Recording Automotive Crash Event Data"88, International Symposium on Transportation Recorders, May 3-5, 1999, Arlington, VA.

[3] Gobelbeckm, John M. , "Crash Data Retrieval Kit Recovers Reconstruction Data From G. M. Black Boxes",Accident Investigation Quarterly, Issue 21, Waldorf , MD, Winter 2000.

[4] Gilman, Don, "Automotive Black Box Data Recovery Systems" , www.tarorigin.com/art/Dgilman, January 23, 2000.

[5] For more information, go to http://dms.gov/ - click on "Search" about halfway down the page – Click on "Docket Search Form" – fill in the docket ID with "5218" – select "NHTSA" for the agency – and "1999" for the calender year and press "Search".

[6] Mentzer James R., *Vehicle Side-slipping and Comparison of "Black Box" Readings*, NATARI Newsletter , 2001.

[7] These are curved skids typified by tire striation marks. They indicate that the vehicle has exceeded the available lateral road friction allowing it to slide sideways while it is also moving forward.

[8] Semon, Mark, "Determination of Speed From Yaw Marks", *Forensic Accident Investigation: Motor Vehicles*, Michie Buttersworth, Charlottesville,VA, 1995.

[9] The case reported herein did not actually occur. It is however compiled from facts representative of similar low speed collisions which I have investigated.

[10] NASS refers to the National Accident Sampling System. It is a database of actual crash events compiled and maintained by the NHTSA. Investigators are instructed to record vehicle crush which has been shown to be related to delta V. Vehicle crush and delta V are then correlated to injury level.

[11] http://www.vetronix.com

[12] http://www.govatosconsulting.com