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Triodyne Inc.
Consulting Engineers & Scientists – Safety Philosophy & Technology
5950 West Touhy Avenue Niles, IL 60714-4610 (847) 677-4730
FAX: (847) 647-2047
e-mail: infoserv@triodyne.com
www.triodyne.com

Crash Data Retrieval Kit Recovers Reconstruction Data from GM Black Boxes

By John M. Goebelbecker, P.E.,* Certified CDR Investigator

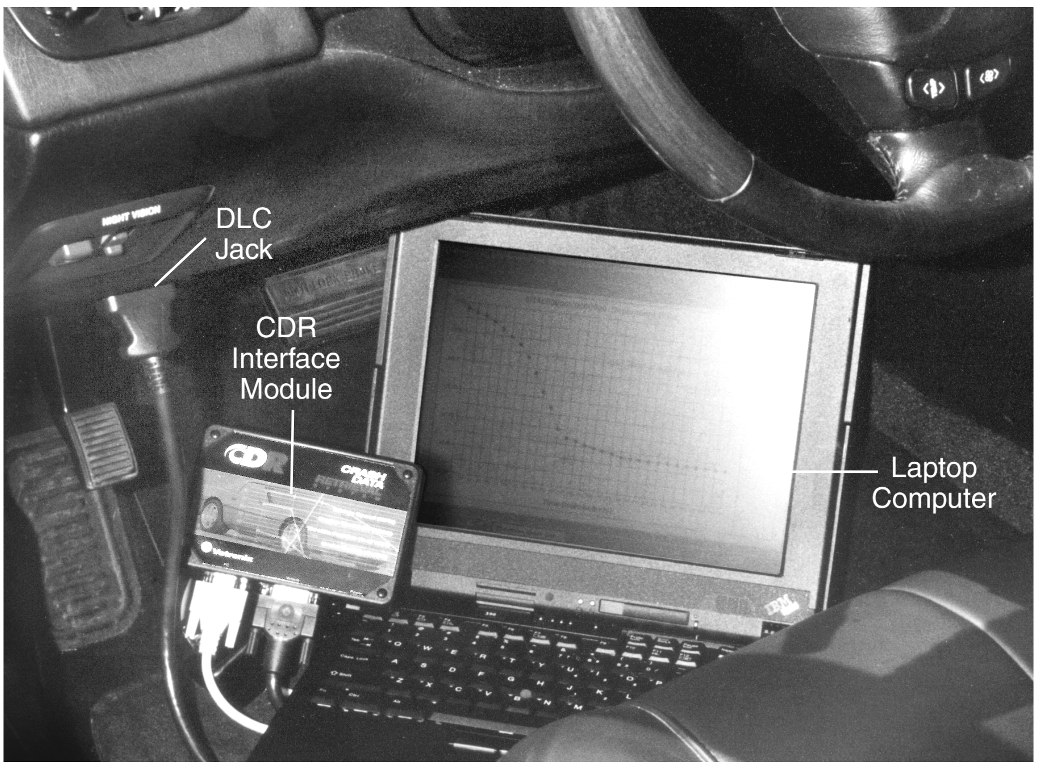

Figure 1 - CDR Tool

General Motors vehicles equipped with air bags and manufactured after 1990 utilize electronic modules to operate their air bag systems. These electronic modules are similar to "black boxes" used in the aviation and railroad industries in their ability to record data in the event an air bag deploys or nearly deploys. While General Motors has utilized these data in their accident investigations, they have not been accessible to the public. Breaking new ground in the area of automotive accident investigation, General Motors has entered into an agreement with an outside vendor to develop, manufacture and distribute a Crash Data Retrieval (CDR) kit for use by independent investigators to download crash data formerly considered to be proprietary information.

*Senior Mechanical Engineer, Vehicle and Mobile Equipment Center, Triodyne Inc., Niles, IL

General Description

The CDR kit consists of an interface module, various cables, power supply equipment and software for use on a laptop computer. Crash data can be retrieved either via a connection to the vehicle underneath the dash (DLC cable) or via a direct connection to the air bag control module. Interfacing through the dash connection is straightforward and the DLC jack is easily accessible (See Figure 1). Often, however, the vehicle's electrical system is damaged during a collision so a direct connection to the air bag control module is required. The location of the air bag control module varies from model to model, but it is generally found in the passenger compartment under the driver's seat, under the front passenger seat, or under the center console. Accessing the control module directly may require removing a seat, carpeting or trim.

Data Description

Although some confusion exists about the amount of data available on specific vehicle models, GM has provided some general guidelines. Vehicles with air bags manufactured between 1990 and 1993 are equipped with several electromechanical switches for detecting crashes and a central control unit called a Diagnostic and Energy Reserve Module, or DERM. The DERM serves three primary functions: [1] It contains a backup energy supply to power the air bag system in case the vehicle's electrical system is damaged during the collision; [2] It evaluates whether the criteria for air bag deployment are met; and [3] It sends an electrical signal to the air bag canisters for deployment, when appropriate. In addition, the DERM records a limited amount of data at the time of the deployment event which will be accessible to investigators through the CDR kit after a software update expected to be released near the end of 2001. The data stored in DERMs after an air bag deployment include the following: the status of the air bag warning light (On/Off), the length of time the warning light was illuminated (if applicable), diagnostic trouble codes (DTCs), the cumulative number of times the vehicle's ignition system had been activated prior to the event, time from vehicle impact to air bag deployment, crash sensing activation times and sensing criteria met.

In 1994, GM began production of air bag systems which utilize a Sensing and Diagnostic Module (SDM) comprised of a single solid state analog accelerometer, electronic circuitry and a computer algorithm. In addition to performing all the functions of its predecessor, DERM, an SDM detects crashes internally by measuring the vehicle's longitudinal acceleration with an integrated accelerometer; electromechanical switches placed throughout the vehicle are no longer needed. The SDM also calculates the resulting longitudinal change in velocity (ΔV) from the measured longitudinal acceleration.

The SDM continuously monitors the vehicle's forward motion. If the SDM senses a significant deceleration (generally greater than decelerations caused by hard braking), the crash-sensing algorithm "wakes up." If the vehicle's acceleration exceeds a pre-defined level, the SDM deploys the air bags and a "Deployment" event is recorded. If the vehicle's acceleration does not exceed the pre-defined level, the air bags are not deployed, but a "Near Deployment" event is recorded. In both cases, change in vehicle forward speed data is calculated and stored every 10 milliseconds for 300 milliseconds. The CDR kit reads these collision data and converts them to a graphical plot (as shown in Figure 2) or into tabular form.

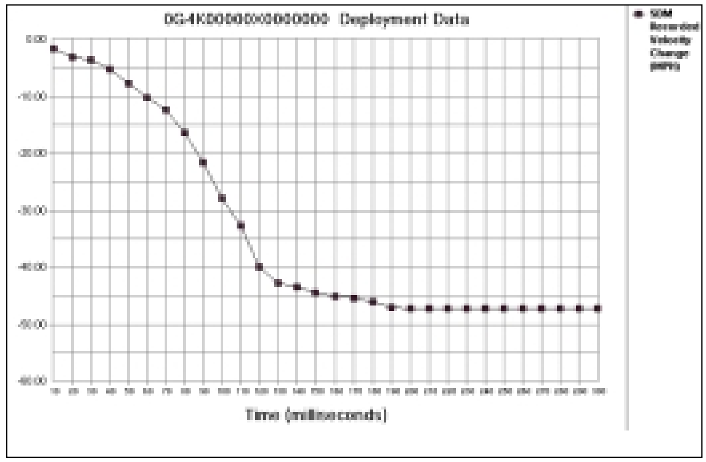

Figure 2 - Deployment Change in Velocity

In addition to the crash data recorded in DERMs, SDMs in 1994 through 1998 models record the following crash data: longitudinal ΔV vs. time for frontal airbag deployment, maximum longitudinal ΔV for near deployment, time from vehicle impact to maximum ΔV, and time between a Near Deployment event and a Deployment event (if within 5 seconds of each other). In addition, the status of the driver's seat belt switch is recorded. The switch is normally closed when the belt is buckled.

In 1999, GM added the capability to record pre-crash data to certain vehicles. Sensors which monitor engine speed, vehicle speed, throttle position and brake switch status continuously transmit data to the vehicle's computer network at one second intervals. The SDM receives the data from the various modules and stores five values for each parameter listed, representing an interval of four seconds. When a new signal is received, the SDM discards the oldest value and retains the new one. In this way, the SDM continuously updates its data buffer file and is prepared to preserve the previous five data values received when the algorithm wakes up. When a Near Deployment or Deployment event occurs, the data in the buffer are captured and stored in non-volatile memory (EEPROM). The result is a four second record of the vehicle's speed, brake switch, engine speed and throttle position prior to a crash. These data are labeled "Pre-Crash Data" and can be viewed on a composite graph, as shown in Figure 3 or in a summary table, as shown in Figure 4. A summary of the data-storing capabilities of the GM air bag system from 1990-2000 is presented in Table 1.

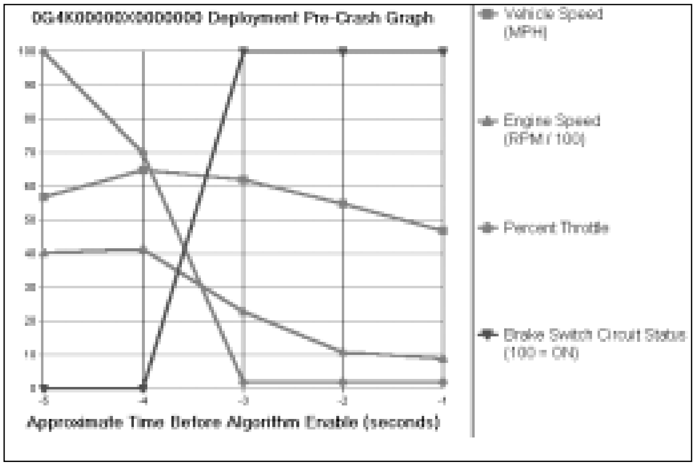

Figure 3 - Pre-Crash Data Graph

Further Discussion of Pre-Crash Data

The Pre-Crash Data graph plotted by the CDR kit requires two points of clarification with respect to the time intervals shown. First, the one second interval between data points for each parameter is correct. However, it is not known what fraction of one second transpired after the last data signal was received before the SDM captured the data from its buffer and stored them in EEPROM. This is why the graph does not show t=0 seconds and the horizontal axis is labeled "*Approximate* Time Before Algorithm Enable." In fact, the time values shown are maximum values and the actual values are up to .999 seconds less. For example, the last value received by the SDM in Figures 3 and 4 for vehicle speed was 47 mph. This value is plotted at t = -1 second, when in fact, it could have been received only .001 seconds before the algorithm was enabled. Second, the CDR software plots all four parameters on the same graph for convenience. However, each set of data from each parameter (vehicle speed, throttle position, engine speed and brake switch) is out of phase with the others. In fact, one channel may be as much as .999 seconds out of phase with another. This is due to the fact that data are being independently transmitted to the vehicle's computer network from several different sources (the ABS module and the powertrain module, for example) at one second intervals. These sources are *not* synchronized to transmit data at the same time.

0G4K00000X0000000 System Status At Deployment	
SIR Warning Lamp Status	OFF
Driver's Belt Switch Circuit Status	UNBUCKLED
Passenger Front Air Bag Suppression Switch Circuit Status	ON
Ignition Cycles At Deployment	187
Ignition Cycles At Investigation	213

PRE-CRASH DATA			Electronic Data Validity Check Status = VALID	
Seconds Before AE	Vehicle Speed (MPH)	Engine Speed (RPM)	Percent Throttle	Brake Switch Circuit Status
-5	57	4032	100	OFF
-4	65	4160	70	OFF
-3	62	2304	2	ON
-2	55	1088	2	ON
-1	47	896	2	ON

Time (Milliseconds)	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150
Recorded Velocity Change (MPH)	-1.54	-3.07	-3.51	-5.27	-7.68	-10.09	-12.29	-16.24	-21.50	-27.86	-32.69	-39.93	-42.78	-43.44	-44.32

Time (Milliseconds)	160	170	180	190	200	210	220	230	240	250	260	270	280	290	300
Recorded Velocity Change (MPH)	-44.98	-45.42	-46.07	-46.95	-47.17	-47.17	-47.17	-47.17	-47.17	-47.17	-47.17	-47.17	-47.17	-47.17	-47.17

Time From Algorithm Enable To Deployment Command (msec)	18.75
Time from Near Deployment to Deployment (sec)	N/A

Figure 4 - Pre-Crash and Deployment Data Summary

Table 1 - Data Stored by Selected GM Air Bag Systems

PARAMETER	1990-1993 DERM	1994-1998 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 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 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	X
ENGINE SPEED (T< 5 SECONDS PRIOR TO IMPACT)			X
VEHICLE SPEED (T< 5 SECONDS PRIOR TO IMPACT)			X
BRAKE STATUS (T< 5 SECONDS PRIOR TO IMPACT)			X
THROTTLE POSITION (T< 5 SECONDS PRIOR TO IMPACT)			X

Pre-crash vehicle speed is determined by the powertrain control module which monitors a sensor located at the output shaft of the transmission. Vehicle speed is related to the rotational speed of the output shaft through the differential gear ratio and the rolling radius of the tires. Strictly speaking, the powertrain module monitors the speed of the tires, not the speed of the vehicle. When tires slip on pavement, for example, tire speed does not represent vehicle speed, and if the drive wheels lock up from emergency braking the vehicle speed calculated by the powertrain module and recorded in the SDM may be zero though the vehicle continues to move. Anti-lock brakes reduce the amount of tire slip, but studies have shown that ABS systems may allow up to 12% tire slip. Hence, under braking conditions, the recorded vehicle speed in the Pre-Crash Data may underestimate the actual speed of the vehicle.

Data Limitations

The air bag sensing system is designed to evaluate longitudinal accelerations such as those which occur during frontal impacts. It currently does not sense lateral accelerations, nor forward longitudinal accelerations which may result from a rear impact. Thus, the ΔV measured and recorded is for the rearward longitudinal direction only.

GM has stated that the accuracy of ΔV measurements is $\pm$10% and the accuracy of vehicle speed measurements is $\pm$4%, assuming the vehicle is equipped with correct tires, wheels and differential. Throttle position is accurate to within $\pm$5% and engine speed is accurate to within $\pm$1 rpm. Validation studies are being conducted by GM, the National Highway Transportation Safety Administration (NHTSA), the Insurance Institute and others. One study utilizes crash data obtained from NHTSA's New Car Assessment Program (NCAP) in which vehicles are crashed into a rigid barrier at some known speed. In those highly specific crashes, the longitudinal ΔV calculated by the vehicle's SDM closely matched the test data ($\pm$ 0.5 mph).

Supported Vehicles

General Motors is currently the only automobile manufacturer to make a data collection system accessible. (Heavy duty diesel engines have had this capability in their electronic control modules for years. See Triodyne Safety Brief Volume 16, No. 2, *Utilizing Electronic Control Module Data in Accident Reconstruction*.) The later-model GM vehicles listed on the following page are currently supported under Version 1.0 of the CDR software.

1998

Buick	Park Avenue
Cadillac	Commercial Chassis
Cadillac	Deville
Cadillac	Eldorado
Cadillac	Limo
Cadillac	Seville

1999

Buick	Century
Buick	Park Avenue
Buick	Regal
Cadillac	Commercial
Cadillac	Deville
Cadillac	Eldorado
Cadillac	Limo
Cadillac	Seville
Chevrolet	Camaro
Chevrolet	Corvette
Pontiac	Firebird
Pontiac	Grand Prix
Saturn	All Models

2000

Buick	Century
Buick	Le Sabre
Buick	Park Avenue
Buick	Regal
Cadillac	Commercial
Cadillac	Deville
Cadillac	Eldorado
Cadillac	Seville
Chevrolet	Astro
Chevrolet	Blazer
Chevrolet	Camaro
Chevrolet	Cavalier
Chevrolet	Corvette
Chevrolet	Express
Chevrolet	Impala
Chevrolet	Malibu
Chevrolet	Monte Carlo
Chevrolet	S10 (gas)
Chevrolet	Silverado
Chevrolet	Suburban
Chevrolet	Tahoe
Chevrolet	Venture
GMC	Jimmy
GMC	Safari
GMC	Savana
GMC	Sierra
GMC	Sonoma
GMC	Yukon
Isuzu	Hombre
Oldsmobile	Alero
Oldsmobile	Bravada
Oldsmobile	Intrigue
Oldsmobile	Silhouette
Pontiac	Bonneville
Pontiac	Firebird
Pontiac	Grand Am
Pontiac	Grand Prix
Pontiac	Montana
Pontiac	Sunfire
Saturn	All but LS

The expected release date of the first CDR software update (V1.1) is September, 2000. The expanded coverage will include the following vehicles:

1996

Buick	Skylark
Buick	Riviera
Chevrolet	Camaro
Chevrolet	Cavalier
Chevrolet/GMC	Astro Vans
Chevrolet/GMC	Safari XT
Chevrolet/GMC	All G Vans
Chevrolet/GMC	Camper Special
Chevrolet/GMC	Commercial
Chevrolet/GMC	Chevy RV
Chevrolet/GMC	Express
Chevrolet/GMC	Rally Camper
Chevrolet/GMC	Rally Wagon
Chevrolet/GMC	RV Cutaway
Chevrolet/GMC	Savana
Chevrolet/GMC	Sportvan
Chevrolet/GMC	Vandura
Oldsmobile	Achieva
Oldsmobile	Aurora
Pontiac	Grand Am
Pontiac	Firebird
Pontiac	Formula/TransAm
Pontiac	Sunfire
Saturn	All Models

1997

Buick	Century
Buick	Le Sabre
Buick	Regal
Buick	Riviera
Buick	Skylark
Chevrolet	Camaro
Chervolet	Cavalier
Chevrolet	Corvette
Chevrolet	Lumina
Chevrolet	Malibu
Chevrolet	Monte Carlo
Chevrolet	Venture
Chevrolet/GMC	All C/K Trucks
Chevrolet	All G Vans
Chevrolet/GMC	Astro
Chevrolet/GMC	Camper Special
Chevrolet/GMC	Chevy RV
Chevrolet/GMC	Commercial
Chevrolet/GMC	Express
Chevrolet/GMC	Safari
Chevrolet/GMC	Savana
Chevrolet/GMC	Sierra
Chevrolet/GMC	Suburban
Chevrolet/GMC	Tahoe
Chevrolet/GMC	Yukon
Oldsmobile	Achieva

1997

Oldsmobile	Aurora
Oldsmobile	Cutlass
Oldsmobile	Eighty-Eight
Oldsmobile	LSS
Oldsmobile	Regency
Oldsmobile	Silhouette
Pontiac	Bonneville
Pontiac	Firebird
Pontiac	Formula/Trans Am
Pontiac	Grand Am
Pontiac	Sunfire
Pontiac	Trans Sport
Saturn	All Models

1998

Buick	Century
Buick	Le Sabre
Buick	Regal
Buick	Riviera
Buick	Skylark
Chervrolet	Blazer
Chevrolet	Camaro
Chervolet	Cavalier
Chevrolet	Corvette
Chevrolet	Lumina
Chevrolet	Malibu
Chevrolet	Monte Carlo
Chevrolet/GMC	All C/K Trucks
Chevrolet	All G Vans
Chevrolet/GMC	Astro
Chevrolet/GMC	Camper Special
Chevrolet/GMC	Chevy RV
Chevrolet/GMC	Commercial
Chevrolet/GMC	Express
Chevrolet/GMC	Safari
Chevrolet/GMC	Savana
Chevrolet/GMC	Sierra
Chevrolet/GMC	Sonoma
Chevrolet/GMC	Suburban
Chevrolet/GMC	S10 Pickup
Chevrolet/GMC	Tahoe
Chevrolet/GMC	Yukon
GMC	Jimmy
Oldsmobile	Achieva
Oldsmobile	Aurora
Oldsmobile	Bravada
Oldsmobile	Cutlass
Oldsmobile	Intrigue
Oldsmobile	Eighty-Eight
Oldsmobile	LSS
Oldsmobile	Regency
Oldsmobile	Silhouette
Pontiac	Bonneville
Pontiac	Firebird
Pontiac	Formula/Trans Am
Pontiac	Grand Am
Pontiac	Grand Prix
Pontiac	Sunfire
Saturn	All Models

1999

Buick	Le Sabre
Buick	Riviera
Chervrolet	Blazer
Chervolet	Cavalier
Chevrolet	Lumina
Chevrolet	Malibu
Chevrolet	Monte Carlo
Chevrolet/GMC	All C/K Trucks
Chevrolet/GMC	All G Vans
Chevrolet/GMC	Astro
Chevrolet/GMC	Camper Special
Chevrolet/GMC	Chevy RV
Chevrolet/GMC	Commercial
Chevrolet/GMC	Express
Chevrolet/GMC	Safari
Chevrolet/GMC	Savana
Chevrolet/GMC	Sierra
Chevrolet/GMC	Sonoma
Chevrolet/GMC	Suburban
Chevrolet/GMC	S10 Pickup
Chevrolet/GMC	Tahoe
Chevrolet/GMC	Yukon
GMC	Jimmy
GMC	EV1
Oldsmobile	Alero
Oldsmobile	Aurora
Oldsmobile	Bravada
Oldsmobile	Cutlass
Oldsmobile	Intrigue
Oldsmobile	Eighty-Eight
Oldsmobile	LSS
Pontiac	Bonneville
Pontiac	Grand Am
Pontiac	Sunfire

2000

Chevrolet	Lumina
GMC	EV1

REFERENCE

Chidester, Augustus “Chip”, et al. “Recording Automotive Crash Event Data,” *International Symposium on Transportation Recorders*, National Transportation Safety Board, Arlington, VA, May 3-5, 1999.

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