THE USE OF AUTOMOTIVE EMBEDDED SYSTEMS FOR FORENSIC ROAD TRAFFIC ACCIDENT ANALYSIS

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Abstract

This paper presents an alternative model for Road Traffic Accident (RTA) investigation using Event Data Recorder (EDR) technology. We highlight the difficulties encountered when using *established techniques* on contemporary vehicles, and present a rationale for a computerised alternative based on EDR technology.

EDR is a sub-function of the Supplementary Restraint System's (SRS) micro-controller, and is found on most vehicles manufactured after Model Year 1997.

Our work was undertaken in co-operation with the Rotterdam Rijnmond Police Force as part of a wider study "to find new and innovative solutions for the technical difficulties experienced in the activities of law enforcement" [1].

Key Words

Road traffic accident investigation, Event Data Recorder

Abbreviations

ABS – Anti-lock Braking System

ASR – Acceleration Skid Regulation

CDR – Crash Data Retrieval

CI – Collision Investigator

CIU – Collision Investigation Unit

DLC – Diagnostic Link Connector

DMA – Direct Memory Access

DTC – Diagnostic Trouble Code

EDR – Event Data Recorder

EEPROM – Electronically Erasable Programmable Read Only Memory

ESP – Electronic Stability Programme

FDR – Flight Data Recorder

NHTSA – National Highway Traffic Safety Administration

OEM – Original Equipment Manufacturer

RTA – Road traffic accident investigation

SRAM – Static Random-Access Memory

Introduction

The level of effectiveness in RTA investigations is largely determined by the assigned Collision Investigator (CI) being able to gather all of the pertinent facts pertaining to the incident [2].

Currently, there are two *formulation methods* employed:

- Deformation measurement, and
- Slide/skid factor.

Measuring vehicle deformation involves feeding crush data into a computer, and scrutinising this data, with the assistance of simulation software, to determine the velocity changes required to produce the degree of deformation displayed in the *involved vehicle*.

The later method, slide factor, is the predominant system, due to its simplicity and cost effectiveness. However, it is heavily reliant on the tyres of the *involved vehicle* leaving continuous skid marks on the road surface. The markings are studied by the CI, and mathematical formulae are applied to compute the pre-impact velocities.

Problem Description

Traditional RTA investigation methods have proved to be grossly ineffective where modern automobiles are concerned. Modern vehicles come equipped with vast arrays of *active safety* devices – e.g. Acceleration Skid Regulation (ASR), Anti-lock Braking System (ABS), Electronic Stability Program (ESP), etc. Consequently, they do not leave behind much in the way of tell-tale skid marks at the accident scene, Figure 1.

Figure 1 Tyre Skid Marks Left by a Vehicle with ABS

EDR Technology Explained

EDR technology is no stranger to the automobile. Indeed, General Motors (GM) has been equipping its vehicles since 1974 [3]. For several decades, EDR was installed on passenger vehicles for research purposes – and as a regular production option thereafter [4]. From its inception, EDR was employed to:

- Record events just prior to a crash,
- Record events during a crash, and
- Control air bag deployments.

In recent years, the U.S. auto industry has been collaborating with the National Highway Traffic Safety Administration (NHTSA) on ways to obtain crash information from vehicles using on-board collision sensing and recording equipment [3]. EDR technology is used to record data on airbag status and crash severity for impacts producing both deployment and near-deployment events. A near-deployment event is not severe enough to necessitate that the airbag(s) be triggered [3].

The EDR function has been adapted, in more recent years, to monitor and record additional vehicle operational parameters [5], such as:

- Vehicle speed,
- Brake on/off,
- Seat belt fastened, and
- G-forces as measured by the accelerometer.

For certain General Motors (GM) vehicles manufactured from model year 1999, the EDR function has some enhanced technical features, which allow it to record pre-crash vehicle events [4], Figure 2.

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

Figure 2 Data Stored by Selected GM Airbag Systems

EDR Construction and Operation

EDR is an integral function of an automotive airbag micro-controller, Figure 3. The system does not record cabin voice conversations like an aeronautical Flight Data Recorder (FDR) [5].

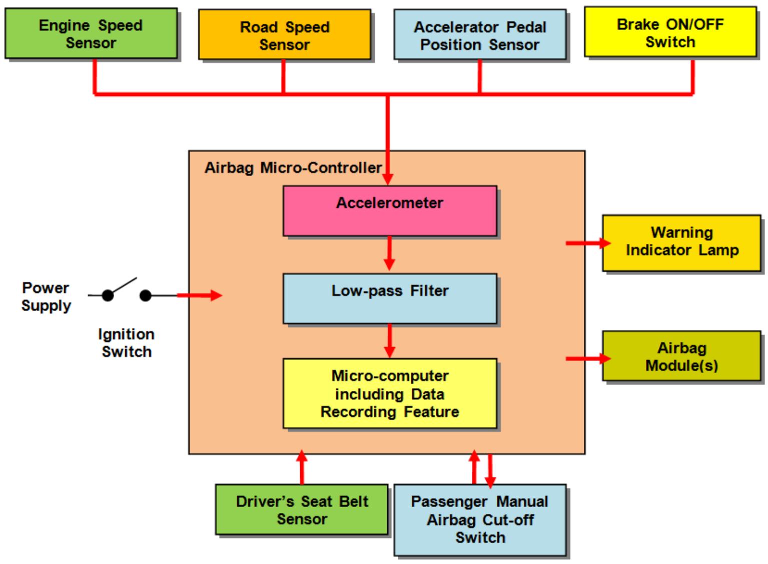


Figure 3 Simplified EDR Block Diagram

The EDR is constantly supplied with a host of electronic data from various vehicular subsystems – i.e. sensors and other micro-controllers. A bus system is used to connect the various subsystems together to form a synergistic network. A data protocol is used to regulate the communications between the various controllers operating on this network.

EDR uses two kinds of external memory to store system data [6]:

- Static Random-Access Memory (SRAM), and
- Electronically Erasable Programmable Read Only Memory (EEPROM).

Static Random-Access Memory

SRAM is a type of semiconductor memory, which utilises bistable latching circuitry to store information. SRAM memory is volatile – i.e. data is lost when the memory's electrical power supply is interrupted. SRAM acts as a fast access ring buffer recording system status data in a continuous loop, which is over-written every five seconds [7].

Electronically Erasable Programmable Read Only Memory

EEPROM (or E^2PROM), on the other hand, is a non-volatile memory – i.e. data is retained even when the memory's electrical power supply is removed. This is why SRAM data is transferred to EEPROM for secure storage. EEPROMs are also used by automotive micro-controllers to store small quantities of data, such as, calibration tables or device configuration settings. Stored EEPROM data can also be electronically erased and *overwritten* with new *learned values* if required [7].

The Rationale for Dual Memory Modules

SRAMs permits fast-access continuous-data-recording, but lose all of their data when powered down. EEPROMs, on the other hand, retain all of their stored data regardless of being powered down and rebooted. Conversely, EEPROMs due to their intrinsic latency inhibit fast-access. Furthermore, EEPROM chip architecture only supports a limited number of write/erase cycles; should this chip be employed as a *ring buffer* it would quickly wear out and fail [6].

Data Retrieval

When the airbag micro-controller's crash sensor reports a *critical event* (deployment/near-deployment); the EDR instructs the SRAM to transfer recorded *system status data* to the EEPROM [3]. The transferred recording containing data of the critical event is *locked* in a five second *freeze-frame*, which stays in the EEPROM until another more serious event occurs and overwrites it. Conversely, should the *critical event* relate to an actual airbag deployment; then the data is permanently *locked*. It is not possible to return a *locked status* (crash data stored) micro-controller to service. The unit must be replaced, and the new/replacement micro-controller *adapted* to the repaired vehicle.

EDR data can only be extracted using a dedicated piece of equipment called a Crash Data Retrieval System. Until 2000, only the Original Equipment Manufacturers (OEMs) of the airbag micro-controllers, like TRW Automotive, had this capability. Since then, several generic crash data retrieval tools have been made commercially available, Figure 4.

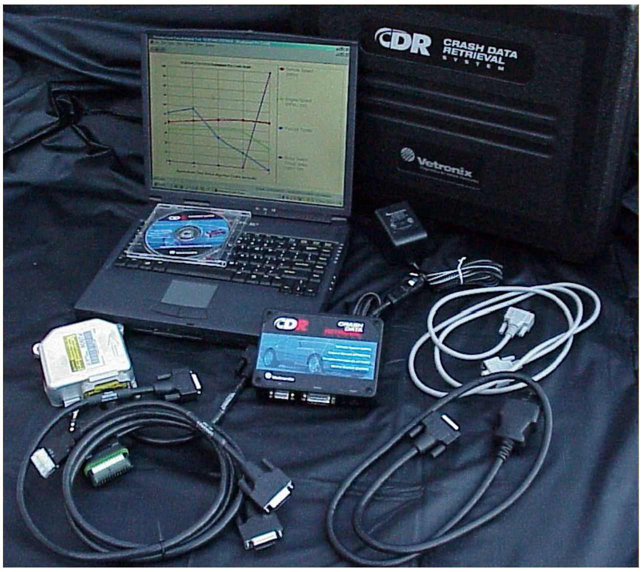


Figure 4 A Crash Data Retrieval Tool (Vetronics Corporation)

The crash data retrieval tool generally connects to EDR via the vehicle's Diagnostic Link Connector (DLC), Figure 5. Conversely, if this is not possible; the tool can also be directly connected to the airbag micro-controller with some *jumper cables* and a Direct Current (DC) bench power supply unit.

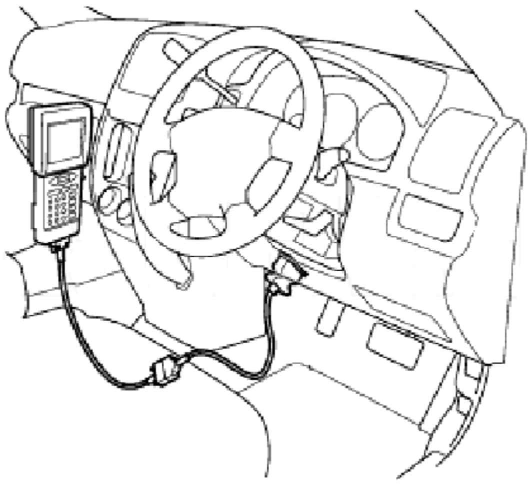


Figure 5 Connecting Crash Data Retrieval Tool to DLC

Analysing Retrieved Crash Data

The system generates a Crash Data Retrieval (CDR) file that stores and *visualises* the information downloaded from the EDR. The combined data is known as an *event file*.

An *event file* typically contains the following items of information:

- Freeze-frame data,
- A pre-crash deployment graph,
- A post-crash graph showing the difference in velocities (Δv), and
- A deployment summary.

Freeze-frame Data

Freeze-frames are a set of *image captures* for a variety of sensor input values (variables) that were generated, and transmitted down the CAN bus lines, at the exact moment the *fault(s)* occurred. A maximum of three sets of data are saved. This, however, does not mean there will always be three sets of data. A Crash Data Retrieval (CDR) tool has the capability to read the *freeze-frames* along with their respective Diagnostic Trouble Codes (DTC) and *definitions*.

Figure 6 shows *freeze-frame* hexadecimal coding, and demonstrates how a CDR tool converts it into something more meaningful (definition) for the Collision Investigator.

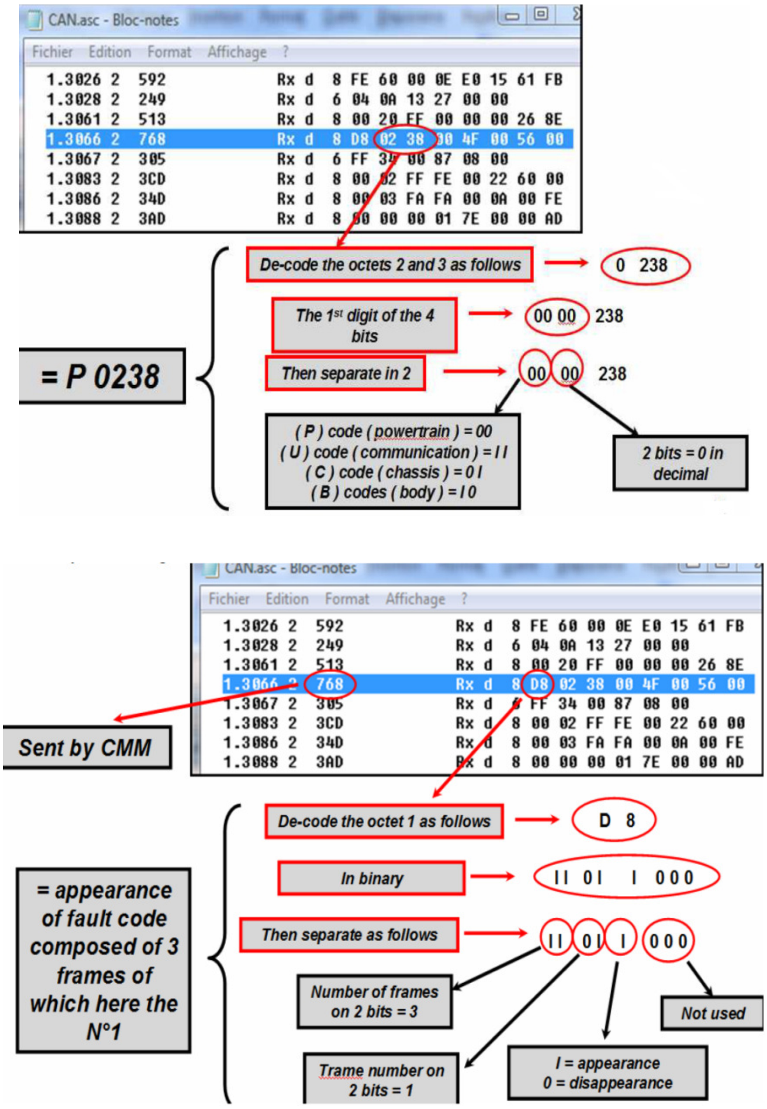


Figure 6 De-coding Freeze-frame Data (Courtesy PSA Peugeot Citroën)

The Event File

The following graphics are an example of an *event file*, which was downloaded using a Crash Data Retrieval Tool. It is poignant to note; that the driver of this vehicle was killed during this particular Road Traffic Accident.

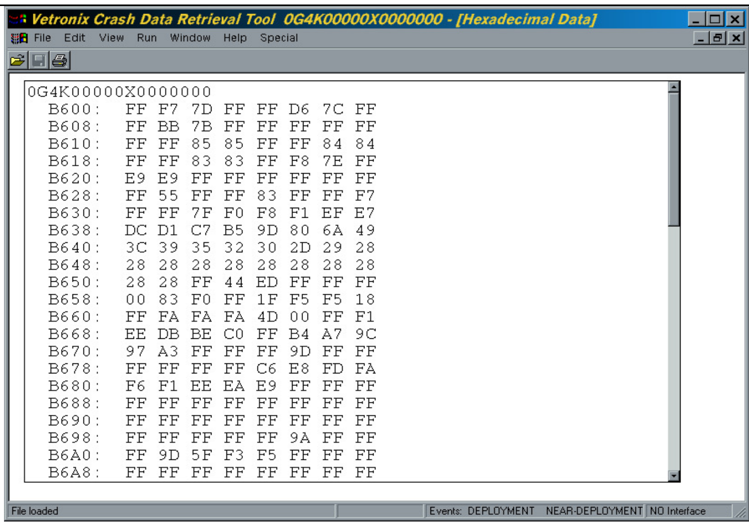


Figure 7 Sample Freeze Frames Containing Hexadecimal Data

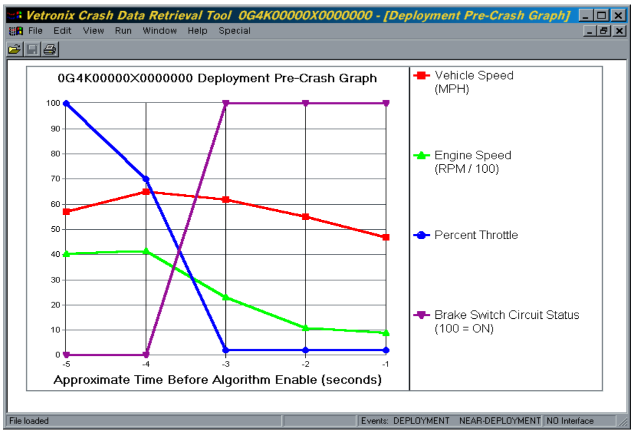


Figure 8 Pre-crash Deployment Graph

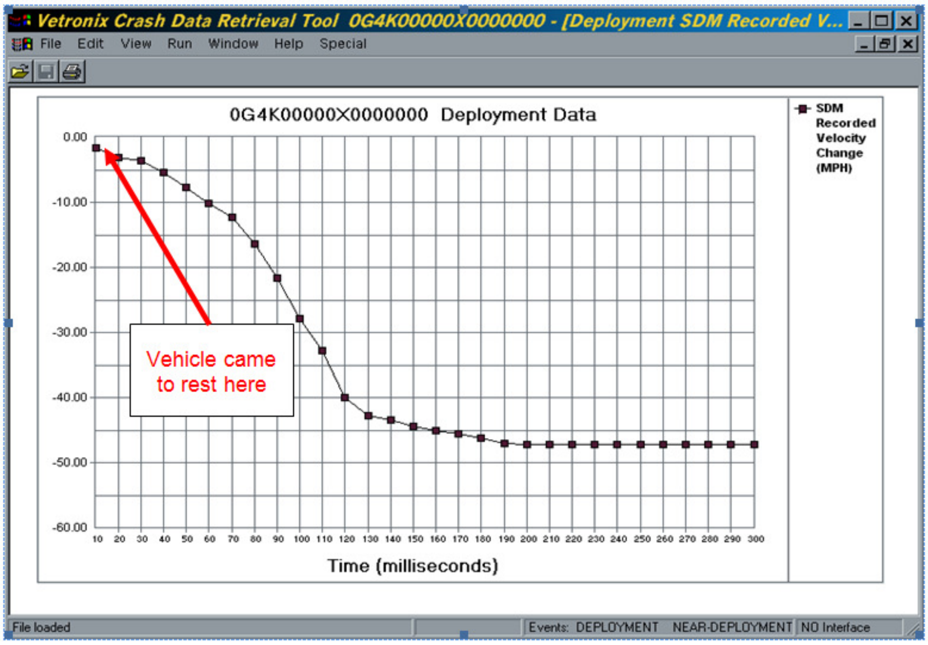
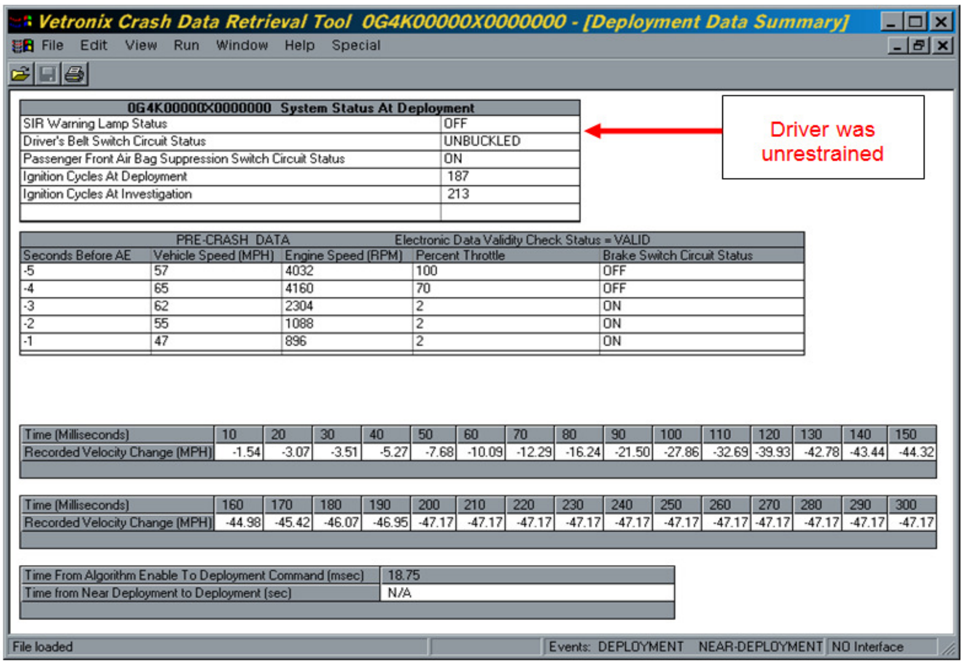


Figure 9 Post-crash Graph for Δv



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 10 Deployment Summary

Conclusion

Airbag micro-controllers with recordable memories (EDR), Controller Area Network (CAN) connectivity, and data transfer using Direct Memory Access (DMA) are becoming familiar features in modern automobiles.

EDR technology is a useful support tool for law enforcement personnel tasked with Road Traffic Accident (RTA) investigation and reconstruction. The Collision Investigator (CI) now can see, in *real time*, the sequence of events as they unfolded within a high degree of accuracy.

Our test results show the EDR method to be more descriptive and reliable than traditional techniques Conversely, EDR data could also be used to provide valuable evidence in the absence of *reliable* witnesses. The assembled data could then be used to corroborate or refute witness testimonies.

References

[1] A.J.T. Hijmering, CrashCube [online], http://www.crashcube.com, 2012.

[2] L. Martinez, Traffic Collision Investigation Manual for Patrol Officers (2nd edition), The Central Regional Law Officers Training Academy, 1994

[3] Unknown, Analysis of Event Data Recorder Data for Vehicle Safety Improvement, NHTSA, 2008.

[4] H.C Gabler, J. Hinch, and J. Steiner, Event Data Recorders: A Decade of Innovation, Society of Automotive Engineers, 2008

[5] J. Halderman, Automotive Technology: Principles, Diagnosis and Service (4th edition), Prentice Hall, 2012

[6] D. Radaelli, Event Data Recorder with Controller Area Network using PSoC® 3 and nvSRAM, Cypress, 2010

[7] S.Skorobogatov, Low Temperature Data Remanence in Static RAM [online], http://www.cl.cam.ac.uk/techreports/UCAM-CL-TR-536.html, 2002