THE ROLE OF EVENT DATA RECORDERS IN VEHICLE COLLISION RECONSTRUCTION

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Modern vehicles are equipped with hundreds of sensors that relay information to numerous electronic modules responsible for controlling various aspects of the vehicle. Some of these modules are capable of recording and storing data which can be used for the forensic analysis of a vehicle collision. Examples of these Event Data Recorders (EDRs) include Airbag Control Modules (ACMs), infotainment and telematics systems, GPS systems (internal and external), and collision mitigation systems. Recorded data can range from vehicle data (e.g. speed, brake on/off, cruise control status), to driver data (e.g. seatbelt status, phone use, steering wheel angle), and location data (e.g. time of collision, GPS coordinates). Collision reconstructionists can use EDR data as an unbiased source of technical information to increase the accuracy of their analyses. EDR data has been accepted as evidence in countless court trials, both civil and criminal. Data limitations and special circumstances must be carefully considered by an analyst, as continuous training is required to stay up to date on the rapidly evolving technology.

Highlights

- Important Functions of the Airbag Control Module
- Role of a Forensic Examiner
- EDR Downloading Methods
- Evolution of EDR Data
- Data Retention of EDRs
- Future of EDRs

In this paper, we will first examine the characteristics of vehicle accident reconstruction and the most common type of EDR. Next, we will discuss how this EDR data is downloaded, what data can be recorded by an EDR and how to preserve the data, the future of EDR data, and lastly, the importance of knowing and understanding how to properly critique EDRs to be of reliable value on a claim or litigated matter.

> "Collision reconstructionists can use EDR data as an unbiased source of technical information to increase the accuracy of their analyses"

The Role of a Forensic Examiner

Motor vehicle collisions are complex phenomena that many people have become accustomed to dealing with in their everyday lives. Whether a collision is responsible for the extra traffic on your way to work or if you have been rear-ended at a red light, collisions have never been a joyous discussion topic. Collisions are responsible for a significant amount of injuries, fatalities, and financial losses every year. In 2018, there were 1,743 motor vehicle fatalities and 108,371 collisions that resulted in personal injuries in Canada[1]. In the same year, there were a total of 36,560 motor vehicle fatalities and 1,894,000 injury-inducing collisions in the United States[2].

1 Canadian Motor Vehicle Traffic Collision Statistics: 2018, Transport Canada, ISSN: 1701-6223 (2020)
2 Traffic Safety Facts Annual Report, National Highway Traffic Safety Administration (NHTSA), 30 June 2020

Vehicle collision reconstruction is a branch of forensic investigation that relies on technical data and analysis to determine the cause of a collision and whether the involved parties could have avoided the incident. A collision reconstructionist can work on either civil or criminal cases and is typically employed by a private engineering firm or a public entity, respectively. Historically, reconstruction investigations have been reliant only on physical data (at the collision scene and/or the involved vehicles) and analysis methods were limited to scientific calculations, often based on assumed variables and engineering judgment.

However, for more than 25 years, there has been a significant increase in the amount of data that a reconstructionist can rely upon. From as early as 1994, select General Motors (GM) vehicles have been capable of recording collision related data such as vehicle speed change and occupant seatbelt status. This data is typically captured by the Airbag Control Module (ACM) and is routinely used for collision reconstruction analyses. An ACM, or any other electronic device that is capable of recording collision related data, is known as an Event Data Recorder (EDR).

Since the introduction of this technology in 1994, many other manufacturers have incorporated collision data recording (i.e. EDRs) into their vehicles. For example, most Ford and Toyota vehicles produced after 2001 are equipped with EDRs, while the majority of Chrysler vehicles produced only after 2006 have EDRs. In 2021, approximately 99% of new passenger vehicles in North America come factory equipped with at least one downloadable EDR.

There are numerous other sources of collision data in modern vehicles, including infotainment and telematics systems, GPS systems, and collision mitigation systems. Modern commercial vehicles (i.e. semi-trucks and semi-trailers) can also be equipped with similar EDRs, albeit with different recording characteristics. However, this paper will be limited to the most common type of passenger vehicle EDR, colloquially referred to as the "black box" and usually contained within the airbag control module.

ACM from a 1999 Chevrolet Suburban

ACM from a 2016 Volkswagen Golf

Important Functions of the Airbag Control Module

Modern vehicles are equipped with tens if not hundreds of sensors and Electronic Control Units (ECUs) that relay information across a complex communication network called the Controller Area Network (CAN bus). This allows for the near-instantaneous transmission of vehicle data between independent nodes that control various aspects of the vehicle, such as the safety system, audio system, or engine control unit.

For the purposes of this paper, we will be focussing on a specific ECU, the airbag control module. An ACM is a compact device that is responsible for monitoring and controlling the occupant restraint systems in a vehicle (e.g. airbags, seatbelts, etc.). It is the little brain in your car that beeps at you when seatbelts are not worn and is in charge of deciding whether to deploy your airbags or seatbelt pretensioners in a low- or high-severity collision. A functional ACM can be the difference between life or death.

A secondary function of an ACM is to record incident-related vehicle data in the event of a collision. Important crash and vehicle parameters are constantly monitored and provided to the ACM in volatile (erasable) memory. When the ACM detects that a crash has occurred (based on a change in vehicle acceleration), it reads a pre-determined amount of data from the volatile memory and stores that data into non-volatile memory.

As decided by one of many algorithms in the ACM, the stored data may or may not be erasable, depending on the type of crash, the severity of the crash, and the type of ACM. The stored data on an ACM can be downloaded by a trained individual with a specific tool, depending on the vehicle make, model, and model year (e.g. 2014 Kia Rio vs. 2019 Toyota Camry).

Methods to Download Event Data Recorder Data

EDR download through the diagnostic link connector (DLC)

There are primarily two methods to download and access EDR data:

1. Downloading the data through the diagnostic link connector (DLC, also known as the OBD II port), typically located below the steering wheel.
2. Downloading the data directly from the ACM (direct to module or D2M).

There is a third method, colloquially known as a "chip swap." However, this method is typically only used as a last resort in the case where extreme damage prevents both a DLC and a D2M download. As there are no differences between any of the download methods in terms of what data is retrieved, the only determinant in deciding which method should be used is the physical and electrical condition of the vehicle.

For example, if the vehicle's electrical system is so damaged that the DLC is no longer communicating with the ACM, or if either component is not receiving power from the vehicle battery, then the module should be downloaded via D2M. Generally, the module is located along the centreline of the vehicle, either below the radio and temperature controls on the dash, or beneath the centre console between the two front seats.

The Evolution of Event Data Recorder Data

Prior to September 2011, the amount of data captured by passenger vehicle EDRs varied significantly among manufacturers. Most EDRs captured, at a minimum, 2 to 2.5 seconds of pre-crash data, which included vehicle speed, brake status, and accelerator pedal status. Additionally, the majority of EDRs captured longitudinal vehicle speed change data (recorded over various lengths) and at a minimum, driver seatbelt status (buckled or not buckled). At this time, EDR data was either incredibly useful or redundant, as there was no legislature or regulations involved.

On September 1, 2011, a new federal regulation was instituted in the United States. This regulation is known as 49 CFR Part 563 – Event Data Recorders. It mandates that any EDR voluntarily installed in a passenger vehicle must be downloadable by a commercially available tool and must comply with certain requirements. Vehicles equipped with an EDR must meet or exceed these minimum requirements, including recording a specific amount of data at specified sample rates for a pre-defined amount of time.

The usefulness and amount of EDR data from most vehicles was improved as a result of 49 CFR 563, while certain others became less useful and less common (due to the introduction of a trigger threshold, which is beyond this scope of discussion). Some of the more useful pre- and post-crash datasets that are available from modern EDRs are summarized below.

In general, EDRs can record up to 5 seconds of pre-crash data, including:

- Vehicle Speed
- Steering Wheel Angle
- Engine Speed (RPM)
- Yaw Rate and Roll Rate
- Brake Pedal and Cruise Control On/Off
- ABS and Stability Control Activity
- Accelerator Pedal Position
- Gear Shift Position

In general, EDRs can record collision data as well, including:

- Recording Complete (Yes/No)
- Odometer and Ignition Cycles
- Diagnostic Trouble Codes
- Passenger Size Classification
- Collision ΔV up to Every 1 msec (Multiple Directions and Angles)
- Safety System Status (Including Driver and Passenger Seatbelt Statuses)

Pre-Crash Data -5 to 0 sec [2 samples/sec] (First Record)

Times (sec)	Speed vehicle indicated MPH [km/h]	Accelerator pedal, % full	Service brake, on/off	Engine RPM	Steering Wheel Angle (degrees)	Stability Control Lateral Acceleration (g)	Stability Control Longitudinal Acceleration (g)
- 5.0	60.3 [97.0]	22	Off	1,900	3.2	-0.042	-0.006
- 4.5	60.3 [97.0]	21	Off	1,900	3.5	-0.005	-0.026
- 4.0	60.3 [97.0]	7	Off	1,900	4.2	0.015	-0.043
- 3.5	60.3 [97.0]	2	Off	1,900	4.7	0.005	-0.065
- 3.0	59.7 [96.0]	0	Off	1,900	4.7	0.005	-0.065
- 2.5	59.0 [95.0]	8	Off	1,800	4.7	0.005	-0.084
- 2.0	59.0 [95.0]	24	Off	2,000	3.5	-0.006	-0.006
- 1.5	59.0 [95.0]	27	Off	1,900	3.2	-0.005	0.008
- 1.0	59.0 [95.0]	19	Off	1,900	-15.2	-0.163	-0.014
- 0.5	54.7 [88.0]	0	On	1,800	-61.5	-0.707	-0.568
0.0	47.2 [76.0]	0	On	1,500	-99.5	-0.904	-0.432

Pre-crash data from a 2012 Ford Escape that began an emergency steering and braking manoeuvre just before impact

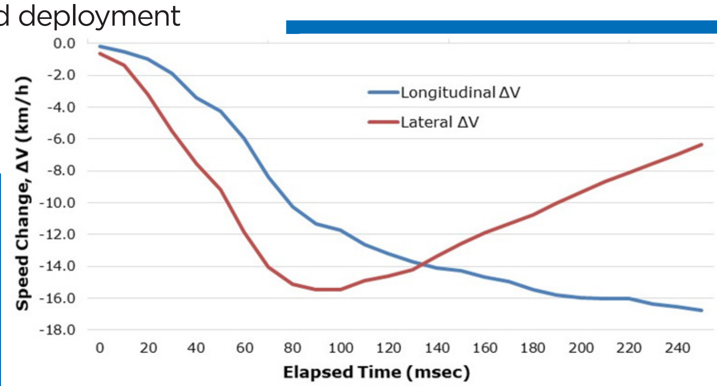
Event Data Recorder Data Retention

In the event of a collision, the ACM will try to predict the severity of the crash and decide whether to deploy the vehicle's safety systems (e.g. seatbelt pretensioners or airbags). If any restraints are deployed, the EDR will classify the collision as a "deployment event." In comparison, if the event is predicted to be of low severity (e.g. fender bender at an intersection), the ACM will not deploy any restraints. In this case, the collision would be classified as a "non-deployment event."

In general (for safety concerns), an ACM must be replaced after it has experienced a deployment event. Conversely, an ACM can typically handle an indefinite number of non-deployment events.

Most EDRs have enough memory to store between one and three collision events. However, some specific modules can store up to six collision events. A stored deployment event is typically permanent and cannot be overwritten. Conversely, a stored non-deployment event can be easily overwritten by subsequent or more severe collisions, or both, depending on the type of module and the available memory.

In terms of storage length, EDR event data will typically never be erased or lost unless the vehicle is involved in another collision (in which case the data will be overwritten). However, some older generation vehicles (i.e. Toyotas, GMs, and Fords) may overwrite data during routine driving operations. The data retention of an EDR is different for every vehicle and can vary drastically between subsequent model years.



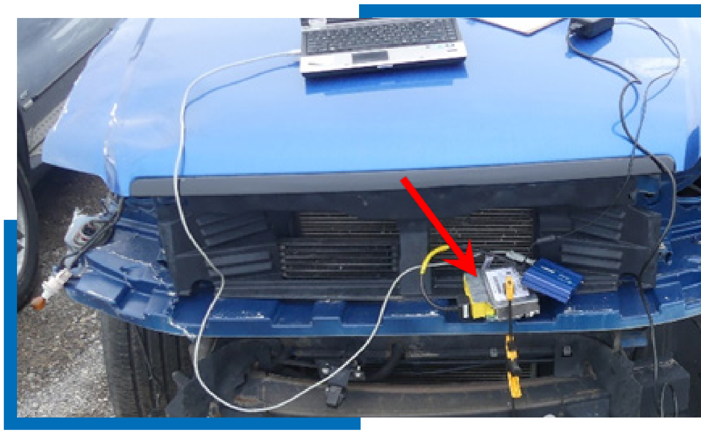
Collision data from a 2012 Ford Escape that sustained a total speed change of about 20 km/h

The best way to preserve EDR data is to stop driving the vehicle. In the case of a deployment event where the ACM is replaced, the old (removed) ACM will have the collision data retained inside. If the removed module is kept safe and not repowered, the collision data will remain downloadable for an indefinite amount of time. For newer (made after 2012) vehicles that have sustained a non-deployment event, collision data will generally be preserved while driving, provided that the vehicle is not involved in a subsequent collision.

The Influence and Future of Event Data Recorders

Prior to the introduction of EDRs in 1994, a reconstructionist could only analyze pre-impact speeds and movements of vehicles when there were pre-impact road markings, such as tire or skid marks. Reconstruction analyses were limited to estimating a vehicle's speed change from the sustained damage and its post-impact movements, utilizing momentum and energy calculations to determine the vehicle speeds at impact.

Direct to module EDR download with the ACM removed from the vehicle



Passenger vehicle EDRs are an invaluable source of collision data, providing a history of vehicle and driver inputs that would otherwise be unknown. EDRs have been accepted in countless trials as technical evidence, and are the foundation for understanding what happened in the seconds before a crash. Approximately 99% of new vehicles are equipped with at least one EDR. Although the ACM generally contains the most relevant information, there are plenty of other sources of electronic collision data.

As we move into the future, the older generation of vehicles will begin to phase out of the market. For example, a 1990 Honda could be replaced by a 2016 Toyota with extensive amounts of vehicle control history data, forward-facing cameras that take pictures of oncoming hazards, and a downloadable module that knows whether the driver was texting on their cell phone prior to a collision. The electronic data on modern vehicles is evolving rapidly and there is more information available to reconstructionists than ever before.

However, EDRs and their counterparts are not all-knowing. A list of pre-impact speeds cannot be validated without knowing the vehicle's tire size and the tire-roadway conditions at the time of the incident. The EDR reported speed change must match the damage profile of the vehicle. A seatbelt switch is only checking for the presence of a latch within the buckle, and whether the occupant was actually wearing their seatbelt can only be confirmed by physically inspecting the seatbelt components and the vehicle interior.

Direct to module EDR download with the ACM still installed in the vehicle

Passenger vehicle EDR data should only be downloaded and analyzed by a trained professional. Failure to follow the correct download procedures can result in a loss or overwriting of collision data, and incorrect analysis can lead to a misunderstanding of the collision sequence and dynamics. EDR data must be analyzed in conjunction with the available vehicle and scene data, as limiting a reconstruction analysis to only EDR data is erroneous.