# EVENT DATA RECORDERS: AN IMPARTIAL WITNESS

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## *Abstract*

*Real world field studies can yield tremendous insight into the factors that precipitate motor vehicle collisions. The strength of such in-depth studies is the quality of the data obtained, especially when this data is based on solid physical evidence. While witness statements can provide some clarification of crash events, the fallibility of eyewitness memory and bias can result in substantial errors. Furthermore, many fatal single vehicle crashes have no witnesses leaving investigators to rely solely on scientific analysis of the available physical evidence. High-level data from real-world collisions regarding crash severity, pre-crash speeds, perception and reaction, evasive inputs and seatbelt use are of great importance in the resolution of legal issues and are critical data elements to researchers conducting studies into vehicle collisions. Many late-model General Motors light-duty vehicles are equipped with event data recorders (EDRs) that capture data relating to the crash pulse, the time history of the velocity change, and in some cases the time history of a number of pre-crash data elements including, vehicle speed, brake switch status, throttle position and engine speed. The objective of this research is to examine the role of the EDR in the reconstruction and understanding of fatal crashes. Thirteen real world collisions involving a driver fatality in a vehicle equipped with an EDR were studied. In each case a detailed collision investigation and reconstruction was conducted to determine the crash events and validate the recorded data. The EDR data greatly improved the understanding of pre-crash events and often provided critical insight that otherwise would have remained unknown.*

## *Résumé*

*Les enquêtes de collisions permettent d'obtenir des renseignements importants sur les facteurs qui sont à l'origine des collisions. La valeur de ces enquêtes en profondeur réside dans la qualité des données recueillies, tout spécialement lorsque ces données sont appuyées sur des évidences physiques concrètes. Bien que les témoins puissent parfois expliquer le déroulement des événements, les oublis et les biais des témoins peuvent aussi introduire des erreurs importantes dans la genèse des événements. De plus, un grand nombre de collisions mortelles avec un seul véhicule ne laisse souvent aucun témoin et ainsi les enquêteurs ne peuvent se baser que sur des évidences physiques. Des données de haute qualité sur la sévérité de l'impact, les vitesses préimpact, les temps de perception et de réaction, les actions correctives et l'utilisation des ceintures sont des éléments importants qui permettent de solutionner les aspects légaux de la collision et sont autant d'éléments critiques pour les chercheurs. Un grand nombre de véhicules de tourisme fabriqués par General Motors sont équipés d'enregistreur de données de collision (EDR) qui recueillent les données préimpact relatives à l'impulsion de la* *collision, la variation de la vitesse ainsi que l'historique de certaines données telles la vitesse, l'utilisation des freins, la position de l'accélérateur et le régime moteur. L'objectif de cette étude est d'examiner le rôle des EDR dans la compréhension et la reconstitution des collisions automobiles. Treize collisions au cours desquelles un conducteur est décédé dans un véhicule équipé d'un EDR ont été étudiées en profondeur. Dans chacun des cas, une enquête détaillée et une reconstitution ont été élaborées pour déterminer la séquence des événements et pour valider les données enregistrées. Les données obtenues de l'EDR améliorent grandement la compréhension des événements antérieurs à la collision et permettent aussi d'obtenir des renseignements qui autrement resteraient inconnus.*

# INTRODUCTION

High-level data from real-world collisions on pre-crash events are fundamental to researchers conducting studies into pre-crash factors. Real world field studies can yield tremendous insight into the factors that precipitate motor vehicle collisions. The strength of such in-depth studies are the quality of data obtained, especially when these data are based on expert reconstruction of physical evidence.

The purpose of this paper is to demonstrate how the Event Data Recorder (EDR) in conjunction with reconstruction of physical evidence can fill the gaps in knowledge regarding collision causation. Recorded pre-crash and longitudinal delta-V data are analyzed in the light of vehicle and scene evidence collected by investigators in order to determine the role of speed, driver inattentiveness and other factors in the causation of a sample of 13 fatal collisions.

## Event Data Recorders (EDR)

Many late-model General Motors' light-duty vehicles are equipped with event data recorders that form part of the sensing and diagnostic modules (SDM) that control deployment of airbag systems. EDRs capture certain information relating to both the pre-crash and crash phases of motor vehicle collisions [1]. These systems can be interrogated by means of a Crash Data Retrieval (CDR) tool allowing the stored data to be retrieved, examined and reported [2 3 4 5 6].

Longitudinal deceleration during the crash event is measured by a uni-axial accelerometer within the SDM. In some late model vehicles, bi-axial accelerometers also record the lateral deceleration thus, providing a more complete picture of the crash event. When a consecutive number of deceleration samples exceeds -2 g (where g is acceleration due to gravity) the deployment decision algorithm is enabled (AE); this determines whether airbag deployment is warranted. The cumulative forward delta-V is determined by integrating the average of four acceleration samples over each 1.25 millisecond period and is recorded every 10 milliseconds.

Pre-crash information typically consists of the vehicle's speed, engine speed (rpm), throttle position (%), and the status of the brake light switch (on or off) for a period of five seconds prior to the event that triggered the recording. In general, pre-crash recording is terminated once algorithm enable occurs. In addition, the EDR indicates the status of the driver's seat belt buckle switch (buckled or unbuckled) at the time of the event. Data records may be captured for both airbag deployment events and certain non-deployment events. In general, a non-deployment event consists of vehicle deceleration sufficient to trigger the sensing algorithm, but not severe enough to require deployment of the airbag. Both types of events occurred in our present series.

A speed sensor mounted directly on the manual or automatic transmission output shaft measures vehicle speed. The speed recorded by the EDR has been found in past studies to be a reliable measure of ground speed [7]. However, when the vehicle is skidding or the ABS is activated prior to impact, the recorded speed may not be an accurate measure of ground speed. Investigators must consider the pre-crash actions of the vehicle when assessing the recorded speed data. Large speed changes in a 1 s interval are often a sign that the recorded speed is no longer an accurate measure of the true ground speed. This may occur when there is significant slipping of the wheel due to hard braking or lateral sliding. In some cases the speed at -1 s to AE may actually occur after the impact. The recorded speed data is likely more reliable prior to any evasive maneuvers or loss of control.

Engine speed is detected by a sensor located on the crankshaft or camshaft of the vehicle. The frequency of the signal generated is used by the Powertrain control module (PCM) to determine crankshaft position and speed. Throttle position is determined by a potentiometer positioned directly on the throttle body assembly. It relays how much throttle the driver is applying by reacting to throttle changes. Both these signals are sent to the PCM to be digitized and then sampled by the airbag module. The brake switch status indicates brake usage by the driver and is reported as either on or off. It is commonly read by a mechanical switch located on the brake pedal. Brake switch status, throttle position and engine speed are useful for determining the actions taken by the driver prior to the collision. When examined in conjunction with the physical evidence, investigators can often tell whether the driver was coasting, driving erratically or braking in the five intervals recorded before deployment and/or non deployment.

**Table 1 Pre-Crash Data**

| Time to AE (s) | Vehicle Speed (km/h) | Engine Speed (rpm) | Percent Throttle (%) | Brake Switch Circuit Status | Steering Wheel Angle (degrees) |
|---|---|---|---|---|---|
| -5 | 93 | 2240 | 42 | OFF | -16 |
| -4 | 93 | 1920 | 14 | ON | -32 |
| -3 | 87 | 1728 | 11 | ON | -48 |
| -2 | 84 | 1536 | 9 | OFF | 16 |
| -1 | 80 | 2816 | 49 | OFF | 112 |

Some EDRs in late model GM vehicles also record the steering wheel angle for a period of five seconds prior to AE. Past investigations have shown that the recorded angles are in integer multiples of ± 16 degrees. One would assume that a complete clockwise revolution of the steering wheel would be recorded as + 360 degrees. This data can be very useful for determining pre-crash steering inputs. Table 1 shows the pre-crash data for a case where a driver steered to avoid an animal on the road prior to striking a tree. Note the sharp steering input between -3 and -1 s to AE.

Other useful information recorded by the EDR is the driver's seatbelt status which reports whether the seatbelt is buckled or unbuckled. This circuit is connected directly to the SDM. It is important to note that if the vehicle electrical system has been compromised during the collision the recorded belt status may be suspect. Thus, in some cases the recorded belt buckled status may not be representative of the actual buckle status at impact. Also, the system cannot recognize if the driver has buckled the seatbelt but is not wearing it. Inspection of the seatbelt using standard accident reconstruction techniques is essential for determining actual belt usage.

# METHODOLOGY

A sample of fatal real-world motor vehicle collision cases, subject to traditional detailed investigation and reconstruction methods have been included in this study. The cases chosen were obtained from Transport Canada's ongoing collision investigation series. These investigations include airbag deployment crashes, severe side impact crashes and a human-factors based study into the causes that precipitate fatal collisions. All eligible crashes required the availability of pre-crash data, downloaded from the event data recorder, in at least one of the involved vehicles. It was also necessary, for the purposes of this study, that EDR pre-crash data be available in a late-model General Motors' vehicle in which the driver was fatally injured. In this demonstration project, no attempt was made to sample crashes in any systematic manner. The intention was merely to capture pre-crash data elements from EDRs to compare to information determined by conventional research techniques. By such means, the utility and limitations of these data with regard to identifying and quantifying issues related to collision causation can be explored.

# RESULTS

A summary of the thirteen fatal crashes under study is provided in Table 2. Narratives and pre-crash data for these collisions are provided below.

**Table 2 Summary of the fatal crashes**

| | Case 1 | Case 2 | Case 3 | Case 4 | Case 5 | Case 6 | Case 7 | Case 8 | Case9 | Case 10 | Case 11 | Case 12 | Case 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **HUMAN** | | | | | | | | | | | | | |
| Driver age / gender | 42 / M | 51 / F | 28 / M | 84 / F | 22 / F | 29 / M | 26 / M | 17 / M | 44 / F | 26 / M | 18 / M | 44 / M | 20 / M |
| Alcohol consumption | N | N | Y | N | N | Y | N | N | N | Y | N | U/K | N |
| Seatbelt use | N | Y | N | Y | N | Y | N | Y | Y | N | N | N | Y |
| Maximum recorded speed (km/h) | 64 | 92 | 113 | 90 | 95 | 145 | 100 | 113 | 77 | 160 | 159 | 156 | 129 |
| Speed in excess of limit (km) | 14 | 2 | 43 | 10 | 15 | 65 | 20 | 33 | -3 | 70 | 79 | 76 | 79 |
| **ENVIRONMENT** | | | | | | | | | | | | | |
| Rural / Urban | U | R | R | R | R | R | R | R | R | R | R | R | U |
| Posted speed limit (km/h) | 50 | 90 | 70 | 80 | 80 | 80 | 80 | 80 | 80 | 90 | 80 | 80 | 50 |
| Intersection | Y | Y | Y | N | N | N | N | N | N | N | N | N | Y |
| Curve | N | N | Y | N | N | Y | N | N | Y | N | N | N | N |
| Road type | Asphalt | Asphalt | Asphalt | Asphalt | Asphalt | Asphalt | Asphalt | Asphalt | Asphalt | Asphalt | Gravel | Gravel | Asphalt |
| Road surface | Dry | Dry | Dry | Dry | Dry | Dry | Dry | Slushy | Dry | Dry | Dry | Dry | Dry |
| Weather | Clear | Clear | Clear | Clear | Clear | Clear | Clear | Clear | Clear | Clear | Clear | Clear | Clear |
| Lighting | Dark | Light | Dark | Light | Dark | Light | Light | Dark | Light | Light | Dark | Dark | Light |
| **VEHICLE** | | | | | | | | | | | | | |
| Number of vehicles | 2 | 3 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 1 | 1 | 1 | 1 |
| Object struck | Truck | Truck | Car | Car | Pickup | Car | Car | Van | Truck | Ground | Ground | Tree | Pole |
| Impact surface (fatal impact) | Right | Front | Rollover | Front | Left | Front | Front | Right | Front | Rollover | Rollover | Left | Left |
| Loss of control | N | N | N | N | Y | Y | Y | Y | N | Y | Y | Y | Y |
| EDR Delta-V (km/h) (frontal impacts only) | N/A | 62 | 40 | 85 | N/A | 83 | 53 | N/A | 115 | N/A | N/A | NA | N/A |
| SLAM Delta-V (km/h) | 48 | 63 | 41 | 83 | 38 | 85 | 52 | 47 | 104 | N/A | N/A | 60 | 26 |
| Rollover speed (km/h) | N/A | N/A | 40 | N/A | N/A | N/A | N/A | N/A | N/A | 69 | 68 | 80 | N/A |
| Maximum throttle (%) | 5 | 0 | 73 | 15 | 100 | 22 | 17 | 18 | 8 | 49 | 97 | 86 | 100 |
| Pre-impact braking recorded | N | Y | Y | Y | Y | Y | Y | Y | N | Y | Y | Y | Y |

## Multiple Vehicle Collisions

**CASE 1:** This crash occurred at night at the traffic-light-controlled intersection of two posted 50 km/h urban arterials. The right side of a westbound 2001 Pontiac Montana minivan was struck by the front end of a southbound tow-truck. The unrestrained 42-year-old male driver of the Montana was ejected and fatally injured. A witness reported that the Montana was northbound when it turned left in front of the tow-truck. The driver of the tow-truck was uncertain about the pre-crash events. The EDR data indicated that the Montana was traveling at a relatively constant speed of 64 km/h with no braking in the five pre-crash intervals and would not likely have been in the process of turning left. Reconstruction of the physical evidence supported the recorded data and it was apparent that one of the vehicles had failed to stop at the red light. The EDR pre-crash data was critical in the reconstruction of this crash.

**Table 3 Pre-Crash Data for CASE 1**

| Seconds to AE (s) | Vehicle Speed (km/h) | Engine Speed (rpm) | Percent Throttle (%) | Brake Switch Circuit Status |
|---|---|---|---|---|
| -5 | 64 | 1216 | 0 | OFF |
| -4 | 64 | 1152 | 0 | OFF |
| -3 | 63 | 1344 | 5 | OFF |
| -2 | 63 | 1280 | 0 | OFF |
| -1 | 63 | 1344 | 0 | OFF |

**Figure 1 2001 Pontiac Montana**

**CASE 2:** This crash occurred in clear daylight hours on a rural highway with a 90 km/h posted speed limit. The fully-restrained 51-year-old female driver of a southbound 2003 Chevrolet Avalanche pickup truck was slowing to make a left turn at an intersection. A northbound tractor-trailer veered into the southbound lane after being struck on its right side by the front end of a westbound vehicle that failed to stop at the stop sign. The truck and Avalanche collided head-on, causing extensive frontal damage to the Avalanche. The EDR recorded a maximum delta-V of 62 km/h at 110 ms; however, the frontal impact appeared to be incomplete at the end of recording. According to the retrieved pre-crash data, the driver of the Avalanche was gradually braking on approach to the intersection, starting at the 4 second to AE interval. A large speed change from -2 to - 1 s to AE was indicative of emergency braking.

**Table 4 Pre-Crash Data for CASE 2**

| Seconds to AE (s) | Vehicle Speed (km/h) | Engine Speed (rpm) | Percent Throttle (%) | Brake Switch Circuit Status |
|---|---|---|---|---|
| -5 | 92 | 1600 | 0 | OFF |
| -4 | 90 | 1536 | 0 | ON |
| -3 | 80 | 1408 | 0 | ON |
| -2 | 68 | 1024 | 0 | ON |
| -1 | 43 | 640 | 0 | ON |

**Figure 2 2003 Chevrolet Avalanche**

**CASE 3:** The 28-year-old unrestrained male driver of a 2000 Chevrolet Blazer SUV was traveling eastbound at high speed around a sharp curve on a posted-70 km/h rural roadway approaching a hidden intersection. A southbound passenger car entered the intersection in front of the Blazer. The driver of the Blazer braked hard but the vehicle's front end struck the front right side of the passenger car. The Blazer subsequently traveled onto the roadside and rolled several times, its driver was ejected and fatally crushed. The belted 26-yr-old female right front passenger sustained only minor injuries. EDR data indicated a top speed of 113 km/h at -3 s to AE and heavy acceleration on the curve. A recorded longitudinal delta-V of 40 km/h was used to calculate an impact speed of approximately 78 km/h for the Blazer. The EDR data was the only evidence of significant pre-impact braking by the driver of the Blazer. The role of speed would not have been known without the EDR data.

**Table 5 Pre-Crash Data for CASE 3**

| Seconds Before AE (s) | Vehicle Speed (km/h) | Engine Speed (rpm) | Percent Throttle (%) | Brake Switch Circuit Status |
|---|---|---|---|---|
| -5 | 109 | 1984 | 51 | OFF |
| -4 | 111 | 1984 | 67 | OFF |
| -3 | 113 | 2496 | 73 | OFF |
| -2 | 111 | 2048 | 0 | ON |
| -1 | 90 | 1664 | 0 | ON |

**Figure 3 2000 Chevrolet Blazer**

**CASE 4:** The 84-year-old belted female driver of a 2000 Pontiac Grand Am was fatally injured when her vehicle collided head-on with another passenger car. The Grand Am was traveling westbound on a dry rural highway in clear daylight. The eastbound passenger car crossed into the oncoming lane and into the path of the Grand Am. Pre-crash data indicated that the Grand Am was initially traveling at 90 km/h which was slightly over the posted speed limit of 80 km/h. The maximum recorded longitudinal delta-V of 85 km/h at 100 ms from AE was supported by damage analysis. The impact speed of the Grand Am was calculated to be 40 km/h and the impact speed of the other vehicle was calculated to be 105 km/h using the physical evidence and EDR data. There was significant pre-impact braking by the driver of the Grand Am in response to what was likely a gradual veering of the passenger car after its driver had fallen asleep. The EDR data validated witness reports that the Grand Am was being driven normally prior to the crash and that the driver of the other vehicle was inattentive.

**Table 6 Pre-Crash Data for CASE 4**

| Seconds to AE (s) | Vehicle Speed (km/h) | Engine Speed (rpm) | Percent Throttle (%) | Brake Switch Circuit Status |
|---|---|---|---|---|
| -5 | 90 | 1792 | 15 | OFF |
| -4 | 90 | 1664 | 15 | OFF |
| -3 | 90 | 1792 | 4 | ON |
| -2 | 64 | 1344 | 4 | ON |
| -1 | 48 | 1152 | 4 | ON |

**Figure 4 2000 Pontiac Grand Am**

**CASE 5:** A 2001 Chevrolet Cavalier Z24 was traveling eastbound on a posted-80 km/h rural roadway at night. The 22-yr-old unrestrained female driver lost control and the vehicle went into a clockwise yaw crossing into the path of a westbound pickup truck. The front end of the pickup struck the front left side of the Cavalier. The pre-crash data indicated a maximum speed of 95 km/h. The brake switch circuit status data was on at -1 s to AE and there was likely hard pre-impact braking. It should be noted that vehicle dynamics and/or data over sampling guarantee that the vehicle speed from the EDR is not representative of the actual speed over the ground at -1s. The driver's belt switch circuit status was recorded as unbuckled and no loading evidence was identified by police. The unrestrained 20-year-old right front male passenger sustained only minor lacerations. He reported that the driver was driving erratically prior to losing control. The EDR data supported this scenario with evidence of large throttle inputs around the time of loss of control.

**Table 7 Pre-Crash Data for CASE 5**

| Seconds to AE (s) | Vehicle Speed (km/h) | Engine Speed (rpm) | Percent Throttle (%) | Brake Switch Circuit Status |
|---|---|---|---|---|
| -5 | 93 | 3136 | 82 | OFF |
| -4 | 93 | 3072 | 100 | OFF |
| -3 | 95 | 3136 | 0 | OFF |
| -2 | 82 | 2688 | 0 | OFF |
| -1 | 3 | 192 | 0 | ON |


**Figure 5 2001 Chevrolet Cavalier Z24**

**CASE 6:** A 2003 Pontiac Sunfire was traveling southbound at high speed on an S-curve section of an 80 km/h-posted rural roadway. The fully-restrained 29-year-old male driver of the Sunfire navigated the first curve to the right but the vehicle egressed onto the right gravel shoulder near the apex of the following curve to the left. The driver steered to the left and the Sunfire traveled back onto the roadway and crossed into the path of an oncoming car. The driver of the Sunfire braked hard just prior to impact. Tire marks were found on the gravel shoulder 100 m north of the point of impact. The maximum recorded longitudinal delta-V of 83 km/h at 105 ms was supported by damage analysis. There were no witnesses but the physical evidence and EDR data supported high speed as a likely factor in loss of control.

**Table 8 Pre-Crash Data for CASE 6**

| Seconds to AE (s) | Vehicle Speed (km/h) | Engine Speed (rpm) | Throttle Position (%) | Brake Switch Circuit Status |
|---|---|---|---|---|
| -5 | 145 | 3392 | 0 | ON |
| -4 | 138 | 3136 | 22 | OFF |
| -3 | 137 | 3200 | 0 | OFF |
| -2 | 129 | 3008 | 0 | OFF |
| -1 | 108 | 2304 | 0 | ON |

**Figure 6 2003 Pontiac Sunfire**

**CASE 7:** The unrestrained 26-year-old male driver of a 2000 Pontiac Sunfire was traveling southbound on an 80 km/h-posted rural roadway just before dawn. A northbound car veered into the southbound lane and the vehicles collided head-on. The EDR data indicated that the Sunfire was being driven at a constant speed of 100 km/h prior to braking. The EDR recorded a maximum longitudinal delta-V of 53 km/h. An impact speed of 85 km/h was calculated using EDR delta-V data and reconstruction of the physical evidence. There was evidently a short interval of pre-impact braking by the driver and the brake status was on at the -1 s to AE interval only. This short interval of braking suggested that the oncoming vehicle suddenly veered into the path of the Sunfire leaving little time to react. The roadway was bordered by grass and there were no shoulders. Pre-crash information for the other vehicle would have been beneficial in determining the actions taken by its driver.

**Table 9 Pre-Crash Data for CASE 7**

| Seconds to AE (s) | Vehicle Speed (km/h) | Engine Speed (rpm) | Percent Throttle (%) | Brake Switch Circuit Status |
|---|---|---|---|---|
| -5 | 100 | 2112 | 17 | OFF |
| -4 | 100 | 2112 | 17 | OFF |
| -3 | 100 | 2112 | 17 | OFF |
| -2 | 100 | 2112 | 17 | OFF |
| -1 | 98 | 2112 | 0 | ON |

**Figure 7 2000 Pontiac Sunfire**

**CASE 8:** This high-severity collision occurred in the afternoon on a slushy 80 km/h-posted two-lane rural highway in light snowfall. A 2006 Pontiac Equinox SUV was traveling eastbound around a curve to the left when the fully-restrained 17-yr-old male driver with a G2 license lost control. The vehicle entered into a counter clockwise rotation and crossed into the path of an oncoming westbound cargo van. The front end of the van struck the right side of the SUV in a T-type configuration. Pre-crash data indicated that the Equinox was being driven at 113 km/h at -4 s to AE. The EDR data indicated hard braking prior to impact. All five occupants of the SUV were fatally injured. The EDR data was critical for determining the initial speed of the SUV. The vehicle may have drifted onto the snow-covered shoulder prior to loss of control. However, speed too fast for conditions was likely a causal factor in this case.

**Table 10 Pre-Crash Data for CASE 8**

| Seconds to AE (s) | Vehicle Speed (km/h) | Engine Speed (rpm) | Percent Throttle (%) | Brake Switch Circuit Status |
|---|---|---|---|---|
| -5 | 108 | 2240 | 18 | OFF |
| -4 | 113 | 2240 | 1 | OFF |
| -3 | 105 | 1856 | 1 | OFF |
| -2 | 85 | 1408 | 1 | ON |
| -1 | 63 | 896 | 1 | ON |

**Figure 8 2006 Pontiac Equinox**

**CASE 9:** A 2005 Chevrolet Malibu Maxx was traveling northbound approaching a curved section of a two-lane rural roadway. The fully-restrained 44-year-old female driver failed to negotiate a curve to the right and crossed into the path of a southbound transport truck. The two vehicles collided head on. Pre-crash data retrieved from the EDR indicated that the driver was traveling at a relatively constant speed of 76 km/h in the five intervals prior to algorithm enable. Witnesses observed the vehicle traveling straight with no sign of braking or steering. The EDR also recorded a steering wheel angle of -16 degrees in all five sampling intervals and there was no evidence of a pre-crash steering input by the driver. The change in velocity was recorded over a period of 300 ms and a maximum delta-V of 115 km/h was recorded. The steady state nature of the EDR data indicated that the driver was very likely being inattentive.

**Table 11 Pre-Crash Data for CASE 9**

| Seconds to AE (s) | Vehicle Speed (km/h) | Engine Speed (rpm) | Percent Throttle (%) | Antilock Brake System Active |
|---|---|---|---|---|
| -5 | 77 | 1408 | 8 | NO |
| -4 | 76 | 1408 | 6 | NO |
| -3 | 76 | 1408 | 6 | NO |
| -2 | 76 | 1408 | 6 | NO |
| -1 | 76 | 1408 | 6 | NO |

**Figure 9 2005 Chevrolet Malibu**

## Single Vehicle Collisions

**CASE 10:** This crash occurred in daylight on a rural highway with a 90 km/h-posted speed limit. The 26-year-old unrestrained male driver of a southbound 2001 Chevrolet Corvette Convertible was traveling at high speed around a gentle curve to the left when the vehicle's right side tires traveled onto the west gravel shoulder. The driver steered to the left and the vehicle crossed into the oncoming lane. The vehicle was equipped with stability control but it was unknown if it was activated. The Corvette continued onto the east gravel shoulder and into the grassy ditch where it tripped and tumbled end for end. No tire marks were identified on the roadway. The fatally injured driver was found in the inverted vehicle at final rest. The vehicle's speed was calculated to be 90 km/h when it left the east shoulder of the roadway. There was insufficient scene evidence to allow calculation of the initial speed when the driver lost control.

**Table 12 Pre-Crash Data for CASE 10**

| Seconds Before AE (s) | Vehicle Speed (km/h) | Engine Speed (rpm) | Percent Throttle (%) | Brake Switch Circuit Status |
|---|---|---|---|---|
| -5 | 161 | 2816 | 49 | OFF |
| -4 | 158 | 2752 | 0 | OFF |
| -3 | 154 | 2624 | 0 | OFF |
| -2 | 143 | 2496 | 0 | ON |
| -1 | 113 | 1920 | 16 | OFF |

**Figure 10 2001 Chevrolet Corvette**

**CASE 11:** The 2000 Chevrolet Cavalier was traveling westbound at high speed on a straight and level rural gravel roadway in the early morning hours. The 18-year-old unrestrained male driver lost control on the roadway and the vehicle traveled onto the north roadside where it tripped and rolled. The driver was ejected and found in close proximity to the vehicle at final rest. The EDR recorded a maximum speed of 159 km/h and heavy throttle. The brake switch status was on at -1 s to AE and braking was very likely a reaction to the loss of control. Tire marks on the gravel indicated that loss of control was gradual and started more than 125 m from where the vehicle tripped and rolled. High speed and too much steering input on a gravel roadway appeared to have caused the loss of control. The speed of the Cavalier at the start of the rollover was calculated to be 70 km/h. However the lack of definitive roadway evidence prevented accurate calculation of initial speed. The EDR pre-crash data provided a valuable estimate of initial speed which otherwise would not have been available.

**Table 13 Pre-Crash Data for CASE 11**

| Seconds Before AE (s) | Vehicle Speed (km/h) | Engine Speed (rpm) | Percent Throttle (%) | Brake Switch Circuit Status |
|---|---|---|---|---|
| -5 | 159 | 3712 | 67 | OFF |
| -4 | 159 | 3712 | 97 | OFF |
| -3 | 159 | 3648 | 82 | OFF |
| -2 | 158 | 3072 | 0 | OFF |
| -1 | 130 | 1408 | 0 | ON |

**Figure 11 2000 Chevrolet Cavalier**

**CASE 12:** The 2002 Chevrolet Silverado Pickup was traveling northbound on an 80 km/h-posted rural gravel roadway at high speed. It was a clear night. The 44-year-old unrestrained male driver lost control. Tire marks on the gravel indicated that the vehicle went into a sudden counterclockwise rotation and traveled onto the west roadside with its right side leading. The pickup furrow-tripped on the grass and went into a lateral rollover just before contacting a large tree with its left side. The driver was partially ejected and fatally injured. The EDR recorded a maximum speed of 156 km/h prior to loss of control. The brake status was on at -2 s to AE. The area where the vehicle began to rotate likely coincided with the onset of hard braking. The recorded speed at -2 s to AE was not indicative of ground speed because of hard braking and lateral sliding. The EDR data verified the reconstruction of the physical evidence and allowed a more exact determination of initial speed.

**Table 14 Pre-Crash Data for CASE 12**

| Seconds Before AE (s) | Vehicle Speed (km/h) | Engine Speed (rpm) | Percent Throttle (%) | Brake Switch Circuit Status |
|---|---|---|---|---|
| -5 | 156 | 4160 | 80 | OFF |
| -4 | 156 | 4160 | 60 | OFF |
| -3 | 150 | 3200 | 0 | OFF |
| -2 | 111 | 1856 | 86 | ON |
| -1 | 101 | 3392 | 0 | OFF |

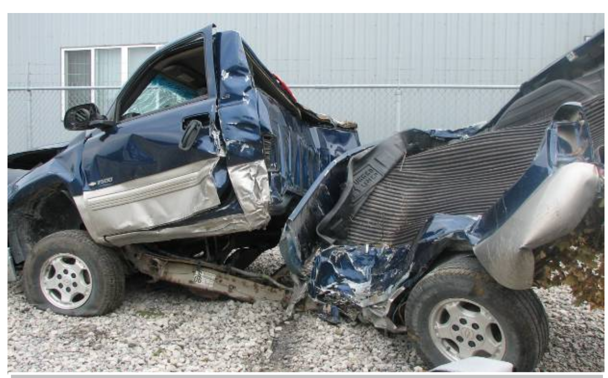

**Figure 12 2002 Chevrolet Silverado**

**CASE 13:** The 2000 Pontiac Grand Am was traveling northbound at high speed on a busy 50 km/h-posted urban arterial approaching an intersection. A vehicle in the southbound passing lane made a left turn to the east at the intersection in front of the Grand Am. The 20-year-old fully-restrained male driver steered left and braked hard to avoid this vehicle. The driver lost control and the Pontiac entered into a clockwise rotation. The left side of the Grand Am stuck a wooden utility pole on the east roadside. The Grand Am then rotated counter-clockwise and struck a concrete step with its front left side. The EDR recorded a speed of 129 km/h at -5 s to AE. The pre-crash data also indicated that the driver was on the brakes in the four intervals prior to AE with the recorded speed dropping to 21 km/h at -1 s to AE. This EDR data confirmed witness statements that the driver of the speeding Pontiac was trying to avoid the turning vehicle when he lost control.

**Table 15 Pre-Crash Data for CASE 13**

| Seconds to AE (s) | Vehicle Speed (km/h) | Engine Speed (rpm) | Percent Throttle (%) | Brake Switch Circuit Status |
|---|---|---|---|---|
| -5 | 129 | 3712 | 100 | OFF |
| -4 | 113 | 2432 | 3 | ON |
| -3 | 89 | 1600 | 3 | ON |
| -2 | 51 | 1088 | 3 | ON |
| -1 | 21 | 768 | 3 | ON |

**Figure 13 2000 Pontiac Grand Am**

# DISCUSSION

## Pre-crash Factors

In 2005 there were 2578 fatal motor vehicle collisions in Canada, resulting in 2923 fatalities including 1557 drivers and 683 passengers. On average for the past 10 years, single-vehicle collisions have accounted for 50 percent of all fatal collisions. Approximately 60% of all motor vehicle occupants killed suffered their injuries in crashes on rural undivided roadways with a posted speed limit of 80 km/h or greater. Non-use of seatbelts and speeding, particularly among victims of single vehicle crashes, have been identified as safety-related issues in a large percentage of these occurrences. A recent Transport Canada study showed that almost 40% of fatally injured drivers were unbelted. Excess speed or speed inappropriate for driving conditions were cited as contributing factors for approximately 25% of all single vehicle fatal crashes [8].

Similar observations regarding belt use, rural crashes and speeding were apparent in the current study. Only 6 of the 13 fatally injured drivers were restrained. Inattentiveness was a factor in at least 5 of the fatal crashes. Eleven of the fatal crashes occurred on rural roadways. Rural area crashes are generally more severe then crashes on urban roads due to differences in operating speeds, road geometry, functionality, enforcement levels and other factors' [9]. Roadway hazards such as utility poles and trees tend to be closer to the road and obstacles such as animals are more common and can cause more dangerous situations in these areas then in urban areas.

Loss of directional control occurred prior to impact in 8 of the 13 fatal crashes with high speed being a major contributing factor in most of these cases. Only one of the vehicles in the series was equipped with Stability Control (Case 10) and it is unknown if it was active at the time of loss of control. Electronic Stability Control (ESC) senses when a vehicle is differing from its intended path of travel by monitoring steering input versus direction. ESC helps to bring the vehicle back under control when these inputs do not match, by applying small amounts of braking separately at one or more of the vehicle wheels or by reducing engine power. It has been shown that vehicles fitted with Stability Control are involved in significantly fewer crashes than those not equipped [10].

## The Role of Speed

Speed played a major contributing role in both crash severity and the causation of many of the fatal crashes. In 3 of the 9 multiple vehicle cases the EDR-equipped case vehicles were exceeding the posted speed limit by 30 km/h or more. In all four single vehicle crashes the vehicle was exceeding the posted limit by over 70 km/h prior to loss of control. The crashes were often very severe with the five fatal frontal impacts having recorded delta-Vs ranging from 53 km/h to 115 km/h (see Figure 14) and the five fatal side impacts having calculated delta-Vs ranging from 26 km/h to 60 km/h. The rollover events were less severe and readily survivable had the three drivers been wearing their seatbelts.

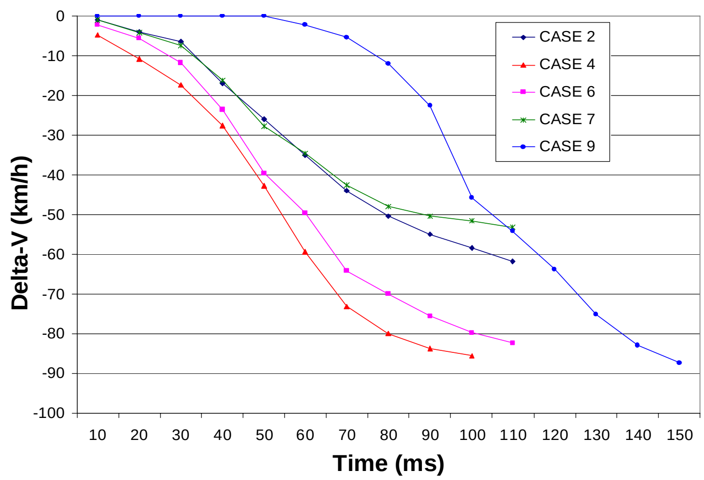


**Figure 14 Cumulative longitudinal delta-V for frontal impacts**

Speed was a contributing factor in 25% of all fatal single vehicle crashes as indicated by data based on motor vehicle accident reports. This may be a substantial under-estimate of the role of speeding in roadway deaths. Motor vehicle accident reports are an important source of road safety information. However, speeding or driving too fast for weather or roadway conditions is likely under-reported in these reports. Police officers must be cautious when assessing the events of a collision and thus report only what they know beyond a reasonable doubt.

It is often difficult for reconstructionists to determine a driver's pre-crash actions with great certainty. Physical evidence of a driver's pre-crash actions is often in short supply following a collision due to weather and roadway conditions and ABS brakes. While hard pre-crash braking is often not evident on the roadway, in 11 of 13 fatal crashes the EDR recorded pre-impact braking. There is usually some pre-crash attempt at collision avoidance by the driver and frequently this is not evident on the roadway. Furthermore, even when there is substantial physical evidence there is often significant uncertainty in its analysis.

Male drivers were involved in 9 of the collision cases in this series. According to a research study conducted by Carnegie Mellon University, men have a greater risk of being involved in a fatal accident for reasons such as fast driving, risk taking and drinking and driving [11]. Also, male drivers tend to travel more kilometers each year then female drivers [12]. Speed and subsequent loss of control were associated with 7 out of the 9 crashes involving male drivers and 6 of the 9 males were unbuckled. Properly wearing a seatbelt can greatly reduce the chance for ejection and can help to prevent severe head injuries in high impact collisions.

## Event Data Recorders

Event Data Recorders (EDRs) were found to be extremely useful for establishing pre-crash actions with great certainty when examined in conjunction with reconstruction of physical evidence. The EDR verified the crash reconstruction in many cases. In addition, the pre-crash data recorded by the EDR often provided insights into the pre-crash events that would not otherwise have been known. The EDR acted as an accurate impartial witness that greatly increased ones' understanding of the crash.

While witness statements can often provide some clarification of the pre-crash events, the fallibility of eyewitness memory and bias can result in substantial errors. In some cases the EDR data provided verification of witness statements and in other cases it was contradictory. For example, in case 1 the recorded data was critical for proving that the travel directions of the vehicles were contrary to that reported by a witness; thus showing that one of the colliding vehicles went through a red light.

Similarly, in case 3, the EDR data was critical for understanding the pre-crash events that occurred. The right front passenger in the Blazer reported that the passenger car ran a stop sign and caused the crash. The high speed of the Blazer was not initially apparent to investigators due to the lack of physical evidence. However, the EDR data indicated that the driver of the Blazer was approaching the hidden intersection at a dangerously high speed thus shifting the fault for this collision. Furthermore, speed-distance-time analysis incorporating the EDR pre-crash speed data showed that the passenger in the Blazer would likely not have been able to see the car until it had traveled past the stop sign and into the intersection.

In case 9 there were questions about the driver's lack of collision avoidance and the potential for a malfunction in the vehicle's steering. However, the EDR data indicated no braking or steering inputs prior to the severe head-on collision with the tractor-trailer. The cause of the crash was driver inattentiveness and upon further investigation it was determined that she was likely on her cell phone as her vehicle veered into the oncoming lane.

Environmental factors did not play an important role in the collisions studied as all occurred in clear weather conditions that had no effect on the driving abilities of the vehicle driver. Twelve of the 13 collisions took place on roadsways that were dry. The lighting conditions varied, with 7 taking place in the daylight hours and 6 taking place while dark. Defects were also not an issue with any of the vehicles involved and therefore did not play a role in collision causation.

Determination of vehicle speed through reconstruction of the physical evidence is one of the major roles of crash reconstructionists. When speed is found to be excessive, criminal charges may result. Successful prosecution of criminal cases requires proof beyond reasonable doubt of reckless high speed. Lack of physical evidence, competing interpretations of physical evidence and uncertainty in calculations are some of the barriers to successful prosecution. The EDR provides extensive supporting documentation that, when combined with competent reconstruction, should increase the probability for successful prosecution.

In the current series of cases, the EDR was found to be very useful at identifying instances of substantial speeding which might otherwise have been overlooked. It is clear that researchers, investigators and other interested parties are receiving many benefits from the collection of EDR data. With further improvements and research into the recording abilities of the SDM, EDRs hold great promise for the future of motor vehicle safety and crash prevention.

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