Recent Advances in EDR Technology
By Jean-Louis Comeau and Alan German

Jean-Louis is the Chief of Transport Canada's Collision Investigations and Research Division. Alan is a past Chief of this same research group. These individuals have been involved in research on the application and utility of Event Data Recorders (EDR), both in staged-crash tests and in real-world collision investigations, as these devices have developed over the past several years.

Résumé

L'introduction de véhicules entièrement autonomes dans le parc de véhicules signifiera qu'à l'avenir, les manoeuvres de véhicules seront régies par des systèmes de prise de décision automatisés, plutôt que par des conducteurs. En fait, c’est déjà le cas bien souvent aujourd’hui, en raison de la présence de plus en plus importante des systèmes avancés d’aide à la conduite. Compte tenu de cette tendance, il est impératif que les systèmes de détection et de contrôle associés aux systèmes automatisés soient surveillés de près et que leurs actions soient enregistrées, afin de pouvoir évaluer leur performance à la suite d’événements imprévus, telles que les collisions. Dans cet article, nous examinons certaines des dernières fonctionnalités propres aux enregistreurs d’événement qui facilitent ce processus.

The potential introduction of fully-autonomous vehicles into the vehicle fleet means that, in future, many vehicle manoeuvres will be governed by automatic systems rather than by vehicle drivers. In fact, this is often the case today due to the increasing implementation of Advanced Driver Assistance Systems (ADAS) in production vehicles. These trends make it imperative that the sensing and control systems associated with on-board automated systems are carefully monitored, and their actions fully recorded, so that their performance can be evaluated following any unexpected event such as a collision. In this article we look at some of the latest features of Event Data Recorders (EDR) that facilitate this process.

On-board crash recorders have evolved considerably from their initial implementation as a set of fuses to record the deployment of the first airbag systems. Significant enhancements to the capabilities of EDR's arrived with the introduction of microprocessor-based systems in the 1990's. This generation of EDR's typically captured a range of pre-crash data, such as vehicle speed (mph), engine speed (rpm), brake-switch status (on/off), accelerator position and throttle opening (%). These variables were recorded at each of five, one-second intervals prior to the occurrence of a crash. The seat-belt status (buckled/unbuckled) for both the driver and right-front passenger were also captured, as were the firing times (ms) for the single-stage, front airbags. Collision severity was recorded through time–series measurements, at 10 ms intervals, typically for a duration of 150-300 ms, of the vehicle's longitudinal change in velocity (ΔV).

Today's EDR's are sophisticated electronic devices that capture a much more comprehensive range of both pre-collision and crash-related data. These data are thus extremely useful in indicating the actions of both a driver and any on-board automated control systems that precede a crash. Similarly, parameters related to the crash severity, and the deployment of restraint technologies such as seat belt pre-tensioners, load limiters, multi-stage front airbags, side airbags, curtains, and knee bolsters, offer considerable insights into the performance of these safety systems, and the levels of injury mitigation that they provide. Indeed, the inputs to the automated control systems and the resulting vehicle responses, and the precise nature of the deployment regime for pyrotechnic restraint system components, would not be known without such detailed recorded information.

As such, these data are invaluable to the automotive engineers who design vehicle safety systems in order that they can fully understand their real-world system performance and make any necessary enhancements. EDR's also provide a wealth of collision-related data that can be used by researchers to explore wide-ranging safety issues, and by regulators to identify opportunities for improving vehicle safety features.

An example of the data captured by an EDR in a recent-model vehicle is highlighted through the following case study of a real-world collision.

A late-model pickup truck was travelling westbound, during daylight hours, along a six-lane, median-divided highway. The asphalt-paved roadway was dry and the weather was clear. The roadway had a slight incline and was curved prior to the impact location, but then became straight and level. Traffic was light and the pickup's driver estimated that the closest vehicle was approximately four vehicle lengths ahead. As the pickup continued along the middle lane of travel, it was overtaking slower-moving vehicles in both adjacent lanes.

Suddenly, the driver heard an alert issued by the vehicle's Forward Collision Warning (FCW) system and became aware that the vehicle was undergoing heavy braking. He indicated that there was no vehicle or object in close proximity to the pickup, yet the braking was such as to bring his vehicle to a complete stop on the highway.

Figure 1. Operation of Forward Collision Warning System

The driver of a tractor-trailer combination, who was following the pickup truck, was unable to brake sufficiently to avoid a collision, and the tractor-trailer struck the rear of the pickup. The seat-belt pre-tensioners for the pickup's driver activated on impact, but no airbags were deployed. The rear-end collision was of minor severity and neither driver sustained any injury.

The report obtained from the pickup truck's EDR contained a wealth of data relating the collision, including the driver's occupant-restraint status, the vehicle's ΔV and, most importantly, a wide range of information on pre-crash factors relating to the FCW system and the brake application.

System Status at Event (Most Recent Event - Deployment)

Event Number	1
Complete File Recorded	Yes
Ignition Cycle, Crash	276
Multi-Event, Number of Event	1
Time From Event 1 to 2 (sec)	>5
Safety Belt Status, Driver	Buckled
Safety Belt Status, Passenger	Unbuckled
Seat Track Position Switch, Foremost, Status, Driver	Not Frontal Zone
Seat Track Position Switch, Foremost, Status, Right Front Passenger	Not Frontal Zone
Occupant Size Classification, Outboard Front Passenger	Child
Maximum Delta-V, Longitudinal (MPH [km/h])	11.8 [19]
Time, Maximum Delta-V, Longitudinal (ms)	72
Maximum Delta-V, Lateral (MPH [km/h])	0.0 [0]
Time, Maximum Delta-V, Lateral (ms)	0
Frontal Airbag Warning Lamp	Off
Operation system time (min)	31.8
Airbag Warning Lamp On Time (min)	<1
Total Number of Events	1

Deployment Command Data (Most Recent Event - Deployment)

Frontal Airbag Deployment, 1st Stage, Driver	No
Frontal Airbag deployment, Time to Deploy 1st stage, Driver (ms)	0
Frontal Airbag Deployment, 2nd Stage, Driver	No
Frontal Airbag deployment, Time to Deploy 2nd stage, Driver (ms)	0
Frontal Airbag Deployment, 3rd Squib, Driver	No
Frontal Airbag deployment, Time to Deploy 3rd Squib, Driver (ms)	0
Frontal Airbag, Deployment 1st Stage, Passenger	No
Frontal Airbag deployment, Time to Deploy 1st stage, Passenger (ms)	0
Front Airbag, Deployment 2nd Stage, Passenger	No
Front Airbag, Time to Deploy 2nd stage, Passenger (ms)	0
Front Airbag, Deployment 3rd Squib, Passenger	No
Front Airbag, Time to Deploy 3rd Squib, Passenger (ms)	0
Adaptive Load Limiter Deployment, Driver	No
Retractor Pretensioner Deployment, Driver	Yes
Anchor Pretensioner Deployment, Driver	Yes
Adaptive Load Limiter Deployment, Passenger	No
Retractor Pretensioner Deployment, Passenger	Yes
Anchor Pretensioner Deployment, Passenger	Yes
Side Seat Airbag Deployment, Front Left	No
Side Curtain Airbag Deployment, Left	No
Side Seat Airbag Deployment, Front Right	No
Side Curtain Airbag Deployment, Right	No

Figure 2. Occupant Restraint System Status/ and Deployment Characteristics

The tables shown in Figure 2 confirmed that the pickup truck driver's seat belt was buckled, that the pre-tensioners on both the seat belt retractor and anchorage were activated, none of the stages of the front airbag and neither the side airbag nor the side curtain were deployed.

As the pickup truck was pushed forwards, the maximum longitudinal ΔV for the rear-end impact was noted as being 19 km/h (11.8 mph) with a duration 72 ms. There was no lateral component to the vehicle's change in velocity. The longitudinal crash pulse is shown in Figure 3.

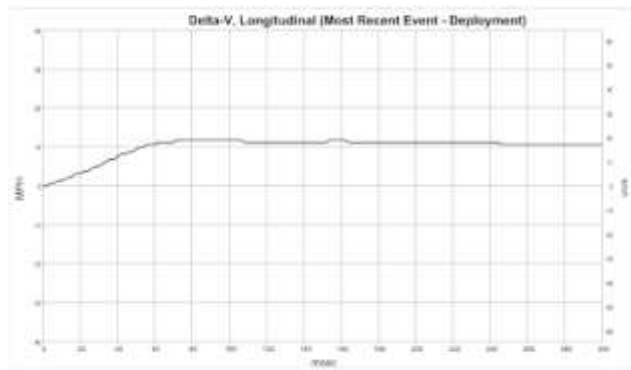

Figure 3. Longitudinal Delta-V (mph)

The EDR in the pickup truck recorded a wide range of pre-crash data at 0.1 s intervals for a period of 5 s prior to the occurrence of the rear-end impact. A graphical depiction of the engine rpm, vehicle speed (mph), the brake status (on/off), the activation of the accelerator pedal (%) and throttle (%) is shown in Figure 4.

The vehicle can be seen to be slowing very gently from t = -5 s to t = -1.8 s. In the initial portion of this time period, there was activation of the braking system by the driver between t = -5 s and t = -3.7 s. There was no further brake application until t = -0.5 s. The accelerator pedal was depressed to a maximum of approximately 14% between t = -2.8 s and t = -1.5 s and thereafter left untouched. It should be noted that the service brake parameter relates specifically to depression of the brake pedal by the vehicle's driver. Braking due to intervention by the FCW system is not reported through this data element.

Between t = -1.8 s and t = -0.6 s, the associated tabular data (Figure 5) show that vehicle's speed dropped from 29 km/h to 3 km/h; however, there was no activation of the service brakes by the vehicle's driver during this time period. Nevertheless, the vehicle's deceleration averaged 0.9 g which, for ABS and the dry asphalt roadway, is indicative of full brake application and an emergency stop procedure.

Additional information relating specifically to the FCW system is contained in a second table of pre-crash data. The relevant portion of this table is shown in Figure 6. In particular, note that between t = -1.2 s and t = -0.8 s the parameter "Braking System, Maximum Braking" was set as "Yes" indicating that the vehicle's brakes were being applied.

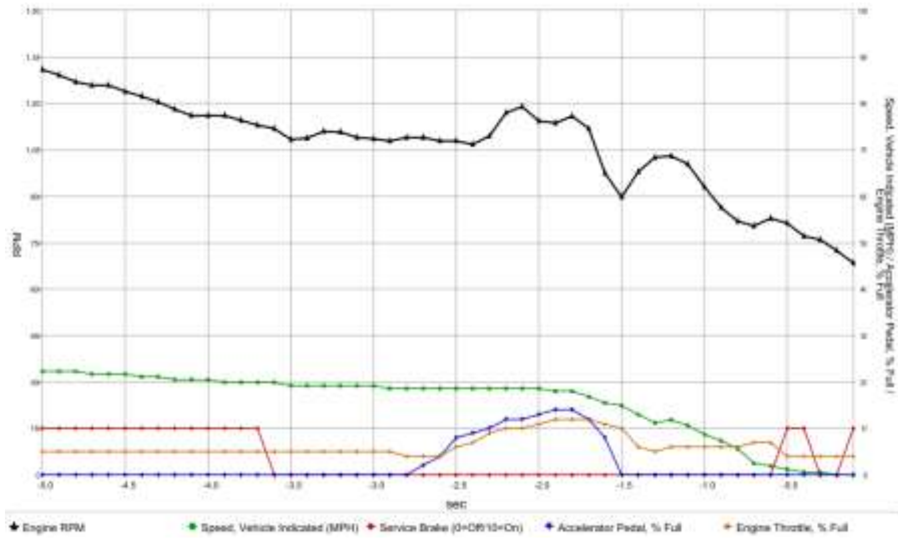

Figure 4. Pre-Crash Data (-5.0 to 0 s)

Time (sec)	Pre-Crash Recorder Status	Speed, Vehicle Indicated (MPH [km/h])	Accelerator Pedal, % Full (%)	Engine Throttle, % Full (%)	Service Brake	Engine RPM (RPM)	ABS Activity	Stability Control
-2.0	Complete	18.6 [30]	13	11	Off	1,144	No	On
-1.9	Complete	18.0 [29]	14	12	Off	1,136	No	On
-1.8	Complete	18.0 [29]	14	12	Off	1,158	No	On
-1.7	Complete	16.8 [27]	12	12	Off	1,120	No	On
-1.6	Complete	15.5 [25]	8	11	Off	974	No	On
-1.5	Complete	14.9 [24]	0	10	Off	897	No	On
-1.4	Complete	13.0 [21]	0	6	Off	980	No	On
-1.3	Complete	11.2 [18]	0	5	Off	1,025	No	On
-1.2	Complete	11.8 [19]	0	6	Off	1,030	No	On
-1.1	Complete	10.6 [17]	0	6	Off	1,004	No	On
-1.0	Complete	8.7 [14]	0	6	Off	930	No	On
-0.9	Complete	7.5 [12]	0	6	Off	865	No	On
-0.8	Complete	5.6 [9]	0	6	Off	820	No	On
-0.7	Complete	2.5 [4]	0	7	Off	804	No	On
-0.6	Complete	1.9 [3]	0	7	Off	829	No	On
-0.5	Complete	1.2 [2]	0	4	On	814	No	On
-0.4	Complete	0.6 [1]	0	4	On	770	No	On
-0.3	Complete	0.6 [1]	0	4	Off	760	No	On
-0.2	Complete	0.0 [0]	0	4	Off	725	No	On
-0.1	Complete	0.0 [0]	0	4	On	684	No	On

Figure 5. Portion of the Pre-Crash Data

Time (sec)	Pre-Crash Recorder Status	Braking System, Maximum Braking	Wheel Speed, LF (RPM)	Wheel Speed, RF (RPM)	Wheel Speed, LR (RPM)	Wheel Speed, RR (RPM)	Yaw Rate (deg/sec)	Object of Interest Distance (m)
-2.0	Complete	No	203	207	203	199	1.28	1
-1.9	Complete	No	199	202	196	199	0.16	11
-1.8	Complete	No	193	192	196	195	0.64	11
-1.7	Complete	No	186	185	189	183	-0.40	11
-1.6	Complete	No	175	172	169	179	-1.04	11
-1.5	Complete	No	154	160	157	164	-0.80	11
-1.4	Complete	No	142	140	144	140	-0.16	11
-1.3	Complete	No	101	109	123	108	-0.24	11
-1.2	Complete	Yes	112	15	101	100	0.16	11
-1.1	Complete	Yes	90	99	89	89	-1.44	11
-1.0	Complete	Yes	74	71	72	71	0.72	11
-0.9	Complete	Yes	57	54	55	32	0.56	11
-0.8	Complete	Yes	35	39	42	41	-0.48	11
-0.7	Complete	No	25	24	25	24	-0.24	5
-0.6	Complete	No	15	15	18	18	-0.40	5
-0.5	Complete	No	9	8	10	11	-0.32	6
-0.4	Complete	No	0	6	6	6	-0.24	6
-0.3	Complete	No	0	0	0	0	-0.16	6
-0.2	Complete	No	0	0	0	0	-0.72	7
-0.1	Complete	No	0	0	0	0	-0.56	8

Figure 6. Additional Pre-Crash Data Elements

A number of other items of note to the current collision situation that are recorded elsewhere in the pre-crash data are that the FCW system was fully on with active braking as well as the audible and visual warnings enabled. The vehicle's regular cruise control and Adaptive Cruise Control (ACC) systems were not engaged. There was little to no steering input by the driver. Of particular note was that the pressure in the master cylinder was zero during the period t = -3.6 s to t = -0.5 s which corresponds to the indication that the driver did not apply the service brakes during this time period.

The other parameter of special note with regard to activation of the FCW system is the "Object of Interest Distance (m)". This is a measure of the headway between the pickup truck and the main object being tracked by the FCW system. The specific values recorded as a function of time are shown in Figure 7.

Initially, the headway was maintained at approximately 11 m. The headway then dropped to about 6 m for 0.7 s. The headway was briefly recorded, for a single interval (at t = -2.6 s), at 197 m, followed by a period of 0.6 s (from t = -2.5 to t = -2.0 s) when the headway was reduced to between 1 and 2 m. Subsequently, the headway remained at 11 m from t = -1.9 s to t = -0.8 s, and between 5 and 8 m after that The highlighted row in Figure 7 for t = -1.2 to -0.8 s corresponds to the activation of the FCW system and the hard-braking event.

t (s)	d (m)
-5.0 to -3.4	10 to 11
-3.3 to -2.7	5 to 6
-2.6	197
-2.5 to -2.0	1 to 2
-1.9 to -1.3	11
-1.2 to -0.8	11
-0.7 to -0.1	5 to 8

Figure 7. Object of Interest Distance

It is clear from the data captured by the EDR in the pickup truck that the FCW activated and abruptly reduced the vehicle's travel speed to near zero in under two seconds. The tractor-trailer following close behind the pickup could not match the pickup's deceleration and the rear-end collision resulted.

The pickup truck's driver maintained that there was no vehicle or object close in front of his vehicle, in which case the FCW system should not have engaged the vehicle's brakes. This seems to be borne out by the EDR indicating a headway of at least 10 m for up to 0.7 s before the hard-braking event occurred. However, the situation is confounded somewhat by the headway measurements immediately prior to this time period where the values go from 197 m for a single 0.1 s sampling interval to between 1 and 2 m over a period of 0.6 s.

The on-road situation, or the vehicle sensing condition, that gave rise to the above-noted headway values is not clear. Certainly an object appearing abruptly within 1 to 2 m of the front of the subject vehicle might well cause the FCW to engage. However, this scenario is at variance with the statement of the vehicle driver that the road ahead was clear and, in particular, that no vehicle was attempting to cut in front of the pickup truck.

As of the time of writing, the specific circumstances of the case collision remain unresolved. Nevertheless, given the wide-ranging nature of the information provided by the EDR in this case, it is clear that the current generation of these devices are of considerable utility in understanding the real-world performance of automated vehicle systems. And, no doubt, as these devices evolve even further, they will become an invaluable tool to enhance safety.

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