ESTIMATING CRASH SEVERITY: CAN EVENT DATA RECORDERS REPLACE CRASH RECONSTRUCTION?

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ABSTRACT

The primary description of crash severity in most crash databases is vehicle delta-V. Delta-V has been traditionally estimated through crash reconstruction techniques using computer codes, e.g. Crash3 and WinSmash. Unfortunately, delta-V is notoriously difficult to estimate in many types of collisions including sideswipes, collisions with narrow objects, angled side impacts, and rollovers. Indeed, approximately 50% of all delta-V estimates in the National Automotive Sampling System / Crashworthiness Data System (NASS/CDS) 2000 are reported as unknown.

The Event Data Recorders (EDRs), now being installed as standard equipment by several automakers, have the potential to provide an independent measurement of crash severity, which avoids many of the difficulties of crash reconstruction techniques. This paper evaluates the feasibility of replacing delta-V estimates from crash reconstruction with the delta-V computed from EDRs. The analysis is based on 225 NASS/CDS cases from 1999 - 2001, which have corresponding EDR datasets. The potential of extracting manual seat belt use from EDRs is also discussed and compared with the corresponding results from NASS/CDS gathered by crash investigators. Although EDRs are expected to greatly enhance the investigation of a crash, it should be noted however that current EDRs are not perfect. The paper discusses the limitations of current EDR technology and the need for enhancement of future Event Data Recorders.

INTRODUCTION

Widespread deployment of Event Data Recorders (EDRs), sometimes called "black boxes," promises a new and unique glimpse of the events that occur during a highway traffic collision. The EDR in a colliding vehicle can in some cases, provide a comprehensive snapshot of the entire crash event – pre-crash, crash, and post-crash. By carefully collecting and analyzing the details provided by the growing number of EDR-equipped vehicles, the crash safety research community has an unprecedented opportunity to understand the interaction of the vehicle-roadside-driver system as experienced in thousands of U.S. highway crashes each year.

Under National Highway Traffic Safety Administration (NHTSA) sponsorship, Rowan University is developing a first-of-a-kind database of EDR data collected from real world traffic crashes in the United States. Although the database is still under development, the EDR data collected to date have a number of potential research applications. The most immediate application of EDR data has been in crash reconstruction, which can use this new tool to supplement conventional methods of determining crash severity.

WinSmash vs. EDR delta-V

The vehicle resultant change in velocity, commonly referred to as simply resultant delta-V, is the primary description of crash severity in most crash databases. For the National Automotive Sampling System / Crashworthiness Data System (NASS/CDS) database, NHTSA estimates both longitudinal and lateral delta-V from detailed measurements of vehicle deformation using a computer code such as WinSmash [Stucki et al, 1998]. WinSmash and similar codes, e.g. Crash3 [NHTSA, 1982], are most accurate for frontal crashes with full frontal engagement. As crashes deviate from this ideal configuration, the estimates become increasingly less accurate [O'Neill et al, 1996; Stucki et al, 1998]. Delta-V for some crash configurations is notoriously difficult to estimate. These configurations include

sideswipe, collisions with narrow objects, e.g. poles and trees, angled side impacts, and rollover. Reflecting this difficulty, approximately 50% of all delta-V estimates in NASS/CDS 2000 are reported as unknown.

EDRs have the potential to provide an independent measurement of crash severity which avoids many of the difficulties of crash reconstruction techniques. For vehicles equipped with an EDR, sensors on the vehicle itself provide a direct measurement of vehicle velocity versus time – and hence delta-V. The GM EDR for example measures longitudinal velocity vs. time. Other automakers record both longitudinal and lateral acceleration vs. time. Unlike WinSmash estimates of delta-V, the availability and validity of this data are unaffected by the crash mode. In fact, a comparison of the NASS/CDS cases for which EDR data are also available shows that an EDR-generated delta-V is available for many of the cases in which the WinSmash-generated delta-V was listed as unknown.

OBJECTIVE

The objective of this paper is to evaluate the potential to supplement and possibly replace WinSmash-estimated delta-Vs with the delta-V recorded in EDRs. The paper will examine those NASS/CDS cases from 1999 - 2001 for which there are corresponding EDR datasets. It should be noted, that because of the small sample currently available (225 events), the primary outcome of this analysis should be regarded only as an initial indication of the more conclusive findings that can be expected from follow-on studies with a larger EDR sample.

DESCRIPTION OF THE ROWAN UNIVERSITY EDR DATABASE

NHTSA has collected EDR records from several hundred crashes investigated as part of NHTSA Special Crash Investigations (SCI), NASS/CDS investigations, and Crash Injury Research and Engineering Network (CIREN) studies. NASS/CDS is a national sample of 4,000 to 5,000 crashes investigated each year by NHTSA at 27 locations throughout the United States. The SCI file is a collection of targeted crash investigations looking at emerging safety issues. Much of the EDR data for the SCI cases have been collected as part of a special study investigating Advanced Occupant Protection Systems (AOPS) conducted in collaboration with several automakers. CIREN is a system of crash investigations, conducted at hospitals, which collects approximately 400 cases each year.

To date, the cases in NASS/CDS involving EDR data are all General Motors vehicles. At the time of this study, General Motors was the only automaker that had publicly released the format of their EDRs. In addition, General Motors has signed an agreement with Vetronix to produce a Crash Data Retrieval System capable of downloading, decoding, and displaying the data recorded in GM EDRs. The SCI cases contain the EDR data from several automakers other than GM, but, under confidentiality agreements with the automakers, NHTSA has not yet publicly released this data. Although CIREN teams have begun to download EDR data, at this time no CIREN cases with EDR data are available for analysis.

As shown in Table 1, NASS/CDS teams from 1999-2001 successfully collected EDR data from 225 vehicles involved in traffic crashes. The number of EDR data sets collected in 2002 investigations is expected to exceed those collected in 2001. The NASS/CDS 2002 data was not available for this analysis as NHTSA development of the database was still underway at the time of this study. An early examination of a partial 2002 dataset was however obtained as the basis for a later section on EDR download difficulties.

Table 1. Contents of the Rowan University EDR Database by Source

Source	Total Number of Cases
NASS/CDS 1999	2
NASS/CDS 2000	34
NASS/CDS 2001	189
Total	225

To analyze this dataset, Rowan University developed a database of the NHTSA EDR cases collected from NASS/CDS 1999-2001. The cases extracted from this database and used in this analysis included only crashes in which an EDR had been successfully downloaded and matched with a corresponding NASS/CDS case. The database consists of the following six (6) tables as described in Gabler et al (2002):

a) NASS/CDS case description
b) General EDR parameters
c) Near Deployment Event – Crash Parameters
d) Deployment Event – Crash Parameters
e) Near Deployment Event – Pre-crash parameters
f) Deployment Event – Pre-crash parameters

DESCRIPTION OF THE GM EDR CASES

GM EDRs have the capability to store a description of both the crash and the pre-crash phase of a traffic collision. Crash event parameters include longitudinal velocity vs. time during the impact, airbag trigger times, and seat belt status. Later versions of the GM EDR also store precrash data including a record of vehicle speed, engine throttle position, engine revolutions per minute and brake status for five seconds preceding the impact. Since their introduction in the early 1990's, GM has continuously improved their EDR design. This has been both a boon and a challenge to researchers who seek to compare the crash performance of vehicles equipped with different generations of the GM EDR.

Computing EDR Delta-V

Arguably, the most valuable data element stored in an EDR is the velocity-time history of the vehicle during the crash. In GM EDRs, the change in longitudinal velocity is recorded every ten milliseconds for up to 300 milliseconds in older EDR designs and up to 150 milliseconds in newer EDR designs. Change in lateral velocity is not recorded.

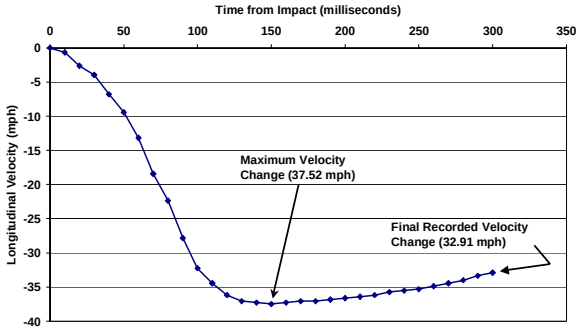

Figure 1. EDR record of Longitudinal Velocity vs. Time for a 1999 Pontiac Grand AM involved in a frontal collision with another vehicle

Figure 1 shows the longitudinal velocity vs. time recorded by an EDR in a 1999 GM Pontiac Grand Am involved in a frontal collision with another vehicle. For this paper, the EDR delta-V was obtained for each case by finding the maximum change in velocity as shown in Figure 1. The maximum delta-V corresponds to the delta-V computed in WinSmash. WinSmash and similar computer codes assume fully plastic deformation, i.e. the vehicles do not separate [Stucki et al, 1998]. In reality, most collisions also involve a rebound phase in which some of the crash energy is restored as kinetic energy. This can be observed in Figure 1, as the final recorded velocity change is approximately 5 mph lower than the maximum velocity change.

Storing Multiple Crash Events

GM EDRs can store a near-deployment event, a deployment event, or both. A near-deployment event is defined as a crash of too low a severity to warrant deploying the airbag. A deployment event is an impact in which the airbag was deployed. For NASS/CDS 1999-2001 cases, Table 2 lists the distribution of cases in the EDR database. As shown in Table 2, the database is comprised primarily of lower severity near-deployment events.

Table 2. Near-deployment vs. Deployment EDR Cases for NASS/CDS 1999-2001

Source	Total
Near Deployment Events Only	107
Case with both Near Deployment + Deployment Events	80
Deployment Events Only	38
Total	225

Availability of EDR Velocity Data

One concern when using current GM EDRs is that velocity-time data was not always recorded in an event. As shown in Table 3, non-zero velocity data could be recovered from only 37% of the EDR near deployment events. In 45% of the near-deployment events, the velocity-time data was completely missing. GM has told us that the missing-time data is characteristic of their first EDR design capable of storing precrash information. In these EDRs, the near deployment crash velocity vs. time data is not meaningful and is not decoded by the Vetronix software. GM has told us that this problem has since been corrected. Indeed, examination of our dataset showed that the missing velocity-time data for near-deployments appears to be roughly confined to GM model years 2000 and 2001. EDRs installed in pre-2000 models and 2002 and later models do not, in general, have this problem.

As shown in Table 4, velocity data were successfully recovered from all but nine of the EDRs that recorded

deployment events. The fact that nine of the 118 cases did not have velocity data is not a reflection on the EDR design. For these nine cases, the research team had only a graphical screenshot from which to extract EDR data rather than an EDR file downloaded using the Vetronix tool. In these nine cases, this screenshot did not include velocity vs. time data. Similarly, in 13 of the 84 near deployment cases without velocity vs. time data, the research team had only a graphical screenshot from which to extract EDR data, and this screenshot did not include velocity vs. time data. If the EDR files had been available for these cases, velocity-time data may have been recoverable.

Table 3. Near-Deployment Events: Availability of EDR Velocity Data

Type of Event	Cases with Velocity vs. time	Cases with Zero Velocity vs. time	Cases Missing Velocity vs. time	Total
Near Deployment Only	52	15	40	107
Near Deployment + Deployment	18	18	44	80
Total	70	33	84	187

Table 4. Deployment Events: Availability of EDR Velocity Data

Type of Event	Cases with Velocity vs. time	Cases with Zero Velocity vs. time	Cases Missing Velocity vs. time	Total
Deployment + Near Deployment	74	-	6	80
Deployment Only	35	-	3	38
Total	109	-	9	118

Distribution of Change in Velocity

Figures 2 and 3 show the distribution of longitudinal delta-V for near-deployment and deployment events respectively. As noted above, non-zero velocity vs. time data was available for 70 EDR non-deployment cases and for 109 EDR deployment cases. As would be expected, near-deployment events are of lower severity than deployment events as measured by delta-V. It should be noted however that in this sample, near-deployments were observed in rare cases for delta-V as high as 30 mph. Figure 3 shows the unexpected finding that over 10% of the airbag deployments occurred for longitudinal delta-V of 5 mph or lower. These cases were primarily either side impacts or collisions with fixed objects, e.g., trees and poles.

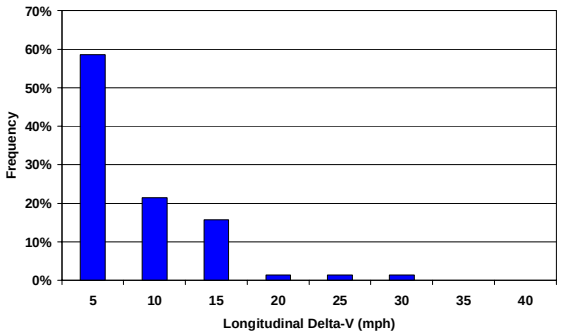

Figure 2. Near-deployment events: Distribution of EDR Longitudinal Delta-V (70 Cases, NASS/CDS 1999-2001)

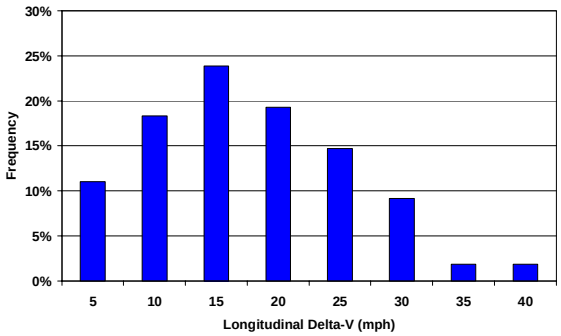

Figure 3. Deployment Events: Distribution of EDR Longitudinal Delta-V (109 Cases, NASS/CDS 1999-2001)

RESULTS

The following section explores the use of EDR data as an improved method of collecting data in crash reconstruction. Specifically, this section discusses (1) the accuracy of recorded EDR velocity versus WinSmash estimates, (2) the feasibility of obtaining delta-V estimates in crashes where a WinSmash estimate was not available, and (3) a comparison of belt usage rate as obtained from crash investigators versus direct EDR measurement.

Can EDRs recover Unknown NASS Delta-Vs?

As shown in Figure 4 and tabulated in Table 5, EDR velocity-time data were frequently available for cases in which NASS/CDS delta-V was coded as unknown. In 117 cases (52%), both the EDR and the NASS/CDS delta-V were available. In an additional 20% of the cases, an unknown NASS/CDS delta-V could be replaced with the delta-V measured by the EDR. However, in 15% of the cases, NASS/CDS investigators were able to estimate a delta-V when the EDR did not record velocity-time data. In 14% of the cases (31 of 225), a delta-V measurement was not available from either WinSmash or the EDR file.

Table 5. EDR vs. NASS: Delta-V Availability

EDR Cases	NASS/CDS delta-V known	NASS/CDS delta-V unknown	Total
Known velocity vs. time	117	44	161
Zero velocity vs. time	7	8	15
Missing velocity vs. time	26	23	49
Total	150	75	225

EDRs are clearly a promising means to determine delta-V for crashes in which crash severity is difficult to estimate using conventional methods. In over half of the cases with an unknown NASS/CDS delta-V (44 of 75), an EDR delta-V estimate was available as an alternative measure. However, counterbalancing this advantage is the problem of missing EDR velocity data even in cases when NASS/CDS investigators were able to estimate a delta-V based upon vehicle damage. GM has told us however that this issue of missing near-deployment velocity data has been corrected in later versions of their EDRs.

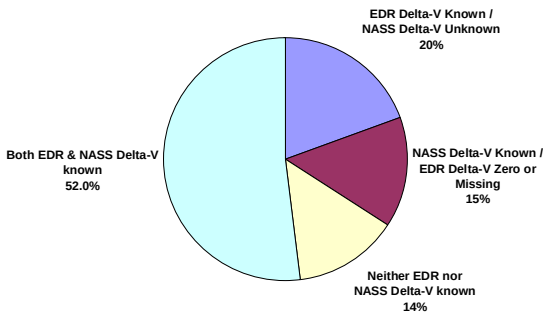

Figure 4. EDR vs. NASS: Delta-V Availability

WinSmash Delta-V versus EDR Delta-V

EDRs directly measure the acceleration of a vehicle from onboard sensors and have the potential to be a more accurate gauge of vehicle response to a crash than would an after-the-fact crash reconstruction. This section compares delta-V as directly measured by EDRs with delta-V as reconstructed using the WinSmash computer code.

Of the NASS/CDS 1999-2001 cases, 117 cases had both a WinSmash-generated longitudinal delta-V and a corresponding EDR file with longitudinal velocity-time data. Seven of these cases were excluded, as the NASS/CDS most harmful event was a rear impact or a side impact with a significant force component from the rear –events which are not captured by EDRs. Figures 5 and 6 compare the delta-V estimated by WinSmash with the corresponding delta-V computed from EDR data for the remaining 110 cases.

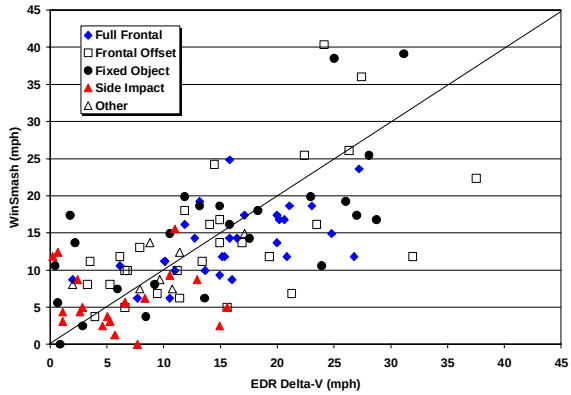

Figure 5. Longitudinal Delta-V comparison by crash mode

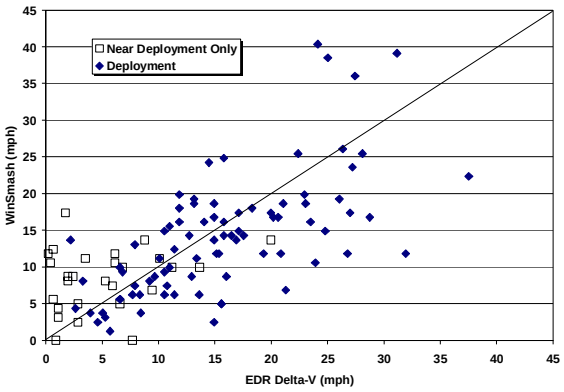

Figure 6. Longitudinal Delta-V comparison by type of event (near-deployment or deployment)

Symbols falling on the line drawn diagonally across the plot are cases where the EDR and WinSmash delta-V perfectly matched. Although there is rarely a perfect match between the two, it can be seen from both plots that the cases roughly cluster about this line. From this limited set of cases, Figure 5 suggests that there is no evidence that EDRs deviate from WinSmash estimates for any particular crash mode. Figure 6 suggests that WinSmash reports higher estimates of delta-V for lower speed near deployment cases.

The WinSmash computer code estimates both the longitudinal and lateral delta-V. While the longitudinal delta-V is extremely important in full frontal crashes, the lateral delta-V is extremely important in side impact crashes. Both delta-V components are important in narrow object and frontal offset crashes. The analysis is limited to a comparison of the longitudinal delta-V recorded by the EDR and estimated by WinSmash.

Driver Seat Belt Status

Seat belt usage status is one of the more important and controversial data elements collected by crash investigators. Because driver seat belt use is mandatory throughout most of the U.S., and is typically collected by a combination of vehicle inspections, medical reports, and interviewing the occupant who may have violated this law, the accuracy of seat belt usage is widely perceived as questionable. However, as GM EDRs record driver seat belt status, EDRs have the potential to more accurately collect this crucial data element. Table 6 compares NASS-reported driver belt usage with EDR-measured driver belt usage.

Table 6. NASS/CDS v. EDR Driver Belt Status

	NASS			
EDR	**Buckled**	**Unbuckled**	**Unknown**	**Total**
Buckled	105	2	8	115
Unbuckled	60	43	7	110
Total	165	45	15	225

For those cases where NASS/CDS investigators could determine belt usage (210 of 225 cases), Figure 7 shows that the EDR and crash investigators agreed in 70% of all cases (105 buckled cases and 43 unbuckled cases). However, in 29% of the cases (60 of 210 cases), NASS/CDS reported a buckled driver while the EDR reported an unbuckled driver. In 2 cases, NASS/CDS reported the driver was unbuckled while the EDR noted a buckled driver.

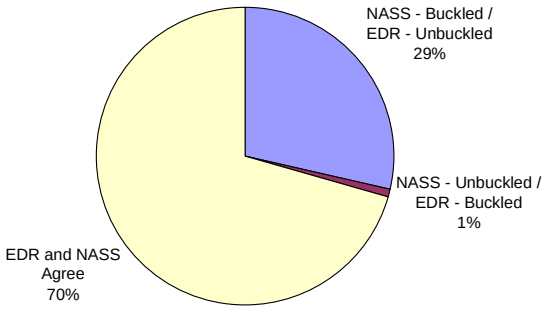

Figure 7. EDR vs. NASS - Driver Belt Usage when NASS/CDS Belt Usage is known

This suggests that NASS belt usage rates may be over-reported. However, it should be noted that in some early GM EDRs, the recorded manual belt usage might be incorrect. In these early designs, the belt sensor was read continuously—both before and during the crash event itself. If the connection between the belt sensor and the EDR was severed or if power was lost to the EDR during the crash, GM has told NHTSA that the EDR may incorrectly record that the belt was unfastened. GM has told us that this issue has been corrected in newer EDR designs that were first installed beginning in some model year 2002 vehicles.

LIMITATIONS OF EDRS

EDRs would appear to provide a better measure of delta-V than WinSmash estimates. EDRs directly measure the acceleration of a vehicle from onboard sensors and are expected to be a more accurate gauge of vehicle response to a crash than would an after the fact crash reconstruction. Although EDRs are expected to greatly enhance the reconstruction of an crash, it should be noted that EDRs are not perfect. In our study, we noted a number of limitations of the current EDR devices in the fleet.

1. The Problem of Multiple Events

A crash is frequently characterized by multiple events. For example as shown in Figure 8, a car may first inadvertently leave the road and glance off a guard-rail – the first event, careen into the path of an oncoming car – the second event, and finally strike a tree on the opposite side of the highway – the third event.

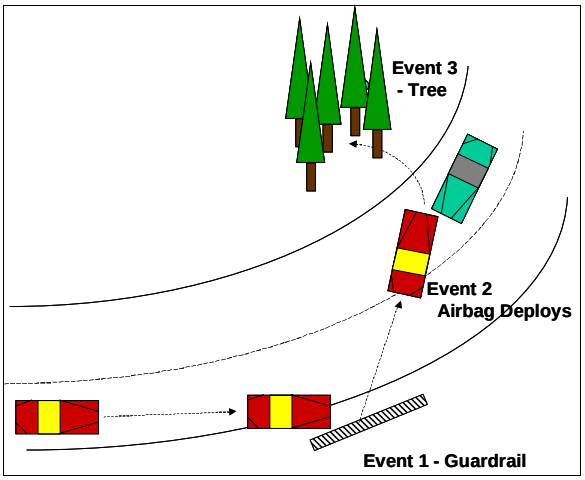

Figure 8. Current EDRs may not capture all events in a crash.

Most current EDRs are not equipped to record all the events that may occur in a crash. The GM EDRs analyzed in this study were capable of capturing two events: a near-deployment event and a deployment event. For some later GM EDR designs, a deployment level event, which occurs after bag deployment, can record over a near deployment event. However, even these newer GM devices can only capture two events. There are other automakers EDRs that are only capable of capturing a single event. As the typical event captured is the event that deployed the airbag, any subsequent events may not be recorded even if these events are more harmful.

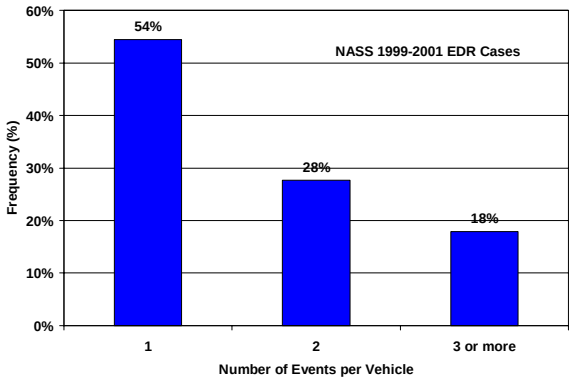

Figure 9. Events per Vehicle for NASS/CDS 1999-2001 EDR Cases

Figure 9 presents the distribution of events per vehicle for the 1999-2001 NASS/CDS cases with a successful EDR download. 46% of the EDR cases involved two or more events. In 18 % of the cases, the vehicle was involved in three or more events. As GM EDRs can only store a maximum of two events, it is likely that potential EDR data was "lost" from one or more events in these crashes.

2. The Difficulty of Correlating the EDR Event with Post-crash Investigations

An additional challenge is determining which events, of the many events a vehicle was subjected to, were captured by the EDR. In our study, we compared EDR-generated delta-V with the NASS/CDS most harmful event delta-V. However, it could not be determined if the NASS/CDS estimated delta-V corresponding to the most harmful event was actually the event recorded by the EDR.

Table 7. Example NASS/CDS case with Multiple Events

Event	CDC	Estimated Delta-V
1	12FREN3	Unknown
2	12FZEW3	19 mph

For example, Table 7 presents the case of a 2001 Chevrolet Monte Carlo along with the delta-V estimated for each of the 2 events to which the car was exposed. The first event is a narrow frontal impact to the rightmost 1/3 of the vehicle. The

second event is an overlapping wide frontal impact to the center and right 2/3 of the vehicle. The front bumper was displaced rearward to just forward of the front bumper. The delta-V measured by the EDR was 26 mph. For this case, it is unclear which event triggered the EDR or was recorded.

As discussed earlier, 46% of the NASS/CDS cases examined were characterized by multiple events. The NASS/CDS database records the delta-V from the event judged by the crash investigator to be the most harmful and the event judged to be the second most harmful. In both cases, it can very difficult to match the EDR delta-V with the correct NASS/CDS estimate of delta-V. In this study, we used our best judgment to attempt to match the two, but it should be noted that in many cases there was no definitive means to ensure a correct match. Research is currently underway to investigate this issue.

Our earlier comparison of WinSmash v. EDR delta-V implicitly assumed that we were comparing delta-Vs from the same event. However, in crashes composed of multiple events, this assumption is not always be true. Some of the differences may be simply the result of comparing two different events of a crash. To explore this possibility, we reexamined the WinSmash v. EDR delta-V as a function of number of events as shown in Figure 10.

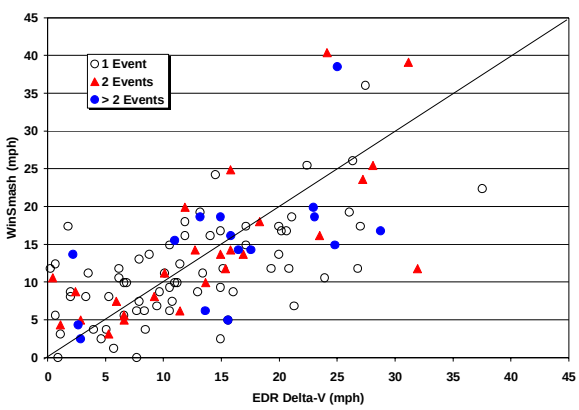

Figure 10. WinSmash v. EDR Delta-V as a function of number of events per vehicle

Our conjecture had been that the scatter in the WinSmash v. EDR comparison might be greatly reduced in single event crashes. In single event crashes, the single NASS/CDS event corresponding to the single EDR event can be identified without ambiguity. However, as seen in Figure 10, even single event crashes exhibit a substantial difference between WinSmash and EDR delta-V.

3. The Need for Longer Recording Times

NHTSA crash tests show that typical offset crashes may last as long as 250 milliseconds (ms). Table 8 shows the time interval over which current generation EDRs record crash pulse or velocity versus time.

Table 8. EDR Recording Intervals

Recorder	Time Interval (milliseconds)
Typical Offset Crash Test	250+
GMC EDR (pre-2000)	300
GMC EDR (post-2000)	150

Note that the most recent GM does not record for a sufficient time interval to fully capture an event as common as a frontal offset crash. EDRs from some automakers record for an even briefer period. These devices would consequently underestimate the delta-V for longer length crash events.

Figure 11 illustrates this issue for four selected EDR cases. In one of the cases (CDC= 11FLAE9), the vehicle reaches a constant velocity at about 125 ms after impact signaling that the crash event is over. Note however that in the other three cases velocity is still decreasing at the point when the EDR stopped recording. In these cases, the EDR does not provide a correct final delta-V.

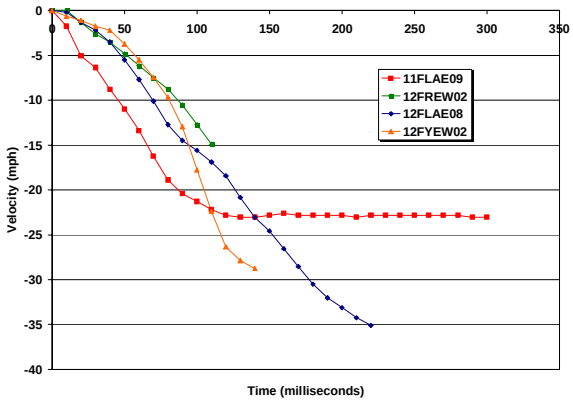

Figure 11. The Effect of Recording Time for four selected GM EDR cases

To determine the extent to which EDRs did not correctly capture delta-V in the current NASS/CDS 1999-2001 data set, those EDR cases, which had 300 ms of data, were artificially clipped at 150 ms.

Delta-V was first computed using the full 300 ms of data and then delta-V was recomputed using only the first 150 ms of data – the recording capacity of the newer GM EDRs. As shown in Figure 12, a cross plot of the two delta-V estimates indicates that while there is some error, it is not extensive.

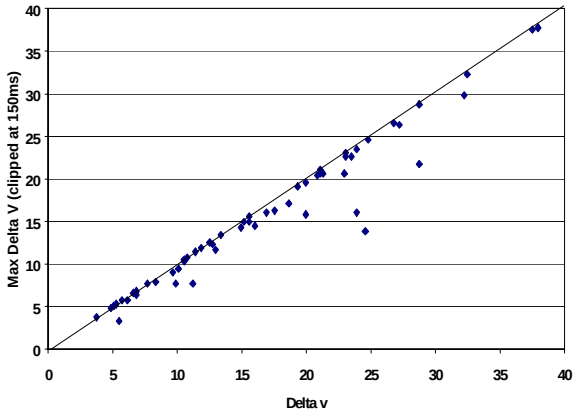

Figure 12. Delta-V error for 150 ms vs. 300 ms recording interval: 300 ms cases from NASS/CDS 1999-2001

4. The Need for Additional Crash Sensor Axes

Crash pulse can only be measured along those axes for which there are active crash sensors. Hence in the GM cases investigated in this study, only the longitudinal velocity-time history corresponding to the frontal airbag sensor was available. Lateral delta-V is only anticipated to be available for those vehicles with side impact airbags. Rear impacts are not recorded, as these events are not relevant to frontal airbag deployment. Similarly, rollovers are not recorded as only a limited number of high-end cars have a rollover sensor.

5. Missing Velocity vs. Time Data

The EDRs in the NASS/CDS 1999-2001 sample recorded velocity data for only about one-third of the near deployment events. This prevents the analysis of very low severity crash events. GM has told us that this problem has been corrected in the later versions of their EDR. Velocity data was typically available for all deployment events.

6. The Need for Additional Event Triggers

Current GM EDRs record only in the event of an airbag deployment or near-deployment. Presumably, the longitudinal accelerometer in these devices, which detects frontal crashes and deploys the airbag, also detects rear impacts. It would be useful if future EDRs could be designed to capture events such as rear impacts, which are detected by current sensors, but which do not necessarily deploy the airbag.

7. Field Data Collection Issues

In the field, NHTSA has found that it is not always possible to download data from the EDR. In the first 11 months of 2002, the NASS/CDS sample and case selection process provided 684 vehicles that were identified as being equipped with an EDR. Of that subset, 60% of those vehicles were successfully downloaded. The remaining 271 vehicles were identified as being equipped with an EDR but the data were not obtained.

The reasons for the inability to obtain the EDR data were culled from case comments entered by NASS/CDS researchers and are described below. In the discussion that follows, it should be noted that the Vetronix system allows the crash investigator to connect to a supported EDR in either of two ways:

- Connection to the vehicle's Onboard Diagnostic connector (OBD) typically located below the steering wheel, or
- Directly connecting to the EDR in cases where the vehicle's electrical system has been damaged during the crash. This option requires access to specialized cables that differ from EDR to EDR.

Figure 13 presents the distribution of NASS 2002 cases for which an attempted EDR download was not successful.

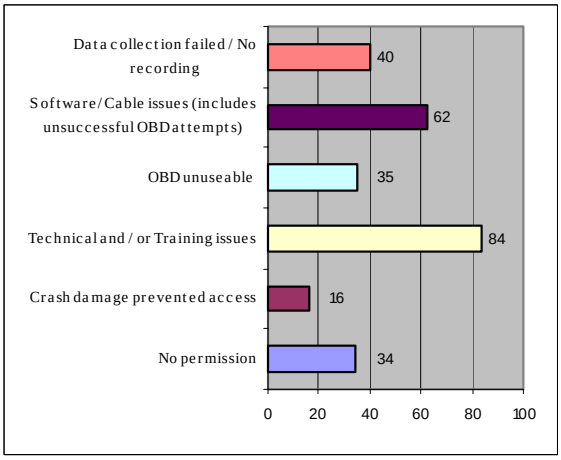

Figure 13. Distribution for the 271 vehicles that data was not obtained in the first 11 months of 2002 NASS/CDS

The reasons for EDR download failures fell into the following major causal categories:

A. ***Data Collection Failed / No Recording*** accounted for 40 vehicles or 15% of the total un-recovered EDR data. This category included situations where the recording device did not record any or all of the expected data or the criteria to record data was not met in the crash. Compromise of the vehicle's electrical system during the crash was the most frequent cause of failed recordings. The air bag control modules are equipped with capacitors to deploy the occupant protection systems, however these capacitors generally do not have the power supply to also record crash data.

B. ***Software/Cable Issues*** accounted for 62 vehicles or 23% of the total un-recovered EDR data. Included in this category are cases where the vehicle was known to have an EDR but the Vetronix software to support the make/model of vehicle was not available to the researcher at the time of inspection. This category also included cases where problems using the direct connection cables prevented communication with the EDR. Direct connection to an EDR requires a cable/connector that are unique to each EDR model. If these cables are not available to a researcher in the field, the EDR cannot be downloaded.

C. ***OBD Unusable*** accounted for 35 vehicles or 13% of the total un-recovered data. This category included those situations where it was impossible to interrogate the EDR via the OBD vehicle diagnostic connector. No attempt to make direct connections to the recording device was annotated in any of these situations.

D. ***Technical/Training Issues*** accounted for 84 vehicles or 30% of the un-recovered data. This category includes circumstances where the crash data was not available due to technical issues such as, inability to access the data-recording device without causing undue damage to the vehicle, partial inspections of vehicles, time constraints as well as a lack of problem solving and technical assistance at the time of the vehicle inspection. An example of a training issue is attempting to download the EDR without checking the Vetronix supported vehicles listing.

E. ***Crash Damage Prevented Access*** accounted for 16 vehicles or 6% of the un-recovered data. This category includes situations where the EDR data could not be accessed due to crash induced deformation. This includes situations where the actual recording-device could not physically be accessed or the interior of the vehicle itself could not be accessed due to crash damage

F. ***No Permission*** accounted for 34 vehicles or 13% of the un-recovered data. NHTSA requires owner permission prior to interrogating the vehicle EDR. This category includes situations when permission was not given to interrogate the EDR. Within the category are situations when permission was denied to perform any vehicle inspection or permission was given to perform a full vehicle inspection less the EDR interrogation.

Proper training of crash investigators in the use of EDRs is essential. In November 2002 NHTSA's National Center for Statistics and Analysis', Crash Investigation Division produced a NASS Event Data Recorder Data Collection Guideline (Roston, 2002). This Guideline has been provided to all NASS, SCI and CIREN personnel and will be provided to new researchers as they attend NASS Basic Training. Additionally, the NASS Basic Training EDR curriculum was reviewed and updated. This rededicated effort to provide additional training in EDR download protocol will, in all likelihood, have a positive impact on all of the training issues that were identified for 2002 un-recovered data.

Of major concern to all users of EDR data is the relationship between the major categories of ***OBD Unusable*** and ***Software/Cable Issues***. As previously mentioned, the "OBD unusable" category includes those situations where it was impossible to interrogate the EDR via the OBD vehicle diagnostic system due to reasons such as loss of power or no keys. The "Software Issues" category includes those situations when issues with the Vetronix software or cabling / connectors prevented downloading the EDR. When cable or connection issues were cited, this implies an unsuccessful attempt to utilize the OBD connection under the dash. If the researcher was attempting to directly connect to the EDR – a backup download measure, we can assume that connection via the OBD connector had failed.

Nearly 25%, (15 of the 62 vehicles in this category) can be attributed to not being able to utilize the OBD plug. As shown in Figure 14, when these situations are combined with the previously recorded OBD unusable vehicles they account for 18% of the total un-recovered data.

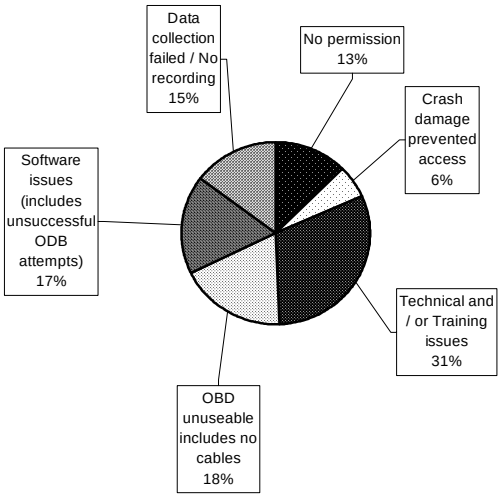

Figure 14. 2002 NASS EDR Data distribution of un-recovered EDRs when the OBD was unusable including cabling issues.

This phenomenon should be considered before recommending that the OBD diagnostic connector also serve as a universal connection to EDRs. Use of the OBD connector requires vehicle power. Generally, vehicles that are involved in a crash of significant severity will be without vehicle power. This can be due to crash - induced damage or from actions taken to render the vehicle safe by first responders. Without vehicle power the OBD plug is basically useless, and connections must be made to the EDR directly. When one considers the requirement that at least one vehicle in a NASS selected case must be towed due to damage, the significance of the universal connection at the OBD plug becomes very apparent.

CONCLUSIONS

The goal of this study was to examine the feasibility of using EDR data to support crash reconstruction. It should be noted, that because of the small sample currently available (225 events), the primary outcome should be regarded only as an initial indication of the findings that can be expected from follow-on studies with a larger EDR sample.

Our conclusions are as follows:

- **Database Development.** Rowan University has developed an EDR Database based on 225 cases from 1999-2001 NASS/CDS in which EDR data was recovered during crash investigation. The cases are composed entirely of GM vehicles of model years 1996-2002.

- **WinSmash vs. EDR Delta-V**. It has been proposed that EDRs could potentially replace delta-V estimates from crash reconstruction with the delta-V recorded in EDRs. Our analysis of 110 cases in which both a NASS/CDS delta-V and EDR change in velocity data was available suggests that there is no evidence that EDRs deviate from WinSmash estimates for any particular crash mode. The analysis suggests however that WinSmash tends to overestimate delta-V for lower speed near deployment cases.

- **EDRs can Recover Unknown Delta-Vs**. EDRs have the potential to provide a delta-V for many of the NASS/CDS cases now listed as having an unknown delta-V. In 58% of the cases with an unknown NASS/CDS delta-V, an EDR delta-V estimate was available as an alternative measure.

- **EDRs do not always record velocity-time data**. One concern when using current GM EDRs is that velocity-time data was not always recorded in an event. In 51% of the cases with zero or missing EDR velocity data, NASS/CDS investigators were able to estimate a delta-V based upon vehicle damage. GM has told us that this problem has been corrected in the later versions of their EDR.

- **Seat Belt Usage.** As GM EDRs record driver seat belt status, EDRs have the potential to more accurately collect this crucial data element. A comparison of NASS-reported driver belt usage with EDR-measured driver belt status suggests that seat belt usage may be over reported in NASS/CDS

- **Limitations of EDR Data.** Although EDRs are expected to greatly enhance the investigation of a crash, current EDRs are by no means perfect. The limitations of current EDR technology include a) insufficient recording times to capture the entire event b) inability to capture multiple events, c) difficulty of correlating EDR events with the events recorded by crash investigators, d) missing velocity v. time data for near deployment events, e) the need for additional

crash sensors to supplement the currently available longitudinal sensor, and f) the need for resultant delta-V to measure crash severity in all crash modes.

- **EDR Download Rates.** This paper has examined the reasons why EDR data downloads are not always successful. Of particular concern is the inability to reliably connect to the EDR through the OBD diagnostic connector, which accounted for 18% of all EDR download failures.

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REFERENCES

1. Chidester, A., Hinch, J., and Roston, T. "Real World Experience With Event Data Recorders". Proceedings of the Seventeenth International Technical Conference on the Enhanced Safety of Vehicles, Amsterdam, Netherlands (June 2001)

2. Gabler, H.C. and Hampton, C., *Event Data Recorders: Engineering Evaluation of Initial Field Data*, Letter Report prepared for National Highway Traffic Safety Administration (September 2002)

3. *CRASH3 User's Guide and Technical Manual*, National Highway Traffic Safety Administration, Final Report. (1981, Revised 1982)

4. *Event Data Recorders, Summary of Findings by the NHTSA Working Group*, National Highway Traffic Safety Administration, Final Report. (April 2001)

5. O'Neill, B, Preuss, C.A., and Nolan, J.M., "Relationships between Computed delta V and Impact Speeds for Offset Crashes", Paper No. 96-S0-O-11, Proceedings of the Fifteenth International Technical Conference on the Enhanced Safety of Vehicles, Melbourne, Australia (May 1996)

6. Roston, T., "NASS Event Data Recorder Data Collection Guideline", National Highway Traffic Safety Administration (November 2002)

7. Stucki, S.L. and Fessahaie, O., "Comparison of Measured Velocity Change in Frontal Crash Tests to NASS Computed Velocity Change", SAE Paper 960649 (February 1998).