Effect of Belt Usage Reporting Errors on Injury Risk Estimates

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Abstract

This thesis presents the results of a research effort investigating the effect of belt usage reporting errors of National Automotive Sampling System-Crash Data System (NASS-CDS) investigators on injury risk estimates. Current estimates of injury risk are developed under the assumption that NASS-CDS investigators are always accurate at determining seat belt usage. The primary purpose of this research is to determine the accuracy of NASS-CDS investigators using event data recorders (EDRs) as the baseline for accuracy, and then recalculating injury risk estimates based on our findings.

The analysis of a 107 EDR dataset, from vehicle tests conducted by the National Highway Traffic Safety Administration (NHTSA) and the Insurance Institute for Highway Safety (IIHS), was conducted to determine the accuracy of Chrysler, Ford, GM and Toyota EDRs. This accuracy was examined by both EDR module type and vehicle make. EDR accuracy was determined for crash delta-V, seat belt buckle status, pre-impact speed, airbag deployment status and front seat position. From this analysis we were able to conclude that EDRs were accurate, within 4.5%, when comparing maximum delta-V of EDRs that recorded the entire crash pulse length. We also determined that EDRs were 100% accurate when reporting driver seat belt status for EDRs that completely recorded the event and recorded a status for the driver's seat belt. All GM, Ford and Chrysler EDRs in our database reported a pre-impact velocity less than 6 mph different than the NHTSA and IIHS reported pre-impact velocities. We also found that all but 2 (101 out of 103) of the GM, Ford, and Toyota EDRs correctly reported airbag deployment status. Lastly we were able to conclude that seat position status was useful in

determining when a smaller sized occupant was the driver or right front occupant. EDRs reported seat position of 5% Hybrid III females as “forward” in every case that seat position was recorded for this smaller occupant size.

Based on the analysis of seat belt status accuracy, a comparison of NASS-CDS investigator driver seat belt status and EDR driver seat belt status was conducted to determine the accuracy of the NASS-CDS investigators. This same comparison was conducted on reports of driver seat belt status provided by police. We found that NASS-CDS investigators had an overall error of 9.5% when determining driver seat belt status. When the EDR stated that the driver was unbuckled, investigators incorrectly coded buckled in of 29.5% of the cases. When the EDR stated that the driver was buckled, NASS-CDS error was only 1.2%. Police officers were less accurate than NASS-CDS investigators, with an overall error of 21.7%. When the EDR stated that the driver was buckled, police had an error of 2.4%. When the EDR stated that the driver’s belt was unbuckled, police had an error of around 69%. In 2008, NASS-CDS investigators reported that drivers had an overall belt usage rate during accidents of 82%. After correcting for the errors we discovered, we estimate that the driver belt buckle status during a crash is around 72.6%.

Injury risk estimates and odd ratio point estimates were then calculated for NASS-CDS investigator and EDR buckled versus unbuckled cases. The cases included only frontal collisions in which there was no rollover event or fire. Injury was defined as AIS 2+. The risk ratios and point estimates were then compared between investigators and EDRs. We found that injury risk for unbelted drivers may be over estimated by NASS-CDS investigators. The unbuckled to buckled risk ratio for EDRs was 8%-12% lower than the risk ratio calculated for NASS-CDS investigators.

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1. INTRODUCTION

1.1 Background

In 2008, the National Highway Traffic Safety Administration (NHTSA) estimated that Americans drove 2.926 billion miles and were involved in over 5.8 million police reported crashes resulting in 37,261 deaths and over 2.3 million injuries; specifically 26,689 and 2.1 million passenger vehicle deaths and injuries (NHTSA, 2008). These numbers do not include the additional 10,572 deaths and 226,000 pedestrians and motorcyclists who are also injured and killed in automotive crashes. The fatality and injury rates per vehicle mile traveled have been steadily decreasing since the 1980's (NHSTA, 2000 and NHTSA, 2008) due in part to an increase in the number of vehicle occupants who are properly wearing their seat belts.

1.1.1 Seatbelt Usage

Currently 49 states and the District of Columbia have laws in effect regarding seatbelt use. In 2009, an estimated 84% of drivers and left front passengers wore their seat belts (NHTSA, 2009). New Hampshire is the only state not requiring vehicle occupants over the age of 18 to wear a seat belt. NHTSA estimates that from 1975 to 2008, seat belts saved approximately 255,115 lives including 13,250 in 2008 alone (NHTSA, 2008). Figure 1 shows historic seatbelt use since 1980 (NHTSA, 2000& and NHTSA, 2009). Seat belt use increased dramatically through the 1980's and early 1990's, and has been consistently increasing through this entire time period. Since 2003 seat belt usage rates has leveled out at around 80%.

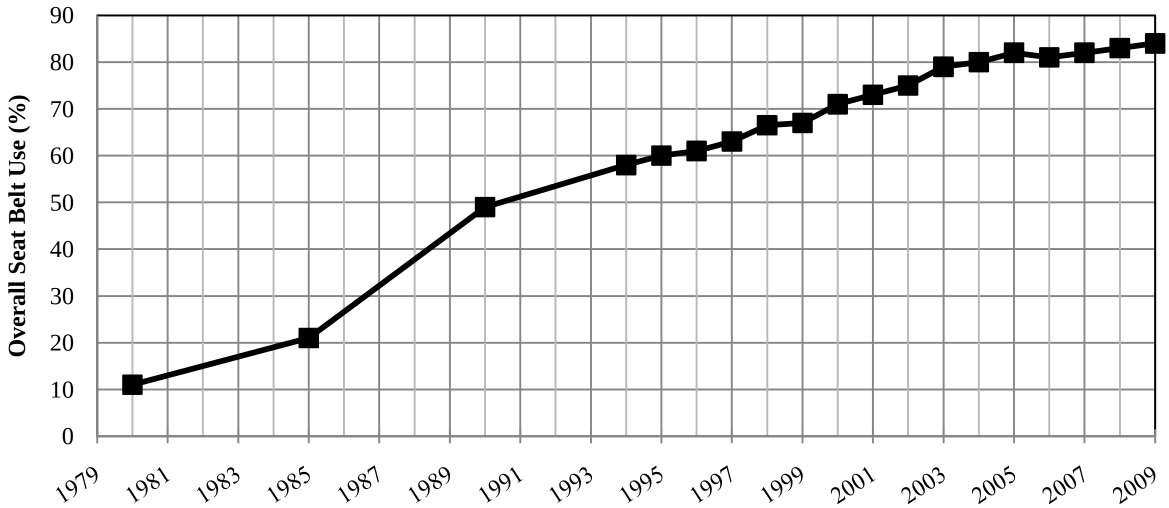

Figure 1. Overall Seat Belt Usage per Year

Figure 2 presents the number of vehicle occupants killed in fatal collisions who were restrained by a seatbelt versus those who were not restrained; collected from NHTSA's 2000 Traffic Safety Facts and FARS. Although the number of overall fatalities has remained relatively constant, fluctuating between 25,000 and 35,000, there is a significant decrease in the number of unrestrained occupants being fatally injured during a crash. This decrease is consistent with the fact that seat belt use rates have increased. However, since the number of fatalities has not significantly changed, the number of belted occupants who were fatally injured in a crash has gone up. There are still more deaths among unbelted occupants than belted.

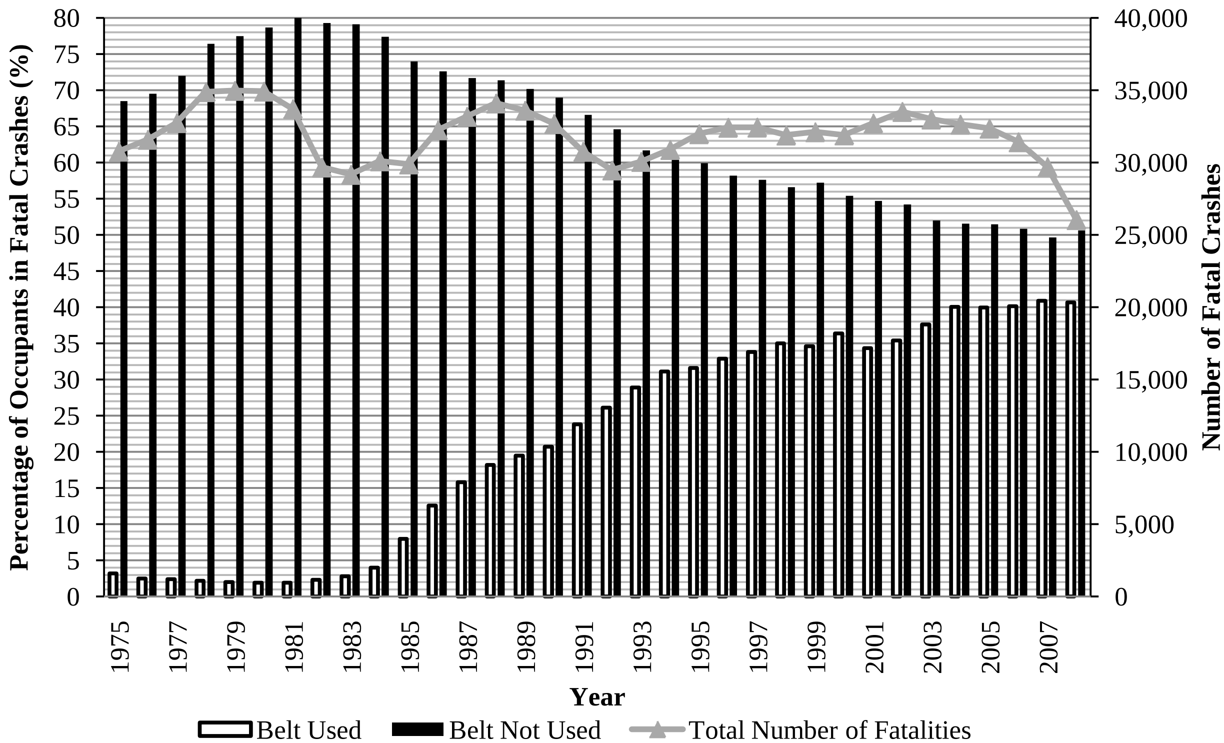

Figure 2. Percentage of Occupants in a Fatal Crash (Belted vs. Unbelted)

1.1.2 Reporting of Seatbelt Usage

Police are responsible for reporting belt usage during an accident. However, there is some question about their accuracy (Moore et al, 2009). Many studies have been conducted which compare police reported belt usage to reports conducted by the National Automotive Sampling System-Crashworthiness Data System (NASS-CDS) investigators, who are trained to determine belt use (Schiff and Cummings, 2004; Moore et al., 2009; Viano and Parenteau, 2009)

Schiff and Cummings (2004) used a NASS-CDS dataset which included 49,115 front seat occupants, and found an 87.7% correlation between what the police reported and what the NASS-CDS investigators found. Police were 30.9 % more likely to misclassify unbuckled occupants as buckled and this occurred more often in accidents where the occupant was uninjured. 46.8% of the occupants misclassified as buckled were uninjured during the crash. Among belted occupants, police were much more accurate, only misclassifying these occupants 4.2% of the time. Unlike with the unbuckled occupants, police officers were more likely to misclassify belted occupants when the crash resulted in a fatality (Schiff and Cummings, 2004). One possible reason for this is that during a fatal collision, there is significantly more damage to the vehicle and injuries to the occupant, which the responding officer may speculate could only occur if the occupant was unbuckled. Schiff and Cummings (2004) also found that agreement between NASS-CDS investigators and police increased as injury severity increased.

Moore et al. (2009) utilized NASS-CDS cases from 1988-2006 to evaluate the accuracy of seat belt reporting by police. This study looked at 174,000 adult outboard vehicle occupants involved in crashes. They also found that police were more accurate at determining seatbelt usage when the occupant was restrained. Police were estimated to be 97% accurate at determining if the occupant was restrained versus 64% when the occupant was unrestrained (Moore et al., 2009). They also found that unrestrained occupants were more likely to be classified correctly as injury severity increased.

Viano and Parenteau (2009) looked at NASS-CDS cases involving adults and teens 12 years and older involved in crashes from 1993-2007. They found that, according to both NASS-CDS investigators and police officers, unbuckled rates increased as injury severity increased. NASS-CDS investigators estimated that 35.4% of occupants were unbuckled during a crash with maximum Abbreviated Injury Scale (MAIS) 3+ injuries and 58.2% of occupants were unbuckled when fatally injured. Police reported these numbers as 27.6% to 53.9% respectively (Viano and Parenteau, 2009).

The differences reported by police officers can be attributed to many different factors. Depending on severity, the occupant may have already left the vehicle so belt use cannot be directly observed by the responding officer (Schiff and Cummings, 2004; Moore et al., 2009). Also, because most states require seatbelt use by law, the occupants might be untruthful about their seat belt use to avoid further prosecution. Many police officers do not inspect the vehicle for belt use (Viano and Parenteau, 2009), and instead rely on self reporting by the occupant (Schiff and Cummings, 2004; Moore et al., 2009; Viano and Parenteau, 2009). NASS-CDS investigators, on the other hand, are specifically trained to look for certain indicators of belt use which the police officers may not be aware of.

1.1.3 Seat Belt Usage Indicators

There are many indicators which may aid in the detection of seat belt use after a car crash. The indicators may be found on the seat belt latch plate, D-ring, the belt webbing, and the interior of the vehicle. The ability to detect these indicators relies heavily on the severity of the crash because in minor crashes, belt use marks may resemble normal usage marks.

Seat Belt Use Indicators of the D-ring and Latch Plate

The D-ring and latch plate often have very similar marks when involved in a crash. This is due to the plastic composition of these components, as well as the belt feed through them. Abrasive markings left by the belt webbing, as well as grooving on the front corner of the D-ring can be effective indicators of seatbelt use (Heydinger et al., 2008). Figure 3 and Figure 4, show damage common to both the latch plate and D-ring during a crash.

Figure 3. Damage to the D-ring after a Crash

Figure 4. Damage to the Latch Plate after a Crash

This type of marking can be a good indicator of belt use, however if the crash is minor, the marks left on the D-ring and latch plate may look similar to that of normal use. Marks, like the one seen in Figure 5 can be caused by normal belt use and can be seen on vehicles which have not been in a collision. In order for friction marks left on the D-ring due to pressure-contact from the belt webbing to occur, Raymond et al. (2006) found that forces have to be greater than 3,866N on the shoulder belt and 3,255N on the lap belt.

Figure 5. Grime and Wear caused by Normal Belt Usage (No Collision- Right Front Passenger)

One accurate way to differentiate between belt usage marks caused by a crash from those caused by normal usage is to look for directionality in the markings (Jakstis et al., 2009). Figure 6 and Figure 7 show the directionality of the seat belt when correctly worn. During a crash, the marks left from the belt webbing onto the D-ring should be downward and forward towards the driver. Brown et al. (2009) estimated that the marks should be between 34°-42° from the vertical axis of the D-ring as shown in Figure 8. Markings on the latch plate should also show some directionality. Grooves in the D-ring caused by the friction of the seatbelt also tend to be in the corner facing the occupant (Heydinger et al., 2008).

Figure 6. Directionality of the Seat Belt Webbing through the Latch Plate when Belt is Properly Worn

Figure 7. Directionality of the Seat Belt Webbing through the D-ring when Belt is Properly Worn

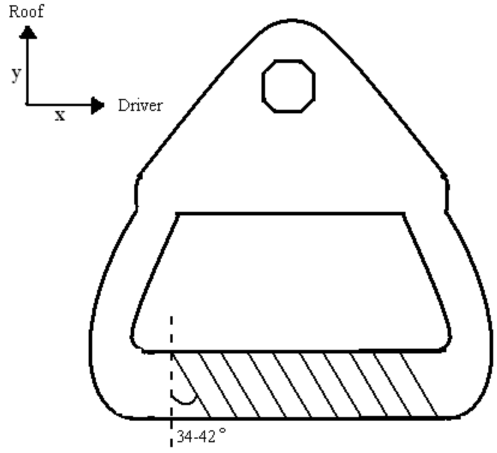

Figure 8. Diagram of Directional Markings on the D-ring caused by the Belt Webbing

Seat Belt Use Indicators of the Belt Webbing

Common indicators may also appear on the seat belt webbing, the most common being transfer of plastic from the D-ring and latch plate (Heydinger et al., 2008). Raymond et al. (2006) found that forces of 6,200N and 4,300N on the shoulder belt and lap belt respectively are needed to produce the friction required for the plastic to melt to the webbing. Distortion and breakage can also be present in the stitching of the webbing and can be used as an indicator of belt use because it shows loading on the belt.

Figure 9. Friction Melted Plastic Transfer from the D-ring to the Webbing

Seat Belt Use Indicators when Pretensioners are Available

The presence of pretensioners can change the type of indicators that can be used to determine seat belt use. They can cause multidirectional striations on the D-ring and latch plate, because they retract the belt at a high rate of speed and then the belt becomes loaded by the occupant putting force on the belt in the opposite direction (Jakstis et al., 2009). Force limiters and pretensioners can also change the length of the marks on the seat belt webbing as well as the amount of distortion on the belt due to occupant loading (Jakstis et al., 2009). Lastly, and possibly most interestingly, some pretensioners, when deployed, will actually cause the seat belt to freeze in the position it was in during the crash. Therefore, if the belt was not being worn and was in the stowed position, it would become frozen in that position causing a "bow string" effect (Jakstis et al. 2009); shown in Figure 10.

Figure 10. Bow String Effect caused by Pretensioner when Seat Belt was Unworn

Seat Belt Use Indicators on Car Interior

Marks on the interior of the vehicle are commonly seen if the occupant was not wearing the seat belt. Damage, in the form of steering wheel deformation, column damage, and knee bolster damage were only present in collisions where the occupant was unbuckled (Tanner et al., 2006). However, these marks could also depend on the distance of the occupant to these objects in the vehicle. If an occupant was buckled and the seat was all the way forward in the vehicle, there is still a chance of some interaction with the knee bolster or the column. However, if an occupant is unbuckled during a crash, the distance from the front of the vehicle is irrelevant.

1.1.4 NASS-CDS Investigators

The National Automotive Sampling System-Crashworthiness Data System (NASS-CDS) is a NHTSA program started in 1979. Each year, NASS-CDS randomly selects a sample of approximately 5,000 minor to severe crashes occurring in the US for in-depth analysis. The investigations focus on passenger cars, light trucks and utility vehicles. NASS-CDS investigators are personnel trained specifically to obtain information, from crash sites and crashed vehicles, on crash causes, crash severities, and injury causes. There are 24 field research teams, referred to as Primary Sampling Units (PSUs), which are responsible for investigating the crashes. Since its initiation in 1979, NASS-CDS has collected data on over 160,000 crashes (NCSA, 2008). They utilize the indicators listed above along with knowledge of injuries to the occupant to determine seat belt usage during a crash.

In all of the studies discussed which try to determine police accuracy for reporting belt usage, the NASS-CDS investigators are used as the benchmark for comparison. What has not been examined however is the accuracy of seat belt usage reported by the NASS-CDS investigators. Therefore developing a method to determine the accuracy of the NASS-CDS investigators would measure both the accuracy of NASS-CDS belt usage estimates and indirectly the accuracy of police-reported seat belt use.

1.1.5 Event Data Recorders (EDRs)

Event Data Recorder (EDR) modules are recording devices installed in most late model passenger vehicles and light trucks. EDRs record data describing the crash just prior to and during the incident. For example, the information below was collected by an EDR involved in the National Highway Traffic Safety Administration’s (NHTSA) New Car Assessment Program (NCAP) test number 5597. This vehicle was a 2006 Chevrolet Colorado. The actual EDR file can be found in the appendices.

From this EDR we determined that two events were recorded, a deployment and a non-deployment event. The EDR also provided a belt buckle status for both the driver and right front passenger, during both events; both buckled during deployment and unbuckled during non deployment. The EDR reported that the first airbag stage deployed at 2.5ms and the second airbag stage deployed at 7.5ms. The EDR reported the number of ignition cycles, i.e. the number of times the engine was turned on, of both the reported event and when the EDR was downloaded, 138 and 139. Passenger seat position was also reported by this EDR as rearward of center.

Other important data elements that were recorded by this EDR include the maximum delta-V of the crash, -35.15mph. The EDR also recorded that the speed of the vehicle for 5 seconds prior to the event was 35mph. This EDR also recorded the engine RPMs for the 5 seconds prior to the event as 0 and the percent throttle for the same period as 0. Brake status of this vehicle can be determined for 8 seconds prior to the crash and during the entire 8 seconds recorded, the brakes were off. Figure 11 shows this information graphically.

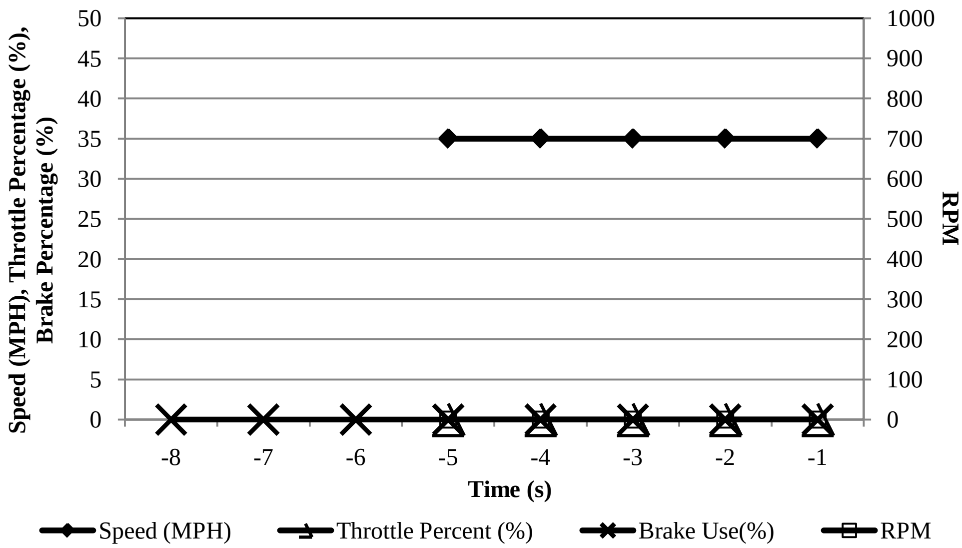

Figure 11. Graph of Pre-crash Vehicle Speed, Engine RPM, %Throttle and %Brake measured by the EDR

Finally a recorded velocity change over time, for 100 ms of the crash was collected and reported. This is done in both a graph and a tabulated format.

Variations in EDRs

There is currently no standard for EDR data. EDRs differ in several different ways. Each automaker has their own version of an EDR which records what they determine to be important information from a crash. EDRs can also vary depending on the model year of the module, type of module and features available in the vehicle. Some EDRs report side airbag deployment separately from frontal airbags. Some also report belt pretensioner status. In the newer, more advanced EDRs information from the 2nd and 3rd seat rows can also be collected.

Unfortunately, the only publicly available system used to download the EDR data is the Bosch Crash Data Retrieval (CDR) system. The Bosch CDR system is only able to download EDR information for a limited number of vehicles. GM vehicles are the most downloadable. Model year 1994-2010 GM vehicles are available for download. Ford and Chrysler have also made some of their vehicle models available for download through the CDR system. For Ford vehicles these include limited models from 2001 to the present. Chrysler vehicle models from 2005 to the present can be downloaded. To date, other automakers such as Honda, Toyota, Nissan and Kia have not made arrangements with Bosch to allow download of their EDRS.

NHTSA Final Rule on Event Data Recorders: 49 CFR Part 563

NHTSA has developed a rule, 49 CFR Part 563, in an attempt to standardize data available from EDRs. Starting September 1st 2012, all EDR modules produced after that date will be required to record the information listed in Table **1**. Recording of data elements such as vehicle speed, brake status, and engine throttle will be required for 5 seconds before an event. Driver seat belt status must also be recorded along with driver and passenger airbag deployment times. Delta-V must be recorded for 250ms or 30ms after the end of the event and maximum delta-V and the time at which it occurs must also be included. Lastly event record complete status, which is important for verifying the accuracy of the EDR, will become a required field.

Unfortunately some elements such as passenger seat belt status, lateral and longitudinal accelerations, lateral delta-V data, and side airbag deployment data will only be required if the EDR has the ability to record and store this information.

Table 1. Required Data Elements of EDRs starting September 1st, 2012 (NHTSA, 49 CFR Part 563)

Data Element	Recording Interval/time (relative to time 0)	Data Sample rate (samples per second)
Delta-V Longitudinal	0-250 ms, or 0 to End of Event Time plus 30 ms whichever is shorter	100
Maximum delta-V, Longitudinal	0-300 ms, or 0 to End of Event Time plus 30 ms whichever is shorter	N/A
Time, maximum delta-V	0-300 ms, or 0 to End of Event Time plus 30 ms whichever is shorter	N/A
Speed, vehicle indicated	-5.0 to 0 sec	2
Engine throttle, % full (or accelerator pedal, % full)	-5.0 to 0 sec	2
Service brake, on/off	-5.0 to 0 sec	2
Ignition cycle, crash	-1 .0sec	N/A
Ignition cycle, download	At time of download	N/A
Safety belt status, driver	-1 .0sec	N/A
Frontal air bag warning lamp, on/off	-1 .0sec	N/A
Frontal air bag deployment, time to deploy, in the case of a single stage air bag, or time to first stage deployment, in the case of a multi-stage air bag, driver	Event	N/A
Frontal air bag deployment, time to deploy, in the case of a single stage air bag, or time to first stage deployment, in the case of a multi-stage air bag, right front passenger	Event	N/A
Multi-event, number of events (1,2)	Event	N/A
Time from event 1 to 2	As needed	N/A
Complete file recorded (yes, no)	Following other data	N/A

One important change to the current EDR data available is that NHTSA rule 49 CFR Part 563 requires that all vehicle manufacturers who include EDRs in their vehicles, must make access to the required data commercially available. This means that vehicle makes such as Honda, Toyota, Nissan and Kia must allow for their EDR information to be downloaded.

Possible Uses of EDRs

Three possible uses of the information gathered from EDRs are for law enforcement, for product liability concerns and for research uses.

After a crash, there are often legal measures brought against the driver. These can range from speeding and breaking seat belt use laws to vehicular homicide. Using EDRs to determine the vehicle speed, brake usage and occupant seat belt usage could possibly implicate or clear a person of such issues. As EDR technology increases and general knowledge of their capabilities improves, EDRs are becoming admissible in more and more court cases. For example the case of Commonwealth vs. Michelle M. Zimmermann (No. 06-P-1240), where the EDR reported that the defendant was going 55mph. Ms. Zimmermann stated she was only traveling 25-30mph.

EDRs can also be used to determine liability after a crash. If an occupant gets in an accident and claims that the brakes did not work, the auto company or an auto mechanic may be at fault. However, if the EDR is downloaded and can prove that the driver, in the 8 seconds prior to the collision, did not apply the brakes, then the fault lies solely with the driver and not the manufacturer or mechanic.

Another possible use of an EDR is for research purposes. Previous studies have been conducted which use data collected from EDRs to accident reconstruction estimates to determine crash severity (Gabler et al., 2004). Other studies have compared NASS-CDS data to data collected from EDRs to determine the effects of delta-V reporting errors on frontal crash risks (Funk et al., 2008). EDRs provide a constant accurate source of data for comparison for many aspects of research, including the research presented in this report.

1.2 Objective

The objective of this study is to determine the accuracy of EDRs in recording seat belt status of vehicle drivers. Once the accuracy of EDRs has been established, the second objective is to determine any possible errors in seat belt reporting by NASS-CDS investigators and police officers. The third objective is to determine the effect of these errors on injury risk estimates.

1.3 Approach

In Chapter 2, the accuracy of EDRs installed in vehicles subjected to NHTSA and IIHS crash tests will be examined. These EDRs will be compared to the NHTSA and IIHS database records of the crashes to determine how accurate the EDRs are in controlled, well monitored crash tests. The EDRs will be compared to the databases to determine their accuracy in 5 different areas. These are belt buckle status, delta-V, pre-impact speed, airbag deployment and seat position for the driver and right front passenger. The accuracy of the EDRs will be determined as a function of EDR module type and vehicle make.

In Chapter 3, using only the EDRs that have proven to be 100% accurate in determining seat belt status, a comparison of EDR seat belt status to the status reported by NASS-CDS investigators and police will be made. NASS-CDS 2000-2008 cases where the EDRs are available will be used. Because of the prevalence of GM EDRs in both the NHTSA and IIHS dataset and the NASS-CDS cases, this study will be limited to comparing seat belt status of drivers of GM vehicles. The seat belt usage accuracy reported by NASS-CDS investigators will be assessed. A reexamination of police reporting accuracy will also be conducted to determine if police are more or less accurate when compared to the EDR data.

In Chapter 4, errors in seat belt reporting by the NASS-CDS investigators will then be applied to injury risk estimates related to seat belt use. New risk curves will be generated, and new measures for the effectiveness of seat belts will be determined.

2. EDR VALIDATION AGAINST CRASH TESTS

2.1 Introduction

Most late model U.S. passenger cars and light trucks now contain an Event Data Recorder (EDR). In the event of a crash, EDRs record information about the vehicle during a crash. Information stored in EDRs may include velocity changes in the longitudinal and sometimes the lateral directions, which airbags deployed, the times at which they deployed, whether or not the seatbelt pretensioners deployed and if the seatbelts were buckled during the crash. These devices can provide important insights into a vehicle's crash performance over a range of impact conditions. However, before using EDRs to study vehicle crash performance, it is important to first establish their accuracy.

This study used EDR data from 94 NHTSA full frontal, frontal offset and side impact tests and 13 IIHS offset and pole tests to determine the accuracy of EDRs in staged collisions. The full dataset was used to determine delta-V and crash pulse length accuracy, while a limited dataset of GM and Ford Vehicles was utilized to study seat belt buckle status, air bag deployment, pre-crash speed, and seat position accuracies.

This study expanded upon two earlier projects (Niehoff, 2005; Gabler et al. 2008) with a newer set of EDRs from late model cars and light trucks. Specifically, this chapter discusses (1) the development of an expanded EDR dataset downloaded from the crash tested vehicle, (2) the method used for assessment of EDR accuracy and (3) the results from the EDR- Crash test data comparisons.

2.2 EDR Dataset

2.2.1 Introduction

This section describes the dataset which included EDR modules from NHTSA and IIHS tests that were conducted from 2001 to 2008. This dataset is the basis for the analysis of EDR accuracy discussed in this chapter.

2.2.2 Approach

Earlier studies have been performed which investigated the accuracy of EDR modules using NHTSA and IIHS tests [Gabler and Niehoff, 2005; Gabler, Thor and Hinch, 2008]. Our approach was to combine the data sets from these two reports with newly collected data, and compare the delta-V from the crash test instrumentation with the corresponding data downloaded directly from the EDR.

Most EDRs in the dataset were downloaded using the Bosch Crash Data Retrieval (CDR) system. At the time of this report, the Bosch system could only download General Motors (GM), some Ford and a few Chrysler EDRs. The CDR files are small (typically a few thousand bytes), can be read again by the Bosch software, are check-summed to prevent tampering and provide an excellent method for archiving EDR data. For vehicle types not supported by the Bosch software, the EDRs were downloaded by the automaker who provided the data to the research team.

The CDR files were matched to corresponding tests found in the NHTSA online database (nhtsa.dot.gov). In order to match a CDR to a NHTSA crash test, VIN, vehicle make, model, year and if available crash test number were verified and recorded.

2.2.3 Results

As shown in Table 2, the EDR dataset contained a total of 107 EDRs predominantly from the older research datasets. The three datasets were combined in this study with the goal of collecting a more inclusive view of EDR performance over a broad range of vehicles and model years.

Table 2. Dataset for Crash Test-EDR Comparison

Test Num	Vehicle Description	Test Type	Closing Speed (mph)	Impact Angle (deg)	Barrier/ Collision Partner	EDR Model	Source	Deploy/ NonDeploy (D/ND)	Event Record Complete
3471	2001 Chevrolet Impala	Full Front	34.9	0	Rigid	SDMGT2001	3	D/ND	Yes
3851	2002 Chevrolet Avalanche	Full Front	35.1	0	Rigid	SDMG2001	1	D	-
3952	2002 Buick Rendezvous	Full Front	35.1	0	Rigid	SDMDG2002	1	D/ND	Yes
4198	2002 Saturn Vue	Full Front	35.0	0	Rigid	SDMD2002	1	D/ND	Yes
4238	2002 Cadillac Deville	Full Front	35.3	0	Rigid	SDMGF2002	1	D	Yes
4244	2002 Chevrolet Trailblazer	Full Front	35.1	0	Rigid	SDMGT2002	1	D	Yes
4259	2003 Cadillac CTS	Full Front	35.2	0	Rigid	SDMGF2002	3	ND	Yes
4437	2003 Chevrolet Suburban	Frontal Off.	24.8	0	MDB	SDMGF2002	1	ND	Yes
4445	2003 Chevrolet Cavalier	Full Front	34.7	0	Rigid	SDMG2001	1	D	-
4453	2003 Chevrolet Silverado	Full Front	24.3	0	Rigid	SDMGF2002	1	D	Yes
4454	2003 Chevrolet Tahoe	Full Front	24.3	0	Rigid	SDMGF2002	1	D	Yes
4464	2003 Chevrolet Avalanche	Full Front	35.1	0	Rigid	SDMGT2002	1	D	Yes
4472	2003 Chevrolet Silverado	Full Front	34.7	0	Rigid	SDMGF2002	1	D/ND	Yes
4487	2003 Saturn Ion	Full Front	34.8	0	Rigid	SDMDW2003	1	D/ND	Yes
4549	2003 Chevy Tahoe	Full Front	35.0	0	Rigid	SDMGF2002	1	D/ND	Yes
4567	2003 Chevrolet Suburban	Full Front	35.0	0	Rigid	SDMGF2002	1	D/ND	Yes
4702	2002 Saturn Vue	Full Front	29.7	0	Rigid	SDMD2002	1	D/ND	Yes
4714	2002 Saturn Vue	Full Front	29.7	0	Rigid	SDMD2002	1	D/ND	Yes
4733	2004 Toyota Sienna	Side	38.2	270	MDB	89170-08050	2	ND^+	Yes
4775	2004 Pontiac Grand Prix	Full Front	34.7	0	Rigid	SDMDW2003	1	D/ND	Yes
4777	2001 Buick LeSabre	Side	32.9	270	MDB	SDMGT2001	3	ND	Yes
4846	2004 Toyota Sienna	Full Front	35.1	0	Rigid	89170-08060	1	D^+	Yes
4855	2004 Toyota Solara	Full Front	34.7	0	Rigid	89170-06240	1	D^+	Yes
4890	2004 Ford F-150	Full Front	35.0	0	Rigid	ARM481+	1	D^+	-
4893	2004 Toyota RAV4	Full Front	35.3	0	Rigid	89170-42160	2	D^+	Yes
4899	2004 Cadillac SRX	Full Front	35.1	0	Rigid	SDMGF2002	1	D/ND	Yes
4918	2004 GMC Envoy XUV	Full Front	35.0	0	Rigid	SDMGT2002	1	D/ND	Yes
4923	2004 Chevrolet Colorado	Full Front	35.2	0	Rigid	SDMGF2002	1	D	Yes
4928	2004 Toyota Camry	Side	38.4	270	MDB	89170-33300	2	ND^+	Yes
4931	2004 Saturn Vue	Full Front	34.7	0	Rigid	SDMDW2003	3	D/ND	Yes

Test Num	Vehicle Description	Test Type	Closing Speed (mph)	Impact Angle (deg)	Barrier/ Collision Partner	EDR Model	Source	Deploy/ NonDeploy (D/ND)	Event Record Complete
4933	2004 Toyota Prius	Full Front	35.4	0	Rigid	89170-47380	2	D+	Yes
4937	1997 Cadillac Seville	Offset	69.6	30 (obq)	97 Honda Accord	SDMCL21997	3	D/ND	No
4955	2000 Cadillac Seville	Offset	70.4	330	Vehicle	SDMG2000	1	D	-
4984	2004 Saturn Ion	Full Front	24.8	0	Rigid	SDMDW2003	1	D/ND	Yes
4985	2005 Chevrolet Equinox	Full Front	35.0	0	Rigid	SDMDW2003	1	D/ND	Yes
4987	2005 Ford Taurus	Full Front	25.0	0	Rigid	ARM481+	1	D+	-
5037	2004 Toyota 4Runner	Full Front	34.9	0	Rigid	89170-35190	2	D+	Yes
5071	2004 Toyota Camry	Full Front	24.6	0	Rigid	89170-33300	1	D+	Yes
5140	2004 Chevrolet Avalanche	Full Front	35.0	0	Rigid	SDMGF2002	2	D/ND	Yes
5157	2005 Toyota Corolla	Side	38.6	270	MDB	89170-02410	2	D+	Yes
5160	2005 Toyota Corolla	Full Front	35.1	0	Rigid	89170-02420	2	D+	Yes
5162	2005 Toyota Matrix	Side	38.6	270	MDB	89170-01060	2	D+	Yes
5209	2005 Toyota Matrix	Full Front	35.1	0	Rigid	89170-01070	2	D+	Yes
5213	2004 Chevrolet Avalanche	Full Front	30.1	0	Rigid	SDMGF2002	2	D/ND	Yes
5217	2005 Toyota Scion TC	Full Front	34.9	0	Rigid	89170-21070	2	D+	Yes
5218	2005 Toyota Tundra	Full Front	35.0	0	Rigid	89170-0C160	2	D+	Yes
5239	2005 Toyota Tundra	Full Front	35.0	0	Rigid	89170-0C190	2	D+	Yes
5249	2005 Ford 500	Full Front	35.3	0	Rigid	N/A	2	D+	-
5250	2005 Pontiac G6	Full Front	35.3	0	Rigid	Epsilon2005	2	D	Yes
5256	2005 Pontiac G6	Side	38.6	270	MDB	Epsilon2005	3	D	Yes
5260	2005 Saturn ION	Side	38.4	270	MDB	SDMDW2003	2	D/ND	Yes
5263	2005 Ford Freestyle	Full Front	35.1	0	Rigid	N/A	2	D+	-
5264	2005 Chevy Uplander	Full Front	35.0	0	Rigid	SDMDW2003	2	D/ND	Yes
5265	2005 Chevy Express	Full Front	35.0	0	Rigid	SDMGF2002	2	D/ND	Yes
5269	2005 Toyota Sienna	Full Front	35.0	0	Rigid	89170-08070	2	D+	Yes
5282	2005 Chevy Colorado	Full Front	35.0	0	Rigid	SDMGF2002	2	D/ND	Yes
5283	2005 Toyota Camry	Full Front	35.1	0	Rigid	89170-06260*4- (89170-33310)	2	D+	Yes
5284	2005 Ford Econoline	Full Front	35.0	0	Rigid	N/A	2	D+	-
5310	2005 Buick Rendezvous	Full Front	34.9	0	Rigid	SDMDW2003	2	D/ND	Yes

Test Num	Vehicle Description	Test Type	Closing Speed (mph)	Impact Angle (deg)	Barrier/ Collision Partner	EDR Model	Source	Deploy/ NonDeploy (D/ND)	Event Record Complete
5312	2005 Toyota Tacoma	Full Front	34.9	0	Rigid	89170-04070	2	D^+	-
5318	2005 Chevy Silverado	Full Front	34.9	0	Rigid	SDMGF2002	2	D/ND	Yes
5324	2005 Pontiac Montana	Full Front	34.8	0	Rigid	SDMDW2003	2	D/ND	Yes
5325	2005 Chevy Cobalt	Side	38.1	270	MDB	Epsilon2005	3	ND	Yes
5326	2005 Chevy Cobalt	Full Front	34.9	0	Rigid	Epsilon2005	2	D	Yes
5468	2006 Pontiac Grand Prix	Full Front	35.1	0	Rigid	SDMDW2003	2	D/ND	Yes
5547	2006 Chevrolet Impala	Full Front	35.2	0	Rigid	SDMC2006	2	D	Yes
5567	2006 Hummer H3	Full Front	35.0	0	Rigid	SDMDS2005	2	D	Yes
5569	2006 Cadillac DTS	Full Front	35.2	0	Rigid	SDMC2006	2	D	Yes
5578	2006 Chevrolet Monte Carlo	Full Front	35.0	0	Rigid	SDMC2006	2	D	Yes
5589	2006 Buick Lucerne CX	Full Front	35.1	0	Rigid	SDMC2006	2	D	Yes
5597	2006 Chevrolet Colorado	Full Front	34.8	0	Rigid	SDMGF2002	2	D/ND	Yes
5602	2006 Chevrolet HHR	Full Front	34.9	0	Rigid	Epsilon2006	2	D	Yes
5603	2006 Chevy Colorado	Full Front	34.9	0	Rigid	SDMGF2002	3	D/ND	Yes
5741	2006 Buick Lucerne	Full Front	24.7	0	Rigid	SDMC2006	2	D	Yes
5830	2006 Pontiac G6	Full Front	24.7	0	Rigid	Epsilon2006	2	D	Yes
5844	2007 Saturn Aura	Full Front	35.1	0	Rigid	Epsilon2006	2	D	Yes
5859	2007 Pontiac Solstice	Full Front	35.0	0	Rigid	Epsilon2006	2	D	Yes
5877	2007 Chevrolet Silverado	Full Front	34.8	0	Rigid	SDMC2006	2	D	Yes
5907	2007 Chevrolet Silverado	Full Front	35.1	0	Rigid	SDMC2006	2	D	Yes
5967	2007 Jeep Patriot	Full Front	34.6	0	Rigid	CHRY0154	3	D^+	Valid
6172	2008 Dodge Caravan	Full Front	35.0	0	Rigid	CHRY0303C	3	D^+	Valid
6200	2008 Saturn Vue	Full Front	34.9	0	Rigid	SDMC2008V	3	D	Yes
6234	2008 Dodge Dakota	Full Front	35.1	0	Rigid	CHRY0303	3	D^+	-
6243	2008 Ford Focus	Full Front	34.8	0	Rigid	Ford_AB9	3	D	Yes
6245	2008 Ford Focus coupe	Side		270	MDB	Ford_AB9	3	D	Yes
6246	2008 Ford Focus	Side		270	MDB	Ford_AB9	3	D	Yes
6256	2008 Ford Focus	Full Frontal	34.7	0	Rigid	Ford_AB9	3	D	Yes
6268	2008 Chevrolet Malibu	Full Frontal	34.9	0	Rigid	Epsilon2006	3	D	Yes
6269	2008 Ford Focus	Side		270	MDB	Ford_AB9	3	D	Yes
6270	2008 Ford Focus coupe	Side		270	MDB	Ford_AB9	3	D	Yes

Test Num	Vehicle Description	Test Type	Closing Speed (mph)	Impact Angle (deg)	Barrier/ Collision Partner	EDR Model	Source	Deploy/ NonDeploy (D/ND)	Event Record Complete
6271	2008 Cadillac CTS	Full Front	34.8	0	Rigid	SDMCG_DELPHI	3	D	Yes
6274	2008 Dodge Caravan	Side	38.7	270	MDB	CHRY0303C	3	D+	-
6298	2008 Saturn Outlook	Frontal Off.	37.2	0	Deform.	SDMC2006	3	D	Yes
6321	2008 Saturn Outlook	Frontal Off.	34.7	0	Deform.	SDMC2006	3	D	Yes
CEF0107	2001 Chevrolet Silverado	Frontal Off.	40.0	0	Deform.	SDMG2000	1	D/ND	-
CEF0119	2002 Chevrolet Trailblazer	Frontal Off.	40.0	0	Deform.	SDMGT2002	1	D/ND	Yes
CEF0209	2003 Cadillac CTS	Frontal Off.	40.0	0	Deform.	SDMGF2002	1	D/ND	Yes
CEF0221	2003 Cadillac CTS	Frontal Off.	40.0	0	Deform.	SDMGF2002	1	D-DL	Yes
CEF0301	2003 Lincoln Towncar	Frontal Off.	40.0	0	Deform.	3W1A	1	D	-
CEF0313	2003 Lincoln Towncar	Frontal Off.	40.0	0	Deform.	3W1A	1	D	-
CEF0326	2004 Cadillac SRX	Frontal Off.	40.0	0	Deform.	SDMGF2002	1	D/ND	Yes
CEF0401	2004 Chevrolet Malibu	Frontal Off.	40.0	0	Deform.	N/A	1	-	-
CEF0406	2004 Chevrolet Malibu	Frontal Off.	40.0	0	Deform.	N/A	1	D+	-
CEF0419	2005 Saturn ION	Frontal Off.	40.0	0	Deform.	N/A	2	D+	-
CEF0506	2005 Chevrolet Colorado	Frontal Off.	39.8	0	Deform.	N/A	2	D/ND	Yes
CEF0511	2005 Buick LaCrosse	Frontal Off.	40.0	0	Deform.	N/A	2	D/ND	Yes
CF05003	2004 Chevrolet Malibu	Pole	39.7	0	Pole	Epsilon	2	D/ND	Yes

Note: MDB = Movable Deformable Barrier
+ Airbag deployment status was determined through inspection of NHTSA or IIHS database photographs

Source: [1] = Niehoff et al., 2005
[2] = Gabler et al., 2008
[3] = New cases

Included in Table 2 are the airbag deployment status and EDR event recording status for each individual EDR. These are indicated differently by individual vehicle manufacturers. Airbag deployment information can be directly collected from GM EDRs. The status can be found in the "Event(s) recovered" field. Some Ford EDRs also collect deployment status. Located in the "first event recorded" field, Ford EDRs can detail if the deployment was frontal or from the side. We could not collect airbag deployment information directly from the Toyota or Chrysler EDR data which was acquired. Airbag deployment status, for vehicles which did not record status in the EDR, was collected for visual inspection of the NHTSA and IIHS database crash photos.

EDR event recording status was determined directly from the "event recording complete" field of GM EDRs. The recording status for Toyota vehicles was determined to be listed under the "Writing Flag" field and completion was indicated by "Writing complete". Some Ford EDRs contained "First Record Recording Status" and "Second Record Recording Status", both of which indicating if the record was complete. The Chrysler EDRs only provided recording status information about pre-crash data.

Table 3 through Table 7 below show the breakdown of the dataset by Researcher, test performer and type of test, model year (MY) of the tested vehicle, make of the tested vehicle and airbag deployment status.

Table 3. Distribution of Dataset by Researcher

Researcher	**Number of EDR Cases**
Niehoff et al. (2005)	37
Gabler et al. (2008)	47
New	23
Total	107

Table 4. Distribution of Crash Test Type for the Investigated Vehicles

Agency	Test Type	Impact Speed (mph)	Number of EDR Cases
	Full Frontal Rigid Barrier	25	7
	Full Frontal Rigid Barrier	30	3
	Full Frontal Rigid Barrier	35	66
	Offset Frontal Impact	25	1
	Offset Frontal Impact	35	1
	Offset Frontal Impact	70	2
	Offset Frontal Impact	38	1
NHTSA	Side Impact	38	13
	40% Frontal Offset	40	12
IIHS	15% Offset Pole	40	1
Total			107

Table 5. Distribution of EDRs in Crash Tests by Model Year

Model Year	Number of EDR Cases
1997	1
2000	1
2001	3
2002	8
2003	14
2004	21
2005	29
2006	11
2007	5
2008	14
Total	107

Table 6. Distribution of EDRs in Crash Tests by Vehicle Make

Vehicle Make	Number of EDR Cases
General Motors	72
Toyota	18
Chrysler	4
Ford	13
Total	107

Table 7: Distribution of Deployment vs. Non-Deployment for the EDR dataset

Deployment Status	Number of EDRs
Deployed	100
Non-Deployed	6
Unknown	1
Total	107

2.3 Method to Time Shift of EDR delta-V Data

2.3.1 Introduction

This section describes the method used to compare instrument-measured crash pulse to its corresponding EDR crash pulse. The validity of the EDR data must be established. To accomplish this, we will download EDRs from the crash test vehicles and compare the recordings from them with the high precision laboratory grade instrumentation installed on each vehicle prior to the crash test. We plan on comparing the vehicle delta-V's recorded at 100ms and at maximum delta-V, the length of the recorded crash pulses, the belt buckled status of the driver and right-front passenger and the effectiveness of the different EDR models.

2.3.2 The Need to Time Shift EDR data

Our approach to determine the validity of the EDR data was to compare the delta-V vs. time as measured by the crash test instrumentation with the corresponding data collected from the EDR. The problem is that the crash test data and the EDR data measured time zero differently. This difference in the recorded start time can cause time-shift discrepancies between the delta-V graphs from the crash test data and EDR. To compare the EDR data and crash test data effectively, we must first align the two curves. For this we chose to define time zero as the time of impact; the time zero from the crash test data.

Figure 12 provides an example of the need to time shift the EDR data. Both the graph of the NHTSA crash test data and EDR data follow the same trend; however the data from the EDR has a significant time-shift to the right.

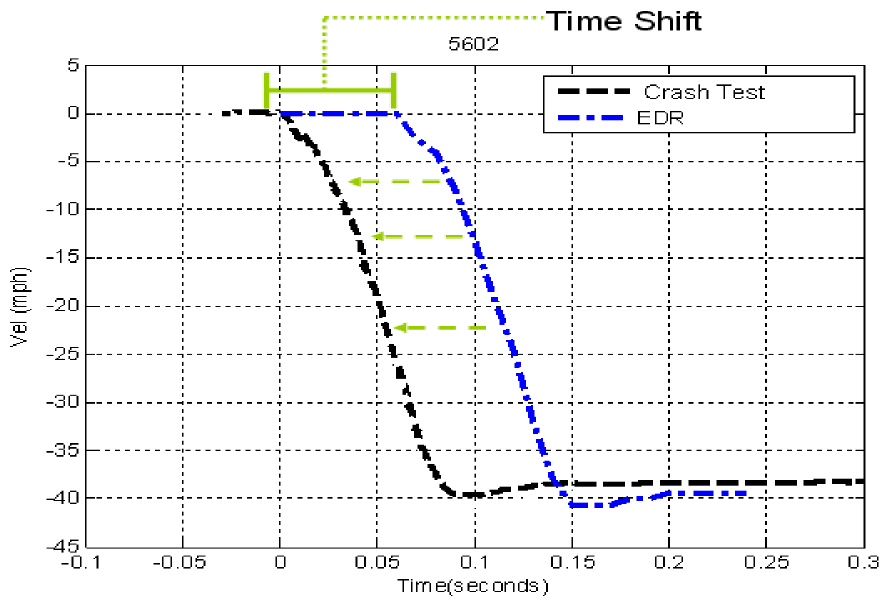

Figure 12. Comparison of Vehicle Velocity vs. Time for NHTSA Crash Test 5602 and the associated EDR Data

Therefore it was important to align the two graphs to get an accurate account of the EDR's performance.

2.3.3 Time-Shifting Method

To remove the time shift we first computed the time shift which minimized the objective function shown below. This method was first developed by Niehoff et al. (2005).

Minimize | Subjected to

$$F = \sum_i \left[\Delta V_i(\Delta t) - \Delta v_i\right]^2 \qquad \Delta t \leq 50\text{ms}$$

Where: | And:

$$\mathbf{\Delta V = V_i + V_{i+1}} \text{ For crash tests} \qquad \Delta v = v_i + v_{i+1} \text{ For EDRs}$$

In a perfect situation, the delta-V values over a set time-step, for the crash test data and corresponding EDR data would be the same. Using a Matlab program, the crash test acceleration data were integrated to compute the velocity. For every 10ms interval of this data, starting with zero [V(t+10ms)-v(t)], the delta-V was computed. This was done because most of the EDR data that was in our data set was recorded at 10ms intervals. By measuring delta-V over 10ms periods in the crash test data, the delta-V's of the two sets of data could more easily be compared.

The difference in delta-V for each 10 ms interval of the crash test data and corresponding EDR data was calculated and the sum of these differences was found. This number was then stored in the Matlab program as an objective function.

Next the 10ms interval was shifted by 1 millisecond to the right ($V_{t-11} - V_{t-1}$). The difference in delta-V for each 10 ms interval of the crash test data and corresponding EDR data was again calculated and summed. If this summed value was lower than the objective function that was previously scored, it was saved as the new objective function to be compared to later, and the previous value was discarded.

The crash test data graph was shifted in one millisecond increments over a 100ms interval (30ms shift to the left and 70ms shift to the right) and lowest objective function was found. The value for the time shift associated with this minimum objective function to could then be determined. The graph of the EDR velocity could then be shifted, with respect to the crash test data velocity graph, by that time step.

Figure 13 and the corresponding Table 8 show the relationship between objective function and time shift. As can be expected, the objective function starts at a higher value, and as the algorithm evaluates different time shifts over the graph, the value goes down until reaching its lowest point, were the time shift is the most accurate, and then starts to go up again as the crash test data graph passes optimal and starts to go further away from the EDR graph in the opposite direction.

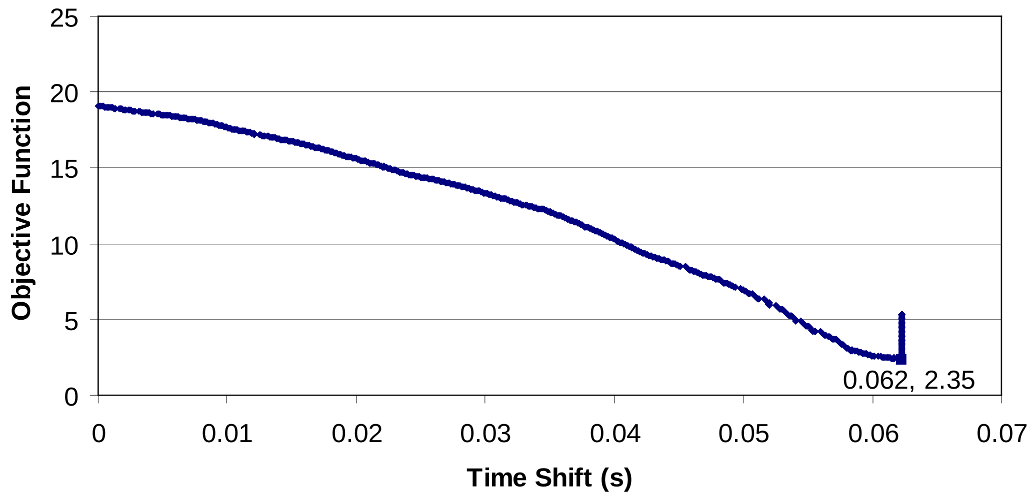

Figure 13. Value of the Objective function score vs. Time shift

Table 8. Important Points on the Graph of Iteration vs. Score

Important Points on the Time Shift vs. Obj. Function Graph	
Lowest Objective Function -	2.34
Best Time Shift -	0.0623s

The following was computed for each vehicle in the dataset: (1) the time-shift which minimized the objective function was stored, (2) the maximum delta-V of both the crash test data and the EDR data and (3) the delta-V of both data sets at 100ms.

2.3.4 Results

Figure 14 below shows the same graph of NHTSA test 5602 comparing the NHTSA graph, the original EDR graph and the shifted EDR graph.

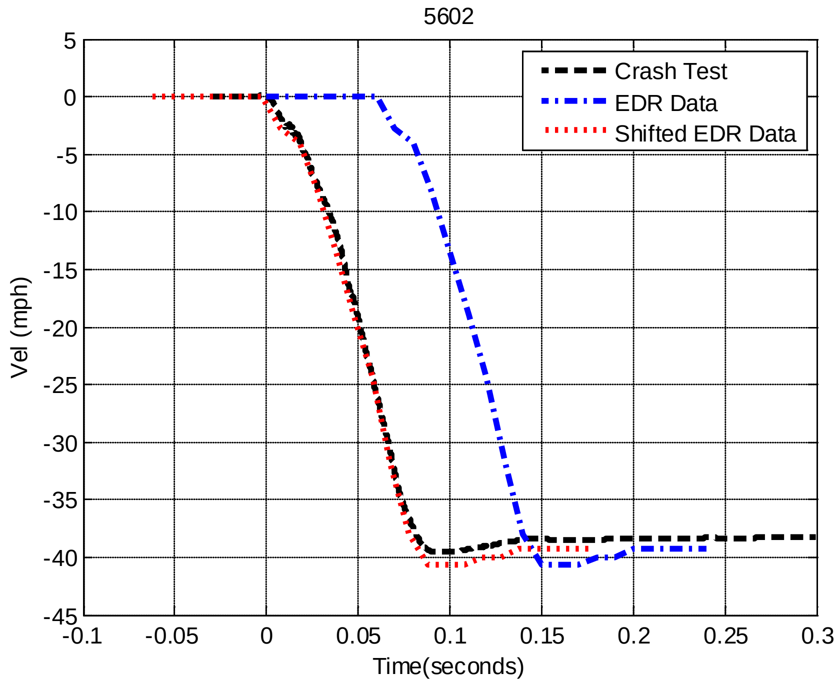

Figure 14. NHTSA vs. CDR delta-V graph showing before and after of time shift

As can be seen, the EDR curve after time shifting was in good agreement with the crash test data. This method was used for every applicable curve in the data set before further analysis was performed.

2.4 Event Data Recorder-Crash Test Data Results

2.4.1 Objective

This section presents the results of the preliminary analysis of the 107 EDR dataset presented earlier. Of these 107 EDRs, 4 cases were involved in a side impact, and did not provide usable longitudinal velocity change data. Also 1 case lost power during the event recording and did not provide usable delta-V data. Therefore only 102 could be analyzed in this section. Discussed will be the results of the delta-V comparison at 100ms as well as at max delta-V. The length of the Crash test data will also be compared to the length of the CDR crash pulse to determine whether or not the EDR was effective at collecting the entire pulse.

2.4.2 Introduction

Many preliminary observations can be made after the time shift was put into place. The accuracy of the EDR will be measured in three different ways. A delta-V comparison at 100ms and max delta-V recorded can both provide important insight into whether or not the EDR performed correctly; the closer the values of these points, the better the performance.

It is also important to determine if the EDR collected the entire length of the crash pulse. By knowing the approximate length of the crash test data as well as the recorded length of the CDR delta-V, the recording error can be determined.

2.4.3 Delta-V and Crash Pulse Length Comparisons, Results and Discussion

Table 9 shows the delta-V and crash pulse lengths recorded by the vehicle EDR and the vehicle crash sensors for each crash test. The percent error between the corresponding values of the EDR and crash test data are also recorded in this table. This information is the basis for the rest of the analysis included in this report. The time-shifted velocity comparison graphs corresponding to the 102 crash test dataset can be found the appendixes of this report.

Table 9. Recorded Delta-V's and Event Time Durations of the Crash test and EDR data

Test Number	EDR Max. delta-V (mph)	Crash Test Max. delta-V (mph)	Max. delta-V Error (%)	Crash Test delta-V @100ms (mph)	EDR delta-V @100ms (mph)	delta-V Error @ 100ms (%)	Time Shift (ms)	EDR Recording Duration (ms)	Crash Pulse Duration Estimated (ms)	Crash Pulse Duration Error (%)
3471	36.0	38.5	6.5%	36.7	35.4	3.6%	-2.6	100.0	129.8	-23.0%
3851	39.1	39.0	0.2%	35.7	37.5	5.0%	2.7	120.0	142.5	-15.8%
3952	41.4	41.7	0.9%	40.9	41.2	0.7%	-1.4	100.0	124.0	-19.4%
4198	38.3	40.8	6.2%	40.3	38.1	5.5%	16.3	120.0	127.2	-5.7%
4238	37.2	40.1	7.3%	39.3	N/A	N/A	12.3	97.5	114.0	-14.5%
4244	36.0	38.9	7.5%	38.0	35.8	5.7%	-4.6	100.0	104.0	-3.8%
4259	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4437	25.7	31.0	17.1%	14.2	12.4	13.0%	-11.4	150.0	206.0	-27.2%
4445	36.4	41.3	11.9%	40.4	36.0	10.9%	5.5	110.0	112.4	-2.1%
4453	24.2	26.9	10.1%	25.6	24.0	6.5%	-7.0	100.0	136.2	-26.6%
4454	25.7	27.8	7.6%	27.5	25.5	7.3%	-8.7	100.0	110.7	-9.7%
4464	36.9	39.3	6.2%	36.5	35.6	2.6%	-6.1	100.0	150.4	-33.5%
4472	36.0	41.4	13.2%	36.8	35.1	4.5%	-4.0	100.0	137.6	-27.3%
4487	38.6	41.3	6.5%	39.4	38.3	2.6%	-2.1	110.0	299.0	-63.2%
4549	36.3	42.7	15.1%	39.0	33.1	15.2%	70.0	100.0	122.5	-18.4%
4567	37.5	40.5	7.5%	36.7	36.4	0.8%	-6.0	100.0	149.4	-33.1%
4702	33.5	33.4	0.3%	33.3	33.2	0.4%	-3.8	100.0	100.4	-0.4%
4714	33.9	32.7	3.7%	32.1	33.8	5.1%	-2.5	100.0	141.0	-29.1%
4733	2.5	2.6	2.3%	2.4	1.8	26.3%	-4.6	150.0	59.9	150.4%
4775	38.6	39.9	3.3%	37.8	37.4	0.8%	1.0	110.0	272.3	-59.6%
4777	0.9	1.3	27.8%	0.7	N/A	N/A	-6.0	70.0	41.8	67.6%
4846	39.4	40.0	1.6%	39.9	38.3	3.9%	-9.6	150.0	109.3	37.2%
4855	36.8	39.0	5.6%	38.8	36.5	5.9%	4.1	150.0	120.8	24.2%
4890	40.5	39.0	3.9%	38.2	40.1	5.1%	-7.8	110.0	132.3	-16.9%
4893	40.3	38.6	4.4%	38.0	39.8	4.7%	4.1	150.0	87.3	71.9%
4899	36.3	39.8	8.8%	39.1	36.3	7.2%	-5.4	100.0	129.3	-22.7%
4918	33.8	38.1	11.4%	36.7	33.8	8.0%	-2.3	100.0	127.1	-21.3%

Test Number	EDR Max. delta-V (mph)	Crash Test Max. delta-V (mph)	Max. delta-V Error (%)	Crash Test delta-V @100ms (mph)	EDR delta-V @100ms (mph)	delta-V Error @ 100ms (%)	Time Shift (ms)	EDR Recording Duration (ms)	Crash Pulse Duration Estimated (ms)	Crash Pulse Duration Error (%)
4923	35.7	39.2	9.2%	38.9	35.6	8.5%	-2.4	100.0	105.7	-5.4%
4928	2.5	1.6	57.6%	1.2	2.1	83.7%	-0.4	150.0	83.8	79.0%
4931	36.9	40.3	8.6%	40.0	36.8	7.9%	-0.4	110.0	113.7	-3.3%
4933	42.0	40.0	4.9%	39.6	41.8	5.4%	4.2	150.0	90.6	65.6%
4937	31.4	35.3	11.1%	26.7	27.1	1.7%	-0.3	190.0	152.6	24.5%
4955	19.0	31.4	39.5%	24.9	N/A	N/A	13.0	110.0	165.2	-33.4%
4984	25.9	28.6	9.4%	28.2	25.8	8.8%	-1.0	110.0	128.8	-14.6%
4985	36.9	41.4	11.1%	40.4	35.9	11.2%	-2.5	110.0	130.7	-15.8%
4987	29.6	28.5	4.0%	28.3	28.9	2.3%	-0.4	120.0	119.0	0.8%
5037	38.5	39.8	3.2%	39.4	38.3	2.8%	1.9	150.0	113.7	31.9%
5071	28.2	28.8	1.9%	27.7	27.9	0.7%	2.7	150.0	299.0	-49.8%
5140	37.5	38.6	2.8%	36.9	37.5	1.7%	0.8	100.0	143.7	-30.4%
5157	3.9	4.3	8.9%	4.1	3.3	19.5%	1.3	150.0	48.7	208.0%
5160	37.6	39.5	4.7%	39.3	37.5	4.7%	4.2	150.0	105.1	42.7%
5162	3.5	4.9	28.9%	3.7	2.8	25.2%	0.1	150.0	48.4	209.9%
5209	37.4	39.8	6.1%	39.7	36.8	7.2%	-2.8	150.0	118.0	27.1%
5213	31.0	34.0	8.7%	32.5	31.0	4.6%	-0.2	100.0	158.3	-36.8%
5217	43.4	40.3	7.8%	40.0	43.4	8.4%	5.1	150.0	90.4	65.9%
5218	36.0	39.5	8.9%	39.5	36.0	8.9%	0.4	150.0	101.1	48.4%
5239	29.5	38.9	24.2%	38.7	28.9	25.4%	-1.5	150.0	115.0	30.4%
5249	39.4	39.2	0.6%	39.0	39.3	0.5%	-3.5	200.0	96.5	107.3%
5250	41.4	39.6	4.4%	39.5	40.8	3.3%	42.6	220.0	94.8	132.2%
5256	2.7	3.6	24.1%	2.2	2.8	26.7%	30.4	150.0	53.2	182.2%
5260	4.4	4.4	1.1%	3.7	4.0	6.1%	1.3	120.0	82.4	45.6%
5263	39.9	40.0	0.2%	39.7	39.2	1.3%	-5.5	200.0	109.9	82.0%
5264	36.9	37.8	2.5%	37.8	36.8	2.6%	-1.9	100.0	102.4	-2.3%
5265	35.3	37.7	6.3%	36.1	34.6	4.1%	-3.9	100.0	115.0	-13.0%
5269	36.5	39.5	7.6%	39.0	36.2	7.2%	-10.1	150.0	108.7	38.1%
5282	36.3	38.0	4.5%	37.0	35.9	2.8%	-6.2	100.0	81.4	22.9%

Test Number	EDR Max. delta-V (mph)	Crash Test Max. delta-V (mph)	Max. delta-V Error (%)	Crash Test delta-V @100ms (mph)	EDR delta-V @100ms (mph)	delta-V Error @ 100ms (%)	Time Shift (ms)	EDR Recording Duration (ms)	Crash Pulse Duration Estimated (ms)	Crash Pulse Duration Error (%)
5283	35.3	37.5	5.8%	37.0	34.6	6.4%	-5.1	150.0	290.7	-48.4%
5284	39.4	39.8	1.1%	39.8	39.3	1.1%	-2.9	200.0	104.2	91.9%
5310	38.2	39.1	2.3%	38.6	38.1	1.3%	-2.9	100.0	123.6	-19.1%
5312	34.4	38.2	9.8%	37.9	34.0	10.5%	-0.9	150.0	117.9	27.2%
5318	35.7	41.8	14.8%	38.4	34.7	9.6%	-7.4	100.0	140.3	-28.7%
5324	34.2	39.4	13.2%	37.6	33.9	9.9%	-1.6	100.0	140.8	-29.0%
5325	2.7	1.3	104.2%	0.9	0.1	111.6%	-6.2	300.0	46.4	547.2%
5326	40.0	39.8	0.5%	39.3	40.0	1.7%	44.0	210.0	59.3	254.1%
5468	39.1	39.5	1.2%	37.9	38.1	0.5%	2.8	110.0	119.8	-8.2%
5547	39.2	40.0	1.9%	38.1	37.7	1.1%	59.7	240.0	121.6	97.4%
5567	37.6	39.4	4.5%	37.4	36.3	3.1%	49.7	290.0	203.1	42.8%
5569	39.2	39.4	0.5%	39.3	38.6	1.6%	62.1	230.0	101.8	126.0%
5578	38.5	39.3	2.0%	37.3	36.2	3.0%	54.3	180.0	121.4	48.3%
5589	39.2	39.5	0.6%	38.7	37.4	3.5%	54.7	190.0	119.1	59.5%
5597	35.0	38.1	8.0%	37.5	34.9	6.8%	-6.0	100.0	119.4	-16.2%
5602	40.7	39.6	2.8%	39.5	40.7	3.1%	62.3	240.0	93.2	157.5%
5603	34.4	38.2	9.8%	37.2	34.0	8.5%	-4.1	100.0	118.2	-15.4%
5741	27.1	26.8	0.9%	24.4	24.6	0.9%	54.9	180.0	148.1	21.5%
5830	28.5	28.3	0.5%	27.5	28.2	2.5%	45.9	180.0	110.2	63.4%
5844	42.7	41.7	2.3%	41.5	42.7	3.0%	43.2	160.0	91.0	75.8%
5859	40.0	41.0	2.6%	40.9	40.0	2.3%	61.1	170.0	104.0	63.5%
5877	38.8	39.7	2.2%	39.4	38.4	2.5%	52.8	300.0	105.2	185.2%
5907	40.0	41.0	2.6%	40.9	38.0	7.1%	53.6	300.0	109.7	173.5%
5967	32.3	39.3	17.6%	39.0	32.1	17.7%	-8.6	140.0	105.7	32.5%
6172	31.8	39.0	18.5%	38.9	31.6	18.8%	-6.1	150.0	103.0	45.6%
6200	39.2	39.3	0.2%	39.2	39.2	0.0%	-13.1	100.0	111.9	-10.6%
6234	35.2	39.3	10.4%	39.0	34.9	10.4%	-14.8	140.0	298.8	-53.1%
6243	39.6	43.6	9.2%	40.0	N/A	N/A	7.0	100.0	63.5	57.5%
6245	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6246	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Test Number	EDR Max. delta-V (mph)	Crash Test Max. delta-V (mph)	Max. delta-V Error (%)	Crash Test delta-V @100ms (mph)	EDR delta-V @100ms (mph)	delta-V Error @ 100ms (%)	Time Shift (ms)	EDR Recording Duration (ms)	Crash Pulse Duration Estimated (ms)	Crash Pulse Duration Error (%)
6256	40.3	39.4	2.2%	38.7	39.5	1.9%	-6.4	100.0	126.4	-20.9%
6268	39.3	40.0	1.7%	39.9	39.3	1.4%	46.9	170.0	92.7	83.4%
6269	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6270	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6271	39.8	40.6	1.9%	40.4	39.2	2.8%	59.0	290.0	87.7	230.7%
6274	2.7	1.7	62.2%	0.9	2.4	168.0%	-5.9	250.0	56.9	339.4%
6298	39.9	41.8	4.5%	32.5	33.0	1.7%	48.9	190.0	165.0	15.2%
6321	38.5	43.7	11.9%	28.7	25.7	10.5%	28.4	180.0	298.8	-39.8%
CEF0107	42.3	42.0	0.7%	24.0	21.3	11.1%	7.5	140.0	191.4	-26.9%
CEF0119	38.4	41.8	8.1%	32.8	33.0	0.6%	1.1	130.0	165.5	-21.5%
CEF0209	41.2	46.1	10.7%	32.3	33.1	2.5%	-5.3	130.0	191.4	-32.1%
CEF0221	36.0	47.0	23.4%	33.4	34.5	3.4%	-7.7	110.0	160.7	-31.5%
CEF0301	14.0	43.8	67.9%	20.5	N/A	N/A	11.2	61.6	177.7	-65.3%
CEF0313	10.8	45.0	75.9%	20.5	N/A	N/A	11.5	60.0	181.2	-66.9%
CEF0326	36.6	43.7	16.3%	37.4	35.6	4.9%	-10.9	110.0	191.4	-42.5%
CEF0401	44.1	43.2	1.9%	35.7	36.7	2.6%	-2.9	175.0	149.6	17.0%
CEF0406	44.1	43.6	1.2%	35.1	36.8	4.9%	-4.2	155.0	150.0	3.3%
CEF0419	37.7	42.7	11.6%	31.1	30.8	1.0%	-1.1	120.0	183.9	-34.7%
CEF0506	36.0	43.9	18.0%	29.9	33.1	10.8%	6.4	120.0	204.2	-41.2%
CEF0511	33.4	42.7	21.9%	27.7	27.5	0.9%	-1.0	110.0	154.9	-29.0%
CF05003	46.1	45.9	0.5%	44.3	43.4	2.1%	29.8	150.0	125.8	19.2%

2.4.4 Comparison of Crash Pulse Duration

Most crash pulses that are recorded by test sensors record crash durations of 200-300ms, while EDR's recorded crash durations range from 30- 300ms. If the crash test data's duration was used to determine whether the EDR recorded the entire crash pulse, many of the EDRs would severely underestimate crash pulse duration. Therefore it was determined, for the purpose of this report, that the approximate recorded duration of the crash test data would be measured from the beginning of the crash pulse to the time at which the crash test data's maximum delta-V was recorded. This pulse duration was chosen because the time between the beginning of the crash and the maximum delta-V is the most important and most severe portion of the crash.

Figure 15 shows the relationship between the time durations of the EDR recordings and the time durations of the crash test data. This is an important relationship because EDRs which do not record the entire event will underestimate the maximum delta-V not because of sensor inaccuracy, but because of recording capacity.

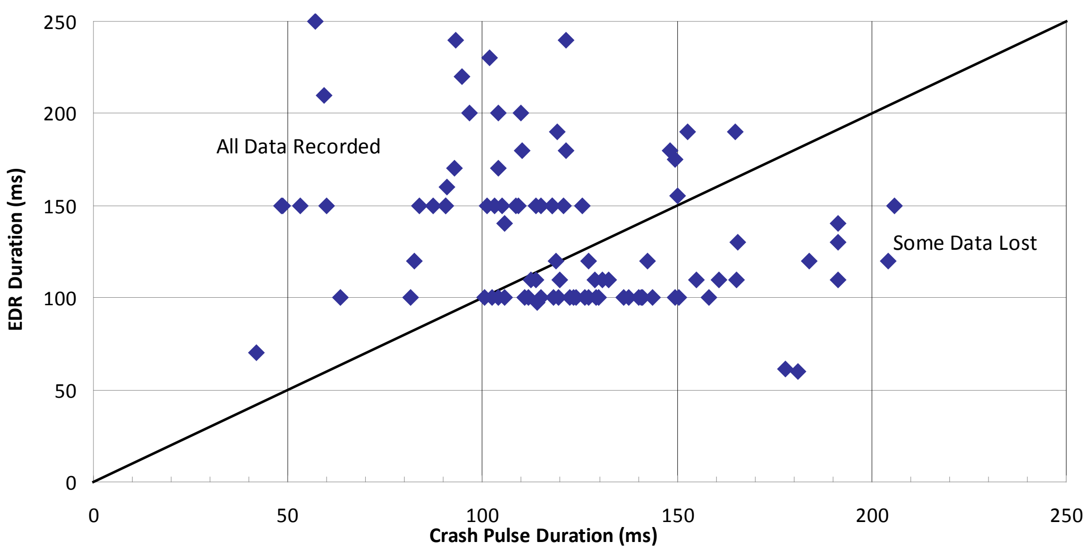

Figure 15. EDR Recording Duration vs. Crash test data Duration

As can be seen in this figure many of the EDRs record between 100 and 150ms. These time durations, in most cases, are not long enough to record the entire crash pulse. This can make determining the accuracy of the EDR difficult because the maximum delta-V of the crash cannot be determined if the entire crash pulse is not recorded. Therefore analysis was also conducted at 100ms to determine an EDR's accuracy at that point.

2.4.5 Comparison of Crash Test Data and EDR at t=100ms

Table 10 compares the difference between the delta-V's of the crash test data and EDR at 100ms. The EDR's perform very well overall, with an average delta-V error of only 9.6%. EDRs performed the best when comparing the error at 100ms for frontal impacts, 5.2%. While EDRs performed poorly for side impacts with an average error of 52.1%. These values, while higher than the 4.3% for frontal crashes and 30.3% for side impacts reported by [Gabler et al., 2008], account for a larger dataset (102 cases in this report vs. 47 in the Gabler et al. report) and a broader range of vehicle MYs and makes, as well as a more diverse set of EDR module types.

Table 10. Error of the delta-V's of all tests at 100 ms

	All Tests	Front Impact Tests					Lateral Tests		
-	-	Full Barrier	40% Offset	50% Offset	Pole Test	All Front	50% Offset / 30°Impact	270° Impact	All
N	102	75	14	1	1	91	2	9	11
Avg. Error	9.6%	5.3%	5.5%	1.7%	2.1%	5.2%	1.7%	58.4%	52.1%
Std. Dev.	21.9%	4.6%	4.6%	N/A	0.0%	4.6%	N/A	57.2%	56.7%
Min. Error	0.04%	0.04%	0.6%	1.7%	2.1%	0.0%	1.7%	6.1%	1.7%
Max. Error	168.0%	25.4%	13.0%	1.7%	2.1%	25.4%	1.7%	168.0%	168.0%

Figure 16 compares EDR and crash test data delta-V's at t=100ms for cases that had a value for both EDR and crash test data at t=100ms. The graph shows a very good correlation between the crash test data and EDR with an R^2 value equal to 0.9572. This shows that EDRs, which record the entire crash pulse, are also more accurate at determining the delta-V at t=100ms.

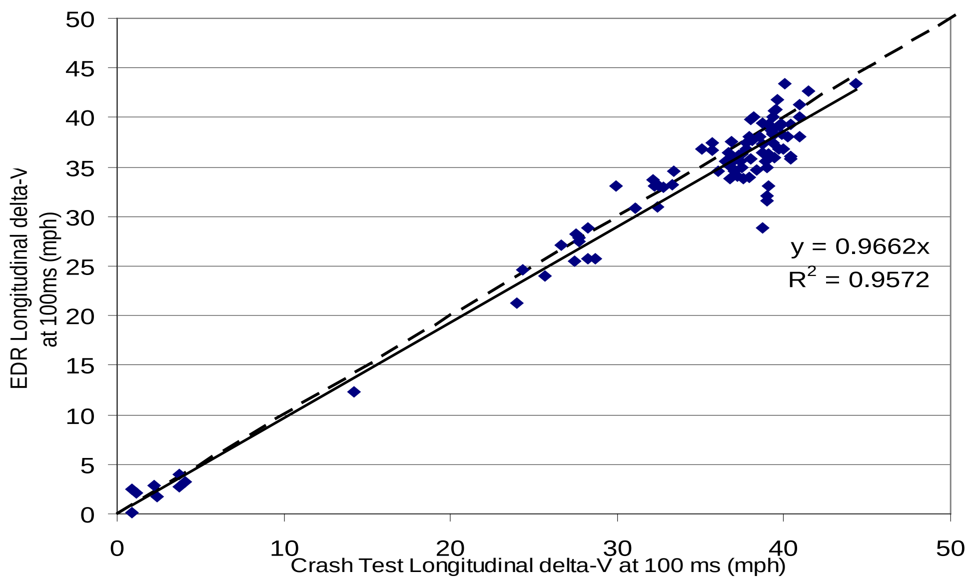

Figure 16. EDR Longitudinal delta-V versus Crash Test delta-V at t=100 ms

2.4.6 Comparison of Crash Test Data and EDR at Maximum delta-V

As shown earlier in the analysis many of the EDRs do not measure the entire crash pulse, and therefore cannot estimate the maximum delta-V of the crash. The analysis that follows is limited to only those crash tests in which the EDR recorded the full crash pulse, or lost no more than 2%. This dataset included about half, (51 of 102), of the original frontal and side impact tests. Table 11 shows the breakdown of this data set as well as the error incurred by these EDR-crash test data comparisons.

Table 11. Percent Error of the Maximum delta-V for Vehicles that Recorded the Entire Crash Event

Fraction of Crash Pulse Duration Unrecorded	All	Side	Frontal
N	51	9	42
Average Error	10.1%	35.2%	4.5%
Standard Deviation	18.5%	33.8%	5.2%
Minimum Error	0.18%	1.1%	0.18%
Maximum Error	104.2%	104.2%	24.2%

It can be seen that the average error of this dataset is slightly higher than that of all recorded frontal crashes at 100ms, 10.1% vs. 9.6%. The standard deviation, and maximum error measured, for the entire dataset, at the maximum delta-V were lower than those measured at t=100ms. This shows that EDRs which record the entire crash pulse length are also accurate at determining the maximum delta-V of a crash.

Figure 17 presents a graphical analysis of the EDR and crash test data maximum delta-V's on the smaller dataset. It can be seen from this graph, that there is a good correlation between maximum crash test data and EDR measured delta-V's with an R^2 value equal to 0.9676. This R^2 value is slightly higher than the value presented in Figure 16. This shows that, even in EDRs that record the entire length of the crash pulse, they are likely to be slightly more accurate in determining maximum delta-V than the delta-V occurring at 100ms.

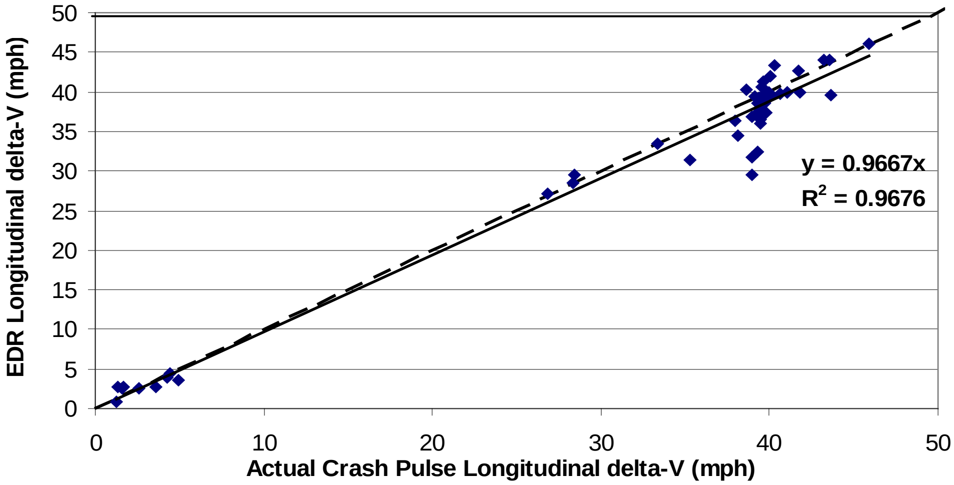

Figure 17. EDR Longitudinal delta-V versus Crash Test Data delta-V Over Full Crash Pulse Duration

2.4.7 Comparison of Crash Test Data and EDR by EDR model

The following section investigates whether EDR accuracy varies by EDR model. Figure 18 through Figure 29 show the crash test data-EDR comparisons of maximum delta-V, delta-V at 100ms and Crash Pulse length for EDR models. The analysis was performed for those EDRs which were installed in at least 5 vehicles in the crash test dataset. This occurred for 4 EDR models; SDMGF2002, SDMDW2003, SDMC2006 and Epsilon2006.

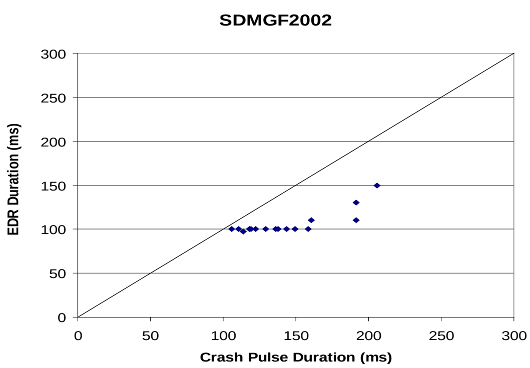

Figure 18. SDMGF2002 Crash Pulse Duration Comparison

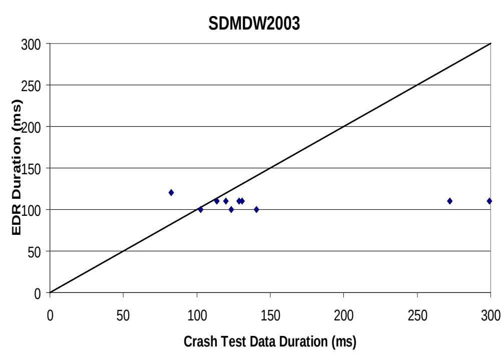

Figure 19. SDMDW2003 Crash Pulse Duration Comparison

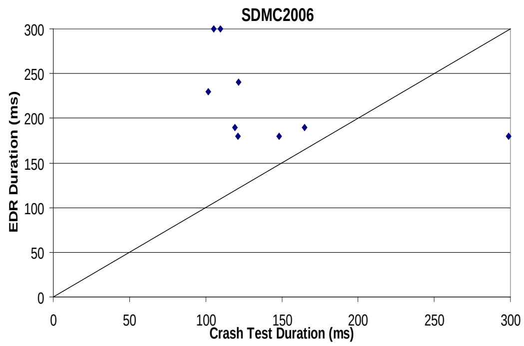

Figure 20. SDMC2006 Crash Pulse Duration Comparison

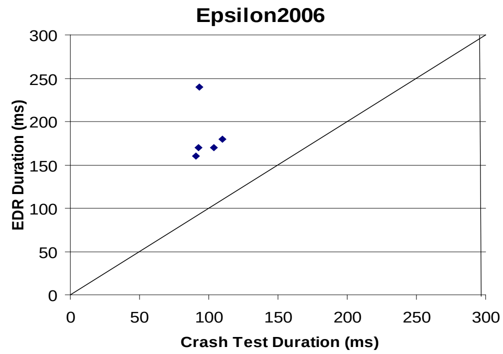

Figure 21. Epsilon2006 Crash Pulse Duration Comparison

Figure 18 through Figure 21 show the Crash Pulse duration comparison between the crash test data and the EDR. It can be seen that the SDMC2006 and Epsilon2006 EDR models were the most efficient at collecting the entire crash pulse length. On the other hand the SDMGF2002 and SDMDW2003 EDR models collected the entire crash pulse very few times.

Figure 22 through Figure 29 show the comparisons of maximum delta-V and delta-V at 100ms for each of the EDR models. Model SDMGF2002 has the worst correlation between Crash test data and EDR data at maximum delta-V, R^2=.818. This can be attributed to the fact that EDR model SDMGF2002 underestimated the crash pulse length in all of its tests.

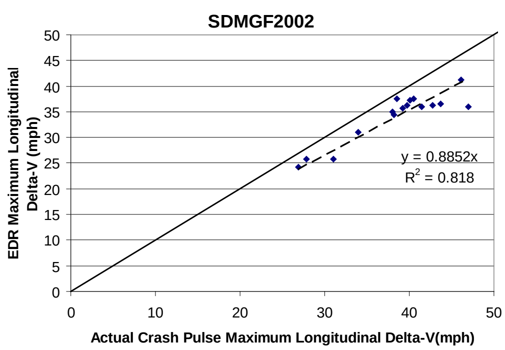

Figure 22. SDMFG2002 Maximum delta-V comparison

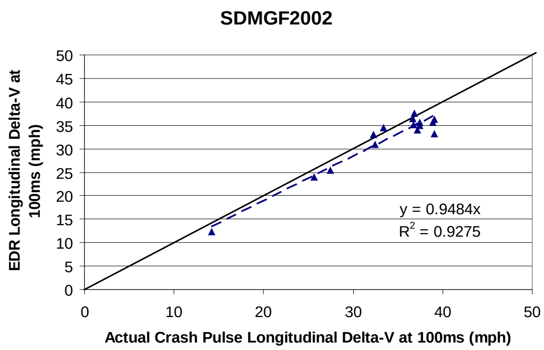

Figure 23. SDMFG2002 delta-V comparison at 100m

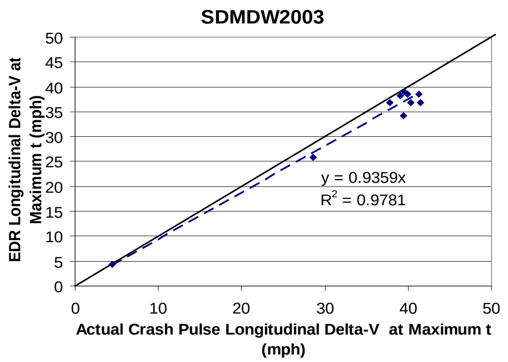

Figure 24. SDMDW2003 Maximum delta-V Comparison

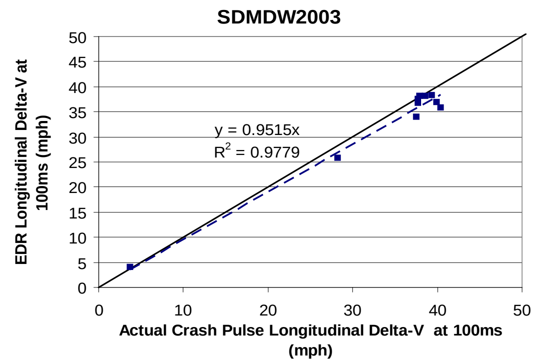

Figure 25. SDMDW2003 delta-V Comparison at 100ms

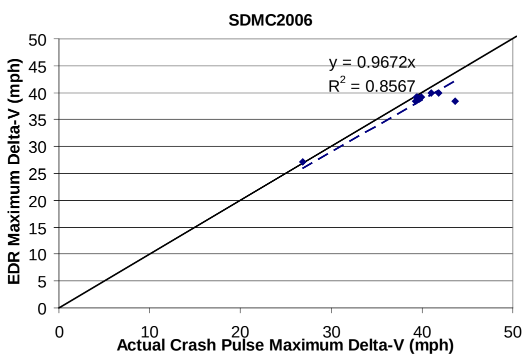

Figure 26. SDMC2006 Maximum delta-V Comparison

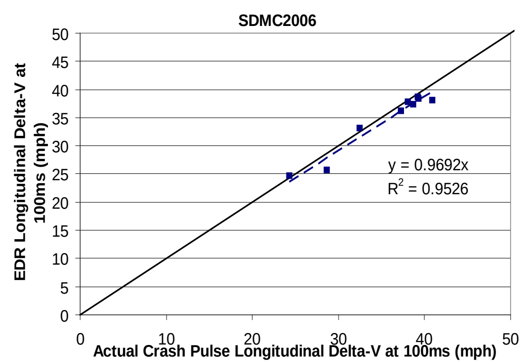

Figure 27. SDMC2006 delta-V Comparison at 100ms

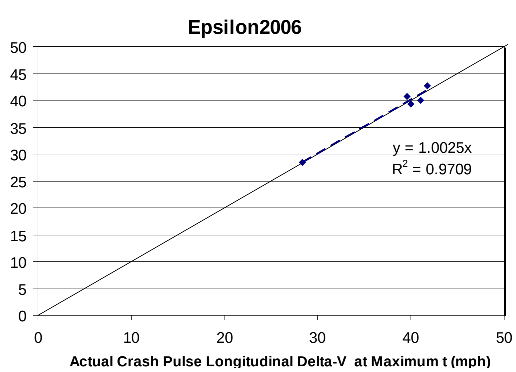

Figure 28. Epsilon2006 Maximum delta-V Comparison

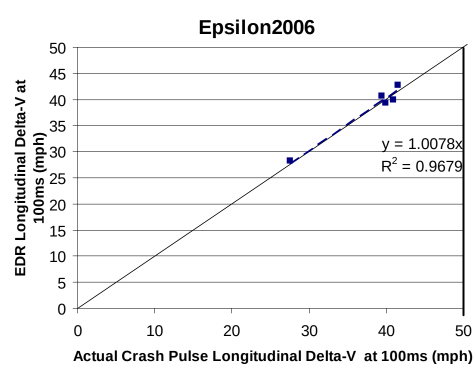

Figure 29. Epsilon2006 delta-V Comparison at 100ms

Table 12 below, shows a summary of the data presented in the above graphs. It can be seen from this table that newer EDR models record for a longer duration capturing more of the crash pulse, as well as recording more accurate maximum delta-Vs and the delta-V of a crash pulse at 100ms. The Epsilon2006 model over-estimated these values by less than 1% while the

SDMC2006 underestimated them by around 3%. Notice, the areas with the “-“occur when there was not sufficient data to run this analysis.

Table 12. % Error at 100ms, Max delta-V and Recording Length by EDR model

EDR Model Name	Num. of EDRs	Avg. Max Delta-V Error (%)	Avg. Delta-V Error @ 100ms (%)	Avg. EDR pulse recorded duration (ms)	Avg. Crash Pulse duration (ms)	Avg. Crash Pulse Duration Error (%)
SDMGT2001	2	-	-	-	-	-
SDMG2001	2	-	-	-	-	-
SDMDG2002	1	-	-	-	-	-
SDMD2002	3	-	-	-	-	-
SDMGF2002	16	-11.48%	-5.16%	106.09	143.41	-26.02%
SDMGT2002	4	-	-	-	-	-
SDMDW2003	10	-6.05%	-4.85%	107.78	137.91	-21.85%
89170-08050	1	-	-	-	-	-
89170-08060	1	-	-	-	-	-
89170-06240	1	-	-	-	-	-
89170-42160	1	-	-	-	-	-
89170-33300	2	-	-	-	-	-
89170-47380	1	-	-	-	-	-
89170-35190	1	-	-	-	-	-
89170-02410	1	-	-	-	-	-
89170-02420	1	-	-	-	-	-
89170-01060	1	-	-	-	-	-
89170-01070	1	-	-	-	-	-
89170-21070	1	-	-	-	-	-
89170-0C160	1	-	-	-	-	-
89170-0C190	1	-	-	-	-	-
89170-04070	1	-	-	-	-	-
89170-08070	1	-	-	-	-	-
ARM481+	2	-	-	-	-	-
Epsilon2005	4	-	-	-	-	-
SDMGF2002	3	-	-	-	-	-
89170-06260*4-(89170-33310)	1	-	-	-	-	-
SDMC2006	9	-3.28%	-3.08%	221.11	143.40	54.19%
SDMDS2005	1	-	-	-	-	-
Epsilon2006	5	0.25%	0.78%	184.00	98.20	87.37%
SDMCG_ DELPHI	1	-	-	-	-	-
SDMCL21997	1	-	-	-	-	-
SDMG2000	1	-	-	-	-	-
CHRY0154	1	-	-	-	-	-

EDR Model Name	Num. of EDRs	Avg. Max Delta-V Error (%)	Avg. Delta-V Error @ 100ms (%)	Avg. EDR pulse recorded duration (ms)	Avg. Crash Pulse duration (ms)	Avg. Crash Pulse Duration Error (%)
CHRY0303	3	-	-	-	-	-
Ford_AB9	2	-	-	-	-	-
SDMC2008V	1	-	-			-
SDMG2000	1	-	-	-	-	-
3W1A	2	-	-	-	-	-
Epsilon	1	-	-	-	-	-
N/A	8	-	-	-	-	-

2.5 Accuracy of Seat Belt Status

2.5.1 Introduction

This section discusses the accuracy of seat belt buckle status conducted on the EDR and Crash test data. The full dataset was analyzed, however due to the lack and variations of information available from the different vehicle makes, the majority of the analysis will focus on the GM, Ford and Toyota EDRs.

EDRs are responsible for collecting many types of data over the length of the crash, including some information right before the event occurs. This information varies from module to module based on the age and manufacturer of the EDR. Some typical types of information that are gathered from most vehicles are seat belt status, seat position, pre-crash speed and airbag deployment.

2.5.2 Seat Belt Accuracy

Approach

Our approach was to compare vehicle's EDR seatbelt status, for drivers and right front passengers, to that of the NHTSA and IIHS crash test databases, for recording accuracy. The overall dataset, used in this analysis, includes 72 GM EDRs, 18 Toyota EDRs, 13 Ford EDRs and 4 Chrysler EDRs. The GM sample was composed of 61 EDRs from NHTSA crash tested vehicles and 5 EDRs from IIHS crash tested vehicles, while the Ford sample was composed of

11 EDRs from NHTSA crash tested vehicles and 2 from IIHS crash tested vehicles. The Toyota and Chrysler samples all came from NHTSA. Seatbelt status for both the driver and passenger of these vehicles was collected from the EDR, as well as, EDR module type, the events recorded by the EDR and whether or not the EDR had completely recorded the events in question.

The seatbelt buckle status was then compared to the information supplied by the NHTSA and IIHS crash test databases. The actual seatbelt status was determined either by visual inspections of the crash test photographs, or by the restraint field stored in the NHTSA vehicle crash test database.

Results and Discussion

The complete dataset can be seen in Table 13, separated by vehicle make. Out of the 72 GM EDRs used, only 6 did not record driver's seatbelt status while 37 did not record right front passenger's seatbelt status. 12 of the 13 Ford EDRs collected both driver and right front passenger belt status, and only one did not record either. All 18 Toyota EDRs recorded driver and right front passenger seat belt status. Of all EDRs, the Chrysler modules were the only one which did not record seat belt status during any test.

35 GM EDRs recorded both a Deployment and a Non-Deployment event, while 29 recorded just a Deployment event, 4 recorded only a Non-Deployment event, and 1 recorded a Deployment/Deployment Level event. Also important to note is that 64 out of the 72 GM EDRs in this dataset were reported to have completed the recording of the events involved. Of the 13 Ford EDRs, only 8 provided an "Events recorded status" for the crash tests. These 8 recorded frontal side deployment events. Also only 7 of the 13 Ford EDRs recorded whether the event was completely recorded. In all cases, for which there was an "event recording complete" flag, the event was successfully recorded. While neither the Toyota nor Chrysler EDRs provided an

"events recorded", all 18 of the Toyota EDRs stated that writing to the EDR had finished. 2 of the 4 Chrysler EDRs completed recording, with the other 2 not recorded.

In the case of the GM EDRs, the recording complete status was not known for 7 of the 72 GM EDRs and only 1 of the 72 EDRs was reported to have failed before the event recording could finish. This is important because it is theorized that loss of power to the EDR, which causes the recording to be incomplete, is also a cause for any inaccuracy in EDR seatbelt status reading.

The NHTSA and IIHS databases provided a buckled or unbuckled status for all vehicle drivers in this dataset. Right front passenger belt status was also available for those tests where passengers were present, however, in 17 out of the 107 cases there were no right front passengers. The belt status for these cases was therefore reported as "No Passenger".

Table 13. Complete Dataset

		GM	Ford	Chrysler	Toyota
Total Number		72	13	4	18
Source					
	NHTSA	61	11	4	18
	IIHS	11	2	0	0
Number of Drivers					
	Buckled	63	12	4	17
	Unbuckled	8	1	0	1
	Not Recorded	1	0	0	0
Number of Right Front Passengers					
	Buckled	48	6	3	13
	Unbuckled	8	1	0	5
	No Passenger	11	6	1	0
Recorded by EDR					
Events Recorded by EDR					
	Deployment	29	4	0	0
	Side Deployment	0	4	0	0
	Non-Deployment	4	0	0	0
	Dep/Non-Dep	35	0	0	0
	Dep/Dep Level	1	0	0	0
	Not Recorded	3	5	4	18

	GM	Ford	Chrysler	Toyota
EDR Driver Status				
Buckled	57	11	0	17
Unbuckled	9	1	0	1
Not Recorded	6	1	4	0
EDR Right Front Passenger Status				
Buckled	21	5	0	13
Unbuckled	14	7	0	5
Not Recorded	37	1	4	0
EDR Event Recording				
Complete	64	6	2	18
Incomplete	1	0	0	0
Not Recorded	7	7	2	0

Table 14 shows the breakdown of this dataset by individual test case. Vehicle description and EDR module are also included in this table.

Table 14. Seatbelt Comparison for EDRs by Test Case

Test Num	Vehicle Description	Driver Seat Belt Status (EDR)	Driver Seatbelt Status (Database)	Right Front Seat Belt Status (EDR	Right Front Seat Belt Status (Database)	EDR Model	Deploy/ NonDeploy (D/ND)	Event Record Complete
3471	2001 Chevrolet Impala	Buckled	Buckled	-	Buckled	SDMGT2001	D/ND	Yes
3851	2002 Chevrolet Avalanche	Buckled	Buckled	-	Buckled	SDMG2001	D	-
3952	2002 Buick Rendezvous	Buckled	Buckled	-	Buckled	SDMDG2002	D/ND	Yes
4198	2002 Saturn Vue	Buckled	Buckled	Unbuckled	Buckled	SDMD2002	D/ND	Yes
4238	2002 Cadillac Deville	Buckled	Buckled	-	Buckled	SDMGF2002	D	Yes
4244	2002 Chevrolet Trailblazer	Buckled	Buckled	-	Buckled	SDMGT2002	D	Yes
4259	2003 Cadillac CTS	Buckled	Buckled	-	Buckled	SDMGF2002	ND	Yes
4437	2003 Chevrolet Suburban	Buckled	Buckled	-	Buckled	SDMGF2002	ND	Yes
4445	2003 Chevrolet Cavalier	Buckled	Buckled	-	Buckled	SDMG2001	D	-
4453	2003 Chevrolet Silverado	Unbuckled	Unbuckled	-	Unbuckled	SDMGF2002	D	Yes
4454	2003 Chevrolet Tahoe	Unbuckled	Unbuckled	-	Unbuckled	SDMGF2002	D	Yes
4464	2003 Chevrolet Avalanche	Buckled	Buckled	-	Buckled	SDMGT2002	D	Yes
4472	2003 Chevrolet Silverado	Buckled	Buckled	-	Buckled	SDMGF2002	D/ND	Yes
4487	2003 Saturn Ion	Buckled	Buckled	Unbuckled	Buckled	SDMDW2003	D/ND	Yes
4549	2003 Chevy Tahoe	Buckled	Buckled	-	Buckled	SDMGF2002	D/ND	Yes
4567	2003 Chevrolet Suburban	Buckled	Buckled	-	Buckled	SDMGF2002	D/ND	Yes
4702	2002 Saturn Vue	Unbuckled	Unbuckled	Unbuckled	Unbuckled	SDMD2002	D/ND	Yes
4714	2002 Saturn Vue	Unbuckled	Unbuckled	Unbuckled	Unbuckled	SDMD2002	D/ND	Yes
4733	2004 Toyota Sienna	Buckled	Buckled	Unbuckled	Unbuckled	89170-08050	-	Yes
4775	2004 Pontiac Grand Prix	Buckled	Buckled	Unbuckled	Buckled	SDMDW2003	D/ND	Yes
4777	2001 Buick LeSabre	Buckled	Buckled	-	No Passenger	SDMGT2001	ND	Yes
4846	2004 Toyota Sienna	Buckled	Buckled	Buckled	Buckled	89170-08060	-	Yes
4855	2004 Toyota Solara	Buckled	Buckled	Buckled	Buckled	89170-06240	-	Yes
4890	2004 Ford F-150	Buckled	Buckled	Buckled	Buckled	ARM481+	-	-
4893	2004 Toyota RAV4	Buckled	Buckled	Buckled	Buckled	89170-42160	-	Yes

Test Num	Vehicle Description	Driver Seat Belt Status (EDR)	Driver Seatbelt Status (Database)	Right Front Seat Belt Status (EDR	Right Front Seat Belt Status (Database)	EDR Model	Deploy/ NonDeploy (D/ND)	Event Record Complete
4899	2004 Cadillac SRX	Buckled	Buckled	-	Buckled	SDMGF2002	D/ND	Yes
4918	2004 GMC Envoy XUV	Buckled	Buckled	-	Buckled	SDMGT2002	D/ND	Yes
4923	2004 Chevrolet Colorado	Buckled	Buckled	-	Buckled	SDMGF2002	D	Yes
4928	2004 Toyota Camry	Buckled	Buckled	Unbuckled	Unbuckled	89170-33300	-	Yes
4931	2004 Saturn Vue	Buckled	Buckled	Unbuckled	Buckled	SDMDW2003	D/ND	Yes
4933	2004 Toyota Prius	Buckled	Buckled	Buckled	Buckled	89170-47380	-	Yes
4937	1997 Cadillac Seville	Unbuckled	Buckled	-	Buckled	SDMCL21997	D/ND	No
4955	2000 Cadillac Seville	Buckled	Buckled	-	Buckled	SDMG2000	D	-
4984	2004 Saturn Ion	Unbuckled	Unbuckled	Unbuckled	Unbuckled	SDMDW2003	D/ND	Yes
4985	2005 Chevrolet Equinox	Buckled	Buckled	Unbuckled	Buckled	SDMDW2003	D/ND	Yes
4987	2005 Ford Taurus	Unbuckled	Unbuckled	Unbuckled	Unbuckled	ARM481+	-	-
5037	2004 Toyota 4Runner	Buckled	Buckled	Buckled	Buckled	89170-35190	-	Yes
5071	2004 Toyota Camry	Unbuckled	Unbuckled	Unbuckled	Unbuckled	89170-33300	-	Yes
5140	2004 Chevrolet Avalanche	Buckled	Buckled	Buckled	Buckled	SDMGF2002	D/ND	Yes
5157	2005 Toyota Corolla	Buckled	Buckled	Unbuckled	Unbuckled	89170-02410	-	Yes
5160	2005 Toyota Corolla	Buckled	Buckled	Buckled	Buckled	89170-02420	-	Yes
5162	2005 Toyota Matrix	Buckled	Buckled	Unbuckled	Unbuckled	89170-01060	-	Yes
5209	2005 Toyota Matrix	Buckled	Buckled	Buckled	Buckled	89170-01070	-	Yes
5213	2004 Chevrolet Avalanche	Unbuckled	Unbuckled	Unbuckled	Unbuckled	SDMGF2002	D/ND	Yes
5217	2005 Toyota Scion TC	Buckled	Buckled	Buckled	Buckled	89170-21070	-	Yes
5218	2005 Toyota Tundra	Buckled	Buckled	Buckled	Buckled	89170-0C160	-	Yes
5239	2005 Toyota Tundra	Buckled	Buckled	Buckled	Buckled	89170-0C190	-	Yes
5249	2005 Ford 500	Buckled	Buckled	Buckled	Buckled	N/A	-	-
5250	2005 Pontiac G6	Buckled	Buckled	-	Buckled	Epsilon2005	D	Yes
5256	2005 Pontiac G6	Buckled	Buckled	-	No Passenger	Epsilon2005	D	Yes
5260	2005 Saturn ION	Buckled	Buckled	Unbuckled	No Passenger	SDMDW2003	D/ND	Yes

Test Num	Vehicle Description	Driver Seat Belt Status (EDR)	Driver Seatbelt Status (Database)	Right Front Seat Belt Status (EDR	Right Front Seat Belt Status (Database)	EDR Model	Deploy/ NonDeploy (D/ND)	Event Record Complete
5263	2005 Ford Freestyle	Buckled	Buckled	Buckled	Buckled	N/A	-	-
5264	2005 Chevy Uplander	Buckled	Buckled	Buckled	Buckled	SDMDW2003	D/ND	Yes
5265	2005 Chevy Express	Buckled	Buckled	-	Buckled	SDMGF2002	D/ND	Yes
5269	2005 Toyota Sienna	Buckled	Buckled	Buckled	Buckled	89170-08070	-	Yes
5282	2005 Chevy Colorado	Buckled	Buckled	-	Buckled	SDMGF2002	D/ND	Yes
5283	2005 Toyota Camry	Buckled	Buckled	Buckled	Buckled	89170-06260*4-(89170-33310)	-	Yes
5284	2005 Ford Econoline	-	Buckled	-	Buckled	N/A	-	-
5310	2005 Buick Rendezvous	Buckled	Buckled	Buckled	Buckled	SDMDW2003	D/ND	Yes
5312	2005 Toyota Tacoma	Buckled	Buckled	buckled	Buckled	89170-04070	-	Yes
5318	2005 Chevy Silverado	Buckled	Buckled	Buckled	Buckled	SDMGF2002	D/ND	Yes
5324	2005 Pontiac Montana	Buckled	Buckled	Buckled	Buckled	SDMDW2003	D/ND	Yes
5325	2005 Chevy Cobalt	Buckled	Buckled	-	No Passenger	Epsilon2005	ND	Yes
5326	2005 Chevy Cobalt	Buckled	Buckled	-	Buckled	Epsilon2005	D	Yes
5468	2006 Pontiac Grand Prix	Buckled	Buckled	Buckled	Buckled	SDMDW2003	D/ND	Yes
5547	2006 Chevrolet Impala	Buckled	Buckled	Buckled	Buckled	SDMC2006	D	Yes
5567	2006 Hummer H3	Buckled	Buckled	Buckled	Buckled	SDMDS2005	D	Yes
5569	2006 Cadillac DTS	Buckled	Buckled	Buckled	Buckled	SDMC2006	D	Yes
5578	2006 Chevrolet Monte Carlo	Buckled	Buckled	Buckled	Buckled	SDMC2006	D	Yes
5589	2006 Buick Lucerne CX	Buckled	Buckled	Buckled	Buckled	SDMC2006	D	Yes
5597	2006 Chevrolet Colorado	Buckled	Buckled	Buckled	Buckled	SDMGF2002	D/ND	Yes
5602	2006 Chevrolet HHR	Buckled	Buckled	Buckled	Buckled	Epsilon2006	D	Yes
5603	2006 Chevy Colorado	Buckled	Buckled	Buckled	Buckled	SDMGF2002	D/ND	Yes
5741	2006 Buick Lucerne	Unbuckled	Unbuckled	Unbuckled	Unbuckled	SDMC2006	D	Yes
5830	2006 Pontiac G6	Unbuckled	Unbuckled	Unbuckled	Unbuckled	Epsilon2006	D	Yes
5844	2007 Saturn Aura	Buckled	Buckled	Buckled	Buckled	Epsilon2006	D	Yes
5859	2007 Pontiac Solstice	Buckled	Buckled	Buckled	Buckled	Epsilon2006	D	Yes

Test Num	Vehicle Description	Driver Seat Belt Status (EDR)	Driver Seatbelt Status (Database)	Right Front Seat Belt Status (EDR	Right Front Seat Belt Status (Database)	EDR Model	Deploy/ NonDeploy (D/ND)	Event Record Complete
5877	2007 Chevrolet Silverado	Buckled	Buckled	Buckled	Buckled	SDMC2006	D	Yes
5907	2007 Chevrolet Silverado	Buckled	Buckled	Buckled	Buckled	SDMC2006	D	Yes
5967	2007 Jeep Patriot	-	Buckled	-	Buckled	CHRY0154	D^{+}	Valid
6172	2008 Dodge Caravan	-	Buckled	-	Buckled	CHRY0303C	D^{+}	Valid
6200	2008 Saturn Vue	Buckled	Buckled	Buckled	Buckled	SDMC2008V	D	Yes
6234	2008 Dodge Dakota	-	Buckled	-	Buckled	CHRY0303	D^{+}	-
6243	2008 Ford Focus	Buckled	Buckled	Buckled	Buckled	Ford_AB9	D	Yes
6245	2008 Ford Focus coupe	Buckled	Buckled	Unbuckled	No Passenger	Ford_AB9	D	Yes
6246	2008 Ford Focus	Buckled	Buckled	Unbuckled	No Passenger	Ford_AB9	D	Yes
6256	2008 Ford Focus	Buckled	Buckled	Buckled	Buckled	Ford_AB9	D	Yes
6268	2008 Chevrolet Malibu	Buckled	Buckled	Buckled	Buckled	Epsilon2006	D	Yes
6269	2008 Ford Focus	Buckled	Buckled	Unbuckled	No Passenger	Ford_AB9	D	Yes
6270	2008 Ford Focus coupe	Buckled	Buckled	Unbuckled	No Passenger	Ford_AB9	D	Yes
6271	2008 Cadillac CTS	Buckled	Buckled	Buckled	Buckled	SDMCG_DELPHI	D	Yes
6274	2008 Dodge Caravan	-	Buckled	-	No Passenger	CHRY0303C	D^{+}	-
6298	2008 Saturn Outlook	Buckled	Buckled	Unbuckled	No Passenger	SDMC2006	D	Yes
6321	2008 Saturn Outlook	Buckled	Buckled	Unbuckled	No Passenger	SDMC2006	D	Yes
CEF0107	2001 Chevrolet Silverado	Buckled	Buckled	-	No Passenger	SDMG2000	D/ND	-
CEF0119	2002 Chevrolet Trailblazer	Buckled	Buckled	-	No Passenger	SDMGT2002	D/ND	Yes
CEF0209	2003 Cadillac CTS	Buckled	Buckled	-	No Passenger	SDMGF2002	D/ND	Yes
CEF0221	2003 Cadillac CTS	Buckled	Buckled	-	No Passenger	SDMGF2002	D-DL	Yes
CEF0301	2003 Lincoln Towncar	Buckled	Buckled	Unbuckled	No Passenger	3W1A	D	-
CEF0313	2003 Lincoln Towncar	Buckled	Buckled	Unbuckled	No Passenger	3W1A	D	-
CEF0326	2004 Cadillac SRX	Buckled	Buckled	-	No Passenger	SDMGF2002	D/ND	Yes
CEF0401	2004 Chevrolet Malibu	-	-	-	-	N/A	-	-
CEF0406	2004 Chevrolet Malibu	-	Buckled	-	No Passenger	N/A	-	-

Test Num	Vehicle Description	Driver Seat Belt Status (EDR)	Driver Seatbelt Status (Database)	Right Front Seat Belt Status (EDR	Right Front Seat Belt Status (Database)	EDR Model	Deploy/ NonDeploy (D/ND)	Event Record Complete
CEF0419	2005 Saturn ION	-	Buckled	-	No Passenger	N/A	-	-
CEF0506	2005 Chevrolet Colorado	-	Buckled	-	No Passenger	N/A	D/ND	Yes
CEF0511	2005 Buick LaCrosse	-	Buckled	-	No Passenger	N/A	D/ND	Yes
CF05003	2004 Chevrolet Malibu	-	Buckled	-	Buckled	Epsilon	D/ND	Yes

Overall EDR- Database Comparison

Figure 30 shows the number of EDRs that matched the database records, did not match the database records, or were not recorded. It can be seen that the majority of GM EDRs, 65 out of the 72 cases, matched the database records. 12 of the 13 Ford EDRs, all 18 Toyota EDRs, and none of the Chrysler EDRs also matched the database records.

Only 1 of the 65 GM EDRs, which reported driver seatbelt status, did not match the information provided by the database. The EDR for this case, NHTSA case 4937 module SDMCL21997, reported that the driver was unbuckled when the database showed that the driver was buckled. One important distinction about this case is that this EDR is also the only EDR to report that event recording failed before completion. Failure of the EDR to complete the recording of the event has been implicated in the inaccuracy of the EDR when reporting seat belt status by Chidester et al. (2001). In a real world scenario involving a 2000 Ford Taurus impacting a pole, there was irrefutable evidence of seat belt usage; however the EDR said that the driver was unbuckled. They determined that this may be due to the loss of data which occurs when event record complete fails (Chidester et al., 2001).

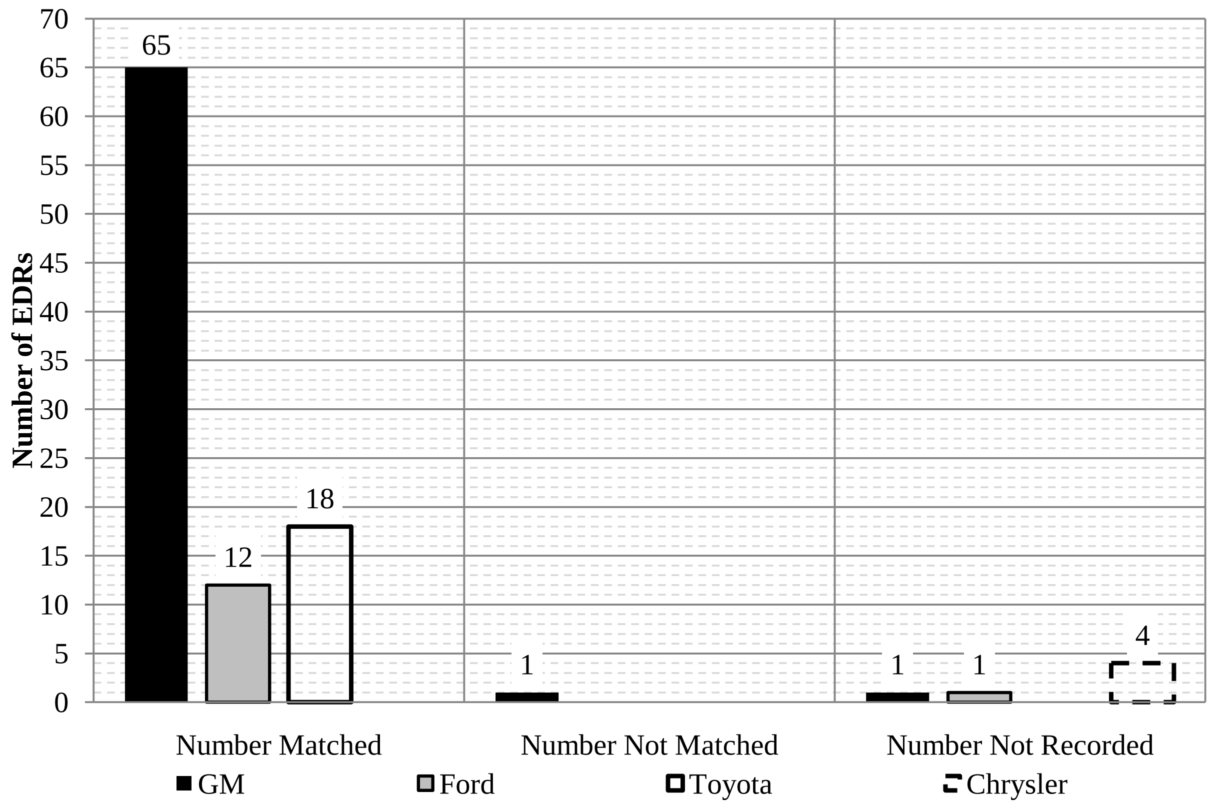

Figure 30. Accuracy of Driver Belt Buckle Status

Table 15 through Table 18, show the breakdown of the above data in a different way.

Table 15. Comparison of GM EDR Seat Belt Accuracy for Drivers

Driver	EDR Buckled	EDR Unbuckled	No Recording	Totals
Crash Test Buckled	57	1	0	58
Crash Test Unbuckled	0	8	0	8
No Driver	0	0	1	1
Totals	57	9	1	67

Table 16. Comparison of Ford EDR Seat Belt Accuracy for Drivers

Driver	EDR Buckled	EDR Unbuckled	No Recording	Totals
Crash Test Buckled	11	0	1	12
Crash Test Unbuckled	0	1	0	1
No Driver	0	0	0	0
Totals	11	1	1	13

Table 17. Comparison of Chrysler EDR Seat Belt Accuracy for Drivers

Driver	EDR Buckled	EDR Unbuckled	No Recording	Totals
Crash Test Buckled	0	0	4	4
Crash Test Unbuckled	0	0	0	0
No Driver	0	0	0	0
Totals	0	0	4	4

Table 18. Comparison of Toyota EDR Seat Belt Accuracy for Drivers

Driver	EDR Buckled	EDR Unbuckled	No Recording	Totals
Crash Test Buckled	17	0	0	17
Crash Test Unbuckled	0	1	0	1
No Driver	0	0	0	0
Totals	17	1	0	18

Figure 31 and Table 19 through Table 22 show the distribution of belt buckle status for right front passengers in this dataset. The ability of an EDR to report right front passenger seatbelt status is relatively new. It is for this reason that only around two-thirds of the EDRs provide a status for the passenger.

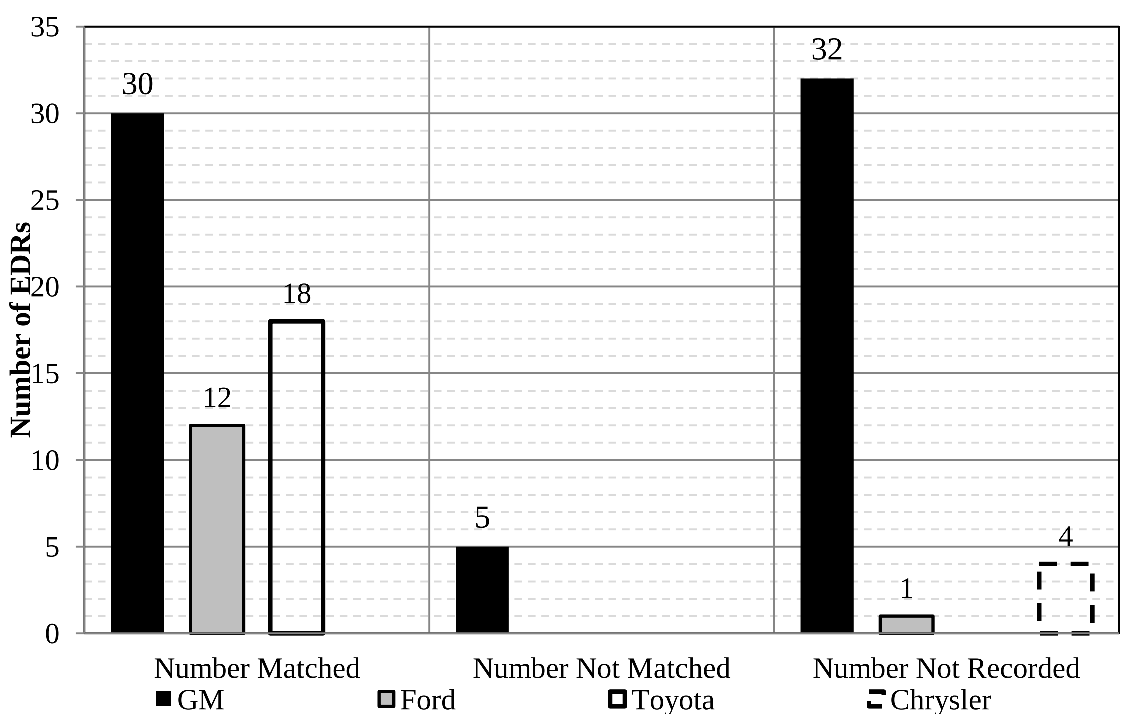

Figure 31. Accuracy of Passenger Belt Buckle Status

Table 19. Accuracy of GM EDR Belt Buckle Status for Right Front Passengers

Passenger	EDR Buckled	EDR Unbuckled	No Recording	Totals
Crash Test Buckled	21	5	22	48
Crash Test Unbuckled	0	6	2	8
No Right Front Passenger	0	3	13	16
Totals	21	14	32	72

Table 20. Accuracy of Ford EDR Belt Buckle Status for Right Front Passengers

Passenger	EDR Buckled	EDR Unbuckled	No Recording	Totals
Crash Test Buckled	5	0	1	6
Crash Test Unbuckled	0	1	0	1
No Right Front Passenger	0	6	0	6
Totals	5	7	1	13

Table 21. Accuracy of Chrysler EDR Belt Buckle Status for Right Front Passengers

Passenger	EDR Buckled	EDR Unbuckled	No Recording	Totals
Crash Test Buckled	0	0	3	3
Crash Test Unbuckled	0	0	0	0
No Right Front Passenger	0	0	1	1
Totals	0	0	4	4

Table 22. Accuracy of Toyota EDR Belt Buckle Status for Right Front Passengers

Passenger	EDR Buckled	EDR Unbuckled	No Recording	Totals
Crash Test Buckled	15	0	0	15
Crash Test Unbuckled	0	3	0	3
No Right Front Passenger	0	0	0	0
Totals	15	3	0	18

Of the 65 EDRs (out of 107) that recorded right front passenger status, only 5 GM EDRs were incorrect. NHTSA tests 4198, 4487, 4775, 4931 and 4985, all reported the right front passenger as buckled in the database while the EDR reported that the passenger was unbuckled. Test number 4198 used an EDR module SDMD2002, while the other three used module SDMDW2003. It is important to note that, when the EDR inaccurately reported the belt buckle status of the right front passenger, the EDR recorded that the belt was unbuckled when in actuality the passenger was restrained. There were no situations in which the EDR reported unbuckled when a driver or right front passenger was unbuckled.

Ford and Toyota were much more effective when determining right front passenger seat belt status. They accurately recorded the status 100% of the time. Chrysler EDRs were unable to record either driver or right front passenger seat belt status.

EDR-Database Comparison for Seat belt Accuracy by EDR Module type

GM and Ford EDRs could also be broken down by module type. This was not done for Toyota or Chrysler EDRs because each Toyota was a different module type and Chrysler provided no seat belt status. Figure 32 shows the distribution of the GM EDR- database matches by EDR module type. The EDR module Epsilon was only represented once in the data, and was the module which did not record driver belt status. Also, model SDMCL21997 was the only module which incorrectly recorded the driver belt status. This module is the oldest in the dataset, and also did not record the whole event involved.

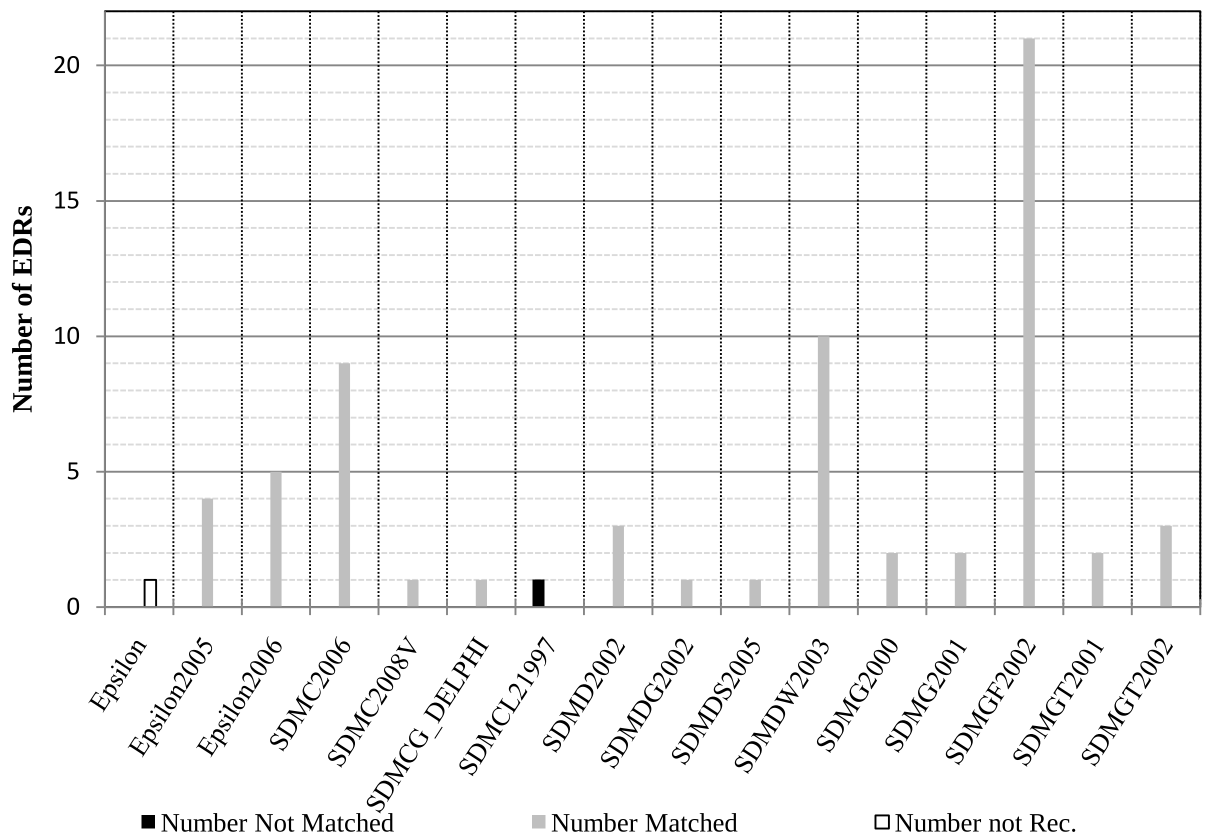

Figure 32. Driver Seatbelt status by GM EDR Module

Figure 33 shows the distribution of Ford EDR- database matches for drivers by EDR module type. Of the 13 cases involved in this study, 3 modules had no module Identifier. There were 3 Ford module types which could be identified and all three were able to accurately record driver seatbelt status for all cases in this database.

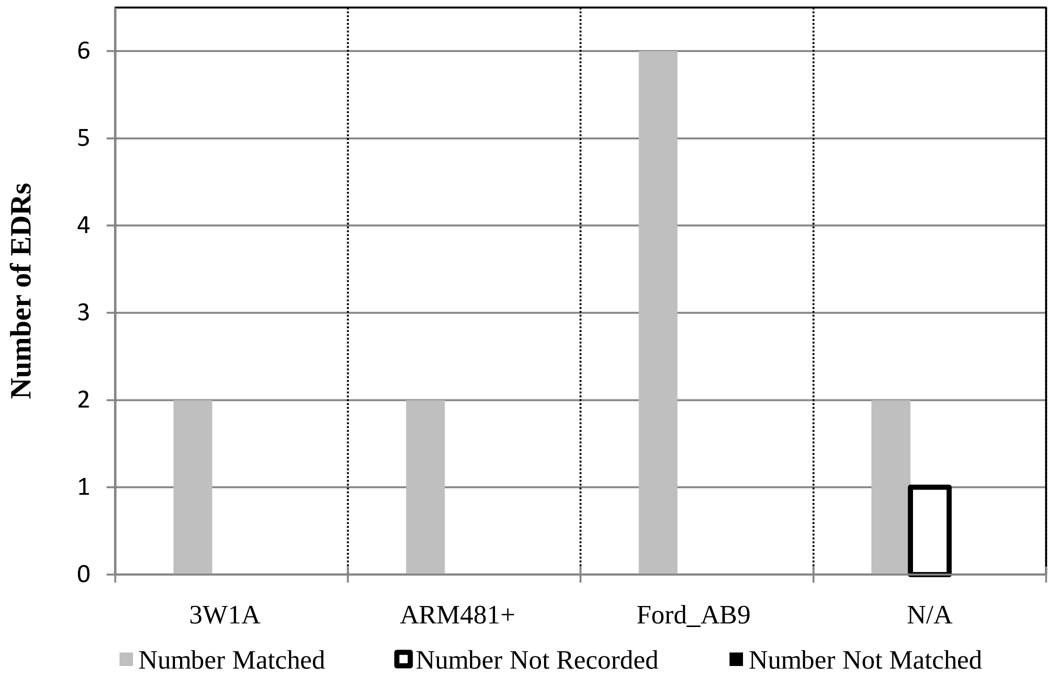

Figure 33. Driver Seatbelt Status by Ford EDR module type

Figure 34 shows the breakdown of the right front passenger belt status by GM EDR module. From this we can see that SDMD2002 and SDMDW2003 were the only two module types which incorrectly reported right front passenger belt buckle status. Modules Epsilon2006, SDMC2006, SDMC2008v, SDMCG_DELPHI and SDMDS2005 recorded the correct belt buckle status for all cases involving these EDRs.

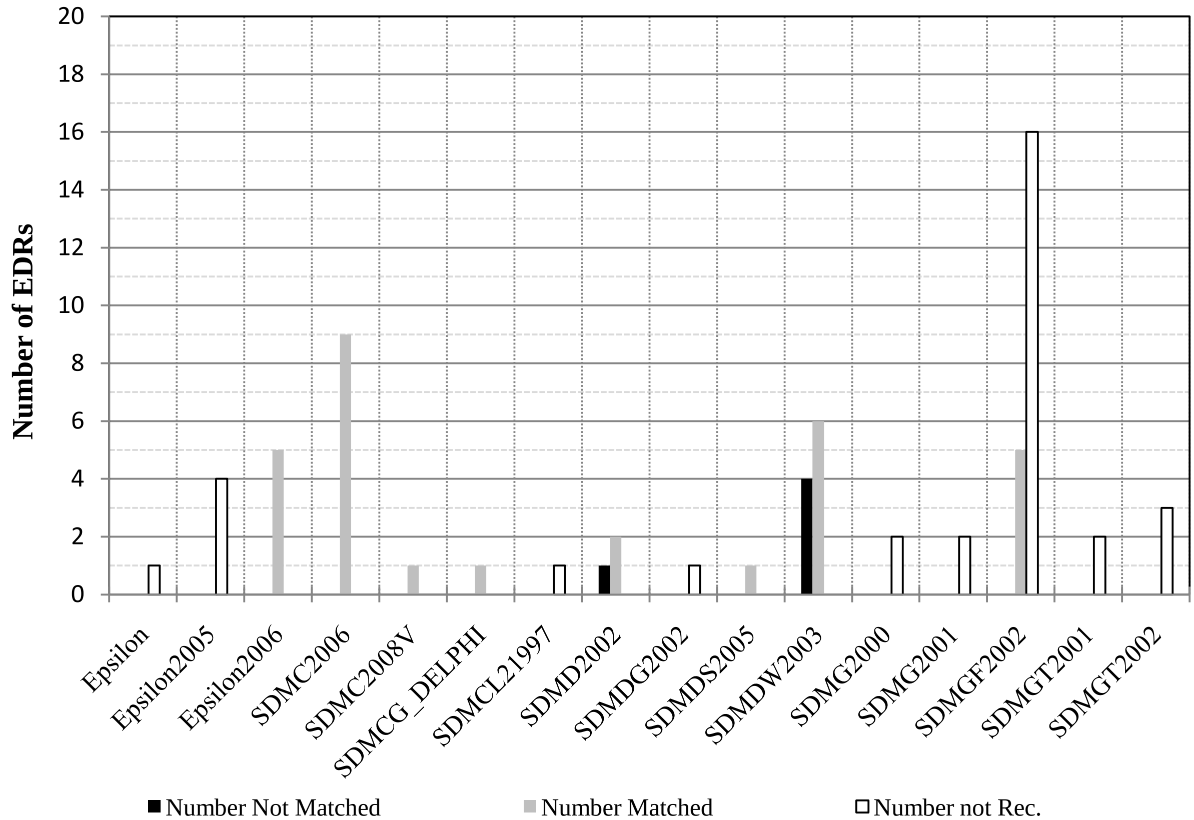

Figure 34. Right Front Passenger Seatbelt Status by GM EDR Module

Figure 35 presents the right front passenger seatbelt status by EDR module type. This data matches exactly with the driver seatbelt status data. Again only 1 EDR did not record the passenger seatbelt status however this module cannot be identified by the information provided.

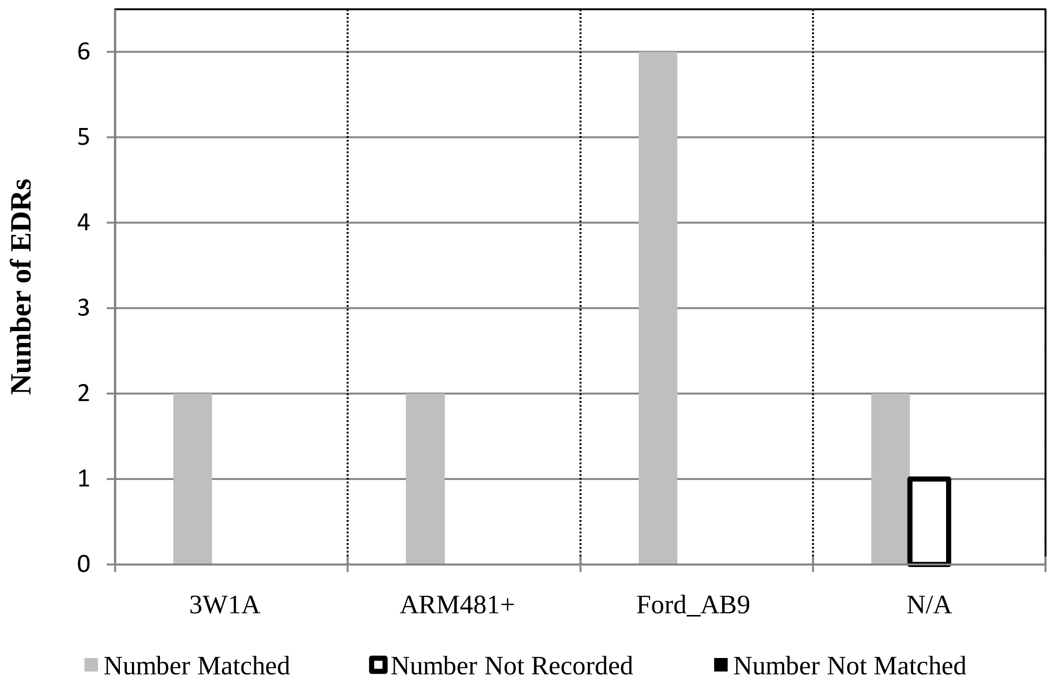

Figure 35. Right Front Passenger Seatbelt Status by Ford EDR module type

2.6 Accuracy of Pre-Impact Speed

2.6.1 Approach

The same dataset used in the previous section was utilized to compare the pre-crash speed recorded by the EDR to that provided by the NHTSA and IIHS databases. This dataset consisted of 72 GM EDRs, 13 Ford EDRs, 18 Toyota EDRs and 4 Chrysler EDRs. The EDR reports vehicle velocity for approximately 5 seconds before the crash. The velocity that will be considered as the pre-impact velocity for this section is the velocity at the pre-crash time closest to the impact.

The EDR pre-crash velocity was compared to the velocity reported by NHTSA and IIHS. The comparison is represented in the form of a percent error for each crash test. The EDRs are separated by manufacturer and also compared by module type.

2.6.2 Results and Discussion

Table 23 below shows the breakdown of the total dataset used for the pre impact speed comparison. The majority of the EDRs had an error of less than 2mph. Only four GM tests were outside that range; NHTSA tests 4259, 4955, 5310 and 6271 had percent errors of -35.2mpg, 87.5mph, -7.8mph and -34.8mph respectively. One GM EDR, 4937 did not record a value for pre impact velocity. This EDR is also the module which did not completely record the events of the crash.

Four of the 13 Ford EDRs provided no pre impact velocity measurement. All of the Ford EDRs, which recorded pre-impact velocity, were accurate to within 1mph in predicting the velocity. The Ford EDRs were accurate in 5 out of the remaining crash tests. These were 4 side impact and 1 frontal impact tests.

The Toyota EDRs recorded a pre-impact velocity in only 6 of the 18 cases. In the rest of the cases, the pre-impact velocity was reported as 0mph. 4 of the 6 Toyota EDRs that recorded pre-impact velocity were side impacts where the stationary vehicle was hit. For these cases the EDR reported 0mph also. For this analysis these are assumed to be accurate readings. The two tests which recorded a value other than 0 for the pre-impact speed were NHTSA test No. 4846 and 5269. For these 2 EDRs, the accuracy was within 1mph.

All 4 Chrysler EDRs reported a pre-impact velocity. The velocities recorded were all within .6mph of actual, with one test being accurate.

Table 23. Breakdown of Dataset for Pre-Impact Speed Comparison

Test Num	Vehicle Description	EDR Model	Impact type	Deploy/ NonDeploy (D/ND)	EDR Pre Crash Speed (mph)	Database Pre Crash Speed (mph)	Error (mph)	Event Record Complete
3471	2001 Chevrolet Impala	SDMGT2001	Full Frontal	D/ND	35.0	34.9	0.1	Yes
3851	2002 Chevrolet Avalanche	SDMG2001	Full Frontal	D	35.0	35.2	-0.2	-
3952	2002 Buick Rendezvous	SDMDG2002	Full Frontal	D/ND	35.0	35.2	-0.2	Yes
4198	2002 Saturn Vue	SDMD2002	Full Frontal	D/ND	35.0	35.0	0.0	Yes
4238	2002 Cadillac Deville	SDMGF2002	Full Frontal	D	34.0	35.3	-1.3	Yes
4244	2002 Chevrolet Trailblazer	SDMGT2002	Full Frontal	D	34.0	35.1	-1.1	Yes
4259	2003 Cadillac CTS	SDMGF2002	Full Frontal	ND	0.0	35.2	-35.2	Yes
4437	2003 Chevrolet Suburban	SDMGF2002	Frontal Offset	ND	24.0	24.9	-0.9	Yes
4445	2003 Chevrolet Cavalier	SDMG2001	Full Frontal	D	35.0	34.8	0.2	-
4453	2003 Chevrolet Silverado	SDMGF2002	Full Frontal	D	24.0	24.4	-0.4	Yes
4454	2003 Chevrolet Tahoe	SDMGF2002	Full Frontal	D	24.0	24.4	-0.4	Yes
4464	2003 Chevrolet Avalanche	SDMGT2002	Full Frontal	D	34.0	35.2	-1.2	Yes
4472	2003 Chevrolet Silverado	SDMGF2002	Full Frontal	D/ND	35.0	34.7	0.3	Yes
4487	2003 Saturn Ion	SDMDW2003	Full Frontal	D/ND	35.0	34.8	0.2	Yes
4549	2003 Chevy Tahoe	SDMGF2002	Full Frontal	D/ND	35.0	35.0	0.0	Yes
4567	2003 Chevrolet Suburban	SDMGF2002	Full Frontal	D/ND	35.0	35.0	0.0	Yes
4702	2002 Saturn Vue	SDMD2002	Full Frontal	D/ND	30.0	29.8	0.2	Yes
4714	2002 Saturn Vue	SDMD2002	Full Frontal	D/ND	29.0	29.7	-0.7	Yes
4733	2004 Toyota Sienna	89170-08050	Side Impact	-	0.0	0.0	0.0	Yes
4775	2004 Pontiac Grand Prix	SDMDW2003	Full Frontal	D/ND	35.0	34.7	0.3	Yes
4777	2001 Buick LeSabre	SDMGT2001	Side Impact	ND	0.0	0.0	0.0	Yes
4846	2004 Toyota Sienna	89170-08060	Full Frontal	-	34.8	35.2	-0.4	Yes
4855	2004 Toyota Solara	89170-06240	Full Frontal	-	0.0	34.7	-34.7	Yes
4890	2004 Ford F-150	ARM481+	Full Frontal	-	-	35.1	-	-
4893	2004 Toyota RAV4	89170-42160	Full Frontal	-	0.0	34.1	-34.1	Yes
4899	2004 Cadillac SRX	SDMGF2002	Full Frontal	D/ND	35.0	35.4	-0.4	Yes
4918	2004 GMC Envoy XUV	SDMGT2002	Full Frontal	D/ND	35.0	35.2	-0.2	Yes

Test Num	Vehicle Description	EDR Model	Impact type	Deploy/ NonDeploy (D/ND)	EDR Pre Crash Speed (mph)	Database Pre Crash Speed (mph)	Error (mph)	Event Record Complete
4923	2004 Chevrolet Colorado	SDMGF2002	Full Frontal	D	35.0	35.2	-0.2	Yes
4928	2004 Toyota Camry	89170-33300	Side Impact	-	0.0	0.0	0.0	Yes
4931	2004 Saturn Vue	SDMDW2003	Full Frontal	D/ND	34.0	34.7	-0.7	Yes
4933	2004 Toyota Prius	89170-47380	Full Frontal	-	0.0	34.2	-34.2	Yes
4937	1997 Cadillac Seville	SDMCL21997	Side Offset	D/ND	-	69.6	-	No
4955	2000 Cadillac Seville	SDMG2000	Side Offset	D	158.0	70.5	87.5	-
4984	2004 Saturn Ion	SDMDW2003	Full Frontal	D/ND	25.0	24.9	0.1	Yes
4985	2005 Chevrolet Equinox	SDMDW2003	Full Frontal	D/ND	35.0	35.0	0.0	Yes
4987	2005 Ford Taurus	ARM481+	Full Frontal	-	-	24.7	-	-
5037	2004 Toyota 4Runner	89170-35190	Full Frontal	-	0.0	33.7	-33.7	Yes
5071	2004 Toyota Camry	89170-33300	Full Frontal	-	0.0	24.6	-24.6	Yes
5140	2004 Chevrolet Avalanche	SDMGF2002	Full Frontal	D/ND	35.0	35.0	0.0	Yes
5157	2005 Toyota Corolla	89170-02410	Side Impact	-	0.0	0.0	0.0	Yes
5160	2005 Toyota Corolla	89170-02420	Full Frontal	-	0.0	33.9	-33.9	Yes
5162	2005 Toyota Matrix	89170-01060	Side Impact	-	0.0	0.0	0.0	Yes
5209	2005 Toyota Matrix	89170-01070	Full Frontal	-	0.0	33.9	-33.9	Yes
5213	2004 Chevrolet Avalanche	SDMGF2002	Full Frontal	D/ND	30.0	30.1	-0.1	Yes
5217	2005 Toyota Scion TC	89170-21070	Full Frontal	-	0.0	33.7	-33.7	Yes
5218	2005 Toyota Tundra	89170-0C160	Full Frontal	-	0.0	33.9	-33.9	Yes
5239	2005 Toyota Tundra	89170-0C190	Full Frontal	-	0.0	33.7	-33.7	Yes
5249	2005 Ford 500	N/A	Full Frontal	-	35.3	35.3	0.0	-
5250	2005 Pontiac G6	Epsilon2005	Full Frontal	D	35.0	35.3	-0.3	Yes
5256	2005 Pontiac G6	Epsilon2005	Side Impact	D	0.0	0.0	0.0	Yes
5260	2005 Saturn ION	SDMDW2003	Side Impact	D/ND	0.0	0.0	0.0	Yes
5263	2005 Ford Freestyle	N/A	Full Frontal	-	35.0	34.1	0.9	-
5264	2005 Chevy Uplander	SDMDW2003	Full Frontal	D/ND	35.0	34.9	0.1	Yes

Test Num	Vehicle Description	EDR Model	Impact type	Deploy/ NonDeploy (D/ND)	EDR Pre Crash Speed (mph)	Database Pre Crash Speed (mph)	Error (mph)	Event Record Complete
5265	2005 Chevy Express	SDMGF2002	Full Frontal	D/ND	34.0	34.9	-0.9	Yes
5269	2005 Toyota Sienna	89170-08070	Full Frontal	-	34.8	33.8	1.0	Yes
5282	2005 Chevy Colorado	SDMGF2002	Full Frontal	D/ND	34.0	35.2	-1.2	Yes
5283	2005 Toyota Camry	89170-06260*4-(89170-33310)	Full Frontal	-	0.0	33.9	-33.9	Yes
5284	2005 Ford Econoline	N/A	Full Frontal	-	35.0	34.9	0.1	-
5310	2005 Buick Rendezvous	SDMDW2003	Full Frontal	D/ND	27.0	34.8	-7.8	Yes
5312	2005 Toyota Tacoma	89170-04070	Full Frontal	-	0.0	33.7	-33.7	Yes
5318	2005 Chevy Silverado	SDMGF2002	Full Frontal	D/ND	35.0	34.9	0.1	Yes
5324	2005 Pontiac Montana	SDMDW2003	Full Frontal	D/ND	35.0	34.8	0.2	Yes
5325	2005 Chevy Cobalt	Epsilon2005	Side Impact	ND	0.0	0.0	0.0	Yes
5326	2005 Chevy Cobalt	Epsilon2005	Full Frontal	D	35.0	34.9	0.1	Yes
5468	2006 Pontiac Grand Prix	SDMDW2003	Full Frontal	D/ND	35.0	35.1	-0.1	Yes
5547	2006 Chevrolet Impala	SDMC2006	Full Frontal	D	35.0	35.1	-0.1	Yes
5567	2006 Hummer H3	SDMDS2005	Full Frontal	D	34.0	35.0	-1.0	Yes
5569	2006 Cadillac DTS	SDMC2006	Full Frontal	D	35.0	35.2	-0.2	Yes
5578	2006 Chevrolet Monte Carlo	SDMC2006	Full Frontal	D	34.0	35.0	-1.0	Yes
5589	2006 Buick Lucerne CX	SDMC2006	Full Frontal	D	35.0	35.1	-0.1	Yes
5597	2006 Chevrolet Colorado	SDMGF2002	Full Frontal	D/ND	35.0	35.1	-0.1	Yes
5602	2006 Chevrolet HHR	Epsilon2006	Full Frontal	D	35.0	34.9	0.1	Yes
5603	2006 Chevy Colorado	SDMGF2002	Full Frontal	D/ND	34.0	34.9	-0.9	Yes
5741	2006 Buick Lucerne	SDMC2006	Full Frontal	D	25.0	24.7	0.3	Yes
5830	2006 Pontiac G6	Epsilon2006	Full Frontal	D	25.0	24.7	0.3	Yes
5844	2007 Saturn Aura	Epsilon2006	Full Frontal	D	35.0	35.1	-0.1	Yes
5859	2007 Pontiac Solstice	Epsilon2006	Full Frontal	D	34.0	35.0	-1.0	Yes
5877	2007 Chevrolet Silverado	SDMC2006	Full Frontal	D	35.0	34.8	0.2	Yes
5907	2007 Chevrolet Silverado	SDMC2006	Full Frontal	D	35.0	35.1	-0.1	Yes
5967	2007 Jeep Patriot	CHRY0154	Full Frontal	-	34.0	34.6	-0.6	Valid

Test Num	Vehicle Description	EDR Model	Impact type	Deploy/ NonDeploy (D/ND)	EDR Pre Crash Speed (mph)	Database Pre Crash Speed (mph)	Error (mph)	Event Record Complete
6172	2008 Dodge Caravan	CHRY0303C	Full Frontal	-	35.0	34.9	0.1	Valid
6200	2008 Saturn Vue	SDMC2008V	Full Frontal	D	34.0	34.9	-0.9	Yes
6234	2008 Dodge Dakota	CHRY0303	Full Frontal	-	35.0	35.1	-0.1	-
6243	2008 Ford Focus	Ford_AB9	Full Frontal	D	34.6	34.8	-0.2	Yes
6245	2008 Ford Focus coupe	Ford_AB9	Side Impact	D	0.0	0.0	0.0	Yes
6246	2008 Ford Focus	Ford_AB9	Side Impact	D	0.0	0.0	0.0	Yes
6256	2008 Ford Focus	Ford_AB9	Full Frontal	D	34.2	34.6	-0.4	Yes
6268	2008 Chevrolet Malibu	Epsilon2006	Full Frontal	D	34.0	34.9	-0.9	Yes
6269	2008 Ford Focus	Ford_AB9	Side Impact	D	0.0	0.0	0.0	Yes
6270	2008 Ford Focus coupe	Ford_AB9	Side Impact	D	0.0	0.0	0.0	Yes
6271	2008 Cadillac CTS	SDMCG_DELPHI	Full Frontal	D	0.0	34.8	-34.8	Yes
6274	2008 Dodge Caravan	CHRY0303C	Side Impact	-	0.0	0.0	0.0	-
6298	2008 Saturn Outlook	SDMC2006	Frontal Offset	D	37.0	37.2	-0.2	Yes
6321	2008 Saturn Outlook	SDMC2006	Frontal Offset	D	37.0	34.7	2.3	Yes
CEF0107	2001 Chevrolet Silverado	SDMG2000	Frontal Offset	D/ND	39.0	40.3	-1.3	-
CEF0119	2002 Chevrolet Trailblazer	SDMGT2002	Frontal Offset	D/ND	40.0	40.1	-0.1	Yes
CEF0209	2003 Cadillac CTS	SDMGF2002	Frontal Offset	D/ND	40.0	39.9	0.1	Yes
CEF0221	2003 Cadillac CTS	SDMGF2002	Frontal Offset	D-DL	40.0	39.9	0.1	Yes
CEF0301	2003 Lincoln Towncar	3W1A	Frontal Offset	D	-	39.8	-	-
CEF0313	2003 Lincoln Towncar	3W1A	Frontal Offset	D	-	39.9	-	-
CEF0326	2004 Cadillac SRX	SDMGF2002	Frontal Offset	D/ND	39.0	39.9	-0.9	Yes
CEF0401	2004 Chevrolet Malibu	N/A	Frontal Offset	-	40.0	40.0	0.0	-
CEF0406	2004 Chevrolet Malibu	N/A	Frontal Offset	-	40.0	40.0	0.0	-
CEF0419	2005 Saturn ION	N/A	Frontal Offset	-	40.0	40.0	0.0	-
CEF0506	2005 Chevrolet Colorado	N/A	Frontal Offset	D/ND	39.0	39.7	-0.7	Yes
CEF0511	2005 Buick LaCrosse	N/A	Frontal Offset	D/ND	39.0	39.9	-0.9	Yes
CF05003	2004 Chevrolet Malibu	Epsilon	Pole	D/ND	39.0	39.7	-0.7	Yes

Table 24 shows the average errors, minimum and maximum recorded errors by vehicle make. Toyota, by far performed the worst when predicting pre-impact velocity but GM had the largest minimum and maximum errors.

Table 24. Error by Vehicle Make

	Average Error (mph)	Min. Error (mph)	Max. Error (mph)	Average Underestimation (mph)	Average Overestimation (mph)
GM	-0.07	-35.20	87.54	-2.57	5.03
Ford	0.04	-0.40	0.90	-0.30	0.50
Toyota	-22.07	-34.67	1.00	-30.64	1.00
Chrysler	-0.15	-0.60	-0.10	-0.35	0.10

EDR-Database Comparison for Pre-Impact Velocity Accuracy by EDR Module type

Table 25, Table 26 and Table 27 provide the averages, minimum error and maximum error for the GM Ford and Chrysler, respectively EDR module types involved in this research. On the GM modules where there were 5 or more tests performed, EDR module SDMC2006 had the lowest average error of .12mph and module type SDMF2002 had the largest error of -2.07mph. For 2 of the Ford module types ARM481+ and 3W1A, average errors could not be calculated because of lack of information. Module type Ford_AB9 was the most commonly occurring and had an average percent error of only -.3%. The rest of the EDR modules could not be identified. The Chrysler EDRs also had a limited dataset. The most common occurring Module, CHRY0303C, had an average error of only .05mph.

Table 25. Pre-Impact Velocity Errors of GM EDRs by Module Type

EDR Module	Number Of Modules	Average Error (mph)	Minimum Error (mph)	Maximum Error (mph)
Epsilon	1	-0.70	-0.70	-0.70
Epsilon2005	4	-0.05	-0.30	0.10
Epsilon2006	5	-0.31	-1.00	0.30
SDMC2006	9	0.12	-1.00	2.33
SDMC2008V	1	-0.90	-0.90	-0.90
SDMCG_DELPHI	1	-34.82	-34.82	-34.82
SDMCL21997	1	-	-	-

EDR Module	Number Of Modules	Average Error (mph)	Minimum Error (mph)	Maximum Error (mph)
SDMD2002	3	-0.16	-0.70	0.24
SDMDG2002	1	-0.17	-0.17	-0.17
SDMDS2005	1	-1.00	-1.00	-1.00
SDMDW2003	10	-0.77	-7.80	0.27
SDMG2000	2	43.14	-1.26	87.54
SDMG2001	2	0.04	-0.17	0.24
SDMGF2002	21	-2.07	-35.20	0.27
SDMGT2001	2	0.05	0.00	0.10
SDMGT2002	3	-0.47	-1.10	-0.10
N/A	5	-0.34	-0.90	0.02

Table 26. Pre-Impact Velocity Errors of Ford EDRs by Module Type

EDR Module	Number Of Modules	Average Error (mph)	Minimum Error (mph)	Maximum Error (mph)
3W1A	2	N/A	N/A	N/A
ARM481+	2	N/A	N/A	N/A
Ford_AB9	6	-0.10	-0.40	0.00
N/A	3	0.33	0.00	0.90

Table 27. Pre-Impact Velocity Errors of Chrysler EDRs by Module Type

EDR Module	Number Of Modules	Average Error (mph)	Minimum Error (mph)	Maximum Error (mph)
CHRY0154	1	-0.6	-0.6	-0.6
CHRY0303C	2	0.05	0	0.1
CHRY0303	1	-0.1	-0.1	-0.1

2.7 Air Bag Deployment Comparison

2.7.1 Approach

For this section, the 107 dataset was used. For the GM EDR, deployment status was determined using the “events recorded” field. For Ford EDRs, the driver/passenger “airbag stage 1” flag or the driver/passenger “First stage airbag deployment time” or driver/passenger “side/curtain airbag deployment time” flags were used to indicate that one or more of the airbags deployed. Toyota EDRs indicated airbag deployment using the “deployment time” and driver/passenger "deployment stage" flags. There were no indicators for the Chrysler EDRs which indicated the deployment of the airbags.

The deployment status' recorded by the EDRs were then compared to both the NHTSA and IIHS databases. To determine deployment from these databases, the post-crash pictures from for each test were visually inspected.

2.7.2 Results and Discussion

Table 28 shows the results of the airbag deployment comparison. All but 2 of the 72 GM EDRs recorded the correct deployment status for the crash test. NHTSA test number 4259, module SDMGF2002, recorded a non-deployment event only, and did not report any airbag deployment. However, inspection of the post-crash photos showed that both the driver and passenger frontal airbags deployed.

In the second case, NHTSA test number 4777, module SDMGT2001, the EDR recorded the event as a non-deployment; however inspection of the post-crash photos showed that the side airbags were deployed. This test was a side impact. It is possible that the deployment field refers only to whether the Frontal airbags regardless of whether the side airbags deployed.

All of the Ford EDRs investigated in this study accurately reported airbag deployment status. It is interesting to note that EDR module Ford_AB9 actually distinguishes between a frontal deployment and a side deployment. Also none of these crashes resulted in a non deployment event. Therefore it is impossible to say that the Ford EDRs would be accurate reporting airbag status in those situations.

Toyota EDRs were also accurate at predicting airbag deployment status. They were accurate in both deployment and non deployment situations.

From the data provided by the Chrysler EDRs it was impossible to tell if the EDR could predict airbag deployment. There were no flags indicating deployment times, or deployment levels. There was also no description of the type of event, deployment/non deployment, which was recorded by the EDR in question. The Chrysler EDRs do indicate however if the airbag control module is "configured for left/right curtain airbags" and "Configured for Passenger Airbag Disable Switch". It is therefore unknown if the EDR does in fact record this data and the Crash Data Retrieval system is unable to report it, or if it is not recorded at all.

Table 28. Database of EDRs for Airbag Analysis

Test Num	Vehicle Description	EDR Model	Impact type	Airbags Deployment Status (EDR)	Driver Airbag Deployment Status (Database)	Passenger Airbag Deployment Status (Database)	Events Recorded (D/ND)	Event Record Complete
3471	2001 Chevrolet Impala	SDMGT2001	Full Frontal	Deployed	Deployed	Deployed	D/ND	Yes
3851	2002 Chevrolet Avalanche	SDMG2001	Full Frontal	Deployed	Deployed	Deployed	D	-
3952	2002 Buick Rendezvous	SDMDG2002	Full Frontal	Deployed	Deployed	Deployed	D/ND	Yes
4198	2002 Saturn Vue	SDMD2002	Full Frontal	Deployed	Deployed	Deployed	D/ND	Yes
4238	2002 Cadillac Deville	SDMGF2002	Full Frontal	Deployed	Deployed	Deployed	D	Yes
4244	2002 Chevrolet Trailblazer	SDMGT2002	Full Frontal	Deployed	Deployed	Deployed	D	Yes
4259	2003 Cadillac CTS	SDMGF2002	Full Frontal	Not Deployed	Deployed	Deployed	ND	Yes
4437	2003 Chevrolet Suburban	SDMGF2002	Frontal Offset	Not Deployed	Not Deployed	Not Deployed	ND	Yes
4445	2003 Chevrolet Cavalier	SDMG2001	Full Frontal	Deployed	Deployed	Deployed	D	-
4453	2003 Chevrolet Silverado	SDMGF2002	Full Frontal	Deployed	Deployed	Deployed	D	Yes
4454	2003 Chevrolet Tahoe	SDMGF2002	Full Frontal	Deployed	Deployed	Deployed	D	Yes
4464	2003 Chevrolet Avalanche	SDMGT2002	Full Frontal	Deployed	Deployed	Deployed	D	Yes
4472	2003 Chevrolet Silverado	SDMGF2002	Full Frontal	Deployed	Deployed	Deployed	D/ND	Yes
4487	2003 Saturn Ion	SDMDW2003	Full Frontal	Deployed	Deployed	Deployed	D/ND	Yes
4549	2003 Chevy Tahoe	SDMGF2002	Full Frontal	Deployed	Deployed	Deployed	D/ND	Yes
4567	2003 Chevrolet Suburban	SDMGF2002	Full Frontal	Deployed	Deployed	Deployed	D/ND	Yes
4702	2002 Saturn Vue	SDMD2002	Full Frontal	Deployed	Deployed	Deployed	D/ND	Yes
4714	2002 Saturn Vue	SDMD2002	Full Frontal	Deployed	Deployed	Deployed	D/ND	Yes
4733	2004 Toyota Sienna	89170-08050	Side Impact	Not Deployed	Not Deployed	No Passenger	-	Yes
4775	2004 Pontiac Grand Prix	SDMDW2003	Full Frontal	Deployed	Deployed	Deployed	D/ND	Yes
4777	2001 Buick LeSabre	SDMGT2001	Side Impact	Not Deployed	Side Deployed	No Passenger	ND	Yes
4846	2004 Toyota Sienna	89170-08060	Full Frontal	Deployed	Deployed	Deployed	-	Yes
4855	2004 Toyota Solara	89170-06240	Full Frontal	Deployed	Deployed	Deployed	-	Yes
4890	2004 Ford F-150	ARM481+	Full Frontal	Deployed	Deployed	Deployed	-	-

Test Num	Vehicle Description	EDR Model	Impact type	Airbags Deployment Status (EDR)	Driver Airbag Deployment Status (Database)	Passenger Airbag Deployment Status (Database)	Events Recorded (D/ND)	Event Record Complete
4893	2004 Toyota RAV4	89170-42160	Full Frontal	Deployed	Deployed	Deployed	-	Yes
4899	2004 Cadillac SRX	SDMGF2002	Full Frontal	Deployed	Deployed	Deployed	D/ND	Yes
4918	2004 GMC Envoy XUV	SDMGT2002	Full Frontal	Deployed	Deployed	Deployed	D/ND	Yes
4923	2004 Chevrolet Colorado	SDMGF2002	Full Frontal	Deployed	Deployed	Deployed	D	Yes
4928	2004 Toyota Camry	89170-33300	Side Impact	Not Deployed	Not Deployed	No Passenger	-	Yes
4931	2004 Saturn Vue	SDMDW2003	Full Frontal	Deployed	Deployed	Deployed	D/ND	Yes
4933	2004 Toyota Prius	89170-47380	Full Frontal	Deployed	Deployed	Deployed	-	Yes
4937	1997 Cadillac Seville	SDMCL21997	Side Offset	Deployed	Deployed	Deployed	D/ND	No
4955	2000 Cadillac Seville	SDMG2000	Side Offset	Deployed	Deployed	Deployed	D	-
4984	2004 Saturn Ion	SDMDW2003	Full Frontal	Deployed	Deployed	Deployed	D/ND	Yes
4985	2005 Chevrolet Equinox	SDMDW2003	Full Frontal	Deployed	Deployed	Deployed	D/ND	Yes
4987	2005 Ford Taurus	ARM481+	Full Frontal	Deployed	Deployed	Deployed	-	-
5037	2004 Toyota 4Runner	89170-35190	Full Frontal	Deployed	Deployed	Deployed	-	Yes
5071	2004 Toyota Camry	89170-33300	Full Frontal	Deployed	Deployed	Deployed	-	Yes
5140	2004 Chevrolet Avalanche	SDMGF2002	Full Frontal	Deployed	Deployed	Deployed	D/ND	Yes
5157	2005 Toyota Corolla	89170-02410	Side Impact	Deployed	Deployed	No Passenger	-	Yes
5160	2005 Toyota Corolla	89170-02420	Full Frontal	Deployed	Deployed	Deployed	-	Yes
5162	2005 Toyota Matrix	89170-01060	Side Impact	Deployed	Deployed	No Passenger	-	Yes
5209	2005 Toyota Matrix	89170-01070	Full Frontal	Deployed	Deployed	Deployed	-	Yes
5213	2004 Chevrolet Avalanche	SDMGF2002	Full Frontal	Deployed	Deployed	Deployed	D/ND	Yes
5217	2005 Toyota Scion TC	89170-21070	Full Frontal	Deployed	Deployed	Deployed	-	Yes
5218	2005 Toyota Tundra	89170-0C160	Full Frontal	Deployed	Deployed	Deployed	-	Yes
5239	2005 Toyota Tundra	89170-0C190	Full Frontal	Deployed	Deployed	Deployed	-	Yes
5249	2005 Ford 500	N/A	Full Frontal	Deployed	Deployed	Deployed	-	-
5250	2005 Pontiac G6	Epsilon2005	Full Frontal	Deployed	Deployed	Deployed	D	Yes
5256	2005 Pontiac G6	Epsilon2005	Side Impact	Deployed	Deployed	No Passenger	D	Yes
5260	2005 Saturn ION	SDMDW2003	Side Impact	Deployed	Deployed	No Passenger	D/ND	Yes

Test Num	Vehicle Description	EDR Model	Impact type	Airbags Deployment Status (EDR)	Driver Airbag Deployment Status (Database)	Passenger Airbag Deployment Status (Database)	Events Recorded (D/ND)	Event Record Complete
5263	2005 Ford Freestyle	N/A	Full Frontal	Deployed	Deployed	Deployed	-	-
5264	2005 Chevy Uplander	SDMDW2003	Full Frontal	Deployed	Deployed	Deployed	D/ND	Yes
5265	2005 Chevy Express	SDMGF2002	Full Frontal	Deployed	Deployed	Deployed	D/ND	Yes
5269	2005 Toyota Sienna	89170-08070	Full Frontal	Deployed	Deployed	Deployed	-	Yes
5282	2005 Chevy Colorado	SDMGF2002	Full Frontal	Deployed	Deployed	Deployed	D/ND	Yes
5283	2005 Toyota Camry	89170-06260*4-(89170-33310)	Full Frontal	Deployed	Deployed	Deployed	-	Yes
5284	2005 Ford Econoline	N/A	Full Frontal	Deployed	Deployed	Deployed	-	-
5310	2005 Buick Rendezvous	SDMDW2003	Full Frontal	Deployed	Deployed	Deployed	D/ND	Yes
5312	2005 Toyota Tacoma	89170-04070	Full Frontal	Deployed	Deployed	Deployed	-	Yes
5318	2005 Chevy Silverado	SDMGF2002	Full Frontal	Deployed	Deployed	Deployed	D/ND	Yes
5324	2005 Pontiac Montana	SDMDW2003	Full Frontal	Deployed	Deployed	Deployed	D/ND	Yes
5325	2005 Chevy Cobalt	Epsilon2005	Side Impact	Not Deployed	Not Deployed	No Passenger	ND	Yes
5326	2005 Chevy Cobalt	Epsilon2005	Full Frontal	Deployed	Deployed	Deployed	D	Yes
5468	2006 Pontiac Grand Prix	SDMDW2003	Full Frontal	Deployed	Deployed	Deployed	D/ND	Yes
5547	2006 Chevrolet Impala	SDMC2006	Full Frontal	Deployed	Deployed	Deployed	D	Yes
5567	2006 Hummer H3	SDMDS2005	Full Frontal	Deployed	Deployed	Deployed	D	Yes
5569	2006 Cadillac DTS	SDMC2006	Full Frontal	Deployed	Deployed	Deployed	D	Yes
5578	2006 Chevrolet Monte Carlo	SDMC2006	Full Frontal	Deployed	Deployed	Deployed	D	Yes
5589	2006 Buick Lucerne CX	SDMC2006	Full Frontal	Deployed	Deployed	Deployed	D	Yes
5597	2006 Chevrolet Colorado	SDMGF2002	Full Frontal	Deployed	Deployed	Deployed	D/ND	Yes
5602	2006 Chevrolet HHR	Epsilon2006	Full Frontal	Deployed	Deployed	Deployed	D	Yes
5603	2006 Chevy Colorado	SDMGF2002	Full Frontal	Deployed	Deployed	Deployed	D/ND	Yes
5741	2006 Buick Lucerne	SDMC2006	Full Frontal	Deployed	Deployed	Deployed	D	Yes
5830	2006 Pontiac G6	Epsilon2006	Full Frontal	Deployed	Deployed	Deployed	D	Yes
5844	2007 Saturn Aura	Epsilon2006	Full Frontal	Deployed	Deployed	Deployed	D	Yes
5859	2007 Pontiac Solstice	Epsilon2006	Full Frontal	Deployed	Deployed	Deployed	D	Yes

Test Num	Vehicle Description	EDR Model	Impact type	Airbags Deployment Status (EDR)	Driver Airbag Deployment Status (Database)	Passenger Airbag Deployment Status (Database)	Events Recorded (D/ND)	Event Record Complete
5877	2007 Chevrolet Silverado	SDMC2006	Full Frontal	Deployed	Deployed	Deployed	D	Yes
5907	2007 Chevrolet Silverado	SDMC2006	Full Frontal	Deployed	Deployed	Deployed	D	Yes
5967	2007 Jeep Patriot	CHRY0154	Full Frontal	-	Deployed	Deployed	-	Valid
6172	2008 Dodge Caravan	CHRY0303C	Full Frontal	-	Deployed	Deployed	-	Valid
6200	2008 Saturn Vue	SDMC2008V	Full Frontal	Deployed	Deployed	Deployed	D	Yes
6234	2008 Dodge Dakota	CHRY0303	Full Frontal	-	Deployed	Deployed	-	-
6243	2008 Ford Focus	Ford_AB9	Full Frontal	Deployed	Deployed	Deployed	D	Yes
6245	2008 Ford Focus coupe	Ford_AB9	Side Impact	Side Deployed	Side Deployed	-	D	Yes
6246	2008 Ford Focus	Ford_AB9	Side Impact	Side Deployed	Side Deployed	-	D	Yes
6256	2008 Ford Focus	Ford_AB9	Full Frontal	Deployed	Deployed	Deployed	D	Yes
6268	2008 Chevrolet Malibu	Epsilon2006	Full Frontal	Deployed	Deployed	Deployed	D	Yes
6269	2008 Ford Focus	Ford_AB9	Side Impact	Side Deployed	Side Deployed	-	D	Yes
6270	2008 Ford Focus coupe	Ford_AB9	Side Impact	Side Deployed	Side Deployed	-	D	Yes
6271	2008 Cadillac CTS	SDMCG_DELPHI	Full Frontal	Deployed	Deployed	Deployed	D	Yes
6274	2008 Dodge Caravan	CHRY0303C	Side Impact	-	Side Deployed	No Passenger	-	-
6298	2008 Saturn Outlook	SDMC2006	Frontal Offset	Deployed	Deployed	No Passenger	D	Yes
6321	2008 Saturn Outlook	SDMC2006	Frontal Offset	Deployed	Deployed	No Passenger	D	Yes
CEF0107	2001 Chevrolet Silverado	SDMG2000	Frontal Offset	Deployed	Deployed	No Passenger	D/ND	-
CEF0119	2002 Chevrolet Trailblazer	SDMGT2002	Frontal Offset	Deployed	Deployed	No Passenger	D/ND	Yes
CEF0209	2003 Cadillac CTS	SDMGF2002	Frontal Offset	Deployed	Deployed	No Passenger	D/ND	Yes
CEF0221	2003 Cadillac CTS	SDMGF2002	Frontal Offset	Deployed	Deployed	No Passenger	D-DL	Yes
CEF0301	2003 Lincoln Towncar	3W1A	Frontal Offset	Deployed	Deployed	No Passenger	D	-
CEF0313	2003 Lincoln Towncar	3W1A	Frontal Offset	Deployed	Deployed	No Passenger	D	-
CEF0326	2004 Cadillac SRX	SDMGF2002	Frontal Offset	Deployed	Deployed	No Passenger	D/ND	Yes
CEF0401	2004 Chevrolet Malibu	N/A	Frontal Offset	-	-	-	-	-
CEF0406	2004 Chevrolet Malibu	N/A	Frontal Offset	-	Deployed	No Passenger	-	-
CEF0419	2005 Saturn ION	N/A	Frontal Offset	-	Deployed	No Passenger	-	-

Test Num	Vehicle Description	EDR Model	Impact type	Airbags Deployment Status (EDR)	Driver Airbag Deployment Status (Database)	Passenger Airbag Deployment Status (Database)	Events Recorded (D/ND)	Event Record Complete
CEF0506	2005 Chevrolet Colorado	N/A	Frontal Offset	Deployed	Deployed	No Passenger	D/ND	Yes
CEF0511	2005 Buick LaCrosse	N/A	Frontal Offset	Deployed	Deployed	No Passenger	D/ND	Yes
CF05003	2004 Chevrolet Malibu	Epsilon	Pole	Deployed	Deployed	Deployed	D/ND	Yes

2.8 Seat Position Recording Accuracy

2.8.1 Approach

The EDR is essentially the airbag control module in most vehicles. The airbag control module in advanced systems can tailor its deployment strategy based on occupant size. Many newer EDRs record this assessment of occupant size. The goal of this analysis was to determine if the EDR could detect the occupant size through seat position.

The seat position comparison was performed on the same 107 EDR database as the previous comparisons. Seat position was determined from the EDR based on inspection of the CDR report. In GM EDRs, seat position was reported using the "Seat Position Status" data element for the driver and right front passenger. Valid GM EDR values were "Forward" or "Rearward". For Ford EDR modules, the seat position status was listed as either "Normal", "Forward", or "Not Forward". However, this was reported under the category "Driver Seat Track Forward of Switch Point at Algorithm Wake-up", not the actual seat position. Toyota EDRs reported seat position under the "Seat Position Driver" flag. Valid Toyota values were either "RW" rearward or "FW" forward. Chrysler EDRs did not report seat position.

The NHTSA Vehicle Crash Test database contains a descriptor called "Seat Position", under the right front/ left front occupant headings, that was used as the indicator for seat position as measured in each crash test. The NHTSA database seat position indicator however does not necessarily coincide with the airbag control module seat position indicator. The database values are reported here for reference purposes, but are not used in the analysis which follows. Seat position was reported as either "rearward of center position", "forward of center position" or "center position". Seat position for the IIHS tests was not available in the IIHS database.

Dummy size was also collected from the NHTSA and IIHS databases. These values can be seen in Table 29. Our hypothesis was that forward seat position should correlate with the smaller dummies, e.g. the 5th-percentile female dummies.

Table 29. Key to Recorded Dummy Sizes

H3, 50% M	Hybrid III 50% male
H3, 5% F	Hybrid III 5% female
H3, 95% M	Hybrid III 95% Male
EuroSID 50% M	EuroSID 50% Male
H3, 10 yr	Hybrid III 10 year old Dummy
SID 5% F	SID 5% Female
SID 50% M H3 HN	SID 50% Male with a Hybrid III Head and Neck

2.8.2 Results and Discussion

Table 32 shows the 107 EDR dataset used for the comparison of the vehicle seat position. Very few EDRs actually reported seat position status. Only 37 of the 107 EDRs reported driver seat position, while 26 of the 107 EDRs reported passenger seat position.

Table 30 and Table 31 show the seat position status reported by the EDR for both the driver and right front passenger. All EDRs that recorded seat position reported all 5% Hybrid III females as “forward”. This is a good indication that the EDRs, when able to determine seat position, can accurately do so because smaller occupants tend to sit closer to the steering wheel. However 11 EDRs stated that a Hybrid III 50% male or EuroSID 50% male were forward. This may be due to special dummy positioning requirements for a particular test. The reasons for this surprising result should be explored in a future study. The seat position for about 80% of the larger dummies (50-percentile and 95-percentile dummies) for which a seat position was known (46 of the 57), were reported as being “rearward”, “not forward” or “normal”.

Overall, without knowing the values associated with the NHTSA reported seat position, it is hard to determine accuracy of the EDR seat position.

Table 30. Driver Seat Position Status Reported by the EDR

Driver Seat Positions Reported by the EDR						
	Forward	Not Forward	Normal	Rearward	Not Recorded	Total
H3, 50% M	5	4	1	15	60	85
H3, 5% F	2	0	0	0	3	5
H3, 95% M	0	0	0	0	2	2
EuroSID 50% M	0	4	0	0	1	5
H3, 10yr	1	0	0	1	0	2
SID 5% F	0	0	0	0	1	1
SID 50% M H3 HN	0	0	0	4	2	6
Unknown	0	0	0	0	1	1
Total	8	8	1	20	70	107

Table 31. Passenger Seat Position Status Reported by the EDR

Passenger Seat Positions Reported by the EDR						
	Forward	Not Forward	Normal	Rearward	Not Recorded	Total
H3, 50% M	5	0	0	17	46	68
H3, 5% F	2	0	0	0	5	7
H3, 95% M	0	0	0	1	1	2
EuroSID 50% M	1	0	0	0	0	1
H3, 10yr	0	0	0	0	1	1
SID 5% F	0	0	0	0	0	0
SID 50% M H3 HN	0	0	0	0	0	0
No Passenger	0	0	0	0	25	25
Unknown	0	0	0	0	3	3
Total	8	0	0	18	81	107

Table 32. Dataset for Seat Position Comparison

Test Num	Vehicle Description	EDR Model	Driver Dummy Type	Passenger Dummy type	Driver Seat position (EDR)	Driver Seat Position (Database)	Passenger Seat position (EDR)	Passenger Seat Position (Database)	Events Recorded (D/ND)	Event Record Complete
3471	2001 Chevrolet Impala	SDMGT2001	H3, 50% M	H3, 50% M	-	Center	-	Center	D/ND	Yes
3851	2002 Chevrolet Avalanche	SDMG2001	H3, 50% M	H3, 50% M	-	Center	-	Center	D	-
3952	2002 Buick Rendezvous	SDMDG2002	H3, 50% M	H3, 50% M	-	Center	-	Center	D/ND	Yes
4198	2002 Saturn Vue	SDMD2002	H3, 50% M	H3, 50% M	-	Center	-	Center	D/ND	Yes
4238	2002 Cadillac Deville	SDMGF2002	H3, 50% M	H3, 50% M	-	Center	-	Center	D	Yes
4244	2002 Chevrolet Trailblazer	SDMGT2002	H3, 50% M	H3, 50% M	-	Center	-	Center	D	Yes
4259	2003 Cadillac CTS	SDMGF2002	H3, 50% M	H3, 50% M	-	Center	-	Rearward	ND	Yes
4437	2003 Chevrolet Suburban	SDMGF2002	H3, 5% F	H3, 5% F	-	Forward	Forward	Forward	ND	Yes
4445	2003 Chevrolet Cavalier	SDMG2001	H3, 50% M	H3, 50% M	-	Center	-	Center	D	-
4453	2003 Chevrolet Silverado	SDMGF2002	H3, 50% M	H3, 50% M	-	Center	Rearward	Center	D	Yes
4454	2003 Chevrolet Tahoe	SDMGF2002	H3, 5% F	H3, 5% F	-	Forward	Forward	Forward	D	Yes
4464	2003 Chevrolet Avalanche	SDMGT2002	H3, 50% M	H3, 50% M	-	Center	Rearward	Center	D	Yes
4472	2003 Chevrolet Silverado	SDMGF2002	H3, 50% M	H3, 50% M	-	Center	Rearward	Center	D/ND	Yes
4487	2003 Saturn Ion	SDMDW2003	H3, 50% M	H3, 50% M	-	Center	-	Center	D/ND	Yes
4549	2003 Chevy Tahoe	SDMGF2002	H3, 50% M	H3, 50% M	-	Center	Rearward	Center	D/ND	Yes
4567	2003 Chevrolet Suburban	SDMGF2002	H3, 50% M	H3, 50% M	-	Center	Rearward	Center	D/ND	Yes
4702	2002 Saturn Vue	SDMD2002	H3, 95% M	H3, 50% M	-	Rearward	-	Center	D/ND	Yes
4714	2002 Saturn Vue	SDMD2002	H3, 50% M	H3, 95% M	-	Center	-	Rearward	D/ND	Yes
4733	2004 Toyota Sienna	89170-08050	SID, 50% M H3 HN	No Passenger	Rearward	Center	No Passenger	-	-	Yes
4775	2004 Pontiac Grand Prix	SDMDW2003	H3, 50% M	H3, 50% M	-	Center	-	Center	D/ND	Yes
4777	2001 Buick LeSabre	SDMGT2001	SID, 5% F	No Passenger	-	Forward	-	-	ND	Yes
4846	2004 Toyota Sienna	89170-08060	H3, 50% M	H3, 50% M	Rearward	Center	-	Center	-	Yes
4855	2004 Toyota Solara	89170-06240	H3, 50% M	H3, 50% M	Rearward	Center	-	Center	-	Yes
4890	2004 Ford F-150	ARM481+	H3, 50% M	H3, 50% M	Normal	Center	-	Center	-	-
4893	2004 Toyota RAV4	89170-42160	H3, 50% M	H3, 50% M	Rearward	Center		Center	-	Yes

Test Num	Vehicle Description	EDR Model	Driver Dummy Type	Passenger Dummy type	Driver Seat position (EDR)	Driver Seat Position (Database)	Passenger Seat position (EDR)	Passenger Seat Position (Database)	Events Recorded (D/ND)	Event Record Complete
4899	2004 Cadillac SRX	SDMGF2002	H3, 50% M	H3, 50% M	-	Center	Rearward	Center	D/ND	Yes
4918	2004 GMC Envoy XUV	SDMGT2002	H3, 50% M	H3, 50% M	-	Center	-	Center	D/ND	Yes
4923	2004 Chevrolet Colorado	SDMGF2002	H3, 50% M	H3, 50% M	-	Center	-	Center	D	Yes
4928	2004 Toyota Camry	89170-33300	SID, 50% M H3 HN	No Passenger	Rearward	Center	-	-	-	Yes
4931	2004 Saturn Vue	SDMDW2003	H3, 50% M	H3, 50% M	-	Center	-	Center	D/ND	Yes
4933	2004 Toyota Prius	89170-47380	H3, 50% M	H3, 50% M	Rearward	Center		Center	-	Yes
4937	1997 Cadillac Seville	SDMCL21997	H3, 50% M	H3, 5% F	-	Center	-	Forward	D/ND	No
4955	2000 Cadillac Seville	SDMG2000	H3, 50% M	H3, 5% F	-	Center	-	Forward	D	-
4984	2004 Saturn Ion	SDMDW2003	H3, 50% M	H3, 50% M	-	Center	-	Center	D/ND	Yes
4985	2005 Chevrolet Equinox	SDMDW2003	H3, 50% M	H3, 50% M	Forward	Center	Forward	Center	D/ND	Yes
4987	2005 Ford Taurus	ARM481+	H3, 5% F	H3, 5% F	Forward	Forward	-	Forward	-	-
5037	2004 Toyota 4Runner	89170-35190	H3, 50% M	H3, 50% M	Rearward	Center	-	Center	-	Yes
5071	2004 Toyota Camry	89170-33300	H3, 5% F	H3, 5% F	Forward	Forward	-	Forward	-	Yes
5140	2004 Chevrolet Avalanche	SDMGF2002	H3, 95% M	H3, 95% M	-	Rearward	Rearward	Rearward	D/ND	Yes
5157	2005 Toyota Corolla	89170-02410	SID, 50% M H3 HN	No Passenger	Rearward	Forward	-	-	-	Yes
5160	2005 Toyota Corolla	89170-02420	H3, 50% M	H3, 50% M	Rearward	Center	-	Center	-	Yes
5162	2005 Toyota Matrix	89170-01060	SID, 50% M H3 HN	No Passenger	Rearward	Center	-	-	-	Yes
5209	2005 Toyota Matrix	89170-01070	H3, 50% M	H3, 50% M	Rearward	Center	-	Center	-	Yes
5213	2004 Chevrolet Avalanche	SDMGF2002	H3, 50% M	H3, 50% M	-	Center	Rearward	Center	D/ND	Yes
5217	2005 Toyota Scion TC	89170-21070	H3, 50% M	H3, 50% M	Rearward	Center	-	Center	-	Yes
5218	2005 Toyota Tundra	89170-0C160	H3, 10yr	H3, 10yr	Rearward	Center	-	Center	-	Yes
5239	2005 Toyota Tundra	89170-0C190	H3, 50% M	H3, 50% M	Rearward	Center	-	Center	-	Yes
5249	2005 Ford 500	N/A	H3, 50% M	H3, 50% M	Not Forward	Center	-	Center	-	-
5250	2005 Pontiac G6	Epsilon2005	H3, 50% M	H3, 50% M	-	Center	-	Center	D	Yes

Test Num	Vehicle Description	EDR Model	Driver Dummy Type	Passenger Dummy type	Driver Seat position (EDR)	Driver Seat Position (Database)	Passenger Seat position (EDR)	Passenger Seat Position (Database)	Events Recorded (D/ND)	Event Record Complete
5256	2005 Pontiac G6	Epsilon2005	SID, 50% M H3 HN	No Passenger	-	Center	-	-	D	Yes
5260	2005 Saturn ION	SDMDW2003	SID, 50% M H3 HN	No Passenger	Forward	Center	Forward	-	D/ND	Yes
5263	2005 Ford Freestyle	N/A	H3, 50% M	H3, 50% M	Not Forward	Center	-	Center	-	-
5264	2005 Chevy Uplander	SDMDW2003	H3, 50% M	H3, 50% M	Forward	Center	Forward	Center	D/ND	Yes
5265	2005 Chevy Express	SDMGF2002	H3, 50% M	H3, 50% M	-	Center	Rearward	Center	D/ND	Yes
5269	2005 Toyota Sienna	89170-08070	H3, 50% M	H3, 50% M	Rearward	Center	-	Center	-	Yes
5282	2005 Chevy Colorado	SDMGF2002	H3, 50% M	H3, 50% M	-	Center	Rearward	Center	D/ND	Yes
5283	2005 Toyota Camry	89170-06260*4-(89170-33310)	H3, 50% M	H3, 50% M	Rearward	Center	-	Center	-	Yes
5284	2005 Ford Econoline	N/A	H3, 50% M	H3, 50% M	-	Center	-	Center	-	-
5310	2005 Buick Rendezvous	SDMDW2003	H3, 50% M	H3, 50% M	Forward	Center	Forward	Center	D/ND	Yes
5312	2005 Toyota Tacoma	89170-04070	H3, 50% M	H3, 50% M	Rearward	Rearward	-	Rearward	-	Yes
5318	2005 Chevy Silverado	SDMGF2002	H3, 50% M	H3, 50% M	-	Center	Rearward	Center	D/ND	Yes
5324	2005 Pontiac Montana	SDMDW2003	H3, 50% M	H3, 50% M	Forward	Center	Forward	Center	D/ND	Yes
5325	2005 Chevy Cobalt	Epsilon2005	SID, 50% M H3 HN	No Passenger	-	Center	-	-	ND	Yes
5326	2005 Chevy Cobalt	Epsilon2005	H3, 50% M	H3, 50% M	-	Center	-	Center	D	Yes
5468	2006 Pontiac Grand Prix	SDMDW2003	H3, 50% M	H3, 50% M	Forward	Center	Forward	Center	D/ND	Yes
5547	2006 Chevrolet Impala	SDMC2006	H3, 50% M	H3, 50% M	-	Center	-	Center	D	Yes
5567	2006 Hummer H3	SDMDS2005	H3, 50% M	H3, 50% M	Rearward	Center	Rearward	Center	D	Yes
5569	2006 Cadillac DTS	SDMC2006	H3, 50% M	H3, 50% M	-	Center	Rearward	Center	D	Yes
5578	2006 Chevrolet Monte Carlo	SDMC2006	H3, 50% M	H3, 50% M	-	Center	-	Center	D	Yes
5589	2006 Buick Lucerne CX	SDMC2006	H3, 50% M	H3, 50% M	-	Center	Rearward	Center	D	Yes
5597	2006 Chevrolet Colorado	SDMGF2002	H3, 50% M	H3, 50% M	-	Center	Rearward	Center	D/ND	Yes
5602	2006 Chevrolet HHR	Epsilon2006	H3, 50% M	H3, 50% M	-	Center	-	Center	D	Yes

Test Num	Vehicle Description	EDR Model	Driver Dummy Type	Passenger Dummy type	Driver Seat position (EDR)	Driver Seat Position (Database)	Passenger Seat position (EDR)	Passenger Seat Position (Database)	Events Recorded (D/ND)	Event Record Complete
5603	2006 Chevy Colorado	SDMGF2002	H3, 50% M	H3, 50% M	-	Center	Rearward	Center	D/ND	Yes
5741	2006 Buick Lucerne	SDMC2006	H3, 50% M	H3, 50% M	-	Center	Rearward	Center	D	Yes
5830	2006 Pontiac G6	Epsilon2006	H3, 5% F	H3, 5% F	-	Forward	-	Forward	D	Yes
5844	2007 Saturn Aura	Epsilon2006	H3, 50% M	H3, 50% M	-	Center	-	Center	D	Yes
5859	2007 Pontiac Solstice	Epsilon2006	H3, 50% M	H3, 50% M	-	Center	-	Center	D	Yes
5877	2007 Chevrolet Silverado	SDMC2006	H3, 50% M	H3, 50% M	Rearward	Center	-	Center	D	Yes
5907	2007 Chevrolet Silverado	SDMC2006	H3, 50% M	H3, 50% M	Rearward	Center	-	Center	D	Yes
5967	2007 Jeep Patriot	CHRY0154	H3, 50% M	H3, 50% M	-	Center	-	Center	-	Valid
6172	2008 Dodge Caravan	CHRY0303C	H3, 50% M	H3, 50% M	-	Center	-	Center	-	Valid
6200	2008 Saturn Vue	SDMC2008V	H3, 50% M	H3, 50% M	-	Center	-	Center	D	Yes
6234	2008 Dodge Dakota	CHRY0303	H3, 50% M	H3, 50% M	-	Center	-	Center	-	-
6243	2008 Ford Focus	Ford_AB9	H3, 50% M	H3, 50% M	Not Forward	Center	-	Center	D	Yes
6245	2008 Ford Focus coupe	Ford_AB9	SID, 50% M H3 HN	No Passenger	Not Forward	Center	-	-	D	Yes
6246	2008 Ford Focus	Ford_AB9	SID, 50% M H3 HN	No Passenger	Not Forward	Center	-	-	D	Yes
6256	2008 Ford Focus	Ford_AB9	H3, 50% M	H3, 50% M	Not Forward	Center	-	Center	D	Yes
6268	2008 Chevrolet Malibu	Epsilon2006	H3, 50% M	H3, 50% M	-	Center	-	Center	D	Yes
6269	2008 Ford Focus	Ford_AB9	SID, 50% M H3 HN	No Passenger	Not Forward	Center	-	-	D	Yes
6270	2008 Ford Focus coupe	Ford_AB9	SID, 50% M H3 HN	No Passenger	Not Forward	Center	-	-	D	Yes
6271	2008 Cadillac CTS	SDMCG_DELPHI	H3, 50% M	H3, 50% M	-	Center	Rearward	Non-Adj.	D	Yes
6274	2008 Dodge Caravan	CHRY0303C	EUROSID, 50% M	No Passenger	-	Center	-	-	-	-
6298	2008 Saturn Outlook	SDMC2006	H3, 50% M	No Passenger	-	Forward	-	-	D	Yes

Test Num	Vehicle Description	EDR Model	Driver Dummy Type	Passenger Dummy type	Driver Seat position (EDR)	Driver Seat Position (Database)	Passenger Seat position (EDR)	Passenger Seat Position (Database)	Events Recorded (D/ND)	Event Record Complete
6321	2008 Saturn Outlook	SDMC2006	H3, 50% M	No Passenger	-	Rearward	-	-	D	Yes
CEF0107	2001 Chevrolet Silverado	SDMG2000	H3, 50% M	No Passenger	-	N/A	-	N/A	D/ND	-
CEF0119	2002 Chevrolet Trailblazer	SDMGT2002	H3, 50% M	No Passenger	-	N/A	-	N/A	D/ND	Yes
CEF0209	2003 Cadillac CTS	SDMGF2002	H3, 50% M	No Passenger	-	N/A	-	N/A	D/ND	Yes
CEF0221	2003 Cadillac CTS	SDMGF2002	H3, 50% M	No Passenger	-	N/A	-	N/A	D-DL	Yes
CEF0301	2003 Lincoln Towncar	3W1A	H3, 50% M	No Passenger	-	N/A	-	N/A	D	-
CEF0313	2003 Lincoln Towncar	3W1A	H3, 50% M	No Passenger	-	N/A	-	N/A	D	-
CEF0326	2004 Cadillac SRX	SDMGF2002	H3, 50% M	No Passenger	-	N/A	-	N/A	D/ND	Yes
CEF0401	2004 Chevrolet Malibu	N/A	-	-	-	-	-	-	-	-
CEF0406	2004 Chevrolet Malibu	N/A	H3, 50% M	No Passenger	-	N/A	-	N/A	-	-
CEF0419	2005 Saturn ION	N/A	H3, 50% M	No Passenger	-	N/A	-	N/A	-	-
CEF0506	2005 Chevrolet Colorado	N/A	H3, 50% M	No Passenger	-	N/A	-	N/A	D/ND	Yes
CEF0511	2005 Buick LaCrosse	N/A	H3, 50% M	No Passenger	-	N/A	-	N/A	D/ND	Yes
CF05003	2004 Chevrolet Malibu	Epsilon	H3, 50% M	H3, 50% M	-	N/A	-	N/A	D/ND	Yes

2.9 Conclusions

2.9.1 Accuracy of EDR delta-V

This report has presented the method used to determine the accuracy of 107 EDRs from MY 1997 – 2008 vehicles which were subjected to NHTSA frontal and side impact tests and IIHS frontal offset and pole tests. In each case the EDRs were compared with data collected during the corresponding NHTSA and IIHS crash tests in their respective databases. Our findings are as follows:

- An automated method was developed to time shift the EDR data to match crash test measurements for each test.
- For those cases in which the EDRs recorded the entire crash pulse, the EDR maximum delta-V recorded by the EDR had an average error of only 4.5% for frontal impacts. The EDRs in side impacts exhibited a much higher error of 35.2%.
- For all EDRs, where the delta-V at 100ms was recorded by the EDR, the average error for frontal impacts was 5.2%. In side impacts, the longitudinal component of delta-V at 100 ms was in error 52.1% on average.
- Insufficient recording duration continues to be a problem for EDRs. 52 out of the 107 EDRs in the combined dataset did not record the entire event. This is worse than recorded by Gabler et al. (2008) however; this may be due to differences in how crash pulse length was estimated in the two studies.
- The newer EDR models, MY 2006 and newer, are significantly better at predicting maximum delta-V, delta-V at 100ms and crash pulse length.

2.9.2 Accuracy of Seat Belt Buckle Status

From this analysis we can conclude the following:

For GM Vehicles:

- For GM cases where the EDR "event record complete" status was complete and a driver belt buckle status was reported, the EDRs were correct 100% of the time.
- Right front passenger seatbelt status is a relatively new feature of the GM EDRs, with first recordings seen in model year (MY) 2002 EDRs. Some MY 2002 EDRs record all right front passenger seatbelt status' (EDR modules SDMD2002), while others record the belt status intermittently (SDMGF2002) and still others do not record belt status at all (SDMGT2002). MY 2002 EDRs, which recorded EDR status 100% of the time, were inaccurate more than half of the times recorded.
- Modules with a model year newer than 2006 (15 of the 107 cases) were accurate 100% of the time in recording right front passenger seatbelt status.
- When a GM EDR fails to accurately report the seatbelt status of a driver or passenger, the EDR always recorded the status as unbuckled.
- When a right front passenger is not present some GM EDRs reported the seatbelt status as "unbuckled". These modules included SDMDW2003 and SDMC2006. In other tests where no passenger was present, the EDR recorded nothing for the seatbelt status. Whether this blank recording was done intentionally is not known.

For EDRs in Ford Vehicles:

- Ford EDRs, have 100% accuracy when they recorded the driver and/or passenger seatbelt status.

- When there is no right front passenger present, the Ford EDR module types 3W1A and Ford_AB9 reported the belt buckle status as “unbuckled”. However, we cannot conclude that this trend is consistent through all Ford EDRs.
- In order to draw better conclusions, a larger Ford dataset should be acquired.

For EDRs in Toyota Vehicles:

- Toyota EDRs do not provide an “events recorded” field, but all 18 did finish recording the event in question.
- All 18 Toyota EDRs in the dataset accurately recorded driver seat belt status.
- All 18 Toyota EDRs also recorded right front passenger seatbelt status correctly.

For EDRs in Chrysler Vehicles:

- Chrysler EDRs did not record an “events recorded” data element, and 2 of the 4 EDRs also did not report if the recording of the event had finished.
- Chrysler EDRs did not provide a seat belt status for driver or right front passenger.

2.9.3 Accuracy of the Recorded Pre Impact Speed

From this analysis we can conclude:

For GM EDRs

- The majority of GM EDRs, 66 out of the possible 72, reported pre impact velocity within 2mph of the actual value.
- Of the module types where 5 or more were present in this dataset, module SDMC2006 was the most accurate with an average error of 0.12 mph
- The average underestimation by the GM EDRs was -2.57 mph, while the average overestimation of the velocity was 5.03 mph.

For Ford EDRs

- Ford EDRs accurately measured pre impact velocity in 5 out of the 9 tests in this database where pre impact velocity was reported by the EDR.
- 2 of the remaining 4 EDRs underestimated pre impact velocity by -.3 mph and the other 2 over estimated it by .5 mph
- A comparison could not be performed on the ARM481+ and 3W1A modules because of lack of data about pre impact velocity provided from the EDR.
- The most commonly occurring EDR module in the dataset, Ford_AB9 had an average error of only -.1mph

For Toyota EDRs

- Toyota EDRs only reported pre-impact velocity for 6 of the 18 EDRs, with the rest giving a value of 0mph.
- Of the 6 reported pre-impact velocities, 4 were 0.0 mph corresponding to side impact collisions.
- Toyota EDRs were the worst at predicting pre-impact velocity with an average error of -22.07mph
- The average underestimation for a Toyota EDR was -30.64 mph compared to 1mph of average overestimation.

For Chrysler EDRs

- All 4 Chrysler EDRs reported a pre-impact velocity
- The Chrysler EDRs had an average error of only -.15mph.

- The most commonly occurring Chrysler EDR, module CHRY0303C, had an average error of only .05mph

2.9.4 Accuracy of the Recorded Airbag Deployment Status

From the analysis we can conclude:

For GM EDRs

- 65 out of the 67 EDRs accurately recorded airbag deployment status of the driver and right front passenger.
- The EDR for NHTSA test 4259, module type SDMGF2002, reported only a non-deployment event when in actuality, the driver and right front passenger airbags deployed. This may have been the result of the event being overwritten.
- Test 4777 was a side impact test in which the side airbags deployed but the frontal ones did not. The EDR, module SDMGT2001 reported this event as a non deployment. This could be because of the age of the EDR which would explain its inability to determine side airbag deployment.

For Ford EDRs

- All of the 13 EDRs in this dataset accurately reported airbag deployment.
- Some Ford EDRs, module Ford_AB9, are able to distinguish between front and side deployment.
- There were no tests in this dataset which resulted in a non-deployment. Therefore it is impossible to determine accuracy of Ford EDRs in non-deployment cases.

For Toyota EDRs

- All Toyota EDRs were accurate at reporting air bag deployment for both deployment and non deployment scenarios.

For Chrysler EDRs

- Chrysler EDRs did not provide an airbag deployment status for any of the tests.
- There were configuration statuses dealing with left/right curtains and passenger airbag disable switches, however no indication of actual deployment was recorded.

2.9.5 Accuracy of the Recorded Seat Position

Seat position is a newer data element in EDRs. This data element was recorded for only 36 of the 107 drivers, and 27 right front passengers in our dataset. EDRs did not provide a quantitative measure of seat position. Seat position was aggregated into either “forward” or not forward. The boundary between “forward” and not forward could not be determined in this analysis. The boundary may vary from automaker by automaker, and vehicle model to model.

The EDR seat position was a useful indicator of occupant size. EDRs reported seat position of 5% Hybrid III females as “forward” in every case that seat position was recorded for this smaller occupant size. Surprisingly, the seat position for approximately 20% (11 of the 57) of larger dummies, i.e. 50-percentile and 95-percentile male dummies, were also reported as “forward”. The remainder of the larger dummies were reported as not forward, i.e., “normal” (1 case), “not forward” (8 cases) or “rearward” (27 cases).

3. ACCURACY OF SEAT BELT USAGE IN NASS-CDS

3.1 Introduction

In this chapter, EDR data are used to determine the accuracy of the seat belt status reported by the NASS-CDS investigators and police officers. Several studies have used NASS-CDS seat belt status as the "gold standard" against which police reported belt use had been compared (Moore et al. 2009; Schiff and Cummings, 2004; Viano and Parenteau 2009) . EDR data provides an independent way to check the accuracy of NASS-CDS investigators seat belt usage reporting.

Many factors may contribute to the determination of seat belt usage by NASS-CDS investigators and police. These include human factors such as gender, race and age as well as crash factors such as crash severity and vehicle type. In this study we limit the investigation to factors which may lead to physical evidence of belt usage.

Figure 36 shows the percentage of drivers who were buckled during a crash according to the NASS-CDS investigators. Belt use according to NASS-CDS has risen since 1993, from 57% to 82%.

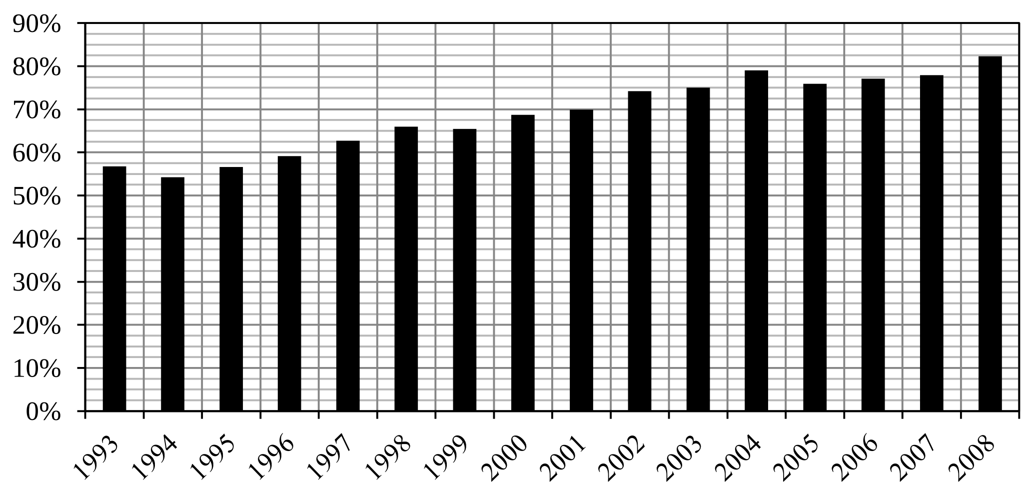

Figure 36. % Belt usage among Drivers according to NASS-CDS

3.2 Objective

The objective of this chapter is to determine the reporting accuracy of seat belt usage by NASS-CDS investigators and explain why these inaccuracies may have occurred. The accuracy of belt usage reported by police officers will also be discussed.

3.3 Methodology

Virginia Tech has a dataset of EDR records downloaded as part of NASS-CDS investigated crashes. These EDRs include 232 Ford and 3685 GM models from 2000 thru 2008. These EDRs were downloaded, by NASS-CDS investigators, directly from the vehicle using either the vehicle's On Board Diagnostics II (OBD-II) port, or direct connection to the EDR using the Bosch CDR system.

3.3.1 Case Selection

Only GM Vehicles from 2000-2008 NASS-CDS cases were analyzed for this study because they provided the largest dataset to work with and also, of the Ford module types available, none were included in the accuracy analysis in Chapter 2. The total dataset of GM EDRs included 3685 modules.

This dataset was further restricted by including only EDRS which were involved in a deployment event. EDRs with non-deployment events only were excluded because the data files for non-deployment events are overwritten with each event. There is no way to determine if the non-deployment event which is currently on the EDR is the same event which caused the crash. Deployment events are locked in the EDR. Only EDRs which included a data element for driver's seat belt status were included; bringing the number of usable cases to 1740. Only EDRs with a status of "yes" for event recording complete were included.

In Chapter 2 of this thesis, we compared EDRs to instrumented crash tests to determine the accuracy of the individual EDR module types. Because of our findings, the EDRs in this analysis were restricted to include only modules which were found to be accurate in Chapter 2. And finally, in order to be included, the vehicles corresponding to the NASS-CDS case had to be fully investigated in order to provide a NASS-CDS investigator and police officer seat belt status report. Some vehicles may not have been located, full permission may not have been granted by the owner, or the vehicle may not have been of interest to the NASS-CDS investigators. Therefore some vehicle investigations were not complete.

There were a total of 359 NASS-CDS cases with vehicle and corresponding EDR information that could be analyzed in this section and the breakdown by number of EDR modules for each of the acceptance parameters can be seen in Table 33.

Table 33. Number of NASS-CDS Case-Vehicles

EDR Module	EDRs with Crash Test Validation	Number of EDRs	EDRS with Driver Seat Belt Status and Deployment	EDRs also with Event Record Complete	Module Type Validated against Crash Test Data	EDR Validated and NASS-CDS Investigated
Epsilon		4				
Epsilon2005	X	36	13	13	13	12
Epsilon2006	X	51	28	28	28	25
SDMA		56	33			
SDMB		30	16			
SDMC2006	X	16	10	10	10	10
SDMCG_DELPHI	X	1				
SDMCL21997		8	2	2		
SDMCL21999		32	15	14		
SDMD2002	X	40	16	16	16	16
SDMDC2007		1				
SDMDG2001		4	4			
SDMDG2002	X	27	10	10	10	9
SDMDS2005	X	17	2	2	2	2
SDMDW2003	X	147	66	66	66	63
SDME		7	3			
SDMG1999		97	43			
SDMG1999N		1	1			
SDMG2000	X	693	305			
SDMG2000S		34	18	9		
SDMG2001	X	823	388			
SDMGF2002	X	295	124	124	124	116
SDMGS		8	3			
SDMGT2001	X	221	92	92	92	91

EDR Module	EDRs with Crash Test Validation	Number of EDRs	EDRS with Driver Seat Belt Status and Deployment	EDRs also with Event Record Complete	Module Type Validated against Crash Test Data	EDR Validated and NASS-CDS Investigated
SDMGT2002	X	112	15	15	15	15
SDMI		5	4			
SDMR		100	64			
SDMRSDD		802	465			
SDMS		3	2			
SDMU		14	3			
Total		3685	1740	401	376	359

Evaluation of the Dataset

Each year, approximately 5000 NASS-CDS cases involving one or more vehicles are investigated. From 2000-2008 there were over 22,000 GM vehicles involved in an investigated case. However, over the same period of time we have only 3685 GM EDRs. Some of the GM vehicles in the NASS-CDS database did not have readable EDRs and many of the GM vehicles may not have been fully investigated, but some vehicles could not be included in this dataset because the NASS-CDS investigators did not read the EDR at all. In order to determine the number of missing cases, the restraints used to determine our dataset were applied to all NASS-CDS cases. All vehicles whose make and model year corresponded to validated EDR module were included in this analysis. An index of EDR module type corresponding to individual GM vehicle make and model year is included in the appendixes.

904 GM vehicles, corresponding to accurate and readable EDRs, were found in the NASS-CDS database. These vehicles were fully investigated, and were involved in a collision that caused the airbags to deploy. 545 vehicles, or 60%, of all GM vehicles which could have been included in our dataset could not be used because the EDR was not collected.

3.3.2 Composition of the Dataset

After the EDRs were matched with their corresponding NASS-CDS case-vehicle, information on the speed of the crash, vehicle type, and crash mode (i.e. frontal, side, rear impact) was collected. Details about the driver, including maximum injury severity and driver weight, were also collected. The pretensioner presence was also collected using the Holmatro (2007) “The Researchers Guide to Vehicle Safety Systems” book. For these vehicles, the presence of a pretensioner implies that the pretensioner is standard equipment for that vehicle and model year. A table providing pretensioner availability by vehicle make, model and model year is included in the appendixes. NASS-CDS also provides a data element corresponding to how belt use was determined for each vehicle. The two options are vehicle inspection or driver/occupant interview. This belt usage source was also collected for each vehicle in the dataset. Table 34 shows all of the parameters collected from the NASS-CDS cases. The seat belt status for the driver, reported by both NASS-CDS investigators and the responding police officer, were also collected.

Table 34. Table of All NASS-CDS Cases Crash Parameters

NASS-CDR Cases		
Total		359
Crash Parameters		
Total delta-V(km/hr)		
	0-20	92
	21-40	156
	41-60	18
	60+	6
	Unknown	87
Crash Mode		
	Frontal	300
	Left Side	26
	Right Side	20
	Rear	0
	Undercarriage	3
	Top	8
	Unknown	2
Rollover		
	Rollover	31
	No Rollover	327
	Unknown	1
NASS-CDS Belt Status		
	Buckled	282
	Unbuckled	76
	Unknown	1
Police Belt Status		
	Buckled	312
	Unbuckled	29
	Unknown	18
Belt Usage Source		
	Vehicle Inspection	354
	Dr/Occ. Interview	5
Vehicle Type		
	Car	184
	Van	24
	SUV	77
	Pickup Truck	73
	Unknown	1
Pretensioner Present		
	Yes	125
	No	232
	Unknown	2
Driver Parameters		
Driver's Weight (kg)		
	0-50	37
	51-66	61
	67-82	79
	83-97	95
	98+	63
	Unknown	24
MAIS		
	AIS 6	3
	AIS 5	3
	AIS 4	12
	AIS 3	26
	AIS 2	45
	AIS 1	177
	AIS 0	76
	Unknown if Injured	3
	AIS 7	14

Comparisons between the NASS-CDS, police, and EDR reported driver seat belt statuses were conducted to determine the accuracy of both the NASS-CDS investigators and police. Variations in accuracy were determined between the crash and driver parameters listed above, as well as by NASS-CDS Primary Sampling Unit (PSU). PSUs are the NASS-CDS individual investigation teams.

3.4 Results and Discussion

3.4.1 Accuracy of NASS-CDS Investigators

Table 35 shows the overall accuracy of the NASS-CDS investigators seat belt status reporting versus what was reported by the EDR. There were 254 cases for which the EDR reported the driver seat belt status as buckled, and 105 where the status was reported as unbuckled. When the EDR driver seat belt status was buckled, the NASS-CDS investigators were accurate in all but 1.2% of cases (3 cases out of the 254). When the EDR reported the driver seat belt status as unbuckled, NASS-CDS accuracy decreased significantly. Of the 105 EDR unbuckled cases, NASS-CDS reported seat belt status incorrectly for 31 cases (29.5%) and could not determine belt status in one other case. Overall NASS-CDS seat belt reporting error rate was 9.5% (34 of the 359 case dataset) which is considerably different than the 0% error rate that NASS-CDS investigators have previously been assumed to have.

Table 35. Overall Accuracy of NASS-CDS Investigators

		EDR		
		Buckled	Unbuckled	**Total**
NASS-CDS Investigator	Buckled	251	31	282
	Unbuckled	3	73	76
	Unknown	0	1	1
	Total	254	105	359

In 2008, NASS-CDS investigators estimated that a total of 82.3% of vehicle drivers were wearing their seatbelts during the collision. After correcting for our findings when compared to the EDR, we believe that a more accurate belt usage percentage, for vehicle drivers involved in a crash, would be around 72.6%. This is about 11.5% different than the seat belt usage rate of all drivers, 84%, reported by NHTSA (2009). Our results suggest that drivers who get into car crashes are less likely to be buckled than all drivers.

Accuracy of NASS-CDS Investigators by Parameter

Table 36 contains the breakdown of NASS-CDS data set by individual accuracies of the NASS-CDS investigators for the investigated parameters. Figure 37 and Figure 38 show the driver's weight and delta-V breakdown by cumulative frequency. There were only 3 parameters which seemed to affect NASS-CDS investigator accuracy; a delta-V less than 20 km/hr, a rollover event and the presence of a pretensioner.

92 of the 359, (25.6%) cases in the dataset in cases had a delta-V of less than 20 km/hr (12.4mph). The NASS-CDS investigators incorrectly reported driver seat belt status for 17 of the 92 cases. In 15 of these 17 cases, the investigator stated that the driver was buckled when according to the EDR they were buckled. Lower delta-V cases may lead to more investigator error due to the lower forces produced during these crashes. In a crash with lower forces, the belt usage indicators discussed in Chapter 1 may be unnoticeable and therefore belt use would be harder to determine.

There were 31 rollover events reported in this 359 case dataset. For all 31, NASS-CDS investigators accurately reported seat belt status. This is probably due to the significant amount of force involved in a rollover. The force would make seat belt use easily apparent.

125 of the 359 case vehicles (about 35%) had a pretensioner installed as standard equipment. Of these 125 cases, only 4 were wrongly reported. In all 4 of these cases, the investigator reported the seat belt as buckled when the EDR said that it was not. In some, less severe, crashes the pretensioner may not fire allowing the belt to lengthen and retract normally. If these 4 cases were minor in severity then the pretensioner's presence may not help the

investigator determine seat belt usage. Of the 34 wrongly reported NASS-CDS investigator cases, 29 occurred when no pretensioner was present and 1 occurred when the pretensioner presence was unknown.

Interestingly, a belt usage source corresponding to a driver or occupant interview does not seem to be analogous with NASS-CDS investigator inaccuracy. In all 5 (out of 359) cases in this dataset where an interview was performed instead of a physical examination of a vehicle, the investigator correctly reported driver seat belt status. This may be due to the fact that the driver does not fear repercussion from an NASS-CDS investigator, and are therefore more likely to be truthful about their seat belt usage.

Table 36. NASS-CDS Investigator Seat Belt Reporting Accuracy by Crash & Driver Parameters

EDR Belt Status		BUCKLED		UNBUCKLED		
NASS-CDS		Buckled	Unbuckled	Unbuckled	Buckled	Unknown
		n=251	n=3	n=73	n=31	n=1
Total delta-V (km/hr)	0-20	63	2	12	15	0
	21-40	118	0	25	12	1
	41-60	15	0	3	0	0
	60+	3	0	3	0	0
	Unknown	52	1	30	4	0
Rollover	Rollover	19	0	12	0	0
	No Rollover	232	3	61	30	1
	Unknown	0	0	0	1	0
Crash Mode	Unknown	2	0	0	0	0
	Front	202	3	66	28	1
	Left	23	0	1	2	0
	Right	17	0	2	1	0
	Top	4	0	4	0	0
	Undercarriage	3	0	0	0	0
Driver Weight (kg)	0-50	27	2	7	1	0
	51-66	50	0	7	4	1
	67-82	58	1	11	9	0
	83-97	59	0	27	9	0
	98+	39	0	16	7	0
	Unknown	18	0	5	1	0
MAIS	AIS 6	2	0	1	0	0
	AIS 5	1	0	2	0	0
	AIS 4	7	1	4	0	0
	AIS 3	16	0	10	0	0
	AIS 2	21	0	19	4	1
	AIS 1	134	2	24	17	0
	AIS 7	6	0	7	1	0
	Unknown	3	0	0	0	0
	AIS 0	61	0	6	9	0

EDR Belt Status		BUCKLED		UNBUCKLED		
NASS-CDS		Buckled	Unbuckled	Unbuckled	Buckled	Unknown
		n=251	n=3	n=73	n=31	n=1
Vehicle Type	Car	133	2	35	14	0
	Van	20	0	4	0	0
	SUV	54	1	15	6	1
	Pickup Truck	44	0	19	10	0
Pretensioner Present	Yes	90	0	31	4	0
	No	160	3	42	26	1
	Unknown	1	0	0	1	0
Belt Usage Source	Vehicle Inspect.	248	3	71	31	1
	Dr/Occ. Interview	3	0	2	0	0

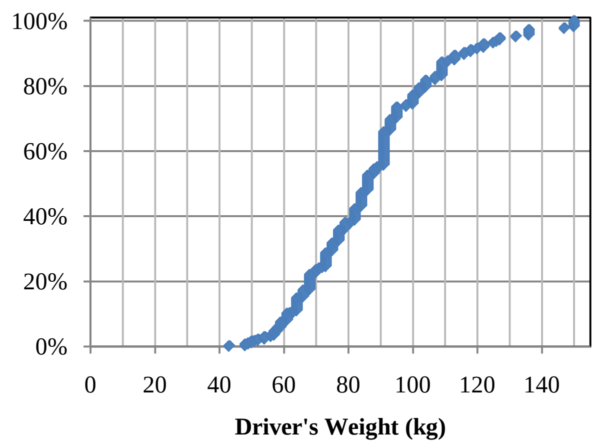

Figure 37. Cumulative Frequency of Driver's Weight in the Dataset

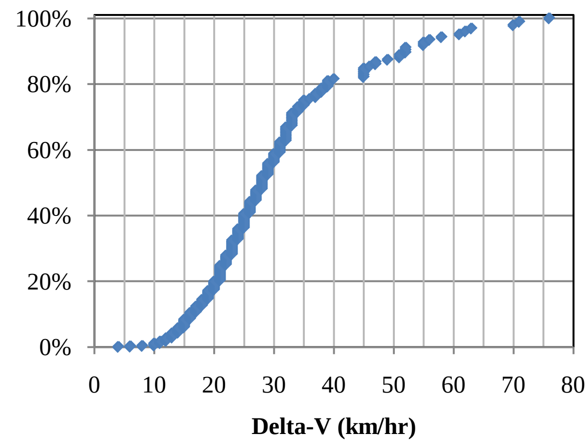

Figure 38. Cumulative Frequency of delta-V crashes

3.4.2 Accuracy of Police Officers

Table 37 represents the overall accuracy of police officers when compared to the EDRs. Police officers were less accurate than NASS-CDS investigators. Police an overall error rate of 21.7% (263 cases correct out of the 359 case dataset) compared to the 9.5% reported for NASS-CDS. When the EDR stated that the driver's belt buckle status was buckled, police were inaccurate or unable to determine belt status for 5.5% of the cases, which is similar to the NASS-CDS investigators error rate of 1.2%, however police perform much worse when the EDR seat belt status is unbuckled. They were incorrect or unable to determine belt status for 82 of the possible 105 cases, resulting in an error rate of 78.1% compared to the 29.5% reported by NASS-CDS.

Table 37. Overall Accuracy of Police Officers

		EDR		
		Buckled	Unbuckled	**Total**
Police	Buckled	240	72	312
	Unbuckled	6	23	29
	Unknown	8	10	18
	Total	254	105	359

Moore et al. (2009) found that police incorrectly report restrained occupants 3% of the time when compared against the NASS-CDS data. This is similar to the 4.3% error rate difference between our findings for NASS-CDS and police officer belt reporting of seat belt status for buckled drivers. They also found a police error rate of 36% when the vehicle occupant was unbuckled (Moore et al., 2009). This is similar to the error rate difference of 48.6% calculated for unbuckled drivers in this report. Schiff and Cummings (2004) reported an overall police error when the occupant was unbuckled of 30.9%. An error of 4.2% was calculated for buckled occupants. These numbers are similar to those found by Moore et al. (2009) and found in this study. Viano and Parenteau (2009), reported an overall difference between NASS-CDS investigators and police to be around 7.8%. This is again similar to the difference in the overall error rates, 12.2%, found in this study.

Accuracy of Police by Parameter

The accuracy of driver seat belt status reported by police was also broken down by the crash and driver parameters listed above as shown in

Table 39. A delta-V of less than 20 km/hr (12.4mph) was found to be a factor of many incorrectly reported police cases. 27 of the 92 cases with a delta-V less than 20 km/hr were reported incorrectly by police. In 24 of these cases, the officer reported the belt as buckled when the EDR reported the status as unbuckled. Lower delta-V crashes were significantly less severe and resulted in fewer injuries. If the police relied on interviewing the driver about seat belt status, instead of physical evidence, the driver may have been inclined to misrepresent their seat belt status.

When the vehicle was involved in a frontal collision, the police officers were also more likely to incorrectly report driver's seat belt status. They were incorrect for 73 of the 300 frontal crashes. Frontal impacts were present in 84% of all cases which the officer wrongly reported seat belt status. While the delta-V of the 300 frontal crashes was not significantly different than the other crash modes, a significant number of drivers involved in these crashes were uninjured or suffered only minor injuries. This could contribute to the inaccuracy of police officers because it is easier for uninjured drivers to not tell the truth about their seat belt use.

Table 38. Average delta-V and Injury equal to AIS 0 or 1 by Crash type

Crash Mode	**Avg. delta-V (km/hr)**	**%AIS=0 or 1**
Frontal	25.7	72.7%
Left	29.3	53.8%
Right	23.5	70.0%
Top	Unknown	37.5%
Undercarriage	Unknown	66.7%
Unknown	15	100.0%

Table 39. Police Seat Belt Reporting Accuracy by Crash & Driver Parameters

EDR Belt Status		BUCKLED			UNBUCKLED		
Police		Buckled	Unbuckled	Unknown	Unbuckled	Buckled	Unknown
		n=240	n=6	n=8	n=23	n=72	n=10
delta-V (km/hr)	0-20	59	3	3	3	24	0
	21-40	113	2	3	7	27	4
	41-60	14	0	1	1	1	1
	61+	3	0	0	0	1	2
	Unknown	51	1	1	12	19	3
Vehicle Type	Car	125	5	5	9	34	6
	Van	19	1	0	0	4	0
	SUV	54	0	1	7	13	2
	Pickup Truck	42	0	2	7	20	2
Rollover	Rollover	17	0	2	5	5	2
	No Rollover	223	6	6	18	66	8
	Unknown	0	0	0	0	1	0
Crash Mode	Unknown	2	0	0	0	0	0
	Front	192	6	7	20	67	192
	Left	22	0	1	0	3	22
	Right	17	0	0	0	2	17
	Top	4	0	0	3	0	1
	Undercarriage	3	0	0	0	0	0
Pretensioner Presence	Yes	85	4	1	6	23	6
	No	154	2	7	17	48	4
	Unknown	1	0	0	0	1	0
Driver Weight (kg)	0-50	25	1	3	2	5	1
	51-66	50	0	0	4	6	1
	67-82	56	1	2	1	18	1
	83-97	55	3	1	12	22	2
	98+	39	0	0	3	18	3
	Unknown	15	1	2	1	3	2
MAIS	AIS 6	1	0	0	1	1	0
	AIS 5	7	1	0	2	1	1
	AIS 4	15	0	1	3	4	3
	AIS 3	21	0	0	6	15	3
	AIS 2	129	3	4	7	31	3
	AIS 1	6	0	0	1	7	0
	AIS 7	3	0	0	0	0	0
	Unknown	56	2	3	2	13	0
	AIS 0	0	0	0	0	0	0

3.4.3 NASS-CDS Accuracy by Primary Sampling Unit

The primary sampling units, PSUs are the investigative groups which are responsible for the actual investigations of the vehicles involved in the crash. In this section, the accuracies of the individual PSUs were calculated.

PSU Accuracy with EDR status Buckled

There were a total of 27 PSUs investigated in this study. Figure 39 shows the accuracy of the PSUs in determining seat belt status in the 254 cases in which the EDR reported driver status as buckled. Of these cases, there were only 3 in which the PSU was incorrect. PSU 41 had the lowest accuracy when determining driver seat belt status. They were incorrect 1/4 of the time or 25% of the time (1 out of the 4 cases). However, because of the small number of cases involved, we are not sure if this is statistically significant. Most PSUs, 23 out of the 27, had an accuracy of 100%.

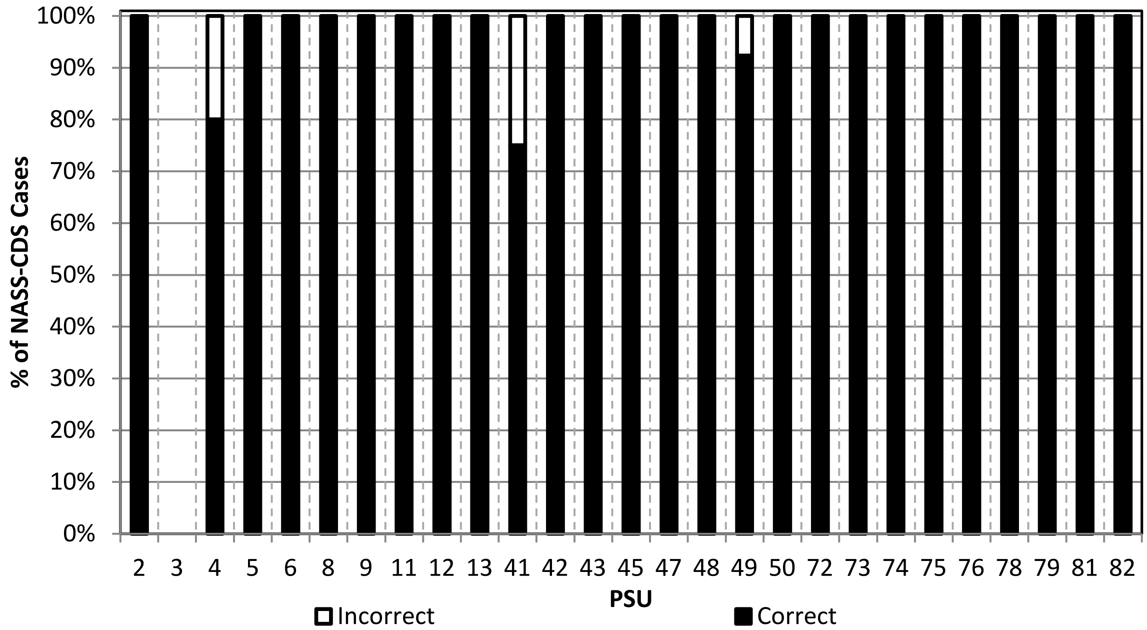

Figure 39. Seat Belt Usage Reporting Accuracy by PSU for Buckled EDR Status

PSU Accuracy with EDR status Unbuckled

Figure 40 shows the breakdown of accuracy by PSU when the EDR driver seat belt status was recorded as unbuckled. PSU error rate was much worse, 29.5%, when the seatbelt status was unbuckled. 6 of the 27 PSUs reported seat belt status incorrectly more often or the same number of times as they reported it correctly. These were PSUs 11, 13, 50, 73, 76, and 79. 13 and 79 had the lowest accuracies, reporting the driver seat belt status incorrectly 66.7% and 100% of the time respectively. The number of cases in both of these PSUs were very small. PSU 79 only had one case reported when the EDR seat belt status was unbuckled while PSU 13 had 3 cases. PSUs 2, 3, 4, 5, 42, 43, 45, 47, 49 and 72 were 100% accurate at determining driver seat belt status and there were no cases available to judge PSUs 6, 81 and 82.

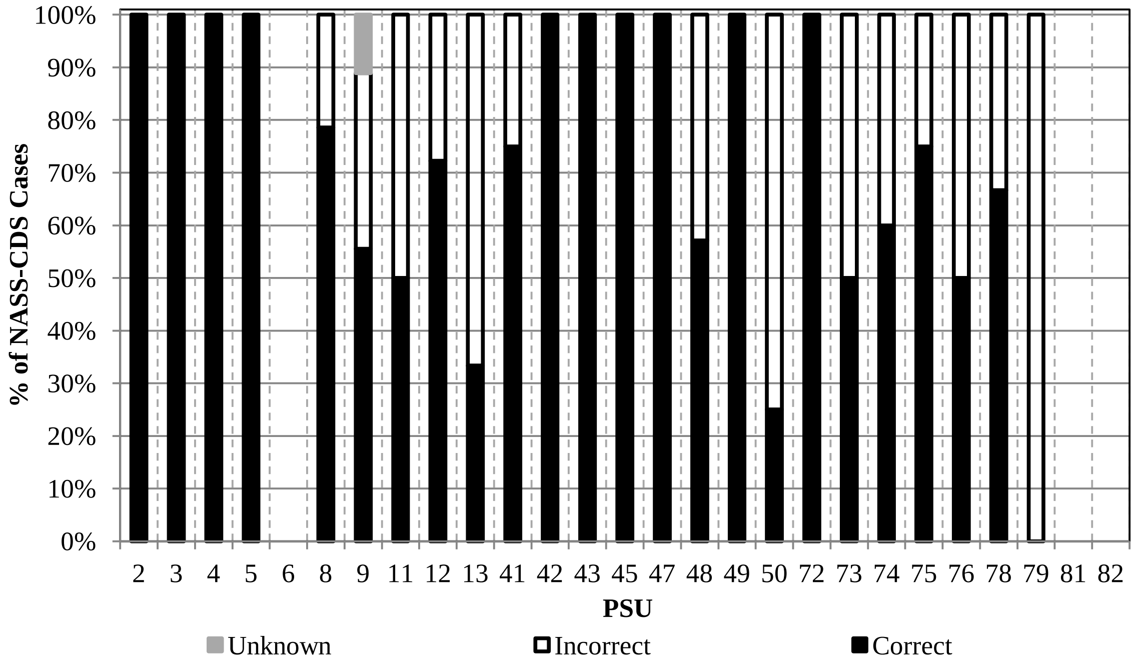

Figure 40. Seat Belt Usage Reporting Accuracy by PSU for Unbuckled EDR status

Overall PSU Accuracy

Figure 41 displays the overall accuracy of the PSUs. From this we see that PSU 9 had the lowest accuracy of 66.7% overall, while PSU 2, 3, 5, 6, 42, 43, 45, 47, 72, 81 and 82 were 100% accurate for all of their cases. About half of all of the overall accuracies were above 90%, 15 of the 27 which is about the overall average PSU accuracy rate (corresponding error rate of 9.5%).

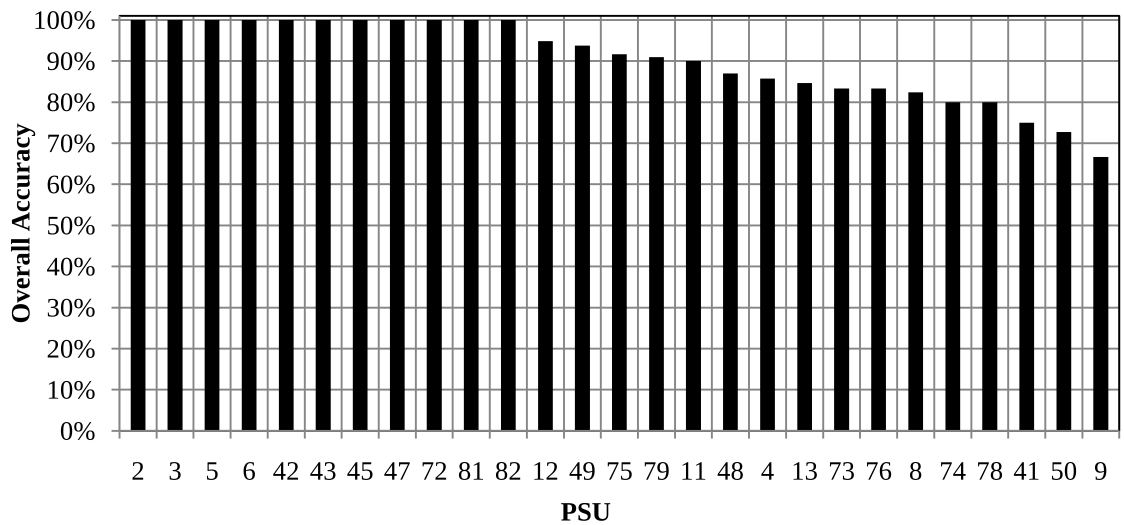

Figure 41. Overall Seat Belt Reporting Accuracy by PSU

3.5 Limitations

This study has the following limitations:

- A report of buckled produced by the EDR simply means that the latch plate was engaged with the belt buckle. This does not however mean that the seat belt was worn properly or at all.
- The dataset of EDRs chosen in Chapter 2 as accurate was relatively small. Only 1 or two EDRs of each module type were available in some situations. Therefore we cannot say conclusively that, because the few EDRs which we validated were correct, all EDRs of that module type are also correct.
- There were also EDR module types found in the NASS-CDS dataset for which we had no crash test validation data. These cases therefore could not be analyzed in this study.
- 12 NASS-CDS cases for which we had a validated EDR had no information seat belt information provided by police or NASS-CDS investigators. Therefore, these cases had to be excluded.

- This study was also limited to GM vehicles. However there are many other vehicle makes on the road which are investigated by the NASS-CDS investigators and police officers. We do not know how our results will generalize if they could be applied to other vehicle makes.
- 60% of all NASS-CDS cases which could be analyzed in this study were excluded because there was no EDR available for the vehicle. If NASS-CDS investigators were more consistent when downloading the EDR, our dataset could have been larger and better conclusions might have been drawn.

3.6 Conclusions

The objective of this chapter is to determine the reporting accuracy of seat belt usage by NASS-CDS investigators and police officers and explain why these inaccuracies may have occurred. The Following are our conclusions:

- NASS-CDS investigators had an overall reporting error rate of 9.5%. When determining driver seat belt status. Accuracy varied by belt buckle status. NASS-CDS investigators had an error rate of only 1.2% when the EDR reported the driver as buckled. Their error rate rose to 29.5% when the EDR reported the driver belt status as unbuckled.
- In 2008, NASS-CDS reported 82% buckled drivers when involved in a crash. When correcting for the NASS-CDS reporting error, we found that driver belt use may be around 72.6% when the driver is involved in a crash.
- Police were less accurate than NASS-CDS investigators when reporting driver seat belt status. When compared with EDRs, police had an overall error rate of 21.7%. When the EDR belt status was buckled, police had an error rate of

2.4% and an unknown error rate of an additional 3.1%. When the EDR belt status was unbuckled, police error rates rose to 69% and 9.5% respectively.

- Seat belt buckle status accuracy was found to be a function of delta-V for both NASS-CDS investigators and police. When the total crash delta-V was less than 20km/hr (12.4mph), 92 cases of the 359, investigators incorrectly reported 17 cases and police incorrectly reported 27. This may be due to lower forces involved in low delta-V crashes producing fewer severe injuries and less physical belt use indicators.
- Presence of a pretensioner was a factor in seat belt buckle status accuracy of NASS-CDS investigators. There were 125 out of 359 cases involving a pretensioner in the dataset. The seat belt buckle status was reported incorrectly for only 4 of these cases. It is unknown if these pretensioners fired.
- Rollover events affected NASS-CDS accuracy. Investigators reported seat belt status correctly 100% of the time.
- Frontal crashes were a factor of seat belt reporting accuracy for police officers. There were 300 frontal crashes in this dataset of 359 cases. Police were incorrect for 73%. This may be due to the fact that frontal crashes resulted in 72% AIS 1 or 0 injuries, and therefore were less severe. Belt status collected from an individual driver interview may be inaccurate.
- Accuracy of the PSUs varied greatly, with the least accurate being PSU 9 with an accuracy of 66.7% (8 correct out of 12) while PSUs 2, 3, 5, 6, 42, 43, 45, 47, 72, 81 and 82 reported 100% overall accuracy. PSUs were more accurate

when reporting driver seat belt status of buckled when the seat was buckled, 23 of 27 having accuracies of 100%.

4. EFFECT OF BELT USAGE REPORTING ERRORS ON INJURY RISK ESTIMATES

4.1 *Introduction*

In chapter 3, we determined that NASS-CDS had an overall error rate of 9.5% when determining seat belt usage rates for vehicle drivers. The majority of errors resulted from cases where the EDR stated that the driver was unbuckled while the investigator said that they were buckled. Many current injury risk estimate methods are dependent on the accuracy of NASS-CDS investigators (NHTSA, 1984; NHTSA, 2008; Viano 1995; Thor, 2008). However, these estimates may be incorrect due to the error in NASS-CDS investigator belt usage rate reporting.

4.2 *Background*

In 2008, NHTSA (2008) estimates that the 13,250 lives were saved due to the use of seat belts; bring the total number of lives saved since 1975 to 255,115. NHTSA (1984) used NASS-CDS data from 1979 to 1982 to determine injury risk for belted and unbelted vehicle occupants. They found that lap and shoulder belts could reduce fatalities by 40-50%, AIS 2-5 injuries by 45-55% and AIS 1 injuries by 10%. Viano (1995) used a double pair comparison method for crashes involving at least one fatality and one non-fatality to determine injury risk estimates. He determined that the use of seat belts reduced risk of injury in drivers by 42% with just the use of a seat belt and 47% with the combination of a seat belt and airbag. Thor (2008) used NASS- CDS cases from 1993 to 2007 to determine the effectiveness of airbags when a vehicle occupant was buckled; finding that airbags increase the risk of AIS 2 and AIS 3 injury to the thoracic cavity and AIS 2 injury to the spine anywhere from 1.1 to 7.4 times.

However, because of the errors found in Chapter 2, the actual fatality and injury risks may be drastically different depending for these studies depending on the effect of the belt reporting errors.

4.3 Objective

The objective of this chapter is to determine the effect of the NASS-CDS belt usage reporting errors on current injury risk estimates. The focus of this study will be on injury risk estimates for GM vehicle drivers involved in frontal collisions which resulted in an airbag deployment.

4.4 Approach

4.4.1 Case Selection

Total Data Set

There were 742 cases included in the total dataset. These cases were chosen using the same parameters used to obtain the Chapter 3 dataset with only one difference. This dataset included EDRs which were validated in chapter 2, but did not include a “event record complete” flag. This total Chapter 4 dataset was limited to only frontal crashes where no rollover was reported and the vehicle did not catch fire. In order to be included in this dataset, the NASS-CDS driver belt status was known. To properly weigh the dataset based on stratification and clustering of the NASS-CDS data, the mean weight of all NASS-CDS cases for the years 2000-2008 was found, and a cutoff was determine to be the mean plus 4 standard deviations (x=5519.88) of that weight. This was done to throw out any extreme outliers in the small dataset which was being used. The un-weighted dataset used in the Chapter 4 can be seen in Table 40.

Table 40. Chapter 4 Total Un-weighted Dataset

EDR Status		Buckled		Unbuckled	
NASS-CDS		Buckled	Unbuckled	Unbuckled	Buckled
		n=485	n=7	n=129	n=121
Drivers Weight (kg)	0-50	45	4	11	11
	51-66	113	-	26	29
	67-82	156	2	34	36
	83-97	107	-	35	28
	98+	64	1	23	17
MAIS	6	6	1	4	-
	5	2	-	2	1
	4	4	-	7	3
	3	22	1	26	7
	2	54	1	32	17
	1	249	3	43	60
	0	148	1	15	33
Total delta-V (kph)	0-20	138	4	20	44
	21-40	216		47	40
	41-60	27	3	11	7
	60+	10	-	5	4
	Unknown	94	-	46	26
Crash Mode	Frontal	485	7	129	121
Rollover	No Rollover	485	7	129	121
Vehicle Type	Car	300	6	80	91
	Pickup Truck	77	-	24	15
	SUV	75	1	19	11
	VAN	33	-	6	4
Belt Use Source	Vehicle Inspection	484	7	127	118
	DR/OCC Interview	1	-	2	2
	Off Injury Data	-	-	-	1

Table 41. Breakdown of Total un-weighted dataset by Buckle Status

		EDR		
		Buckled	Unbuckled	Total
NASS-CDS Investigator	Buckled	485	121	606
	Unbuckled	7	129	136
	Total	492	250	742

There were a total of 742 matched NASS-CDS to EDR cases in our database. The distribution of NASS-CDS investigators reported belt buckle status based on the EDRs belt buckle status can be seen in Table 41. The 742 cases dataset was then weighed using the NASS-CDS ratwgt field. There were a total of 223,198 cases in the total dataset when the weights were applied. The breakdown of this dataset can be seen in Table 42 and the distribution by belt buckle status is shown in Table 43.

Table 42. Weighted Total Dataset

EDR Status		Buckled		Unbuckled	
NASS-CDS		Buckled	Unbuckled	Unbuckled	Buckled
		n=145,927	n=468	n=31,827	n=44,976
Drivers Weight (kg)	0-50	21,356	434	1,962	4,445
	51-66	38,799	-	8,531	13,621
	67-82	43,412	24	7,026	13,220
	83-97	23,227	-	10,245	6,920
	98+	19,134	11	4,064	6,770
MAIS	6	462	11	158	-
	5	44	-	107	81
	4	257	-	445	201
	3	1,408	9	2,534	634
	2	7,694	103	5,696	3,005
	1	72,333	322	16,998	21,075
	0	63,728	24	5,890	19,981
Total delta-V (kph)	0-20	54,634	425	5,303	19,617
	21-40	2,386	-	11,015	15,244
	41-60	732	44	1,000	221
	60+	732	-	324	344
	Unknown	54,870	-	14,185	9,550
Crash Mode	Frontal	145,927	468	31,827	44,976
Rollover	No Rollover	145,927	468	31,827	44,976
Vehicle Type	Car	96,675	365	15,127	34,044
	Pickup Truck	11,688	-	6,831	5,199
	SUV	19,734	104	9,592	5,384
	VAN	17,830	-	278	350
Belt Use Source	Vehicle Inspection	145,793	468	31,312	43,959
	DR/OCC Interview	134	-	516	343
	Off Injury Data	-	-	-	675

Table 43. Breakdown of Total Weighted Dataset by Buckle Status

		EDR		
		Buckled	Unbuckled	Total
NASS-CDS Investigator	Buckled	145,927	44,976	190,903
	Unbuckled	468	31,827	32,295
	Total	146,395	76,803	223,198

Subset: Chapter 3 Dataset

In order to be more thorough, the Chapter 3 subset was also analyzed. Again, the cases were limited to those which were frontal crashes where there was no rollover or fire during the crash. A value for NASS-CDS investigator belt usage was also available. The weighted values of this subset can be seen in Table 44. There were a total of 78,404 cases when the weights were applied. The breakdown of the weighted subset by driver seat belt status can be seen in

Table 44. Weighted Subset from Ch 3 dataset

EDR Status		Buckled		Unbuckled	
NASS-CDS		Buckled	Unbuckled	Unbuckled	Buckled
		n=52,435	n=118	n=15,013	n=10,838
Drivers Weight (kg)	0-50	6,283	104	725	128
	51-66	16,379	-	1,002	595
	67-82	8,721	14	2,298	4,738
	83-97	13,685	-	8,410	1,231
	98+	7,367	-	2,578	4,147
MAIS	6	40	-	63	-
	5	-	-	-	-
	4	41	-	268	-
	3	805	-	845	-
	2	1,910	-	2,706	521
	1	24,063	118	7,795	5,164
	0	25,575	-	3,336	5,154
Total delta-V (kph)	0-20	22,297	118	1,930	8,379
	21-40	21,563	-	4,254	1,802
	41-60	1,535	-	182	-
	60+	369	-	187	-
	Unknown	6,671	-	8,460	658
Crash Mode	Frontal	52,435	118	15,013	10,838
Rollover	No Rollover	52,435	118	15,013	10,838
Vehicle Type	Car	28,217	14	5,747	2,127
	Pickup Truck	6,895	-	3,915	4,014
	SUV	9,707	104	5,215	4,698
	Van	7,616	-	137	-
Belt Use Source	Vehicle INSPECT	52,300	118	14,497	10,838
	DR/OCC Interview	134	-	516	-

Table 45. Breakdown of Weighted Subset by Buckle Status

		EDR		
		Buckled	Unbuckled	Total
NASS-CDS Investigator	Buckled	52,435	10,838	63,273
	Unbuckled	118	15,013	15,131
	Total	52,553	25,851	78,404

4.4.2 Data Analysis

For this analysis, injury was determined to be AIS 2 or greater, and AIS 7 injuries which were also reported as a fatality were included. All other AIS 7 injuries were not included. Weighted injury risk ratios for belted and unbelted vehicle drivers were calculated based on both the NASS-CDS investigator belt status, and the belt status reported by the EDR. The risk ratio values were graphed according to buckled and unbuckled status for each source, NASS-CDS and EDR.

Odds ratios for injury risk were also calculated for this data using the proc surveyLogistic function in SAS to form a linear regression model. In this model, occupant age and delta-V are included as continuous variables and belt status, as reported by NASS-CDS or the EDR, is included as a categorical variable (with the values of buckled or unbuckled). The unbuckled vs. buckled point estimate from these results was graphed with the 95% Wald confidence limits.

4.5 Results and Discussion

4.5.1 Risk ratios

Total Weighted Dataset

Figure 42 presents the total weighted dataset injury risk ratios for buckled vs. unbuckled drivers based on the NASS-CDS investigator buckle status and the EDR belt buckle status, weighted for stratification and clustering of the NASS-CDS data. The graph shows that, the risk of injury for belted drivers remain about the same for both NASS-CDS and EDR, 7.22% and 6.82% respectively. The injury risk for unbuckled drivers however, is lower according to the EDR seat belt status; 16.74% for EDR data versus 28.06% for NASS-CDS unbuckled belt status. This means that seat belts, according to the EDR are less effective at preventing risk, than previously thought when looking at the NASS-CDS data.

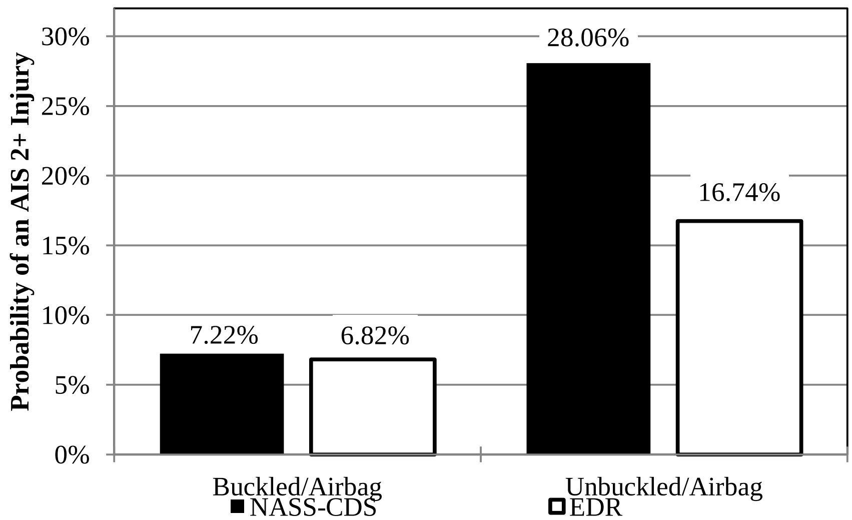

Figure 42. Total Weighted Risk of Injury based on NASS-CDS and EDR Driver Belt Status

Weighted Subset

The risk ratio for the weighted Chapter 3 subset is shown in Figure 42. The subset also shows that the risk when buckled is relatively consistent between NASS-CDS investigators and EDRs; EDR risk being 5.32% and NASS-CDS risk being 5.24%. EDR risk when unbuckled is again lower than that of the NASS-CDS investigator (17.03% vs. 25.66%). This shows that when the EDRs are proven 100% accurate, they still show a lower risk of injury, when the driver is unbuckled, than previously predicted by the NASS-CDS investigators.

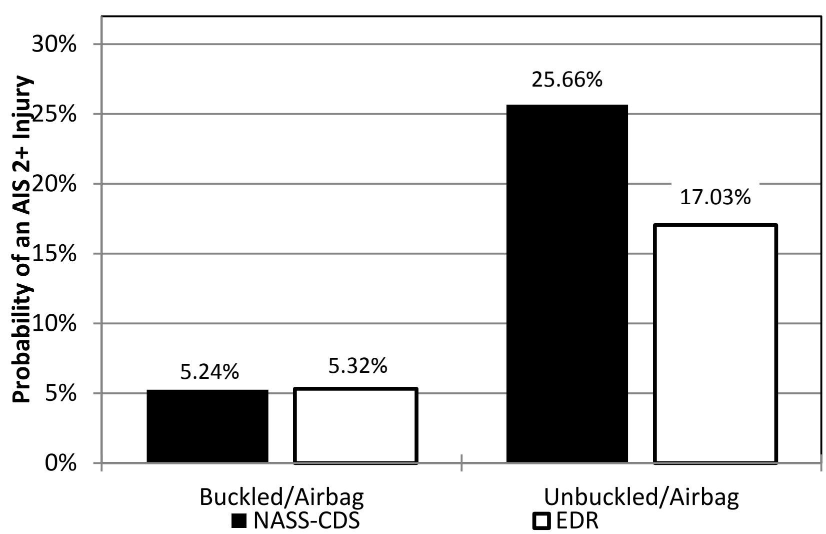

Figure 43.Weighted Subset Risk of Injury based on NASS-CDS and EDR Driver Belt Status

4.5.2 Odds Ratio

Weighted Total Dataset

Figure 44 presents the point estimate odds ratio for AIS 2+ injury for unbuckled vs. buckled vehicle drivers for the total weighted dataset. The confidence intervals are also included. From this analysis we see that the odds ratio point estimate for the EDR data is similar to that of the NASS-CDS data, after correction for age and delta-V; 2.43 versus 3.17 respectively. While the driver is still more likely to suffer an injury when unbuckled in both cases, a driver is more likely to be injured according to the NASS-CDS data. These results are not statistically significant however because of the confidence interval range.

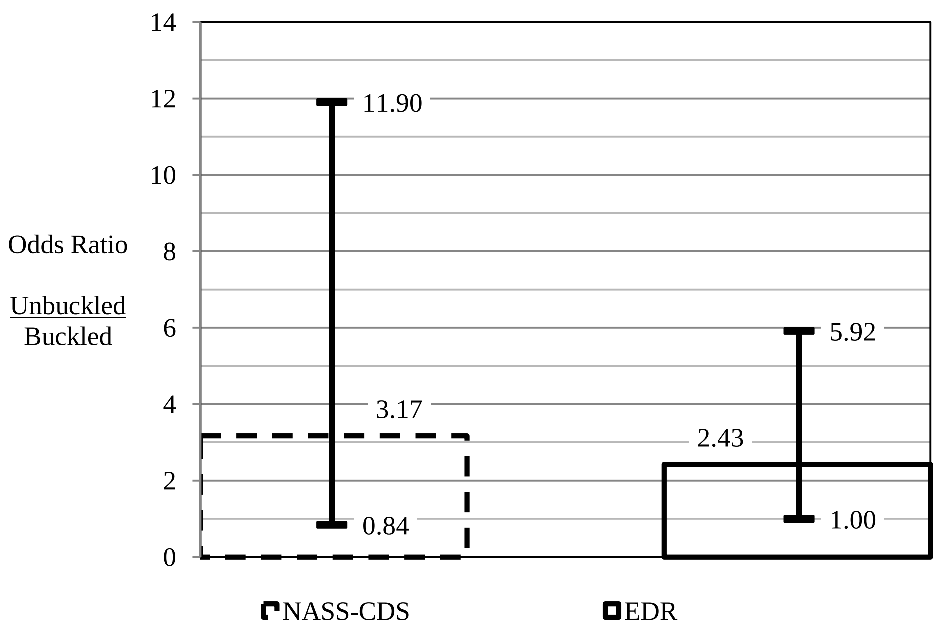

Figure 44. Total Weighted Dataset Point Estimate Odds Ratio of Unbuckled vs. Buckled Injury for NASS-CDS and EDR Belt Status

Weighted Subset

Figure 45 shows the odds ratio for the weighted subset. In the subset, the point estimate for unbuckled/ buckled injury is 8.47 for NASS-CDS investigators and 5.41 for EDRs. This again means that the risk of injury predicted by NASS-CDS investigators is still higher than the risk predicted by EDRs.

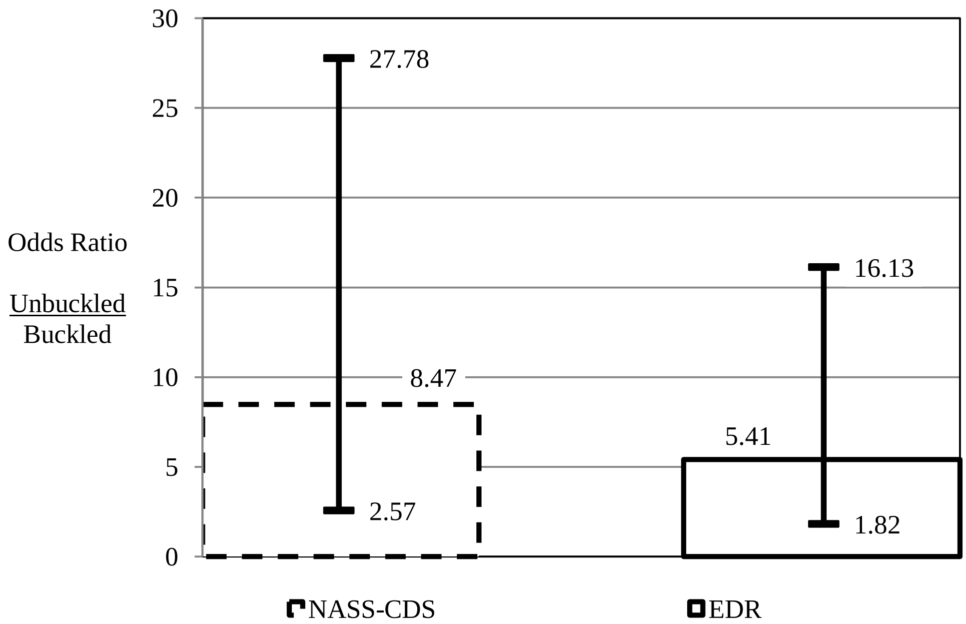

Figure 45. Weighted Subset Point Estimate Odds Ratio of Unbuckled vs. Buckled Injury for NASS-CDS and EDR Belt Status

4.6 Conclusions

The objective of this chapter was to determine the effect of the NASS-CDS belt usage reporting errors on current injury risk estimates by comparing risk ratios and odds ratios for NASS-CDS data and EDR data. Our results show that injury risk for unbuckled drivers may be overestimated by NASS-CDS investigators. This is supported by the risk ratio values of 28.06% for investigators and 16.74% for EDRs using the total weighted dataset. The subset risk ratios also show this trend with the investigator unbuckled risk ratio being 25.66% and the EDR value being 17.03%. The odds ratios point estimates for NASS-CDS investigators was also higher in both datasets; 3.17 vs. 2.43 for the total weighted dataset and 8.47 vs. 5.41 for the weighted subset. While we did see differences in the injury risk estimates according to belt buckle status for both the risk ratio and odds ratios, we were not able to conclude that either was significant. We feel that this analysis should be completed again when a larger dataset can be utilized.

5. CONCLUSIONS

The overall objective of this thesis was to determine the effect of NASS-CDS belt status reporting errors on injury risk estimates. We first validated Event Data Recorders (EDRs) against standard NHTSA and IIHS crash tests. Using the accurately validated EDR module types and model years we then compared our database of EDRs collected from NASS-CDS investigated crashes to the driver belt buckle status reported by the NASS-CDS investigators. A comparison of driver belt status reported by police to those recorded by the EDRs was also completed. Finally we developed two weighted datasets, to perform comparisons of injury risk between the NASS-CDS investigators and EDRs. The following are the conclusions from this analysis:

5.1 Accuracy of Event Data Recorders

This report has presented the method used to determine the accuracy of 107 EDRs from MY 1997 – 2008 vehicles which were subjected to NHTSA frontal and side impact tests and IIHS frontal offset and pole tests. In each case the EDRs were compared with data collected during the corresponding NHTSA and IIHS crash tests in their respective databases. The accuracy was determined for overall delta-V, seat belt status, pre-impact velocity, airbag deployment and seat position. The following are our conclusions about EDR accuracy:

5.1.1 Accuracy of EDR delta-V

Our findings are as follows:

- Insufficient recording duration continues to be a problem for EDRs. 51% (52 out of the 107 EDRs in the combined dataset) did not record the entire event. In contrast, Gabler et al. (2008) reported that 29.2% of their 48 EDR dataset did not record the entire event. This may be due to differences in how crash pulse length was estimated in the two studies.

- The newer EDR models, SDMC2006 and Epsilon2006 accurately predicted maximum delta-V by an average of -3.28% and .25% respectively. This is better than the older modules SDMGF2002 with an average error of -11.48% and SDMDW2003 with an error of -6.09%.
- EDRs accurately record delta-V in frontal impacts. For those cases in which the EDRs recorded the entire crash pulse, the EDR maximum delta-V recorded by the EDR had an average error of only 4.5% for frontal impacts. The EDRs in side impacts exhibited a much higher error of 35.2%.
- For all EDRs, where the delta-V at 100ms was recorded by the EDR, the average error for frontal impacts was 5.2%. In side impacts, the longitudinal component of delta-V at 100 ms was in error 52.1% on average.

5.1.2 Accuracy of Seat Belt Buckle Status

From this analysis we can conclude the following:

For GM Vehicles:

- EDR driver buckle status was correct for every GM case in our dataset where the EDR "event record complete" status was complete and a driver belt buckle status was reported (65 of the total 67 cases).
- EDRs correctly recorded right front passenger seatbelt status for all modules with a model year newer than 2006.
- Right front passenger seatbelt status is a relatively new feature of the GM EDRs, with first recordings seen in model year (MY) 2002 EDRs. Some MY 2002 EDRs

record all right front passenger seatbelt status' (EDR modules SDMD2002), while others record the belt status intermittently (SDMGF2002) and still others do not record belt status at all (SDMGT2002). MY 2002 EDRs, which recorded EDR status 100% of the time, were inaccurate more than half of the times recorded.

- When a GM EDR fails to accurately report the seatbelt status of a driver (1 of the 72 cases) or passenger (8 of 72), the EDR always recorded the status as unbuckled.
- When a right front passenger is not present some GM EDRs reported the seatbelt status as "unbuckled". These modules included SDMDW2003 and SDMC2006. In other tests where no passenger was present, the EDR recorded nothing for the seatbelt status. Whether this blank recording was done intentionally is not known.

For EDRs in Ford Vehicles:

- Ford EDRs, have 100% accuracy when they recorded the driver and/or passenger seatbelt status.
- When there is no right front passenger present, the Ford EDR module types 3W1A and Ford_AB9 reported the belt buckle status as "unbuckled". However, we cannot conclude that this trend is consistent through all Ford EDRs.
- The analysis of Ford EDR buckle status was conducted with a dataset of 13 cases. These conclusions should be considered preliminary and should be revisited when a larger Ford dataset is available.

For EDRs in Toyota Vehicles:

- Toyota EDRs do not provide an “events recorded” field. Instead they have a field called “Writing Flag”. It is assumed that all 18 cases did finish recording the event in question because the “Writing Flag” field stated “Finished Writing”.
- All 18 Toyota EDRs in the dataset accurately recorded driver seat belt status. All 18 Toyota EDRs also recorded right front passenger seatbelt status correctly.

For EDRs in Chrysler Vehicles:

- Chrysler EDRs did not record an “events recorded” data element, and 2 of the 4 EDRs also did not report if the recording of the event had finished.
- Chrysler EDRs did not provide a seat belt status for driver or right front passenger.

5.1.3 Accuracy of the Recorded Pre Impact Speed

From this analysis we can conclude:

For GM EDRs

- The majority of GM EDRs, 66 out of the possible 67, reported pre impact velocity within 2mph of the actual value. The average underestimation by the GM EDRs was -2.57 mph, while the average overestimation of the velocity was 5.03 mph. Of the module types where 5 or more were present in this dataset, module SDMC2006 was the most accurate with an average error of 0.12 mph.

For Ford EDRs

- Ford EDRs accurately measured pre impact velocity in 5 out of the 9 tests in this database where pre impact velocity was reported by the EDR. 2 of the remaining

4 EDRs underestimated pre impact velocity by -.3 mph and the other 2 over estimated it by .5 mph. The most commonly occurring EDR module in the dataset, Ford_AB9 had an average error of only -.1mph

For Toyota EDRs

- Toyota EDRs only reported pre-impact velocity for 6 of the 18 EDRs. The rest had a pre-impact value of 0mph. Of the 6 reported pre-impact velocities, 4 were 0.0 mph corresponding to side impact collisions. Toyota EDRs were the worst at predicting pre-impact velocity with an average error of -22.07mph. The average underestimation for a Toyota EDR was -30.64 mph compared to 1mph of average overestimation.

For Chrysler EDRs

- All 4 Chrysler EDRs reported a pre-impact velocity. The Chrysler EDRs had an average error of only -.15mph. The most commonly occurring Chrysler EDR, module CHRY0303C, had an average error of only .05mph

5.1.4 Accuracy of the Recorded Airbag Deployment Status

From the analysis we can conclude:

- GM EDRs, in 65 out of the 67 crash tests accurately recorded airbag deployment status of the driver and right front passenger. The EDR for NHTSA test 4259, module type SDMGF2002, reported only a non-deployment event when in actuality, the driver and right front passenger airbags deployed. Test 4777 was a side impact test in which the side airbags deployed but the frontal ones did not. The EDR, module SDMGT2001 reported this event as a non deployment. This could be because of the age of the EDR which would explain its inability to determine side airbag deployment.

- All Ford EDRs in the dataset (13 cases) accurately reported airbag deployment. Some Ford EDRs, module Ford_AB9, are able to distinguish between front and side deployment. There were no tests in this dataset which resulted in a non-deployment. Therefore it is impossible to determine accuracy of Ford EDRs in non-deployment cases.
- All Toyota EDRs were accurate at reporting air bag deployment for both deployment and non deployment scenarios.
- Chrysler EDRs did not provide an airbag deployment status for any of the tests. There were configuration statuses dealing with left/right curtains and passenger airbag disable switches, however no indication of actual deployment was recorded.

5.1.5 Accuracy of the Recorded Seat Position

Seat position is a newer data element in EDRs. This data element was recorded for only 36 of the 107 drivers, and 27 right front passengers in our dataset. EDRs did not provide a quantitative measure of seat position. Seat position was aggregated into either "forward" or not forward. The boundary between "forward" and not forward could not be determined in this analysis. The boundary may vary from automaker by automaker, and vehicle model to model.

The EDR seat position was a useful indicator of occupant size. EDRs reported seat position of 5% Hybrid III females as "forward" in every case that seat position was recorded for this smaller occupant size. Surprisingly, the seat position for approximately

20% (11 of the 57) of larger dummies, i.e. 50-percentile and 95-percentile male dummies, were also reported as “forward”. The remainder of the larger dummies were reported as not forward, i.e., “normal” (1 case), “not forward” (8 cases) or “rearward” (27 cases).

5.2 Accuracy of Seat Belt Usage in NASS-CDS

The reporting accuracy of seat belt usage reports by NASS-CDS investigators as well as police was determined by comparison with EDRs. Possible reasons for the errors were also presented. This study was based on 359 cases which had associated EDR downloads. Following are our conclusions:

- NASS-CDS investigators had an overall reporting error rate of 9.5% when determining driver seat belt status. Accuracy varied by belt buckle status. NASS-CDS investigators had an error rate of only 1.2% when the EDR reported the driver as buckled. The NASS-CDS investigator error rate rose to 29.5% when the EDR reported the driver belt status as unbuckled.
- In 2008, NASS-CDS reported 82% buckled drivers when involved in a crash. When correcting for the NASS-CDS reporting error, we found that driver belt use may be around 72.6%, when the driver is involved in a crash.
- Police were less accurate than NASS-CDS investigators when reporting driver seat belt status. When compared with EDRs, police had an overall error rate of 21.7%. When the EDR belt status was buckled, police had an error rate of 2.4% and an unknown error rate of an additional 3.1%. When the EDR belt status was unbuckled, police error rates rose to 69% and 9.5% respectively.
- Seat belt buckle status accuracy was found to be a function of delta-V for both NASS-CDS investigators and police. The total crash delta-V was less than

20km/hr (12.4mph) in 92 cases. In the low delta-V cases investigators incorrectly reported in 18.5% of cases (17 of 92). Police incorrectly reported belt use in 29.3% of cases (27 of 92). Low delta-V crashes may produce less physical belt use indicators and fewer severe injuries.

- Presence of a pretensioner improved seat belt buckle status accuracy of NASS-CDS investigators. There were 125 cases involving a pretensioner in the dataset. The seat belt buckle status was reported incorrectly for only 4 of these cases.
- Rollover events affected NASS-CDS accuracy. Investigators reported seat belt status correctly 100% of the time.
- Frontal crashes were a factor of seat belt reporting accuracy for police officers. There were 300 frontal crashes in this dataset. Police were incorrect in 73% of the cases. This may be due to the fact that frontal crashes resulted in 72% AIS 1 or 0 injuries, and therefore were less severe.
- Accuracy of driver belt buckle status varied by PSU. The least accurate was PSU 9 with an accuracy of 66.7% (8 correct out of 12) while PSUs 2, 3, 5, 6, 42, 43, 45, 47, 72, 81 and 82 reported 100% overall accuracy. PSUs were more accurate when reporting driver seat belt status of buckled when the seat was buckled, 23 of 27 having accuracies of 100%.

5.3 Effect of Belt Usage Reporting Errors

The overall objective of this thesis was to determine the effect of NASS-CDS belt usage reporting errors on injury risk estimates. Our approach was to determine risk ratios and odds ratio point estimates for NASS-CDS investigators and EDRs. The results were then compared to determine and differences. Our results show that injury risk for unbuckled drivers may be overestimated by NASS-CDS investigators. This is supported by the risk ratio values of 28.06% for investigators and 16.74% for EDRs using the total weighted dataset. The subset risk ratios also show this trend with the investigator unbuckled risk ratio being 25.66% and the EDR value being 17.03%. The odds ratios point estimates for NASS-CDS investigators was also higher in both datasets; 3.17 vs. 2.43 for the total weighted dataset and 8.47 vs. 5.41 for the weighted subset. While we did see differences in the injury risk estimates according to belt buckle status for both the risk ratio and odds ratios, we were not able to conclude that either was significant. We feel that this analysis should be revisited when a larger dataset can be utilized.

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APPENDIX A: SAMPLE EDR DOWNLOAD

This appendix presents the EDR data downloaded from NHTSA crash test 5597. This was a standard New Car Assessment Program (NCAP) test run at 35mph into a rigid barrier. The vehicle involved was a 2006 Chevrolet Colorado 4-door pickup truck. The actual NHTSA reported impact speed was 34.55 mph and it was a full frontal crash.

CDR File Information

User Entered VIN	1GCDT136668175975
User	
Case Number	
EDR Data Imaging Date	
Crash Date	
Filename	CHEVY-COLORADO-1GCDT136668175975.CDR
Saved on	Thursday, August 17 2006 at 04:40:07 PM
Collected with CDR version	Crash Data Retrieval Tool 2.800
Reported with CDR version	Crash Data Retrieval Tool 3.3
EDR Device Type	airbag control module
Event(s) recovered	Deployment Non-Deployment

IMPORTANT NOTICE: Robert Bosch LLC recommends that the latest production release of Crash Data Retrieval software be utilized when viewing, printing or exporting any retrieved data from within the CDR program. This ensures that the retrieved data has been translated using the most recent information including but not limited to that which was provided by the manufacturers of the vehicles supported in this product.

Data Limitations

Recorded Crash Events:
There are two types of Recorded Crash Events. The first is the Non-Deployment Event. A Non-Deployment Event records data but does not deploy the air bag(s). It contains Pre-Crash and Crash data. The SDM can store up to one Non-Deployment Event. This event can be overwritten by an event that has a greater SDM recorded vehicle longitudinal velocity change. This event will be cleared by the SDM, after approximately 250 ignition cycles. This event can be overwritten by a second Deployment Event, referred to as a Deployment Level Event, if the Non-Deployment Event is not locked. The data in the Non-Deployment Event file will be locked, if the Non-Deployment Event occurred within five seconds before a Deployment Event. A locked Non Deployment Event cannot be overwritten or cleared by the SDM.
The second type of SDM recorded crash event is the Deployment Event. It also contains Pre-Crash and Crash data. The SDM can store up to two different Deployment Events, if they occur within five seconds of one another. If multiple Non-Deployment Events occur within five seconds prior to a Deployment Event, then the most severe Non-Deployment Event will be recorded and locked. If multiple Non-Deployment Events precede a Deployment Event, and occur within five seconds of each other (but not necessarily all within five seconds of the Deployment Event), then the most severe of the Non-Deployment Events (which may have occurred more than five seconds prior to the Deployment Event) will be recorded and locked. If a Deployment Level Event occurs within five seconds after the Deployment Event, the Deployment Level Event will overwrite any non-locked Non-Deployment Event. If multiple Non-Deployment Events occur within five seconds prior to a Deployment Event, and one or more of those events was a Pretensioner Deployment Event, then the most recent Pretensioner Deployment Event will be recorded and locked. Deployment Events cannot be overwritten or cleared by the SDM. Once the SDM has deployed an air bag, the SDM must be replaced.

Data:
-SDM Recorded Vehicle Longitudinal Velocity Change reflects the change in longitudinal velocity that the sensing system experienced during the recorded portion of the event. SDM Recorded Vehicle Longitudinal Velocity Changeis the change in velocity during the recording time and is not the speed the vehicle was traveling before the event, and is also not the Barrier Equivalent Velocity. For Deployment Events, the SDM will record 100 milliseconds of data after deployment criteria is met and up to 50 milliseconds before deployment criteria is met. For Non-Deployment Events, the SDM can record up to the first 150 milliseconds of data after algorithm enable. Velocity Change data is displayed in SAE sign convention.
-Event Recording Complete will indicate if data from the recorded event has been fully written to the SDM memory or if it has been interrupted and not fully written.
-SDM Recorded Vehicle Speed accuracy can be affected by various factors, including but not limited to the following:
  -significant changes in the tire's rolling radius
  -final drive axle ratio changes
  -wheel lockup and wheel slip
-Brake Switch Circuit Status indicates the open/closed state of the brake switch circuit.
-Pre-Crash data is recorded asynchronously.
-Pre-Crash Electronic Data Validity Check Status indicates "Data Invalid" if:
  -the SDM receives a message with an "invalid" flag from the module sending the pre-crash data
  -no data is received from the module sending the pre-crash data
  -no module present to send the pre-crash data
-Engine Speed is reported at two times the actual value in the following vehicles, if the vehicle is equipped with a 6.6L Duramax diesel engine (RPO LB7, LBZ, LLY, or LMM):
  -2001-2006 Chevrolet Silverado
  -2007 Chevrolet Silverado Classic
  -2001-2006 GMC Sierra
  -2007 GMC Sierra Classic
  -2006-2007 Chevrolet Express
  -2006-2007 GMC Savana
  -2003-2009 Chevrolet Kodiak
  -2003-2009 GMC Topkick
-Driver's and Passenger's Belt Switch Circuit Status indicates the status of the seat belt switch circuit. If the vehicle's electrical system is compromised during a crash, the state of t Select & Zoom elt Switch Circuit may be reported other than the actual state.

-The Time between Non-Deployment to Deployment Events is displayed in seconds. If the time between the two events is greater than five seconds, "N/A" is displayed in place of the time.
-If power to the SDM is lost during a crash event, all or part of the crash record may not be recorded.
-Multiple Events will indicate whether one or more associated events preceded the recorded event.
-Multiple Events Not Recorded can be used in the following senieos:
    -If a single event is recorded, this parameter will indicate whether one or more associated events prior to the recorded event was not recorded due to insufficient record space (because there were more events than there were available event records).
    -If two associated events are recorded, this parameter for the first event will indicate whether one or more associated events prior to the first event was not recorded due to insufficient record space.
    -If two associated events are recorded, this parameter for the second event will indicate whether one or more associated events between the first and second events was not recorded due to insufficient record space.
-All data should be examined in conjunction with other available physical evidence from the vehicle and scene.

Data Source:
All SDM recorded data is measured, calculated, and stored internally, except for the following:
-Vehicle Speed, Engine Speed, and Percent Throttle data are transmitted once a second by the Powertrain Control Module (PCM), via the vehicle's communication network, to the SDM.
-Brake Switch Circuit Status data is transmitted once a second by either the ABS module or the PCM, via the vehicle's communication network, to the SDM.
-The Belt Switch Circuit is wired directly to the SDM.

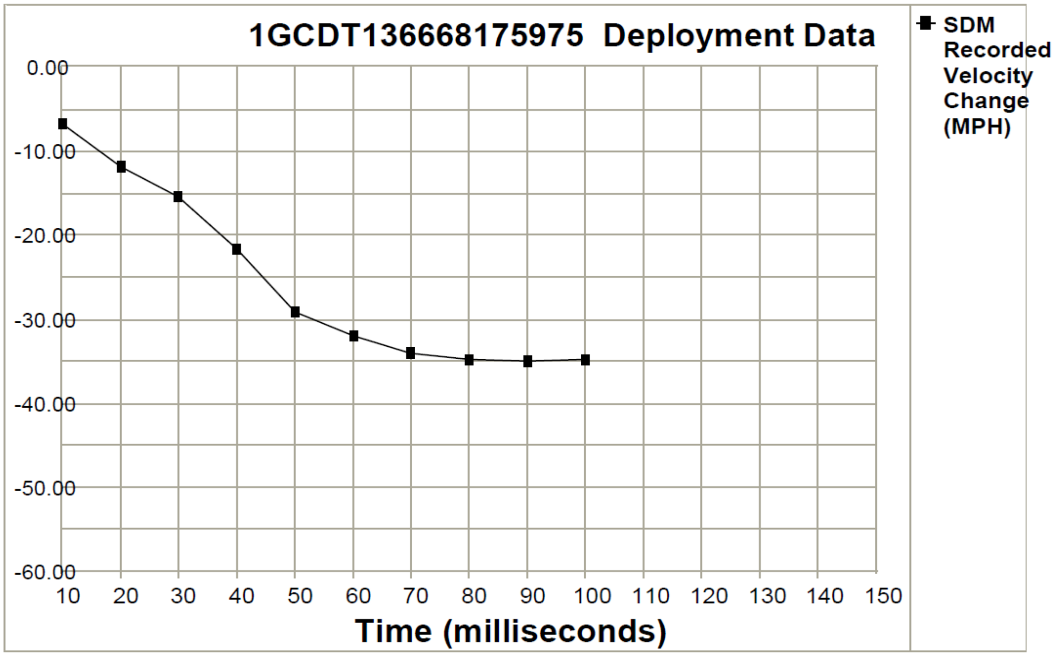
BOSCH CDR CRASH DATA RETRIEVAL SYSTEM

System Status At Deployment

SIR Warning Lamp Status	OFF
Driver's Belt Switch Circuit Status	BUCKLED
Passenger's Belt Switch Circuit Status	BUCKLED
Passenger Seat Position Switch Circuit Status	Rearward
Ignition Cycles At Deployment	138
Ignition Cycles At Investigation	139
Maximum SDM Recorded Velocity Change (MPH)	-35.15
Algorithm Enable to Maximum SDM Recorded Velocity Change (msec)	87.5
Driver 1st Stage Time From Algorithm Enable to Deployment Command Criteria Met (msec)	2.5
Driver 2nd Stage Time From Algorithm Enable to Deployment Command Criteria Met (msec)	7.5
Passenger 1st Stage Time From Algorithm Enable to Deployment Command Criteria Met (msec)	2.5
Passenger 2nd Stage Time From Algorithm Enable to Deployment Command Criteria Met (msec)	7.5
Time Between Non-Deployment And Deployment Events (sec)	N/A
Frontal Deployment Level Event Counter	1
Event Recording Complete	Yes
Multiple Events	No
Multiple Events Not Recorded	No

Seconds Before AE	Vehicle Speed (MPH)	Engine Speed (RPM)	Percent Throttle
-5	35	0	0
-4	35	0	0
-3	35	0	0
-2	35	0	0
-1	35	0	0

Seconds Before AE	Brake Switch Circuit Status
-8	OFF
-7	OFF
-6	OFF
-5	OFF
-4	OFF
-3	OFF
-2	OFF
-1	OFF



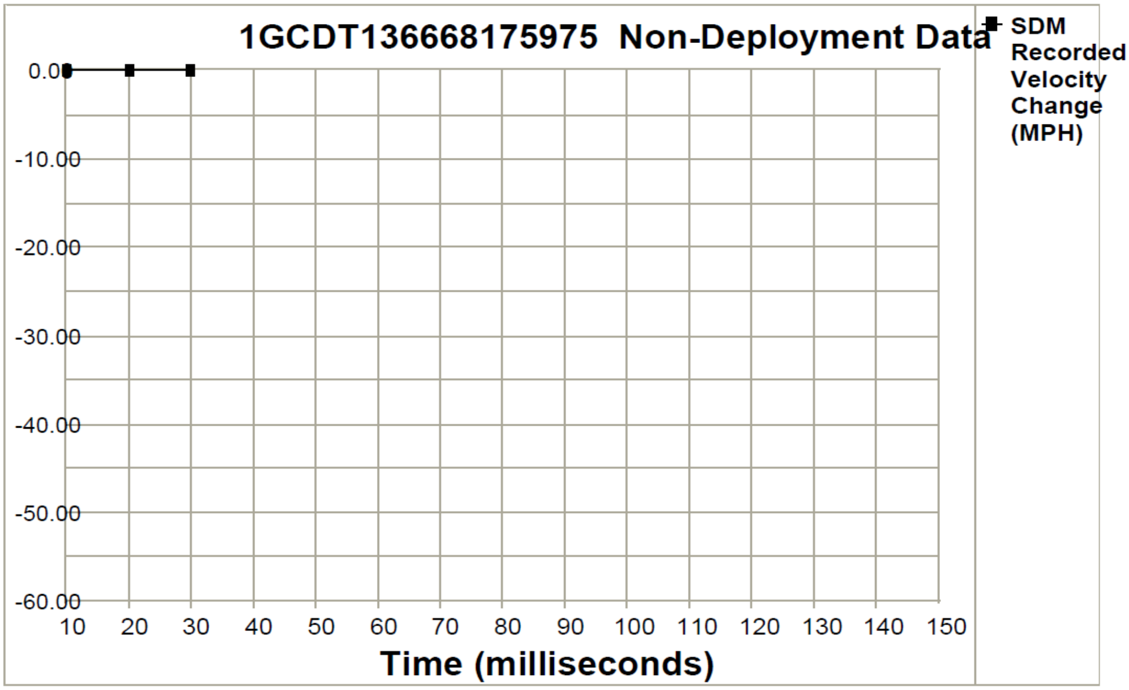
Time (milliseconds)	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150
Recorded Velocity Change (MPH)	-6.82	-11.78	-15.50	-21.70	-29.14	-31.93	-34.10	-34.72	-35.03	-34.72	N/A	N/A	N/A	N/A	N/A

System Status At Non-Deployment

SIR Warning Lamp Status	OFF
Driver's Belt Switch Circuit Status	UNBUCKLED
Passenger's Belt Switch Circuit Status	UNBUCKLED
Passenger Seat Position Switch Circuit Status	Rearward
Ignition Cycles At Non-Deployment	48
Ignition Cycles At Investigation	139
Maximum SDM Recorded Velocity Change (MPH)	-0.19
Algorithm Enable to Maximum SDM Recorded Velocity Change (msec)	2.5
Crash Record Locked	No
Event Recording Complete	Yes
Multiple Events	No
Multiple Events Not Recorded	No

Seconds Before AE	Vehicle Speed (MPH)	Engine Speed (RPM)	Percent Throttle
-5	0	1088	0
-4	0	1088	0
-3	0	1088	0
-2	0	1088	0
-1	0	1088	0

Seconds Before AE	Brake Switch Circuit Status
-8	OFF
-7	OFF
-6	OFF
-5	OFF
-4	OFF
-3	OFF
-2	OFF
-1	OFF



Time (milliseconds)	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150
Recorded Velocity Change (MPH)	0.00	0.00	0.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Hexadecimal Data

Data that the vehicle manufacturer has specified for data retrieval is shown in the hexadecimal data section of the CDR report. The hexadecimal data section of the CDR report may contain data that is not translated by the CDR program. The control module contains additional data that is not retrievable by the CDR system.

$01	F0	3C	E3	42	C2	E4
$02	60	60	00	00	C4	00
$03	41	53	35	32	36	36
$04	4B	36	37	34	43	31
$05	00	00	00	00	00	00
$06	10	35	63	08	00	00
$07	00	00	00	00	00	00
$08	00	00	00	00	00	00
$09	00	00	00	00	00	00
$0A	00	00	00	00	00	00
$0B	00	00	00	00	00	00
$0C	00	00	00	00	00	00
$0D	00	00	00	00	00	00
$0E	00	00	00	00	00	00
$0F	00	00	00	00	00	00
$10	FF	EE	F8	00	00	00
$11	83	82	84	80	7F	81
$12	BA	A5	A4	21	21	11
$13	FF	02	00	00	00	00
$14	03	03	00	00	6C	00
$15	FA	FA	FA	FA	FA	FA
$16	FA	FA	FA	FA	FA	FA
$17	FA	FA	00	00	00	00
$18	00	CF	05	EC	F5	00
$19	09	00	0A	00	00	64
$1A	00	00	00	00	00	00
$1B	00	00	00	00	00	00
$1C	00	0C	00	00	00	00
$1D	00	00	00	00	00	00
$1F	FE	00	00	00	00	00
$20	12	FD	00	00	FF	FF
$21	FF	FF	FF	FF	FF	FF
$22	FF	FF	FF	FF	FF	FF
$23	FF	FF	FF	FF	FF	FF
$24	D0	00	0A	02	01	03
$25	01	00	00	00	FF	FF
$26	00	00	00	00	00	00
$27	00	00	00	00	00	00
$28	00	00	00	03	FF	F9
$29	FF	A5	FF	FF	FF	FF
$2A	FF	FF	FF	FF	FF	FF
$2B	FF	FF	FF	FF	FF	FF
$2C	FF	FF	FF	FF	FF	FF
$2D	FF	FF	00	00	00	00
$30	B2	FE	00	00	FF	FF
$31	FF	FF	FF	FF	FF	FF
$32	FF	FF	FF	FF	FF	FF
$33	FF	FF	FF	FF	FF	FF
$34	76	00	03	02	01	03
$35	00	03	02	01	03	00
$36	35	07	03	03	00	35
$37	07	03	03	07	14	3B
$38	23	03	40	20	00	00
$39	CF	00	00	11	00	00
$3A	16	26	32	46	5E	67
$3B	6E	70	71	70	00	00
$3C	00	00	00	0A	FF	EE

$3D	FC	A5	00	00	00	00
$40	38	38	38	38	38	00
$41	00	00	00	00	00	00
$42	00	00	00	00	00	00
$43	00	00	0E	F8	00	00
$44	00	00	00	00	00	00
$45	00	00	00	00	00	00
$46	00	00	11	11	11	11
$47	11	00	03	FE	00	00
$48	37	38	38	38	38	00
$49	00	00	00	00	00	00
$4A	00	00	00	00	00	00
$4B	00	00	0E	F8	00	00
$4C	37	38	38	38	38	00
$4D	00	00	00	00	00	00
$4E	00	00	00	00	00	00
$4F	00	00	0E	F8	00	00
$50	FF	FF	FF	FF	FF	FF
$51	FF	FF	FF	FF	FF	FF
$52	FF	FF	FF	FF	FF	FF
$53	FF	FF	FF	FF	FF	FF
$54	FF	FF	FF	FF	FF	FF

Disclaimer of Liability

The users of the CDR product and reviewers of the CDR reports and exported data shall ensure that data and information supplied is applicable to the vehicle, vehicle's system(s) and the vehicle ECU. Robert Bosch LLC and all its directors, officers, employees and members shall not be liable for damages arising out of or related to incorrect, incomplete or misinterpreted software and/or data. Robert Bosch LLC expressly excludes all liability for incidental, consequential, special or punitive damages arising from or related to the CDR data, CDR software or use thereof.

APPENDIX B: CRASH DELTA-V VS. EDR DELTA-V PLOTS

The following figures compare the longitudinal delta-V recorded by the EDR with the longitudinal delta-V measured by the crash test instrumentation. By looking at these graphs, it is easy to visualize the accuracy of the EDR data. The significantly greater occurrence of error between the EDRs and crash test data during side impacts can easily be seen.

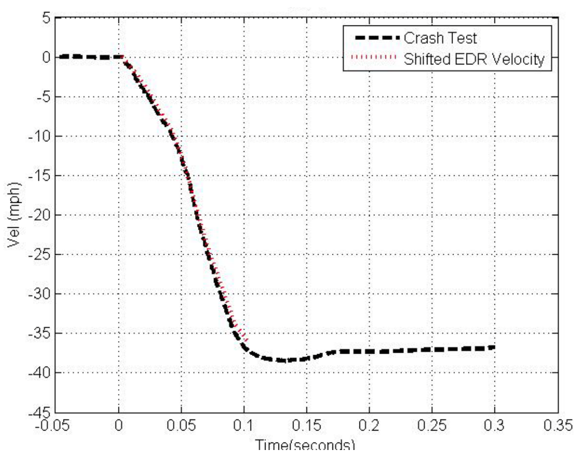


Figure 46. NHTSA test 3471: 2001 Chevrolet Impala; Frontal (with EDR shift of -2.6ms)

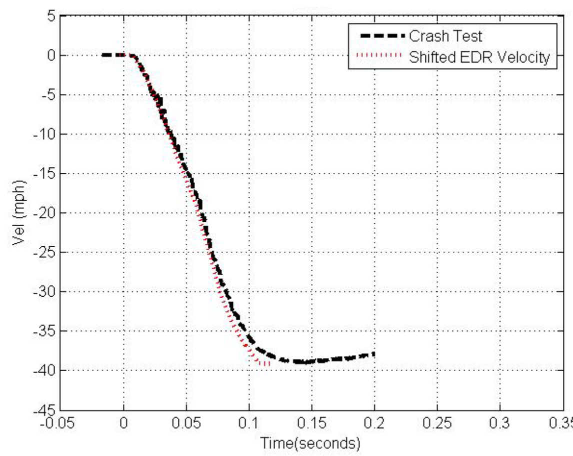


Figure 47. NHTSA test 3851: 2002 Chevrolet Avalanche; Frontal (with EDR shift of 2.7ms)

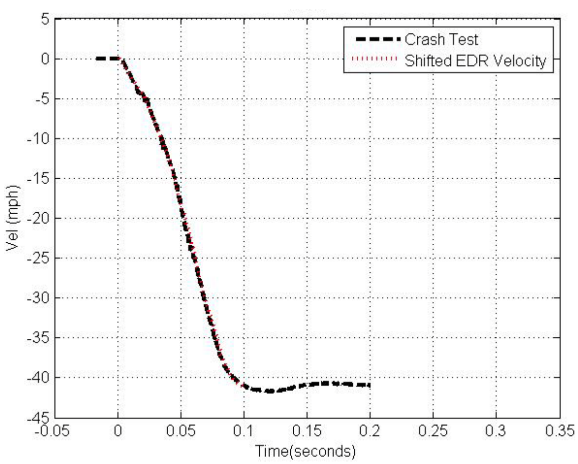


Figure 48. NHTSA test 3952: 2002 Buick Rendezvous; Frontal (with EDR shift of -1.4ms)

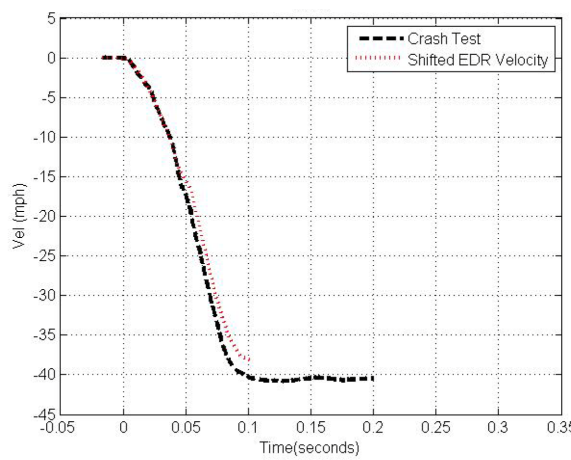


Figure 49. NHTSA test 4198: 2002 Saturn Vue; Frontal (with EDR shift of 16.3ms)

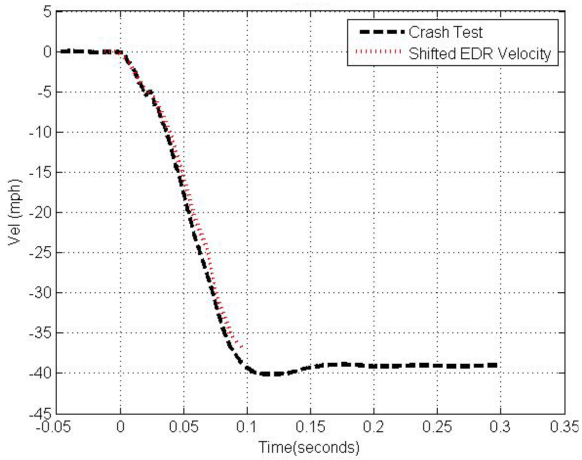


Figure 50. NHTSA test 4238: 2002 Cadillac Deville; Frontal (with EDR shift of 12.3ms)

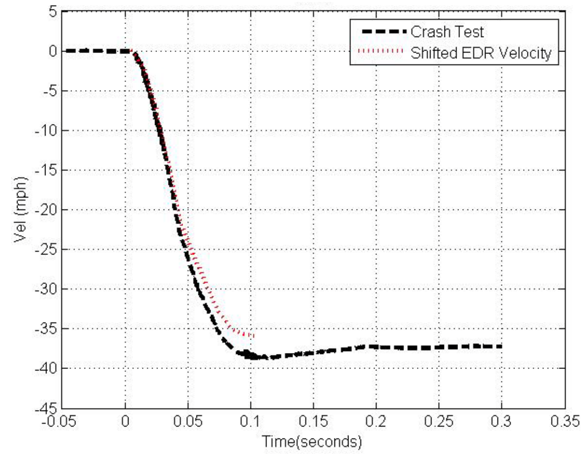


Figure 51. NHTSA test 4244: 2002 Chevrolet Trailblazer; Frontal (with EDR shift of -4.6ms)

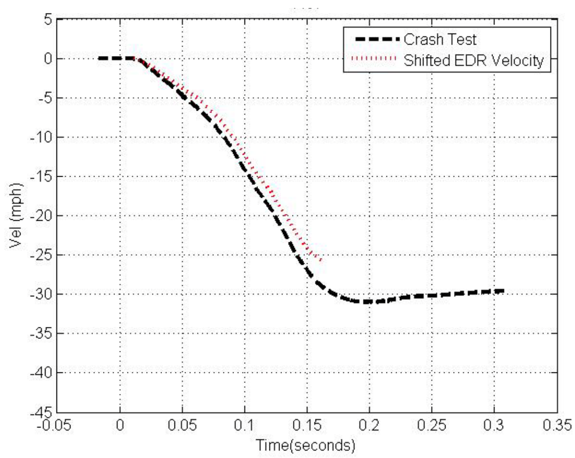


Figure 52. NHTSA test 4437: 2003 Chevrolet Suburban; Frontal (with EDR shift of -11.4ms)

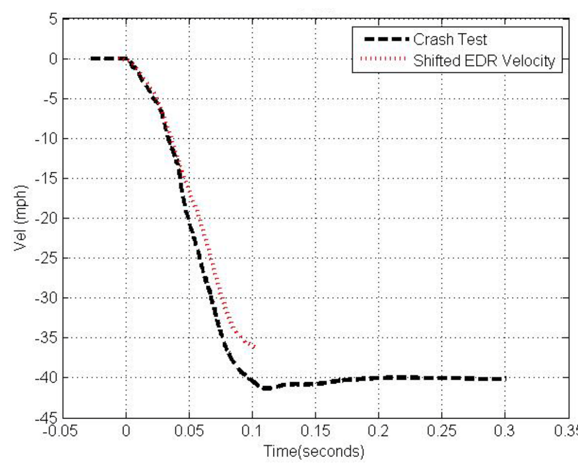


Figure 53. NHTSA test 4445: 2003 Chevrolet Cavalier; Frontal (with EDR shift of 5.5ms)

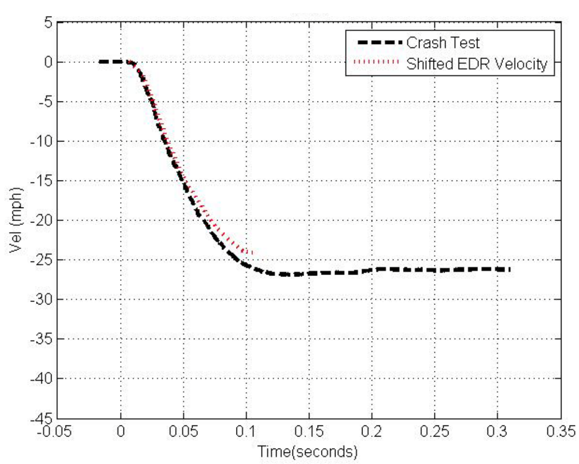


Figure 54. NHTSA test 4453: 2003 Chevrolet Silverado; Frontal (with EDR shift of -7.0ms)

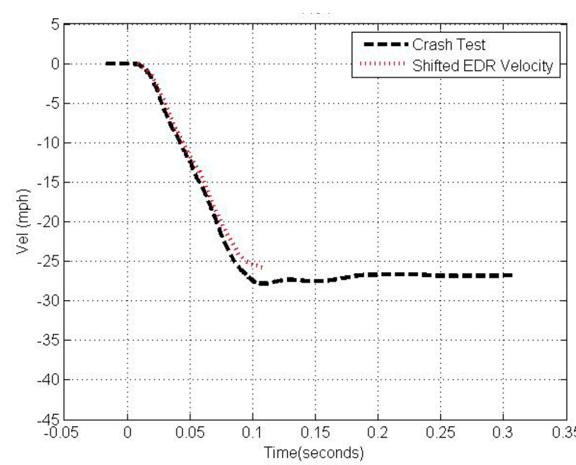


Figure 55. NHTSA test 4454: 2003 Chevrolet Tahoe; Frontal (with EDR shift of -8.7ms)

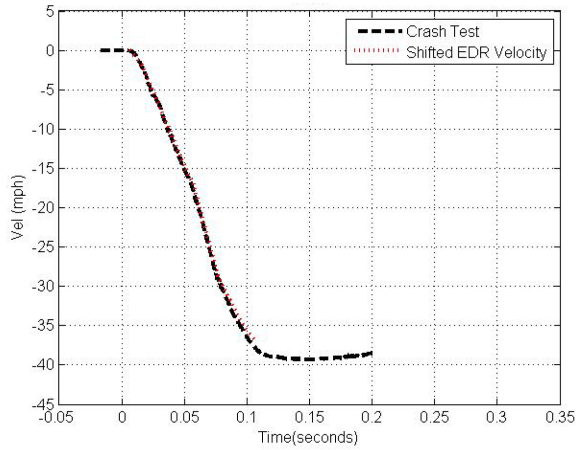


Figure 56. NHTSA test 4464: 2003 Chevrolet Avalanche; Frontal (with EDR shift of -6.1ms)

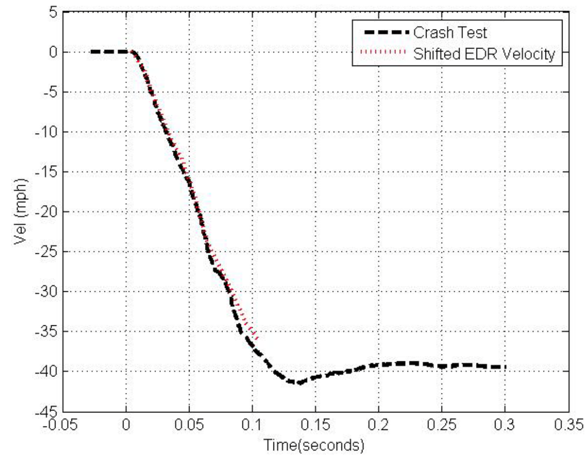


Figure 57. NHTSA test 4472: 2003 Chevrolet Silverado. Frontal (with EDR shift of -4.0ms)

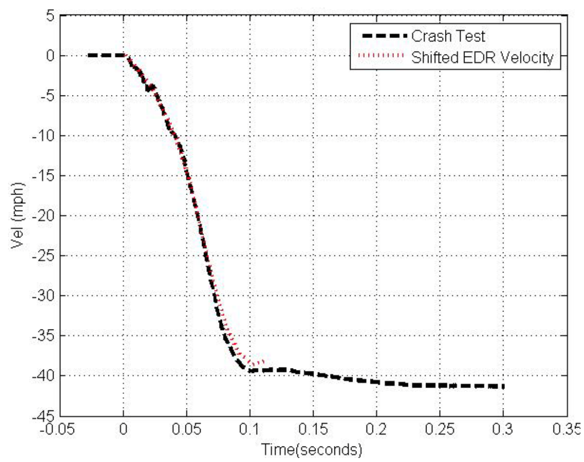


Figure 58. NHTSA test 4487: 2003 Saturn Ion; Frontal (with EDR shift of -2.1ms)

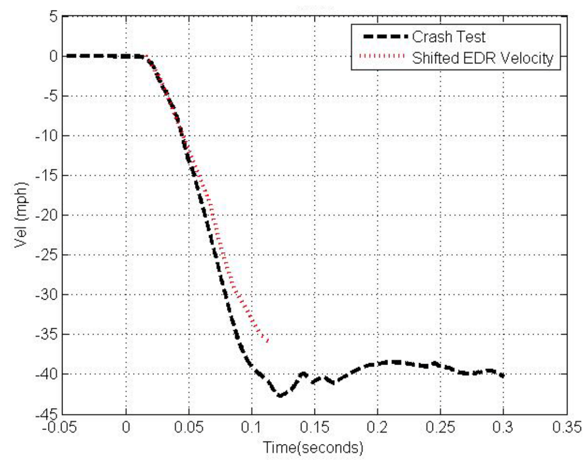


Figure 59. NHTSA test 4549: 2003 Chevy Tahoe; Frontal (with EDR shift of 70.0 ms)

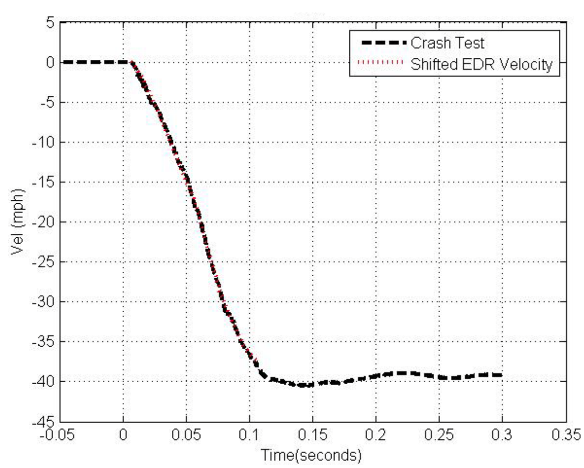


Figure 60. NHTSA test 4567: 2003 Chevrolet Suburban, Frontal (with EDR shift of -6.0ms)

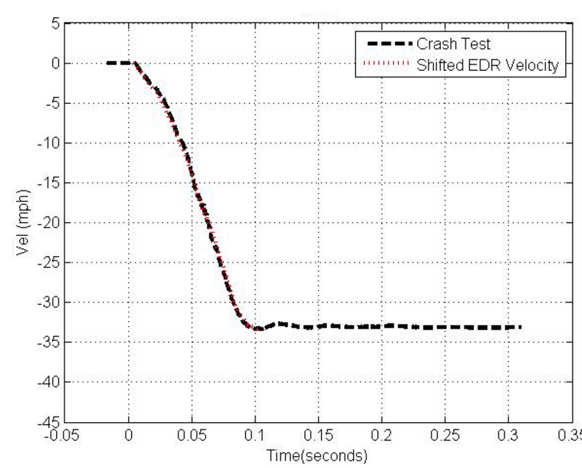


Figure 61. NHTSA test 4702: 2002 Saturn Vue; Frontal (with EDR shift of -3.8ms)

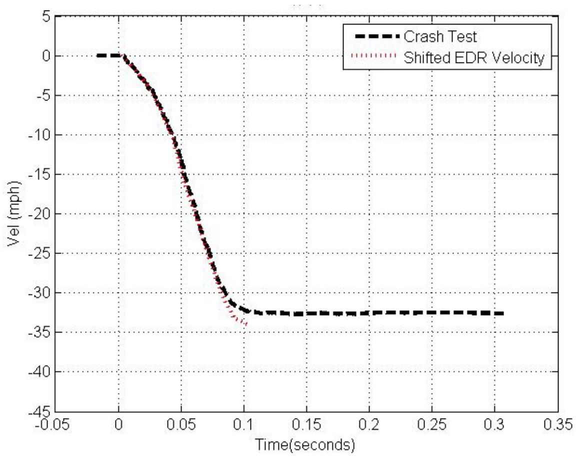


Figure 62. NHTSA test 4714: 2002 Saturn Vue; Frontal (with EDR shift of -2.5ms)

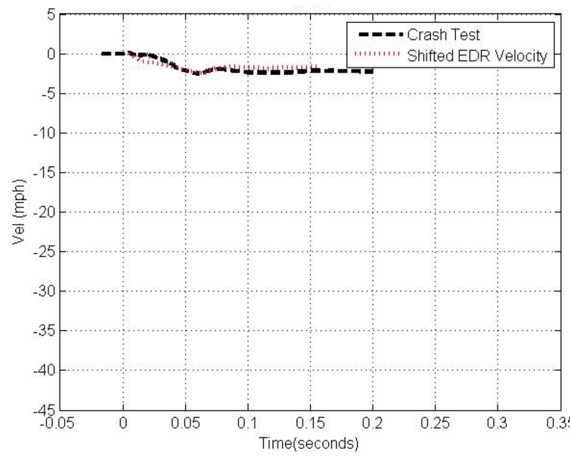


Figure 63. NHTSA test4733: 2004 Toyota Sienna; Side (with EDR shift of -4.6ms)

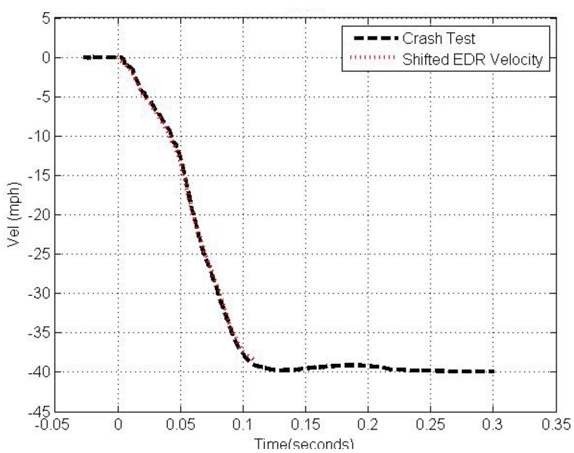


Figure 64. NHTSA test 4775: 2004 Pontiac Grand Prix; Frontal (with EDR shift of 1.0ms)

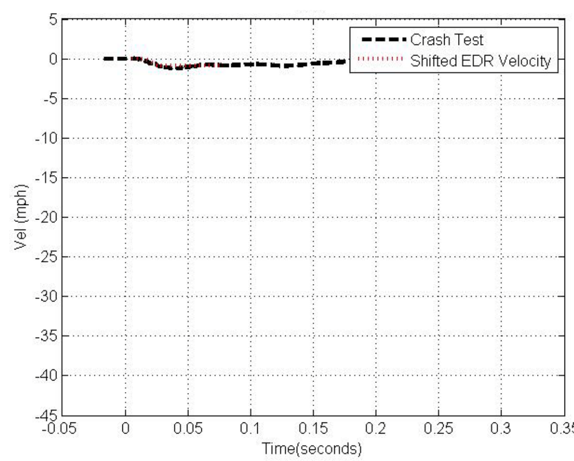


Figure 65. NHTSA test 4777: 2001 Buick LeSabre; Side (with EDR shift of -6.0ms)

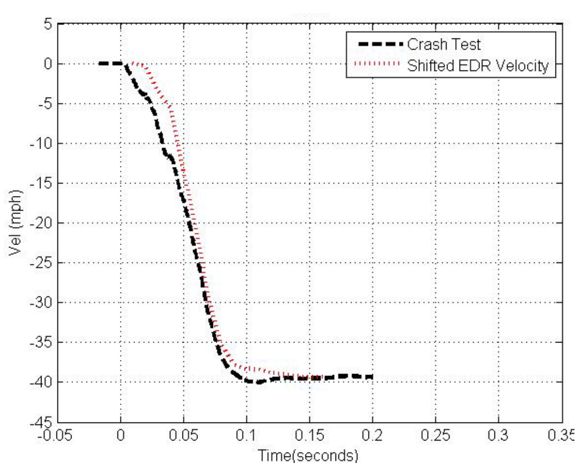


Figure 66. NHTSA test 4846: 2004 Toyota Sienna; Frontal (with EDR shift of -9.6ms)

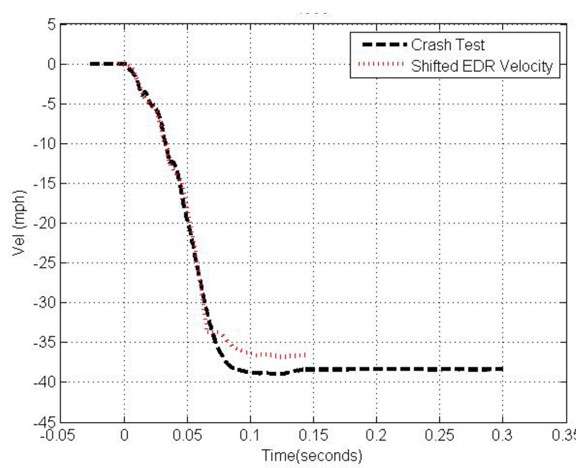


Figure 67. NHTSA test 4855: 2004 Toyota Solara; Frontal (with EDR shift of 4.1ms)

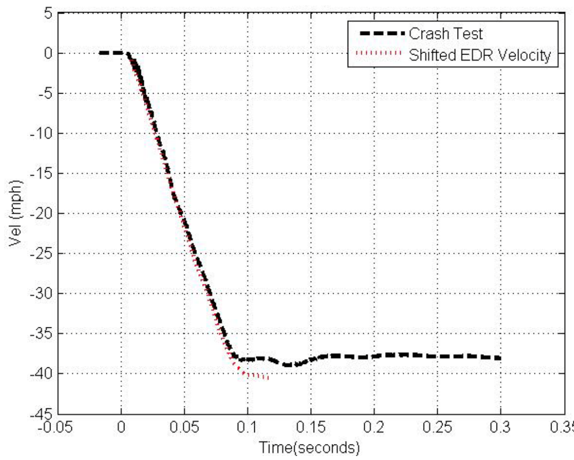


Figure 68. NHTSA test 4890: 2004 Ford F-150; Frontal (with EDR shift of -7.8ms)

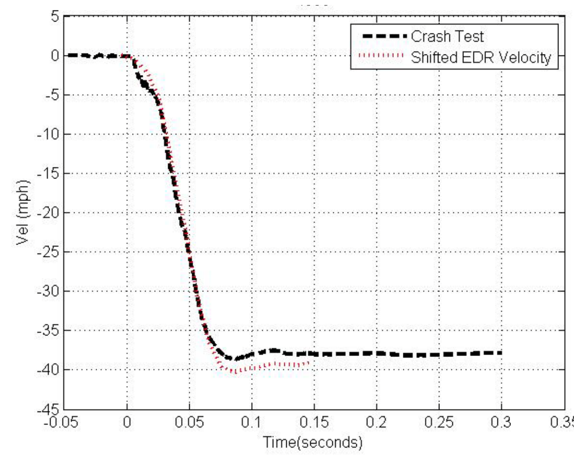


Figure 69. NHTSA test 4893: 2004 Toyota RAV4; Frontal (with EDR shift of 4.1ms)

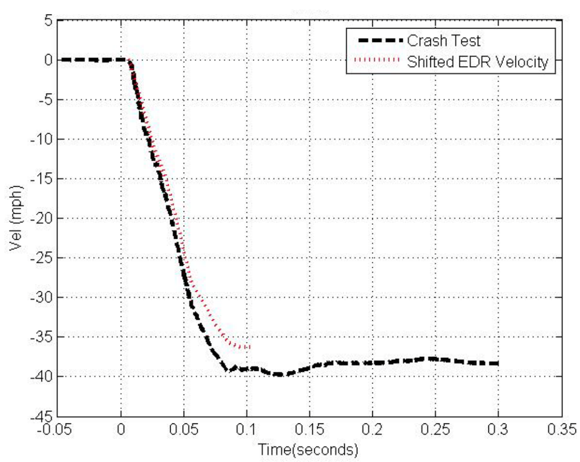


Figure 70. NHTSA test 4899: 2004 Cadillac SRX; Frontal (with EDR shift of -5.4ms)

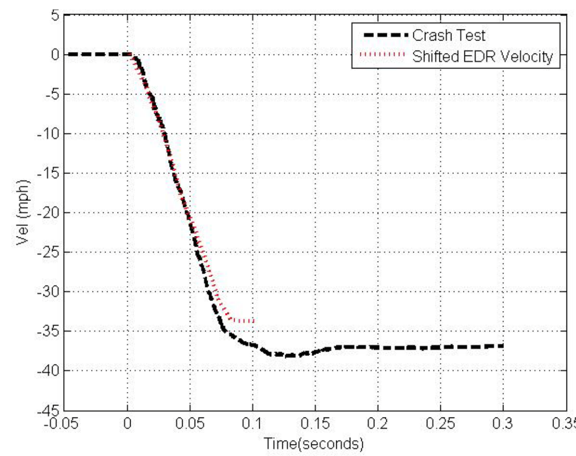


Figure 71. NHTSA test 4918: 2004 GMC Envoy XUV, Frontal (with EDR shift of -2.3ms)

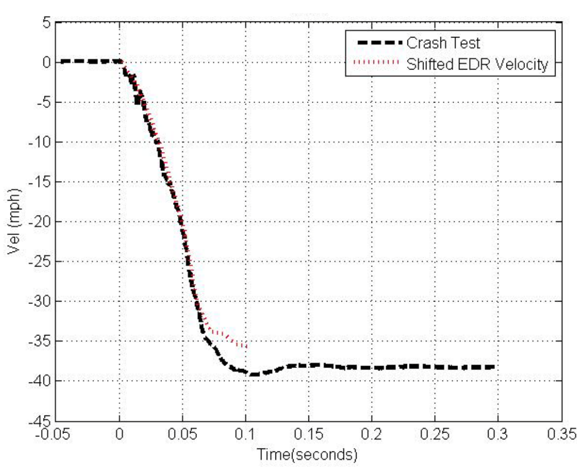


Figure 72. NHTSA test 4923: 2004 Chevrolet Colorado; Frontal (with EDR shift of -2.4ms)

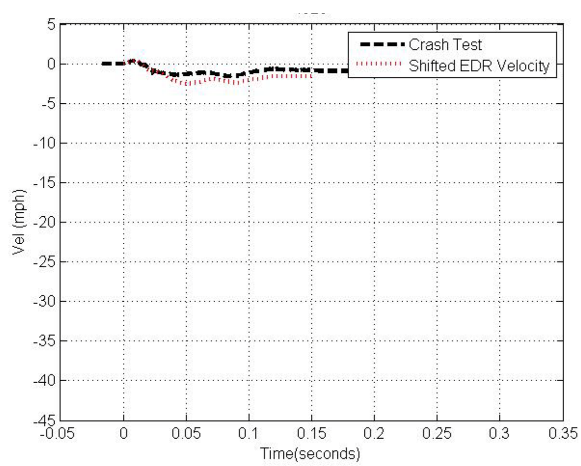


Figure 73. NHTSA test 4928: 2004 Toyota Camry; Side (with EDR shift of -0.4ms)

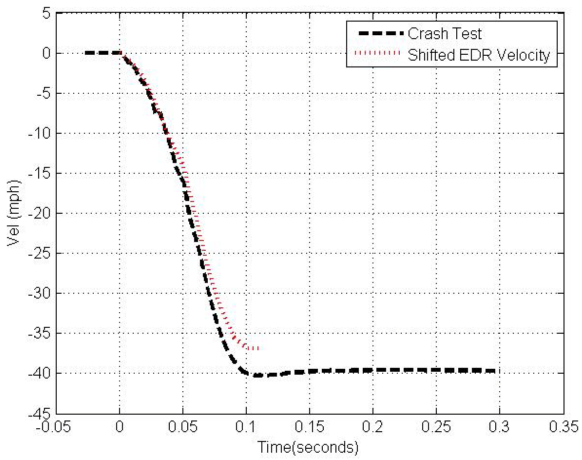


Figure 74. NHTSA test 4931: 2005 Chevy Colorado; Frontal (with EDR shift of -0.4ms)

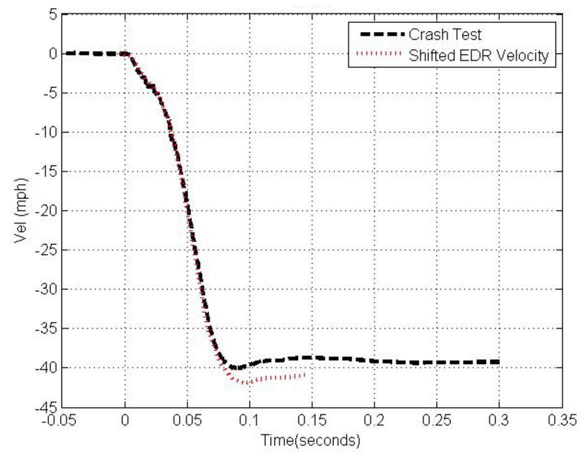


Figure 75. NHTSA test 4933: 2004 Toyota Prius; Frontal (with EDR shift of 4.2ms)

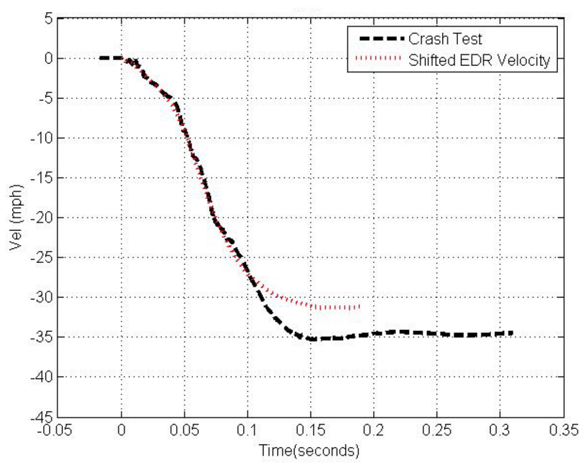


Figure 76. NHTSA test 4937: 1997 Cadillac Seville; Frontal (with EDR shift of -.03ms)

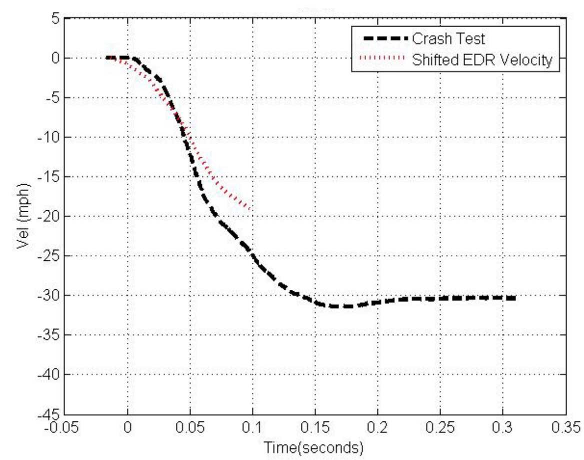


Figure 77. NHTSA test 4955: 2000 Cadillac Seville; Frontal (with EDR shift of 13.0ms)

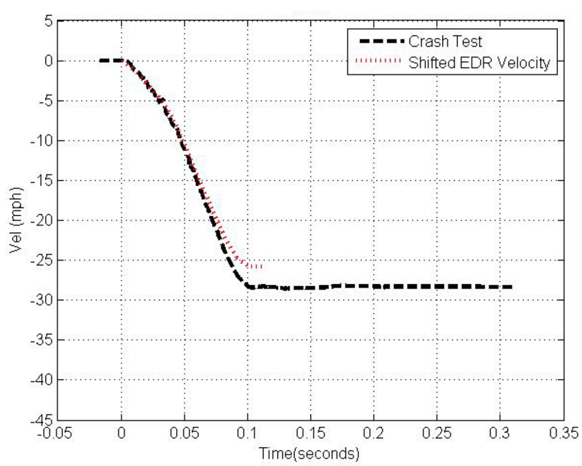


Figure 78. NHTSA test 4984: 2004 Saturn Ion; Frontal (with EDR shift of -1.0ms)

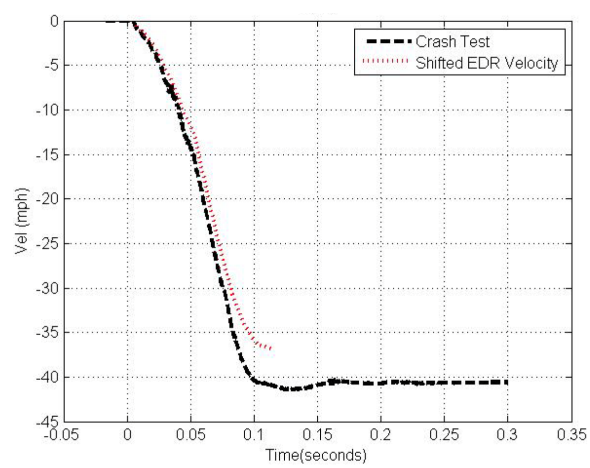


Figure 79. NHTSA test 4985: 2005 Chevrolet Equinox; Frontal (with EDR shift of -2.5ms)

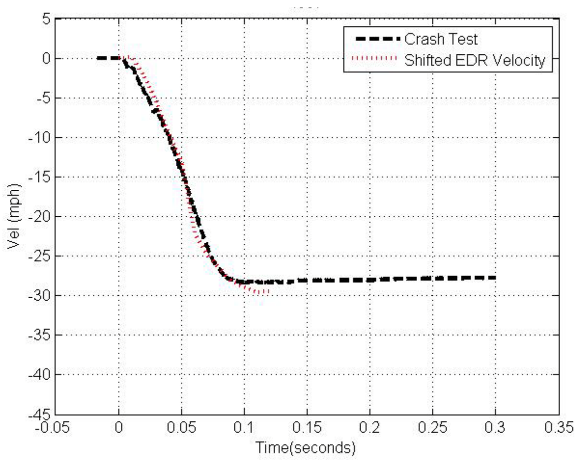


Figure 80. NHTSA test 4987: 2005 Ford Taurus; Frontal (with EDR shift of -0.4ms)

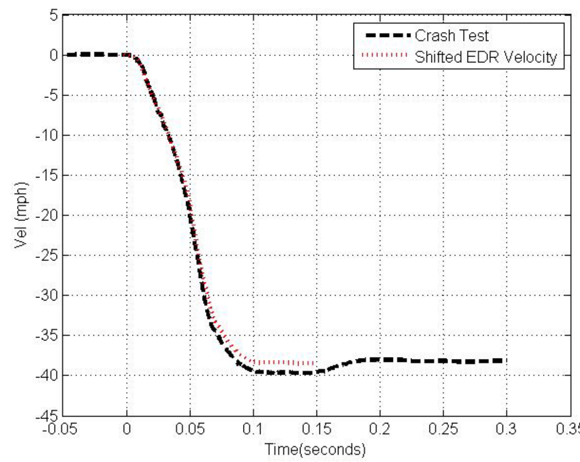


Figure 81. NHTSA test 5037: 2004 Toyota 4Runner; Frontal (with EDR shift of 1.9ms)

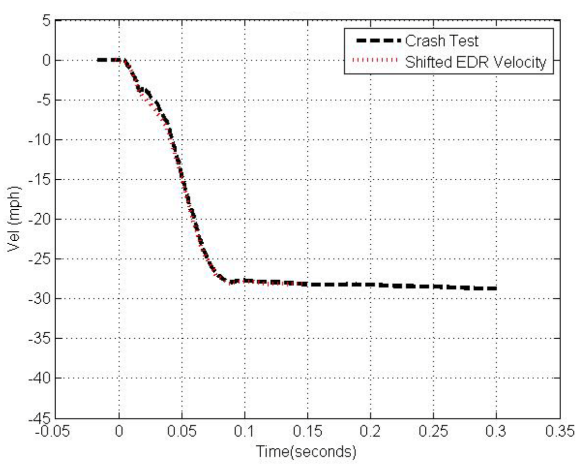


Figure 82. NHTSA test 5071: 2004 Toyota Camry; Frontal (with EDR shift of 2.7ms)

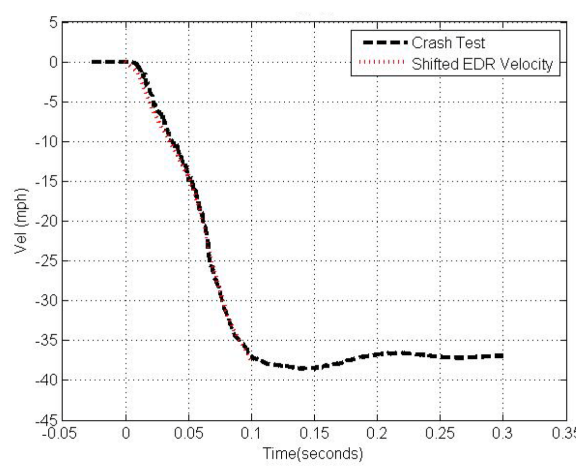


Figure 83. NHTSA test 5140: 2004 Chevrolet Avalanche; Frontal (with EDR shift of 0.8ms)

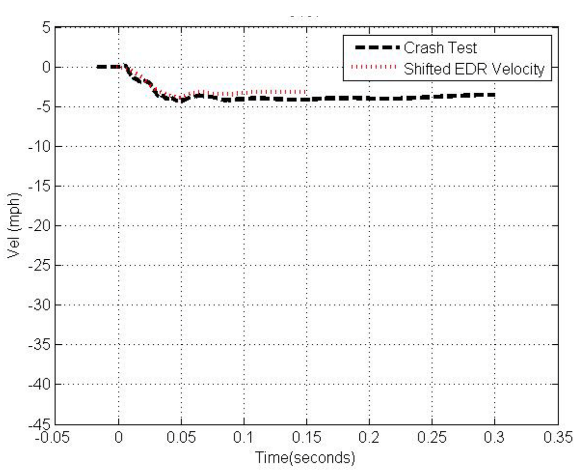


Figure 84. NHTSA test 5157: 2005 Toyota Corolla; Side (with EDR shift of 1.3ms)

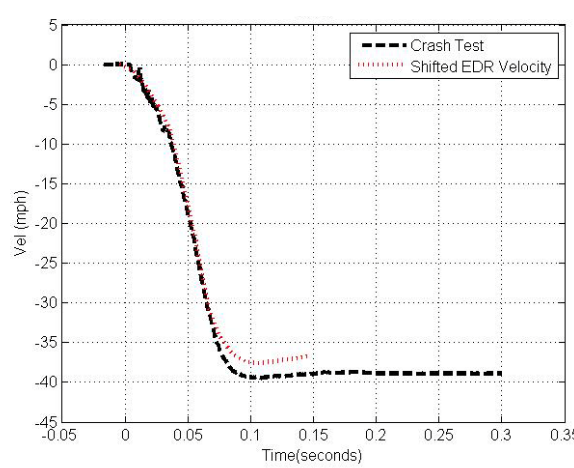


Figure 85. NHTSA test 5160: 2005 Toyota Corolla; Frontal (with EDR shift of 4.2ms)

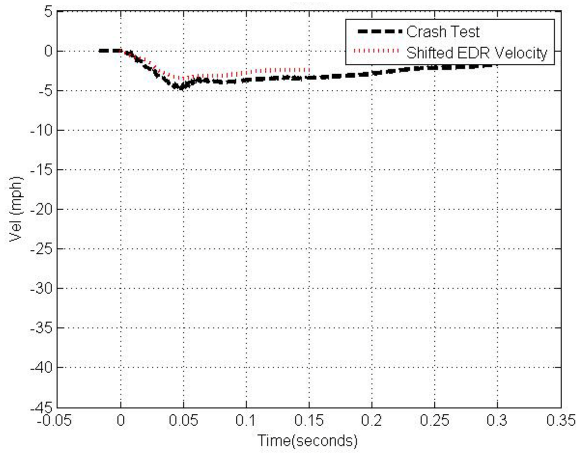


Figure 86. NHTSA test 5162: 2005 Toyota Matrix; Side (with EDR shift of 0.1ms)

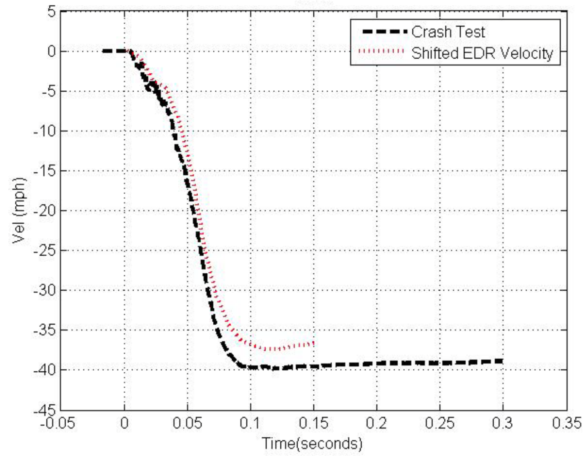


Figure 87. NHTSA test 5209: 2005 Toyota Matrix; Frontal (with EDR shift of -2.8ms)

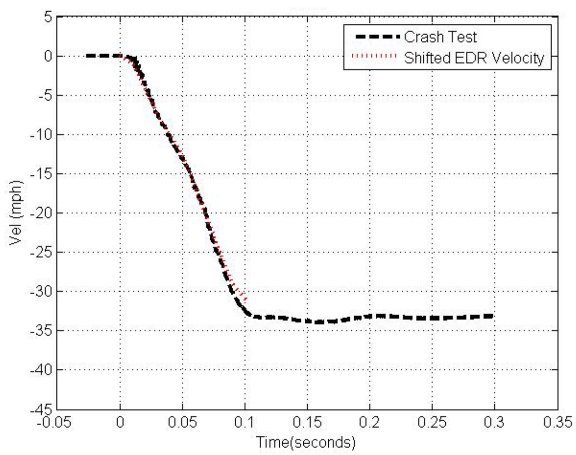


Figure 88. NHTSA test 5213: 2004 Chevrolet Avalanche; Frontal (with EDR shift of -0.2ms)

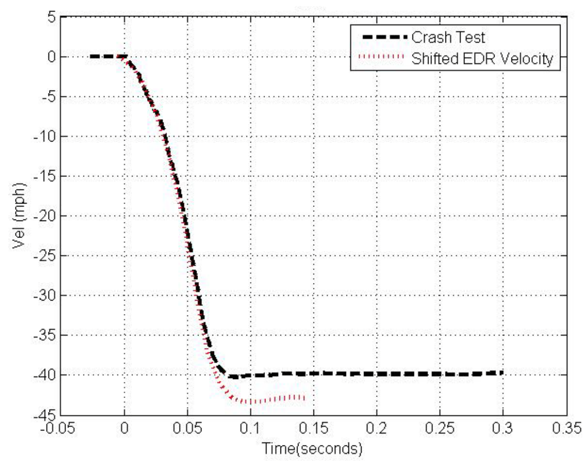


Figure 89. NHTSA test 5217: 2005 Toyota Scion TC; Frontal (with EDR shift of 5.1ms)

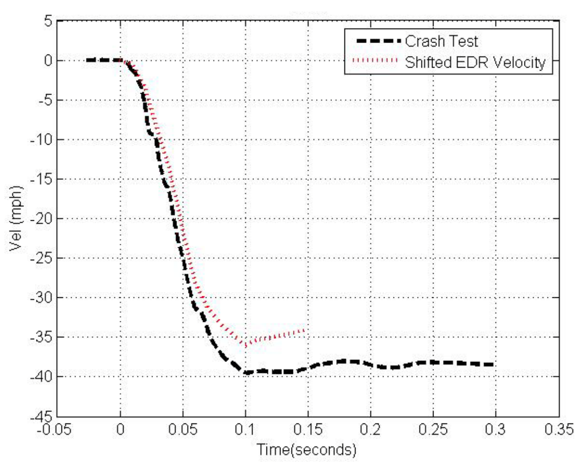


Figure 90. NHTSA test 5218: 2005 Toyota Tundra; Frontal (with EDR shift of 0.4ms)

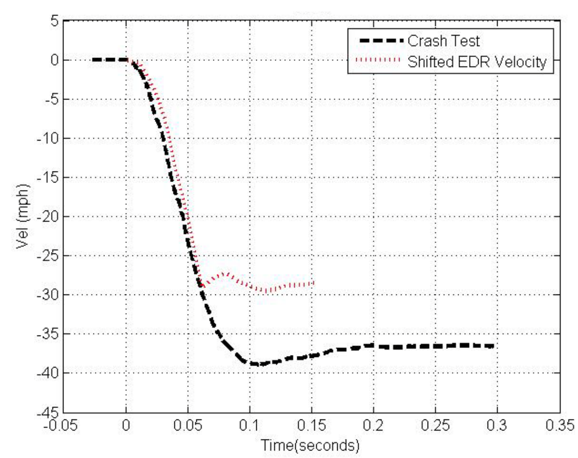


Figure 91. NHTSA test 5239: 2005 Toyota Tundra; Frontal (with EDR shift of -1.5ms)

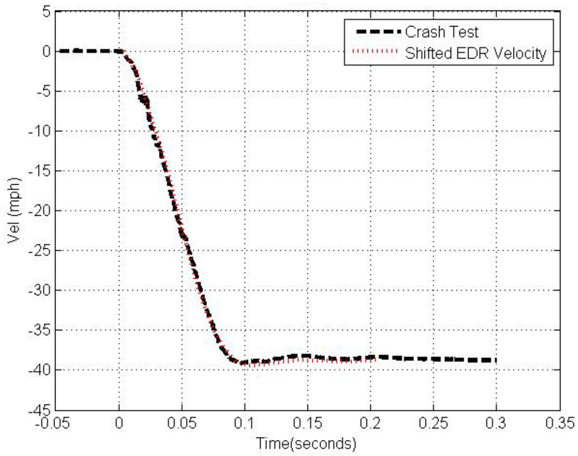


Figure 92. NHTSA test 5249: 2005 Ford 500; Frontal (with EDR shift of -3.5ms)

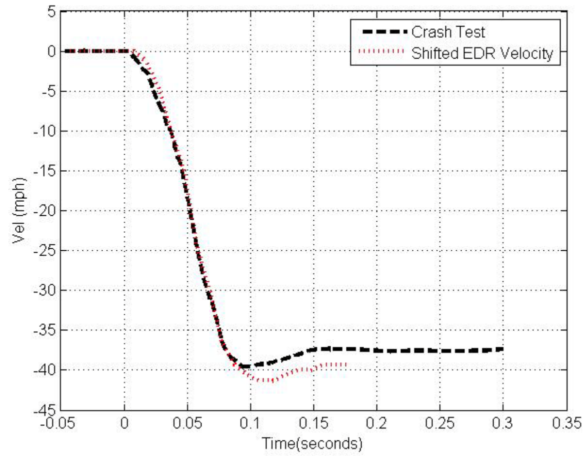


Figure 93. NHTSA test 5250: 2005 Pontiac G6; Frontal (with EDR shift of 42.6ms)

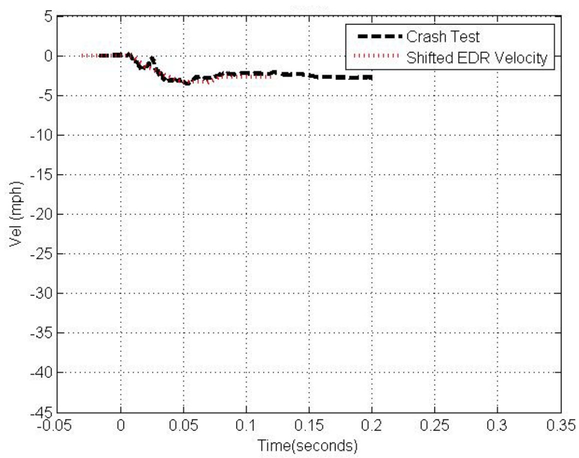


Figure 94. NHTSA test 5256: 2005 Pontiac G6, Side (with EDR shift of 30.4ms)

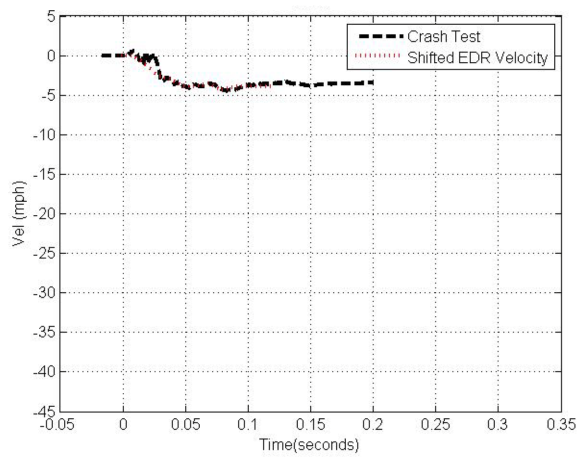


Figure 95. NHTSA test 5260: 2005 Saturn ION; Side (with EDR shift of 1.3ms)

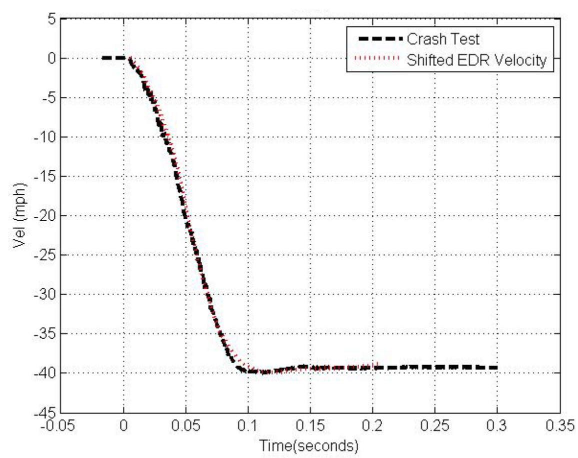


Figure 96. NHTSA test 5263: 2005 Ford Freestyle; Frontal (with EDR shift of -5.5ms)

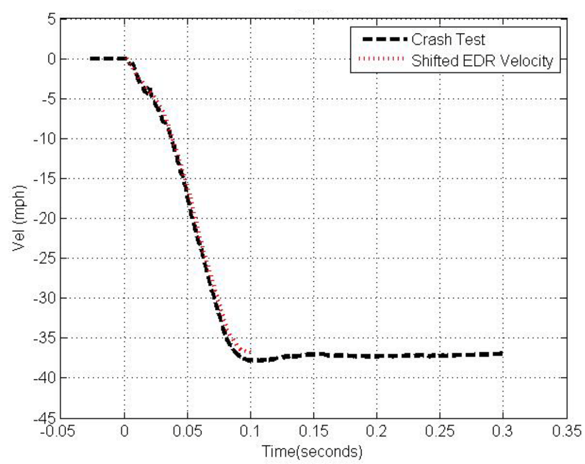


Figure 97. NHTSA test 5264: 2005 Chevy Uplander, Frontal (with EDR shift of -1.9ms)

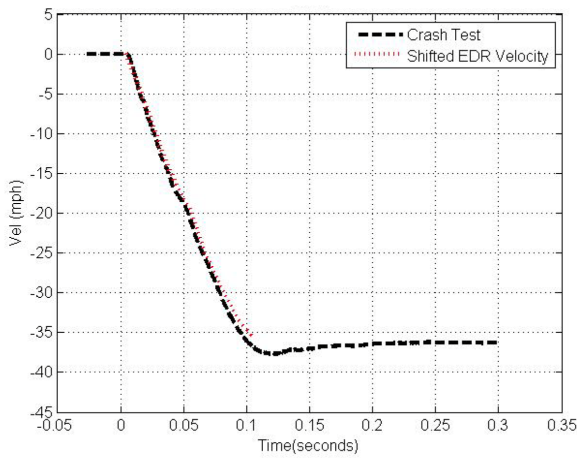


Figure 98. NHTSA test 5265: 2005 Chevy Express; Frontal (with EDR shift of -3.9ms)

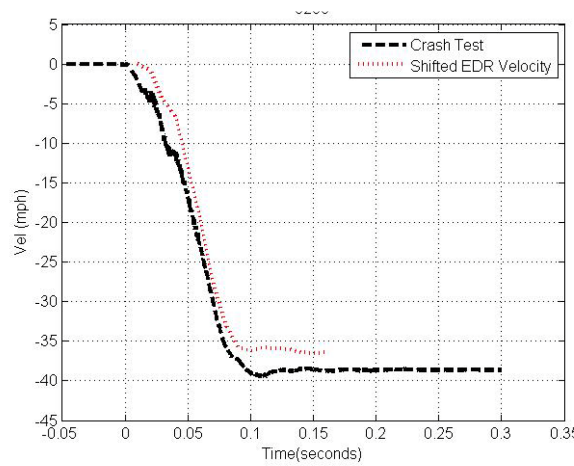


Figure 99. NHTSA test 5269: 2005 Toyota Sienna; Frontal (with EDR shift of -10.1ms)

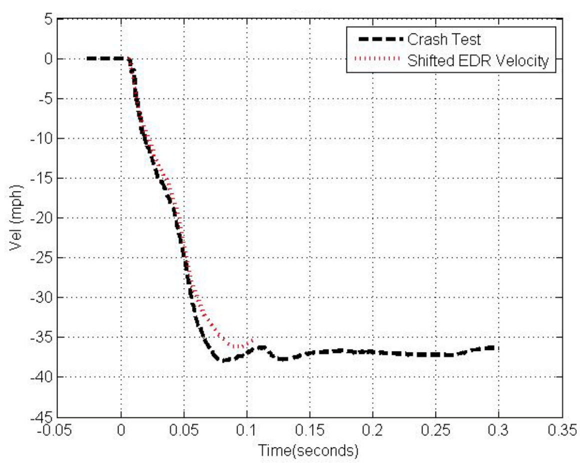


Figure 100. NHTSA test 5282: 2005 Chevy Colorado; Frontal (with EDR shift of -6.2ms)

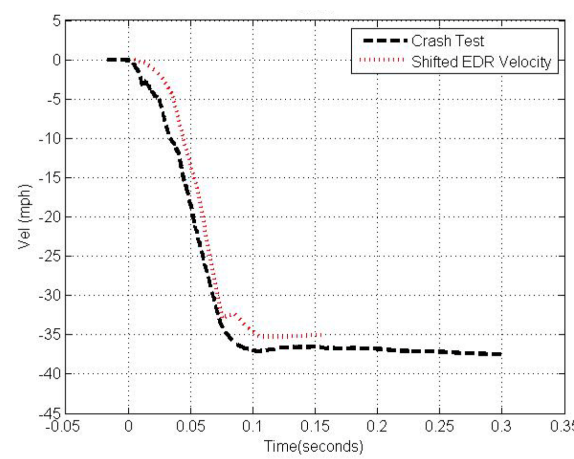


Figure 101. NHTSA test 5283: 2005 Toyota Camry; Frontal (with EDR shift of -5.1ms)

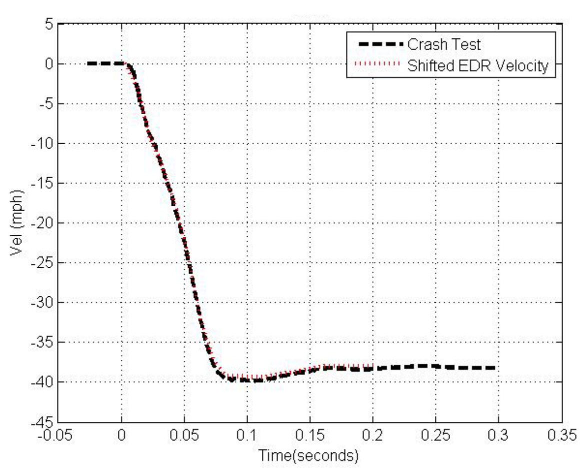


Figure 102. NHTSA test 5284: 2005 Ford Econoline; Frontal (with EDR shift of -2.9ms)

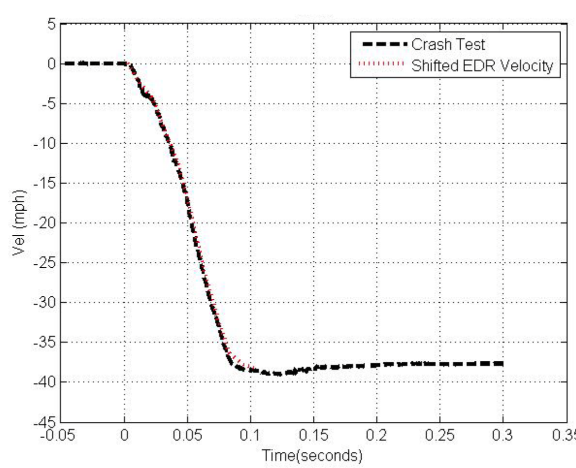


Figure 103. NHTSA test 5310: 2005 Buick Rendezvous; Frontal (with EDR shift of -2.9ms)

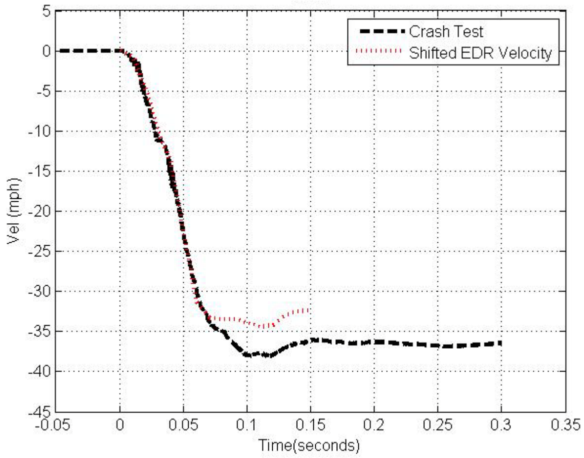


Figure 104. NHTSA test 5312: 2005 Toyota Tacoma; Frontal (with EDR shift of -0.9ms)

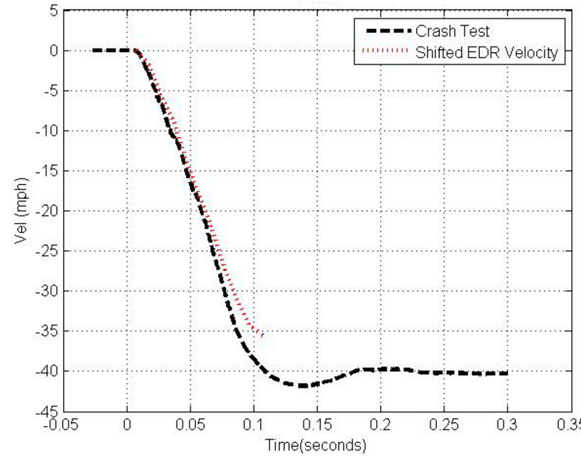


Figure 105. NHTSA test 5318: 2005 Chevy Silverado; Frontal (with EDR shift of -7.4ms)

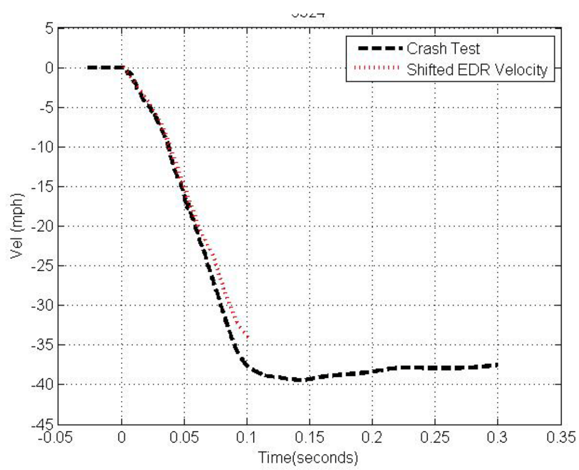


Figure 106. NHTSA test 5324: 2005 Pontiac Montana; Frontal (with EDR shift of -1.6ms)

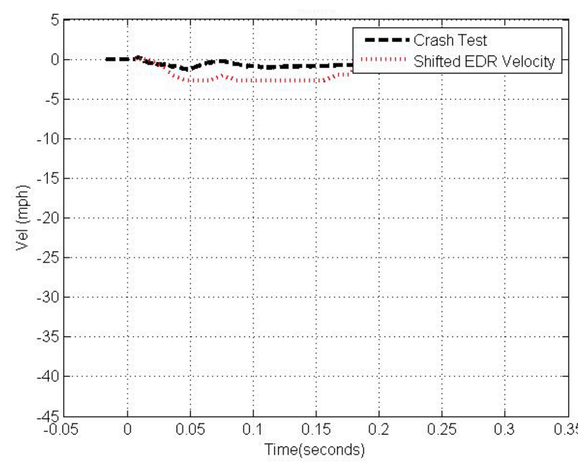


Figure 107. NHTSA test 5325: 2005 Chevy Cobalt; Side (with EDR shift of -6.2ms)

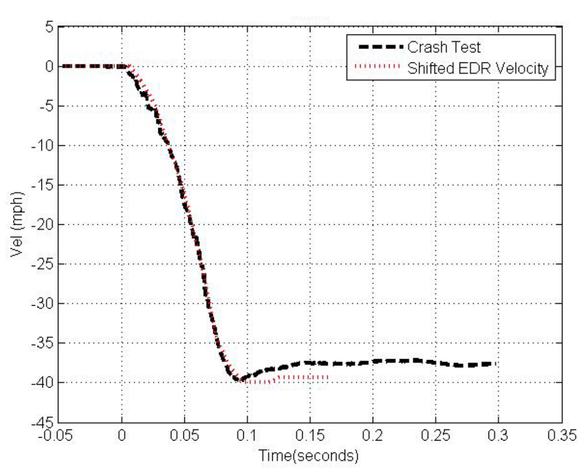


Figure 108. NHTSA test 5326: 2005 Chevy Cobalt; Frontal (with EDR shift of 44.0ms)

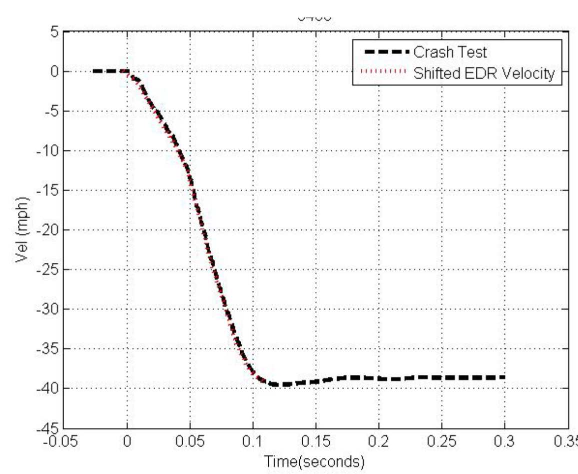


Figure 109. NHTSA test 5468: 2006 Pontiac Grand Prix; Frontal (with EDR shift of 2.8ms)

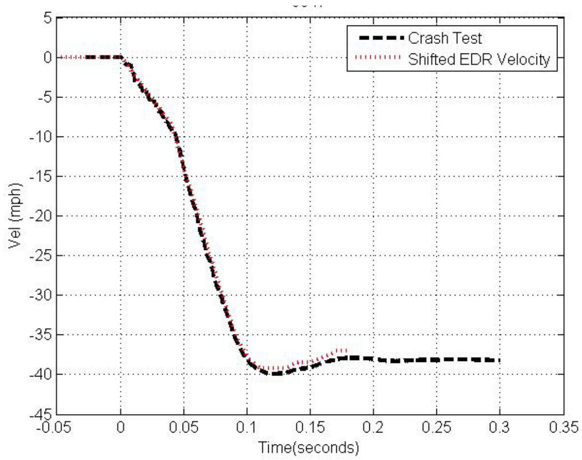


Figure 110. NHTSA test 5547: 2006 Chevrolet Impala; Frontal (with EDR shift of 59.7ms)

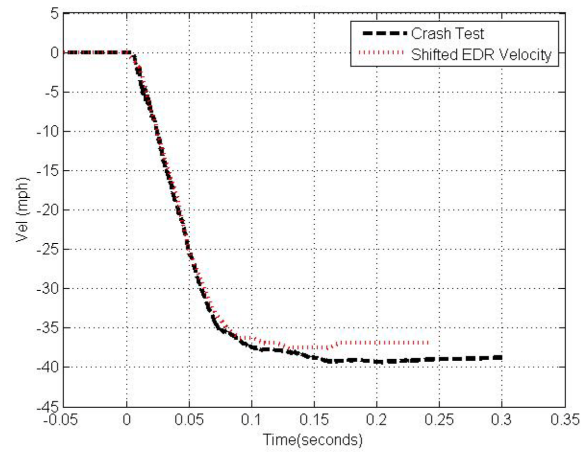


Figure 111. NHTSA test 5567: 2006 Hummer H3; Frontal (with EDR shift of 49.7ms)

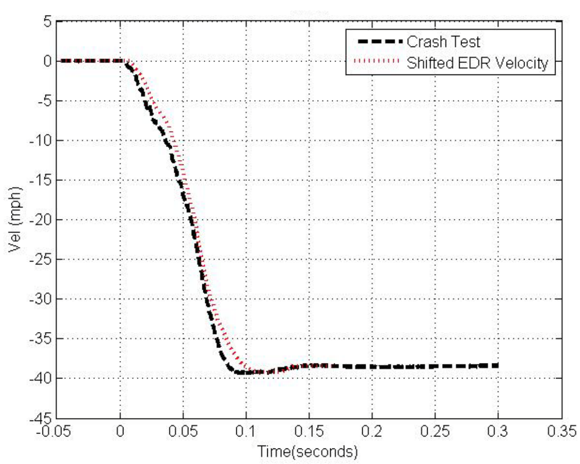


Figure 112. NHTSA test 5569: 2006 Cadillac DTS; Frontal (with EDR shift of 62.1ms)

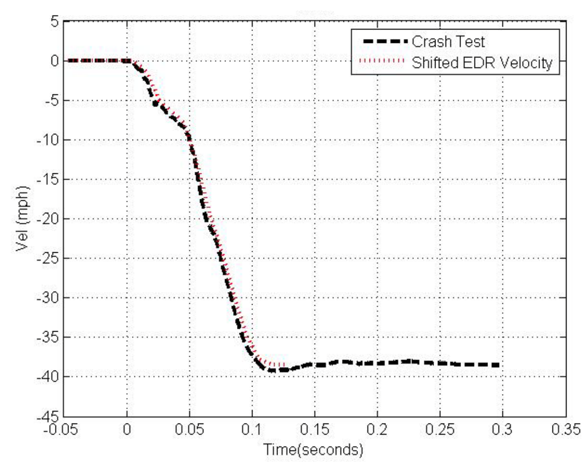


Figure 113. NHTSA test 5578: 2006 Chevrolet Monte Carlo; Frontal (with EDR shift of 54.3ms)

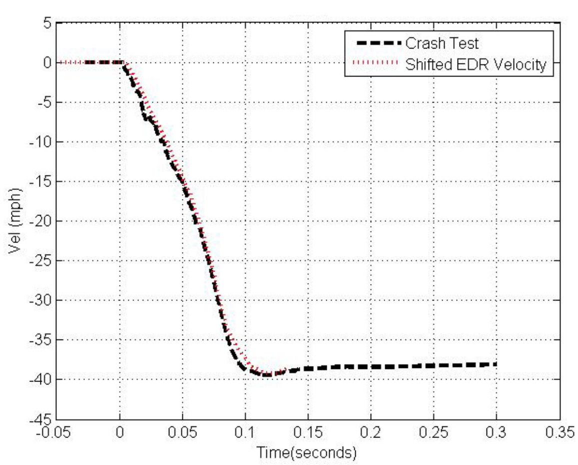


Figure 114. NHTSA test 5589: 2006 Buick Lucerne CX; Frontal (with EDR shift of 54.7ms)

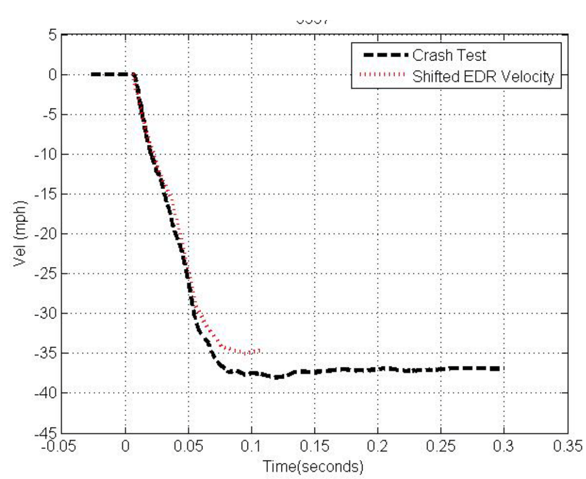


Figure 115. NHTSA test 5597: 2006 Chevrolet Colorado; Frontal (with EDR shift of -6.0ms)

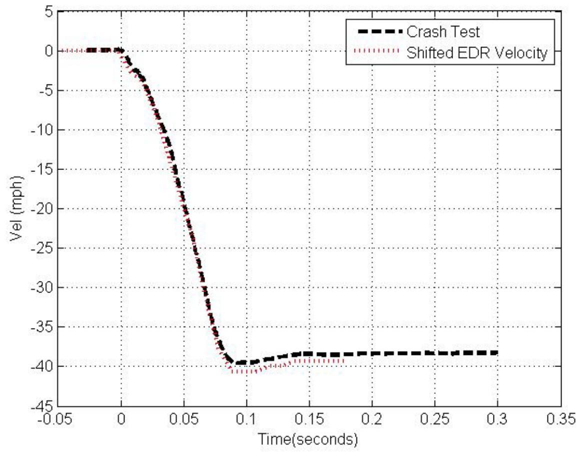


Figure 116. NHTSA test 5602: 2006 Chevrolet HHR; Frontal (with EDR shift of 62.3ms)

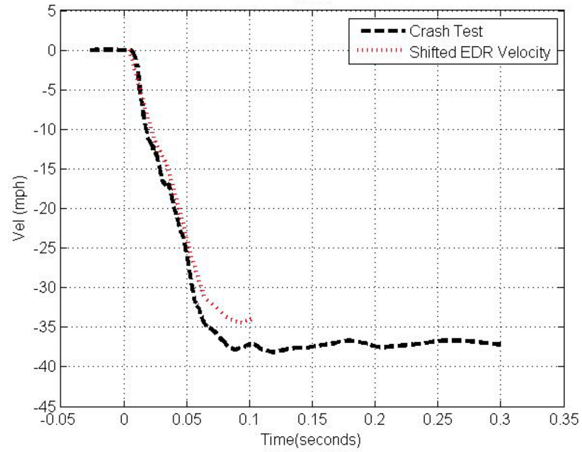


Figure 117. NHTSA test 5603: 2006 Chevy Colorado; Frontal (with EDR shift of -4.1ms)

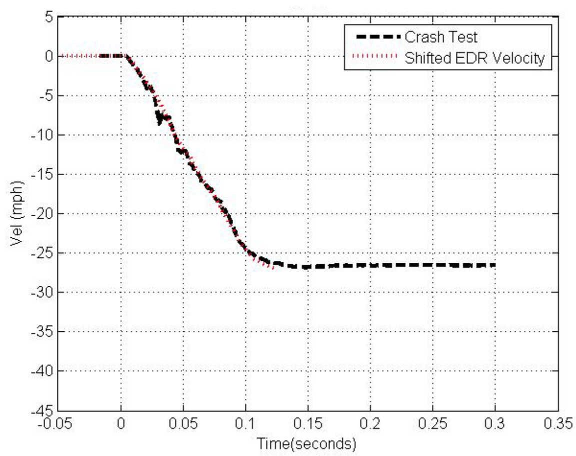


Figure 118. NHTSA test: 5741, 2006 Buick Lucerne; Frontal (with EDR shift of 54.9ms)

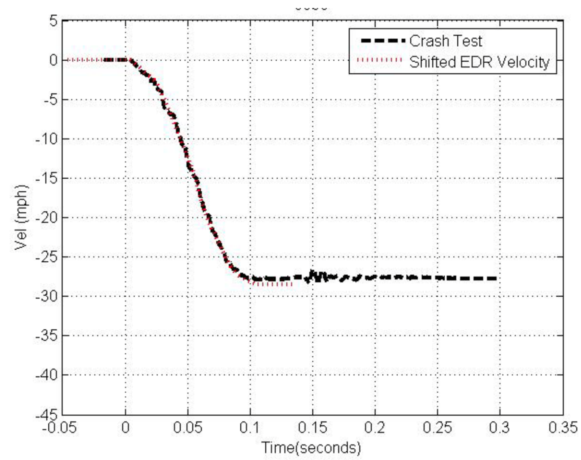


Figure 119. NHTSA test 5830: 2006 Pontiac G6; Frontal (with EDR shift of 45.9ms)

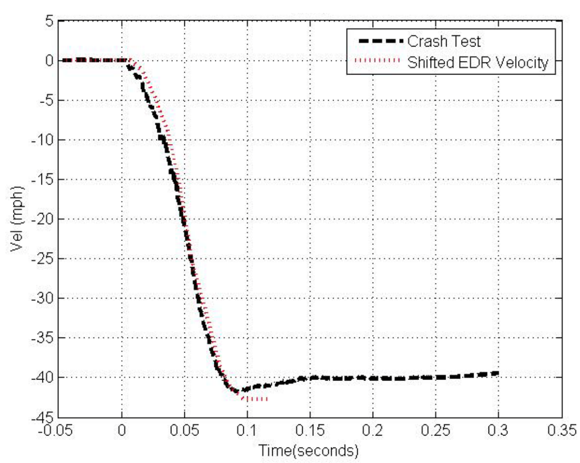


Figure 120. NHTSA test 5844: 2007 Saturn Aura, Frontal (with EDR shift of 43.2ms)

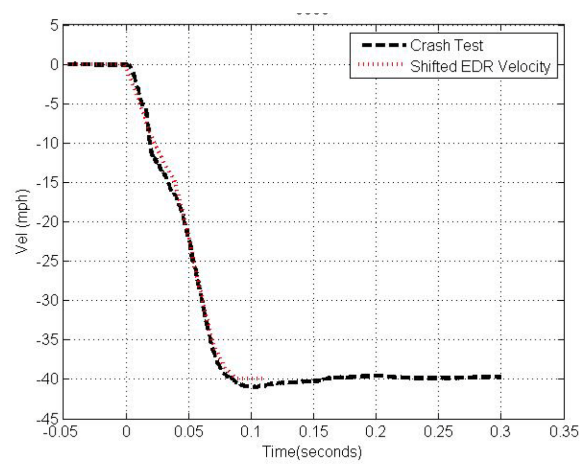


Figure 121. NHTSA test 5859: 2007 Pontiac Solstice; Frontal (with EDR shift of 61.1ms)

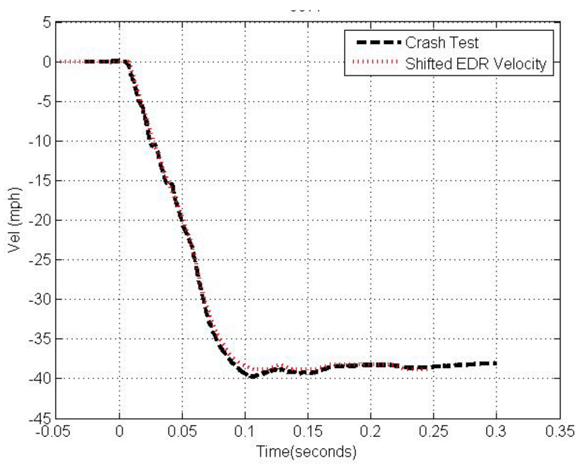


Figure 122. NHTSA test 5877: 2007 Chevrolet Silverado; Frontal (with EDR shift of 52.8ms)

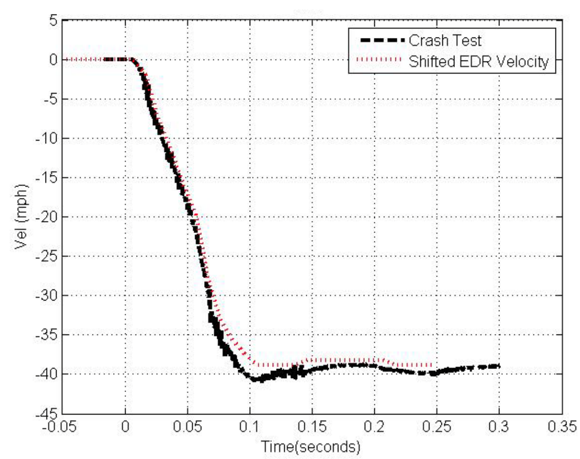


Figure 123. NHTSA test 5907: 2007 Chevrolet Silverado; Frontal (with EDR shift of 53.6ms)

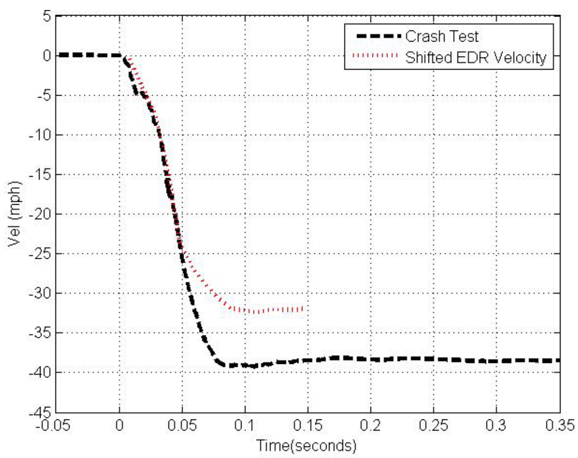


Figure 124. NHTSA test 5967: 2007 Jeep Patriot; Frontal (with EDR shift of -8.6ms)

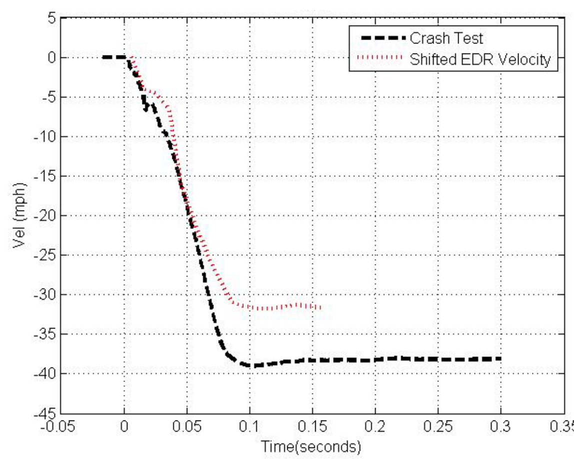


Figure 125. NHTSA test 6172: 2008 Dodge Caravan; Frontal (with EDR shift of -6.1ms)

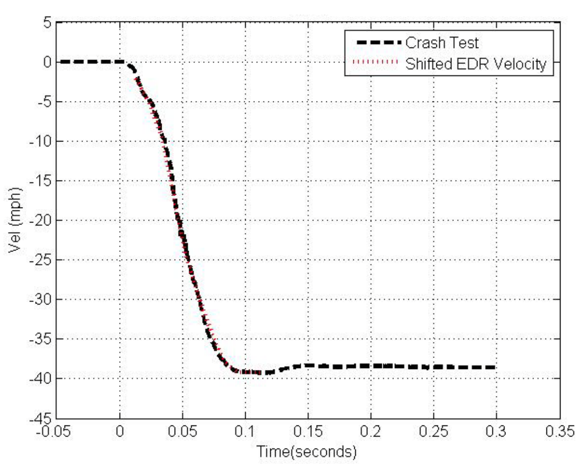


Figure 126. NHTSA test 6200: 2008 Saturn Vue; Frontal (with EDR shift of -13.1ms)

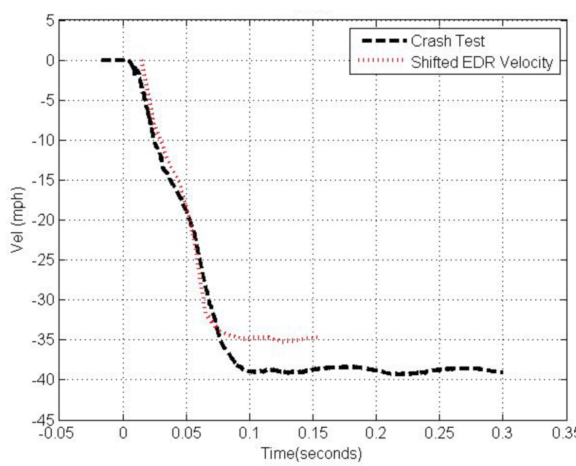


Figure 127. NHTSA test 6234: 2008 Dodge Dakota; Frontal (with EDR shift of -14.8ms)

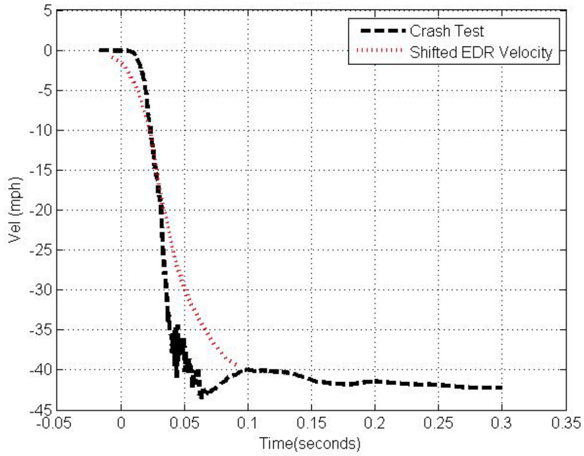


Figure 128. NHTSA test 6243: 2008 Ford Focus; Frontal (with EDR shift of 7.0ms)

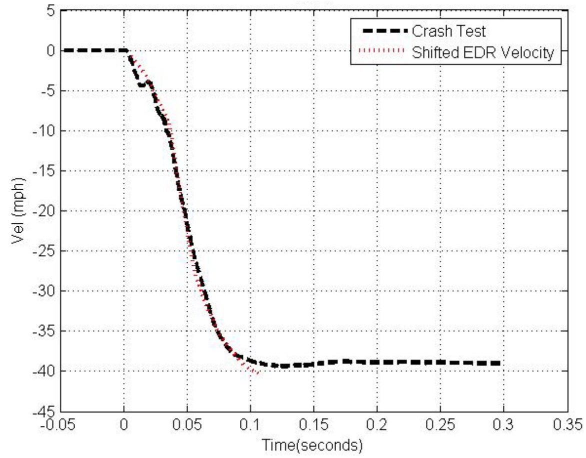


Figure 129. NHTSA test 6256: 2008 Ford Focus; Frontal (with EDR shift of -6.4 ms)

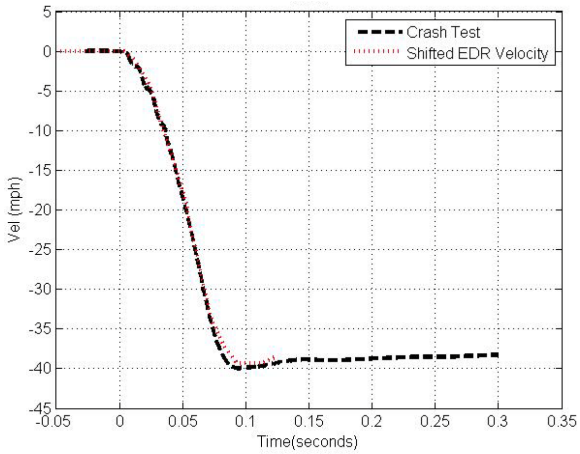


Figure 130. NHTSA test 6268: 2008 Chevrolet Malibu; Frontal (with EDR shift of 46.9ms)

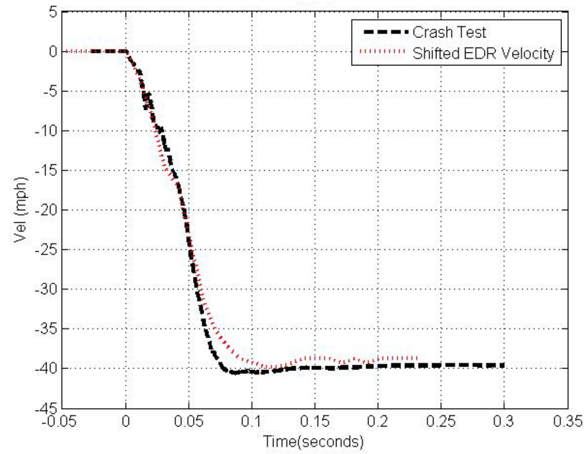


Figure 131. NHTSA test 6271: 2008 Cadillac CTS; Frontal (with EDR shift of 59.0ms)

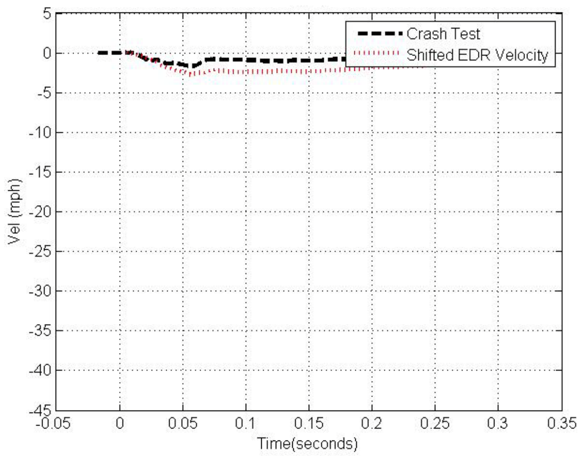


Figure 132. NHTSA test 6274: Dodge Grand Caravan SE; Side (with EDR shift of -5.9ms)

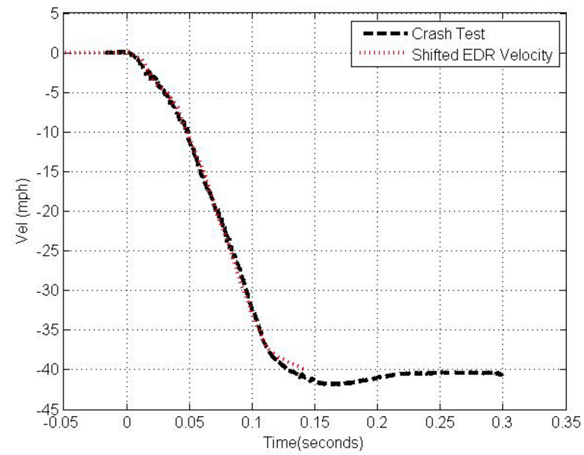


Figure 133. NHTSA test 6298: 2008 Saturn Outlook; 50% Front (with EDR shift of 48.9ms)

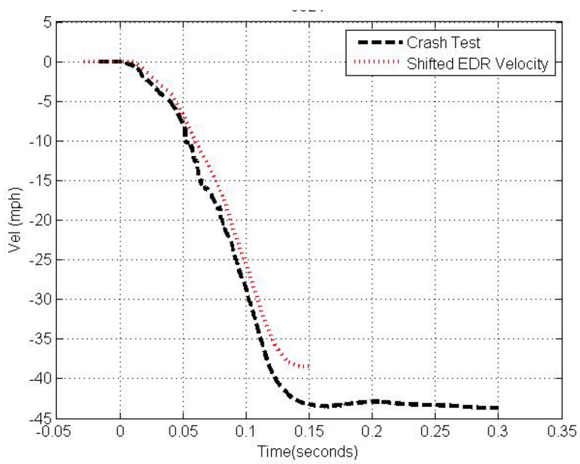


Figure 134. NHTSA test 6321: 2008 Saturn Outlook; 40% Front Offset (with EDR shift of 28.4ms)

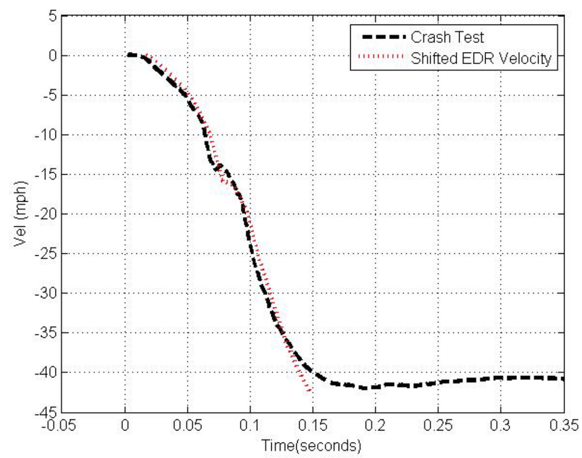


Figure 135. IIHS Test CEF0107: 2001 Chevy Silverado; Frontal Offset (with EDR shift of 7.5ms)

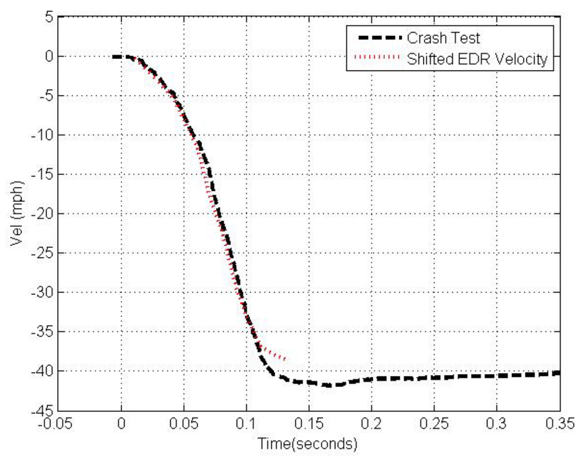


Figure 136. IIHS Test CEF0119: 2002 Chevy Trailblazer; Frontal Offset (with EDR shift of 1.1ms)

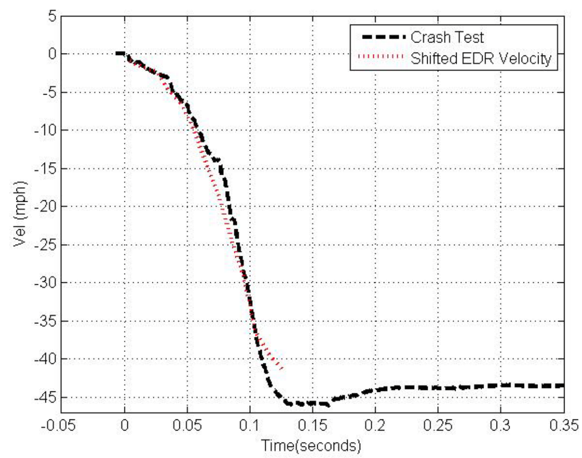


Figure 137. IIHS Test CEF0209: 2003 Cadillac CTS; Frontal Offset (with EDR shift of -5.3ms)

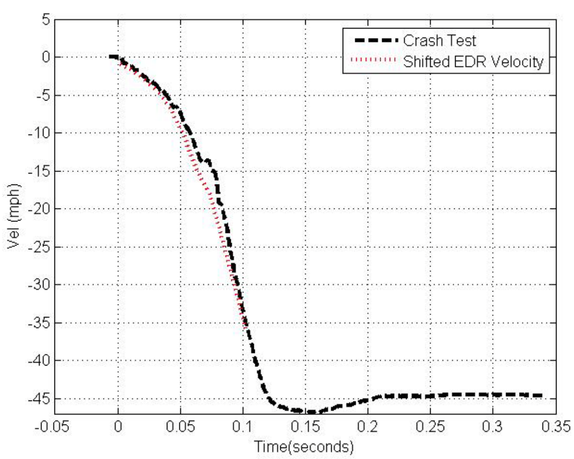


Figure 138. IIHS Test CEF0221: 2003 Cadillac CTS; Frontal Offset (with EDR shift of -7.7ms)

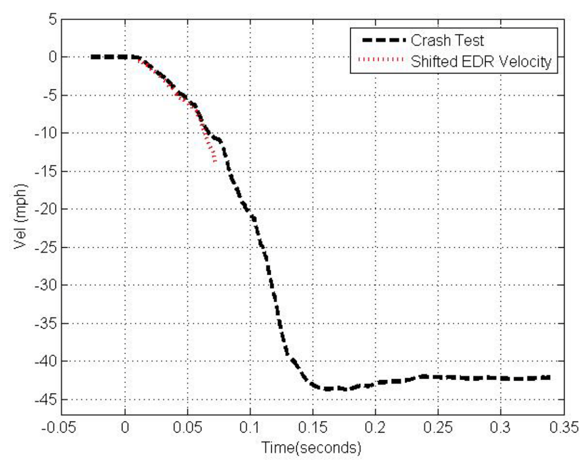


Figure 139. IIHS Test CEF0301: 2003 Lincoln Towncar; Frontal Offset (with EDR shift of 11.2 ms)

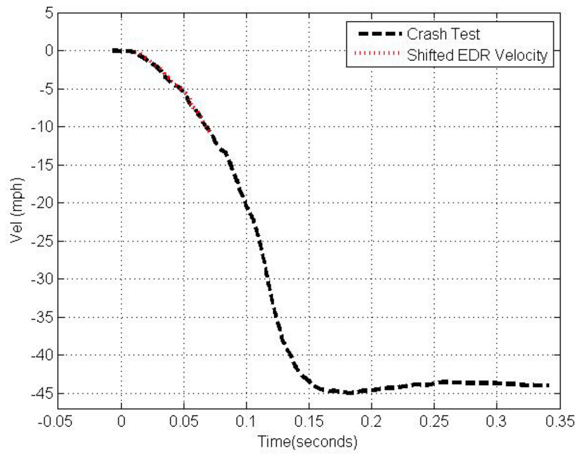


Figure 140. IIHS Test CEF0313: 2003 Lincoln Towncar; Frontal Offset (with EDR shift of 11.5 ms)

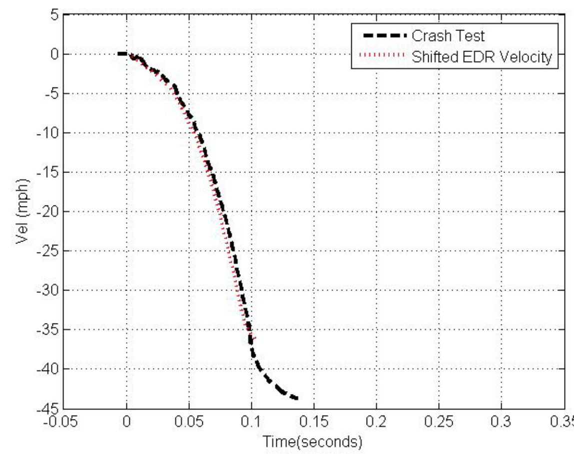


Figure 141. IIHS Test CEF0326: 2004 Cadillac SRX; Frontal Offset (with EDR shift of -10.9 ms)

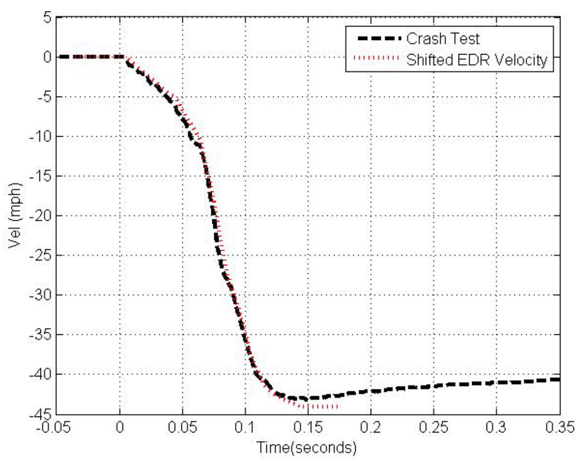


Figure 142. IIHS Test CEF0401: 2004 Chevrolet Malibu; Frontal Offset (with EDR shift of -2.9ms)

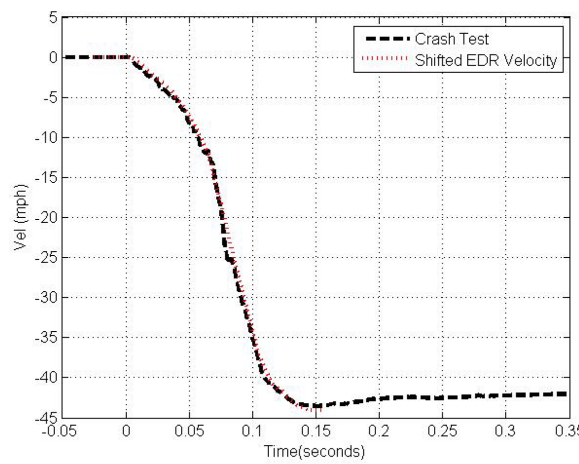


Figure 144. IIHS Test CEF0406: 2004 Chevrolet Malibu; Frontal Offset (with EDR shift of -4.2ms)

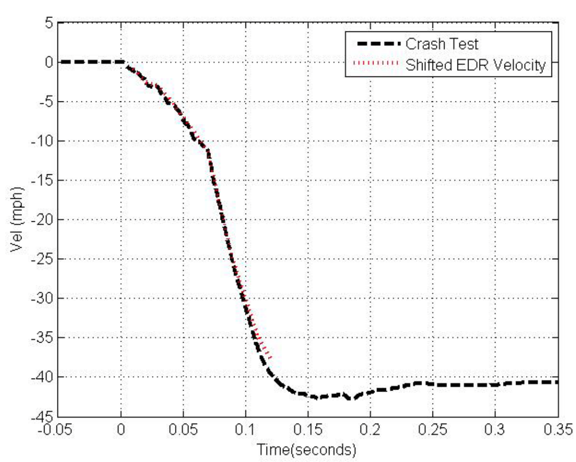


Figure 143. IIHS Test CEF0419: 2005 Saturn ION; Frontal Offset (with EDR shift of -1.1ms)

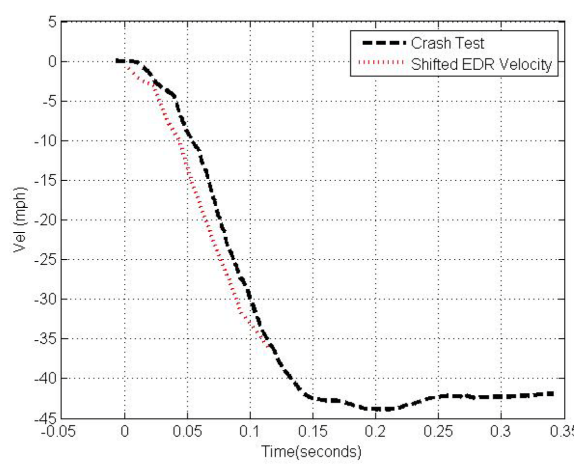


Figure 145. IIHS Test CEF0506: 2005 Chevrolet Colorado, Frontal Offset (with EDR shift of 6.4ms)

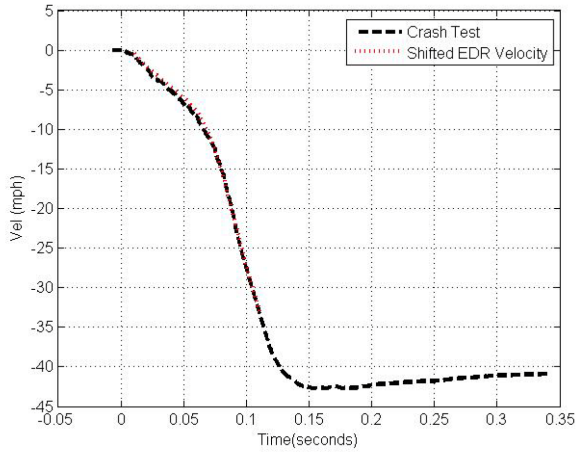


Figure 146. IIHS Test CEF0511: 2005 Buick LaCrosse; Frontal Offset (with EDR shift of -1.0ms)

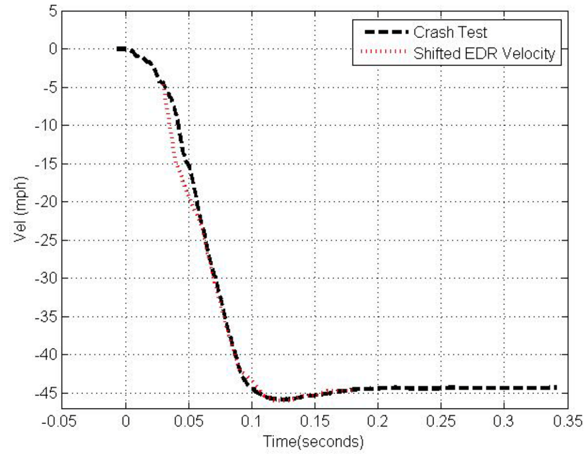


Figure 147. IIHS Test CF05003: 2004 Chevrolet Malibu; Pole Test (with EDR shift of 29.8ms)

APPENDIX C: VEHICLE MODEL AND MODEL YEAR BY EDR MODULE TYPE

This table includes the EDR module types validated in Chapter 2, and the vehicles and model years to which they correspond.

Table 46. EDR Module and Corresponding Vehicles and Model Years

CDR Module Name	GM Vehicle Make	Model Year
SDMGT2001	BUIC Lesabre/Wildcat/Centurion	2001
SDMGT2001	CHEV Caprice/Impala	2001
SDMGT2001	CHEV Monte Carlo(FWD)	2001
SDMGT2001	OLDS Aurora	2001
SDMGT2001	PONT Bonneville/Catalina	2001
SDMD2002	CHEV Lumina APV	2002
SDMD2002	OLDS Silhouette	2002
SDMD2002	PONT Trans Sport	2002
SDMDG2002	BUIC Rendezvous	2002
SDMDG2002	PONT Aztek	2002
SDMGF2002	CADI Deville/Fleetwood	2002
SDMGF2002	CADI Seville	2002
SDMGT2001	BUIC Lesabre/Wildcat/Centurion	2002
SDMGT2001	CHEV Caprice/Impala	2002
SDMGT2001	CHEV Monte Carlo(FWD)	2002
SDMGT2001	OLDS Aurora	2002
SDMGT2001	PONT Bonneville/Catalina	2002
SDMGT2002	CHEV Trail Blazer	2002
SDMGT2002	OLDS Bravada	2002
SDMGT2002	GMC Jimmy/S-15 based	2002
SDMD2002	CHEV Lumina APV	2003
SDMD2002	PONT Trans Sport	2003
SDMD2002	SATN Vue	2003
SDMDG2002	BUIC Rendezvous	2003
SDMDG2002	PONT Aztek	2003
SDMDW2003	PONT Grand Prix	2003
SDMDW2003	SATN Ion	2003
SDMGF2002	CADI Deville/Fleetwood	2003
SDMGF2002	CADI CTS	2003
SDMGF2002	CADI Escalade	2003
SDMGF2002	CHEV S-10 Blazer	2003
SDMGF2002	CHEV Fullsize Blazer	2003
SDMGF2002	CHEV Suburban	2003
SDMGF2002	CHEV G-series Van	2003
SDMGF2002	CHEV S-10	2003
SDMGF2002	CHEV C/K-series Pickup	2003
SDMGF2002	CHEV Avalanche	2003
SDMGF2002	GMC Jimmy fullsize	2003
SDMGF2002	GMC G-series Van	2003
SDMGF2002	GMC C,K,R,V-series P/U	2003
SDMGT2001	BUIC Lesabre/Wildcat/Centurion	2003
SDMGT2001	CHEV Caprice/Impala	2003
SDMGT2001	CHEV Monte Carlo(FWD)	2003
SDMGT2001	PONT Bonneville/Catalina	2003
SDMGT2002	CHEV Trail Blazer	2003
SDMGT2002	OLDS Bravada	2003
SDMGT2002	GMC Jimmy/S-15 based	2003
SDMDW2003	BUIC Rendezvous	2004
SDMDW2003	CHEV Lumina APV	2004
SDMDW2003	OLDS Silhouette	2004
SDMDW2003	PONT Grand Prix	2004
SDMDW2003	PONT Aztek	2004
SDMDW2003	PONT Trans Sport	2004
SDMDW2003	SATN Ion	2004
SDMGF2002	CADI Deville/Fleetwood	2004
SDMGF2002	CADI CTS	2004
SDMGF2002	CADI SRX	2004
SDMGF2002	CADI Escalade	2004
SDMGF2002	CADI Escalade ESV	2004
SDMGF2002	CHEV Fullsize Blazer	2004
SDMGF2002	CHEV Suburban	2004
SDMGF2002	CHEV G-series Van	2004
SDMGF2002	CHEV Colorado	2004
SDMGF2002	CHEV C/K-series Pickup	2004
SDMGF2002	CHEV Avalanche	2004
SDMGF2002	CHEV Other lt truck	2004
SDMGF2002	GMC Jimmy fullsize	2004
SDMGF2002	GMC C,K,R,V-series P/U	2004
SDMGT2001	BUIC Lesabre/Wildcat/Centurion	2004
SDMGT2001	CHEV Caprice/Impala	2004
SDMGT2001	CHEV Monte Carlo(FWD)	2004
SDMGT2001	PONT Bonneville/Catalina	2004
SDMGT2002	BUIC Rainier	2004
SDMGT2002	CHEV S-10 Blazer	2004
SDMGT2002	CHEV Trail Blazer	2004
SDMGT2002	GMC Jimmy/S-15 based	2004
Epsilon2005	CHEV Cobalt	2005
Epsilon2005	CHEV Malibu(97-)	2005
Epsilon2005	PONT G6	2005
SDMDS2005	BUIC Rainier	2005
SDMDS2005	CHEV Trail Blazer	2005
SDMDS2005	GMC Jimmy/S-15 based	2005
SDMDW2003	BUIC Lacrosse	2005
SDMDW2003	BUIC Rendezvous	2005
SDMDW2003	BUIC Terraza	2005
SDMDW2003	CHEV Equinox	2005
SDMDW2003	CHEV Lumina APV	2005
SDMDW2003	CHEV Uplander	2005
SDMDW2003	PONT Grand Prix	2005
SDMDW2003	PONT Trans Sport	2005
SDMDW2003	SATN Ion	2005
SDMDW2003	SATN Vue	2005

CDR Module Name	GM Vehicle Make	Model Year
SDMDW2003	SATN Relay	2005
SDMGF2002	AM Hummer	2005
SDMGF2002	CADI Deville/Fleetwood	2005
SDMGF2002	CADI CTS	2005
SDMGF2002	CHEV S-10 Blazer	2005
SDMGF2002	CHEV Fullsize Blazer	2005
SDMGF2002	CHEV Suburban	2005
SDMGF2002	CHEV G-series Van	2005
SDMGF2002	CHEV Colorado	2005
SDMGF2002	CHEV C/K-series Pickup	2005
SDMGF2002	CHEV Avalanche	2005
SDMGF2002	GMC Jimmy fullsize	2005
SDMGF2002	GMC C,K,R,V-series P/U	2005
SDMGT2001	BUIC Lesabre/Wildcat/Centurion	2005
SDMGT2001	CHEV Caprice/Impala	2005
SDMGT2001	CHEV Monte Carlo(FWD)	2005
SDMGT2001	PONT Bonneville/Catalina	2005
Epsilon2006	CADI STS	2006
Epsilon2006	CHEV Cobalt	2006
Epsilon2006	CHEV HHR	2006
Epsilon2006	CHEV Malibu(97-)	2006
Epsilon2006	PONT G6	2006
Epsilon2006	PONT Soltice	2006
SDMC2006	BUIC Lucerne	2006
SDMC2006	CHEV Caprice/Impala	2006
SDMDS2005	BUIC Rainier	2006
SDMDS2005	BUIC Terraza	2006
SDMDS2005	CHEV Trail Blazer	2006
SDMDW2003	BUIC Lacrosse	2006
SDMDW2003	BUIC Rendezvous	2006
SDMDW2003	CHEV Equinox	2006
SDMDW2003	PONT Grand Prix	2006
SDMDW2003	PONT Torrent	2006
SDMDW2003	SATN Ion	2006
SDMGF2002	CADI CTS	2006
SDMGF2002	CHEV Fullsize Blazer	2006
SDMGF2002	CHEV Colorado	2006
SDMGF2002	CHEV C/K-series Pickup	2006
Epsilon2006	SATN Aura	2007
SDMC2006	CHEV C/K-series Pickup	2007
Epsilon2006	CHEV Cobalt	2008
Epsilon2006	CHEV HHR	2008
SDMC2006	BUIC Enclave	2008
SDMC2006	CHEV Caprice/Impala	2008
SDMC2006	CHEV C/K-series Pickup	2008
SDMDW2003	PONT Grand Prix	2008
SDMGF2002	CHEV Colorado	2008

APPENDIX D: PRETENSIONER PRESENCE BY VEHICLE MODEL AND MODEL YEAR

This appendix includes the make, model and model year of the vehicles included in the 359 case dataset from Chapter 3. The presence of a pretensioner is indicated by an "X". Pretensioner presence was determined using the Holmatro (2007) manual.

Table 47. Presence of Pretensior based on Vehicle Make/Model and Model Year

Vehicle Make and Model	Model Year	Pretensioner Present
BUIC Lesabre/Wildcat/Centurion	2001	
CHEV Caprice/Impala	2001	
CHEV Monte Carlo(FWD)	2001	
PONT Bonneville/Catalina	2001	
BUIC Lesabre/Wildcat/Centurion	2002	
BUIC Rendezvous	2002	
CADI Seville	2002	X
CHEV Caprice/Impala	2002	
CHEV Monte Carlo(FWD)	2002	
CHEV Trail Blazer	2002	
CHEV Lumina APV	2002	X
OLDS Aurora	2002	
OLDS Silhouette	2002	X
PONT Bonneville/Catalina	2002	
PONT Aztek	2002	
PONT Trans Sport	2002	X
GMC Jimmy/S-15 based	2002	
BUIC Lesabre/Wildcat/Centurion	2003	
BUIC Rendezvous	2003	
CADI Deville/Fleetwood	2003	X
CADI CTS	2003	X
CADI Escalade	2003	
CHEV Caprice/Impala	2003	
CHEV Monte Carlo(FWD)	2003	
CHEV Trail Blazer	2003	
CHEV Fullsize Blazer	2003	
CHEV Suburban	2003	
CHEV Lumina APV	2003	X
CHEV G-series Van	2003	X
CHEV S-10	2003	
CHEV C/K-series Pickup	2003	
CHEV Avalanche	2003	
PONT Bonneville/Catalina	2003	
PONT Aztek	2003	
PONT Trans Sport	2003	X
GMC Jimmy/S-15 based	2003	
GMC Jimmy fullsize	2003	
GMC C,K,R,V-series P/U	2003	
SATN Ion	2003	X
SATN Vue	2003	
BUIC Lesabre/Wildcat/Centurion	2004	
BUIC Rendezvous	2004	X
CADI Deville/Fleetwood	2004	X

Vehicle Make and Model	Model Year	Pretensioner Present
CADI CTS	2004	X
CADI Escalade	2004	
CADI Escalade ESV	2004	
CHEV Caprice/Impala	2004	
CHEV Monte Carlo(FWD)	2004	
CHEV S-10 Blazer	2004	
CHEV Trail Blazer	2004	
CHEV Fullsize Blazer	2004	
CHEV Suburban	2004	
CHEV Lumina APV	2004	X
CHEV G-series Van	2004	X
CHEV Colorado	2004	X
CHEV C/K-series Pickup	2004	
CHEV Avalanche	2004	
OLDS Silhouette	2004	X
PONT Grand Prix	2004	
PONT Aztek	2004	
PONT Trans Sport	2004	X
GMC Jimmy/S-15 based	2004	
GMC Jimmy fullsize	2004	
GMC C,K,R,V-series P/U	2004	
SATN Ion	2004	X
BUIC Lesabre/Wildcat/Centurion	2005	
BUIC Lacrosse	2005	X
BUIC Rendezvous	2005	X
CADI CTS	2005	X
CHEV Caprice/Impala	2005	
CHEV Cobalt	2005	X
CHEV Monte Carlo(FWD)	2005	
CHEV Malibu(97-)	2005	X
CHEV Equinox	2005	X
CHEV Fullsize Blazer	2005	
CHEV Suburban	2005	
CHEV Lumina APV	2005	X
CHEV Uplander	2005	X
CHEV G-series Van	2005	X
CHEV Colorado	2005	X
CHEV C/K-series Pickup	2005	
CHEV Avalanche	2005	
PONT Bonneville/Catalina	2005	
PONT Grand Prix	2005	
PONT G6	2005	X
PONT Trans Sport	2005	X

Vehicle Make and Model	Model Year	Pretensioner Present
GMC Jimmy fullsize	2005	
GMC C,K,R,V-series P/U	2005	
SATN Ion	2005	**X**
SATN Vue	2005	**X**
SATN Relay	2005	**X**
BUIC Lacrosse	2006	**X**
BUIC Rendezvous	2006	**X**
BUIC Rainier	2006	**X**
BUIC Terraza	2006	**X**
CADI CTS	2006	**X**
CHEV Caprice/Impala	2006	**X**
CHEV Cobalt	2006	**X**
CHEV HHR	2006	**X**
CHEV Malibu(97-)	2006	**X**
CHEV Equinox	2006	**X**
CHEV Colorado	2006	**X**
CHEV C/K-series Pickup	2006	
PONT Grand Prix	2006	
PONT G6	2006	**X**
PONT Torrent	2006	**X**
SATN Ion	2006	**X**
CHEV C/K-series Pickup	2007	**X**
SATN Aura	2007	**X**
CHEV Caprice/Impala	2008	**X**
CHEV Cobalt	2008	**X**
CHEV HHR	2008	**X**
CHEV Colorado	2008	**X**
CHEV C/K-series Pickup	2008	**X**
PONT Grand Prix	2008	**X**