

# Event Data Recorders in Toyota Vehicles

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## Abstract

Increasingly, vehicle manufacturers are developing tools which allow access to data stored on on-board event data recorders (EDR). The information stored by such devices have the potential for providing levels of insight into crashes well beyond that achievable with conventional collision reconstruction techniques. The current work identifies the nature of the stored data that can be retrieved from the on-board event data recorders in Toyota vehicles, and evaluates the accuracy of the crash pulse data based on information obtained from frontal crash tests. An overview of the pre-crash and crash-pulse data provided by Toyota EDR's is presented. The accuracy of the crash-pulse data is explored from a series of staged collisions with EDR-equipped vehicles. Data downloaded from the EDR's are compared to equivalent information captured by laboratory instrumentation. Full-frontal crash tests, over a range of test speeds, and conducted on a number of different model vehicles, are used in the study.

## Résumé

De plus en plus, les constructeurs de véhicules conçoivent des outils qui donnent accès à des données stockées sur des enregistreurs de données routières (EDR) se trouvant à bord. Les données stockées sur ces dispositifs peuvent offrir des niveaux de précision sur les collisions de loin supérieurs à ceux que permettent d'atteindre les techniques conventionnelles de reconstitution des collisions. Les travaux actuels permettent de déterminer la nature des données stockées qui peuvent être retrouvées à partir des enregistreurs de données routières se trouvant à bord de véhicules de marque Toyota, et d'évaluer l'exactitude des données selon les renseignements obtenus à partir de tests de collision frontale. On présente un aperçu des données sur l'impulsion des pré-collisions et des collisions fournies par Toyota. On explore l'exactitude des données sur l'impulsion des collisions à partir d'une série d'essais de collisions menés avec des véhicules équipés d'EDR. Les données obtenues des EDR sont comparables aux renseignements équivalents obtenus à l'aide d'appareils de laboratoires. L'étude a mené des essais de collision frontale sur une gamme de vitesses d'essais et à l'aide d'un certain nombre de modèles différents de véhicules.

## Introduction

Event data recorders capture information about the status of various vehicle safety systems, such as seat belt use and air bag deployment; details of pre-crash driver actions such as inputs to the throttle and brake; and the nature of the crash pulse in the form of the vehicle's velocity change and/or acceleration time history. [1]

The objective collision data provided by EDR's have proven useful to a variety of interest groups, including automobile manufacturers, government regulators, safety researchers, law enforcement personnel, vehicle insurers, and the legal community. The data have allowed vehicle safety systems to be refined, vehicle regulations to be enhanced, safety-related defects to be identified and corrected, and have provided the basis for the resolution of court cases and insurance claims. [2]

General Motors Corporation (GM) pioneered the installation of EDR's in its vehicles, and was the first manufacturer to provide access to the data captured by these devices through a publicly-available crash data retrieval (CDR) tool. [3] In 2003, Ford Motor Company was the second manufacturer to adopt the CDR system for its EDR's. Subsequently, in 2008, Chrysler announced its use of the same tool for the EDR's in its vehicles.

Toyota started phasing EDR's into certain of its vehicles in 2001, and all vehicles from the 2007 model year forward are equipped with these devices. [4] While the large majority of Toyota and Lexus vehicles have EDR's equipped to record both pre-crash and crash-phase data, several models have units that do not capture any pre-crash data. By the end of 2010, all newly-manufactured Toyota and Lexus vehicles were equipped with EDR's that record both pre-crash and crash-phase data.

While a publicly-available crash data retrieval tool is not yet available for use with Toyota EDR's, the company has provided prototype units to both Transport Canada and the National Highway Traffic Administration (NHTSA). It is one of the units provided to Transport Canada that has facilitated the present work to compare crash pulses recorded by EDR's installed in vehicles subject to crash testing to equivalent data captured by laboratory instrumentation.

Similar research conducted on General Motors' vehicles has been reported previously [5], while other prior work has included both GM and Toyota vehicles. [6,7].

## Toyota Event Data Recorders

Toyota categorizes the EDR's installed in its vehicles as either Type A or Type B. Both types of EDR provide similar information; however, there are subtle differences in some of the data elements. In addition, the reports produced for the two EDR's are in different formats. Extracts from exemplar reports of both EDR types are shown in Figures 1-3.

## IMAGING TOOL REPORT

### Event Data

INVESTIGATION DATE	03/29/2010
INVESTIGATOR	
ACCIDENT DATE	
VEHICLE	
MODEL YEAR	2010
VIN NUMBER	
Tool Version(download)	
Tool Version(display)	Ver.1.5.1.0

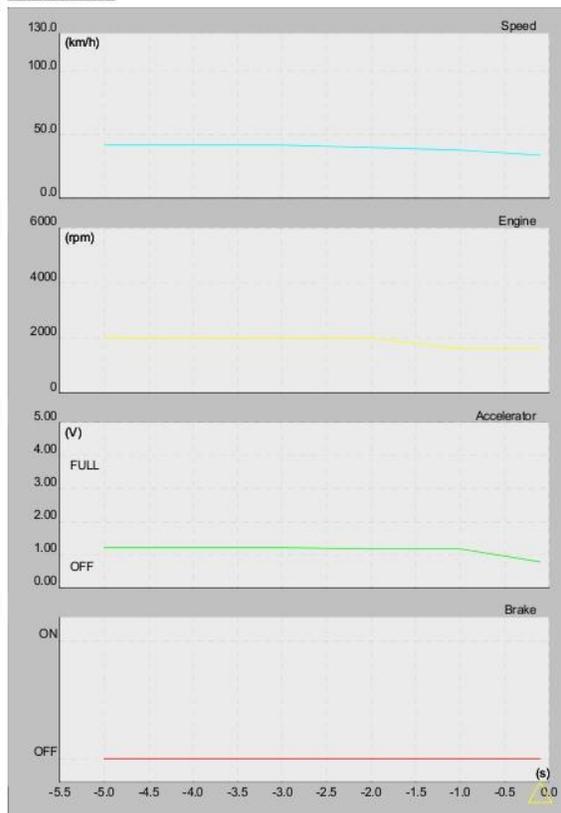
### Graph Data

Latest/Frozen	PAGE1
Freeze Signal	Freeze
Record Status	Recorded

### Individual Data

Data Name	Data
Time From Previous Event	880 ms
Time From Last PreCrash Data	900 ms
Pre-Crash Data Flag	ON ON ON ON ON ON
Shift Position	Drive(The shift position is in any forward drive gear. For example, D or 1 or 2 or 3.)
Seat Position Driver	RW
Belt Switch Status Driver	Belted
Belt Switch Status Passenger	UnBelted
Occupant Detection Passenger	Unoccupied
PAB-Manual Cut OFF(N/A)	(N/A)
Ignition Cycles	0 times
Lamp On Term	0 minutes
Diag Code	00 00 00 00 00 00 00 00 00 00
Event counter	2
Writing Flag	Finished Writing

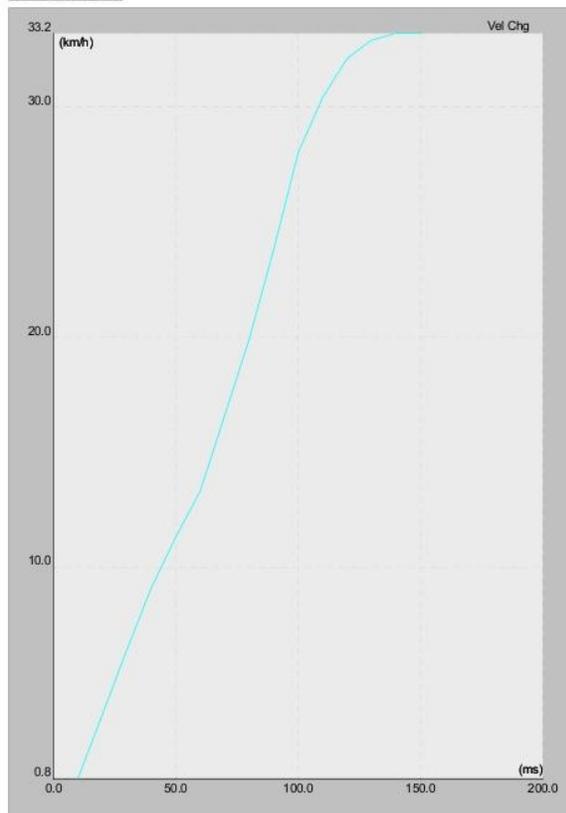
### Pre-Crash Data



### Pre-Crash Data

s	Speed	Engine	Accelerator	Brake	s	Speed	Engine	Accelerator	Brake
-5.0	42.0	2000	1.21	OFF	-0.1	34.0	1600	0.78	OFF
-4.0	42.0	2000	1.21	OFF					
-3.0	42.0	2000	1.21	OFF					
-2.0	40.0	2000	1.17	OFF					
-1.0	38.0	1600	1.17	OFF					

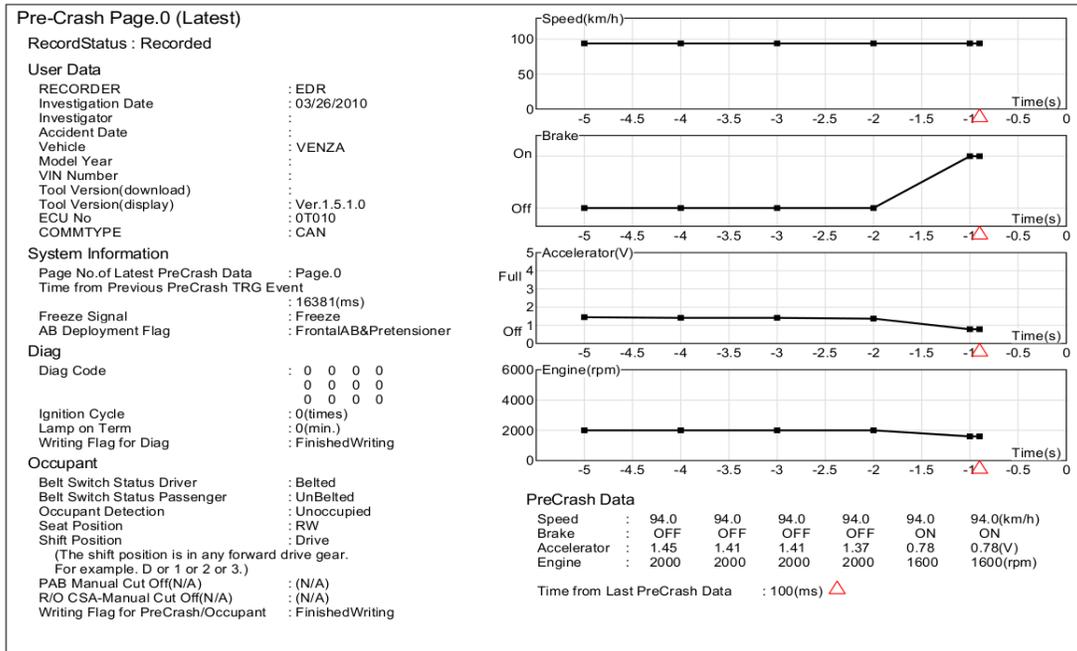
### Post-Crash Data



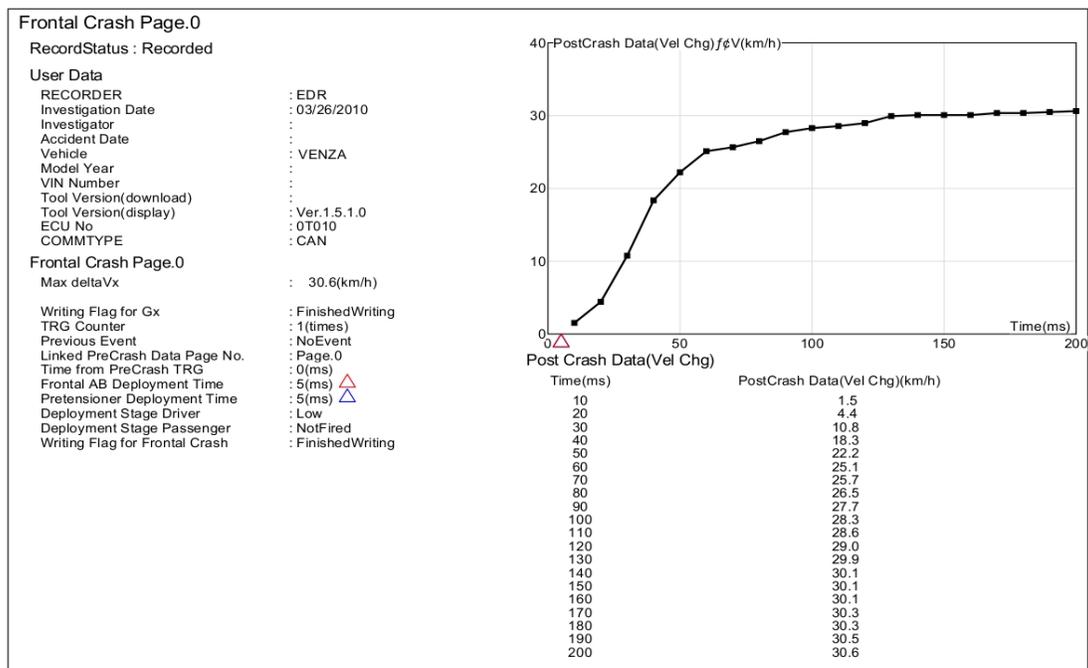
### Post-Crash Data

ms	Vel Chg	ms	Vel Chg	ms	Vel Chg
10.0	0.8	60.0	13.3	110.0	30.4
20.0	3.6	70.0	16.6	120.0	32.1
30.0	6.4	80.0	19.9	130.0	32.9
40.0	9.1	90.0	23.8	140.0	33.2
50.0	11.3	100.0	28.0	150.0	33.2

**Figure 1. Pre-Crash and Longitudinal Crash Pulse Data from a 2010 Toyota Corolla (Type A EDR)**



**Figure 2. Pre-Crash Data from a 2009 Toyota Venza (Type B EDR)**



**Figure 3. Crash Pulse Data from a 2009 Toyota Venza (Type B EDR)**

Type A modules can record up to three frontal events: (1) the latest/frozen, (2) the next most recent, and (3) the past maximum delta-V. Depending on the precise vehicle specifications, these units may also record one side collision event and one rollover event.

Type B modules can record two events: (1) the latest, and (2) the next most recent. Each of these events can store data on one frontal crash, one side crash, and one rollover. A third event will overwrite the first event regardless of delta-V.

Any deployment of a pyrotechnic device, i.e. an air bag or a seat belt pre-tensioner, will send a freeze signal to the EDR and the stored files are labelled with an event counter which is displayed in the report.

Both Type A and Type B reports contain identification data, vehicle data, pre-crash data (however, not all Type A units record pre-crash information), deployment data, and post-crash delta-V.

Identification Data: Each EDR report contains identification data, some of which is optionally entered by the collision investigator, such as the investigator's name, the date of the investigation, and that of the collision, the vehicle year, model, and Vehicle Identification Number (VIN). The software automatically records the version number used to download the EDR, and that of the software being used to produce the report.

Vehicle Data: Stored data include the transmission shift position (P, N, R, D), the driver's seat position (FW [forward], RW [rearward]), the seat belt switch status for both driver and passenger (Belted, UnBelted), and the occupant detection status for the passenger (Adult, Child, AM50 [50<sup>th</sup> percentile male], AF05 [5<sup>th</sup> percentile female], Unoccupied).

Pre-crash Data: Data elements include vehicle speed (maximum value for Type A is 126 km/h, maximum value for Type B is 122 km/h, resolution is 2 km/h), brake status (ON, OFF), accelerator position (OFF, MIDDLE, FULL or 0 to 4.96 volts) and engine speed (in 400 RPM increments).

Deployment Data: The firing time (milliseconds) for air bag deployment is recorded together with the deployment stage for both the driver and passenger bags (Not Fired, Extra Low, Low, High). A count of ignition cycles may also be provided; however this is not a continuous counter, it is simply a record of the number of key cycles after a diagnostic fault code has been detected.

Post-crash Delta-V: Type A modules record delta-V over a period of 150 ms, at 10 ms intervals, while Type B modules record for 200 ms at 10 ms intervals.

Where no data are recorded for any specific data element, the EDR report indicates that the parameter is in its "Initial State".

## Crash Test Methodology

Vehicle acceleration data were obtained from a series of staged collisions conducted by Transport Canada that involved Toyota vehicles equipped with event data recorders. Four vehicle models were used for the present work, the 2005 Camry, the 2009-10 Corolla, and the 2009 Matrix and Venza. Full frontal rigid barrier (FFRB) crash tests were conducted at speeds of 40, 48 or 56 km/h. In the following table, these tests are designated as FFRB(40), FFRB(48) and FFRB(56), respectively.

Test No.	Test Vehicle	Test Protocol	Test Speed (km/h)
TC05-202	2005 Toyota Camry	FFRB(40)	40.42
TC05-119	2005 Toyota Camry	FFRB(48)	47.93
TC05-203	2005 Toyota Camry	FFRB(56)	56.06
TC09-243	2009 Toyota Corolla	FFRB(40)	40.36
TC10-211	2010 Toyota Corolla	FFRB(40)	40.26
TC09-244	2009 Toyota Corolla	FFRB(48)	47.85
TC10-149	2010 Toyota Corolla	FFRB(48)	47.97
TC09-245	2009 Toyota Corolla	FFRB(56)	56.07
TC09-220	2009 Toyota Matrix	FFRB(40)	40.27
TC09-145	2009 Toyota Matrix	FFRB(48)	47.70
TC09-219	2009 Toyota Matrix	FFRB(48)	48.01
TC09-262	2009 Toyota Matrix XRS	FFRB(48)	47.91
TC09-261	2009 Toyota Matrix XRS	FFRB(56)	55.80
TC09-146	2009 Toyota Venza	FFRB(48)	47.96

**Figure 4. Crash Test Matrix**

The instrumentation used for the staged collisions conducted at Transport Canada's Motor Vehicle Test Centre included accelerometers with a sampling frequency of 10 kHz. The test vehicle was instrumented with several such accelerometers, the most relevant of which, for the present purposes, were units mounted on the floor at the base of the left and right B-pillars, and on the central tunnel, at the vehicle's centre of gravity. These three accelerometers were in the closest proximity to the vehicle's original-equipment event data recorder which was located on the vehicle's centreline, ahead of the transmission selector lever.

A tape switch mounted on the vehicle's front bumper was used to establish the time of first contact with the barrier structure. The impact speed of the vehicle was captured by means of an external speed trap.



**Figure 5. 2005 Toyota Camry (TC05-119)**



**Figure 6. 2009 Toyota Matrix (TC09-220)**

All the data from the laboratory instrumentation were sampled over 400 ms, and subsequently filtered in accordance with SAE Recommended Practice J221-1. [8] For each test vehicle, the acceleration data were integrated to provide the vehicle's change in velocity (delta-V) over each 10 ms time increment of the crash. The equivalent changes in velocity recorded by the on-board EDR were retrieved from each vehicle using Toyota's Read Out Tool (ROT).

## Crash Test Results

In the following charts, the vehicle's delta-V computed from the accelerometer installed at the vehicle's centre of gravity is annotated in the form TC05-202\_CG\_DV, where TC05-202 refers to the number assigned to a specific crash test. Similarly, the delta-V computed from the accelerometer mounted at the left-side B-pillar is designated as TC05-202\_LS\_DV, and that from the accelerometer mounted at the right-side B-pillar as TC05-202\_RS\_DV.

## Pre-Crash Data

The pre-crash speed of each test vehicle, as recorded by the test centre's speed trap and, where available, the speed at  $t = -1$  s stored in the EDR's pre-crash data, are compared in Figure 7. The differences in initial speed range between 0.20 km/h and -2.27 km/h. The average difference in measured speed in the test series is -1.65 km/h (-3.57%) which is in line with the stated 2 km/h resolution of the pre-crash speeds captured by the EDR.

The vehicle EDR's also provided a range of data elements relating to the pre-crash status of the test dummies as vehicle occupants, and of the disposition of the vehicles' air bag systems. These data are shown in Figure 8 where the dummies used in the crash tests are referred to as Female (5<sup>th</sup> percentile female) and Male (50<sup>th</sup> percentile male).

All of the crash tests were run with both dummies, driver and passenger, being fully restrained. In general, the vehicle's seat was placed forward of centre for the 5<sup>th</sup> percentile female dummy, and rearward of centre for a 50<sup>th</sup> percentile male dummy. The exceptions were Tests TC09-262, TC10-149 and TC10-211 where 5<sup>th</sup> percentile female dummies were located in rearward seating positions.

Test No.	Test Vehicle	Test Speed (km/h)	EDR Speed at t -1s (km/h)	Difference (km/h)	Difference (%)
TC05-202	2005 Toyota Camry	40.42			
TC05-119	2005 Toyota Camry	47.93			
TC05-203	2005 Toyota Camry	56.06			
TC09-243	2009 Toyota Corolla	40.36	40	-0.36	-0.89
TC10-211	2010 Toyota Corolla	40.26	38	-2.26	-5.61
TC09-244	2009 Toyota Corolla	47.85	46	-1.85	-3.87
TC10-149	2010 Toyota Corolla	47.97	46	-1.97	-4.11
TC09-245	2009 Toyota Corolla	56.07	54	-2.07	-3.69
TC09-220	2009 Toyota Matrix	40.27	38	-2.27	-5.64
TC09-145	2009 Toyota Matrix	47.70	46	-1.70	-3.56
TC09-219	2009 Toyota Matrix	48.01	46	-2.01	-4.19
TC09-262	2009 Toyota Matrix XRS	47.91	46	-1.91	-3.99
TC09-261	2009 Toyota Matrix XRS	55.80	56	0.20	0.36
TC09-146	2009 Toyota Venza	47.96	46	-1.96	-4.09
			Average	-1.65	-3.57

**Figure 7. Pre-Crash Vehicle Speeds**

Test No.	Test Dummy		Seat Position Driver	Belt Switch		Occupant Detection Passenger	Air Bag Deployment		
	Driver	Passenger		Driver	Passenger		Time (ms)	Stage Driver	Stage Passenger
TC05-202	Female	Female	FW	Belted	Belted	AF05	8	ExLo	Hi
TC05-119	Female	Female	FW	Belted	Belted	AF05	8	ExLo	Hi
TC05-203	Female	Female	FW	Belted	Belted	AF05	4	ExLo	Hi
TC09-243	Female	Female	FW	Belted	Belted	Invalid	8	ExLo	ExLo
TC10-211	Female	Female	RW	Belted	Belted	Adult	8	Hi	Hi
TC09-244	Female	Female	FW	Belted	Belted	Invalid	6	ExLo	ExLo
TC10-149	Female	Female	RW	Belted	Belted	Adult	8	Hi	Hi
TC09-245	Female	Female	FW	Belted	Belted	Invalid	6	ExLo	ExLo
TC09-220	Female	Female	FW	Belted	Belted	Invalid	6	ExLo	Hi
TC09-145	Male	Male	RW	Belted	Belted	Adult	6	Hi	Hi
TC09-219	Female	Female	FW	Belted	Belted	Invalid	4	ExLo	Hi
TC09-262	Female	Female	RW	Belted	Belted	Adult	4	Hi	Hi
TC09-261	Female	Female	FW	Belted	Belted	Invalid	6	ExLo	Hi
TC09-146	Male	Male	RW	Belted	Belted	AM50	6	Hi	Hi

**Figure 8. Air Bag Deployment and Pre-Crash Setup**

In all cases, the seat belt status was reported by the EDR as belted, which is entirely consistent with Transport Canada's test procedure. Similarly, the drivers' seat positions were correctly identified, with the two 50<sup>th</sup> percentile males noted as being rearward of centre, nine of the 5<sup>th</sup> percentile female dummies being located forward of centre, and the three noted exceptions where 5<sup>th</sup> percentile female dummies were located in seats rearward of centre.

Where the occupant detection status for the passenger was reported as either AF05 or AM50, the dummies used in the tests were identified correctly as 5<sup>th</sup> percentile females or 50<sup>th</sup> percentile males, respectively.

The results in four of the tests, where the passenger was classified in the EDR report as Adult were mixed. This designation should have referred to the 50<sup>th</sup> percentile male dummy; however, while this was the case for a single test, the 5<sup>th</sup> percentile female dummy was being used in the three other tests. In six other tests, the occupant detection status was reported as Invalid.

The above-noted discrepancies appear to be the result of errors present in the version of the data retrieval software that was used to interpret and report on the current EDR files. For example, an earlier version of the software, operating on the same data files, provided different results for the "Invalid" category, classifying these occupants as AF05 and thus indicating the 5<sup>th</sup> percentile female which is correct.

## **Air Bag Deployment**

Where 5<sup>th</sup> percentile female dummies were located in forward seating positions, the air bag deployment stage used was reported as ExLo (extra low). In the cases where either 50<sup>th</sup> percentile male dummies or 5<sup>th</sup> percentile female dummies occupied rearward positioned driver seats, the EDR's reported the air bag deployment stage as Hi (high).

The use of the lower-power deployments for forward of centre seating positions evidently reflects the closer proximity of these drivers to the air bag modules located in the steering wheel assembly.

Air bag deployment times in all of the crash tests in the present series were extremely short, ranging between 4 and 8 ms. Such low firing times have been noted previously in staged crashes with rigid barriers. [9]

## **Delta-V**

The change in velocity obtained from the EDR in each test vehicle is plotted against the changes in velocity computed from the accelerations recorded by the laboratory instrumentation in Figures 9-22.

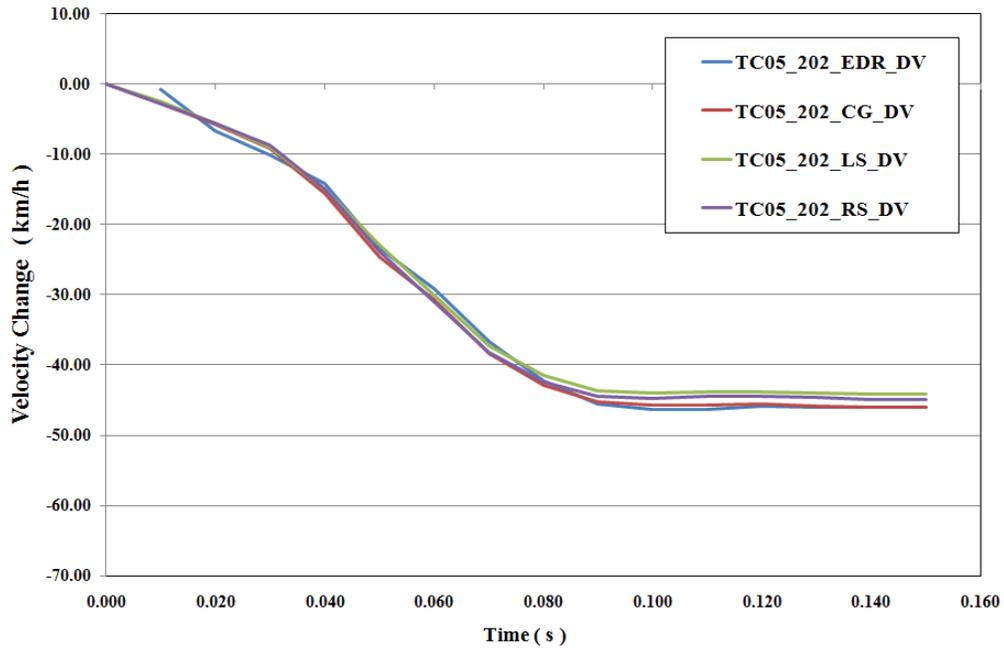


Figure 9. 2005 Toyota Camry (TC05-202)

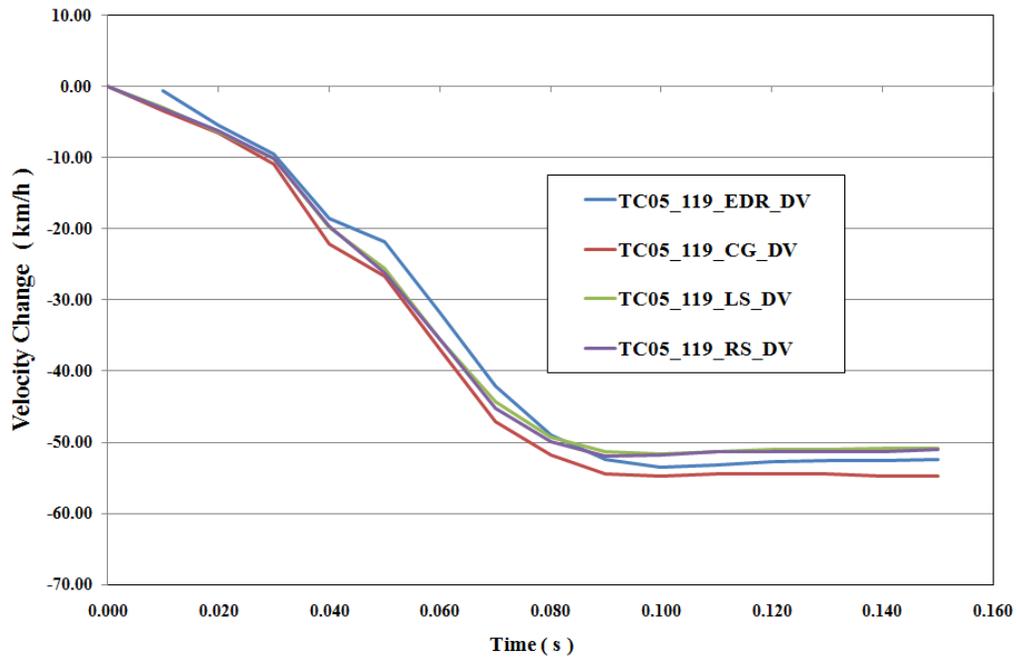
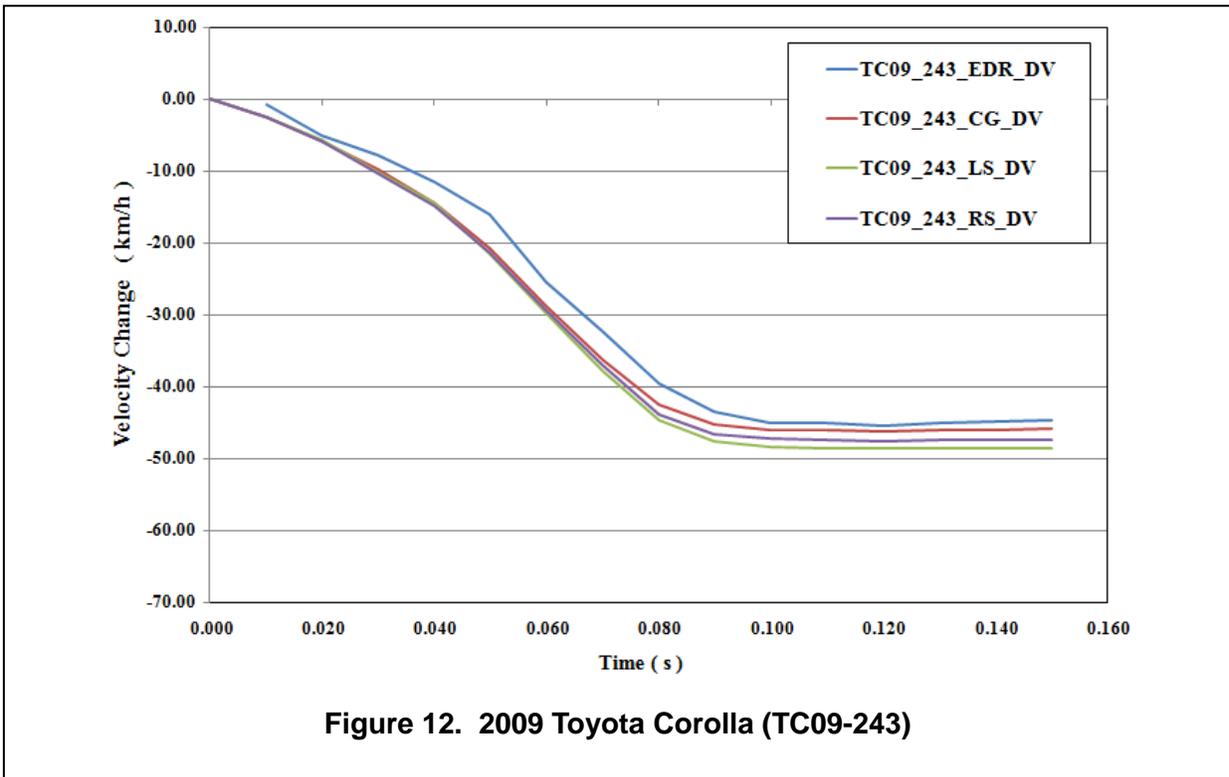
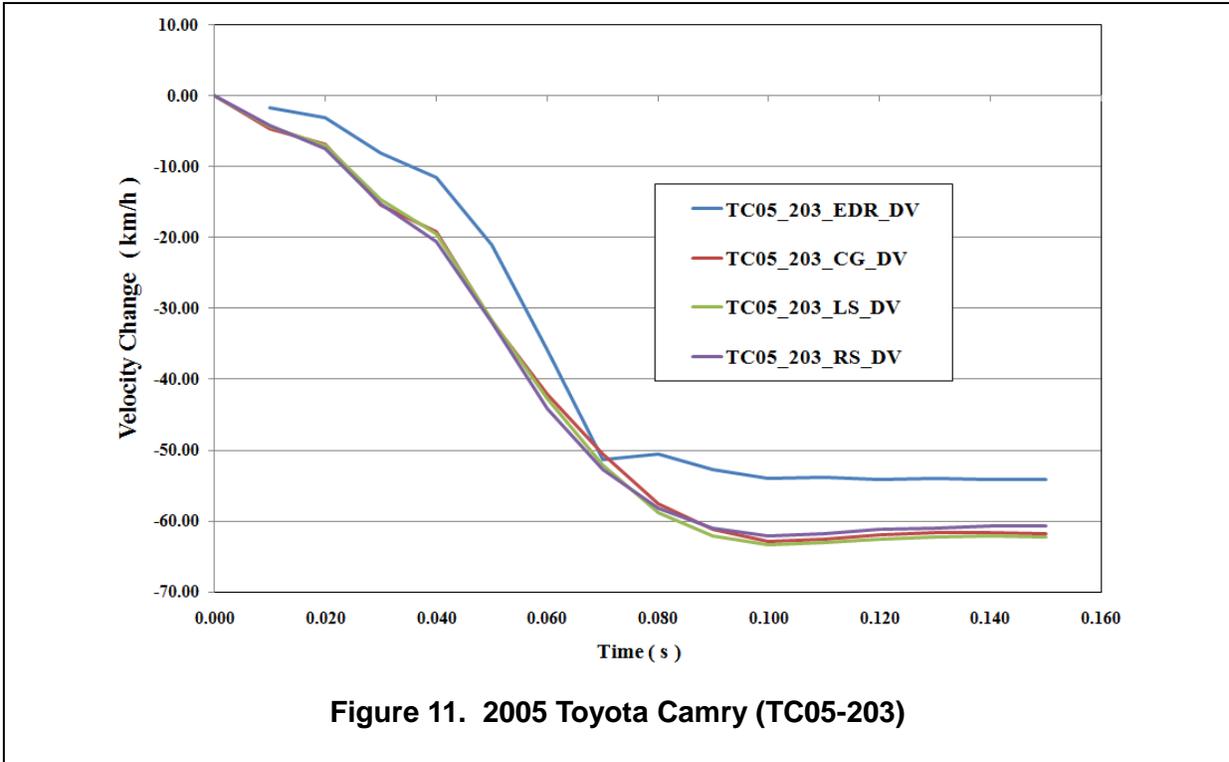


Figure 10. 2005 Toyota Camry (TC05-119)



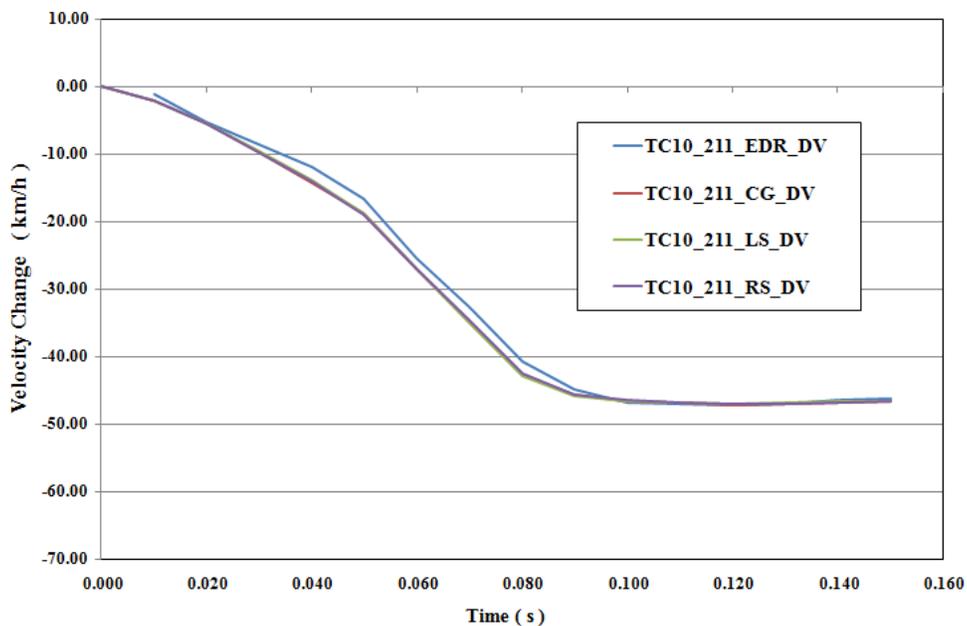


Figure 13. 2010 Toyota Corolla (TC10-211)

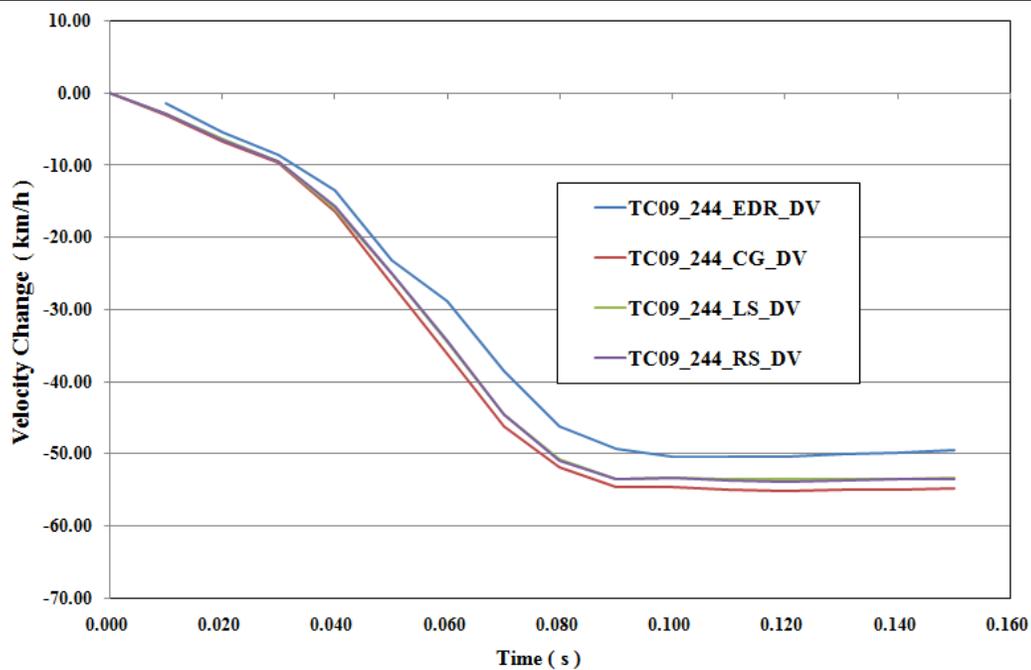
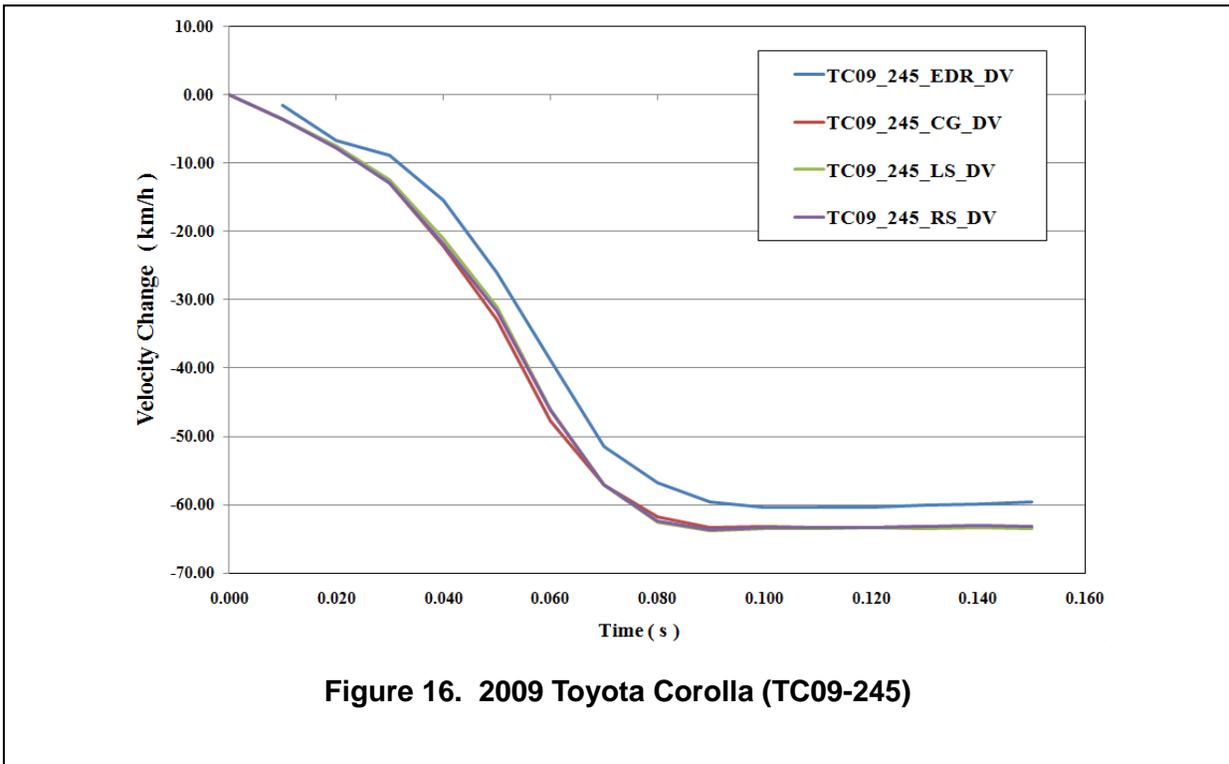
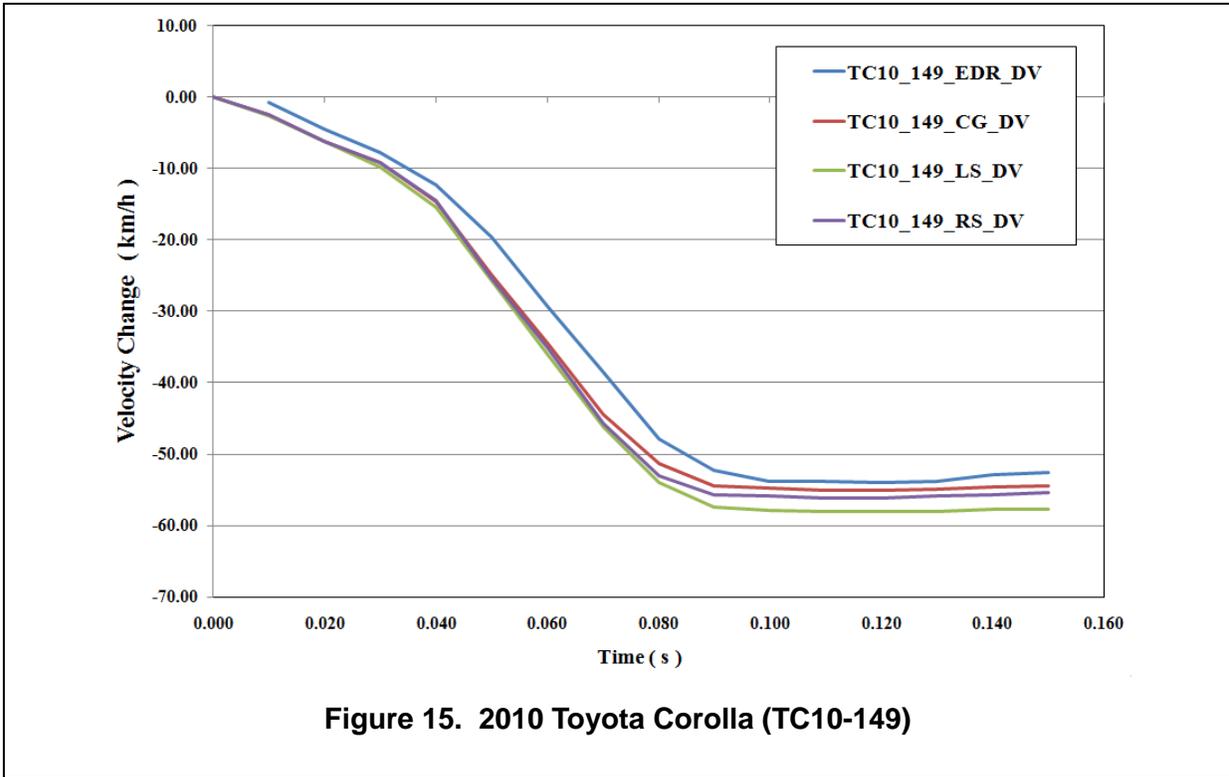


Figure 14. 2009 Toyota Corolla (TC09-244)



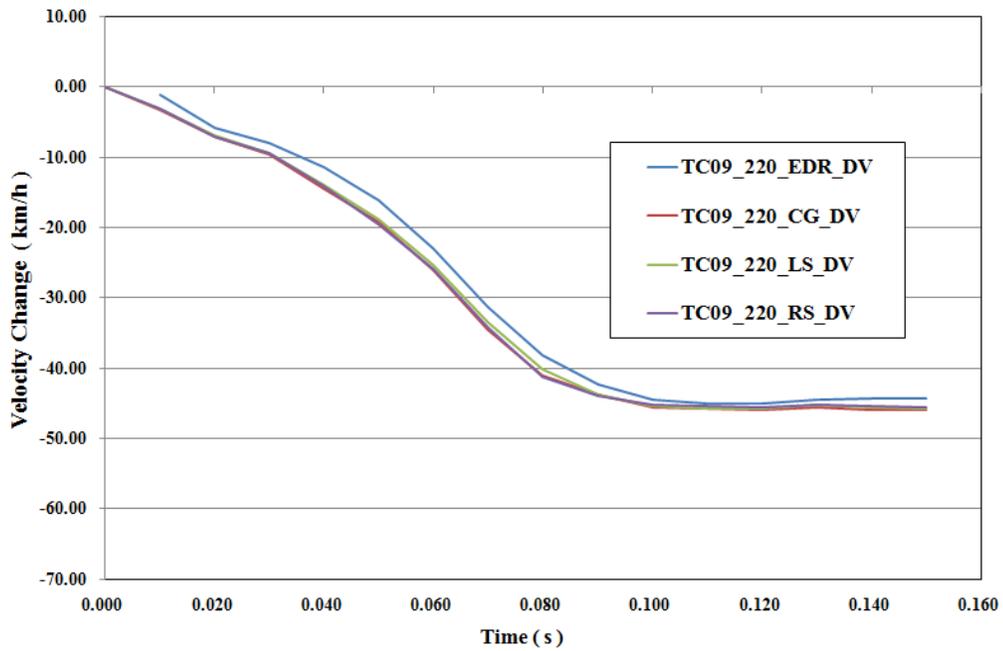


Figure 17. 2009 Toyota Matrix (TC09-220)

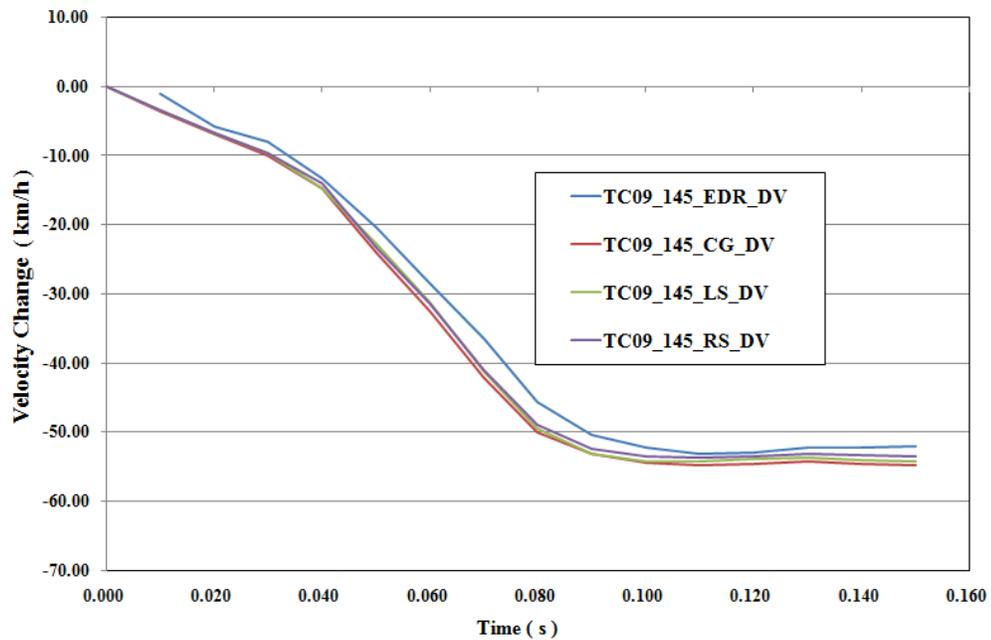
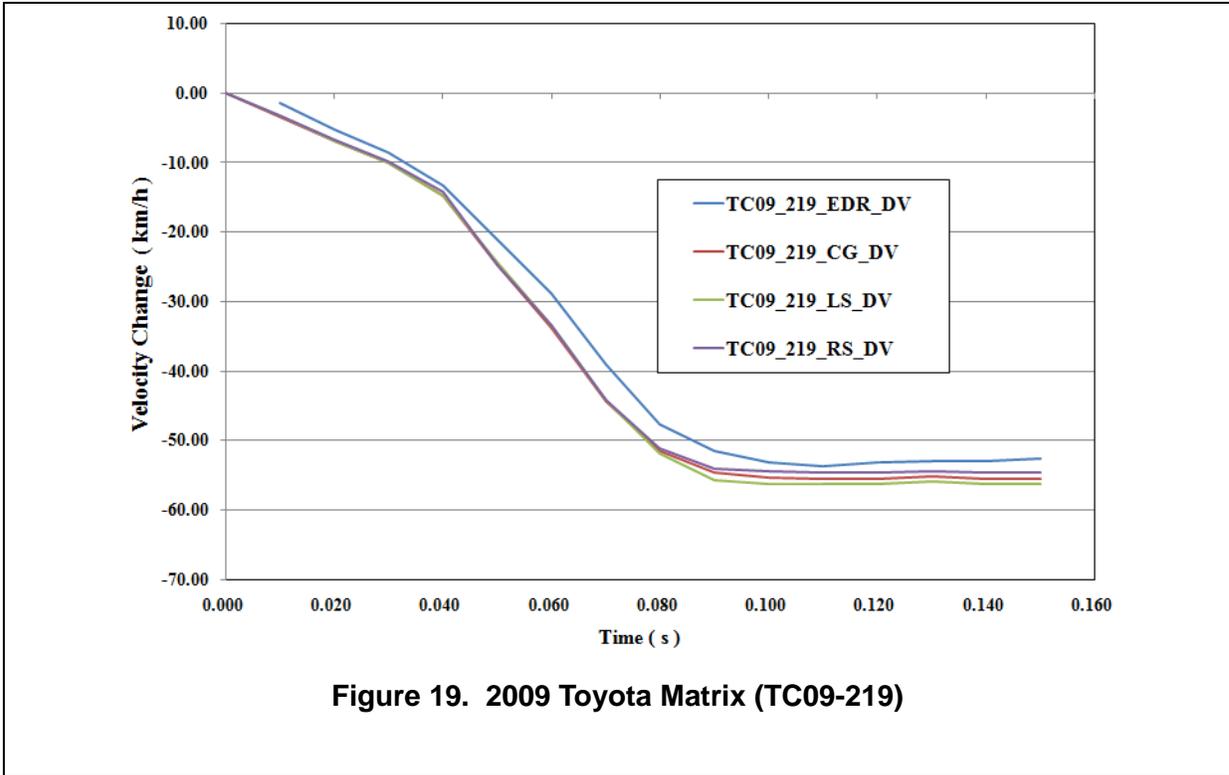
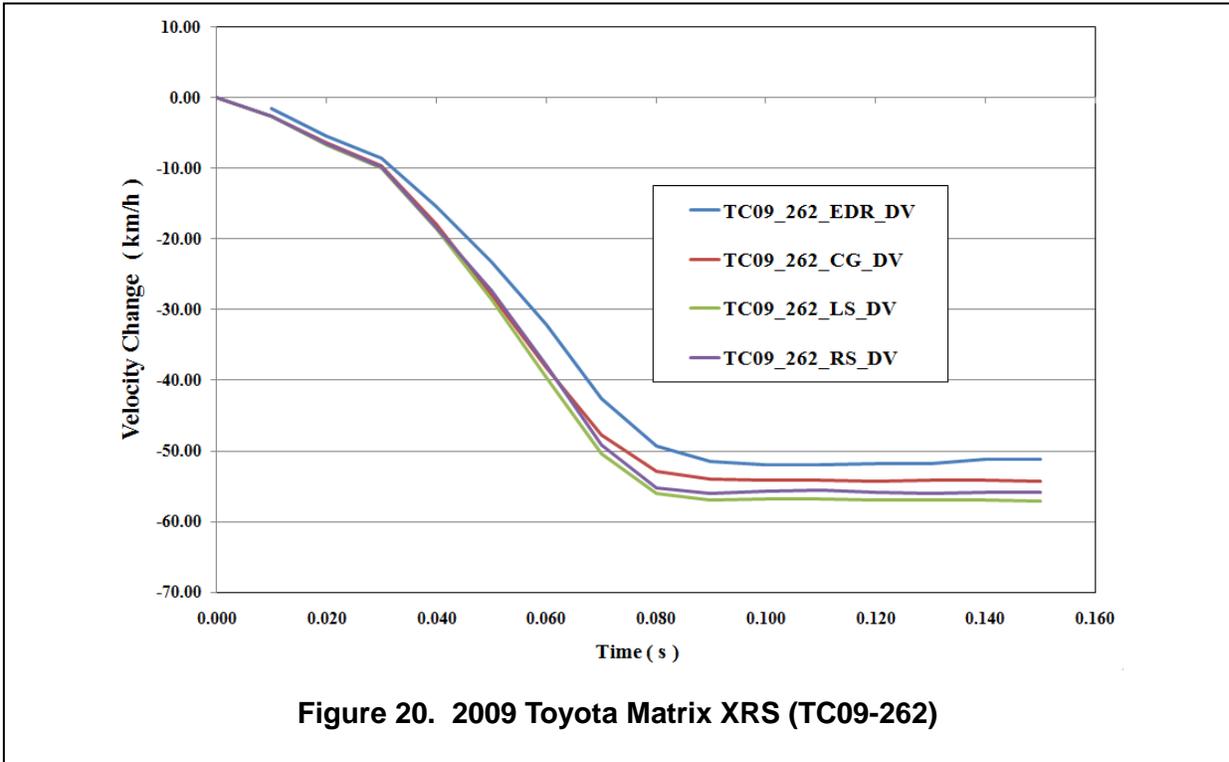


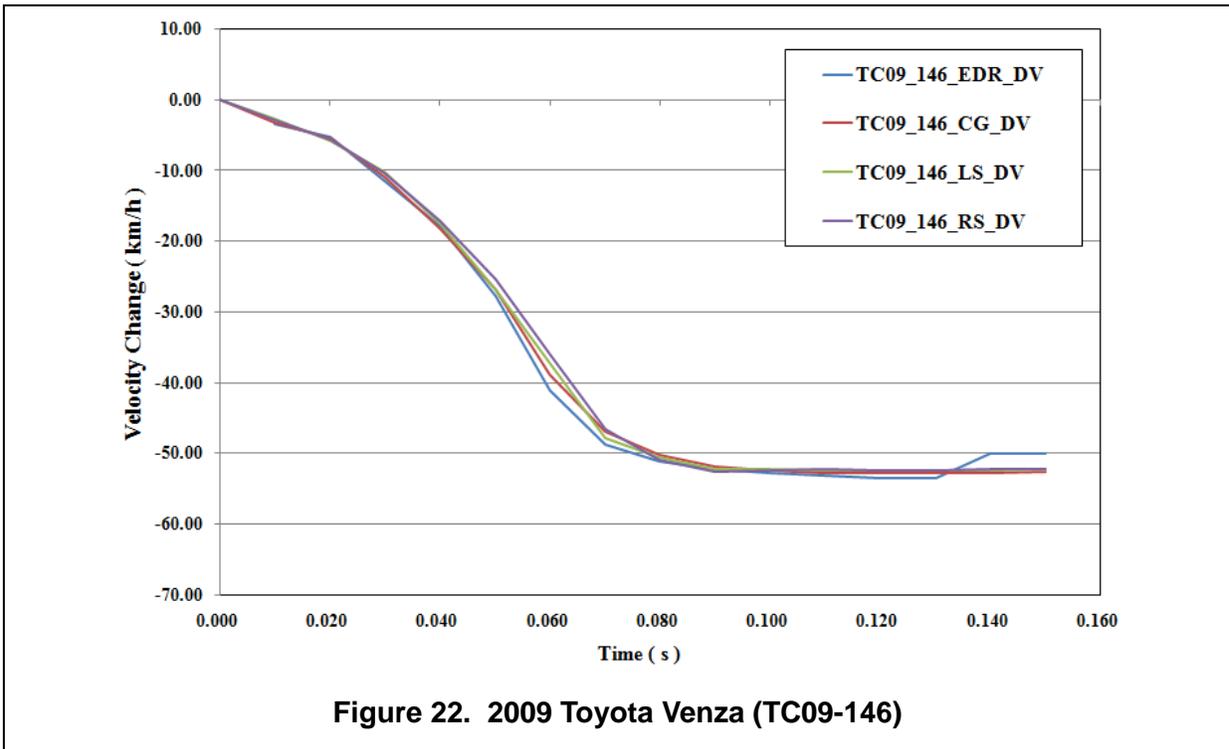
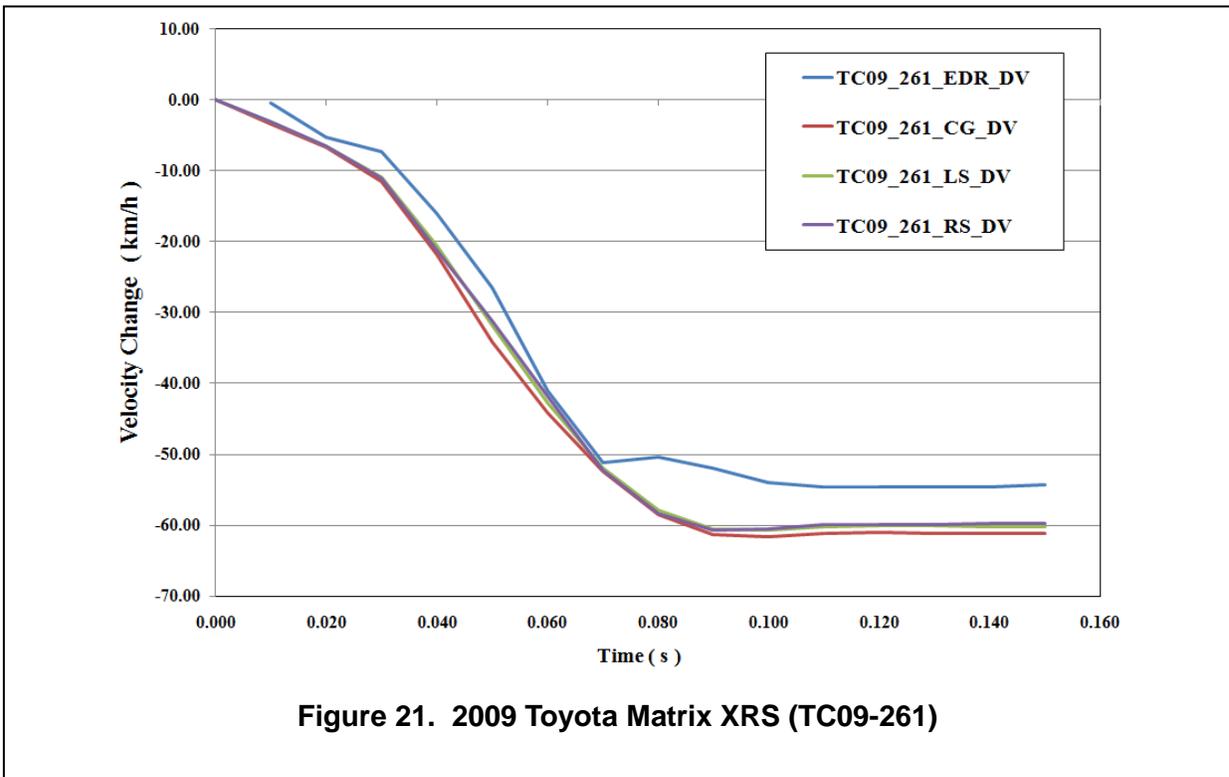
Figure 18. 2009 Toyota Matrix (TC09-145)



**Figure 19. 2009 Toyota Matrix (TC09-219)**



**Figure 20. 2009 Toyota Matrix XRS (TC09-262)**



The individual velocity changes calculated from the three laboratory accelerometers are generally in good agreement showing the quality of this instrumentation, and reflecting the symmetrical nature of the frontal crashes.

There is usually good agreement between the two datasets, both in terms of the final velocity change attained (maximum delta-V), and in the shapes of the curves. Such agreement is best exemplified by the 40 km/h test of a 2005 Toyota Camry (Test No. TC05-202) and the 56 km/h test of a 2009 Toyota Venza (Test No. TC09-146) where the curves are essentially overlaid on the chart.

Most of the other tests, even though the shape and range of the curves are very similar, are subject to time shifting, in that the plot of the EDR data is somewhat separated in time from the associated curves based on the laboratory data. This effect has been noted previously and is related to the different timing information available from the EDR's and the crash tests. [6,9]

In the laboratory, "time zero" is well defined through the use of a tape switch mounted on the vehicle's front bumper. In contrast, the EDR continually monitors vehicle acceleration and requires a brief time period for the recording (and air bag deployment) algorithm to "wake up" when it recognizes that a collision is occurring.

The brief time period between the onset of the crash and algorithm enable (AE) is not known and results in an arbitrary time zero for the crash profile obtained from the EDR. It must also be noted that the vehicle is decelerating over this time, but the EDR is not recording this portion of the deceleration profile, which results in a small amount of missing data.

The chart for the 56 km/h test of a 2005 Toyota Camry (Test No. TC05-203) and that for the 56 km/h test of a 2009 Toyota Matrix (Test No. TC09-261) show discontinuities in the delta-V traces at around 70 ms. The delta-V curves rise slightly in the following 10 ms interval, and then continue to decay. The positive value of delta-V noted above would suggest that the vehicle is accelerated at this point in the crash which is not consistent with the continual deceleration shown in the laboratory data. Furthermore, both of the EDR curves subsequently flatten out such that the maximum delta-V's are slightly less than the pre-crash vehicle speeds. The small (between 1.5 and 2 km/h) but positive final velocities would suggest that the vehicles were still moving towards the barrier which is clearly not the case.

The maximum changes in velocities for all the tests are shown in Figure 23. The delta-V recorded by the EDR differs from that calculated from the acceleration data provided by the laboratory instrumentation by between 0.47 and -8.84 km/h, with an average difference of -2.39 km/h (-4.09%).

The two crash tests that exhibit discontinuities in the EDR data are the two outliers in terms of the difference between the delta-V values, at -7.11 km/h and -8.84 km/h, respectively. While the reasons for the discrepancies in the EDR data in the latter two tests are not clear, it should be noted that the calculated vehicle velocities, and the changes in velocities, recorded by the EDR's, are within about -14% of the actual values.

Test No.	Test Speed (km/h)	Delta-V (Laboratory) (km/h)	Delta-V (EDR) (km/h)	Difference (km/h)	Difference (%)
TC05-202	40.42	-46.21	-46.35	0.14	0.30
TC05-119	47.93	-55.17	-53.43	-1.74	-3.16
TC05-203	56.06	-62.92	-54.07	-8.84	-14.05
TC09-243	40.36	-46.16	-45.38	-0.77	-1.67
TC10-211	40.26	-47.19	-47.31	0.13	0.27
TC09-244	47.85	-55.13	-50.37	-4.75	-8.62
TC10-149	47.97	-55.16	-53.91	-1.24	-2.26
TC09-245	56.07	-63.41	-60.35	-3.05	-4.82
TC09-220	40.27	-46.02	-45.06	-0.96	-2.09
TC09-145	47.70	-54.80	-53.11	-1.69	-3.09
TC09-219	48.01	-55.50	-53.75	-1.75	-3.16
TC09-262	47.91	-54.29	-51.98	-2.31	-4.26
TC09-261	55.80	-61.67	-54.56	-7.11	-11.53
TC09-146	47.96	-52.96	-53.43	0.47	0.89
			Average	-2.39	-4.09

**Figure 23. Differences in Delta-V Between the Vehicle's EDR Record**

## Conclusions

The EDR correctly reported seat belt use and the driver's seat position, but the types of dummies reported by the occupant detection system were not always accurate. However, it should be noted that the data retrieval tool and the associated software being used to interrogate the EDR's were prototypes. The inconsistencies identified will be brought to the manufacturer's attention and no doubt these will be rectified in a future release of the tool.

The pre-crash speeds recorded by the EDR's differed from those measured by the laboratory instrumentation by approximately 2 km/h and so were within the tolerance specified by Toyota.

Most of the changes in velocities captured by the EDR's installed in the vehicles tested were close to those obtained from laboratory instrumentation used in the crash tests. The delta-V's recorded by the EDR's were generally under-reported by approximately 4%, primarily as a result of the data capture process employed in the EDR.

For two vehicles, crash tests at 56 k/h produced anomalous results, with the EDR's reporting the vehicles to have apparently reached positive post-impact velocities. The reasons for these results are not clear; however, the laboratory data shows that the vehicles experienced normal

deceleration profiles. The delta-V values reported in these two cases were under-reported by 12-14%, this range being somewhat higher than for the worst case of just under 9% for the other vehicles tested.

Overall, the results from the series of crash tests undertaken in this study, for a number of different vehicle models, and with a number of different initial speeds, indicate that end users of the output from Toyota EDR's can have some confidence in the accuracy of these data.

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The opinions, findings and conclusions expressed in this paper are solely those of the authors and do not necessarily represent the views and/or policies of Transport Canada.

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