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## **ON-SITE CERTIFIED ADVANCED 208- COMPLIANT VEHICLE INVESTIGATION**

CASE NUMBER - IN-04-023

LOCATION - Texas

VEHICLE - 2004 GMC Yukon

CRASH DATE - June 2004

Submitted:

July 18, 2005



Contract Number: DTNH22-01-C-07002

Prepared for:

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National Highway Traffic Safety Administration  
National Center for Statistics and Analysis  
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The crash investigation process is an inexact science which requires that physical evidence such as skid marks, vehicular damage measurements, and occupant contact points be coupled with the investigator's expert knowledge and experience of vehicle dynamics and occupant kinematics in order to determine the pre-crash, crash, and post-crash movements of involved vehicles and occupants.

Because each crash is a unique sequence of events, generalized conclusions cannot be made concerning the crashworthiness performance of the involved vehicle(s) or their safety systems.

## Technical Report Documentation Page

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15. <i>Supplementary Notes</i> On-site air bag deployment investigation involving a 2004 GMC Yukon with manual safety belts and dual front advanced air bag system, and a 2001 Chevrolet Silverado K1500 pickup truck.			
16. <i>Abstract</i> This report covers an on-site investigation of an air bag deployment crash involving a 2004 GMC Yukon (case vehicle) and a 2004 Chevrolet Silverado K1500 pickup truck (other vehicle). This crash is of special interest because the case vehicle was equipped with multiple Advanced Occupant Protection System (AOPS) features, including certified advanced 208-compliant front air bags, and the case vehicle's driver (56 year-old female) sustained a police reported "C" (possible) injury, possibly from her deploying air bag. The case vehicle was traveling eastbound in the inside left turn lane of a multiple lane divided urban trafficway and was in the process of making a left turn at a signalized four-leg intersection. The Chevrolet was westbound in the inside through lane and was traveling straight through the intersection. The front of the Chevrolet impacted the left front of the case vehicle causing a first stage deployment of the case vehicle's driver air bag. The front right passenger air bag was suppressed by the case vehicle's AOPs system because there was no front right passenger in the vehicle. The case vehicle rotated counterclockwise, the Chevrolet rotated clockwise and both vehicles came to final rest in the intersection facing northwest. Just prior to the crash the driver was seated in a nominal upright driving position. She most likely had both hands on the steering wheel and one foot on the brake as she was slowing to negotiate a left turn. It is not known if she took any actions to avoid the crash. She was restrained by her integral, manual, lap-and-shoulder safety belt system and her seat was most likely adjusted to its full rear position, and the seat back was slightly reclined. The impact with the Chevrolet caused her to move forward and to the right and her face and chest most likely impacted her deployed air bag. She also impacted her right knee on the knee bolster and the left side of the center console. The driver remained restrained in her seat as the case vehicle came to final rest. She most likely exited the case vehicle under her own power. The driver's use of her safety belt system and the first stage deployment of her air bag mitigated her interaction with the case vehicle's interior frontal components.			
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This on-site investigation was brought to NHTSA's attention on or before July 8, 2004 by NASS CDS/GES sampling activities. This crash involved a 2004 GMC Yukon (case vehicle) and a 2001 Chevrolet Silverado K1500 pickup truck (other vehicle). The crash occurred in June 2004, at 9:20 a.m., in Texas and was investigated by the applicable city police department. This crash is of special interest because the case vehicle was equipped with multiple Advanced Occupant Protection System (AOPS) features, including certified advanced 208-compliant air bags, as well as an Event Data Recorder (EDR) and the case vehicle's driver [56-year-old, White (unknown ethnic origin) female] sustained a police reported "C" (possible) injury, possibly from her deploying driver air bag. This contractor inspected the case vehicle and downloaded the EDR on July 29, 2004 and inspected the crash scene on July 30, 2004. This contractor was unable to locate the driver of the case vehicle, and the Chevrolet had been transported out of the state and was not inspected. This report is based on the police crash report, scene and case vehicle inspections, occupant kinematic principles, and this contractor's evaluation of the evidence.

## SUMMARY

The case vehicle was traveling eastbound in the inside left turn lane of a multiple lane divided urban trafficway and was in the process of making a left turn at a signalized four-leg intersection. The Chevrolet was westbound in the inside through lane and was traveling straight through the intersection. The front of the Chevrolet impacted the left front of the case vehicle causing a first stage deployment of the case vehicle's driver air bag. The front right passenger air bag was suppressed by the case vehicle's AOPs system because there was no front right passenger in the vehicle. The case vehicle rotated counterclockwise, the Chevrolet rotated clockwise and both vehicles came to final rest in the intersection facing northwest. The weather at the time of the crash was clear, the roadway was dry and traffic density was heavy.

The CDC for the case vehicle was determined to be **02-RYEW-3 (50 degrees)**. The CDC for the Chevrolet could not be determined because it was not inspected and no photographs of it were available. The WinSMASH reconstruction program, missing vehicle algorithm calculated the case vehicle's Total, Longitudinal and Lateral Delta Vs respectively as: 15 km.p.h. (9.3 m.p.h.), -9.6 km.p.h. (6.0 m.p.h.), and -11.5 km.p.h. (-7.1 m.p.h.). Based on the damage to the case vehicle, the results appeared low. The maximum longitudinal component of Delta V was recorded by the EDR as 28.36 km.p.h. (-17.62 m.p.h.). The Total and Lateral components of Delta V based on the EDR data and the case vehicle's principal direction of force were calculated as 44.10 km.p.h. (27.41 mph.) and 33.76 km.p.h. (-20.98 m.p.h.).

Just prior to the crash the driver was seated in a nominal upright driving position. She most likely had both hands on the steering wheel and one foot on the brake as she was slowing to negotiate a left turn. It is not known if she took any actions to avoid the crash. She was restrained by her integral, manual, lap-and-shoulder safety belt system and her seat was most likely adjusted to its full rear position, and the seat back was slightly reclined. The impact with the Chevrolet caused her to move forward and to the right and her face and chest most likely impacted her deployed air bag. She also impacted her right knee on the knee bolster and the left side of the center console. The driver remained restrained in her seat as the case vehicle came to final rest. She most likely exited the case vehicle under her own power. The driver's use of her safety belt system and the first stage deployment of her air bag mitigated her interaction with the case vehicle's interior

frontal components.

The police crash report indicated that the case vehicle's driver sustained a "C" (possible) injury and refused treatment at the scene. It is not known if the driver sustained any injury.

### CRASH CIRCUMSTANCES

**Crash Environment:** The trafficway on which both vehicles were traveling was a multi-lane, two-way, divided city street traversing in an east and west direction. The trafficway formed a four leg intersection with the entrances to two shopping malls. The case vehicle's approach roadway had three through lanes, a right turn lane and two left turn lanes. The Chevrolet's approach roadway had three through-lanes and a left turn lane. Each lane was approximately 3.3 meters wide (10.8 feet) and the roadway was divided by raised, concrete, curbed medians. The median on the east side of the intersection was 1.1 meters (3.6 feet) wide and the median on the west side of the intersection was 3.7 meters wide (12.1 feet). The intersection was controlled by multiple three phase traffic signals for each travel direction, and each roadway was bordered by barrier curbs. The speed limit for both vehicles was 56 km.p.h. (35 m.p.h.). At the time of the crash the light condition was daylight, the atmospheric condition was clear, and the roadway pavement was level, dry bituminous with a coefficient of friction of approximately 0.72. Traffic density was heavy and the site of the crash was urban commercial. See the Crash Diagram at the end of this report.

**Pre-Crash:** The case vehicle was eastbound in the inside left turn lane (**Figure 1**). The driver was intending to continue into the intersection and turn left (north) into a shopping mall. The Chevrolet was traveling west in the left inside through lane (**Figure 2** below). The driver was intending to continue straight through the intersection and continue west. It is unknown if the case vehicle's driver took any actions to avoid the crash. The EDR pre-crash braking and acceleration data is consistent with slowing to negotiate the turn. It is not known if the braking just prior to the crash is an avoidance action, or simply part of the actions the driver was taking while turning. The crash occurred within the intersection (**Figure 3** below).



**Figure 1:** Approach of case vehicle eastbound in inside left turn lane

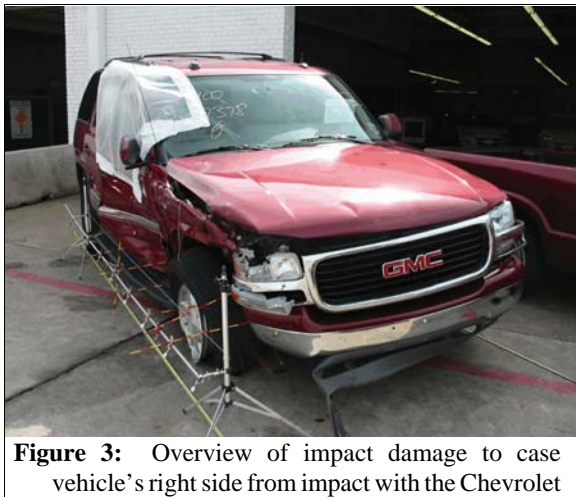
**Crash:** The front of the Chevrolet impacted the case vehicle's right bumper corner, right fender, right front wheel and right front door (**Figures 4** below), causing the case vehicle's driver air bag to deploy. The case vehicle's front right air bag did not deploy because there was no front right occupant in the case vehicle. The sensors in the front right seat properly determined the absence of an occupant and suppressed deployment of the front right air bag.



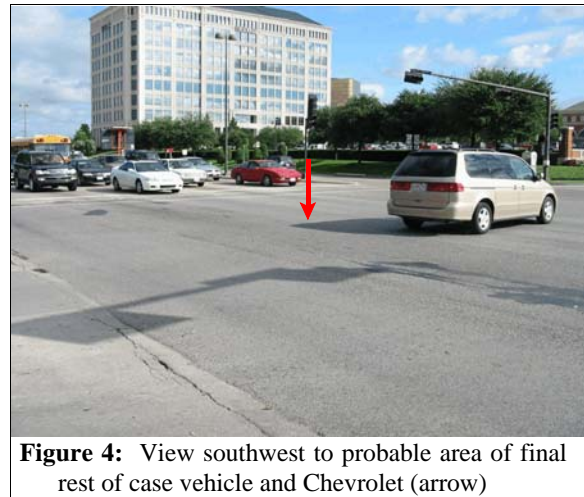
**Figure 2:** Approach of Chevrolet westbound in inside through lane



**Figure 3:** Overview of impact area (arrow) from case vehicle's approach



**Figure 3:** Overview of impact damage to case vehicle's right side from impact with the Chevrolet



**Figure 4:** View southwest to probable area of final rest of case vehicle and Chevrolet (arrow)

**Post-Crash:** As a result of the impact, the case vehicle rotated counterclockwise and the Chevrolet rotated clockwise. Both vehicles most likely came to final rest within the intersection facing northwest (**Figure 4**). The specific area of final rest of both vehicles could not be determined because no evidence was observed at the scene, and the police crash schematic showed no final rest position of either vehicle.

### CASE VEHICLE

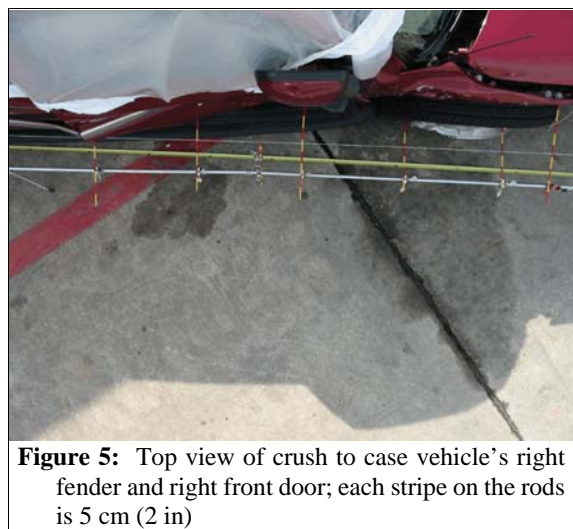
The 2004 GMC Yukon was a rear wheel drive, four-door sport utility vehicle (VIN: 1GKEC13Z54R-----) equipped with a 5.3 L, V-8 engine, four-speed automatic transmission, four wheel, anti-lock brakes; electronic traction control, tire inflation monitor, driver and front right passenger bucket seats with seat position sensors, adjustable head restraints and integral, lap-and-shoulder safety belt systems with seat belt usage sensors; driver and front right passenger dual stage air bags, and a front right occupant detection and automatic air bag suppression system and an air bag suppression switch. The second seat row was equipped with bucket seats with adjustable head restraints and three-point, lap and shoulder safety belt systems. The third seat row was equipped with a split bench seat with three-point, lap and shoulder safety belt systems. In addition, the case

vehicle was equipped with a LATCH system for securing child safety seats and an EDR housed within the air bag system’s Sensing and Diagnostic Module (SDM). Driver and front right passenger seat back-mounted, side-impact air bags were an option, but the case vehicle was not so equipped. The case vehicle’s wheelbase was 295 centimeters (116 inches). The odometer reading at inspection could not be determined because the case vehicle was equipped with an electronic odometer.

The various sensors in the case vehicle’s advanced occupant restraint system analyze a combination of factors including the predicted crash severity, driver and front right passenger safety belt usage and seat position to determine the front air bag inflation level appropriate for the severity of the crash. For the front right seat position, an occupant weight pressure sensor and a seat belt tension sensor provide data to the electronic control module. The electronic control module compares the seat pressure and seat belt tension data to threshold values, determines if the front right air bag should be suppressed or enabled and communicates the decision to the air bag control module. The air bag will be suppressed when the seat pressure is at or below what a six-year-old child in a booster seat produces (the value is unknown) or when the belt tension is above 6.8 kilograms (15 pounds). The air bag will be enabled if the seat pressure is at or above what a 46.7 kilograms (103 pound) occupant produces and the seat belt tension is below 6.8 kilograms (15 pounds).

**CASE VEHICLE DAMAGE**

**Exterior Damage:** The case vehicle sustained direct damage to its right front bumper corner, right fender, right front wheel and right front door due to the impact with the Chevrolet. The direct damage began at the right corner of the front bumper and extended 171 centimeters (67.3 inches) along the case vehicle’s right fender and right front door. Direct damage also involved the right headlamp/turn lamp assembly and the hood. Crush measurements were taken at the lower door level. Maximum crush was measured as 47 centimeters (18.5 inches) occurring 20 centimeters forward of at C<sub>5</sub> (**Figure 5**). The table below shows the case vehicle’s right side crush profile.



**Figure 5:** Top view of crush to case vehicle’s right fender and right front door; each stripe on the rods is 5 cm (2 in)

Units	Event	Direct Damage		Field L	C <sub>1</sub>	C <sub>2</sub>	C <sub>3</sub>	C <sub>4</sub>	C <sub>5</sub>	C <sub>6</sub>	Direct	Field L
		Width CDC	Max Crush								±D	±D
cm	1	171	47	217	0	8	26	12	13	13	88	110
in		67.3	18.5	85.4	0.0	3.2	10.2	4.7	5.1	5.1	34.6	43.3



The case vehicle’s right side wheelbase was reduced 18 centimeters (seven inches) and the left side wheelbase extended two centimeters (0.8 inch). Induced damage involved the hood, front bumper, grille and right front and rear doors. No obvious induced damage or remote buckling was noted to the remainder of the vehicle.

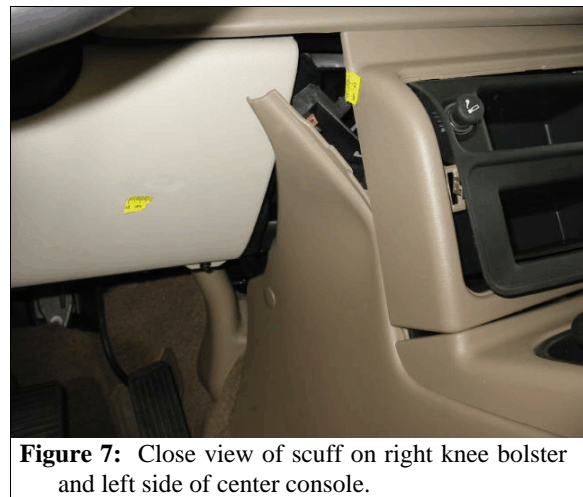
The case vehicle’s recommended tire size was: P265/70R17 and the vehicle was equipped with tires of this size. The case vehicle’s tire data are shown in the table below.

Tire	Measured Pressure		Recommend Pressure		Tread Depth		Damage	Restricted	Deflated
	kpa	psi	kpa	psi	milli-meters	32 <sup>nd</sup> of an inch			
LF	248	36	221	32	10	12	None	No	No
RF	0	0	221	32	10	12	Tire debaded	No	Yes
LR	248	36	221	32	9	11	None	No	No
RR	248	36	221	32	9	11	None	No	No

**Interior Damage:** Inspection of the case vehicle’s interior (**Figure 6**) revealed an occupant contact scuff on the driver’s right knee bolster and left side of the center console (**Figures 7**). The two occupant contact marks indicate the driver’s right knee impacted and scuffed the right knee bolster and the left side of the center console. The damage to the center console visible in **Figure 7** was due to the intrusion of the right front door, which has displaced the instrument panel to the left. No occupant contact marks were found on the driver’s air bag; however, three small possible blood spots were found on the top left and upper right edge of the air bag. No other occupant contact evidence was found.



**Figure 6:** Overview of the steering wheel, instrument panel and windshield



**Figure 7:** Close view of scuff on right knee bolster and left side of center console.

The case vehicle sustained four intrusions due to the impact with the Chevrolet. There were three intrusions into the front right occupant space as follows: the right sill intruded laterally 29 centimeters (11.4 inches); the side panel forward of the right A-pillar intruded laterally 28

centimeters (11 inches) and the right front door panel intruded laterally 25 centimeters (9.8 inches). In addition, the left side panel of the center console intruded laterally 4 centimeters (1.6 inches), and the glove box door opened during the crash. Finally, there was no evidence of compression of the energy absorbing steering column, and no deformation of the steering wheel rim was observed (**Figure 8**).



**Figure 8:** Overview of case vehicle steering wheel and steering column

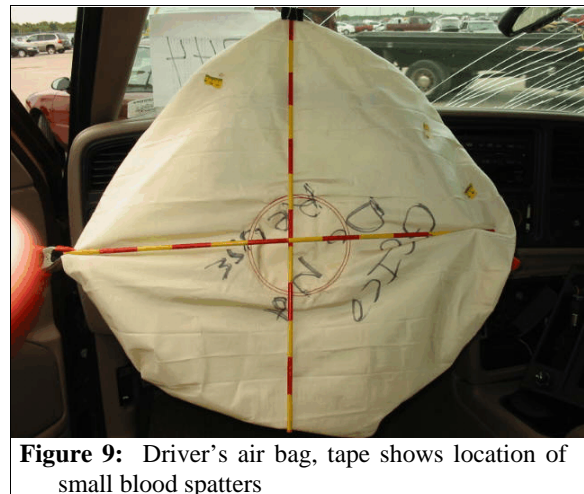
**Damage Classification:** Based on the vehicle inspection, the CDC for the case vehicle was determined to be **02-RYEW-3 (50 degrees)**.

The WinSMASH reconstruction program, missing vehicle algorithm, was used to reconstruct the case vehicle's Delta V. The preliminary Total, Longitudinal, and Lateral Delta Vs are, respectively: 15 km.p.h. (9.3 m.p.h.), -9.6 km.p.h. (6.0 m.p.h.), and -11.5 km.p.h. (-7.1 m.p.h.). Based on the damage to the case vehicle, the reconstruction results appear to be low. Maximum Delta V data was recorded by the case vehicle's EDR. However, the EDR reports only the longitudinal component of the Delta V, which was recorded as -28.36 km.p.h. (-17.62 m.p.h.). The Total and Lateral Delta Vs can be calculated based on the longitudinal Delta V and the assigned 50 degree direction of principal force. The Total, and Lateral Delta Vs based on these data are, respectively: 44.10 km.p.h. (27.41 mph.) and -33.76 km.p.h. (-20.98 m.p.h.). The case vehicle was towed due to damage.

### **AUTOMATIC RESTRAINT SYSTEM**

The case vehicle was equipped with certified advanced 208-compliant front air bags at the driver and front right passenger positions. The driver's front air bag deployed as a result of the impact with the Chevrolet. The front right passenger air bag did not deploy because there was no front right passenger seated in the case vehicle. The case vehicle's advanced occupant restraint system properly determined the absence of a passenger and suppressed deployment of the front right air bag.

The case vehicle's driver air bag was located in the steering wheel hub. An inspection of the air bag module cover flaps and the air bag fabric revealed that the cover flaps opened at the designated tear points. There was no evidence of damage during the deployment to the air bag module cover flaps or the air bag fabric. Three small blood spots were found on the top left and upper right edge of the air bag; however, no clear occupant contact marks were observed on the air bag. The deployed driver's air bag (**Figure 9**) was round with a diameter of approximately 65



**Figure 9:** Driver's air bag, tape shows location of small blood spatters

centimeters (25.6 inches). The air bag was designed with two tethers, each approximately 12 centimeters (4.7 inches) in width and had two vent ports (**Figure 10**), each approximately 3 centimeters (1.2 inches) in diameter, located at the 10 and 2 o'clock positions. The air bag module cover flaps (**Figure 11**) were constructed of pliable vinyl and the tear seams were in an “I” configuration across the top, bottom and vertically down the middle. Each module flap was 7.5 centimeters (3.0 inches) in width at the top, 5.0 centimeters (2.0 inches) in width at the bottom and 13 centimeters (5.1 inches) in height at the vertical tear seam.

The front right passenger front air bag was located in the middle of the instrument panel (**Figure 12**). The deployment of the front right passenger air bag was properly suppressed by the case vehicle’s advanced occupant restraint system because no front right passenger was seated in the case vehicle.

**CRASH DATA RECORDING**

The download of the case vehicle’s EDR was done during the vehicle inspection via direct connection to the SDM. The EDR recorded a deployment event and a non-deployment event. The non-deployment event was recorded 59 ignition cycles prior to the deployment event and was therefore not related to this crash. The EDR reports for the deployment event are presented at the end of this report (**Figures 15, 16 and 17**). The EDR recorded the SIR warning lamp as off, the driver’s safety belt switch circuit as buckled and the front right passenger’s safety belt switch circuit as unbuckled. The maximum SDM velocity change was recorded as -28.35 km.p.h. (-17.62 m.p.h.) occurring 140 milliseconds after algorithm enable (AE). In addition, the system status report shows that the first stage deployment criteria was met 15 milliseconds after algorithm enable, a second stage deployment was not required and the deployment event recording was complete with no multiple events associated with the record.



**Figure 10:** Location of case vehicle’s driver air bag vent ports (arrows)



**Figure 11:** Case vehicle’s steering wheel and driver air bag module flaps



**Figure 12:** Case vehicle’s front right air bag module door located above glove box door

The pre-crash data graph indicates the driver was not applying the throttle from five seconds to one second prior to the crash (i.e., AE). In addition, the brake switch circuit status was recorded as on at five and four seconds prior to the crash, off at three seconds and on again at two seconds and one second prior to the crash. The case vehicle slowed from 45 km.p.h. (28 m.p.h.) to 31 km.p.h. (19 m.p.h.) during this time. The pre-crash data is consistent with the driver slowing to negotiate the turn and indicates the driver was not stopped at the traffic signal prior to executing her left turn.

### CASE VEHICLE DRIVER KINEMATICS

The case vehicle's driver [56-year-old, White (unknown ethnic origin) female; unknown height and weight] was most likely seated in a nominal upright driving posture. The EDR data indicates she most likely had one of her feet on the brake. It is also likely she had both hands on the steering wheel because she was executing a left turn at the time of the crash. At the time of the case vehicle inspection, the driver's seat track was adjusted to the full rear position and her seat back was slightly reclined. The tilt steering wheel was located between its center and full down position.

The evidence indicates the case vehicle's driver was using her manual, three-point, lap-and-shoulder safety belt system. The seat belt was observed to be stretched and the shoulder belt was jammed in the belt guide (**Figure 13**). The length of the belt in its jammed configuration (**Figure 14**) was consistent with it being used by the driver in the crash. In addition, the police report indicated the driver was using her lap and shoulder belt, and the EDR data indicates the driver's seat belt was buckled.

It is not known if the driver took any actions to avoid the crash. The EDR data indicates the brakes were being applied just prior to the crash. However, the deceleration of the vehicle during this period is consistent with light braking, not crash avoidance braking. It is possible the driver could have applied the brakes harder during the last second prior to the impact; however, the EDR data does not capture pre-crash data following the recording of the one second time increment prior to the crash.



**Figure 13:** Case vehicle driver's shoulder belt jammed in the shoulder belt guide



**Figure 14:** Overview of case vehicle driver's lap and shoulder belt in its jammed condition

The case vehicle's impact with the Chevrolet caused the driver to move forward and to the right along a path opposite the case vehicle's 50 degree direction of principal force as the case vehicle decelerated. The impact locked the driver's safety belt retractor and she loaded the safety, belt and her face and chest most likely made contact with her deployed air bag. The driver's right knee contacted and scuffed the right knee bolster and contacted the left side of the center console (**Figure 6** above). The driver remained in her seat restrained by her lap and shoulder belt and most likely moved back to her left as the case vehicle rotated counterclockwise to its final rest position. It is likely the driver was able to exit the case vehicle without assistance. The driver's use of her safety belt system and the first stage deployment of her air bag mitigated her interaction with the case vehicle's interior frontal components.

#### **CASE VEHICLE DRIVER INJURIES**

The police crash report indicated the driver sustained a "C" (possible) injury. The police crash report also indicates the driver refused treatment at the scene. It is not known if the driver sustained any injury.

#### **OTHER VEHICLE**

The 2001 Chevrolet Silverado K1500 was a full size, four-wheel drive, extended cab, pickup truck (VIN: 1GCGK13U21F-----). The Chevrolet was equipped with driver and front right passenger redesigned air bags which deployed as a result of the impact with the case vehicle.

**Exterior Damage:** The Chevrolet was not inspected. It had been moved out of the state. With no available vehicle photographs, a CDC could not be estimated. The Chevrolet was towed due to damage.

**Chevrolet's Occupants:** According to the police crash report, the Chevrolet's driver [64-year-old, White (unknown ethnic origin) male] was restrained by his manual three-point, lap-and-shoulder, safety belt system. The police crash report indicated the driver sustained a "C" (possible) injury and was transported by ambulance to a treatment facility.

According to the police crash report, the Chevrolet's front right passenger [57-year-old (unknown race and ethnic origin) male] was restrained by his manual advanced occupant restraint system properly determined the absence of a passenger and suppressed deployment of the front right air bag., three-point, lap-and-shoulder safety belt system. The police crash report indicated the front right passenger sustained a "C" (possible) injury and was transported by ambulance to a treatment facility.

**EVENT DATA RECORDER DATA**

IN-04-023

1GKEC13Z54Rxxxxxx System Status At Deployment															
SIR Warning Lamp Status	OFF														
Driver's Belt Switch Circuit Status	BUCKLED														
Passenger's Belt Switch Circuit Status	UNBUCKLED														
Ignition Cycles At Deployment	354														
Ignition Cycles At Investigation	360														
Maximum SDM Recorded Velocity Change (MPH)	-17.62														
Algorithm Enable to Maximum SDM Recorded Velocity Change (msec)	140														
Driver First Stage Time Algorithm Enabled to Deployment Command Criteria Met (msec)	15														
Driver Second Stage Time Algorithm Enabled to Deployment Command Criteria Met (msec)	N/A														
Passenger First Stage Time Algorithm Enabled to Deployment Command Criteria Met (msec)	N/A														
Passenger Second Stage Time Algorithm Enabled to Deployment Command Criteria Met (msec)	N/A														
Time Between Non-Deployment And Deployment Events (sec)	N/A														
Frontal Deployment Level Event Counter	1														
Event Recording Complete	Yes														
Multiple Events Associated With This Record	No														
One Or More Associated Events Not Recorded	No														
Time (milliseconds)	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150
Recorded Velocity Change (MPH)	-0.31	-1.24	-3.41	-4.65	-6.82	-8.68	-11.16	-13.02	-14.88	-15.81	-16.74	N/A	N/A	N/A	N/A
PRE-CRASH DATA															
Seconds Before AE	Vehicle Speed (MPH)	Engine Speed (RPM)	Percent Throttle	Brake Switch Circuit Status											
-5	28	768	0	ON											
-4	25	704	0	ON											
-3	21	640	0	OFF											
-2	21	802	0	ON											
-1	19	768	0	ON											

**Figure 15:** Case vehicle's System Status at Deployment report

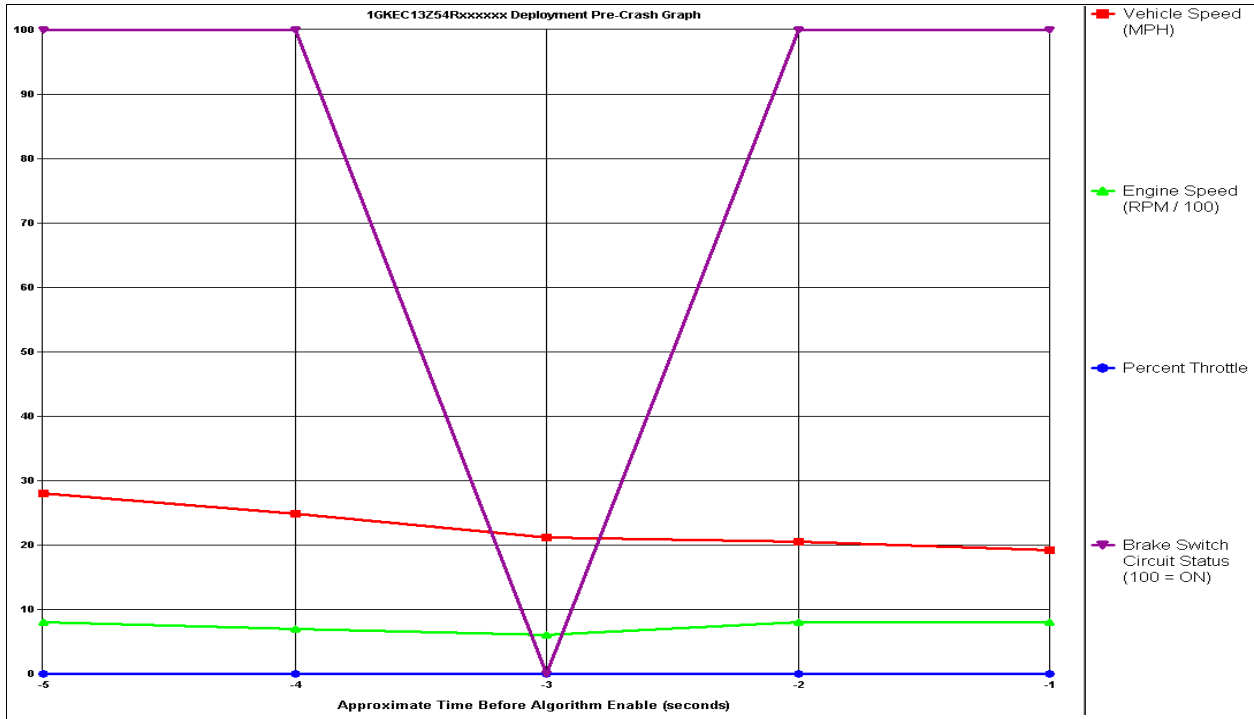


Figure 16: Case vehicle's Deployment Pre-crash Graph

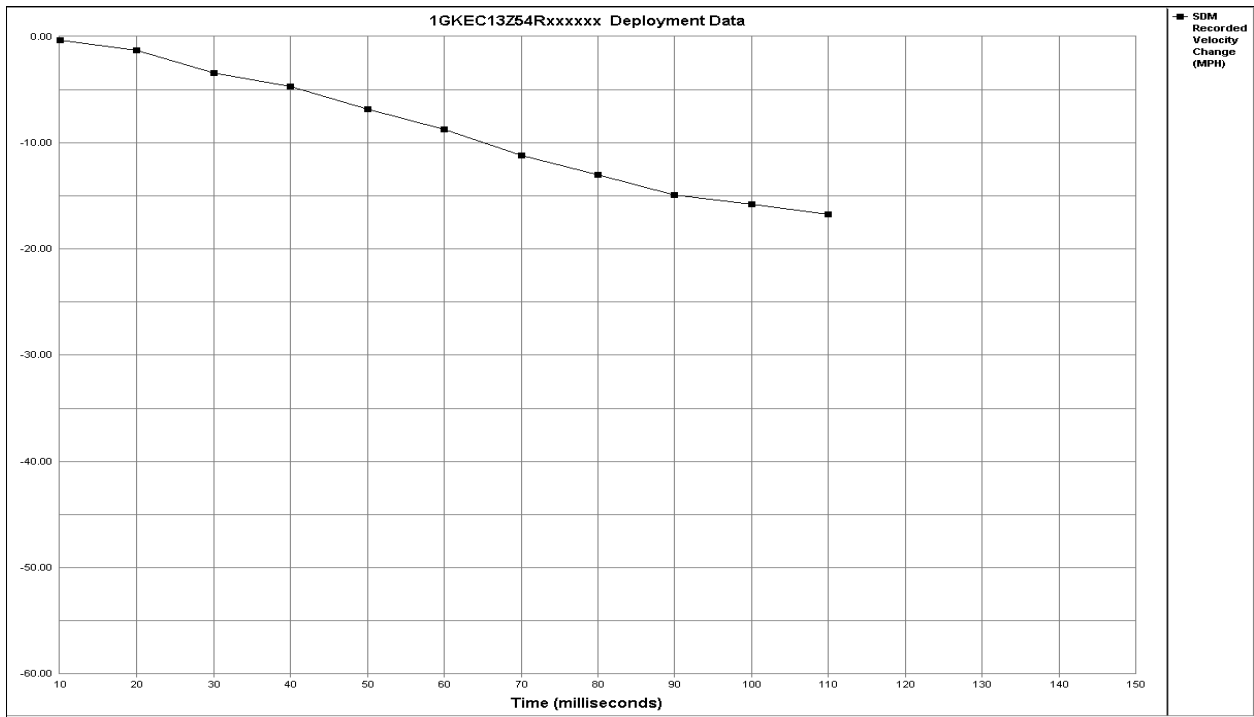


Figure 17: Case vehicle's SDM Recorded Velocity Change graph

