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ON-SITE CERTIFIED ADVANCED 208-COMPLIANT VEHICLE INVESTIGATION

CASE NUMBER - IN-04-040
LOCATION - Texas
VEHICLE - 2004 GMC K1500 SIERRA, EXTENDED CAB
CRASH DATE - October 2004

Submitted:

October 19, 2005
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Contract Number: DTNH22-01-C-07002

Prepared for:

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National Highway Traffic Safety Administration
National Center for Statistics and Analysis
Washington, D.C. 20590-0003

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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. *Supplementary Notes* On-site air bag investigation involving a 2004 GMC Sierra K1500, extended cab pickup truck with manual safety belts and dual front advanced air bag system.			
16. *Abstract* This report covers an on-site investigation of an air bag deployment crash that involved a 2004 GMC Sierra K1500 extended cab pickup truck (case vehicle),which impacted the back of a 2004 Hummer H2 (other vehicle). This crash is of special interest because the case vehicle is certified by the manufacturer to be compliant to the Advanced Air Bag portion of Federal Motor Vehicle Safety Standard (FMVSS) No. 208 and was equipped with multiple Advanced Occupant Protection System (AOPS) features, an Event Data Recorder (EDR), and the case vehicle's driver (44 year-old, male) sustained a police reported "B" (non-incapacitating-evident) injury as a result of the crash. The trafficway on which both vehicles were traveling was a ten-lane, divided Interstate highway traversing in a easterly and westerly direction. Both vehicle's were traveling in a westerly direction in the left center lane. The case vehicle was directly behind the Hummer. The Hummer's driver braked for slowing traffic. The case vehicle's driver braked, and the front of the case vehicle impacted and underrode the back of the Hummer causing a first stage deployment of the case vehicle's driver air bag. The impact involved the full front of the case vehicle and was approximately centered on the back of the Hummer. As a result, both vehicles probably did not rotate following the impact and came to rest in their original travel lane. The case vehicle driver's seat track was located in it's rearmost track position, the seat back was slightly reclined, and the tilt steering column was located in its center position. The driver was restrained by his integral, three-point, lap-and-shoulder safety belt. He sustained a sprained left ankle due to contact with the toe pan, abrasions and contusions to his left forearm from the air bag, and contusions to his right forearm from the air bag.			
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BACKGROUND IN-04-040

This on-site investigation was brought to NHTSA's attention on or before November 9, 2004 by NASS CDS sampling activities. This crash involved a 2004 GMC K1500 Sierra extended cab pickup truck(case vehicle) and a 2004 Hummer H2 (other vehicle). The crash occurred in October, 2004 at 3:23 p.m., in Texas and was investigated by the applicable city police department. This crash is of special interest because the case vehicle is certified by the manufacturer to be compliant to the Advanced Air Bag portion of Federal Motor Vehicle Safety Standard (FMVSS) No. 208 and was equipped with multiple Advanced Occupant Protection System (AOPS) features, an Event Data Recorder (EDR), and the case vehicle's driver [44-year-old, White (unknown if Hispanic) male] sustained a police reported "B" (non-incapacitating-evident) injury, possibly from his deploying driver air bag. This contractor inspected the scene and case vehicle, and downloaded the onboard EDR on 6-8 December, 2004. This contractor was unable to contact and interview the case vehicle's driver. This report is based on the police crash report, scene and vehicle inspections, driver's emergency room medical records, occupant kinematic principles, and this contractor's evaluation of the evidence.

SUMMARY

The case vehicle was westbound in heavy traffic in the left center lane of a multiple lane Interstate highway and was directly behind the Hummer. The Hummer's driver braked for slowing traffic. The case vehicle's driver braked and the front of the case vehicle impacted and underrode the back of the Hummer causing a first stage deployment of the case vehicle driver's air bag. The front right air bag did not deploy because there was no front right passenger in the case vehicle. Both vehicles probably did not rotate following the impact and came to rest in their original travel lane. The weather at the time of th crash was cloudy and the roadway pavement was dry.

The CDC for the case vehicle was determined to be **12-FDEW-2** (**0** degrees). The WinSMASH reconstruction program, missing vehicle algorithm calculated the case vehicle's Total, Longitudinal, and Lateral Delta Vs respectively as: 20.0 km.p.h. (12.4 m.p.h.), -20.0 km.p.h. (-12.4 m.p.h.), and 0.0 km.p.h. (0.0 m.p.h.). The EDR data indicated that the case vehicle's maximum recorded longitudinal Delta V was -16.94 km.p.h. (-10.53 m.p.h.). The case vehicle was towed due to damage. The Hummer was driven from the scene by the driver.

Just prior to the impact, the case vehicle's driver was probably seated in an upright driving posture. He had one foot on the brake, and he probably had both hands on the steering wheel bracing for impact. The driver's seat track was located in its rearmost track position, the seat back was slightly reclined, and the tilt steering wheel was located in its center position. The driver was restrained by his integral, three-point, lap-and-shoulder safety belt system. The pre-impact braking probably caused the driver's safety belt retractor to lock, and he continued forward into his safety belt. The impact with the Hummer caused the driver to continue forward opposite the case vehicle's 0 degree direction of principal force as the case vehicle decelerated and loaded his safety belt. The driver's face and chest probably contacted his deployed air bag, and both of his arms contacted the deployed air bag causing abrasions and contusions to his left forearm and contusions to his right forearm. He also sustained a sprained left ankle due to contact with the toe

pan. The driver probably rebounded back into his seat following the impact. It is not known if the driver was able to exit the case vehicle under his own power. His emergency room record indicated he was not ambulatory at the scene.

The driver sustained a police reported "B (non-incapacitating-evident) injury. He was transported by ambulance to a local hospital and was treated and released from the emergency room.

CRASH CIRCUMSTANCES

Crash Environment: The trafficway on which both vehicles were traveling was a ten-lane, divided, Interstate highway, traversing in an easterly and westerly direction (**Figure 1**). Both the eastbound and westbound roadways had five through lanes, and the inside lanes were designated for High Occupancy Vehicles (HOV) and motorcycles. Each travel lane was approximately 3.7 meters (12 feet) wide. The trafficway was divided by a concrete median barrier with an approximate 1 meter (3.3 feet) wide concrete shoulder. The outside concrete shoulder was approximately 3 meters (10 feet) wide. Roadway pavement markings consisted of broken white/black lane lines, solid white edge lines, double white HOV lane line with "Bots Dots", and solid yellow median edge lines. At the time of the crash the light condition was daylight, the weather condition was cloudy, and the roadway pavement was dry concrete with an approximate 3% negative grade and an estimated coefficient of friction of 0.70. Traffic density was heavy, and the site of the crash was a combination of urban residential and commercial. See the Crash Diagram at the end of this report.

Figure 1: View east back to both vehicles approach showing overview of the trafficway

Pre-Crash: The case vehicle was traveling in a westerly direction in the left center lane (**Figure 2** below), and the driver was intending to proceed straight ahead. The Hummer was also traveling in a westerly direction in the same lane, and was directly in front of the case vehicle. The Hummer's driver braked for traffic slowing in front of her. The EDR data indicates the case vehicle's driver applied the brakes just prior to the crash. The crash occurred within an interchange area in the westbound left center lane of the roadway.

Figure 2: Approach of case vehicle and Hummer to area of impact

Crash: The front of the case vehicle (**Figure 3** below) impacted and underrode the back of the Hummer causing the case vehicle driver's air bag to deploy. The downloaded EDR data indicated only the first stage of the dual-stage air bag activated. The case vehicle was equipped with a front right passenger air bag suppression switch that was set to the "Auto" position. This air bag properly did not deploy during the crash sequence because there was no passenger seated in the front right seat.

Post-Crash: The impact involved the full front of the case vehicle approximately centered on the back of the Hummer. As a result, both vehicles probably did not rotate following the impact and came to rest in their original travel lane.

Figure 3: Case vehicle's front damage due to impact with back of Hummer, each stripe of rod is 5 cm (2 in)

CASE VEHICLE

The 2004 GMC Sierra was a four wheel drive, four-door, extended cab pickup truck (VIN: 2GTEK19TX41------) equipped with a 5.3L, V-8 engine and a four-speed automatic transmission. Braking was achieved by power assisted, four wheel, anti-lock disc brakes. The front seat row was equipped with driver and front right passenger bucket seats with adjustable head restraints; integral, three-point, lap-and-shoulder safety belts with seat belt usage sensors; dual stage driver and front right passenger air bags, seat position sensors, front right passenger air bag suppression switch and an occupant detection system in the front right seat. The back bench seat was equipped with adjustable head restraints and manual, three-point, lap-and-shoulder safety belt systems in the outboard seat positions, a lap belt in the center seat position and a LATCH system for securing child safety seats. The case vehicle was also equipped with an EDR contained within the case vehicle's Sensing and Diagnostic Module (SDM). The case vehicle's wheelbase was 365 centimeters (143.7). The odometer reading is not known because the case vehicle had an electronic odometer and the vehicle had no power.

The various sensors in the case vehicle's advanced occupant restraint system analyze a combination of factors including the predicted crash severity and driver and front right passenger safety belt usage to determine the front air bag inflation level appropriate for the severity of the crash. For the front right seat, an occupant pressure sensor and a seat belt tension sensor provide data to the electronic control module. The electronic control module (a) compares the seat pressure and seat belt tension data to threshold values, (b) determines if the front right air bag should be suppressed or enabled, and (c) communicates the decision to the air bag control module. The air bag will be suppressed when the seat pressure is at or below the established threshold or there is above normal tension on the safety belt (e.g., a secured child seat). The air bag will be enabled if the pressure is above the threshold and the seat belt tension is normal (e.g., a restrained adult occupant) or below (e.g., unrestrained occupant).

Exterior Damage: The case vehicle's contact with the Hummer involved the full width of the frontal plane. The case vehicle's grille, radiator, hood, both headlamp/turn lamp assemblies, and the front of both fenders were directly damaged and crushed rearward (**Figure 4**). There was no residual crush at the bumper level because the front bumper underrode the back of the Hummer, and the bumper was displaced slightly forward from it's normal position, probably due to snagging as the two vehicle's separated. The residual maximum crush above the bumper (measured at the radiator support) was measured as 29 centimeters (11.4 inches) occurring at both C_5 and C_6 (**Figure 4**). The table below shows the case vehicle's crush profile after averaging the bumper and above bumper crush values.

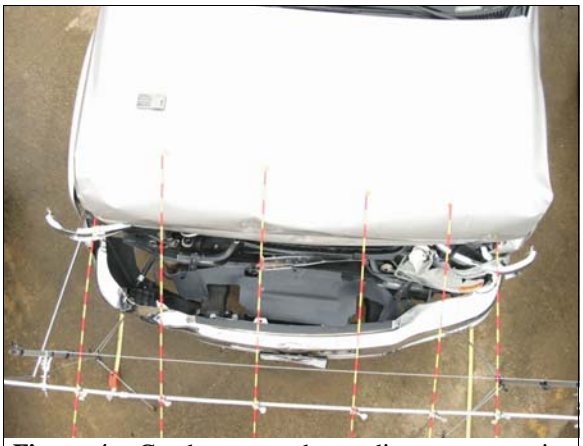


Figure 4: Crush measured at radiator support via projection of ends of measurement rods

Units	Event	Direct Damage		Field L	C_1	C_2	C_3	C_4	C_5	C_6	Direct	Field L
		Width CDC	Max Crush								±D	±D
cm	1	172	29	172	0	7	8	11	15	15	0	0
in		67.7	11.4	67.7	0.0	2.8	3.2	4.3	5.9	5.9	0.0	0.0

The case vehicle's wheelbase was unchanged. In addition to the direct damage, the induced damage also involved the hood and both fenders. No other obvious induced damage or remote buckling was observed to the remainder of the case vehicle's exterior.

The recommended tire size was P265/70R17, and the case vehicle was equipped with tires of this size. None of the case vehicle's tires were damaged or restricted as a result of the crash. 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	32nd of an inch			
LF	214	31	241	35	9	11	None	No	No
RF	207	30	241	35	6	7	None	No	No
LR	207	30	241	35	8	10	None	No	No
RR	221	32	241	35	9	11	None	No	No

Vehicle Interior: Inspection of the case vehicle's interior (**Figure 5**)revealed a probable driver contact scuff on the air bag and a load mark on the driver's shoulder belt. There was no intrusion of the occupant compartment. In addition, there was no evidence of compression of the energy absorbing steering column or deformation of the steering wheel rim (**Figure 6** below).

Figure 5: Overview of steering wheel, windshield and instrument panel

Figure 6: Steering wheel and steering column were not deformed

Damage Classification: Based on the vehicle inspection, the CDC for the case vehicle was determined to be: **12-FDEW-2** (**0** degrees).

The WinSMASH reconstruction program, missing vehicle algorithm was used to reconstruct the case vehicle's Delta V. The Total, Longitudinal, and Lateral Delta Vs are, respectively: 20.0 km.p.h. (12.4 m.p.h.), -20.0 km.p.h. (-12.4 m.p.h.), and 0.0 km.p.h. (0.0 m.p.h.). The EDR data indicated that the case vehicle's maximum recorded longitudinal Delta V was -16.94 km.p.h. (-10.53 m.p.h.). The case vehicle was towed due to damage.

AUTOMATIC RESTRAINT SYSTEM

The case vehicle was equipped with certified advanced 208-compliant air bags at the driver and front right passenger positions. The driver's air bag deployed as a result of the impact with the Hummer. The front right air bag did not deploy because no front right passenger was present in the case vehicle at the time of the crash. The case vehicle's advanced occupant restraint system properly determined the absence of a front right passenger and suppressed the 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 or the cover flaps. The air bag module cover consisted of "I" configuration cover flaps made of pliable vinyl. Each flap was approximately 7.3 centimeters (2.9 inches) in width at the top, 5 centimeters (2 inches) in width at the bottom and 11.5 centimeters (4.5 inches) in height at the center tear seam. The driver's air bag was designed with two tethers, each approximately 10 centimeters (3.9 inches) in width. The deployed driver's air bag (**Figure 7** below) was round with

a diameter of approximately 65 centimeters (25.6 inches) and had two vent ports (**Figure 8**), approximately 3 centimeters (1.2 inches) in diameter, located at the 11 and 1 o'clock positions. The distance between the mid-center of the driver's seat back, as positioned at the time of the vehicle inspection, and the front surface of the air bag at full excursions was 45 centimeters. An inspection of the driver's air bag fabric revealed a probable occupant contact scuff at 12 o'clock approximately 21 centimeters (8.3 inches) above the center of the air bag.

Figure 7: Case vehicle's driver air bag, yellow tape shows probable occupant scuff

The front right passenger's air bag was located in the middle of the instrument panel (**Figure 9**). This air bag properly did not deploy because there was no passenger seated in the front right seat. The case vehicle's advanced occupant restraint system properly determined the absence of a front right passenger and suppressed the deployment of the front right air bag. The air bag was also equipped with a suppression switch, which was set to the "Auto" position.

Figure 8: Back of driver's air bag, arrows show air bag vent ports

CRASH DATA RECORDING

The download of the case vehicle's EDR was done during the vehicle inspection via direct connection to the case vehicle's Sensing and Diagnostic Module (SDM). The EDR reports are presented at the end of this report (**Figures 12 - 17**). The downloaded data indicated that a non-deployment event and deployment event were recorded. In addition, the data indicate there were one or more associated events that were not recorded. The non-deployment event occurred during this crash because it was recorded on the same ignition cycle as the deployment event. The non-recorded event(s) probably occurred during minor secondary contact(s) between the front of the case vehicle and back of the Hummer following the initial impact. The damage to the case vehicle's front bumper indicated there was snagging between the two vehicles during separation that pulled the case vehicle's front bumper forward slightly.

Figure 9: Arrow shows location of front right air bag

The EDR system status reports show that the SIR warning lamp was recorded as off, and the driver's seat belt switch circuit was recorded as buckled. In addition, the maximum SDM recorded velocity change was recorded as -16.94 km.p.h. (-10.53 m.p.h.) for the deployment event occurring 115 milliseconds after algorithm enable (AE), and -1.94 km.p.h. (-3.12 m.p.h.) for the non-deployment event occurring 60 milliseconds after AE. The system status report for the deployment event shows that the first stage deployment criteria for the driver's air bag was met 27.5 milliseconds after AE, and the second stage deployment criteria for the driver's air bag was not met.

The pre-crash data indicate that the case vehicle was traveling 79 km.p.h. (49 mph) at 0% throttle five seconds prior to AE. The throttle remained at 0% for the remaining four sample periods. At one second prior to AE the case vehicle's brake switch is recorded as on and the speed is recorded as 60 km.p.h. (37 m.p.h) indicating the driver applied the brakes just prior to the impact.

Figure 10: Overview of driver' seat and safety belt, orange dots show location of load mark on driver's shoulder belt, arrow shows displaced shoulder belt guide

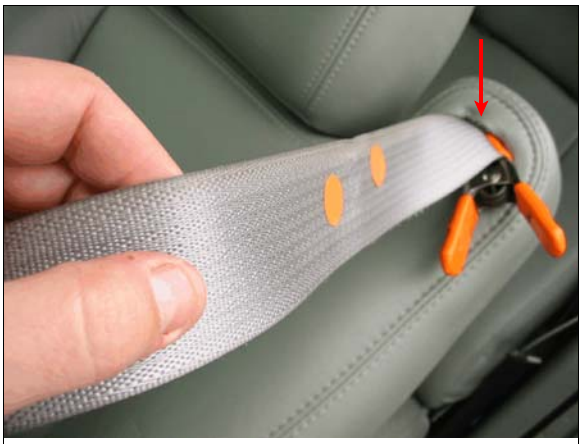


Figure 11: Close view of load mark on driver's shoulder belt, arrow shows installed location of displaced shoulder belt guide

CASE VEHICLE DRIVER KINEMATICS

Immediately prior to the crash, the case vehicle's driver [44-year-old, White (unknown if Hispanic) male, unknown height and weight] was probably seated in an upright driving posture. The driver probably had both hands on the steering wheel and was bracing for impact. The EDR data indicate that the brake switch circuit was on just prior to the crash indicating the driver had one of his feet on the brake pedal. The driver's seat track was located in its rearmost position, the seat back was slightly reclined, and the tilt steering wheel was located in its center position.

Based on this contractor's vehicle inspection and supported by the EDR data, the case vehicle's driver was restrained by his integral, three-point, lap-and-shoulder safety belt system. Inspection of the driver's safety belt assembly showed evidence

of loading (**Figures 10** and **11** above). The plastic shoulder belt guide to the integral housing was displaced from the seat back and there was a light load mark on the shoulder belt.

The case vehicle's driver applied the brakes just prior to the crash. As a result of the braking, the driver's safety belt retractor probably locked and he continued forward into his safety belt. The case vehicle's front impact with the back of the Hummer caused the case vehicle's driver to continue forward along a path opposite the case vehicle's 0 degree direction of principal force as the case vehicle decelerated and he loaded his safety belt. The driver's face and chest probably contacted his deployed air bag. In addition, both of the driver's forearms contacted the deployed air bag causing an abrasion and contusion to his left forearm and a contusion to his right forearm. His left foot also impacted the toe pan causing a sprain to his left ankle. After the impact, the driver probably rebounded back into his seat. It is unknown if the driver was able to exit the case vehicle under his own power following the crash. The driver's emergency room records indicated he was not ambulatory at the scene.

CASE VEHICLE DRIVER INJURIES

The driver sustained a police reported "B (non-incapacitating-evident) injury. He was transported by ambulance to a local hospital and treated and released from the emergency room. The table below shows the driver's injuries and injury mechanisms.

Injury Number	Injury Description (including Aspect)	NASS Injury Code & AIS 90	Injury Source (Mechanism)	Source Confidence	Source of Injury Data
1	Sprain left ankle with splint/cast applied and crutches provided	minor 850206.1,2	Floor (including floor pan)	Probable	Emergency room records
2	Abrasions left forearm, not further specified	minor 790202.1,2	Air bag, driver's	Probable	Emergency room records
3	Contusions, left and right forearms, not further specified	minor 790402.1,3	Air bag, driver's	Probable	Emergency room records

OTHER VEHICLE

The 2004 Hummer H2 was a four wheel drive, four-door sport utility vehicle (VIN: 5GRGN23UX4H------) equipped with 6.0L, V-8 engine and a four-speed automatic transmission. The Hummer was equipped with redesigned driver and front right passenger air bags that did not deploy as a result of this vehicle's impact.

Exterior Damage: With no inspection and no available vehicle photographs, the CDC for the Hummer is not estimable. The Hummer was driven from the scene by the driver.

Hummer's Occupants: According to the police crash report, the Hummer's driver [45-year-old, White (unknown if Hispanic) female] was restrained by her manual, three-point, lap-and-shoulder safety belt system. The driver did not sustain any police reported injuries as a result of the crash.

2GTEK19TX41xxxxxx System Status At Deployment	
SIR Warning Lamp Status	OFF
Driver's Belt Switch Circuit Status	BUCKLED
Ignition Cycles At Deployment	1736
Ignition Cycles At Investigation	1738
Maximum SDM Recorded Velocity Change (MPH)	-10.53
Algorithm Enable to Maximum SDM Recorded Velocity Change (msec)	115
Driver First Stage Time Algorithm Enabled to Deployment Command Criteria Met (msec)	27.5
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)	Suppressed
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)	0.00	-0.62	-1.55	-2.48	-2.79	-3.72	-4.34	-6.51	-8.99	-9.92	-10.23	-10.23	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	49	1344	0	OFF
-4	49	1344	0	OFF
-3	49	1344	0	OFF
-2	49	1344	0	OFF
-1	37	1024	0	ON

Figure 12: Case vehicle's System Status at Deployment report

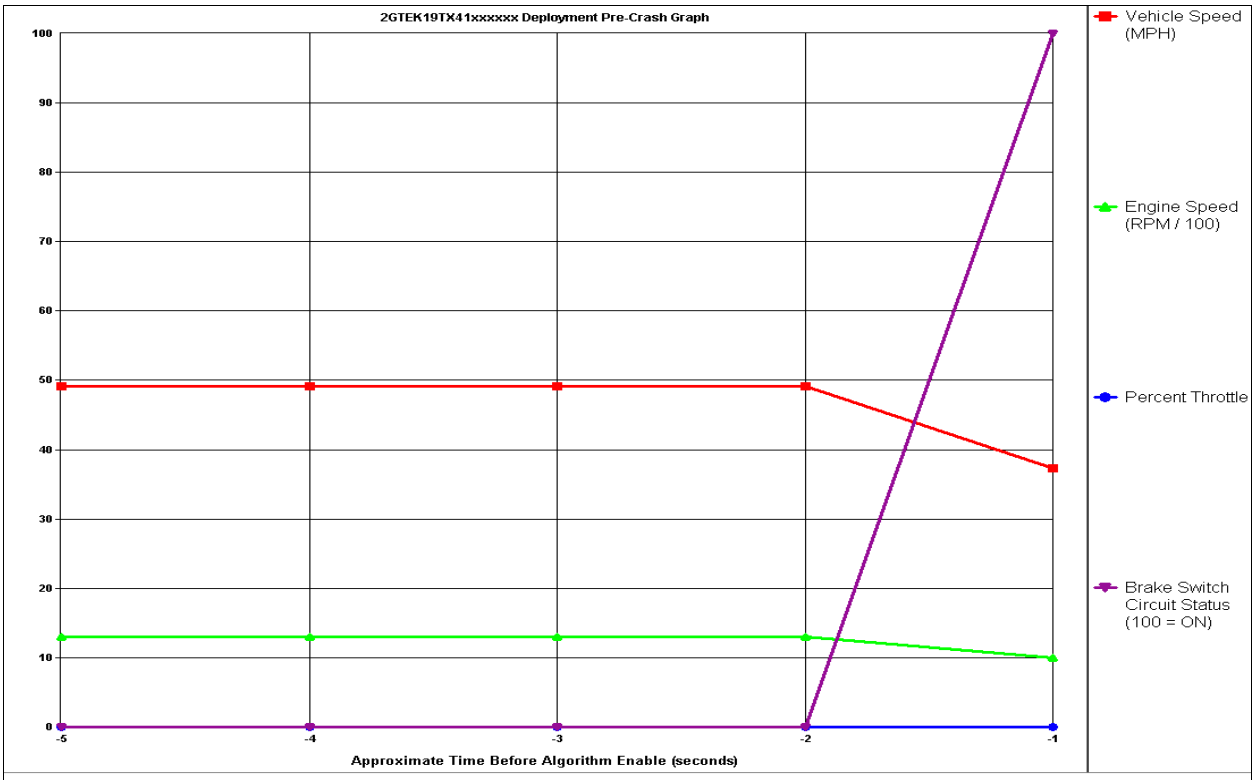


Figure 13: Case vehicle's Deployment Pre-Crash Graph

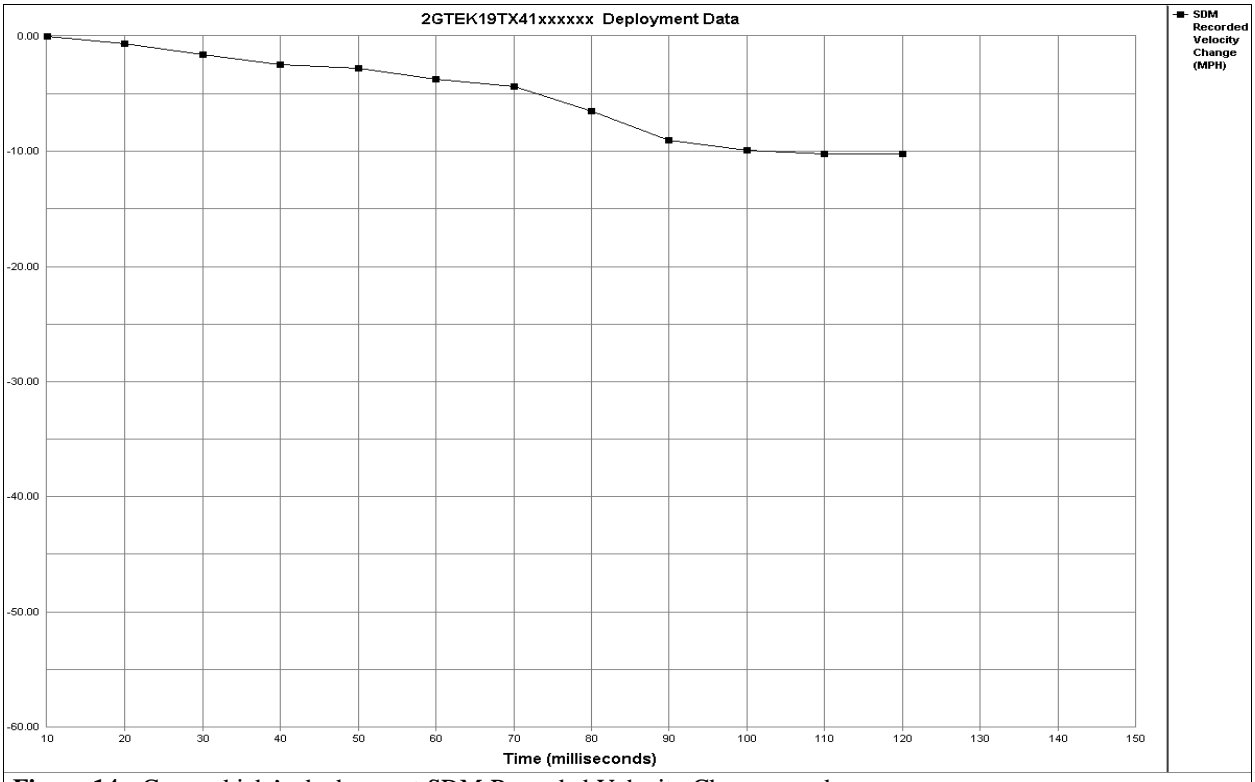


Figure 14: Case vehicle's deployment SDM Recorded Velocity Change graph

2GTEK19TX41xxxxxx System Status At Non-Deployment	
SIR Warning Lamp Status	OFF
Driver's Belt Switch Circuit Status	BUCKLED
Ignition Cycles At Non-Deployment	1736
Ignition Cycles At Investigation	1738
Maximum SDM Recorded Velocity Change (MPH)	-1.94
Algorithm Enable to Maximum SDM Recorded Velocity Change (msec)	60
Event Recording Complete	Yes
Multiple Events Associated With This Record	Yes
One Or More Associated Events Not Recorded	Yes

Time (milliseconds)	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150
Recorded Velocity Change (MPH)	-0.31	-0.62	-0.93	-1.24	-1.55	-1.86	-1.86	-1.86	-1.86	-1.86	-1.86	-1.55	-1.55	-1.55	-1.55

PRE-CRASH DATA				
Seconds Before AE	**Vehicle Speed (MPH)**	**Engine Speed (RPM)**	**Percent Throttle**	**Brake Switch Circuit Status**
-5	49	1344	0	OFF
-4	49	Invalid	0	OFF
-3	49	1344	0	OFF
-2	49	1024	0	OFF
-1	37	0	0	ON

Figure 15: Case vehicle's System Status at Non-deployment report

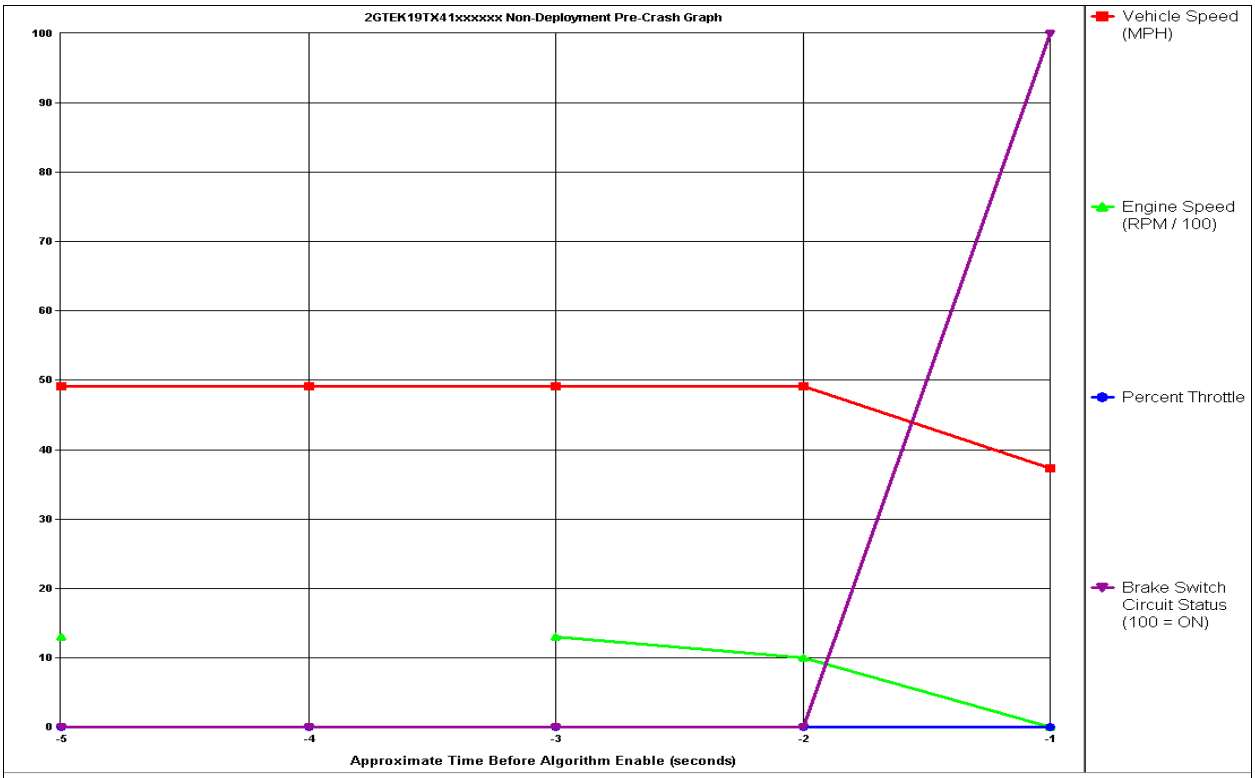


Figure 16: Case Vehicle's Non-Deployment Pre-Crash Graph

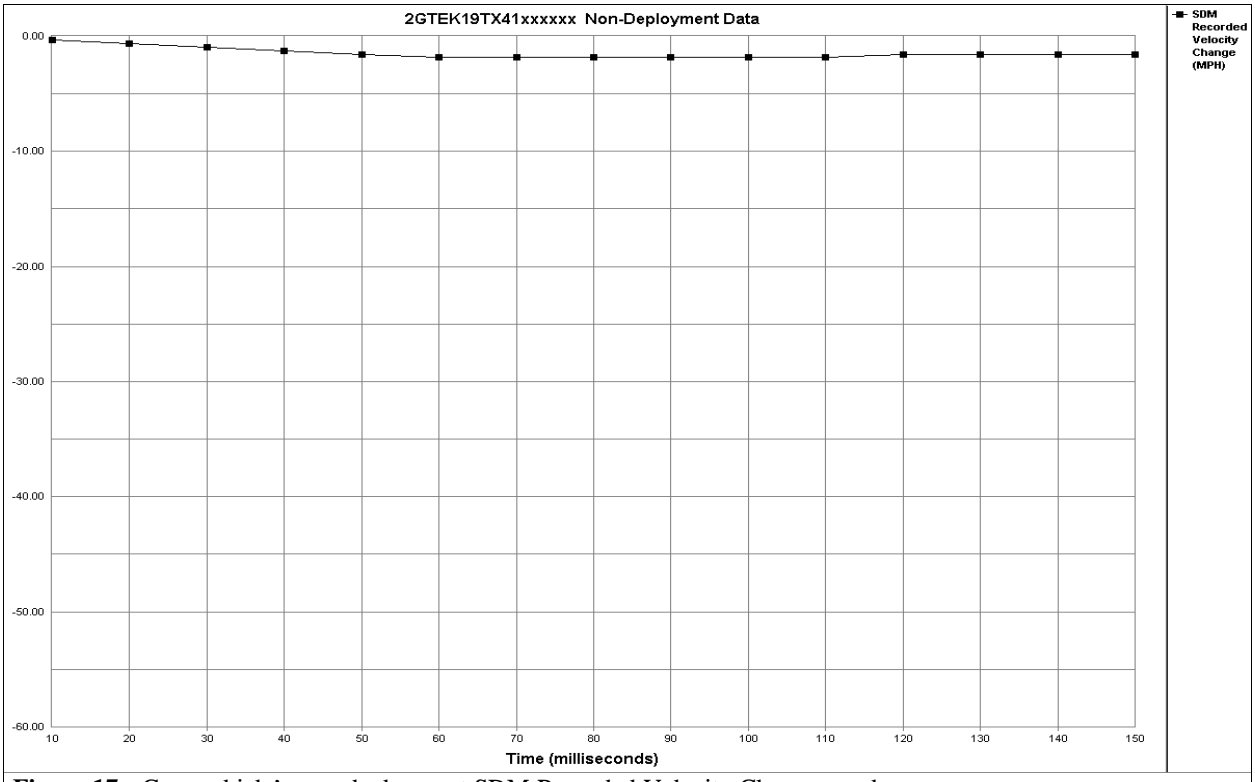
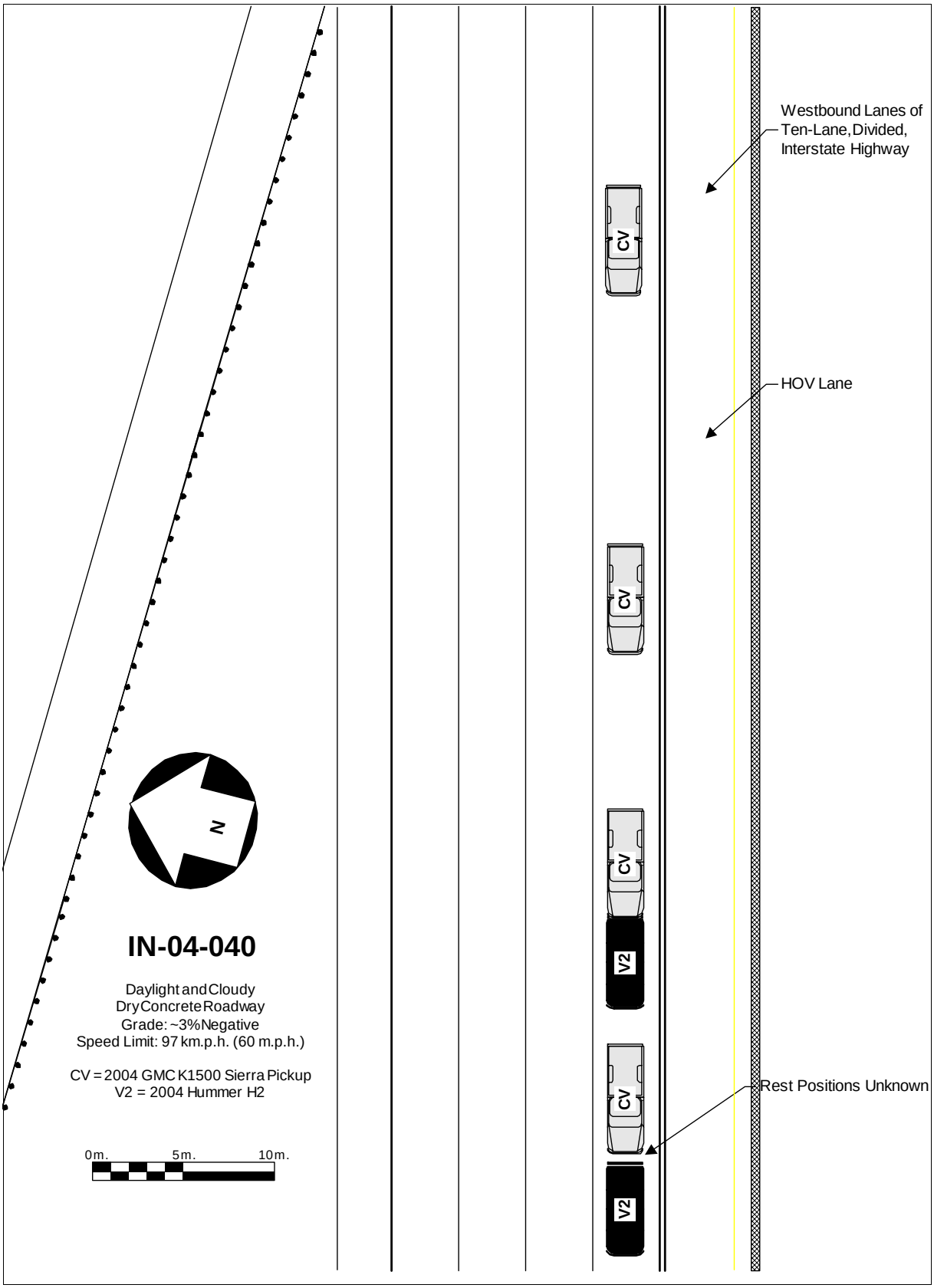


Figure 17: Case vehicle's non-deployment SDM Recorded Velocity Change graph


Westbound Lanes of
Ten-Lane, Divided,
Interstate Highway
HOV Lane
Rest Positions Unknown
CV
CV
CV
V2
CV
V2
N
IN-04-040
Daylight and Cloudy
Dry Concrete Roadway
Grade: ~3% Negative
Speed Limit: 97 km.p.h. (60 m.p.h.)
CV = 2004 GMC K1500 Sierra Pickup
V2 = 2004 Hummer H2
0m.
5m.
10m.