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ON-SITE CERTIFIED ADVANCED 208-COMPLIANT VEHICLE INVESTIGATION

CASE NUMBER - IN-04-001
LOCATION - TEXAS
VEHICLE - 2003 CHEVROLET C1500 TAHOE
CRASH DATE - December 2003

Submitted:

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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 deployment investigation involving a 2003 Chevrolet C1500 Tahoe, four-door sport utility vehicle, with manual safety belts and dual front advanced air bags which ran-off-road impacting multiple fixed objects

16. *Abstract*
This report covers an on-site investigation of an air bag deployment crash that involved a 2003 Chevrolet Tahoe (case vehicle) which ran-off-road and impacted a fixed object before rolling over. This crash is of special interest because the case vehicle was equipped with multiple **A**dvance **O**ccupant **P**rotection **S**ystem (**AOPS**) features, including certified advanced 208-compliant air bags, as well as an **E**vent **D**ata **R**ecorder (**EDR**) and the case vehicle's driver(37-year-old, female) sustained only a moderate injury as a result of the crash. The trafficway on which the case vehicle was traveling was a one-lane, undivided, exit/entrance ramp connecting a multi-lane, divided, north-south interstate highway to a multi-lane, divided, east-west U.S. highway. The ramp curved to the right–from straight north to straight east. The case vehicle was traveling in a northeasterly direction on the exit/entrance ramp. The case vehicle's driver lost control and departed the left-hand (northwestern) side of the roadway. The crash occurred within the interchange area, on the left-hand (northwestern) roadside of the exit/entrance ramp. The front of the case vehicle impacted a metal longitudinal barrier [i.e., a "W" beam guard rail (1st event)] on the northwestern roadside. The case vehicle's driver and front right passenger supplemental restraints (advanced air bags) did not deploy. The case vehicle vaulted over the guardrail, resulting in multiple impacts with the guardrail (2nd and 4th event) and the nearby delineator posts (3rd event). Eventually the case vehicle began to flip end-over-end (i.e., rollover initiation– 5th event), enabling the back of the case vehicle, which was upside down, to impact a bridge support pillar, at a height of approximately 3 meters (10 feet) off the ground (6th event). As a result of the bridge pillar impact, the case vehicle rotated clockwise about its vertical axis, fell to earth because of gravity, and rotated two quarter turns leftward about its longitudinal axis. The case vehicle struck the ground, most likely with its right side leading. The case vehicle's impact with the ground deflated all four tires. The case vehicle came to rest on its four wheels heading westward. The case vehicle's driver was seated with her seat track located between its middle and forward-most positions, and the tilt column was located in its center position. The driver was restrained by her available, active, three-point, integral lap-and-shoulder, safety belt system and sustained, according to her interview and her medical records, moderate injuries which included: a cerebral concussion and contusions to her left parietal scalp and the lateral surface of her left leg–from knee to ankle. In addition, she sustained an acute lumbar strain.

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This investigation was brought to NHTSA's attention on or before January 14, 2003 by NASS GES sampling activities. This crash involved a 2003 Chevrolet Tahoe (case vehicle) which ran-off-road and impacted a fixed object before rolling over. The crash occurred in December 2003 at 7:28 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 **A**dvance **O**ccupant **P**rotection **S**ystem (**AOPS**) features**,** including certified advanced 208-compliant air bags, as well as an **E**vent **D**ata **R**ecorder (**EDR**) and the case vehicle's driver[37-year-old, Black (non-Hispanic) female sustained only a moderate injury as a result of the crash. This contractor inspected the case vehicle on January 28, 2004 and downloaded the data from the onboard EDR. This contractor inspected the scene and interviewed the driver of the case vehicle on January 30, 2004. This report is based on the Police Crash Report, an interview with case vehicle's driver, scene and vehicle inspections, occupant kinematic principles, occupant medical records, and this contractor's evaluation of the evidence.

SUMMARY

The trafficway on which the case vehicle was traveling was a one-lane, undivided, exit/entrance ramp connecting a multi-lane, divided, north-south interstate highway to a multi-lane, divided, east-west U.S. highway. The ramp curved to the right–from straight north to straight east. At the time of the crash the light condition was daylight, the atmospheric condition, according to both the Police Crash Report and the driver, was raining (i.e., a "light mist"), and the road pavement was slightly wet. The case vehicle was traveling in a northeasterly direction on the exit/entrance ramp and intended to negotiate the right-hand curve and travel eastward on the eastbound roadway. According to the interview with the case vehicle's driver, she felt a loss of traction to the back end of the vehicle and steered leftward (i.e., into the rotation) and braked, without lock-up, in an effort to regain control. The case vehicle departed the left-hand (northwestern) side of the roadway. The crash occurred within the interchange area, on the left-hand (northwestern) roadside of the exit/entrance ramp.

The front of the case vehicle impacted a metal longitudinal barrier [i.e., a "W" beam guard rail (1st event)] on the northwestern roadside. The case vehicle's driver and front right passenger supplemental restraints (advanced air bags) did not deploy. The case vehicle vaulted over the guardrail in a tangential fashion. While overriding the guardrail, the guardrail snagged and broke off a portion of the right running board and damaged the lower right rear door (2nd event). Furthermore, while overriding the guardrail, the left side of case vehicle struck one or more delineator posts, depositing white vertically oriented marks along the case vehicle's left fender and left front door and knocked the left outside rearview mirror inward (3rd event). Eventually because of gravity, the front of the case vehicle dipped downward, re-contacting the guardrail. In addition, the front right corner–especially the front right hood area, most likely contacted one of the guardrail support posts (4th event) enabling the case vehicle to begin flipping end-over-end (i.e., rollover initiation– 5th event). The case vehicle rotated two quarter turns about its lateral axis while also rotating slightly clockwise about its longitudinal axis. The back of the case vehicle, which was upside down, impacted a bridge support pillar, at a height of approximately 3 meters (10 feet) off the ground (6th event). Because the back of the case vehicle was closer to the ground

than the front, the back structures were moved upward. As a result of the bridge pillar impact, the front of the case vehicle was lifted vertically, and the case vehicle rotated clockwise about its vertical axis. Together these movements enabled the case vehicle's left rear tire to contact and deposit a black scuff mark on the corner of the bridge pillar. Although the bridge support pillar halted the case vehicle's northeastward movement, the pillar still enabled the case vehicle to rotate clockwise about its vertical axis. Gravity caused the case vehicle to fall earthward. As the case vehicle fell, it rotated two quarter turns leftward about its longitudinal axis while still rotating clockwise about its vertical axis. The case vehicle struck the ground, most likely with its right side leading, depositing grass and dirt near the right rear door when the vehicle impacted the ground. The case vehicle's impact with the ground deflated all four tires. The case vehicle came to rest on its four wheels heading westward.

The 2003 Chevrolet Tahoe was a rear wheel drive (4x2), four-door sport utility vehicle (VIN: 1GNEC13ZX3J------) and was **C**ERTIFIED **A**DVANCED **208-C**OMPLIANT . The case vehicle was equipped with dual stage driver and front right passenger air bag inflators, and a driver seat belt sensing system. Front seat back-mounted side impact air bags were optional for this model, but this vehicle was not so equipped; however, this vehicle was equipped with power-adjustable pedals and the pedals were adjust to the mid-position. Finally, the case vehicle was also equipped with an **E**vent **D**ata **R**ecorder (**EDR**).

Based on the vehicle inspection, the six CDCs for the case vehicle were determined to be: **12-FDEW-1** (**0** degrees–1st event), **00-RPLN-1** (2nd event), **12-LYMS-1** (**350** degrees–3rd event), **00-FRMN-1** (4th event), **00-UDDO-1** (5th event), and **00-BDAW-2** (**190** degrees–6th event). The case vehicle sustained two horizontal impacts and four non-horizontal impacts. Because there was no clear rollover damage to either side of the vehicle or its top, an undercarriage CDC was assigned to "best" represent this event in the crash sequence. The WinSMASH reconstruction program, barrier algorithm, was used on both the case vehicle's highest severity impact and its second highest severity impact in order to provide an estimate of the Barrier Equivalent Speed (**BES**) that would have been necessary to have produced the observed damage pattern, had the damage been horizontally oriented. The highest severity impact involved the back of the case vehicle striking the bridge support pillar while the case vehicle was upside down. The second highest severity impact involved the case vehicle's initial impact with the "W" beam guardrail. For the highest severity impact, the Total, Longitudinal, and Lateral Delta Vs are, respectively: 21.8 km.p.h. (13.5 m.p.h.), -21.5 km.p.h. (-13.4 m.p.h.), and +3.8 km.p.h. (+2.4 m.p.h.). For the second highest severity impact, the Total, Longitudinal, and Lateral Delta Vs are, respectively: 19.4 km.p.h. (12.1 m.p.h.), -19.4 km.p.h. (-12.1 m.p.h.), and 0.0 km.p.h. (0.0 m.p.h.). Although these results are not encodable because the collision does not fit the reconstruction model, based on the vehicle inspection and the data from the **EDR**–for the initial impact only, the results appear to be reasonable. The case vehicle was towed due to damage.

The data downloaded from the case vehicle's **EDR** showed that the driver's seat belt status was buckled, neither stage of the multi-stage air bags was activated, and the Delta V reached a value of 16.46 km.p.h. (10.23 m.p.h.) at the 150 millisecond mark of recorded data. Maximum Delta V was 17.30 km.p.h. (10.75 m.p.h.), and this value was occurred 167.5 milliseconds after algorithm enable.

Immediately prior to the crash the case vehicle's driver was seated in a reclined posture with her back against the seat back, her left foot on the floor, her right foot on the brake, and both hands bracing against the steering wheel. Her seat track was located between its middle and forward-most positions, the seat back was slightly reclined, and the tilt column was located in its center position. The driver was restrained by her available, active, three-point, integral lap-and-shoulder, safety belt system and sustained, according to her interview and her medical records, moderate injuries which included: a cerebral concussion and contusions to her left parietal scalp and the lateral surface of her left leg–from knee to ankle. In addition, she sustained an acute lumbar strain.

CRASH CIRCUMSTANCES

Crash Environment: The traffic way on which the case vehicle was traveling was a one-lane, undivided, exit/entrance ramp (**Figure 1**) connecting a multi-lane, divided, north-south interstate highway to a multi-lane, divided, east-west U.S. highway. The ramp curved to the right–from straight north to straight east, and had an unmeasured grade negative to the north-northeast, followed by a sag to the northeast, followed by an unmeasured grade positive to the east-northeast (i.e., an upgrade in the case vehicle's direction of travel). Near the case vehicle's initial impact, the roadway was essential level because the exit ramp was in a sag at this approximate location. Furthermore, the roadway had an 8.2% superelevation from south-to-north at the approximate area of the initial impact. The pavement was concrete, but traveled, and the width of the travel lane was 3.9 meters (12.8 feet). The shoulders were improved (i.e., concrete), with a 1.6 meter (5.2 foot) wide paved shoulder adjacent to a mountable curb on the northwest side of the roadway and a measured 2.3 meter (7.5 foot) wide paved shoulder on the southeast side of the roadway prior to the mountable curb. Both sides of the exit roadway had longitudinal barriers (i.e., "W"-beam guardrails), located behind their respective mountable curbs, protecting the northwest and southeast roadsides and underpass support pillars, respectively (**Figure 2**). Pavement markings for the roadway consisted of a solid yellow edge line on the left-hand (west-to-north) side and a solid white edge line on right-hand (east-to-south) side. Furthermore, raised pavement markers were present along the shoulders–yellow markers on the left-hand side and white

Figure 1: Case vehicle's north-northeastern travel path on exit/entrance ramp; Note: arrow indicates impact area (1st event) with guardrail (case photo #01)

Figure 2: Case vehicle's northeastward travel path in rightward curving exit/entrance ramp; Note: oblique arrow indicates approximate point of impact and vertical arrow shows beginning of replacement guardrail (case photo #03)

markers on the right-hand side. In addition, there were white delineator posts along both roadsides, behind the longitudinal barriers. The estimated coefficient of friction was 0.65 when dry. There were no visible traffic controls in the immediate area of the crash. The speed limit was 64 km.p.h. (40 m.p.h.). No regulatory speed limit sign was posted near the crash site. At the time of the crash the light condition was daylight, the atmospheric condition, according to both the Police Crash Report and the driver, was raining (i.e., a "light mist"), and the road pavement was slightly wet. Traffic density was light, and the site of the crash was primarily rural commercial; see **CRASH DIAGRAM** at end.

Figure 3: Case vehicle frontal damage from impact with "W" beam guardrail with contour gauge set at bumper level; Note: highlighted area on front right hood most likely from impact with guardrail support post (case photo #12)

Pre-Crash: The case vehicle was traveling in a northeasterly direction on the exit/entrance ramp and intended to negotiate the right-hand curve and travel eastward on the eastbound roadway (**Figure 2** above). According to the interview with the case vehicle's driver, she felt a loss of traction to the back end of the vehicle. As a result, she steered leftward (i.e., into the rotation) and braked, without lock-up, in an effort to regain control. The case vehicle departed the left-hand (northwestern) side of the roadway. The crash occurred within the interchange area, on the left-hand (northwestern) roadside of the exit/entrance ramp.

Figure 4: Damage to case vehicle's right rear door and running board most likely from sustained contact with deformed "W" beam (case photo #25)

Crash: The front (**Figure 3**) of the case vehicle impacted a metal longitudinal barrier [i.e., a "W" beam guard rail (1st event–**Figure 2** above)] on the northwestern roadside. The case vehicle's driver and front right passenger supplemental restraints (advanced air bags) did not deploy. The case vehicle vaulted over the guardrail in a tangential fashion.

Figure 5: Close-up of damage to case vehicle's right rear door and running board most likely from sustained contact with deformed "W" beam guardrail (case photo #27)

Post-Crash: While overriding the guardrail, the guardrail snagged and broke off a portion of the right running board and damaged the lower right rear door (2nd event–**Figures 4 and 5**). Furthermore, while overriding the guardrail, the left side

of case vehicle struck one or more delineator posts, depositing white vertically oriented marks along the case vehicle's left fender and left front door; the posts also knocked the left outside rearview mirror inward (3rd event–**Figure 6**). Eventually because of gravity, the front of the case vehicle dipped downward and contacted the guardrail again. In addition, the front right corner–especially the front right hood area (**Figures 7** and **8** below), most likely contacted one of the guardrail support posts (4th event–**Figure 9** below) enabling the case vehicle to begin flipping end-over-end (i.e., rollover initiation– 5th event).

Figure 6: Case vehicle's left fender and left front door areas showing white, vertically oriented, contact evidence most likely from contact with delineator post(s) originally positioned behind guardrail; Note: left outside rearview mirror contacted front-to-back (case photo #16)

Figure 7: Case vehicle's frontal damage viewed from right along reference line; Note: damage area on front right hood possibly from contact with guardrail support post (case photo #27a)

Figure 8: Case vehicle's frontal damage from impact with longitudinal barrier (i.e., "W" beam guard-rail) viewed from right of front; Note: damage area on front right hood possibly from contact with guardrail support post (case photo #27b)

The case vehicle rotated two quarter turns about its lateral axis while also rotating slightly clockwise about its longitudinal axis. The back of the case vehicle, which was upside down, impacted a bridge support pillar, at a height of approximately 3 meters (10 feet) off the ground (6th event–**Figure 10** below). Because the back of the case vehicle was closer to the ground than the front, the back structures were moved upward (**Figure 11** below). As a result of the bridge pillar impact, the front of the case vehicle was lifted vertically, and the case vehicle rotated clockwise about its vertical axis. Together these movements enabled the case vehicle's left rear tire to contact and deposit a black scuff mark on the corner of the bridge pillar. Although the bridge support pillar halted the case vehicle's northeastward movement, the pillar still enabled the case vehicle to rotate clockwise about its vertical axis. Gravity caused the case vehicle to fall earthward. As the case vehicle fell, it rotated two quarter turns leftward about its longitudinal axis

while still rotating clockwise about its vertical axis. The case vehicle struck the ground, most likely with its right side leading, depositing grass and dirt near the right rear door when the vehicle impacted the ground. The case vehicle's impact with the ground deflated all four tires. The case vehicle came to rest on its four wheels heading westward. The bridge pillar was located approximately 18.3 meters (60 feet) from the case vehicle's point of departure on the ramp's road edge (**Figure 12**).

Figure 9: Case vehicle's area of roadway departure and contact with longitudinal barrier (i.e., "W" beam guardrail) located on northwest roadside of exit/entrance ramp; Note: unidentified tire mark on shoulder **and** arrow indicates suspected contact with guardrail support post (case photo #05)

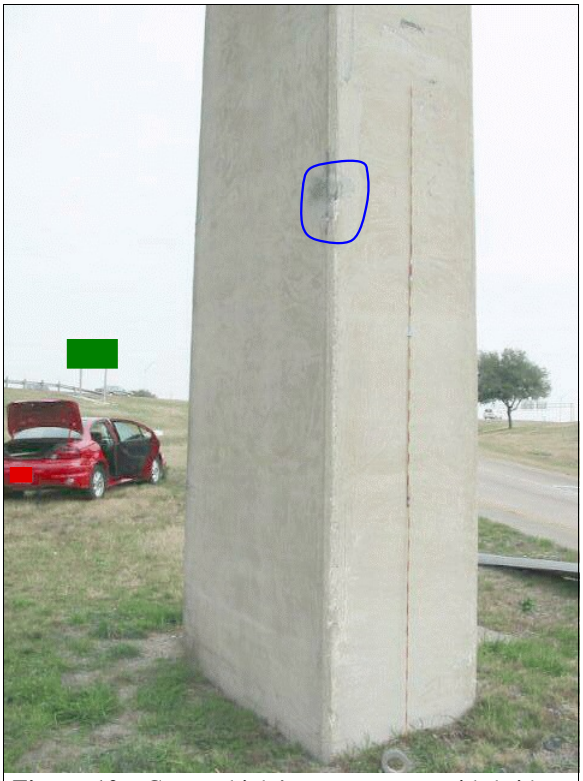


Figure 10: Case vehicle's contact area with bridge pillar; Note: height of contact area above ground and highlighted tire scuff mark (case photo #07)

Figure 11: Non-horizontal damage to case vehicle's back from contact with bridge pillar, viewed from left of back with contour gauge set at bumper level; Note: vehicle was airborne and upside down at time of impact (case photo #19)

Figure 12: Southwesterly view from case vehicle's approximate final rest position of vehicle's north-easterly pre-crash travel path in right-hand curve in exit/entrance ramp; Note: distance from "W" beam guardrail to bridge pillar (case photo #10)

CASE VEHICLE

The 2003 Chevrolet Tahoe was a rear wheel drive (4x2), five-passenger, four-door sport utility vehicle (VIN: 1GNEC13ZX3J------) equipped with a 5.3L, V-8 engine and a four-speed

automatic transmission. Braking was achieved by a power-assisted, front and rear disc, four-wheel, anti-lock system. The case vehicle's wheelbase was 295 centimeters (116.0 inches), and the odometer reading at inspection is unknown because the case vehicle was equipped with an electronic odometer. The case vehicle was **CERTIFIED ADVANCED 208-COMPLIANT** and was equipped with dual stage driver and front right passenger air bag inflators, and a driver seat belt sensing system. Furthermore, there was an occupant detection and automatic air bag suppression system for the front right passenger seating position. In addition, front seat back-mounted side impact air bags were optional for this model, but this vehicle was not so equipped. 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 seat belt usage to determine the front air bag inflation level appropriate for the severity of the crash. For the front right seating position, 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). This vehicle was equipped with LATCH system features and power-adjustable pedals which were adjust to the mid-position. Finally, the case vehicle was also equipped with an **E**vent **D**ata **R**ecorder (**EDR**).

Inspection of the vehicle's interior revealed adjustable front bucket seats with adjustable head restraints; a non-adjustable back bench seat with adjustable head restraints for the back outboard seating positions; continuous loop, three-point, integral lap-and-shoulder, safety belt systems at the front outboard positions and at the back center position; and continuous loop, three-point, lap-and-shoulder, safety belt systems at the back outboard positions. The back outboard seat belt systems were not equipped with manually operated, upper anchorage adjusters. The vehicle was equipped with knee bolsters for both the driver and front right seating positions, neither of which showed evidence of occupant contact or deformation. Automatic restraint was provided by a Supplemental Restraint System (SRS) that consisted of a redesigned frontal air bag for the driver and front right passenger seating positions. Neither frontal air bag deployed as a result of the case vehicle's frontal impact with the metal longitudinal barrier.

Figure 13: Overhead view of case vehicle's front damage from impact with longitudinal barrier (i.e., "W" beam guardrail); Note: crush greatest at front right corner (case photo #27d)

CASE VEHICLE DAMAGE

Exterior Damage: The case vehicle's initial contact with the longitudinal barrier (i.e., "W" beam guard rail) involved its front (**Figures 2** and **8** above). Direct damage extended across the entire front bumper, a measured distance of 159

centimeters (62.6 inches). The undeformed end width was determined to be: 180 centimeters (70.9 inches). Residual maximum crush was measured as 25 centimeters (9.8 inches) at C_6 (**Figure 13** above). The table below shows the case vehicle's crush profile.

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	159	25	180	19	11	12	6	0	25	0	0
in		62.6	9.8	70.9	7.5	4.3	4.7	2.4	0.0	9.8	0.0	0.0
cm	6	133	30	168	30	25	15	11	10	2	-8	0
in		52.4	11.8	66.1	11.8	9.8	5.9	4.3	3.9	0.8	-3.2	0.0

The case vehicle's contact with the deforming guardrail (2nd event) involved its right side–specifically the rearward portion of the right running board and the lower portion of the right rear door (**Figures 4** and **5** above). The case vehicle's contact (most likely) with one or more delineator posts (3rd event) involved its left side and started at the left fender, continuing to the left rearview mirror and left front door (**Figure 6** above). In the 4th event, the case vehicle's front most likely re-contacted the crumping guardrail and more specifically, the front right corner contacted a guardrail support post (**Figures 7** and **8** above). The 5th event involved the vehicle flipping end-over-end and resulted in the case vehicle's back contacting a bridge support pillar (6th event) while it was upside down (**Figure 11** above and **Figure 14**). For the bridge pillar impact, the direct damage began at the back left bumper corner and extended 133 centimeters (52.4 inches) across the bumper and tailgate. Residual maximum crush was measured as 30 centimeters (11.8 inches) at a distance of 9 centimeters (3.5 inches) leftward of C_2. The table above shows the case vehicle's crush profile.

Figure 14: Non-horizontal damage to case vehicle's back from impact with bridge pillar; Note: vehicle was airborne and upside down at time of impact and trunk was closer to the ground than the engine compartment (case photo #21a)

As a result of the crash, the wheelbase on the case vehicle's left side was unaltered while the right side was shortened approximately 5 centimeters (2.0 inches). As a result of the guardrail impacts, the case vehicle's front bumper, bumper fascia, grille, hood, right headlight and turn signal assemblies, and right fender were directly damaged and crushed rearward and upward. The back portion of the right running board was broken off and the lower portion of the right rear door was crushed inward (**Figure 5** above). As a result of the case vehicle's inverted contact with bridge pillar, the back left bumper, bumper fascia, lift gate, left quarter panel, tailpipe, and left and right taillights and turn signal assemblies were directly damaged and crushed forward and upward (**Figure 14**). There was induced damage to the left headlight and turn signal assemblies

as well as the hood, the glazing of the backlite and the left rear window, both the left and right fenders, and both the left and right quarter panels. No obvious induced damage or remote buckling was noted to the remainder of the case vehicle's exterior.

The recommended tire size was: P265/170R16 and the case vehicle was equipped as such. 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	0	0	241	35	9	11	None	Yes	Yes
RF	0	0	241	35	9	11	None	No	Yes
LR	0	0	241	35	8	10	None	No	Yes
RR	0	0	241	35	9	11	None	No	Yes

Interior Damage: Inspection of the case vehicle's interior revealed no evidence of occupant contact on the interior surfaces (**Figures 15** and **16** and **Figure 17** below). There was longitudinal intrusion from the lift gate into the truck/storage area behind the back seats. Finally, there was no evidence of compression to the energy absorbing shear capsules in the steering column and no deformation to the steering wheel rim.

Figure 15: Case vehicle's driver seating area showing non-deployed driver air bag and no apparent evidence of occupant contact to steering wheel, instrument panel, or greenhouse areas (case photo #31)

Figure 16: Case vehicle's front right seating area showing non-deployed front right air bag and no apparent evidence of occupant contact to center and right instrument panels and greenhouse area (case photo #33)

Damage Classification: Based on the vehicle inspection, the six CDCs for the case vehicle were determined to be: **12-FDEW-1** (**0** degrees–1st event), **00-RPLN-1** (2nd event), **12-LYMS-1** (**350** degrees–3rd event), **00-FRMN-1** (4th event), **00-UDDO-1** (5th event), and **00-BDAW-2** (**190**

Figure 17: Case vehicle's second seating area viewed from right showing no apparent evidence of occupant contact to roof above driver's head and no indication of distortion or damage to driver's seat back (case photo #34)

degrees–6th event). The case vehicle sustained two horizontal impacts and four non-horizontal impacts. This contractor identified three distinct areas of impact that occurred to the case vehicle during its roll over, and as a result, assigned each a CDC reflecting the specific identifiable damage. Because there was no clear rollover damage to either side of the vehicle or its top, an undercarriage CDC was assigned to "best" represent this event in the crash sequence. The WinSMASH reconstruction program was not applicable to either of the horizontal impacts that the case vehicle sustained because one involved a yielding object (i.e., guardrail was overridden) and overlapping damage and the other a sideswipe. However, crush measurements were taken on both the case vehicle's front and back, and the WinSMASH reconstruction program, barrier algorithm, was used on both the case vehicle's highest severity impact and its second highest severity impact in order to provide an estimate of the Barrier Equivalent Speed that would have been necessary to have produced the observed damage pattern, had the damage been horizontally oriented. The highest severity impact involved the back of the case vehicle striking the bridge support pillar while the case vehicle was upside down. The second highest severity impact involved the case vehicle's initial impact with the "W" beam guardrail. For the highest severity impact, the Total, Longitudinal, and Lateral Delta Vs are, respectively: 21.8 km.p.h. (13.5 m.p.h.), -21.5 km.p.h. (-13.4 m.p.h.), and +3.8 km.p.h. (+2.4 m.p.h.). For the second highest severity impact, the Total, Longitudinal, and Lateral Delta Vs are, respectively: 19.4 km.p.h. (12.1 m.p.h.), -19.4 km.p.h. (-12.1 m.p.h.), and 0.0 km.p.h. (0.0 m.p.h.). Although these results are not encodable because the collision does not fit the reconstruction model, based on the vehicle inspection and the data from the EDR–for the initial impact only, the results appear to be reasonable. The case vehicle was towed due to damage.

AUTOMATIC RESTRAINT SYSTEM

The case vehicle was equipped with a Supplemental Restraint System (SRS) that contained dual stage frontal air bags at the driver and front right passenger positions. Neither frontal air bag deployed as a result of the frontal impact with the longitudinal barrier. The case vehicle's driver air bag was located in the steering wheel hub (**Figure 15** above) and the front right passenger's air bag was located in the middle of the instrument panel (**Figure 16** above).

CRASH DATA RECORDING

The data downloaded from the case vehicle's **EDR** showed the vehicle's SIR warning lamp status, driver's seat belt buckle status, vehicle's speed and brake switch status for the five recorded sample periods preceding the **ALGORITHM ENABLE**, ignition cycles at non-deployment, time from

algorithm enable to maximum **SDM** (i.e., ***SENSING AND DIAGNOSTIC MODULE***) recorded velocity change, and velocity change (i.e., Delta V). Downloaded data of interest indicated the following. At the 5th recorded sampling period prior to algorithm enable, the case vehicle's driver was braking, and the vehicle was traveling at a speed of approximately 97 km.p.h. (60 m.p.h.). The speed limit for the exit ramp was 64 km.p.h. (40 m.p.h.). During the 4th, 3rd, and 2nd sampling periods proceeding algorithm enable, the driver let off the brake allowing the vehicle to decelerate slowly. The vehicle's speed during this period decreased from 89 to 85 km.p.h. (55 to 53 m.p.h.). At the last (1st) sampling period prior to algorithm enable, the driver was again braking hard, and the vehicle's speed decreased approximately 29 km.p.h. (18 m.p.h.) to 68 km.p.h. (42 m.p.h.). The driver's seat belt status showed it was buckled, neither stage of the multi-stage air bags was activated, and the Delta V reached a value of 10.23 km.p.h. (16.46 m.p.h.) at the 150 millisecond mark of recorded data; see **EVENT DATA RECORDER DATA** (**Figures 19** through **21**) below. It is also indicated that two (at least) non-deployment events occurred during the crash sequence and that the data cannot specifically identify exactly where in the crash sequence that data was recorded. Given that the time from algorithm enable to the recorded maximum velocity change was 167.5 milliseconds, this indicates that the longitudinal change in velocity sensed by the EDR was elongated (i.e., versus spiking) during this crash sequence. The Maximum recorded Delta V was 17.30 km.p.h. (10.75 m.p.h.). This contractor believes that the recorded Delta V seems reasonable considering the elongated time frame over which the deformation to the case vehicle's front occurred.

CASE VEHICLE DRIVER KINEMATICS

Immediately prior to the crash the case vehicle's driver [37-year-old, Black (non-Hispanic) female; 152 centimeters and 61 kilograms (60 inches, 134 pounds)] was seated in a reclined posture with her back against the seat back, her left foot on the floor, her right foot on the brake, and both hands bracing against the steering wheel. Her seat track was located between its middle and forward-most positions, the seat back was slightly reclined, and the tilt steering wheel was located, according to the driver, in its down-most position. During our vehicle inspection, the tilt column was located in its center position.

Based on this contractor's vehicle inspection and substantiated by the **EDR** data, the case vehicle's driver was restrained by her available, active, three-point, integral lap-and-shoulder, safety belt system; however, the belt system was not equipped with a pretensioner. Furthermore, there was no evidence of belt pattern bruising and/or abrasions to the driver's body, but the inspection of the driver's seat belt webbing and latch plate showed trace evidence of loading (**Figure 18**).

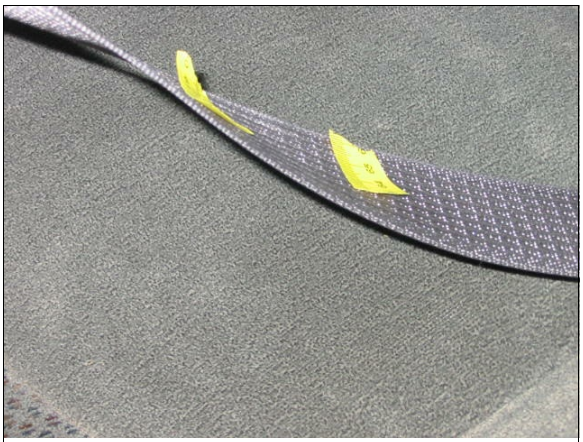


Figure 18: Loading evidence (i.e., slight waving and wear mark) on webbing of case vehicle's driver safety belt (case photo #31a)

The case vehicle's driver, according to her interview, felt a loss of traction to the back end of

the vehicle and steered leftward (i.e., into the rotation) and braked, without lock-up, in an effort to regain control. According to the collision configuration and substantiated by the **EDR** data, the case vehicle was going over 97 km.p.h. (60 m.p.h.) when she first started braking. As a result of these attempted avoidance maneuvers and the use of her available safety belts, she most likely moved slightly forward and to the right just prior to the case vehicle's initial impact with the longitudinal barrier (i.e., "W" beam guardrail). The case vehicle's initial impact with the guardrail enabled the case vehicle's driver to continue forward and possibly, slightly downward–because of the upward movement of the frontal damage, toward the case vehicle's **0** degree Direction of Principal Force as the case vehicle decelerated. At this point the case vehicle vaulted the guardrail and became airborne while rotating slightly clockwise. The case vehicle's impacts with the crumpling guardrail (2nd event) and the delineator posts (3rd event) had little or no effect on the driver's posture. When the front of the vehicle began to dip downwards and the front re-contacted the guardrail (4th event), enabling the case vehicle to begin flipping end-over-end (5th event), the driver moved upwards and forwards loading her available safety belts. The exact posture of the driver as the case vehicle rotated about its lateral axis (i.e., flipped over) is unknown, but she most likely moved initially forward and then upwards during this period. The driver's use of her safety belts restricted her movements enabling her to remain bent forward in her seat. When the case vehicle impacted the bridge support pillar (6th event) with its back in an upside down position, the driver was forced rearward and upward against her seat back which maintained its pre-impact position at impact (**Figure 17** above). Because the case vehicle had rotated clockwise about its vertical axis during the flip over, the impact to the bridge pillar also caused the driver to move to her left toward the left "B"-pillar, left roof side rail, and interior surface of the driver's door. When the front of the case vehicle moved upward as back of the vehicle was pushed downward (i.e., an upward flow of crush for a vehicle in its upright position), the driver moved closer to the roof and left "B"-pillar and/or roof side rail. Once again, the driver's safety belts restricted her upward movement. As the case vehicle rotated clockwise off the pillar and rotated leftward about its longitudinal axis before falling to the ground, the exact movement of the driver is unknown, but upon striking the ground with its wheels first, the driver would have moved downward loading her seat cushion. The vehicle most likely bounced upon impact with the ground, creating an up and down, somewhat jarring motion to the driver before it came to final rest. According to her interview, the driver remembers going over the guardrail and then being "awakened" inside her upright vehicle. The exact posture of the driver at final rest is unknown, but she was most likely slumped forward in her seat. The case vehicle's driver was conscious and removed from the vehicle because of her perceived injuries.

CASE VEHICLE DRIVER INJURIES

The driver was transported by ambulance to the hospital. She sustained a moderate injury and was treated and released. The driver subsequently made several visits to a private physician over the next two months. According to her medical records and her interview, the injuries sustained by the case vehicle's driver included: a cerebral concussion and contusions to her left parietal scalp and the lateral surface of her left leg–from knee to ankle. In addition, she sustained an acute lumbar strain. Her concussion and left scalp contusion were most likely caused by contacting the vehicle's left side roof rail, and her leg contusion most likely resulted from loading

the interior surface of her door. Her back strain most likely resulted from her rotation over and about the lap portion of her safety belt.

Injury Number	Injury Description (including Aspect)	NASS Injury Code & AIS 90	Injury Source (Mechanism)	Source Confidence	Source of Injury Data
1	Nonanatomic brain injury: concussion (i.e., momentary loss of consciousness) with enduring headaches	moderate 161000.2,0	Roof, left front side rail	Probable	Emergency room records
2	Contusion left parietal scalp	minor 190402.1,2	Roof, left front side rail	Probable	Emergency room records
3	Strain, acute, lumbar (low back)	minor 640678.1,8	Lap portion of safety belt system	Probable	Medical Clinic
4	Contusions lateral left lower leg from below knee to above ankle	minor 890402.1,2	Left side interior surface, excluding hardware and/or armrest	Probable	Emergency room records

1GNEC13ZX3J	System Status At Non-Deployment
SIR Warning Lamp Status	OFF
Driver's Belt Switch Circuit Status	BUCKLED
Ignition Cycles At Non-Deployment	1699
Ignition Cycles At Investigation	1709
Maximum SDM Recorded Velocity Change (MPH)	-10.75
Algorithm Enable to Maximum SDM Recorded Velocity Change (msec)	167.5
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)	0.00	0.00	-0.31	-0.93	-1.55	-1.86	-2.79	-3.72	-4.65	-5.89	-7.13	-8.06	-8.99	-9.61	-10.23

PRE-CRASH DATA				
Seconds Before AE	**Vehicle Speed (MPH)**	**Engine Speed (RPM)**	**Percent Throttle**	**Brake Switch Circuit Status**
-5	60	1728	0	ON
-4	55	1600	0	OFF
-3	53	1536	0	OFF
-2	53	1472	0	OFF
-1	42	2304	0	ON

Figure 19: Case vehicle's non-deployment data including: pre-crash speed, brake switch status, restraint system status, time (in milliseconds) from algorithm enable to maximum SDM recorded velocity, and the case vehicle's change in velocity (Delta V) over the first 150 milliseconds post algorithm enablement

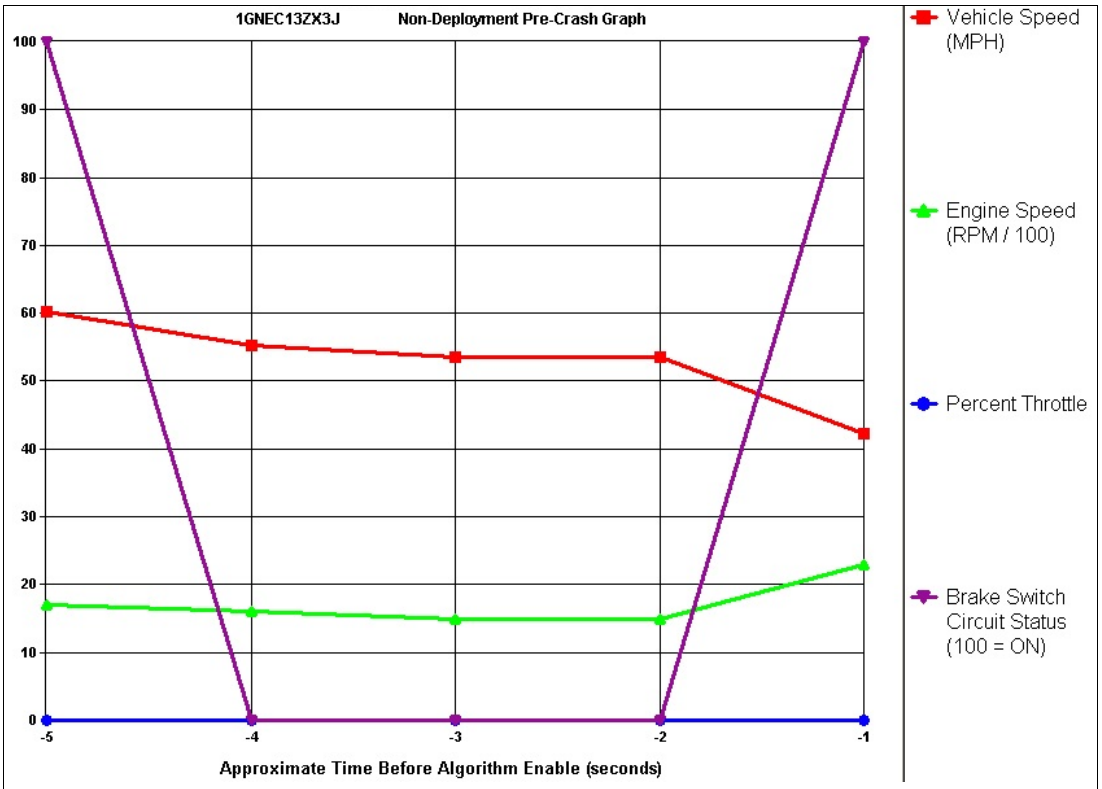


Figure 20: Case vehicle's pre-crash speed and brake switch circuit status showing that the vehicle's speed was recorded at 68 km.p.h. (42 m.p.h.) when the brake was reactivated approximately 1 second prior to algorithm enable, and that the brake switch had been activated, deactivated, and reactivated during the five recorded sample periods.

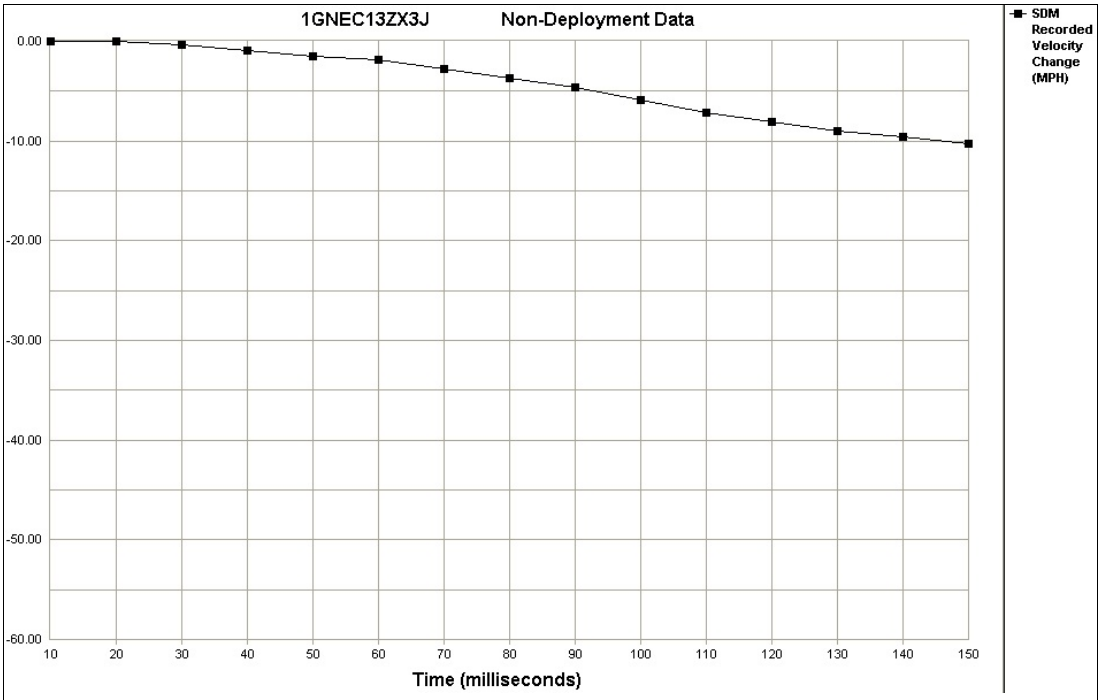
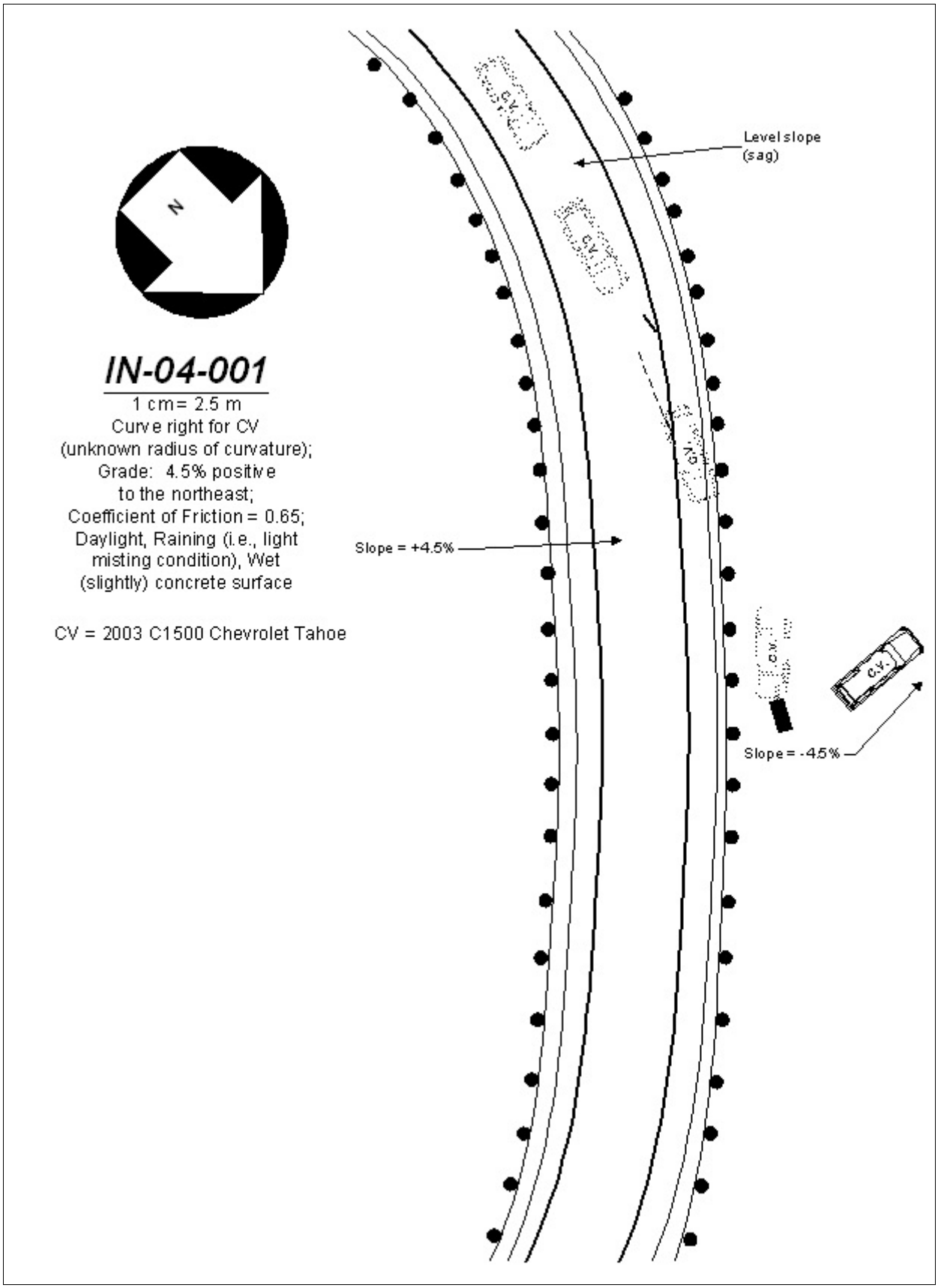


Figure 21: The case vehicle sustained a velocity change of approximately 16.4 km.p.h. (10.2 m.p.h.) during the first 150 milliseconds after the algorithm was enabled


N
IN-04-001
1 cm = 2.5 m
Curve right for CV
(unknown radius of curvature);
Grade: 4.5% positive
to the northeast;
Coefficient of Friction = 0.65;
Daylight, Raining (i.e., light
misting condition), Wet
(slightly) concrete surface
CV = 2003 C1500 Chevrolet Tahoe
Level slope
(sag)
Slope = +4.5%
Slope = -4.5%
C.V.
C.V.
C.V.
C.V.