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ON-SITE CERTIFIED ADVANCED 208-COMPLIANT VEHICLE INVESTIGATION

CASE NUMBER - IN-05-005
LOCATION - TEXAS
VEHICLE - 2005 CADILLAC CTS
CRASH DATE - December 2004

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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.

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On-site air bag investigation involving a 2005 Cadillac CTS with manual safety belts and dual front certified advanced 208-compliant air bag system.

16. *Abstract*

This report covers an on-site investigation of an air bag deployment crash that involved a 2005 Cadillac CTS (case vehicle),which ran-off-road, impacted a curb and a tree and then rolled over. 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 (29 year-old, male) sustained a police reported "B" (non-incapacitating-evident) injury as a result of the crash. The case vehicle was traveling north in the center lane of a six lane, divided city street at a high rate of speed. The case vehicle was traveling in a right curve and down a small hill. The driver lost control of the vehicle in the curve, and it entered the outside lane. The driver steered left as he exited the curve. The case vehicle began to rotate counterclockwise as it traveled up hill and toward the median. The driver applied the brakes just prior to the crash. The right front wheel impacted the median curb breaking the wheel rim and spokes. This impact most likely caused the case vehicle's front right seat back-mounted side impact air bag and the right side curtain air bag to deploy. The right rear wheel and the inside of the left front and left rear wheels also impacted the curb. The case vehicle entered the median and its right rear door impacted a tree causing a first stage deployment of the driver's air bag. The force of the impact uprooted the tree. The case vehicle traveled up and over the tree as it was being uprooted and rolled over passenger side leading two quarter turns onto its roof. The case vehicle slid across the southbound lanes on its roof and came to final rest across the outside and center southbound lanes facing northeast. The driver was restrained by his integrated, three-point, lap-and-shoulder safety belt. He sustained a fractured left clavicle from his safety belt and a nonanatomic brain injury with loss of conscious due to contact with the roof during the rollover. He was transported to a local hospital and admitted.

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BACKGROUND

This investigation was brought to NHTSA's attention on or before January 14, 2005 by NASS CDS/GES sampling activities. This crash involved a 2005 Cadillac CTS (case vehicle) that ran-off-road, impacted a curb and a tree and then rolled over. The crash occurred in December, 2004 at 12:18 p.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 [29-year-old, White (Hispanic) male] sustained a police reported "B" (non-incapacitating-evident) injury as a result of the crash. This contractor inspected the case vehicle and harvested the Sensing and Diagnostic Module (SDM), which contains the EDR, on February 10, 2005. The scene was inspected on February 11, 2005. The driver was not interviewed. He could not be contacted. This report is based on the police crash report, scene and vehicle inspections, driver medical records, occupant kinematic principles, and this contractor's evaluation of the evidence.

SUMMARY

The case vehicle was traveling north in the center lane of a six lane, divided city street at a high rate of speed. The case vehicle was traveling in a right curve and down a small hill. The driver lost control of the vehicle in the curve, and it entered the outside lane. The driver steered left as he exited the curve. The case vehicle began to rotate counterclockwise as it traveled up hill and toward the median. The EDR data indicated the case vehicle's driver applied the brakes just prior to the crash. The EDR recorded the vehicle's travel speed as 150 to 158 km.p.h. (93 to 98 m.p.h.) just prior to brake application. As the case vehicle rotated counterclockwise, the right front wheel impacted the median curb breaking the wheel rim and spokes. This impact most likely caused the case vehicle's front right seat back-mounted side impact air bag and the right side curtain air bag to deploy. The right rear wheel and the inside of the left front and left rear wheels also impacted the curb. The case vehicle entered the median and its right rear door impacted a tree causing a first stage deployment of the driver's air bag. The force of the impact uprooted the tree. The case vehicle traveled up and over the tree as it was being uprooted and rolled over passenger side leading two quarter turns onto its roof. The case vehicle slid across the southbound lanes on its roof and came to final rest across the outside and center southbound lanes facing northeast. At the time of the crash the light condition was daylight, the weather was clear, and the roadway pavement was dry concrete.

The CDCs for the case vehicle were determined to be: **02-RFWN-1** (**60** degrees) and **02-RBWN-1** (**60** degrees) for the right side wheel impacts with the curb, and **00-RPAW-6** for the right rear door impact with the tree. A non-horizontal direction of principal force was assigned for the tree impact due to the outward vertical angulation of the crush pocket that resulted as the case vehicle uprooted the tree and began to rollover. The maximum residual crush for this impact was measured as 119 centimeters (46.9 inches). A CDC of **00-TDDO-4** was assigned for the rollover damage.

Wheel impacts, non-horizontal impacts, and rollovers are out-of-scope for the WinSMASH reconstruction program. However, the case vehicle's Delta-Vs for the tree impact were calculated

using the EDR data. The case vehicle's EDR recorded the maximum longitudinal component of Delta-V as -21.0 km.p.h. (-13.0 m.p.h) for this impact. Using a force angle of 70 degrees based on the approach path of the case vehicle's center of gravity (i.e., the slip angle), the total and lateral components of Delta-V were calculated respectively as 61.2 km.p.h (38 m.p.h) and -57.5 km.p.h. (-35.7 m.p.h). The case vehicle was towed due to damage.

Immediately prior to the crash, the case vehicle's driver was most likely seated in a nominal upright driving position. The driver most likely had both hands on the steering wheel, was bracing for impact and was leaning to the right due to the case vehicle's counterclockwise yaw. The EDR data indicates that the brake switch was on just prior to the curb impact indicating the driver had one of his feet on the brake pedal. The driver's seat track was located in the approximate mid-track position, the seat back was most likely slightly reclined, and the tilt steering column was located in its center position. The driver was restrained by his integrated, three-point, lap-and-shoulder safety belt system.

As a result of the pre-crash yaw, the driver's safety belt retractor locked and the driver moved forward and to the right loading the safety belt. The case vehicle's right front wheel impact with the curb caused the driver to continue forward and to the right opposite the case vehicle's 60 degree direction of principal force and the case vehicle decelerated, and he loaded his safety belt. His right thigh most likely contacted the center console, and his right lower leg most likely contacted the lower side of the center console below the instrument panel. The driver continued to load his safety belt as the case vehicle traveled over the curb and through the median. The case vehicle's right side impact with the tree then caused the driver to move to the right and forward, and he loaded his safety belt fracturing his left clavicle. His face and upper chest also most likely contacted his deployed air bag. His right thigh most likely contacted the center console, and his hip contacted his safety belt buckle and the lower right portion of his seat back, which deformed due to the right side intrusion. In addition, his right lower leg most likely contacted the lower side of the center console below the instrument panel. As the case vehicle rolled over, passenger side leading, the driver moved to the right and toward the roof and continued to load his safety belt. As the case vehicle landed on its roof, the driver contacted his head on the intruding roof causing a non anatomic brain injury with loss of conscious. The driver remained restrained in his seat as the case vehicle slid across the pavement on its roof and came to rest. The driver remained restrained in his seat upside down and was removed from the case vehicle by rescue personnel. The driver was transported from the scene and admitted to a local hospital. The driver's use of his integrated, three-point, lap-and -shoulder safety belt and the deployment of his air bag mitigated his interaction with the case vehicle's interior components and reduced his injury potential.

CRASH CIRCUMSTANCES

Crash Environment: The trafficway on which the case vehicle was traveling was a six-lane, divided, city street, traversing in a north and south direction (**Figure 1** below). Both the northbound and southbound roadways had three travel lanes and were divided by a raised, curbed, grass median containing trees and luminaire poles. Each travel lane was approximately 3.3 meters (10.8 feet) in width. The median was 3.9 meters (12.8 feet) in width. The travel lanes were bordered by barrier curbs. The travel lane lines were designated by "Bots Dots". The case vehicle's approach was curved right and the vertical alignment was slightly negative. The roadway's vertical alignment then changed to an approximate 2.6% positive grade in the straight section prior to the crash location. At the time of the crash the light condition was daylight, the weather was clear, and the roadway pavement was dry concrete. In addition, the pavement surface had been augmented with perpendicular groves to increase its coefficient of friction. The groves had been considerably worn down in the tire paths of each lane. The estimated pavement coefficient of friction was 0.72. The traffic density at the time of the crash is unknown. The site of the crash was urban industrial. See the Crash Diagram at the end of this report.

Figure 1: Overview of case vehicle's northbound approach, arrow shows area of curb and tree impacts

Pre-Crash: The case vehicle was traveling north in the center lane at a high rate of speed in a right curve and down a small hill. The case vehicle's driver was intending to continue northbound. The driver lost control of the vehicle in the curve, and it entered the outside lane. The driver steered left as he exited the curve, and the case vehicle began to rotate counterclockwise and left yaw marks on the pavement from all four wheels (**Figures 2** and **3**). The case vehicle continued to rotate counter-clockwise across the roadway as it traveled up hill and toward the median. The EDR data indicated the case vehicle's driver applied the brakes just prior to the crash. The EDR recorded the case vehicle's travel speed as 150 to 158 km.p.h. (93 to 98 m.p.h.) just prior to brake application. The crash occurred in the median.

Figure 2: Police on-scene photo of case vehicle's yaw marks, highlighted in orange

Crash: As the case vehicle rotated counter-clockwise, the right front wheel impacted the median curb (**Figure 3**) breaking the wheel rim and spokes (**Figure 4** below). This impact most likely caused the case vehicle's front right seat back-mounted side impact air bag and right side curtain air bag to deploy. The right rear wheel also impacted the curb, which dented the rim (**Figure 5** below) and the tire debeaded as it

Figure 3: Police on-scene photo of case vehicle's yaw marks and wheel impacts with curb; tire marks are, from left to right: left front, right front, left rear and right rear

furrowed into the ground. In addition, the inside of the left front and left rear wheels impacted the curb. These impacts did not damage the wheels. The case vehicle entered the median and its right rear door (**Figure 5**) impacted a tree (**Figure 6**). The force of the impact uprooted the tree. The case vehicle traveled up and over the tree as it was being uprooted and rolled over passenger side leading two quarter turns onto its roof (**Figure 7**). It is this contractor's opinion that the tree impact produced sufficient longitudinal deceleration to deploy the driver's air bag. The EDR data indicated that only the first stage of the dual stage air bag system deployed.

Figure 4: Damage to case vehicle's right front suspension and wheel due to curb impact

Figure 5: Damage to case vehicle's right side from tree impact [each increment on rod is 5 cm (2 in)], arrow shows dent in right rear rim from curb impact

Figure 6: Police photo of location of tree impacted and uprooted by the case vehicle

Figure 7: Overview of rollover damage to the top of the case vehicle

Post-Crash: The case vehicle slid across the southbound lanes on its roof. It rotated clockwise approximately 120 degrees and came to final rest across the outside and center southbound lanes facing northeast (**Figures 8** and **9** below).

The 2005 Cadillac CTS was a rear wheel drive, four-door, sedan (VIN:1G6DP567550------) equipped with a 3.6L, V6 engine; five speed manual transmission; four wheel, anti-lock disc brakes and traction control. The front seating row was equipped with bucket seats with adjustable head restraints, dual stage driver and front right passenger air bags, driver and front right passenger seat back-mounted side impact air bags, front and rear side curtain air bags, driver and front right passenger integrated, three-point, lap-and-shoulder safety belt systems with seat belt buckle switch sensors, buckle-mounted pretensioners, energy management retractors, and a front right passenger occupant detection system with automatic air bag suppression. The rear seating row was equipped with a bench seat with integrated, three-point, lap-and-shoulder safety belt systems in all three seat positions. In addition, the case vehicle was equipped with a LATCH system for securing child safety seats and an EDR located within the vehicle's SDM. The case vehicle's wheelbase was 288 centimeters (113.4 inches). The odometer reading at the time of the vehicle inspection is unknown because the case vehicle was equipped with an electronic odometer.

Figure 8: Police photo showing final rest position of case vehicle in southbound lanes facing northeast

Figure 9: Police photo looking southeast back through case vehicle's rest position to impact

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 position, an occupant weight sensor in the seat cushion determines if an occupant is on the seat and enables or suppresses deployment of the air bag based on the amount of weight on the seat.

CASE VEHICLE DAMAGE

Exterior Damage: The curb impact to the case vehicle's right front wheel broke the wheel rim and spokes, and the wheel separated from the vehicle (**Figure 4** above and **Figure 10** below). The curb impact to the right rear wheel dented the rim, and the tire debeaded as it furrowed into ground (**Figure 11** below). The right rear door impact with the tree involved the door sill, door and roof side rail. The resulting crush pocket (**Figure 12** below) was angled vertically outward approximately 35 degrees due to the combination of uprooting of the tree and rolling over while the vehicle was still in contact with the tree. The direct damage from the tree impact began 71 centimeters (28 inches) forward of the right rear axle and extended 100 centimeters (39.4 inches) along the door and the sill. The crush pocket in the door approximated the shape of the tree. Crush measurements were taken at the sill level. The residual maximum crush was measured as119 centimeters (46.9inches) occurring at C_4. The table below shows the right side 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								$\pm D$	$\pm D$
cm	1	100	119	265	0	1	32	119	41	3	-11	-91
in		39.4	46.9	104.3	0.0	0.4	12.6	46.9	16.1	1.2	-4.3	-35.8

Figure 10: Damage to case vehicle's right front wheel from curb impact

Figure 11: Dent in case vehicle's right rear rim (arrow) from curb impact, and dirt in bead and rim from furrowing into the ground adjacent to the curb

Figure 12: Tree impact damage to case vehicle's right rear door

Figure 13: Overview of crush to the case vehicle's roof from the rollover

The direct damage from the rollover impact involved primarily the top of the case vehicle (**Figure 13**). The roof was crushed down extensively. The area of maximum residual crush occurred at the windshield header and A-pillars and was approximately 36 centimeters (14.2 inches). There was extensive scratching to the top plane of the vehicle with the scratches angulated in multiple directions, indicating the vehicle was rotating while sliding on its top across the roadway. Some of these scratches are also related to righting the vehicle as are the scratches noted on the driver's side. The police photos showed that the case vehicle was rolled over onto its left side and then onto its wheels by the tow truck.

The case vehicle's wheelbase was reduced 24 centimeters (9.5 inches) on the right side and extended 13 centimeters (5.1 inches) on the left side. Induced damage involved the entirety of the case vehicle.

The recommended tire size was P225/50R17; however, the case vehicle was equipped with P245/40R18 size tires. 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	200	29	207	30	5	6	None	No	No
RF	0	0	207	30	8	10	Wheel broken off vehicle, but no visible tire damage	N/A	Yes
LR	172	25	207	30	6	8	None	No	No
RR	0	0	207	30	6	8	Grass and dirt in bead, some scuffs on sidewall	No	Yes

Vehicle Interior: Inspection of the case vehicle's interior (**Figure 14** and **Figure 15** below) revealed blood stains on the roof above the driver's seat and on the upper back portion of the driver's air bag. No other evidence of occupant contact to any interior surfaces or components was observed. There was extensive intrusion into all passenger compartment seating positions. The roof was the primary intruding component into all the seat positions. The most severe intrusions into the driver's space occurred along the vertical axis. There was 36 centimeters (14.2 inches) of windshield header intrusion, 27 centimeters (10.6 inches) of roof intrusion, 18 centimeters (7.1 inches) of windshield intrusion, 17 centimeters

Figure 14: Left side view of steering wheel, instrument panel and driver's seat

(6.7 inches) of left A-pillar intrusion and 17 centimeters (6.7 inches) of roof side rail intrusion. In addition the right rear door intruded laterally 48 centimeters (18.9 inches) into the right rear seat position. Lastly, there was no evidence of compression of the energy absorbing steering column or deformation of the steering wheel rim (**Figure 16**).

Figure 15: Right side view of front seat area and instrument panel

Figure 16: Left side view of steering column and steering wheel showing lack of deformation

Damage Classification: Based on the vehicle inspection, the CDCs for the case vehicle were determined to be: **02-RFWN-1** (**60** degrees) and **02-RBWN-1** (**60** degrees) for the right side wheel impacts with the curb, and **00-RPAW-6** for the right rear door impact with the tree. A non-horizontal direction of principal force was assigned for the tree impact due to the outward vertical angulation of the crush pocket that resulted as the case vehicle uprooted the tree and began to rollover. A CDC of **00-TDDO-4** was assigned for the rollover damage.

Wheel impacts, non-horizontal impacts, and rollovers are out-of-scope for the WinSMASH reconstruction program. However, the case vehicle's Delta-Vs for the tree impact were calculated using the EDR data. The case vehicle's EDR recorded the maximum longitudinal component of Delta-V as -21.0 km.p.h. (-13.0 m.p.h) for this impact. Using a force angle of 70 degrees based on the approach path of the case vehicle's center of gravity (i.e., the slip angle), the total and lateral components of Delta-V were calculated respectively as 61.2 km.p.h (38 m.p.h) and -57.5 km.p.h. (-35.7 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 air bag deployed as a result of the case vehicle's impact with the tree. The front right passenger air bag did not deploy. The right front seat back-mounted side impact air bag and right side curtain air bags deployed due to the initial curb impact to the right front wheel.

The case vehicle's driver air bag was located in the steering wheel hub. An inspection of the air bag module's cover flaps and the air bag's fabric revealed that the cover flaps opened at the designated tear points (**Figure 17**). There was no evidence of damage during the deployment to the air bag or the cover flaps. The module cover consisted of two approximately triangular-shaped cover flaps made of thick, pliable vinyl. The right cover flap was constructed with a circular Cadillac emblem. The left cover flap had a semi-circular cut-out that accommodated the left half of the Cadillac emblem. Each cover flap was 8.5 centimeters (3.3 inches) in width at the top, 3.5 centimeters (1.4 inches) in width at the bottom and 13 centimeters (5.1 inches) in height. The driver's air bag was designed with two tethers, each approximately 7 centimeters (2.8 inches) in width. The deployed driver's air bag (**Figure 18**) was round with a diameter of approximately 60 centimeters (23.6 inches) and had two vent ports (**Figure 19**), each approximately 3.5 centimeters (1.4 inches) in diameter, located at approximately the 11 and 1 o'clock positions. An inspection of the driver's air bag fabric revealed no evidence of occupant contact on the front of the air bag. However, a blood stain was noted on the back of the air bag in the top, right area.

Figure 17: Case vehicle's driver air bag module flaps

Figure 18: Driver's air bag, each increment on rods is 5 cm (2 in)

Figure 19: Driver's air bag vent ports (arrows)

Figure 20: Right front, seat back-mounted, side impact air bag

The front right passenger's air bag was located in the middle of the instrument panel. This air bag properly did not deploy because no passenger was seated in the front right seat.

The right front seat back-mounted side impact air bag was centrally located in the right side of the seat back. There was no evidence of damage during the deployment to the air bag or the single air bag module cover flap. The deployed side impact air bag (**Figure 20** above) was rectangular in shape and was approximately 39 centimeters (15.4 inches) in length and approximately 23 centimeters (9.1 inches) in width. The air bag was designed without vents or tethers. Inspection of the air bag was unremarkable. There was no occupant seated in the front right seat.

The right side curtain air bag was located along the right roof side rail (**Figure 21**) inside the headliner and extended along the front right and back right seat positions. Due to the extent of damage to the right side and the roof, a thorough documentation of the air bag was not possible. The air bag was anchored to the right C-pillar. The air bag was approximately 33 centimeters (13 inches) in height. The length of the air bag could not be accurately determined due to the level of damage and intrusion to the right side of the case vehicle. The air bag was designed without tethers or vent ports. There was an approximate 6 centimeter (2.4 inches) cut on the outside of the air bag located about 23 centimeters (9.1 inches) forward of the right C-pillar. The cut occurred in the area of the tree impact. The remainder of the air bag was unremarkable.

Figure 21: Right side curtain air bag

CRASH DATA RECORDING

The case vehicle's SDM was harvested, and the EDR download was completed subsequent to the vehicle inspection. The downloaded data indicated that a non-deployment and a deployment event were recorded. The EDR reports for both events are presented in **Figures 23-30** at the end of this report. The EDR data indicated there were multiple events associated with the deployment record, and one or more of the associated events were not recorded. The non-deployment event and non-recorded events are most likely associated with the wheel/curb impacts that occurred prior to the tree impact. The pre-crash data reported on the system status reports for both the non-deployment and deployment records are identical. This is most likely due to the short time that occurred between the non-deployment event and deployment event. The system status report for the deployment event reported this time as 0.7 seconds. It is this contractor's understanding that if the time between events is less than one second, there will be insufficient time for the system to update the pre-crash data.

The EDR system status reports show that the SIR warning lamp was recorded as off, and the driver's safety belt switch circuit was recorded as buckled. In addition, the maximum SDM recorded velocity change was -20.92 km.p.h. (-13.00 m.p.h.) for the deployment event occurring 237.5 milliseconds after algorithm enable (AE), and -1.30 km.p.h. (-0.81 m.p.h.) for the non-deployment event occurring 37.5 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 20 milliseconds after AE. The second stage deployment criteria was not met. In addition, the report indicates the front right passenger air bag was suppressed.

The pre-crash data indicates that five seconds prior to AE, the case vehicle was at 82% throttle traveling at 150 km.p.h. (93 m.p.h.), and the brake switch was recorded off. At three seconds prior to AE, the throttle increases to 98 % with the speed recorded as 158 km.p.h. (98 m.p.h.), and the brake switch recorded off. The percent throttle falls to 80% at two seconds prior to AE, and to 50% at one second with the speed recorded as132 km.p.h. (82 m.p.h.) and the brake switch recorded on. The graphs of the pre-crash data for the deployment and non-deployment events are presented in **Figures 26** and **29** at the end of this report.

CASE VEHICLE DRIVER KINEMATICS

Immediately prior to the crash, the case vehicle's driver [29-year-old, White (Hispanic) male, unknown height and weight] was most likely seated in a nominal upright driving position. The driver most likely had both hands on the steering wheel, was bracing for impact and was leaning to the right due to the case vehicle's counterclockwise yaw. The EDR data indicates that the brake switch was on just prior to the curb impact indicating the driver had one of his feet on the brake pedal. Based on the vehicle inspection, the driver's seat track was located in the approximate mid-track position. The driver's seat back appeared to have been slightly reclined prior to the crash, although it had been somewhat deformed due to the right side intrusion and the roof intrusion. The tilt steering column 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 integrated, three-point, lap-and-shoulder safety belt system. The safety belt had been cut off the driver by the rescue crew (**Figure 22**).

Figure 22: Overview of driver's seat and safety belt, note cut belt from rescue activities

Just prior to the crash, the case vehicle was in a counterclockwise yaw. As a result of the yaw, the driver's safety belt retractor locked and the driver moved forward and to the right loading the safety belt. The case vehicle's right front wheel impact with the curb caused the driver to continue forward and to the right opposite the case vehicle's 60 degree direction of principal force and the case vehicle decelerated, and he loaded his safety belt. His right thigh most likely contacted the center console, and his right lower leg most likely contacted the lower side of the center console below the instrument panel. The driver continued to load his safety belt as the case vehicle traveled over the curb and through the median. The case vehicle's right side impact with the tree then caused the driver to move to the right and forward, and he loaded his safety belt fracturing his left clavicle. His face also most likely contacted his deployed air bag. His right thigh most likely contacted the center console, and his hip contacted his safety belt buckle and the lower right portion of his seat back, which deformed due to the right side intrusion. In addition, his right lower leg most likely contacted the lower side of the center console below the instrument panel. As the case vehicle rolled over, passenger side leading, the driver moved to the right and toward the roof and continued to load his safety belt. As the case vehicle landed on its roof, the driver contacted his head on the intruding roof causing a non anatomic brain injury with loss of conscious. The driver remained restrained in his seat as the case vehicle slid across the pavement on its roof and came to rest. The driver remained restrained in his seat upside down and was removed from the case vehicle by rescue personnel. The driver's use of his integrated, three-point, lap-and -shoulder safety belt and the deployment of his air bag mitigated his interaction with the case vehicle's interior components and reduced his injury potential.

CASE VEHICLE DRIVER INJURIES

The case vehicle's driver sustained a police reported "B (non-incapacitating-evident) injury. The police report indicated the driver was transported to a hospital by helicopter. The driver was admitted to the hospital. The number of days the driver spent in the hospital is not known. The driver's injuries and injury mechanisms are shown in the table below.

Injury Number	Injury Description (including Aspect)	NASS Injury Code & AIS 90	Injury Source (Mechanism)	Source Confidence	Source of Injury Data
1	Nonanatomic brain injury with prior loss of consciousness, awake and alert on assessment	moderate 160406.2,0	Roof	Probable	Emergency room records
2	Fracture, comminuted, slightly displaced, left clavicle	moderate 752200.2,2	Torso portion of safety belt system	Certain	Emergency room records
3	Laceration, 2-3 cm (0.8-1.2 in) dorsum, posterior, left hand	minor 790602.1,2	Unknown contact mechanism	Unknown	Emergency room records
4	Avulsion, superficial, volar (palm) surface left hand	minor 790802.1,2	Unknown contact mechanism	Unknown	Emergency room records

SDM Data Limitations

SDM Recorded Crash Events:
There are two types of SDM recorded crash events. The first is the Non-Deployment Event. A Non-Deployment Event is an event severe enough to "wake up" the sensing algorithm but not severe enough to deploy the air bag(s). It contains Pre-Crash and Crash data. The SDM can store up to one Non-Deployment Event. This event can be overwritten by an event that has a greater SDM recorded vehicle forward velocity change. This event will be cleared by the SDM after the ignition has been cycled 250 times.
The second type of SDM recorded crash event is the Deployment Event. It also contains Pre-Crash and Crash data. The SDM can store up to two different Deployment Events, if they occur within 25.4 seconds of one another. Deployment Events cannot be overwritten or cleared from the SDM. Once the SDM has deployed the air bag, the SDM must be replaced.
The data in the Non-Deployment Event file will be locked after a Deployment Event, if the Non-Deployment Event occurred within 5 seconds before the Deployment Event. If multiple Non-Deployment Events occur within 5 seconds prior to a Deployment Event, then the most severe Non-Deployment Event will be recorded and locked. If multiple Non-Deployment Events precede a Deployment Event, and multiple Non-Deployment Events occur within 5 seconds of each other (but not necessarily all within 5 seconds of the Deployment Event), and subsequent Non-Deployment Events are less severe than prior Non-Deployment Events, and the last of the multiple Non-Deployment Events occurs within 5 seconds of a Deployment Event, then the most severe of the Non-Deployment Events (which may have occurred more than 5 seconds prior to the Deployment Event) will be recorded and locked.

SDM Data Limitations:
-SDM Recorded Vehicle Forward Velocity Change reflects the change in forward velocity that the sensing system experienced during the recorded portion of the event. SDM Recorded Vehicle Forward Velocity Change is the change in velocity during the recording time and is not the speed the vehicle was traveling before the event, and is also not the Barrier Equivalent Velocity. This data should be examined in conjunction with other available physical evidence from the vehicle and scene when assessing occupant or vehicle forward velocity change. For Deployment Events and Deployment Level Events, the SDM will record 100 milliseconds of data after deployment criteria is met and up to 50 milliseconds before deployment criteria is met. For Non-Deployment Events, the SDM will record the first 150 milliseconds of data after algorithm enable.
-Event Recording Complete will indicate if data from the recorded event has been fully written to the SDM memory or if it has been interrupted and not fully written.
-SDM Recorded Vehicle Speed accuracy can be affected if the vehicle has had the tire size or the final drive axle ratio changed from the factory build specifications.
-Brake Switch Circuit Status indicates the status of the brake switch circuit.
-Pre-Crash Electronic Data Validity Check Status indicates "Data Invalid" if the SDM receive an invalid message from the module sending the pre-crash data.
-Driver's and Passenger's Belt Switch Circuit Status indicates the status of the seat belt switch circuit. If the vehicle's electrical system is compromised during a crash, the state of the Belt Switch Circuit may be reported other than the actual state.
-The Time Between Non-Deployment and Deployment Events is displayed in seconds. If the time between the two events is greater than 25.4 seconds, "N/A" is displayed in place of the time.
-If power to the SDM is lost during a crash event, all or part of the crash record may not be recorded.
-Multiple Events Associated with this Record: This parameter will indicate whether one or more associated events

Figure 23: Case vehicle's SDM Data Limititions

preceded the recorded event.
-One or More Associated Events Not Recorded: If a single event is recorded, this parameter will indicate whether one or more associated events, prior to the recorded event, was not recorded.
If two associated events are recorded, this parameter for the first event will indicate whether one or more associated events, prior to the first event, was not recorded.
If two associated events are recorded, this parameter, for the second event, will indicate whether one or more associated events, between the first and second events, was not recorded.

SDM Data Source:
All SDM recorded data is measured, calculated, and stored internally, except for the following:
-Vehicle Speed, Engine Speed, and Percent Throttle data are transmitted once a second by the Powertrain Control Module (PCM), via the vehicle's communication network, to the SDM.
-Brake Switch Circuit Status data is transmitted once a second by either the ABS module or the PCM, via the vehicle's communication network, to the SDM.
-The SDM may obtain Belt Switch Circuit Status data a number of different ways, depending on the vehicle architecture. Some switches are wired directly to the SDM, while others may obtain the data from various vehicle control modules, via the vehicle's communication network.

Figure 24: Case vehicle's SDM Data Limitations continued

1G6DP567550xxxxxx System Status At Deployment	
SIR Warning Lamp Status	OFF
Driver's Belt Switch Circuit Status	BUCKLED
Ignition Cycles At Deployment	1042
Ignition Cycles At Investigation	1044
Maximum SDM Recorded Velocity Change (MPH)	-13.00
Algorithm Enable to Maximum SDM Recorded Velocity Change (msec)	237.5
Driver First Stage Time Algorithm Enabled to Deployment Command Criteria Met (msec)	20
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)	.7
Frontal Deployment Level Event Counter	1
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)	-1.24	-1.55	-1.55	-1.24	-0.31	-0.62	-0.62	-0.31	0.00	0.00	0.00	0.00	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	93	4416	82	OFF
-4	94	4544	74	OFF
-3	98	4736	98	OFF
-2	98	4672	80	OFF
-1	82	3520	50	ON

Figure 25: Case vehicle's System Status at Deployment report

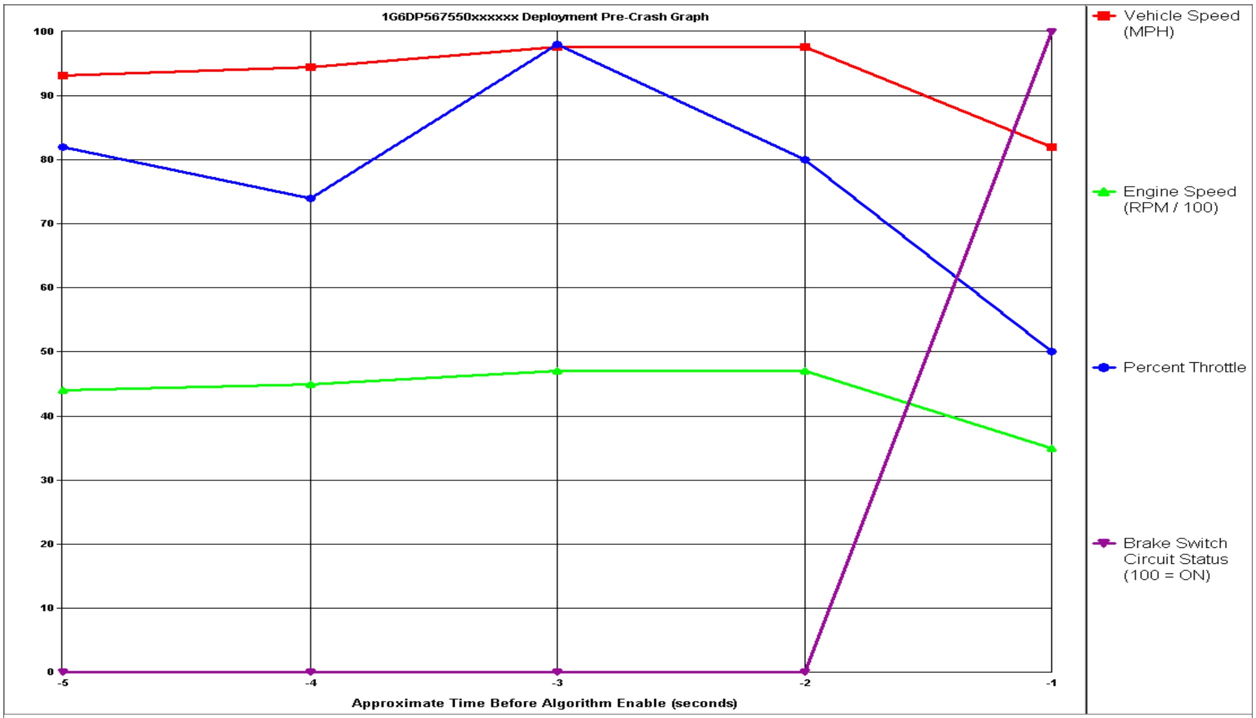


Figure 26: Case vehicle's Deployment Pre-Crash Graph

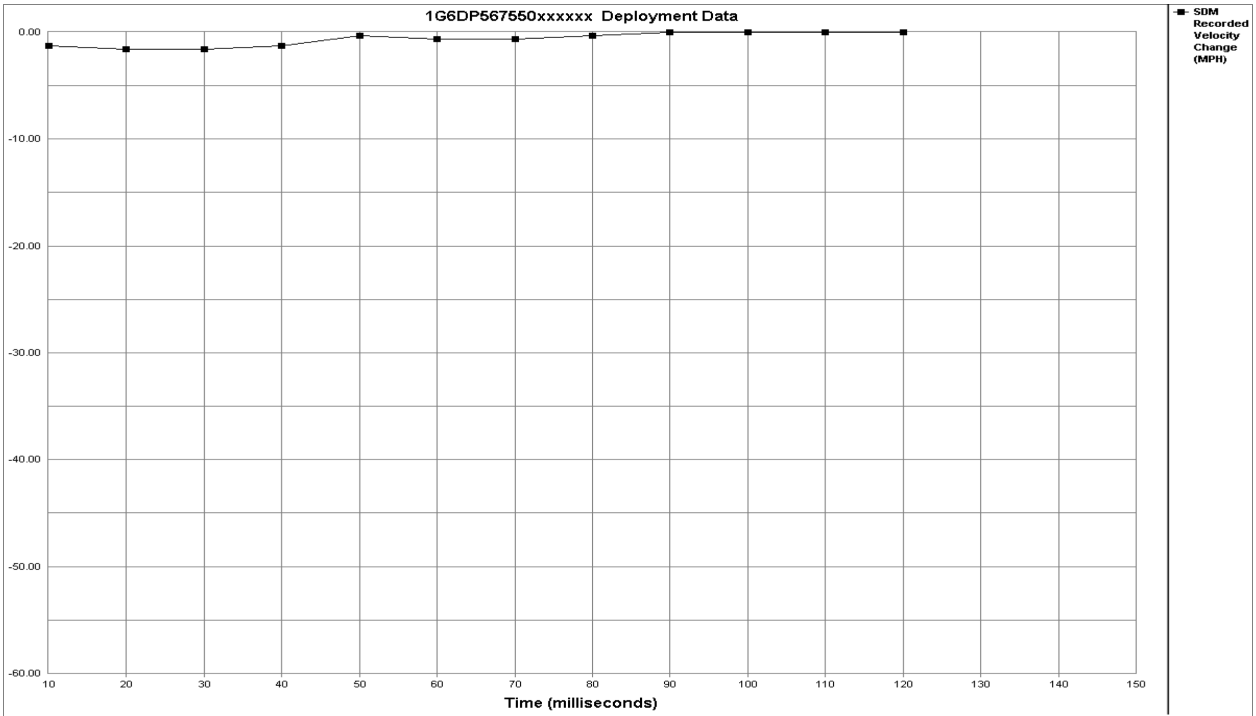


Figure 27: Case vehicle's deployment SDM Recorded Velocity Change graph

1G6DP567550xxxxxx System Status At Non-Deployment	
SIR Warning Lamp Status	OFF
Driver's Belt Switch Circuit Status	BUCKLED
Ignition Cycles At Non-Deployment	1042
Ignition Cycles At Investigation	1044
Maximum SDM Recorded Velocity Change (MPH)	-0.81
Algorithm Enable to Maximum SDM Recorded Velocity Change (msec)	37.5
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	0.00	-0.31	-0.62	0.00	0.00	0.00	0.00	0.00	N/A	N/A	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	93	4416	82	OFF
-4	94	4544	74	OFF
-3	98	4736	98	OFF
-2	98	4672	80	OFF
-1	82	3520	50	ON

Figure 28: Case vehicle's System Status at Non-Deployment report

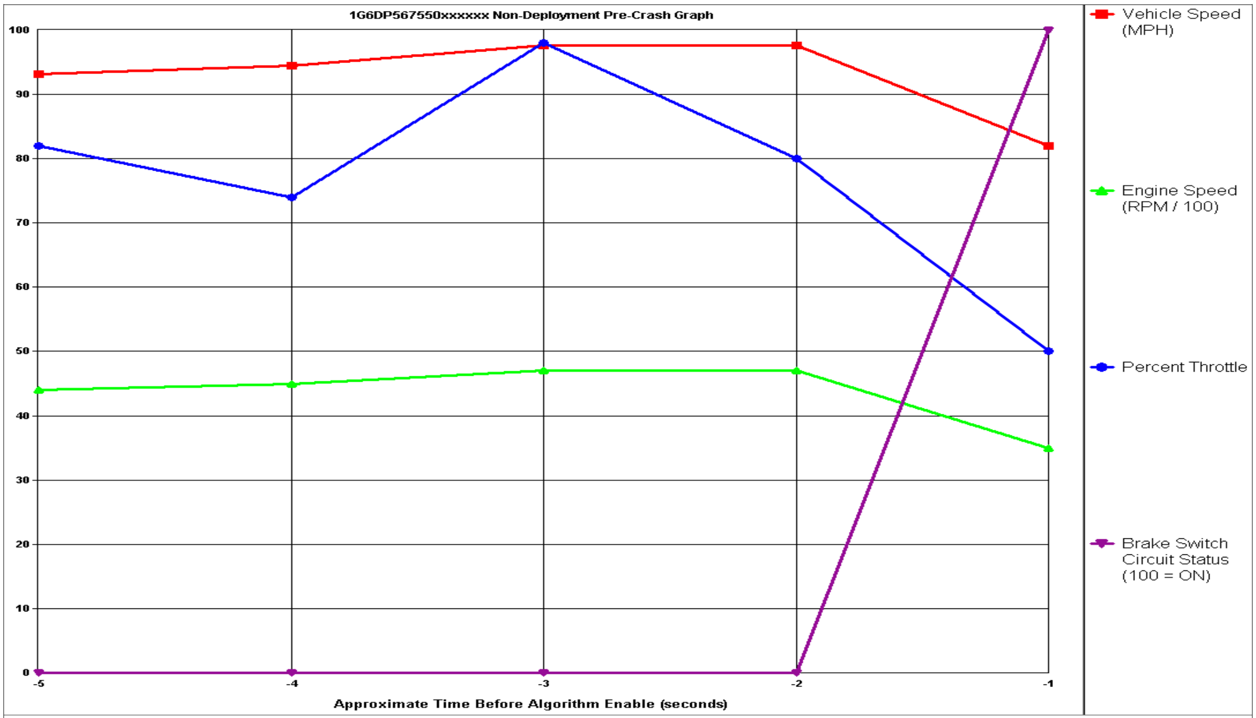


Figure 29: Case vehicle's Non-Deployment Pre-Crash Graph

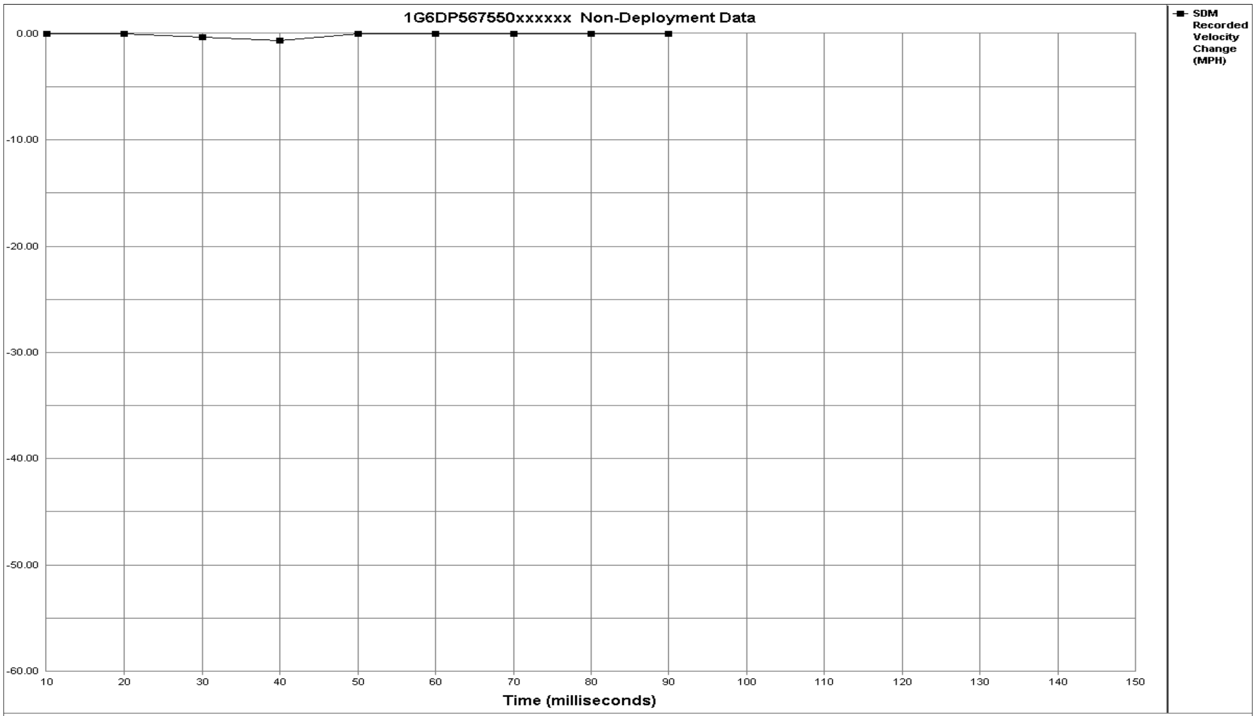
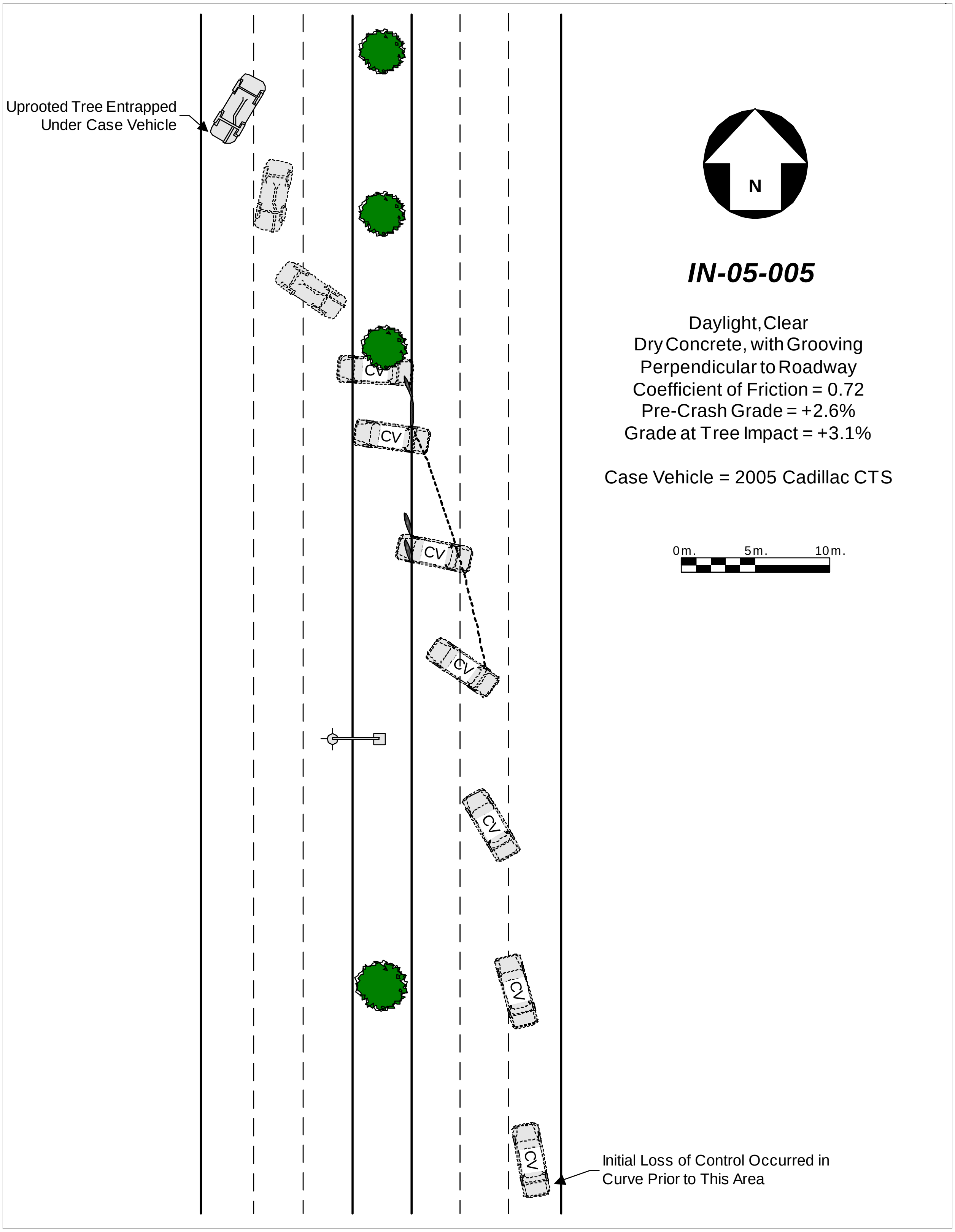


Figure 30: Case vehicle's non-deployment SDM recorded velocity change graph



Uprooted Tree Entrapped
Under Case Vehicle
N
IN-05-005
Daylight, Clear
Dry Concrete, with Grooving
Perpendicular to Roadway
Coefficient of Friction = 0.72
Pre-Crash Grade = +2.6%
Grade at Tree Impact = +3.1%
Case Vehicle = 2005 Cadillac CTS
0m.
5m.
10m.
CV
CV
CV
CV
CV
CV
CV
Initial Loss of Control Occurred in
Curve Prior to This Area