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SCI/NASS COMBINATION SIDE IMPACT INFLATABLE OCCUPANT PROTECTION REPORT

CASE NUMBER - NASS-2003-50-110C

LOCATION - Texas

VEHICLE - 2000 BMW 323i

CRASH DATE - December 2003

Submitted:
June 29, 2004

Revised:
October 12, 2005



Contract Number: DTNH22-01-C-07002

Prepared for:

U.S. Department of Transportation
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

1. <i>Report No.</i> NASS-2003-50-110C		2. <i>Government Accession No.</i>		3. <i>Recipient's Catalog No.</i>	
4. <i>Title and Subtitle</i> SCI/NASS Combination Side Impact Inflatable Occupant Protection System Report Vehicle - 2000 BMW 323i Location - Texas			5. <i>Report Date:</i> June 29, 2004		
			6. <i>Performing Organization Code</i>		
7. <i>Author(s)</i> Special Crash Investigations Team #2			8. <i>Performing Organization Report No.</i>		
9. <i>Performing Organization Name and Address</i> Transportation Research Center Indiana University 222 West Second Street Bloomington, Indiana 47403-1501			10. <i>Work Unit No. (TRAIS)</i>		
			11. <i>Contract or Grant No.</i> DTNH22-01-C-07002		
12. <i>Sponsoring Agency Name and Address</i> U.S. Department of Transportation (NRD-32) National Highway Traffic Safety Administration National Center for Statistics and Analysis Washington, D.C. 20590-0003			13. <i>Type of Report and Period Covered</i> Technical Report Crash Date: December 2003		
			14. <i>Sponsoring Agency Code</i>		
15. <i>Supplementary Notes</i> SCI/NASS combination investigation of an air bag deployment crash involving a 2000 BMW 323i, equipped with multiple frontal and side impact inflatable occupant protection devices, that impacted a 2003 GMC 3500 Sierra pickup truck					
16. <i>Abstract</i> This report covers a SCI/NASS combination investigation of a crash involving a 2000 BMW 323i (case vehicle) and a 2003 GMC Sierra 3500 pickup truck (other vehicle). This crash is of special interest because the case vehicle was equipped with advanced frontal air bags, door-mounted side impact air bags and roof rail-mounted tubular head protection air bags. The two frontal air bags plus the driver's side impact and head protection air bags deployed. In addition, the other vehicle was equipped with an Event Data Recorder that was successfully downloaded. The case vehicle was traveling east in an eastbound through lane of a five-lane roadway that was part of a divided trafficway, approaching a four-leg intersection and intending to continue east. The other vehicle was traveling south in a southbound through lane of the intersecting four lane, one-way local road and was intending to continue south. The front of the case vehicle impacted the right side of the other vehicle, causing the case vehicle's frontal air bags to deploy. The case vehicle rotated clockwise, the other vehicle rotated counterclockwise and the case vehicle's left rear area impacted the other vehicle's right rear, causing the case vehicle driver's door-mounted side air bag and roof rail-mounted head protection air bag to deploy. Both vehicles were re-directed toward the southeast. The other vehicle's front right corner impacted a traffic signal pole on a traffic island and came to rest in the roadway, heading southwest. The case vehicle ran off road at the southeast corner of the intersection, its front impacted a concrete wall and it came to rest heading southeast. The case vehicle driver (27-year-old female) and front right passenger (28-year-old female) were transported via ambulance to a hospital, where both were treated and released for minor injuries. There were no other occupants in the case vehicle.					
17. <i>Key Words</i> Side Air Bag Deployment			Motor Vehicle Traffic Crash Injury Severity		18. <i>Distribution Statement</i> General Public
19. <i>Security Classif. (of this report)</i> Unclassified	20. <i>Security Classif. (of this page)</i> Unclassified		21. <i>No. of Pages</i> 14	22. <i>Price</i> \$2,200	

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This SCI/NASS combination investigation was brought to the NHTSA's attention in December 2003 by NASS/CDS sampling activities and was designated for SCI on February 10, 2004. This crash involved a 2000 BMW 323i (case vehicle) and a 2003 GMC Sierra 3500 pickup truck (other vehicle). The crash occurred in December 2003, at 12:26 p.m., in Texas, and was investigated by the applicable municipal police department. This crash is of special interest because the case vehicle was equipped with advanced frontal air bags, door-mounted side impact air bags and roof rail-mounted tubular head protection air bags. The two frontal air bags and the driver's side impact and head protection air bags deployed. In addition, the other vehicle was equipped with an Event Data Recorder (EDR) that was successfully downloaded. The case vehicle driver (27-year-old female, black, non-Hispanic) and front right passenger (28-year-old female, black, non-Hispanic) were transported via ambulance to a hospital, where both were treated and released for minor injuries. There were no other occupants in the case vehicle. This report is based on the coded NASS case, the other vehicle's EDR report, medical data, occupant kinematic principles and this contractor's evaluation of the evidence.

CRASH CIRCUMSTANCES

The case vehicle was traveling eastward in the third eastbound through lane of a five-lane roadway that was part of a divided trafficway, approaching a four-leg intersection and intending to continue east (i.e., the roadway consisted on a right turn lane, three through lanes and a left turn lane, with a raised concrete median). The other vehicle was traveling southward in the outside southbound through lane of the intersecting four lane, one-way local road and was intending to continue south. It was daylight, the weather was clear, the concrete road surface was dry and with no apparent defects. The speed limit for both roadways was 64 km.p.h. [40 m.p.h.]. The other vehicle entered the intersection across the case vehicle's path.

The crash occurred within the intersection. The front of the case vehicle impacted the right side of the other vehicle, causing the case vehicle's frontal air bags to deploy. The case vehicle rotated clockwise, the other vehicle rotated counterclockwise and the case vehicle's left rear area impacted the other vehicle's right rear, causing the case vehicle driver's door-mounted side air bag and roof rail-mounted head protection air bag to deploy. Both vehicles were re-directed

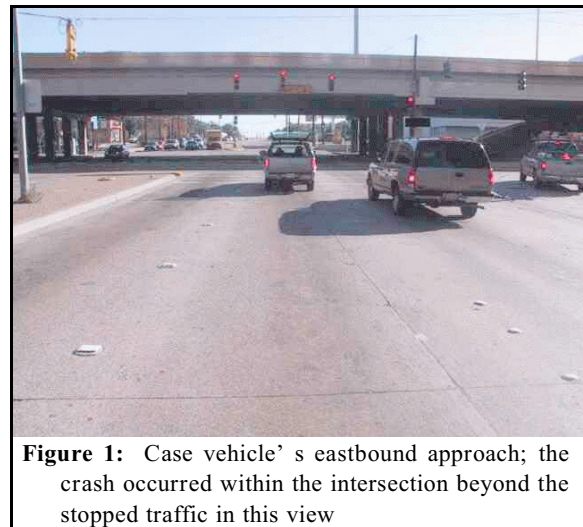


Figure 1: Case vehicle's eastbound approach; the crash occurred within the intersection beyond the stopped traffic in this view

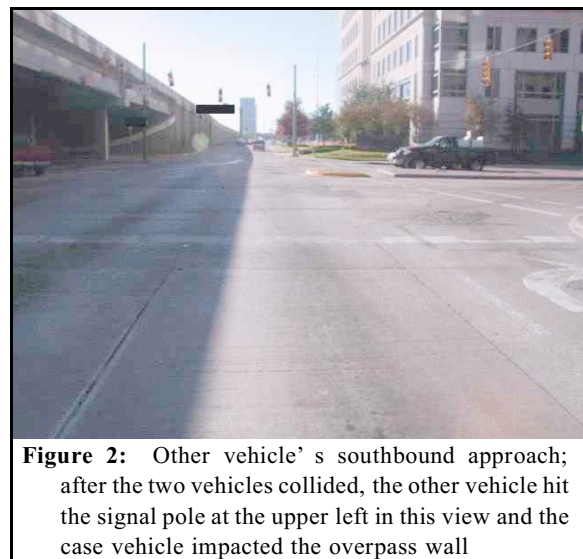


Figure 2: Other vehicle's southbound approach; after the two vehicles collided, the other vehicle hit the signal pole at the upper left in this view and the case vehicle impacted the overpass wall

toward the southeast. The other vehicle's front right corner impacted a traffic signal pole on a traffic island. The other vehicle rotated approximately 90 degrees clockwise and came to rest in the roadway, heading southwest. The case vehicle mounted the traffic island's curb, crossed the island, crossed a channelized turn lane, ran off road at the southeast corner of the intersection and its front impacted a concrete wall. The case vehicle came to rest against the wall heading southeast.

CASE VEHICLE

The case vehicle was a 2000 BMW 323i rear wheel drive¹, four-door, five-passenger sedan (VIN: WBAAM333XYC-----), equipped with a 3.5 liter 6 cylinder gasoline engine and an automatic transmission with a console-mounted selector lever. Four-wheel anti-lock brakes and traction control were standard for this model. The case vehicle was equipped with dual stage frontal air bags, door-mounted side impact air bags, roof rail-mounted tubular head protection air bags and safety belt pretensioners for the two front seats. Its odometer reading is not known, but the driver estimated 96,561 kilometers [60,000 miles]. Its wheelbase was 273 centimeters [107.3 inches]. The case vehicle was towed due to damage.

The case vehicle sustained direct contact damage across its entire front from the first impact with the other vehicle (event #1) and subsequently sustained a second frontal impact with a concrete wall (event #4), resulting in overlapping damage (Figures 3 and 4). The front bumper, grille, headlamp assemblies and both fenders were crushed rearward. The hood was displaced, with the front folded down and crushed rearward. Maximum crush was measured as 45 centimeters [17.7 inches] on the bumper near the center, where the case vehicle contacted the other vehicle's right front wheel assembly. The wheelbase was shortened 4 centimeters [1.6 inches] on the left and 3 centimeters [1.2 inches] on the right. None of the tires were deflated or restricted. The windshield had a star-pattern crack on the left above the steering wheel, probably a result of occupant contact, and stress cracking on the right, probably a result of the hood being pushed rearward. The left rear window glazing was disintegrated due to the left side impact (discussed below), and there was no other glazing damage.



Figure 3: Case vehicle's front and right; note, overlapping damage from two impacts on the front



Figure 4: Case vehicle's left front area

¹The NASS case coding indicates " front wheel drive", but that is a coding error.

Immediately following the first impact with the pickup, the case vehicle rotated clockwise while the pickup rotated counterclockwise and the left rear of the case vehicle (**Figure 5**) impacted the right rear of the pickup. The pickup was equipped with dual rear wheels with rear fenders made of plastic/fiberglass projecting out from the pickup's bed. The case vehicle sustained direct contact on the left rear door, wheel well and rear overhang. The damage pattern shows that the case vehicle's wheel well impacted the pickup's rear tire, with a circular imprint and rubber transfer around the perimeter of wheel well. The case vehicle also contacted the pickup's very large fender, with crush on the case vehicle fore and aft of the wheel well and the left rear door window glazing shattered. Direct contact was measured as 101 centimeters [39.8 inches] and the crush profile was measured as 181 centimeters [71.3 inches] with maximum crush 4 centimeters [1.6 inches] along the top edge of the wheel well.



Figure 5: Case vehicle's left rear area

The CDC for the case vehicle's first frontal impact (event #1, with the other vehicle) was determined to be **10-FDEW-3 (310)**. For the second frontal impact (event #4, with the concrete wall), a partial CDC was assigned as **12-FDEW-? (10)**, with the extent zone unknown due to multiple impacts in the same area. Because of the overlapping damage on the case vehicle and overlapping damage on the other vehicle, a WinSMASH reconstruction was not possible. The NASS investigator estimated that the first frontal impact was of moderate severity (24-40 km.p.h. [15-25 m.p.h.]) for the case vehicle, with the second frontal impact's severity unknown.

The CDC for the case vehicle's left rear impact (event #2) was determined to be **09-LZEW-2 (270)**. The WinSMASH reconstruction program was used on this impact. Because the body parts on the other vehicle were plastic/fiberglass and its crush profile could not be measured, this reconstruction was based on the CDC-only algorithm. The total, longitudinal and lateral deltaVs are, respectively: 6 km.p.h. [3.7 m.p.h.], + 1 km.p.h. [+ 0.6 m.p.h.] and + 6 km.p.h. [+ 3.7 m.p.h.]. This is a borderline reconstruction and the results appear low, but the case vehicle's second impact was certainly of minor severity (1-13 km.p.h. [1-8 m.p.h.]).

AUTOMATIC RESTRAINT SYSTEM

The case vehicle was equipped with dual stage frontal air bags, door-mounted side impact air bags and roof-rail mounted tubular head protection air bags, for a total of six air bags in this vehicle. The two frontal air bags, the driver's door-mounted side air bag and the left roof rail-mounted tubular head protection deployed as a result of the collision events.

The driver's frontal air bag was mounted in the steering wheel hub, with the module cover flaps in the H configuration (**Figures 6 and 7**). The upper and lower cover flaps both measured 15.5 centimeters [6.1 inches] horizontally and 9 centimeters [3.5 inches] vertically. The deployed

driver's air bag was round with a diameter of 60 centimeters [23.6 inches]. The cover flaps opened at the tear points and there was no evidence of damage to the air bag, the cover flaps or the adjacent structures. The driver's air bag did not have any tethers and there was one vent port, of unknown size, at the 12:00 o' clock position on the back of the air bag. There was no evidence of occupant contact, nor any other marks, on the driver's frontal air bag.



Figure 6: Front of driver's frontal air bag



Figure 7: Driver's frontal air bag cover flaps

The driver's side impact air bag was mounted in the driver's door arm rest with the top surface of the arm rest serving as the module cover flap (**Figures 8 and 9**). The cover flap measured 24 centimeters [9.4 inches] longitudinally and 9 centimeters [3.5 inches] laterally, with the hinge along the inboard edge of the arm rest. The cover flap opened at the tear points and there was no evidence of damage to the cover flap or the adjacent structures. At the time of the inspection, the air bag was caught in the door and the door was jammed shut such that the air bag could not be pulled free for complete examination. (The NASS investigator indicated that the air bag must have gotten caught in the door when someone gained access to the vehicle post-crash, and there was no evidence of any malfunction of the air bag during deployment.) A complete inspection was not possible. The investigator indicated that the air bag measured 32 centimeters

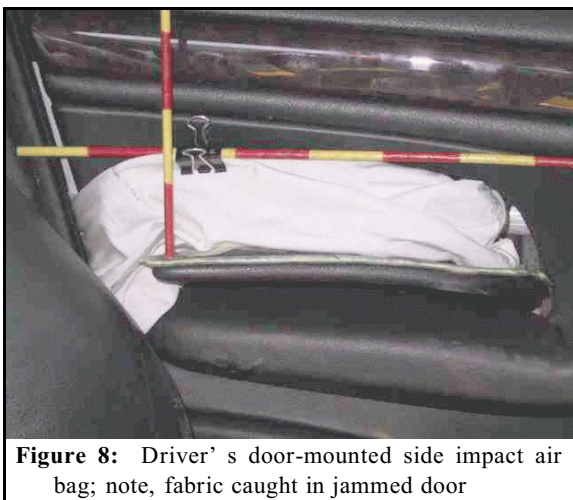


Figure 8: Driver's door-mounted side impact air bag; note, fabric caught in jammed door

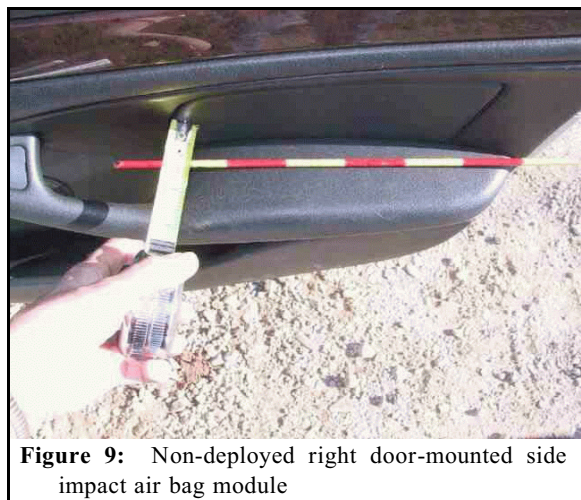


Figure 9: Non-deployed right door-mounted side impact air bag module

[12.6 inches] longitudinally. The air bag's shape is unknown, there were no tethers and no vent ports. There was no evidence of occupant contact, nor any other marks, on the parts of the air bag that could be examined.

The driver's tubular head protection air bag was mounted in the left roof rail (**Figures 10 and 11**). The air bag deploys through the seam where the side trim panels meet the roof headliner and there is no cover flap. The seam opened at the tear points and there was no evidence of damage to the air bag or the adjacent structures. The deployed tubular air bag measured 125 centimeters [49.2 inches] longitudinally and was circular in profile with a diameter of 12 centimeters [4.7 inches]. There were no internal tethers or vent ports. The forward end of the air bag was tethered to the base of the upper A-pillar and the rearward end was tethered to the top of the C-pillar. There was no evidence of occupant contact, nor any other marks, on the air bag.

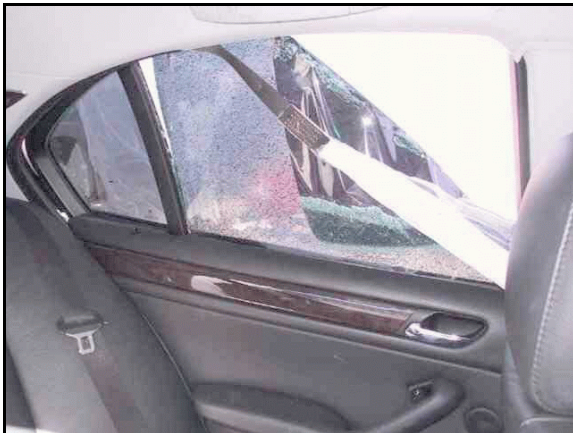


Figure 10: Rear portion of left roof rail-mounted tubular head protection air bag

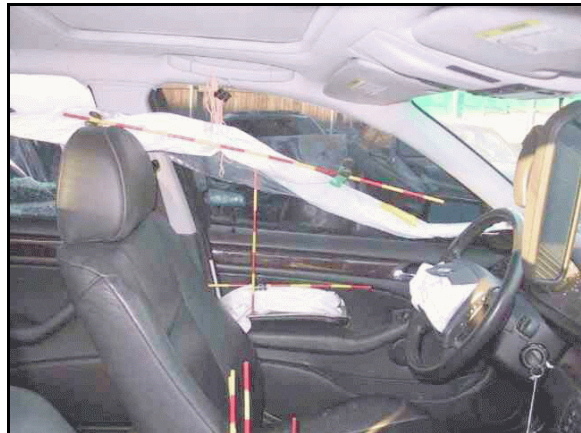


Figure 11: Front portion of left roof rail-mounted tubular head protection air bag

The front right passenger's frontal air bag was located in the top of the right instrument panel. The single module cover flap was irregular in shape, with the left edge curved, the right edge sculpted to fit around a vent port and the hinge on the forward (top) edge (**Figure 12**). The

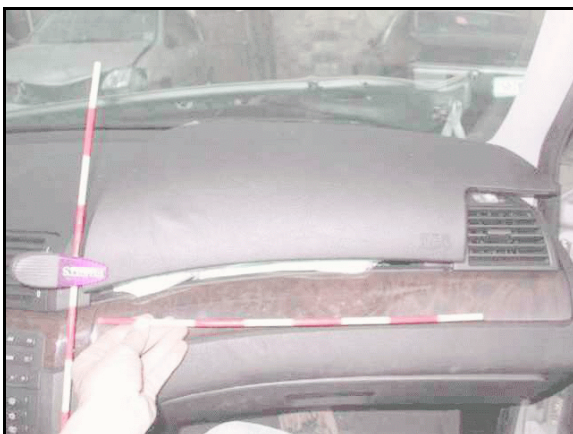


Figure 12: Front right module cover flap



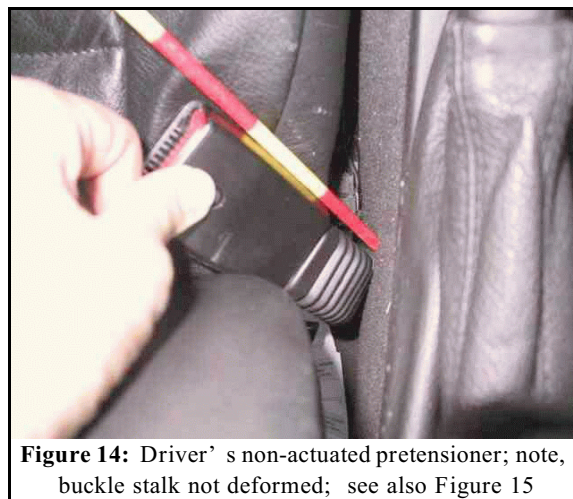
Figure 13: Front of front right air bag

cover flap' s overall dimensions were measured as 51 centimeters [20 inches] horizontally and 21 centimeters [8.3 inches] vertically. The cover flap opened at the tear points and there was no evidence of damage to the air bag, the cover flap or the adjacent structures. The deployed front right passenger' s frontal air bag was rectangular (**Figure 13**), measuring 53 centimeters [20.9 inches] horizontally and 60 centimeters [23.6 inches] vertically. There were two vent ports, at the 10:00 o' clock and 2:00 o' clock locations, and no tethers. There was no evidence of occupant contact nor any other marks on the air bag.

CASE VEHICLE DRIVER' S KINEMATICS

The case vehicle driver (27-year-old female, black, non-Hispanic, 150 centimeters, 73 kilograms [59 inches, 161 pounds]) was not restrained by the available manual, three-point, lap-and-shoulder safety belt system. She was seated in a normal driving posture, with the seat back slightly inclined, the seat track adjusted between the forward and middle position, and the tilt steering wheel adjusted at the center position.

The driver did not attempt any avoidance maneuvers and her posture did not change prior to the first impact. The front of the case vehicle struck the right side of the other vehicle, causing the case vehicle' s frontal air bags to deploy and causing the driver to move forward and leftward, toward the 10:00 o' clock direction of force. The driver' s safety belt system was equipped with a buckle pretensioner that did not actuate because the buckle was not fastened (**Figure 14**). She probably encountered the air bag with her face and chest and did not sustain any injuries. The case vehicle rotated clockwise and its left rear area impacted the right rear area of the other vehicle, causing the case vehicle' s left door-mounted side impact air bag and left roof rail-mounted tubular head protection air bag to deploy and causing the driver to move leftward, toward the 9:00 o' clock direction of force. The case vehicle driver probably encountered the side impact air bag with the left side of her thorax and may have contacted the head protection air bag with the left side of her head, but there was no evidence of contact readily apparent on any of the air bags that deployed into the driver' s seating area. The case vehicle was redirected in a southeasterly direction, ran over a traffic island and the case vehicle' s front impacted a concrete wall. The case vehicle driver was jostled erratically as the vehicle bumped across the traffic island and the driver pitched forward, toward the 12:00 o' clock direction of force, compressing and deflating the steering wheel-mounted frontal air bag. She sustained contusions as her forehead impacted the windshield, her chest impacted the steering wheel hub/spoke and both thighs impacted the steering wheel rim. Her limbs flailed and she sustained contusions when her right forearm contacted the instrument panel and her right ankle contacted the foot controls. Her posture at final rest is not known.



The driver was transported via ambulance to a hospital, where she was treated and released.

Injury Number	Injury Description (including Aspect)	NASS Injury Code & AIS 90	Injury Source (Mechanism)	Source Confidence	Source of Injury Data
1	Left forehead contusion	minor 290402.1,7	Windshield	Certain	Interviewee
2	Central chest contusion	minor 490402.1,4	Steering wheel rim/hub/spoke	Certain	Interviewee
3	Bilateral thigh contusions	minor 890402.1,3	Steering wheel rim	Certain	Interviewee
4	Right forearm contusion	minor 790402.1,1	Left instrument panel	Certain	Interviewee
5	Right ankle contusion	minor 890402.1,1	Foot controls	Certain	Interviewee

CASE VEHICLE FRONT RIGHT PASSENGER' S KINEMATICS

The case vehicle front right passenger (28-year-old female, black, non-Hispanic, 160 centimeters, 77 kilograms [63 inches, 170 pounds]) was restrained by the available, manual, three-point, lap-and-shoulder safety belt system. She was seated in a normal passenger posture, with her seat back slightly reclined and the seat track adjusted at the middle position.

The driver did not attempt any avoidance maneuvers and the front right passenger' s posture did not change prior to the first impact. The front of the case vehicle struck the right side of the other vehicle, causing the case vehicle' s frontal air bags to deploy and causing the passenger to move forward and leftward, toward the 10:00 o' clock direction of force, but she was held in place by the safety belt system. The passenger' s safety belt system was equipped with a buckle pretensioner that actuated (**Figure 15**). The NASS investigator determined that the pretensioner' s piston moved 4 centimeters [1.6 inches]. She probably encountered the air bag with her face and chest and did not sustain any injuries. The case vehicle rotated clockwise and its left rear area impacted the right rear area of the other vehicle, causing the case vehicle' s left door-mounted side impact air bag and left roof rail-mounted tubular head protection air bag to deploy and causing the front right passenger to move leftward, toward the 9:00 o' clock direction of force. The case vehicle was redirected in a southeasterly direction, ran over a traffic island and the case vehicle' s front impacted a concrete wall. The front right passenger was jostled erratically as the vehicle bumped across the traffic island and she pitched forward, toward the 12:00 o' clock direction of



Figure 15: Passenger' s actuated pretensioner; note, buckle stalk deformed; see also Figure 14

force, but was held in place by the safety belt system. She sustained a contusion on her chest from the torso portion of the safety belt webbing, and a contusion on her right knee from impacting the knee bolster. Her posture at final rest is not known.

CASE VEHICLE FRONT RIGHT PASSENGER' S INJURIES

The front right passenger was transported to a hospital via ambulance, where she was treated and released.

Injury Number	Injury Description (including Aspect)	NASS Injury Code & AIS 90	Injury Source (Mechanism)	Source Confidence	Source of Injury Data
1	Central chest contusion	minor 490402.1,4	Belt restraint system	Certain	Interviewee
2	Right knee contusion	minor 890402.1,1	Knee bolster	Certain	Interviewee

OTHER VEHICLE

The other vehicle was a 2003 GMC Sierra 3500 4x4, Crew Cab, four-door pickup truck (VIN: 1GTJK33113F-----), equipped with a 6.6 liter V8 Diesel engine and dual rear wheels. Four-wheel anti-lock brakes were standard for this model. The Sierra was equipped with an EDR that was successfully downloaded. Its wheelbase was 424 centimeters [167.0 inches]. The Sierra was towed due to damage.



Figure 16: Other vehicle, showing overlapping damage at front right corner area



Figure 17: Other vehicle, front and left side, showing front damage

The Sierra was involved in three events. First, the front of the case vehicle impacted the Sierra' s right front wheel, fender and door. Second, the left rear area of the case vehicle impacted the Sierra' s right rear tandem wheels and fender (side slap). Third, the Sierra' s front right area impacted a non-breakaway traffic signal support pole.

The first and third events caused overlapping damage (**Figures 16, 17 and 18**). The right

front wheel assembly/axle was broken with the wheel bent inward at the top. Direct contact extended rearward along the fender and onto the front right door. The crush profile was measured as 186 centimeters [73.2 inches] long, with maximum crush 12 centimeters [4.7 inches] low on the door, slightly aft of the A-pillar. The CDC for the first impact was determined to be **01-RYEW-3 (40)**. Because of overlapping damage on the Sierra and on the case vehicle, a reconstruction was not possible. The NASS investigator estimated that the first impact was of moderate severity (24-40 km.p.h. [15-25 m.p.h.]) for the Sierra.

The second event (**Figure 19**) involved the Sierra's right rear tandem wheel assembly and fender. The fender was made of plastic/fiberglass and portions of the fender shattered and broke away such that a crush profile could not be obtained. The CDC for the side slap was determined to be **03-RBEW-1 (90)**. The WinSMASH reconstruction program was used on this impact. Because the crush profile could not be measured, this reconstruction was based on the CDC-only algorithm. The total, longitudinal and lateral deltaVs for the Sierra are, respectively: 3 km.p.h. [1.9 m.p.h.], 0 km.p.h. [0 m.p.h.] and -3 km.p.h. [-1.9 m.p.h.]. This is a borderline reconstruction and the results appear low, but the Sierra's second impact was certainly of minor severity (1-13 km.p.h. [1-8 m.p.h.]).



Figure 18: Sierra's right front area, showing wheel and side damage plus front overlapping damage



Figure 19: Sierra's right rear area, showing shattered plastic/fiberglass fender

The impact with the pole (event #3) involved the Sierra's front right corner area. Direct contact was measured as 21 centimeters [8.3 inches] wide, with maximum crush measured as 72 centimeters [28.3 inches] slightly inboard from the right bumper corner. The CDC for the third event was determined to be **12-FREE-3 (0)**. The WinSMASH reconstruction program, barrier algorithm based on the measured frontal profile, was used on the pole impact. The total, longitudinal and lateral deltaVs are, respectively: 28 km.p.h. [17.4 m.p.h.], -28 km.p.h. [-17.4 m.p.h.] and 0 km.p.h. [0 m.p.h.]. This is a borderline reconstruction because of the overlapping damage at the right front corner, but the results appear reasonable. The pole impact was of moderate severity (24-40 km.p.h. [15-25 m.p.h.]) for the Sierra.

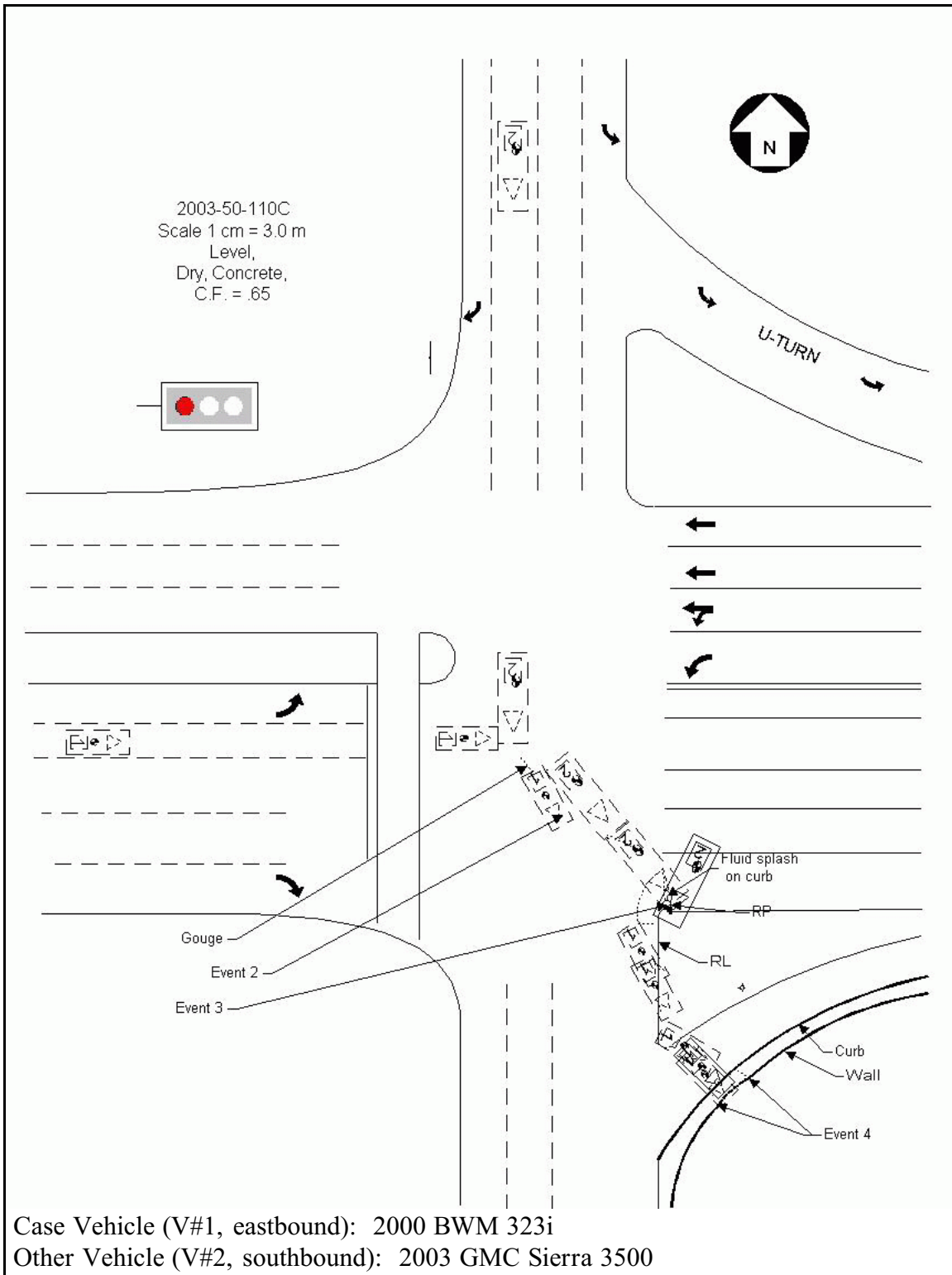
The other vehicle's driver (37-year-old male) was transported via ambulance to a hospital, where he was treated and released for minor injuries. There was no other occupant in the Sierra.

The Sierra was equipped with an Event Data Recorder (EDR) that was successfully downloaded using the Crash Data Retrieval tool, version 2.2.4. The EDR recorded a non-deployment and a deployment event. The Sensing and Diagnostic Module (SDM) reports are included as **Figures 20 - 25**.

The System Status at Non-Deployment (**Figure 20**) and System Status at Deployment (**Figure 23**) reports indicate that both events were recorded on ignition cycle 2,171 and the download was accomplished on ignition cycle 2,173. On both reports, the warning lamp is reported as off, indicating no faults in the automatic restraint system, and the driver' s safety belt is reported as unbuckled. The Deployment report indicates that there were 1.2 seconds between the non-deployment and the deployment events. The non-deployment event was the first harmful event in the NASS case (front of case vehicle into right side of Sierra) and the deployment event was event #3 in the NASS case (front of Sierra into a non-breakaway pole).

The Non-Deployment Pre-Crash data and graph (**Figures 20 and 21**) indicate that the Sierra was stopped, with engine rpms at idle speed and the brake light circuit open at approximately 5 seconds prior to the non-deployment algorithm enable (AE). The Sierra' s driver apparently accelerated, with throttle percentage, engine rpms and travel speed increasing over the next four seconds. The Sierra was traveling 32 km.p.h. [20 m.p.h.] with 74 percent throttle and no braking at approximately one second prior to the non-deployment AE. The Non-Deployment Velocity Change data and graph (**Figures 20 and 22**) show a gradual drop to -11.5 km.p.h. [-7.13 m.p.h.] at 150 milliseconds [0.15 seconds] after AE. The maximum recorded longitudinal velocity change for the non-deployment event is reported as 12.0 km.p.h. [-7.47 m.p.h.] at 132.5 milliseconds [0.1325 seconds] after AE.

The Deployment Pre-Crash data and graph (**Figures 23 and 24**) repeat the non-deployment pre-crash data, with one additional data point added (i.e., the deployment pre-crash recording for -5 through -2 seconds is identical to the non-deployment data for -4 through -1 seconds). For the last one second interval prior to AE for the deployment event, the throttle dropped to zero percent input, engine rpms dropped proportionally, travel speed declined to 30.6 km.p.h. [19 m.p.h.] and the brake light circuit remained open. The System Status at Deployment report (**Figure 23**) indicates that first stage deployment of the driver and front right passenger air bags was commanded at 72.5 milliseconds [0.0725 seconds] after AE for the deployment event. The report also indicates that second stage deployment was not commanded. The Deployment Velocity Change data and graph (**Figures 23 and 25**) show a steady drop to -26.4 km.p.h. [-16.43 m.p.h.] at 150 milliseconds [0.15 seconds] after AE, after which the recording ceased. The maximum longitudinal velocity change is reported as -32.7 km.p.h. [-20.31 m.p.h.] at 220 milliseconds [0.22 seconds] after AE.



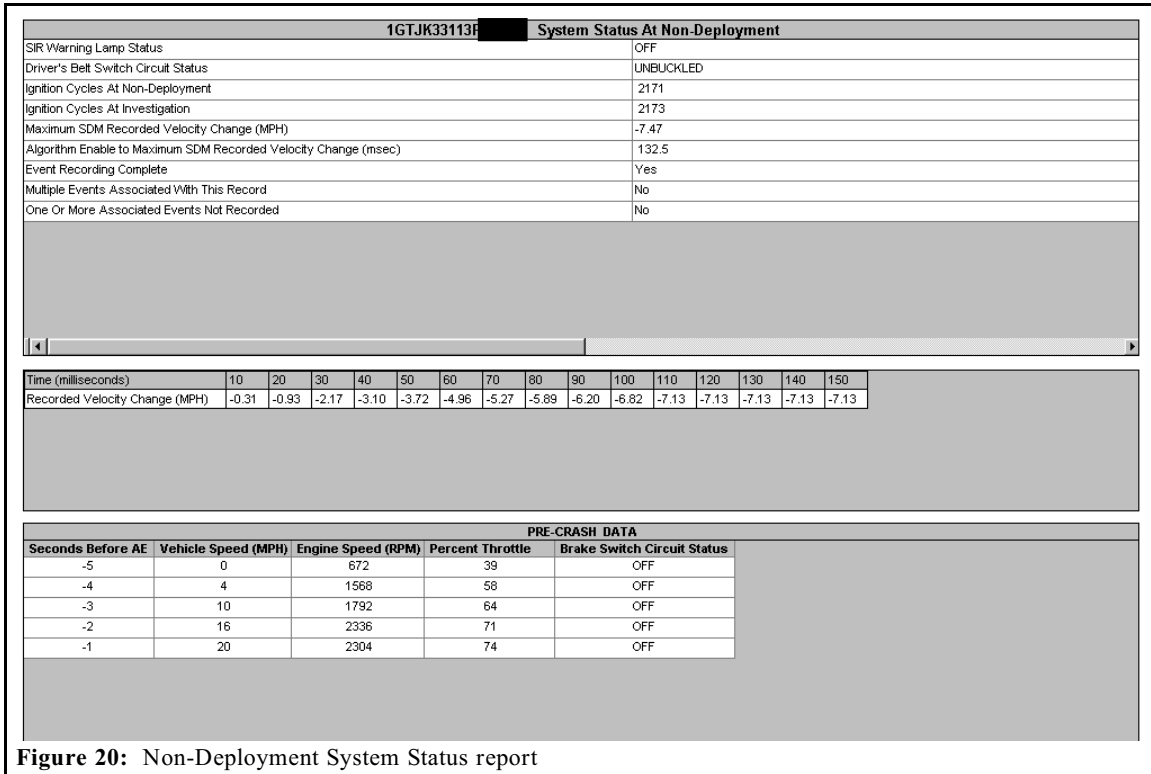


Figure 20: Non-Deployment System Status report

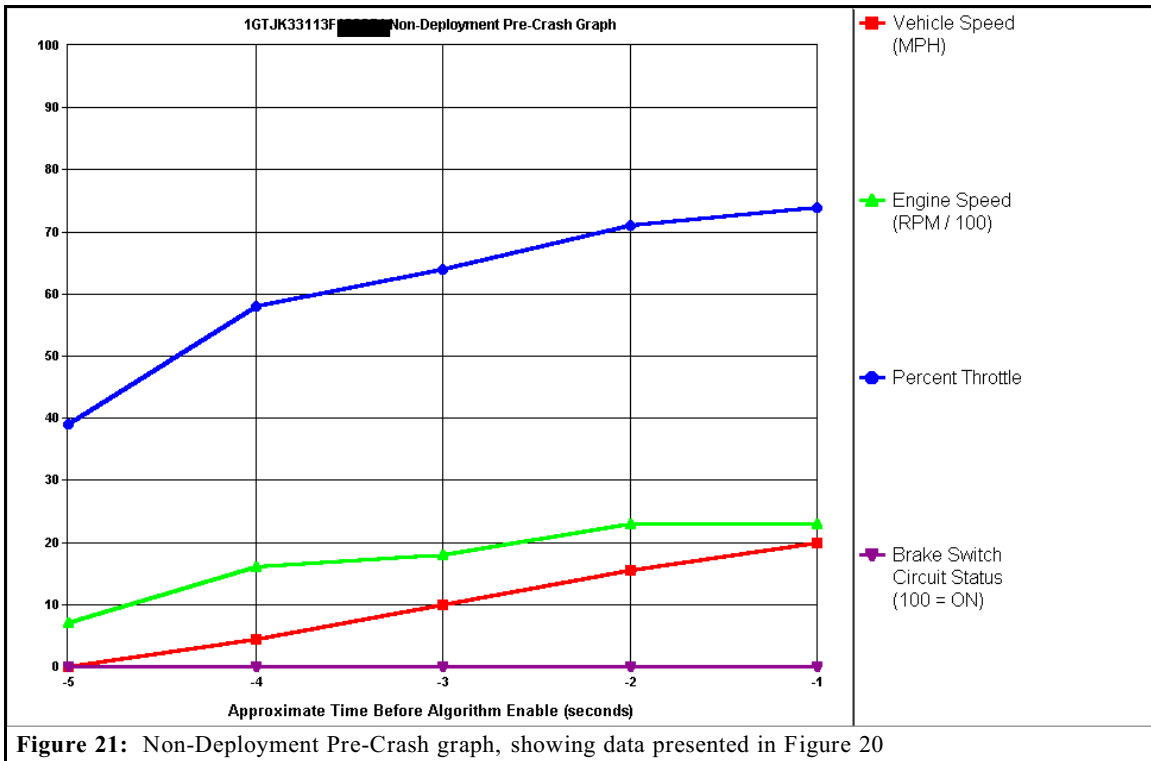


Figure 21: Non-Deployment Pre-Crash graph, showing data presented in Figure 20

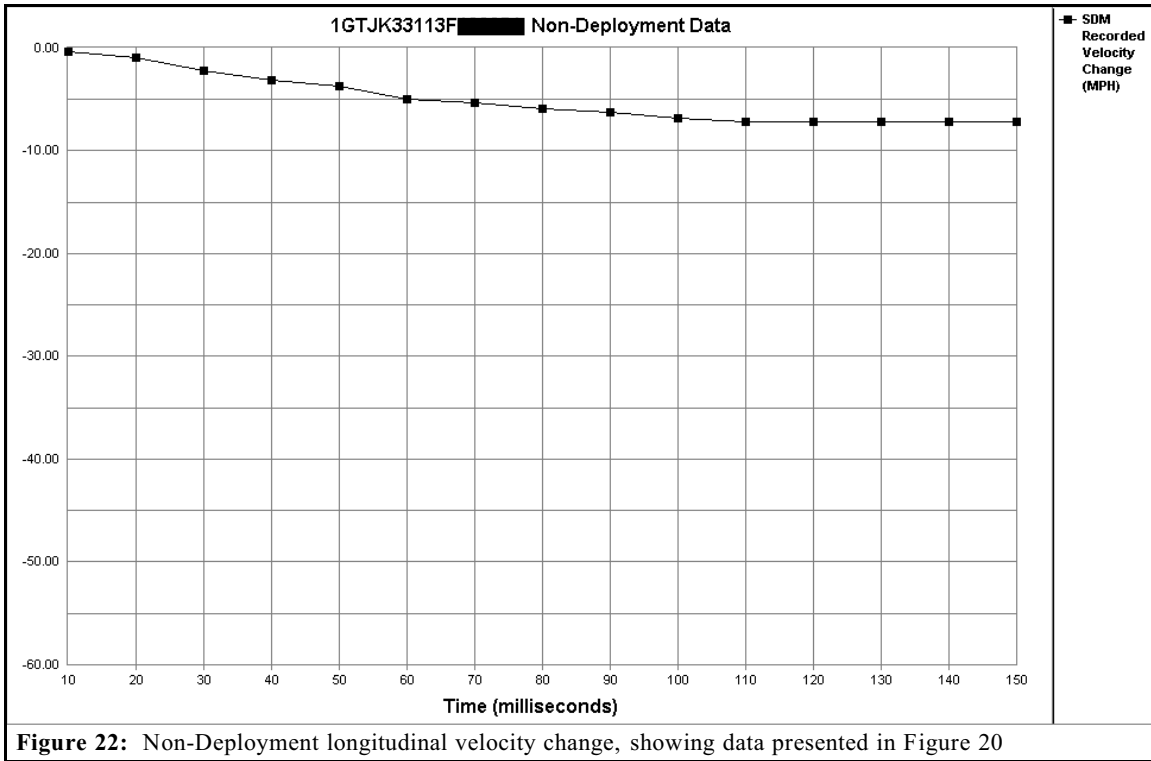


Figure 22: Non-Deployment longitudinal velocity change, showing data presented in Figure 20

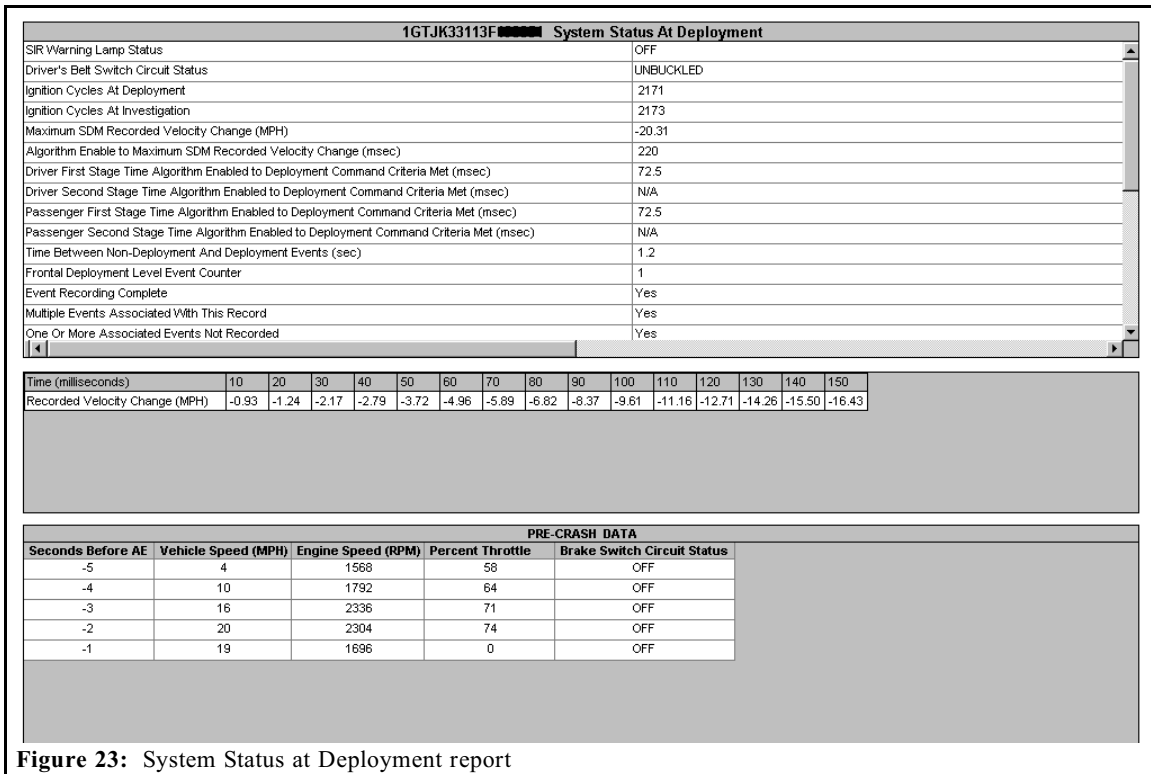


Figure 23: System Status at Deployment report

