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ON-SITE AIR BAG INVESTIGATION

CASE NUMBER - IN98-018
LOCATION - TEXAS
VEHICLE - 1988 MERCEDES BENZ 190E
CRASH DATE - September, 1997

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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 deployment investigation involving a 1988 Mercedes Benz 190E, four-door sedan, with manual safety belts and driver's air bag, and a 1988 Nissan Sentra, four-door sedan

16. *Abstract*

This report covers an on-site investigation of an air bag deployment crash that involved a 1988 Mercedes Benz 190E (case vehicle) and a 1988 Nissan Sentra (other vehicle). This crash is of special interest because the case vehicle's driver (56-year-old female) sustained a fatal neck injury during a crash in which her driver air bag deployed. It was initially thought that the air bag caused the fatal lesion; however subsequent information showed that the fatal lesion was not associated with the air bag. The case vehicle had been traveling eastward in the outside eastbound lane of a six-lane, divided, interstate trafficway and changed lanes into the center through lane (i.e., both the east and westbound roadways had three through lanes). The Nissan had been traveling eastward in the inside eastbound through lane of the same interstate trafficway when it also changed lanes into the center through lane. The crash occurred in the center through lane of the eastbound roadway. The left front of the case vehicle was impacted by the right back of the Nissan. As a result, the Nissan rotated approximately 190-200 degrees clockwise while traveling further eastward before it impacted a guardrail on the south roadside and came to rest heading northwestward. Following the impact with the Nissan, the case vehicle's driver over steered, first to the right and then to the left. As a result, the case vehicle went into a counterclockwise yaw and crossed the eastbound lanes before impacting the median guardrail with its front right corner, causing the case vehicle's driver air bag to deploy. The case vehicle rotated rapidly counterclockwise and re-impacted the guardrail with its right side and back right before rotating counterclockwise back out into the eastbound roadway of the interstate where it came to rest heading northeastward. The driver was seated with her seat track located between its middle and forward-most positions, and the vehicle was not equipped with a tilt steering wheel. She was not using her available, active, three-point, lap-and-shoulder, safety belt system, and sustained, according to her autopsy: a transection of the spinal cord at C_2 with associated dislocation and fracture of C_2; severe cerebral edema with associated transtentorial and tonsillar herniation of the brain stem; secondary contusions of hippocampal gyri (i.e., inferior cerebrum); and contusions to the right shoulder, right buttock, and right knee. The driver's nonuse of her safety belts most likely contributed to this occupant's fatal lesions. The front right passenger (daughter of driver; 21-year-old female) was seated with her seat track located in its middle position and was restrained by her available, active, three-point, lap-and-shoulder, safety belt system. She sustained minor injuries and was treated and released, but her injuries are unknown.

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This on-site investigation was brought to NHTSA's attention on April 16, 1998 by an attorney representing the family of the deceased driver. This crash involved a 1988 Mercedes Benz 190E (case vehicle) and a 1988 Nissan Sentra (other vehicle). The crash occurred in September, 1997, at 10:05 p.m., in Texas and was investigated by the applicable city police department. This crash is of special interest because the case vehicle's driver [56-year-old, White (Hispanic) female] sustained a fatal neck injury during a crash in which her driver air bag deployed. ***Please note that this crash was originally listed as a confirmed air bag-related fatality; however, subsequent pictures and medical information show that the fatal lesion was not associated with the air bag and, as a result, this crash was dropped from the "confirmed" status.*** This contractor inspected the scene and case vehicle on 28-29 April, 1998. This report is based on the Police Crash Report, inspection of the scene and case vehicle, occupant kinematic principles, the driver's autopsy records, a letter from the chief medical examiner, a deposition given by the forensic pathologist who performed the autopsy, and this contractor's evaluation of the evidence.

SUMMARY

The case vehicle had been traveling essentially eastward in the outside eastbound lane of a six-lane, divided, interstate trafficway when it began to change lanes into the center through lane, intending to continue its eastward travel path (i.e., both the east and westbound roadways had three through lanes). The Nissan had been traveling essentially eastward in the inside eastbound through lane of the same six-lane, divided, interstate trafficway when it changed lanes into the center through lane. Based on the available information, the Nissan appears to have established itself within the center lane and to have been pulling ahead of the case vehicle when the case vehicle began to enter the lane. Based upon the vehicular damage patterns, the case vehicle's driver most likely saw the Nissan "flashing by" and steered to the right, attempting to avoid the collision. The crash occurred in the center through lane of the eastbound roadway; see **CRASH DIAGRAM** below.

The left front of the case vehicle was impacted by the right back of the Nissan and, as a result, both vehicles ended up going out of control. The Nissan rotated approximately 190-200 degrees clockwise while traveling, a police estimated, 274 meters (900 feet) further eastward before it impacted a guardrail on the south roadside and came to rest heading northwestward. Following the impact with the Nissan, the case vehicle's driver over steered, first, to the right back into the outside eastbound lane and, second, back to the left. As a result of the leftward steering maneuver, the case vehicle went into a counterclockwise yaw, depositing critical curve scuffs, and moved in a northeasterly direction. The case vehicle crossed first, the middle and inside eastbound lanes and, then went into the median with its right side leading. The case vehicle had rotated approximately 105 degrees counterclockwise from its original direction of travel in the outside eastbound lane.

The case vehicle's front right corner impacted the median guardrail, causing the case vehicle's driver air bag to deploy. The case vehicle rotated rapidly counterclockwise and impacted (i.e., first slapping and then sliding along) the guardrail with its right side and right quarter panel.

Because the trafficway, and thus the median's longitudinal barrier (i.e., guardrail) was curving to the right, the case vehicle's back right corner dug into and snagged on the guardrail. As a result, the case vehicle rebounded off the guardrail, rotated counterclockwise back out into the eastbound roadway of the interstate, crossed the inside and center eastbound through lanes, and came to rest in the outside eastbound lane, with its left front wheel straddling the lane line, heading northeastward.

The 1988 Mercedes Benz 190E was a rear wheel drive, four-door sedan (VIN: WDBDA28D3JF------). The case vehicle was equipped with four-wheel, anti-lock brakes. Based on the vehicle inspection, the CDCs for the case vehicle were determined to be: **07-LFEW-1 (220)**–1st event, **01-FZEW-2 (40)**–2nd (i.e., deployment) event, **03-RDEW-2 (100)**–3rd event, and **06-BREW-2 (180)**–4th event. The WinSMASH reconstruction program, barrier algorithm, was used on the case vehicle's highest severity impact (i.e., 2nd crash event, first with guardrail). The Total, Longitudinal, and Lateral Delta Vs are, respectively: 20.4 km.p.h. (12.7 m.p.h.), -15.6 km.p.h. (-9.7 m.p.h.), and -13.1 km.p.h. (-8.1 m.p.h.). Given that the struck barrier was a guardrail, these results should be considered a high range estimate. The case vehicle was towed due to damage.

The case vehicle's first event was a sideswiping impact with the Nissan that involved the left fender. Direct damage began 29 centimeters (11.4 inches) behind the left front axle and extended, a measured distance of 91 centimeters (35.8 inches), forward along the left front wheel well. Maximum crush was measured as 4 centimeters (1.6 inches). The case vehicle's second event (first impact with the guardrail) involved the front right corner. Direct damage began 21 centimeters (8.3 inches) to the right of the case vehicle's center and extended, a measured distance of 57 centimeters (22.4 inches), to the front right bumper corner. Residual maximum crush was measured as 25 centimeters (9.8 inches) at C_6. The third event (second impact with the guardrail) involved almost the entire right side. Direct damage began 82 centimeters (32.3 inches) behind the right rear axle and extended, a measured distance of 355 centimeters (139.8 inches), forward along the right side. Maximum crush was measured as 14 centimeters (5.5 inches). The fourth and final event (third guardrail impact) involved the case vehicle's back right. Direct damage began 37 centimeters (14.6 inches) inward from the back right bumper corner and extended, a measured distance of 151 centimeters (59.4 inches), leftward along the back bumper. The wheelbase on the case vehicle's left side was shortened 3 centimeters (1.2 inches) while the right side was shortened 5 centimeters (2.0 inches). The case vehicle's front and back bumpers, front and back bumper fascia, grille, radiator, right and left fenders, right quarter panel, front right headlight and turn signal assemblies, back right brake light and turn signal assemblies, and right front and right rear doors were directly damaged and crushed inward. Both of the case vehicle's right side tires were physically restricted, and the right front tire was deflated and rotated outward from the case vehicle's first impact with the median's guardrail. There was induced damage to the case vehicle's windshield (i.e., stress fracture), hood, trunk lid, left quarter panel, and left front headlight and turn signal assemblies.

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 air bag revealed that the cover flaps opened at the designated tear points, and there was no evidence of damage during the deployment to the air bag or the cover

flaps. The driver's air bag was designed with four tethers, each 7 centimeters (2.8 inches) in width and located at the 12, 3, 6, and 9 o'clock positions. The driver's air bag had four vent ports, approximately 2 centimeters (0.8 inches) in diameter, located at the 2, 4, 8, and 10 o'clock positions. The deployed driver's air bag was round with a diameter of 73 centimeters (28.7 inches). An inspection of the air bag's fabric revealed a spot of blood located toward the 1 o'clock position [i.e., 10 centimeters (3.9 inches) to the right of the vertical centerline and 5 centimeters (2.0 inches) downward from the apex of the air bag's front surface]. Furthermore, there was a blue transfer located just below the center of the air bag [i.e., 31 centimeters (12.2 inches) inward from the left outermost part of the front surface and 41 centimeters (16.1 inches) downward from the apex]. The case vehicle was not equipped with a front right passenger air bag.

Inspection of the case vehicle's interior revealed only a scuff mark on the left side of the center instrument panel, most likely from contact by the driver's right knee.

The 1988 Nissan Sentra was a front wheel drive, four-door sedan (VIN: JN1PB21S2JU------). Anti-lock brakes were not available for the Nissan. Based on the available police photographs, the CDCs for the Nissan are estimated as: **01-RBEW-1 (40)**–1st event, and **06-LBMS-1 (180)**–5th event. The Nissan was towed due to damage.

Immediately prior to the crash the exact posture of the case vehicle's driver [165 centimeters and 54 kilograms (65 inches, 119 pounds)] is unknown, but presumably she was seated upright with her back against the seat back, her left foot on the floor, her right foot letting off the accelerator, and at least one if not both hands on the steering wheel, attempting to steer to the right. Her seat track was located between its middle and forward-most positions, the seat back was upright, and the vehicle was not equipped with a tilt steering wheel. It should be noted that "upright" for this particular seat back was approximately 27 degrees rearward of perpendicular to the floor.

For the following reasons, it is believed that the case vehicle's driver was not using her available, active, three-point, lap-and-shoulder, safety belt system. First, there was no mention in the autopsy of belt pattern bruising and/or abrasions to the driver's body. Second, the case vehicle's front outboard safety belts were equipped with retractor-mounted, Emergency Tension Retractors (**ETR**s) and, although the inspection of the driver's seat belt webbing, "D"-ring, and latch plate showed evidence of recent usage (i.e., a heat abrasion on the webbing), the preponderance of the restraint evidence indicated that the driver's safety belt was not in use during this crash. Finally, the driver's safety belt was found along left "B"-pillar and could be extended.

In comparison, the inspection of the front right passenger's seat belt showed evidence of loading (heat abrasion markings) on the plastic free sliding latch plate and a related heat abrasion on the webbing. This contractor would have expected to have found some type of loading evidence on the driver's seat belt system. Furthermore, it should be noted that the **ETR** on the front right belt system was still locked in place with the belt webbing extended, preventing the belts movement. The **ETR** on the driver's belt system had not actuated when the air bag deployed, allowing the belt webbing to reel in and out.

The case vehicle's driver most likely saw the Nissan "flashing by" and steered to the right, attempting to avoid the collision. As a result of this attempted avoidance maneuver and the nonuse of her available safety belts, the driver most likely moved slightly to her left just prior to impact. The case vehicle impact with the Nissan most likely had a negligible effect upon the case vehicle's driver. Following the impact with the Nissan and the driver's right steering maneuver, the case vehicle veered back into the outside eastbound lane. The driver, while trying to regain control, over corrected by steering sharply back to the left and, as a result, the case vehicle went into a counterclockwise rotation and the driver most likely moved slightly forward and toward her right. The case vehicle's front right corner impact (i.e., primary impact) with the guardrail enabled the unrestrained driver to continued forward, rightward, and upward toward the case vehicle's **40** degree Direction of Principal Force as the case vehicle decelerated. As the case vehicle reached maximum engagement, it continued to rotated rapidly counterclockwise. Based on the available evidence, the head of the case vehicle's driver was most likely to the right of the driver air bag module when it deployed. The deploying driver air bag may have struck the driver on the left side of her torso or it may have missed the driver completely. The combination of the deceleration caused by the guardrail impact combined with the driver's nonuse of her safety belts, the **40** degree Direction of Principal Force, and the lateral momentum associated with the counterclockwise rotation (i.e., the movement of the case vehicle's center of gravity was approximately oriented 75-90 degrees toward the perpendicular to the case vehicle's heading angle at first impact with guardrail) most likely enabled the driver to move upwards into the center roof or windshield header area at impact. Given that there was a contusion to the medial side of the driver's right knee, and the available evidence indicates that the inside of the right knee impacted the left side of the center instrument panel, then the driver's head should have been near the roof, somewhere over the center console area. Given that there are no integumentary injuries to the driver's head or neck and that there are no discernable points of contact to the case vehicle's roof and/or greenhouse areas, the exact point of occupant to vehicle interaction is uncertain.

As the case vehicle continued rotating counterclockwise, it impacted the guardrail with its right side. As a result, the driver would have moved to the right towards the **100** degree Direction of Principal Force. Specifically, the driver's head most likely moved laterally to the right along the roof during this slapping impact with the guardrail. When the back right corner of the case vehicle snagged into the angling guardrail (i.e., fourth event), the driver most likely moved slightly back and to the right toward the **180** degree Direction of Principal Force. Based on the opinion of the pathologists associated with driver's autopsy, the driver's chin was forced downward into the driver's chest by a force applied to the top or back of her head. The hyperflexion of the driver's neck as a result of this force caused the driver's fatal cervical lesions. In this contractor's opinion, the driver's head was forced downward from her head contacting the roof and as a result of the continued guardrail interaction, her head was kept forced downward continuing the pressure on her cervical spine throughout the case vehicle's three guardrail impacts.

When the case vehicle continued its counterclockwise rotation off the guardrail and back onto the interstate and across the eastbound through lanes, the driver most likely contacted the front right passenger and/or right roof side rail and/or right "B"-pillar. As the case vehicle spun to final rest, the driver rebounded back to her left towards her seating area. The exact posture of

the case vehicle's driver at final rest is unknown, but she was most likely in or near her seat at this time.

The driver was transported by ambulance to a hospital. She sustained fatal injuries and was hospitalized in a vegetative state prior to being pronounced dead five days post-crash. Based on the autopsy, the injuries sustained by the case vehicle's driver included: a transection of the spinal cord at C_2 with associated dislocation and fracture of C_2; severe cerebral edema with associated transtentorial and tonsillar herniation of the brain stem; secondary contusions of hippocampal gyri (i.e., inferior cerebrum); and contusions to the right shoulder, right buttock, and right knee. Therefore, the driver's nonuse of her safety belts in conjunction with the circumstances of this collision and not the air bag most likely contributed to this occupant's fatal lesions.

The exact posture of the case vehicle's front right passenger [daughter of driver; 21-year-old, White (Hispanic) female; unknown height and weight] is unknown, but presumably she was seated upright with her back against the seat back and both feet on the floor. However, the exact position of her hands is unknown. Based on the vehicle inspection, her seat track was located in its middle position, and her seat back was upright. Once again, it should be noted that "upright" for this particular seat back was approximately 28 degrees rearward of perpendicular to the floor.

The case vehicle's front right passenger was restrained by her available, active, three-point, lap-and-shoulder, safety belt system. The case vehicle was not equipped with a front right supplemental restraint (air bag). As discussed above, the inspection of the front right passenger's seat belt showed evidence of loading (heat abrasion markings) on the plastic free sliding latch plate and a related heat abrasion on the webbing. It should be noted that the **ETR** on the passenger's belt system was still locked in place with the belt webbing extended, preventing the belt's movement during this contractor's inspection.

The front right passenger was transported by ambulance to the hospital. Based on the available evidence, she sustained minor injuries and was treated and released. The injuries sustained by the front right passenger are unknown.

CRASH CIRCUMSTANCES

The case vehicle had been traveling essentially eastward in the outside eastbound lane (**Figure 1**) of a six-lane, divided, interstate trafficway when it began to change lanes into the center through lane, intending to continue its eastward travel path (i.e., both the east and westbound roadways had three through lanes). The Nissan had been traveling essentially eastward in the inside eastbound through lane of the same six-lane, divided, interstate trafficway when it changed lanes into the center through lane. Based on the available information, the Nissan appears to

Figure 1: Case vehicle's travel path as it attempted to change lanes from outside eastbound lane to center eastbound lane just prior to impact; Note: impact occurred on upgrade just prior to hill crest (case photo #03)

have established itself within the center lane and to have been pulling ahead of the case vehicle when the case vehicle began to enter the lane. Based upon the vehicular damage patterns, the case vehicle's driver most likely saw the Nissan "flashing by" and steered to the right, attempting to avoid the collision. The crash occurred in the center through lane of the eastbound roadway; see **CRASH DIAGRAM** below.

The interstate highway was straight and level (i.e., actual slope was slightly positive to the east as the two vehicle approached a hill crest–**Figure 1** above) just prior to the initial area of impact. Between the initial impact and the final rest positions of the two vehicles, the eastbound roadway was curved slightly to the right for eastbound traffic and had a unmeasured negative grade to the east (i.e., a downgrade in direction of travel for both vehicles). The pavement was bituminous, but new, and the width of the travel lanes for both vehicles (inside, center, and outside) was approximately 3.7 meters (12 feet). The shoulders were improved (i.e., concrete), with a 2.4 meter (8 foot) wide paved shoulder on both the north and south sides of the roadway prior to the adjacent longitudinal barriers (i.e., W-beam guardrail), both in the median (on the north) and protecting the south roadside. No curbs were present. Pavement markings consisted of dashed white lane lines, and the roadway was bordered by a solid yellow edge line on the north (median) side and a solid white edge line on south side. A regulatory **SPEED LIMIT** sign (MUTCD, R2-1) as well as a warning **MERGE** sign (MUTCD, W4-1) were posted near the crash site. The estimated coefficient of friction was 1.00. The legal speed limit is 97 km.p.h. (60 m.p.h.). At the time of the crash the light condition was dark, but illuminated by overhead street lamps at the area of impact, the atmospheric condition was clear, and the road pavement was dry. Traffic density is unknown, but was most likely moderate, and the site of the crash was primarily urban commercial with some apartment dwellings.

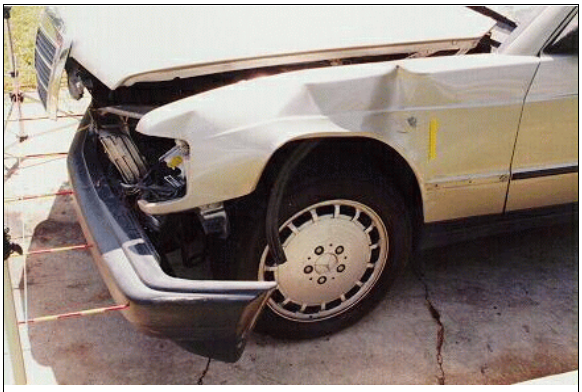

Figure 2: Damage to case vehicle's left fender from initial sideswipe impact with Nissan's right quarter panel (case photo #18)

The left front (**Figure 2**) of the case vehicle was impacted by the right back (**Figure 3**) of the Nissan and, as a result, both vehicles ended up going out of control. As a result of the initial impact to its right rear from the case vehicle, the Nissan's driver most likely steered to his left and then overcorrected back to the right sending the Nissan into a clockwise rotation. The Nissan rotated approximately 190-200 degrees clockwise while traveling, a police estimated, 274 meters (900 feet) further eastward across the eastbound lanes before it impacted a guardrail on the south roadside and came to rest heading northwestward.

Figure 3: On-scene photo looking south-southeast at Nissan's final rest position on south shoulder; Note: sideswipe damage to right quarter panel from impact with case vehicle's left front fender (case photo #13)

Following the impact with the Nissan, the case vehicle's driver over steered, first, to the right back into the outside eastbound lane and, second, back to the left. As a result of the leftward steering maneuver, the case vehicle went into a counterclockwise yaw, depositing critical curve scuffs, and moved in a northeasterly direction (**Figure 4**). The case vehicle crossed first, the middle and inside eastbound lanes and, then went into the median with its right side leading (**Figure 5**). The case vehicle had rotated approximately 105 degrees counterclockwise from its original direction of travel in the outside eastbound lane.

Figure 4: On-scene photo showing case vehicle's counterclockwise rotation across all three eastbound lanes when driver overcorrected following initial impact with Nissan; Note: scuffs on roadway (case photo #05a)

Figure 5: On-scene photo showing case vehicle's travel path into median's guardrail on north roadside during counterclockwise rotation; Note: tire scuffs and damaged guardrail (case photo #05b)

Figure 6: Case vehicle's frontal damage with contour gauge present; Note: yellow tape marks leftward end of direct damage and leftward shift of front bumper (case photo #15)

The case vehicle's front right corner (**Figure 6**) impacted the median guardrail, causing the case vehicle's driver air bag to deploy. The case vehicle rotated rapidly counterclockwise and impacted (i.e., first slapping and then sliding along) the guardrail with its right side and right quarter panel (**Figures 7** and **8** below). Because the trafficway, and thus the median's longitudinal barrier (i.e., guardrail) was curving to the right, the case vehicle's back right corner dug into and snagged on the guardrail (**Figure 8** below). As a result, the case vehicle rebounded off the guardrail, rotated counterclockwise back out into the eastbound roadway of the interstate, crossed the inside and center eastbound through lanes, and came to rest in the outside eastbound lane, with its left front wheel straddling the lane line, heading northeastward (**Figures 9** and **10** below).

The 1988 Mercedes Benz 190E was a rear wheel drive, five-passenger, four-door sedan (VIN: WDBDA28D3JF------) equipped with a 2.3L, I-4 engine and a four-speed automatic transmission. Braking was achieved by a power-assisted, front disc and rear drum, four-wheel, anti-lock system. The case vehicle's wheelbase was 266 centimeters (104.9 inches), and the odometer reading at inspection was 194,383 kilometers (120,784 miles).

Figure 7: Case vehicle's right side damage from slapping impact with median guardrail (case photo #24)

Figure 8: Multiple impact damage to case vehicle's right quarter panel and back right corner from median guardrail; Note: outline of top of guard-rail can be seen along right quarter panel and right rear door and inward crush through back, with restriction of right rear tire, from snagging impact with guardrail (case photo #23)

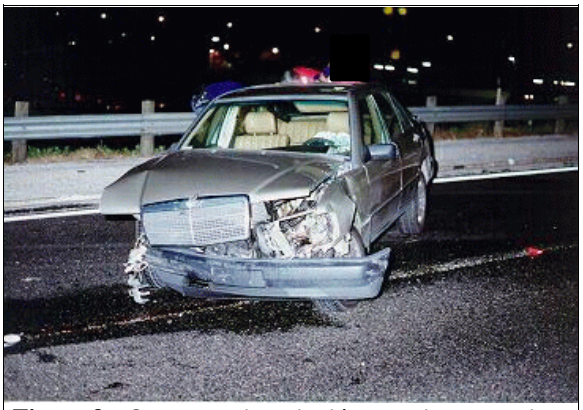

Figure 9: On-scene photo looking southwestward at case vehicle's final rest position straddling lane line between inside and center eastbound lanes; Note: left shift to case vehicle's bumper from impact with median guardrail (case photo #08)

Figure 10: On-scene photo looking east-southeast at case vehicle's final rest position straddling inside and center eastbound lanes (case photo #09)

Inspection of the vehicle's interior revealed adjustable front bucket seats with adjustable head restraints; a non-adjustable back bench seat with separate backs cushions and without head restraints for the back outboard seating positions; continuous loop, three-point, lap-and-shoulder, safety belt systems at the front and back outboard positions; and a two-point, lap belt system at the back center position. The front seat belt systems were equipped with Emergency Tension Retractors (**ETR**s) which pull in the belt webbing's slack but without manually operated height adjusters for the "D"-rings. The vehicle was equipped with a knee bolster for the driver's seating

position and it was not deformed. Automatic restraint was provided by a Supplemental Restraint System (SRS) that consisted of a frontal air bag for the driver's seating position. The front air bag deployed as a result of the case vehicle's front right impact with the median guardrail.

CASE VEHICLE DAMAGE

The case vehicle's first event was a sideswiping impact with the Nissan that involved the left fender (**Figure 2** above). Direct damage began 29 centimeters (11.4 inches) behind the left front axle and extended, a measured distance of 91 centimeters (35.8 inches), forward along the left front wheel well. Maximum crush was measured as 4 centimeters (1.6 inches). The field "L" began 58 centimeters (22.8 inches) behind the left front axle (i.e., just forward of the left "A"-pillar) and extended, a measured distance of 119 centimeters (45.7 inches), forward along the left fender. The case vehicle's second event (first impact with the guardrail) involved the front right corner (**Figure 6** above). Direct damage began 21 centimeters (8.3 inches) to the right of the case vehicle's center and extended, a measured distance of 57 centimeters (22.4 inches), to the front right bumper corner. Residual maximum crush was measured as 25 centimeters (9.8 inches) at C_6. The field "L" went from bumper corner to bumper corner, a measured distance of 149 centimeters (58.7 inches). The third event (second impact with the guardrail) involved almost the entire right side (**Figures 7** and **8** above). Direct damage began 82 centimeters (32.3 inches) behind the right rear axle and extended, a measured distance of 355 centimeters (139.8 inches), forward along the right side. Maximum crush was near the right "B"-pillar and was measured as 14 centimeters (5.5 inches). The fourth and final event (third guardrail impact) involved the case vehicle's back right (**Figure 8** above). Direct damage began 37 centimeters (14.6 inches) inward from the back right bumper corner and extended, a measured distance of 151 centimeters (59.4 inches), leftward along the back bumper. Maximum crush was measured as 20 centimeters (7.9 inches) at the back right bumper corner. The wheelbase on the case vehicle's left side was shortened 3 centimeters (1.2 inches) while the right side was shortened 5 centimeters (2.0 inches). The case vehicle's front and back bumpers, front and back bumper fascia, grille, radiator, right and left fenders, right quarter panel, front right headlight and turn signal assemblies, back right brake light and turn signal assemblies, and right front and right rear doors were directly damaged and crushed inward. Both of the case vehicle's right side tires were physically restricted, and the right front tire was deflated and rotated outward from the case vehicle's first impact with the median's guardrail. There was induced damage to the case vehicle's windshield (i.e., stress fracture), hood, trunk lid, left quarter panel, and left front headlight and turn signal assemblies.

Figure 11: Case vehicle's driver knee bolster and left side of center instrument panel showing no contact evidence on knee bolster and driver's right knee contact to instrument panel (case photo #32)

Inspection of the case vehicle's interior revealed only a scuff mark on the left side of the center instrument panel, most likely from contact by the driver's right knee (**Figure 11**). The contractor was not allowed access to the case

vehicle's energy absorbing steering column in order to assess any evidence of compression. This contractor's visual inspection showed no evidence of compression to the energy absorbing shear capsules in the base of the steering column. In addition, there was no deformation to the steering wheel rim. The case vehicle's right "B"-pillar and front right seat back showed some minor intrusion with 1 centimeter (0.4 inches) and 3 centimeters (1.2 inches) respectively.

Based on the vehicle inspection, the CDCs for the case vehicle were determined to be: **07-LFEW-1 (220)**–1st event, **01-FZEW-2 (40)**–2nd (i.e., deployment) event, **03-RDEW-2 (100)**–3rd event, and **06-BREW-2 (180)**–4th event. The WinSMASH reconstruction program, barrier algorithm, was used on the case vehicle's highest severity impact (i.e., 2nd crash event, first with guardrail). The Total, Longitudinal, and Lateral Delta Vs are, respectively: 20.4 km.p.h. (12.7 m.p.h.), -15.6 km.p.h. (-9.7 m.p.h.), and -13.1 km.p.h. (-8.1 m.p.h.). Given that the struck barrier was a guardrail, these results should be considered a high range estimate. The case vehicle was towed due to damage.

AUTOMATIC RESTRAINT SYSTEM

The case vehicle was equipped with a Supplemental Restraint System (SRS) that contained a frontal air bag at the driver (only) seating position. The driver's air bag deployed as a result of the front right impact with the median guardrail. The case vehicle's driver air bag was located in the steering wheel hub. The module cover consisted of asymmetrical "H"-configuration cover flaps made of thick vinyl with overall dimensions of 23.5 centimeters (9.3 inches) at the top horizontal seam, 23 centimeters (9.1 inches) at the bottom horizontal seam, 6 centimeters (2.4 inches) vertically for the upper flap and 6.5 centimeters (2.6 inches) vertically for the lower flap. An inspection of the air bag module's cover flaps and air bag revealed that the cover flaps opened at the designated tear points, and there was no evidence of damage during the deployment to the air bag or the cover flaps. The driver's air bag was designed with four tethers, each 7 centimeters (2.8 inches) in width, sewn to the interior center face of the air bag, and located at the 12, 3, 6, and 9 o'clock positions. The driver's air bag had four vent ports, approximately 2 centimeters (0.8 inches) in diameter, located at the 2, 4, 8, and 10 o'clock positions. The deployed driver's air bag was round with a diameter of 73 centimeters (28.7 inches). An inspection of the air bag's fabric revealed a spot of blood located toward the 1 o'clock position [i.e., 10 centimeters (3.9 inches) to the right of the vertical centerline and 5 centimeters (2.0 inches) downward from the apex of the air bag's front surface (**Figure 12**)]. Furthermore, there was a blue transfer located just below the center of the air bag [i.e., 31 centimeters (12.2 inches) inward from the left outermost part of the front surface and 41 centimeters (16.1 inches) downward from the apex (**Figure 12**)]. The case vehicle was not equipped with a front right passenger air bag.

Figure 12: Case vehicle's deployed driver air bag with yellow tape indicating blood spot near 1 o'clock position blue ink transfer just left and below center (case photo #34)

Immediately prior to the crash the exact posture of the case vehicle's driver [56-year-old, White (Hispanic) female; 165 centimeters and 54 kilograms (65 inches, 119 pounds)] is unknown, but presumably she was seated upright with her back against the seat back, her left foot on the floor, her right foot letting off the accelerator, and at least one if not both hands on the steering wheel, attempting to steer to the right. Her seat track was located between its middle and forward-most positions, the seat back was upright, and the vehicle was not equipped with a tilt steering wheel. It should be noted that "upright" for this particular seat back was approximately 27 degrees rearward of perpendicular to the floor. The measured distance from the steering wheel hub to the center of driver's seat back against was approximately 56 centimeters (22.0 inches).

Figure 13: Case vehicle's driver safety belt showing heat abrasion indicating at least previous usage (case photo #38)

Figure 14: Case vehicle's driver safety belt system shown along "B"-pillar with belt webbing free to reel in and out; Note: emergency tension retractor did not actuated when air bag deployed because safety belt was not buckled (case photo #44)

For the following reasons, it is believed that the case vehicle's driver was not using her available, active, three-point, lap-and-shoulder, safety belt system. First, there was no mention in the autopsy of belt pattern bruising and/or abrasions to the driver's body. Second, the case vehicle's front outboard safety belts were equipped with retractor-mounted, Emergency Tension Retractors (**ETR**s) and, although the inspection of the driver's seat belt webbing, "D"-ring, and latch plate showed evidence of recent usage (i.e., a heat abrasion on the webbing–**Figure 13**), the preponderance of the restraint evidence indicated that the driver's safety belt was not in use during this crash. Finally, the driver's safety belt was found along left "B"-pillar and could be extended (**Figure 14**).

In comparison, the inspection of the front right passenger's seat belt showed evidence of loading (**Figure 15** below) on the plastic free sliding latch plate (heat abrasion markings) and a related heat abrasion on the webbing (**Figure 16** below). This contractor would have expected to have found some type of loading evidence on the driver's seat belt system. Furthermore, it should be noted that the **ETR** on the front right belt system was still locked in place with the belt webbing

extended, preventing the belts movement (**Figure 15**). The **ETR** on the driver's belt system had not actuated when the air bag deployed, allowing the belt webbing to reel in and out (**Figure 14** above).

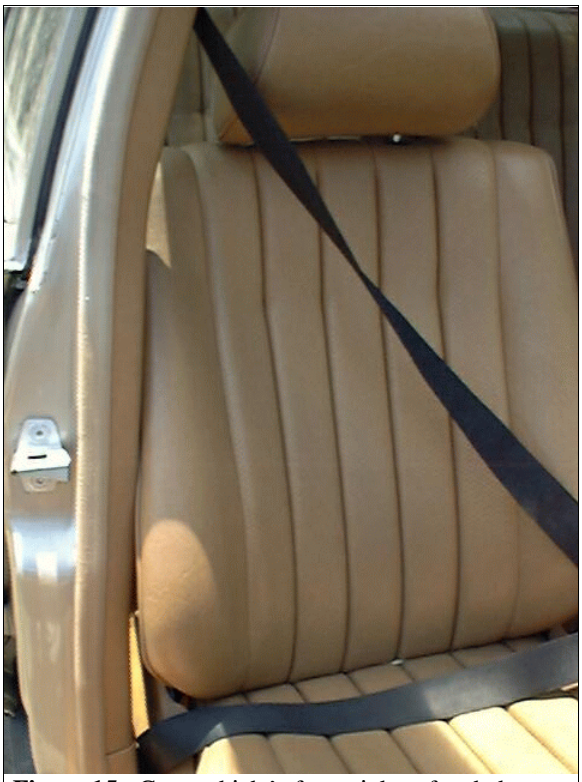

Figure 15: Case vehicle's front right safety belt system showing belt fully extend and not retractable because pretensioner had actuated accompanying deployment of driver's air bag (case photo #43)

Figure 16: Case vehicle's front right safety belt showing heat abrasion mark on belt's webbing (case photo #42)

The case vehicle's driver most likely saw the Nissan "flashing by" and steered to the right, attempting to avoid the collision. As a result of this attempted avoidance maneuver and the nonuse of her available safety belts, the driver most likely moved slightly to her left just prior to impact. The case vehicle impact with the Nissan most likely had a negligible effect upon the case vehicle's driver. Following the impact with the Nissan and the driver's right steering maneuver, the case vehicle veered back into the outside eastbound lane. The driver, while trying to regain control, over corrected by steering sharply back to the left and, as a result, the case vehicle went into a counterclockwise rotation and the driver most likely moved slightly forward and toward her right. The case vehicle's front right corner impact (i.e., primary impact) with the guardrail enabled the unrestrained driver to continued forward, rightward, and upward toward the case vehicle's **40** degree Direction of Principal Force as the case vehicle decelerated. As the case vehicle reached maximum engagement, it continued to rotate rapidly counterclockwise. Based on the available evidence, the head of the case vehicle's driver was most likely to the right of the driver air bag module when it deployed. The deploying driver air bag may have struck the driver on the left side of her torso or it may have missed the driver completely. The combination of the deceleration caused by the guardrail impact combined with the driver's nonuse of her safety belts, the **40** degree Direction of Principal Force, and the lateral momentum associated with the counterclockwise rotation (i.e., the movement of the case vehicle's center of gravity was approximately oriented 75-90 degrees toward the perpendicular to the case vehicle's heading angle at first impact with guardrail) most likely enabled the driver to move upwards into the center roof or windshield header area at impact. Given that there was a contusion to the medial side of the driver's right knee, and the available evidence indicates that the inside of the right knee impacted the left side of the center instrument panel (**Figure 11** above), then the driver's head should have been near

the roof, somewhere over the center console area. Given that there are no integumentary injuries to the driver's head or neck and that there are no discernable points of contact to the case vehicle's roof and/or greenhouse areas (**Figures 17** and **18**), the exact point of occupant to vehicle interaction is uncertain.

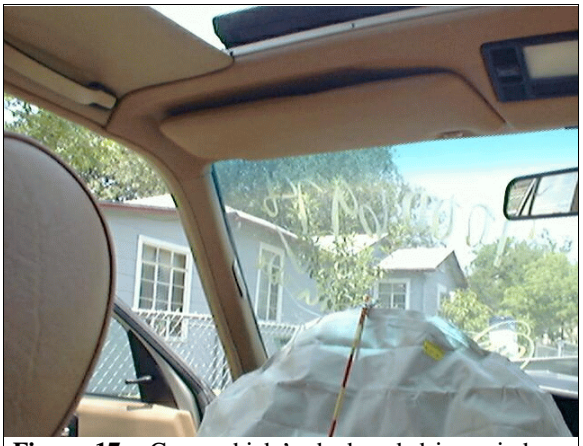

Figure 17: Case vehicle's deployed driver air bag and driver's greeenhouse area showing no obvious occupant contact evidence (case photo #30)

Figure 18: Case vehicle's center and front right greenhouse areas showing no obvious occupant contact evidence (case photo #31)

As the case vehicle continued rotating counterclockwise, it impacted the guardrail with its right side. As a result, the driver would have moved to the right towards the **100** degree Direction of Principal Force. Specifically, the driver's head most likely moved laterally to the right along the roof during this slapping impact with the guardrail. When the back right corner of the case vehicle snagged into the angling guardrail (i.e., fourth event), the driver most likely moved slightly back and to the right toward the **180** degree Direction of Principal Force. Based on the opinion of the pathologists associated with driver's autopsy, the driver's chin was forced downward into the driver's chest by a force applied to the top or back of her head. The hyperflexion[1] of the driver's neck as a result of this force caused the driver's fatal cervical lesions. In this contractor's opinion, the driver's head was forced downward from her head contacting the roof and as a result of the continued guardrail interaction, her head was kept forced downward continuing the pressure on her cervical spine throughout the case vehicle's three guardrail impacts.

When the case vehicle continued its counterclockwise rotation off the guardrail and back onto the interstate and across the eastbound through lanes, the driver most likely contacted the front right passenger and/or right roof side rail and/or right "B"-pillar. As the case vehicle spun to final rest, the driver rebounded back to her left towards her seating area. The exact posture of the case vehicle's driver at final rest is unknown, but she was most likely in or near her seat at this time.

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[1] The following terms are defined in DORLAND'S ILLUSTRATED MEDICAL DICTIONARY as follows:
hyperextension (hi"per-ek-sten'shen): extreme or excessive extension of a limb or part. **Neck backward**
hyperflexion (hi"per-flek'shen): forcible overflexion of a limb or part. **Neck forward**

The driver was transported by ambulance to a hospital. She sustained fatal injuries and was hospitalized in a vegetative state prior to being pronounced dead five days post-crash. Based on the autopsy, the injuries sustained by the case vehicle's driver included: a transection of the spinal cord at C_2 with associated dislocation and fracture of C_2; severe cerebral edema with associated transtentorial and tonsillar herniation of the brain stem; secondary contusions of hippocampal gyri (i.e., inferior cerebrum); and contusions to the right shoulder, right buttock, and right knee. Although this crash was originally listed as a confirmed air bag-related fatality, pictures and medical information that was obtained subsequent to the initial determination show that the fatal lesion was not associated with the air bag and, as a result, this crash was dropped from the ***"confirmed"*** status. In fact, the driver's nonuse of her safety belts in conjunction with the circumstances of this collision most likely contributed to this occupant's fatal lesions.

Injury Number	Injury Description (including Aspect)	NASS Injury Code & AIS 90	Injury Source (Mechanism)	Source Confidence	Source of Injury Data
1	Laceration {transection}, complete, of spinal cord at C2 with extensive fracture (not further specified) to posterior of spinal column and dislocation {widening} between the 1st and 3rd cervical vertebra	640276.6[2] untreatable	Roof	Probable	Autopsy
2	Edema, cerebrum, severe with flattening of gyri, notching of unci, and coning of cerebellar tonsils[3] [Aspect = Unknown]	140666.5 critical	Roof	Probable	Autopsy
3	Compression brain stem with both transtentorial (uncal) and cerebellar tonsillar herniation[3]	140202.5 critical	Roof	Probable	Autopsy
4	Contusions cerebrum (i.e., hippocampal gyri[3]) [Aspect = Unknown]	140611.3 serious	Roof	Probable	Autopsy
5	Hemorrhage, subarachnoid, not significant [Aspect = Unknown]	140684.3 serious	Roof	Probable	Autopsy
6	Contusion, 6 cm (2.4 in), apex right shoulder	790402.1 minor	Roof	Probable	Autopsy
7	Contusion, irregular, right buttock, not further specified	890402.1 minor	Center console	Probable	Autopsy

[2] The choice of injury code is difficult because the NASS CDS Injury Coding manual presumes that one knows whether there was a complete or an incomplete cord syndrome. Because the only available medical record is an autopsy, the syndrome issue is not discernable (i.e., you cannot determine the difference in a dead person). In the absence of protocol, this contractor chooses to assume that the syndrome was complete.

[3] See section entitled **CEREBRAL EDEMA AND BRAIN SWELLING** at the end of this report.

Injury Number	Injury Description (including Aspect)	NASS Injury Code & AIS 90	Injury Source (Mechanism)	Source Confidence	Source of Injury Data
8	Contusion, 5 x 1 cm (2.0 x 0.4 in) medial[4] right knee	890402.1 minor	Center instrument panel and below	Probable	Autopsy

CASE VEHICLE FRONT RIGHT PASSENGER KINEMATICS

The exact posture of the case vehicle's front right passenger [daughter of driver; 21-year-old, White (Hispanic) female; unknown height and weight] is unknown, but presumably she was seated upright with her back against the seat back and both feet on the floor. However, the exact position of her hands is unknown. Based on the vehicle inspection, her seat track was located in its middle position, and her seat back was upright. Once again, it should be noted that "upright" for this particular seat back was approximately 28 degrees rearward of perpendicular to the floor.

The case vehicle's front right passenger was restrained by her available, active, three-point, lap-and-shoulder, safety belt system. The case vehicle was not equipped with a front right supplemental restraint (air bag). As discussed above, the inspection of the front right passenger's seat belt showed evidence of loading (heat abrasion markings) on the plastic free sliding latch plate and a related heat abrasion on the webbing. It should be noted that the **ETR** on the passenger's belt system was still locked in place with the belt webbing extended, preventing the belt's movement during this contractor's inspection (**Figure 15** above).

The case vehicle's driver most likely saw the Nissan "flashing by" and steered to the right, attempting to avoid the collision. As a result of this attempted avoidance maneuver and the use of her available safety belts, the front right passenger most likely moved slightly to her left just prior to impact. The case vehicle impact with the Nissan most likely had a negligible effect upon the case vehicle's front right passenger. Following the impact with the Nissan and the driver's right steering maneuver, the case vehicle veered back into the outside eastbound lane. The driver, while trying to regain control, over corrected by steering sharply back to the left and, as a result, the case vehicle went into a counterclockwise rotation and the front right passenger most likely moved slightly forward and toward her right where she loaded her safety belts. The case vehicle's front right corner impact (i.e., primary impact) with the guardrail enabled the restrained front right passenger too continued forward and slightly rightward and upward toward the case vehicle's **40** degree Direction of Principal Force as the case vehicle decelerated. However, the **ETR** on the case vehicle's passenger seat belt system engaged removing the slack from the front right passenger's seat belt preventing her from being thrown into the instrument panel (**Figure 19** below) and/or right "A"-pillar (**Figure 18** above). As the case vehicle reached maximum engagement, it continued to rotate rapidly counterclockwise and impacted the guardrail with its right side. As a result, the front right passenger would have moved to the right toward the **100** degree Direction of Principal Force. Based on the available evidence, the case vehicle's front right passenger most likely loaded the interior surface of the right front door, door sill, and

[4] The specific location of the right knee contusion was provided in a deposition given by the pathologist who performed the autopsy.

window frame. When the back right corner of the case vehicle snagged into the angling guardrail (i.e., fourth event), the front right passenger most likely moved slightly back and to the right toward the **180** degree Direction of Principal Force. As a result, she loaded her seat back and/or right "B"-pillar areas. When the case vehicle continued its counterclockwise rotation off the guardrail and back onto the interstate and across the eastbound through lanes, the front right passenger most likely moved slightly forward and to her right loading her safety belts again and possibly contacting the interior surface of the right front door, door sill, and window frame. The passenger's interaction with the case vehicle's interior was minimized because of her safety belt system usage. As the case vehicle spun to final rest, the front right passenger rebounded back to her left toward the center console, but her safety belts limited her movement. The exact posture of the case vehicle's front right passenger at final rest is unknown, but she was most likely sitting upright near her pre-crash seating position.

Figure 19: Case vehicle's front right instrument panel and windshield's glazing showing no obvious occupant contact evidence (case photo #40)

CASE VEHICLE FRONT RIGHT PASSENGER INJURIES

The front right passenger was transported by ambulance to the hospital. Based on the available evidence, she sustained minor injuries and was treated and released. The injuries sustained by the front right passenger are unknown.

OTHER VEHICLE

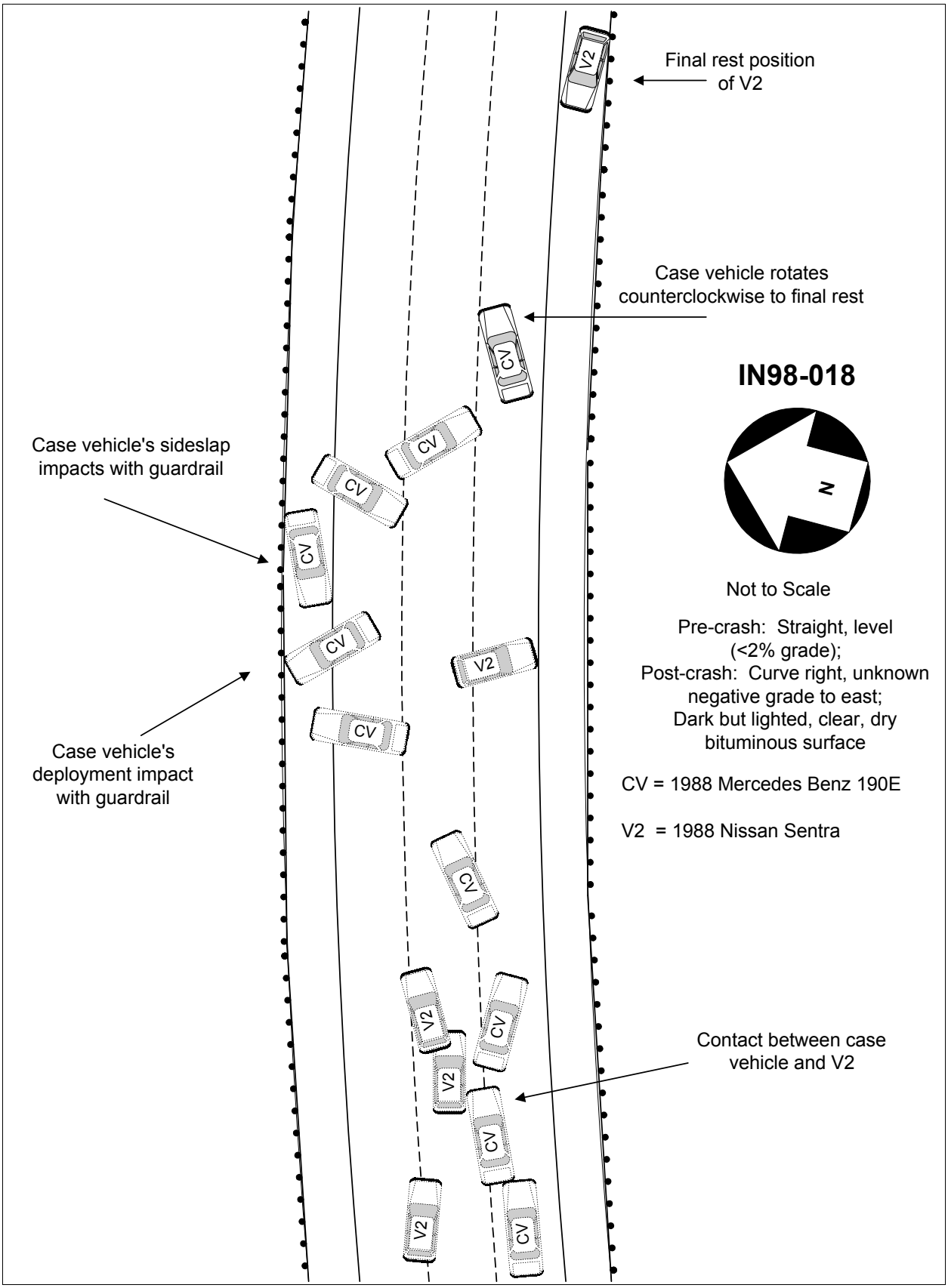
The 1988 Nissan Sentra was a front wheel drive, four-passenger, four-door sedan (VIN: JN1PB21S2JU------) equipped with a 1.6L, I-4 engine and a either the standard five-speed manual or optional four-speed automatic transmission. Anti-lock brakes were not available for this model. The case vehicle's wheelbase was 243 centimeters (95.7 inches), and the odometer reading is unknown because the Nissan was not inspected.

Based on the available police photographs, the Nissan was equipped with adjustable front bucket seats with adjustable head restraints; a non-adjustable back bench seat without head restraints for any of the back seating positions; continuous loop, three-point, lap-and-shoulder, safety belt

Figure 20: On-scene photo looking west at Nissan's final rest position with left rear corner against guardrail on south roadside (case photo #14)

systems at the front outboard positions; and two-point, lap belt system for the back seating positions. The front seat belt systems were not equipped with manually operated height adjusters for the "D"-rings.

The Nissan's right rear impact from the case vehicle caused the right quarter panel to be crushed inward (**Figure 3** above). Based on the photograph, the direct damage started at the right rear bumper corner and continued forward to the right rear axle. The Nissan's left rear side impact with the guardrail caused minor damage to the left quarter panel and rear bumper corner (**Figure 20** above). Based on the available police photographs, the CDCs for the Nissan are estimated as: **01-RBEW-1 (40)**–1st event, and **06-LBMS-1 (180)**–5th event. The Nissan was towed due to damage.


Final rest position of V2
Case vehicle rotates counterclockwise to final rest
IN98-018
N
Case vehicle's sideslap impacts with guardrail
Case vehicle's deployment impact with guardrail
Not to Scale
Pre-crash: Straight, level (<2% grade);
Post-crash: Curve right, unknown negative grade to east;
Dark but lighted, clear, dry bituminous surface
CV = 1988 Mercedes Benz 190E
V2 = 1988 Nissan Sentra
Contact between case vehicle and V2
CV
V2

The following material is taken from the book: FORENSIC PATHOLOGY, 2ND EDITION by Vincent J. DiMaio, M.D., and Dominick J. DiMaio, M.D., CRC Press, Boca Raton, Florida, 2001; Chapter Six: Trauma to the Skull and Brain: Craniocerebral Injuries, ***Traumatic Brain Swelling and Edema***, pages 177-179.

Following significant head injury, whether clinically mild or severe, swelling of the brain may occur. Brain swelling may be focal, adjacent to an area of brain injury; or diffuse, involving one or both cerebral hemispheres. **BRAIN SWELLING** is due to an **increase in intravascular cerebral blood volume secondary to vasodilation (congestive brain swelling) *or* an absolute increase in the water content of the brain tissue**, or a combination of the two. An increase in tissue water content, or **CEREBRAL EDEMA**, is often incorrectly considered synonymously with brain swelling. If continued long enough, brain swelling caused by an increase in the intravascular cerebral blood volume progresses to cerebral edema, presumably due to increased vascular permeability. The magnitude of the brain swelling does not necessarily correspond to the severity of the injury. Massive cerebral (congestive) swelling can occur within 20 minutes following head trauma.

Swelling of one cerebral hemisphere is seen most commonly with an ipsilateral[5] subdural hematoma. The secondary swelling may, in fact, cause a more serious mass effect than the original hematoma. The rapid onset of the swelling suggests that the etiology is congestive.

With severe brain injury, diffuse brain swelling of a severe degree may occur immediately without the individual regaining consciousness. Brain swelling, however, may not occur immediately after an injury, but rather develop minutes to hours later. Delayed brain swelling of a significant degree is rare. It is usually diffuse and more often associated with the less severe forms of brain injury. Typically, the patient receives a concussion *{non-anatomic brain injury}*, regains consciousness, only to become stuporous and lapse into coma minutes to hours later. Until recently, it was felt that children were more susceptible than adults to developing diffuse swelling, even after minor trauma. Recent studies have challenged this contention. Lang et al. found that, while diffuse swelling might occur more readily in children it is more benign. Thus, in their study 75% of children with diffuse swelling had a benign course, while two thirds of adults had a poor outcome. The researchers believed that a number of the previous studies had problems in that they were not able to adequately study changes in the brain in children because the studies were performed without CT scans.

If brain swelling develops to a severe degree and continues over a sufficient time, there can be herniation of the brain or secondary brain stem hemorrhage. A rapid expanding intracranial mass or severe brain swelling can produce tonsillar[6],

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[5] The following term is defined in DORLAND'S ILLUSTRATED MEDICAL DICTIONARY as follows:
ipsilateral (ip"si-lat'ar-al): situated on, pertaining to, or affecting the same side, as opposed to contralateral.

[6] The following terms are defined in DORLAND'S ILLUSTRATED MEDICAL DICTIONARY as follows:
falcial (fal'shal): pertaining to a falx.

transtentorial[6], and/or subfalcial[6] herniation[6] of the brain, with resultant necrosis[7], secondary infarction[7], and Duret hemorrhages[8] (Figure 6.15 below). Herniation may be either symmetrical, due to brain swelling, or asymmetrical, due to a mass in one side of the brain or subdural space, for example, a subdural hematoma or intracerebral hemorrhage. In the case of diffuse brain swelling, there is usually symmetrical herniation of the cerebellar tonsils without brain stem hemorrhage. The brain stem and cerebellar tonsils are forced into the foramen magnum, with resultant dysfunction or even infarction of the brain stem. The individual becomes unconscious and develops respiratory difficulty that proceeds to arrest and death. Severe herniation of the cerebellar tonsils can result in infarction. In some individuals with prolonged survival, the authors have seen the upper spinal cord encased in necrotic cerebellar tissues shed into the cerebrospinal fluid. In dealing with an asymmetrical herniation caused by a subdural hematoma, in addition to ipsilateral cerebellar tonsil herniation, one often has a secondary brain stem hemorrhage (a Duret hemorrhage) involving the midbrain and pons.

Transtentorial or uncal herniation is due to a rapidly expanding supratentorial mass lesion. It may be either unilateral or bilateral, though unilateral herniation is more common because rapidly expanding lesions are usually unilateral. A rapidly expanding

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falx (falks) pl. ***fal′ces***: a sickle-shaped organ or structure; used as a general term in anatomical nomenclature to designate such a structure.
- ***f. ce′rebri, f. of cerebrum***: the sickle-shaped fold of dura mater that extends downward in the longitudinal cerebral fissure and separates the two cerebral hemispheres.

herniation (her"ne-a′shen): the abnormal protrusion of an organ or other body structure through a defect or natural opening in a covering, membrane, muscle, or bone.
- ***caudal transtentorial h.***: tentorial h.
- ***subfalcial h.***: not defined in Dorland's, but means below a falx (see falcial above).
- ***tentorial h.***: downward displacement of the medially-placed cerebral structures through the tentorial notch, caused by a supratentorial mass. Pressure is exerted on underlying structures, including the brain stem. Called also *caudal transtentorial h.*, *transtentorial h.*, and *uncal h.*
- ***tonsillar h.***: protrusion of the cerebellar tonsils through the foramen magnum, exerting pressure on the medulla oblongata. Called also *tonsillar hernia*.
- ***transtentorial h.***: tentorial h.
- ***uncal h.***: tentorial h.

tonsil (ton′sil): a small rounded mass of tissue, especially of lymphoid tissue. The term is often used without qualification to designate the palatine tonsil. Called also *tonsilla*.
- ***t. of cerebellum***: tonsilla cerebelli.

tonsilla (ton-sil′a) pl. ***tonsil′lae***: tonsil – a general term for a small rounded mass of tissue, especially of lymphoid tissue.
- ***t. cerebel′li, t. of cerebellum***: a rounded mass forming part of the caudal lobe of the hemisphere of the cerebellum continuous with the uvula of the vermis; called also *amygdala of cerebellum*.

tonsillar (ton′si-lar): of or pertaining to a tonsil; amygdaline.

uncal (ung′kal): of or pertaining to the uncus.

unci (un′si): genitive and plural of *uncus*.

uncus (ung′kas): 1. any hook-shaped structure. 2. the medially curved anterior end of the parahippocampal gyrus; called also *u. gyri fornicati*, *u. gyri hippocampi*, and *u. gyri parahippocampalis*.

[7] The following terms are defined in DORLAND'S ILLUSTRATED MEDICAL DICTIONARY as follows:

infarct (in′fahrkt): an area of coagulation necrosis in a tissue due to local ischemia resulting from obstruction of circulation to the area, most commonly by a thrombus or embolus.

infarction (in-fahrk′shen): 1. the formation of an infarct. 2. an infarct.

necrosis (na-kro′sis) pl. ***necro′ses***: the sum of the morphological changes indicative of cell death and caused by the progressive degradative action of enzymes; it may affect groups of cells or part of a structure or an organ.

[8] The following term is defined in DORLAND'S ILLUSTRATED MEDICAL DICTIONARY as follows:

lesion (le′zhen): any pathological or traumatic discontinuity of tissue or loss of function of a part.
- ***Duret's l.***: effusion of blood in the region of the fourth ventricle of the cerebrum as a result of slight injury.

mass in a cerebral hemisphere means that ipsilateral uncal herniation can be expected. If severe enough, there will be displacement of the brain stem against the contralateral tentorial edge with injury to the brain stem and production of Kernohan's notch[9].

Figure 6.15: Drawing illustrating (1) tonsillar, (2) transtentorial, and (3) subfalcial herniation of brain

Transtentorial or uncal herniation is due to a rapidly expanding supratentorial mass lesion. It may be either unilateral or bilateral, though unilateral herniation is more common because rapidly expanding lesions are usually unilateral. A rapidly expanding mass in a cerebral hemisphere means that ipsilateral uncal herniation can be expected. If severe enough, there will be displacement of the brain stem against the contralateral tentorial edge with injury to the brain stem and production of Kernohan's notch[5].

The third type of herniation is subfalcial or transfalcial herniation. This occurs when there is a rapidly expanding mass in one cerebral hemisphere or at least in the subdural space on one side. This causes herniation of the cerebral hemisphere across the midline below the edge of the falx. The herniating tissue is most often the cingulate or supracingulate gyrus.

As previously noted, herniation with compression of the brain stem can result in Duret hemorrhages. These are secondary herniation hemorrhages of the midbrain and pons. They may range from small streaks to massive confluent hemorrhage. They are in the midline and are most commonly associated with asymmetrical herniation of the brain stem. Duret hemorrhages may develop in only 30 minutes.

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[9] The following term is defined in DORLAND'S ILLUSTRATED MEDICAL DICTIONARY as follows:
notch (noch): an indentation or depression, especially one on the edge of a bone or other organ. See also *incisura*.
Kernohan's n.: a groove in the cerebral peduncle caused by displacement of the brain stem against the tentorium in some cases of transtentorial herniation.