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ON-SITE AIR BAG INVESTIGATION

CASE NUMBER - IN98-028
LOCATION - TEXAS
VEHICLE - 1995 FORD B800 WITH WAYNE BODY
CRASH DATE - November, 1998

Submitted:

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The crash investigation process is an inexact science which requires that physical evidence such as skid marks, vehicular damage measurements, and occupant contact points be coupled with the investigator's expert knowledge and experience of vehicle dynamics and occupant kinematics in order to determine the pre-crash, crash, and post-crash movements of involved vehicles and occupants.

Because each crash is a unique sequence of events, generalized conclusions cannot be made concerning the crashworthiness performance of the involved vehicle(s) or their safety systems.

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16. *Abstract*

This report covers an on-site investigation of a school bus crash that involved a 1995 Ford B800 conventional chassis-cab with a Wayne school bus body (case vehicle) and a 1991 Chevrolet Camaro RS (other vehicle). This crash is of special interest because the case vehicle was a school bus equipped with an on-board video camera that recorded passenger kinematics in a crash that resulted in minor injuries to six student occupants. The case vehicle had been traveling east in the eastbound lane of a two-lane, undivided, county roadway, had stopped on the west (bottom) leg of a "T"-intersection, and was making a left-hand turn onto the intersecting roadway. The Chevrolet was traveling south in the southbound lane of a two-lane, undivided, state roadway. The crash occurred on the north leg of the "T"-intersection. The left side of the case vehicle was impacted by the front and top of the Chevrolet, in an underride configuration, with the Chevrolet contacting the case vehicle's left frame rail and drive shaft after impacting the bottom of the left side panel. Both vehicles moved north-northeastward and the left rear tandem wheels of the case vehicle came to rest on the Chevrolet's hood. The case vehicle's driver (29-year-old male) was seated with his seat track located in its rearmost position. The case vehicle was not equipped with a tilt steering wheel. He was restrained by his available, active, three-point, lap-and-shoulder, safety belt system. Six of the case vehicle's passengers [females aged 16, 13, and 12; males aged 16 and two aged 14] were transported from the scene by ambulance to a local medical facility and were all treated and released for minor injuries. One passenger (14-year-old male), who was seated at the left window in the eleventh row of the bus, sustained abrasions and contusions to his right abdomen (flank). The case vehicle's driver, a bus monitor (34-year-old female), and the other 29 uninjured student passengers were transported from the scene in another school bus to a local medical facility for precautionary medical examinations. Based on the available information, no additional injuries were discovered.

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BACKGROUND IN98-028

This on-site investigation was brought to NHTSA's attention in November, 1998, by the investigating police officer. This crash involved a 1995 Ford B800 conventional chassis-cab with a Wayne school bus body (case vehicle) and a 1991 Chevrolet Camaro RS (other vehicle). The crash occurred in November, 1998, at 7:10 a.m., in Texas, and was investigated by the applicable state police department. This crash is of special interest because the case vehicle was a school bus equipped with an on-board video camera that recorded passenger kinematics in a crash that resulted in minor injuries to six student occupants. This contractor inspected the case vehicle on November 9, 1998, and the scene and the Chevrolet on November 10, 1998. This contractor also spoke briefly with the Chevrolet's driver in the storage lot the same day as the vehicle inspection. This contractor interviewed the case vehicle's driver on November 13, 1998. This report is based on the Police Crash Report; an interview with the case vehicle's driver; conversations with the Chevrolet's driver, the investigating police officer, and a representative of the school corporation; scene and vehicle inspections; occupant kinematic principles; a video tape from the case vehicle's on-board video camera; one occupant's medical records; and this contractor's evaluation of the evidence.

SUMMARY

The case vehicle had been traveling east in the eastbound lane of a two-lane, undivided, county roadway, had stopped on the west (bottom) leg of a "Tee" intersection, and was making a left-hand turn onto the intersecting roadway, intending to travel northward. The Chevrolet was traveling south in the southbound lane of a two-lane, undivided, state roadway, and intended to pass through the intersection and continue its southerly travel path. Attempting to avoid the crash, the case vehicle's driver first accelerated and turned the steering wheel more to the left, in order to complete the left-hand turn. Next, the driver turned the steering wheel to the right, to get the school bus as far to the right (east) side of the state highway as possible, because the Chevrolet's combined steering and braking avoidance maneuvers caused it to move into the northbound travel lane. The crash occurred in the northbound lane of the "Tee" intersection's north leg (see **CRASH DIAGRAM** below).

The left side of the case vehicle was impacted by the front and top of the Chevrolet, in an underride configuration, with the Chevrolet contacting the case vehicle's left frame rail and drive shaft after impacting the bottom of the left side panel. Post-impact the case vehicle continued in a north-northeasterly direction and came to rest, primarily on the east roadside of the trafficway. The Chevrolet rotated approximately 40 degrees counterclockwise and was driven backwards as the case vehicle continued in its forward movement. The Chevrolet came to rest diagonal to the roadway and heading southeast, with the case vehicle's left rear dual wheels atop its hood.

The case vehicle's driver [29-year-old, White (Non-Hispanic) male; 188 centimeters and 147 kilograms (74 inches, 325 pounds)] was restrained by his available, active, three-point, lap-and-shoulder, safety belt system. Although there was no evidence of belt pattern bruising and/or abrasions to the driver's body, inspection of the driver's seat belt webbing, "D"-ring, and latch plate showed evidence of fabric waffling and stitching pulls at the ends of the lap-and-shoulder, safety belt system, near the male connector.

The case vehicle's driver first accelerated and steered left, trying to complete the left-hand turn. Second, he steered right onto the roadside, trying to get the bus as far right (east) as possible in an attempt to avoid the crash. As a result of these attempted avoidance maneuvers and the use of his available safety belt, he and his 36[1] passengers most likely moved slightly to the right, then slightly to the left, just prior to impact. The case vehicle's impact with the Chevrolet thrust the driver and his passengers slightly leftward and forward. As the case vehicle continued forward on the right roadside and slightly onto the side of a drainage ditch, its left rear tandem tires climbed on top of the Chevrolet's hood at final rest. The combination of the case vehicle's left rear tandem tires atop the Chevrolet's hood and its right side tires on the downward side of a drainage ditch, the case vehicle was tipped to its right, with its left rear higher than its right side. This tipping caused the case vehicle's passengers to be thrown left-to-right.

Six of the case vehicle's passengers were transported from the scene by ambulance to a local medical facility. The injured case vehicle passengers included: a 12-year-old female, a 13-year-old female, two 14-year-old males, a 16-year-old female, and a 16-year-old male (heights and weights for five of the six injured bus passengers are unknown). They were all treated for "B" (non-incapacitating evident) injuries and released. One passenger [14-year-old, White (non-Hispanic) male; 165 centimeters and 86 kilograms (65 inches, 189 pounds)], who was seated at the left window in the eleventh row of the bus, sustained abrasions and contusions to his right abdomen (flank). The exact nature of the injuries sustained by the other five occupants is unknown. The case vehicle's driver, a bus monitor [34-year-old, (unknown race or ethnic origin) female], and the other 29 uninjured student passengers were transported from the scene in another school bus to a local medical facility for precautionary medical examinations. Based on the available information, no additional injuries were discovered.

The case vehicle was a rear wheel drive, 1995 Ford B800, conventional bus chassis with a 66-passenger, Wayne school bus body attached (VIN: IFDXB80C6SV------). The case vehicle had a tilt hood, a 5.9L, I-6, diesel engine, and was not equipped with anti-lock brakes. The 1991 Chevrolet Camaro RS was a rear wheel drive, two-door, "T"-top, sport coupe (VIN: 1G1FP23T3ML------). The Chevrolet was equipped with a driver supplemental restraint system (air bag) which deployed as a result of its frontal impact. The case vehicle and the Chevrolet were both towed due to disabling damage.

The case vehicle is not CDC/TDC applicable. The case vehicle's drive shaft was separated at the rearmost spindle connection, just forward of the universal joint, and the left rear tandem wheels were pushed rearward. Other than the foregoing damage descriptions, crash severity estimates for large trucks and buses (including the case vehicle) are currently undefined. The CDC for the Chevrolet was determined to be: **01-FDAW-7** [maximum crush was 44.5 centimeters (17.5 inches)]. The WinSMASH reconstruction program, barrier algorithm, was used on the Chevrolet's highest severity impact. The Total, Longitudinal, and Lateral Delta Vs are, respectively: 39.1 km.p.h. (24.3 m.p.h.), -33.9 km.p.h. (-21.1 m.p.h.), and -19.6 km.p.h. (-12.2

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[1] The Police Crash Report and the school corporation both indicated that there were 37 passengers (i.e., one adult monitor and 36 students) on the school bus; however, this contractor's careful review of the video tape from the school bus's on-board video camera revealed only 35 student passengers present. The seating chart at the back of this report reflects the school corporation's assigned seating positions.

m.p.h.). Inspection of the case vehicle's interior determined it was not equipped with supplemental restraints (air bags) nor safety belts, other than for the driver. In addition, there was no evidence that the case vehicle's driver contacted any interior surface.

Immediately prior to the crash, the case vehicle's driver was seated upright with his back against the seat back, his left foot on the floor, his right foot on the accelerator, and both hands on the steering wheel. His seat track was located in its rearmost position, and the seat back was not adjustable. The case vehicle was not equipped with a tilt steering wheel. The remaining part of the case vehicle's passenger compartment consisted of 11 rows of cushioned bench seats, with the last left side seat being a shortened seat (i.e., only two positions). Each bench seat, except the shortened seat, was 99 centimeters (39.0 inches) wide and 38 centimeters (15.0 inches) deep, with the seat cushion's bottom 36 centimeters (14.2 inches) off the floor. The shortened seat was 66 centimeters (26.0 inches) wide, with the rest of the measurements the same as the other seats. Seat backs were 99 centimeters (39.0 inches) high, measured from the floor to the cushion's top. The distance from the seat backs to the back of the seat immediately ahead of it ranged from 67 to 69 centimeters (26.4 to 27.2 inches) for right side seats, and from 60 to 71 centimeters (23.6 to 28.0 inches) for left side seats; row 3 (left) had the 60 centimeter distance and row 6 (left), the left-side emergency exit door location, had the 71 centimeter distance. Interior width of the passenger compartment was 230 centimeters (90.6 inches), window sill to window sill. The center aisle was 34 centimeters (13.4 inches) wide at seat cushion height and 56 centimeters (22.0 inches) wide at the top of the seat backs. For the side windows, the window sills measured 82 centimeters (32.3 inches) from the floor, while the top of the side windows were 150 centimeters (59.1 inches) from the floor. The window sills were 35 centimeters (13.8 inches) from the top of the seat cushions. Each seat cushion was approximately 8 centimeters (3.1 inches) thick.

Seat positions for both the injured and uninjured student passengers are shown in the **SCHOOL BUS OCCUPANT SEATING DIAGRAM** below. No contacts were noted on the case vehicle's left interior side surface, glazing, or left side seats. For the case vehicle's right side, the lower half of row 11's window glazing on the right side was disintegrated from occupant contact. A small trace of blood was present around and slightly forward of a rivet at the bottom rear of the damaged, right side window. A possible contact smudge on the center of row 11's right upper glazing was also noted. Immediately below that window on the side panel was a possible skin transfer, and rearward of the window were possible black contact smudges. Row 11's right seat back, at the seam with the seat cushion, was bent rearward, and the bottom right corner of the back of row 10's seat was pushed forward. Possible occupant contact points (i.e., scuffs) were noted to: row 8's right side panel, below the window sill; the seat backs of rows 2, 3, 4, and 7; a smudge on the lower portion of the window, slightly forward of row 5's seat back; and the roof panel over seat 4.

The Chevrolet's driver [29-year-old, White (unknown if Hispanic) female; unknown height and weight] was wearing her available, active, three-point, lap-and-shoulder, safety belt system. The Chevrolet's driver air bag was mounted in the steering wheel hub and deployed due to crash forces. The air bag module was in a symmetrical "H" configuration. The air bag had a circular shape, with a diameter of 50 centimeters (19.7 centimeters). No tethers were detected, but the air bag fabric did contain two vent ports, each 2 centimeters (0.8 inches) in diameter, located at the

11 and 1 clock positions. Several blood stains were noted at the lower vertical midline and the upper right quadrant of the fabric. The Chevrolet's driver sustained "A" (incapacitating) injuries, one of which was a laceration to the bridge of her nose. She was transported by ambulance to a local medical facility. She was reportedly treated and released.

CRASH CIRCUMSTANCES

The case vehicle had been traveling east in the eastbound lane of a two-lane, undivided, county roadway (**Figure 1**), had stopped on the west (bottom) leg of a "Tee" intersection, and was making a left-hand turn onto the intersecting roadway, intending to travel northward (**Figure 2**). The Chevrolet was traveling south in the southbound lane of a two-lane, undivided, state roadway, and intended to pass through the intersection and continue its southerly travel path (**Figure 3**). The State roadway was straight but had a 3.3% grade negative to the south (i.e., a down grade in the Chevrolet's direction of travel), and the pavement was bituminous. Pavement markings consisted of a single broken yellow centerline for southbound traffic augmented by a single solid yellow "no passing" line for northbound traffic; no edge lines were present. There were no improved shoulders, and there were some areas of pavement drop off measuring nearly 8 centimeters (3.1 inches). The estimated coefficient of friction was 0.60, not including the 3.3% grade. A warning SCHOOL BUS STOP AHEAD sign (Manual on Uniform Traffic Control Devices, S3-1) with a 40 M.P.H. (64 km.p.h.) advisory speed plate (MUTCD, W13-1), was located prior to the hillcrest for southbound traffic. The statutory speed limit was 89 km.p.h. (55 m.p.h.). No speed limit sign was posted near the crash site. For the county roadway there was a stop sign on the southwest quadrant of the intersection. Ambient conditions were daylight, clear, and dry pavement. Traffic density was light, and the site of the crash was a combination of rural residential and agricultural.

Figure 1: Case vehicle's eastbound travel path on west leg of "T"-intersection (case photo #01)

Figure 2: Case vehicle's northward view from west leg of "T"-intersection; Note hillcrest and negative grade for southbound traffic, unimproved shoulders, and drop off along west pavement edge (case photo #04)

Figure 3: Chevrolet's southbound travel path approaching west leg (arrow) of "T"-intersection (case photo #09)

Attempting to avoid the crash, the case vehicle's driver first accelerated and turned the

steering wheel more to the left, in order to complete the left-hand turn. Next, after noticing the Chevrolet skidding towards him and angling left-of-center, the driver turned the steering wheel to the right, to get the school bus as far to the right (east) side of the state highway as possible. The Chevrolet's combined steering and braking avoidance maneuvers caused it to move into the northbound travel lane. The Chevrolet deposited nearly 61.0 meters (200 feet) of pre-impact skid marks. The crash occurred in the northbound lane of the "Tee" intersection's north leg; see **CRASH DIAGRAM** below.

Figure 4: Underride damage to case vehicle's left side (case photo #19)

The left side of the case vehicle (**Figure 4**) was impacted by the front and hood top of the Chevrolet (**Figures 5** and **6**), in an underride configuration, with the Chevrolet contacting the case vehicle's left frame rail and drive shaft after impacting the bottom of the left side panel. Post-impact the case vehicle continued in a north-northeasterly direction and came to rest, primarily on the east roadside of the trafficway. The Chevrolet rotated approximately 40 degrees counterclockwise and was driven backwards as the case vehicle continued in its forward movement. The Chevrolet came to rest diagonal to the roadway and heading southeast, with the case vehicle's left rear dual wheels atop its hood (**Figure 7** below). With the case vehicle's right rear tandem wheels on the down slope of the east drainage ditch and the left rear tandem wheels resting on the Chevrolet's hood, the case vehicle was tilted at a severe angle (i.e., left side high and right side low).

Figure 5: Chevrolet's frontal damage with contour gauge present and positioned above bumper; Note: contact to top of hood (case photo #60)

Figure 6: Direct contact to Chevrolet's hood and left roof rail, "A"- pillar, and upper "B"- pillar, viewed from front of left (case photo #65)

CASE VEHICLE

The case vehicle was a rear wheel drive, 1995 Ford B800, conventional bus chassis with a 66-passenger, Wayne school bus body attached (VIN: IFDXB80C6SV------) equipped with power-assisted, rack-and-pinion steering, a 5.9L, I-6 diesel engine, and a four-speed automatic transmission. The selection lever was attached to the steering column. The case vehicle had a tilt hood and was equipped with air brakes but not anti-lock brakes. The case vehicle's wheel base

was 699 centimeters (275.0 inches), and the odometer reading at inspection was 125,423 kilometers (77,934 miles). It was painted school bus yellow with black lettering. Two convex mirrors, each 18 centimeters wide by 26 centimeters high (7.1 by 10.2 inches), and one banana mirror, 40 centimeter long by 18.5 centimeter high (15.7 by 7.3 inches), were present on each side of the case vehicle's front end. The case vehicle was towed due to disabling damage.

Figure 7: On-scene view of case vehicle and the Chevrolet in contact at final rest; Note: angle of case vehicle and position of its left rear tandem wheels on the Chevrolet's hood (case photo #14)

The interior of the case vehicle had a box mounted, front bucket seat for the driver, with a non-adjustable seat back and no head restraint. A manual, three-point, lap-and-shoulder, safety belt system was provided for the driver and was the only restraint system available in the case vehicle. No shoulder belt upper anchorage adjustor was present for the driver's belt. The case vehicle was not equipped with a supplemental restraint system (air bag).

The passenger portion of the case vehicle's occupant compartment consisted of 11 rows of cushioned bench seats (**Figure 8**), with the last left side seat being a shortened seat (i.e., only two positions). Each bench seat, except the shortened seat, was 99 centimeters (39.0 inches) wide and 38 centimeters (15.0 inches) deep, with the seat cushion's bottom 36 centimeters (14.2 inches) off the floor. The shortened seat was 66 centimeters (26.0 inches) wide, with the rest of the measurements the same as the other seats. Seat backs were 99 centimeters (39.0 inches) high, measured from the floor to the cushion's top. The distance from the seat backs to the back of the seat immediately ahead of it ranged from 67 to 69 centimeters (26.4 to 27.2 inches) for right side seats, and from 60 to 71 centimeters (23.6 to 28.0 inches) for left side seats; row 3 (left) had the 60 centimeter distance and row 6 (left), the left-side emergency exit door location, had the 71 centimeter distance. Interior width of the passenger compartment was 230 centimeters (90.6 inches), window sill to window sill. The center aisle was 34 centimeters (13.4 inches) wide at seat cushion height and 56 centimeters (22.0 inches) wide at the top of the seat backs. For the side windows, the window sills measured 82 centimeters (32.3 inches) from the floor, while the top of the side windows were 150 centimeters (59.1 inches) from the floor. The window sills were 35 centimeters (13.8 inches) from the top of the seat cushions. Each seat cushion was approximately 8 centimeters (3.1 inches) thick.

Figure 8: Case vehicle's interior seating area showing 65 passenger seating positions (case photo #45)

The left side of the case vehicle was impacted by the front and hood top of the Chevrolet, in an underride configuration. Beginning 208 centimeters (81.9 inches) rearward of the left front axle, the damage extended rearwards 507 centimeters (199.6 inches) to the left rear axle (**Figure 4** above). Underride contact by the Chevrolet reached the case vehicle's left frame rail and the drive shaft after impacting the bottom of the left side panel. Left frame rail contact was measured 81 centimeters (31.9 inches) inward from the case vehicle's left side panel, while the drive shaft contact measured 122 centimeters (48.0 inches) inward (**Figure 9**). The case vehicle's drive shaft was separated at the rearmost universal connection, just forward of the differential, and the left rear tandem wheels were pushed rearward an estimated 16 centimeters (6.3 inches). The case vehicle is neither CDC nor TDC applicable. Other than the foregoing damage descriptions, crash severity estimates for medium and large trucks and buses (which includes the case vehicle) are currently undefined. In addition, there was no evidence of intrusion to the case vehicle. The case vehicle was towed due to disabling damage.

Figure 9: Contacts to case vehicle's left frame rail and drive train; Note: the positioning of the left rear tandem wheels (case photo #20)

There was no evidence that the case vehicle's driver contacted any interior surface. In addition, no contacts were noted on the left interior side surface, glazing, or left side seats of the case vehicle. However, for the case vehicle's right side, the lower half of row 11's window glazing was disintegrated from occupant contact (**Figure 10**). Also, a small trace of blood was present around and slightly forward of a rivet to the bottom rear of the row 11's damaged right side window. A possible contact smudge on the center of that window's upper glazing was also noted. Immediately below that window on the side panel was a possible skin transfer, and rearward of the window were possible black contact smudges. Row 11's right side seat back, at the lower seam with the seat cushion, was bent rearward, and the bottom right corner of the back of row 10's right seat was pushed forward. There were also possible occupant contact points to row 8's right side panel below the window sill and to the back of row 7's right seat. Possible occupant contacts were found on the back of row 4's right seat, and a contact was found on the lower window glazing slightly forward of row 5's right side seat back. Possible contacts were noted to the roof panel over row 4's right seat and a small scrape on the back of row 3's right seat. There was a possible contact to the back of row 2's right seat

Figure 10: Case vehicle's rearmost window on the right side; Note: disintegrated window glazing and blood stains (yellow tape) on the interior side panel (case photo #56)

The case vehicle was not equipped with a supplemental restraint system (air bags). As well, there were no knee bolsters on the lower side of the instrument panel.

CASE VEHICLE DRIVER KINEMATICS

The case vehicle's driver [29-year-old, White (Non-Hispanic) male; 188 centimeters and 147 kilograms (74 inches, 325 pounds)] was restrained by his available, active, three-point, lap-and-shoulder, safety belt system. Although there was no evidence of belt pattern bruising and/or abrasions to the driver's body, inspection of the driver's seat belt webbing, "D"-ring, and latch plate showed evidence of fabric waffling and stitching pulls at the ends of the lap-and-shoulder, safety belt system, near the male connector.

Immediately prior to the crash, the case vehicle's driver was seated upright with his back against the seat back, his left foot on the floor, his right foot on the accelerator, and both hands on the steering wheel. His seat track was located in its rearmost position, and the seat back was not adjustable. The case vehicle was not equipped with a tilt steering wheel.

The case vehicle's driver first accelerated and steered left, trying to complete the left-hand turn. Second, he steered right onto the roadside, trying to get the bus as far right (east) as possible in an attempt to avoid the crash. As a result of these attempted avoidance maneuvers and the use of his available safety belt, he most likely moved slightly to the right, then slightly to the left, just prior to impact. The case vehicle's impact with the Chevrolet thrust the driver slightly leftward and forward. As the case vehicle continued forward on the right roadside and slightly onto the side of a drainage ditch, its left rear tandem tires climbed on top of the Chevrolet's hood at final rest. The combination of the case vehicle's left rear tandem tires atop the Chevrolet's hood and its right side tires on the downward side of a drainage ditch, the case vehicle was tipped to its right, with its left rear higher than its right side. This tipping caused the case vehicle's driver to load his safety belt system prior to rebound back into his seat. At final rest the case vehicle's driver was in the driver's seat.

CASE VEHICLE DRIVER INJURIES

The case vehicle's driver was uninjured, but he was transported to a medical facility in another school corporation bus for a precautionary medical examination and blood test. The blood test was negative for alcohol and drugs, and he was released after the precautionary examination.

CASE VEHICLE PASSENGER KINEMATICS

According to the Police Crash Report and the school corporation, there were 36 students in addition to the driver and the one adult monitor riding in the case vehicle. Seat positions for both the injured and uninjured student passengers are shown in the **SCHOOL BUS OCCUPANT SEATING DIAGRAM** below. In conflict with the Police Crash Report and seat assignments from the school corporation, the on-board video camera's tape yields only 35 students on the school bus, not the reported 36. The area in question is Seat-Left-9, where the seat chart indicates two males were

seated but the video tape shows only one male student in that seat. Additionally, prior to impact, there were four seat positions with less than 100 percent video coverage. They are:

- ¶ Seat-Right-1, occupied by two males–only the top of the aisle occupant's head was visible;
- ¶ Seat-Left-1, occupied by the 34-year-old female monitor–top of head and forehead was visible twice prior to impact;
- ¶ Seat-Left-2, occupied by a male and female–the female at the window position was unseen until after impact; and
- ¶ Seat-Left-3, occupied by two males–the window student was seen twice before impact.

At the time of the crash, 20 students were evaluated as being "out-of-position" (i.e., their backs were not against and squared to the seat back and their feet were not extended towards the front of the bus). The four students and the adult monitor previously mentioned as not being visible to the camera obviously could not be evaluated for proper seating posture. The following is a list of those "out-of-position" occupants immediately prior to impact (R=right, L=left, 1-11=row numbers, a=aisle, m=middle, w=window):

R-2-a: bent over at a 45 degree angle picking something off the floor, looking up with right shoulder against the forward seat back at impact

R-4-a: upper torso leaning into aisle at impact

L-4-a: first student to see the approaching Chevrolet, being pushed laterally towards aisle by seat mate at the window position

L-4-w: warned by seat mate at aisle position of the approaching Chevrolet, began leaning laterally towards aisle and away from location of impending impact

R-5-a: leaning towards aisle while talking with middle seat mate

L-5-a: third student to see approaching The Chevrolet, stuck right leg into aisle as a brace against the impact and began turning torso in a clockwise motion towards the aisle

R-6-w: seat chart indicated this occupant in middle seat position but video indicates occupant reclined against bus right side panel with feet towards the aisle

L-6-a: student rotated approximately 45 degrees counterclockwise talking to seat mate next to window and occupants in Left-7 seat

L-6-w: student rotated clockwise (back to bus's left side panel) talking to seat mate on aisle and occupants in Left-7 seat

L-7-a: student sitting rotated clockwise 90 degrees with feet in aisle

L-7-w: student leaning forward against seat back with her arms draped over the top of the seat back

R-8-w: student rotated counterclockwise approximately 45 degrees and watching older students in rear seats

R-8-a: student began to stand and rotated counterclockwise, may have heard occupants in front screaming

L-8-w: seat chart indicated this occupant in middle seat position but video indicates occupant reclined against bus left side panel with feet towards the aisle

R-9-w: student reclined against bus right side panel with feet towards the aisle

L-9-w: student reclined against bus left side panel with feet towards the aisle

R-10-a: seat chart indicated this occupant in window seat position but video indicates occupant rotated approximately 45 degrees counterclockwise at aisle end of seat

L-10-w: student reclined against bus left side panel with feet towards the aisle
R-11-a: seat chart indicated this occupant in window seat position but video indicates occupant rotated approximately 45 degrees counterclockwise at aisle end of seat
L-11-w: student sitting at a 45 degree (clockwise) angle, with his right shoulder against the seat back and his left shoulder against the left side panel of the bus. According to this occupant's returned questionnaire, he was seated upright, facing forward, with his feet on the floor, one hand in his lap (most likely left), and one hand (most likely right) on the back of the seat's cushion.

All of the remaining 11 passengers [i.e., (35 - 20 - 4)] had a "normal" pre-crash posture.

The case vehicle's driver first accelerated and steered left, trying to complete the left-hand turn. Second, he steered right onto the roadside, trying to get the bus as far right (east) as possible in an attempt to avoid the crash. As a result of these attempted avoidance maneuvers, and independent of the unavailability of any safety belts, occupant kinematic principles indicate that the 36 passengers most likely moved slightly to the right, then slightly to the left, just prior to impact. The case vehicle's impact with the Chevrolet thrust the passengers slightly leftward and forward. As the case vehicle continued forward onto the right roadside and slightly onto the side of a drainage ditch, its left rear tandem tires climbed on top of the Chevrolet's hood and came to rest. The combination of the case vehicle's left rear tandem tires atop the Chevrolet's hood and its right side tires on the downward side of the drainage ditch (**Figure 7** above), caused the case vehicle to tip to its right, with its left rear higher than its right side. This tipping caused the case vehicle's passengers to be thrown left-to-right.

Based on the tape from the on-board video camera, there were three forces that acted upon the school bus occupants. First, during the left turn maneuver the school bus encountered an uneven road surface; second, the left side of the school bus was contacted by the Chevrolet; and third, the left rear dual wheels of the school bus climbed atop the Chevrolet's hood. Unfortunately, the video camera was shaken by the vehicle-to-vehicle impact and a little more than one second of occupant kinematic movement was unclear.

Based on the video tape, as the school bus began its left turn and the pavement changed from concrete to asphalt, there was a slight elevation lip (low-to-high, west-to-east) between the two surfaces. This elevation lip was sufficient to create a bump and, as the left and right rear dual wheels alternately crossed that lip, the movement caused the bus passengers to sway left-right-left-right. Less than two seconds later, the Chevrolet struck the left side of the school bus. This impact caused all school bus occupants to move slightly forward and to their left. The most violent force acting on the bus occupants, however, was the left-to-right movement caused by the left rear dual wheels of the school bus climbing atop the Chevrolet's hood and severely canting the back plane of the school bus. The left rear dual wheels were sitting on the Chevrolet's hood and the right rear dual wheels were off the pavement edge, resting on the down slope of the roadway's east drainage ditch. Although unmeasured, the height of the school bus's back plane was sufficient for all bus occupants, including the 34-year-old female school bus monitor, to completely disappear from the camera's view when jumping from the floor of the bus to the pavement. It should be noted that all bus occupants but the student in seat **R-5-w**, including the

adult monitor and the driver, were ambulatory. The **R-5-w** occupant seemed to be the only student crying and two passengers, one older male and one older female, helped this occupant to her feet and she hopped to the end of the bus (i.e., it appeared as if a leg or foot had been injured). No other occupant required any assistance to exit the school bus post-crash. With the crash occurring at time 07:05:29 (video camera time), the last student to exit the school bus did so at 07:07:53 (144 seconds or 2 minutes, 24 seconds post-crash). The adult monitor exited the bus at 07:08:00, and the driver was still in the bus when the video tape in possession of this contractor ended at 07:08:03.

Compartmentalization of school bus occupants during the initial impact was successful for those students "properly" seated (i.e., with their backs against the seat backs and their feet pointed towards the front part of the bus). For those students visible in the video, the following presents the observed occupant kinematics as a result of the initial impact to the left side of the school bus.

R-2-w: properly seated, moved slightly forward and left, no visible contact injury
R-2-a: out-of-position, moved slightly forward and left, right side of face and right shoulder contacted **R-1's** seat back
L-2-a: properly seated, moved slightly forward and left, no visible contact injury
R-3-w: properly seated, moved slightly forward and left, no visible contact injury
R-3-a: properly seated, moved forward and left, may have struck right side of face on **R-2's** seat back
L-3-a: properly seated, moved slightly forward and left, no visible contact injury
R-4-w: properly seated, moved slightly forward and left, no visible contact injury
R-4-a: out-of-position, moved forward and slightly left, contacted **R-3's** aisle end of the seat back with her right torso and rotated onto the seat back's end as she slid to the floor
L-4-a: out-of-position, moved forward but left movement hindered by seat mate leaning into her, slid down to floor, unknown if contacted **L-3's** seat back
L-4-w: out-of-position, moved slightly forward and left, likely contacted the left side panel and, perhaps, the window glazing
R-5-w: properly seated, movement obscured by shaking camera and other occupants, unknown if contacted anything (crying after bus came to final rest and only occupant to require any assistance in exiting the school bus)
R-5-m: properly seated, movement slightly forward and left, unknown if contacted anything
R-5-a: out-of-position, moved forward and left, slides to floor, unknown if contacted anything
L-5-a: out-of-position, moved slightly forward and left, unknown if contacted anything other than her seat mate
L-5-w: properly seated, moved slightly forward and left, seemed to contact the left side panel of the bus with her left side
R-6-w: out-of-position, slid along seat to the left while rotating 180 degrees, did not appear to contact anything
L-6-a: out-of-position, moved slightly forward and left, did not appear to contact anything
L-6-w: out-of-position, moved forward along left side panel, may have struck **L-5's** seat back with her left shoulder
R-7-w: properly seated, moved slightly forward and to the left and upwards, did not appear to contact anything

R-7-a: properly seated, moved forward and to the left, both arms flailed and almost slid off seat into aisle but did not appear to contact anything
L-7-a: out-of-position, moved slightly forward but mostly left with back leading, may have contacted seat mate with his back
L-7-w: out-of-position, rotated slightly clockwise with head moving downward, left side likely contacted the left side panel and the torso contacted **L-6's** seat back
R-8-w: out-of-position, moved slightly forward and to the left and upwards (higher than **R-7-w** occupant), did not appear to contact anything
R-8-a: out-of-position, moved slightly forward and left, did not appear to contact anything
L-8-a: out-of-position, moved slightly forward but mostly left, torso disappeared and then reappeared as though occupant had lain across the seat, unknown if contacted anything
R-9-w: out-of-position, torso bent slightly forward and to the left, did not appear to contact anything
L-9-w: out-of-position, moved forward and left while rotating nearly 90 degrees counterclockwise and rising upwards, torso may have contacted **L-8's** seat back
R-10-a: out-of-position, movement and possible contacts obscured by shaking camera and other bus occupants
L-10-w: out-of-position, movement and possible contacts obscured by shaking camera and **L-9-w** occupant
R-11-a: out-of-position, movement and possible contacts obscured by shaking camera and other bus occupants
L-11-w: out-of-position, movement and possible contacts obscured by shaking camera and other bus occupants

As stated previously, the most violent force acting upon the school bus occupants was the tipping of the bus body when the left rear dual wheels climbed atop the Chevrolet's hood. All bus occupants moved left to right, with the left side of the passenger compartment high and the right side low. The following presents the observed occupant kinematics as a result of the school bus tipping rightward as its left side dual tires came to rest on the hood of the Chevrolet.

Driver: not visible, movement not evaluated
R-1-w: not visible, movement not evaluated
R-1-a: not visible, movement not evaluated
L-1-m: not visible, movement not evaluated
R-2-w: her rump and thighs likely contacted the right side panel of the bus
R-2-a: moved little as seat mate (**R-2-w**) laid across her back, her only contact
L-2-a: slid right across seat and stood up in aisle, contacting nothing but being slightly contacted by his seat mate (**L-2-w**)
L-2-w: slid right across seat and her right side made slight contact with her seat mate's (**L-2-a**) left side
R-3-w: moved right, with right shoulder and hip contacting the right side panel and his left side contacted by his seat mate's (**R-3-a**) back side
R-3-a: rebounding away from the **R-2** seat back, he rotated approximately 75 degrees counterclockwise and contacted his seat mate's (**R-3-w**) left side with his back side

L-3-a: from a 45-degree forward and left position, he straightened to his original seated position and stayed there, contacting nothing

L-3-w: unknown movement, does not appear in video until occupants begin to exit bus

R-4-w: rebounded laterally left across seat and behind seat mate (**R-4-a**) with her left side leading, the back side and backpack of occupant **L-4-a** contacts this occupant's left shoulder and face

R-4-a: with the seat back end (**R-3**) touching her torso and her left arm on the forward portion of that seat back, this occupant slid rightward behind the R-3 seat back and in front of her seat mate (**R-4-w**), with **R-4-w's** right arm slowing **R-4-a's** rightward slid, the left side of this occupant's head was contacted by **L-4-a's** backpack

L-4-a: holding on with her right arm and hand extended to the **L-3** seat back, this occupant's left side was contacted by her seat mate's (**L-4-w**) right side and pushed off the seat into the aisle and on into seat **R-4**, while rotating counterclockwise and contacting both seat **R-4** students with her back side and backpack, actually pushing both **R-4** occupants to the right

L-4-w: rebounded from first impact to begin sliding across the seat cushion left-to-right with her right side pushing her seat mate's (**L-4-a**) left side, both students slid off their seat, with this occupant sliding to the aisle floor onto her knees, contacting no one else

R-5-w: lifted to almost a standing position with right side against the right side panel, rebounded down into seat and her left side was contacted by seat mate **R-5-m** and pushed into the right side panel (this is the only occupant seen to be crying and needed some assistance by two older students to exit the bus)

R-5-m: rebounded from first impact (bent forward and left) along back side of **R-4's** seat back, almost falling to floor, slid right into seat mate **R-5-w**, unknown if contacted by seat mate **R-5-a**, but was contacted by student from seat position **L-5-a**

R-5-a: fell to floor during first impact, seen standing up in front of Occupant **L-5-a** who had come across the aisle and contacted her seat mate **R-5-m**, unknown if contacted anything or anyone

L-5-a: intentionally turns 90 degrees clockwise and is projected across the aisle into seat **R-5** and contacts occupant **R-5-m**, unknown if stepped on occupant **R-5-a**

L-5-w: begins sliding across seat cushion from left-to-right and rotating almost 90 degrees clockwise, slides off seat end and lands in aisle, did not seem to contact anyone or anything

R-6-w: rebounded away from right side panel of bus, rotated almost 180 degrees clockwise onto back and slid laterally across seat cushion, right-to-left, and extended head and trunk into aisle, unknown if contacted anything or anyone

L-6-a: began to slid left-to-right, grabbed the top of **L-5** seat back which swung this occupant counterclockwise, off the seat end, and onto the floor, unknown if she contacted anyone or anything

L-6-w: had back to left side panel and facing right, bent slightly at the waist but moved little, contacted nothing

R-7-w: may have moved upward but did not seem to contact anything or anyone

R-7-a: wrapped left arm around **R-6's** seat back end, did not seem to contact anyone or anything

L-7-a: already facing right with feet in aisle, occupant projected out of seat, across aisle, and into seat **R-7**, other occupants obscure possible contacts by this student

L-7-w: as occupant had chest against **L-6's** seat back and her arms draped over the seat back's top, she experienced little movement

R-8-w: as back was already against the right side panel, occupant seemed to stand up, then sit down, and seat mate (**R-8-a**) may have contacted this occupant's left side

R-8-a: slid across seat cushion left-to-right on right side and head may have contacted seat mate's (**R-8-w**) left side

L-8-a: occupant was facing aisle with feet off the seat end and leaned back towards the left side panel and slid enough rightwards to lay his back on the seat cushion, unknown if he contacted anything, did not seem like he contacted anyone

R-9-w: as occupant already had back against the right side panel, his movement was little more than a rocking motion, his left side was contacted by **L-9-w's** right side

L-9-w: occupant had back against left side panel and was projected across the aisle while he rotated approximately 90 degrees counterclockwise and contacted **R-9-w's** left side with his right side

R-10-a: occupant's movement and possible contacts are obscured by the shaking camera and other bus occupants

L-10-w: occupant had back against left side panel and was projected across the aisle, his possible contacts were obscured by the shaking camera and other bus occupants

Note: a backpack from seat **L-11** was projected left-to-right and struck the right side panel between the 10th and 11th windows at their frame tops and slid to the floor

R-11-a: occupant sitting sideways at his seat edge with his feet in the aisle and seemed to be projected nearly upright from left-to-right and struck the right side panel's 11th window at its upper pane with his right shoulder, the right side of his head may have contacted the right upper portion of the side panel near the roof, his lower left extremity may have been contacted by **L-11-w's** back

L-11-w: occupant sitting at a 45-degree angle and was projected across the aisle, rotating approximately 135 degrees counterclockwise and contacting **R-11-a's** lower left extremity with his back

CASE VEHICLE PASSENGER INJURIES

Six of the case vehicle's passengers were transported from the scene by ambulance to a local medical facility. Injured student passengers were located at row 1, right side, aisle seat (14-year-old male); row 2, left side, window seat (16-year-old female); row 5, left side, aisle seat (13-year-old female); row 6, left side, window seat (12-year-old female); row 11, left side, window seat (14-year-old male); and row 11, right side, window seat (16-year-old male). Heights and weights for five of the six injured bus passengers are unknown. They were all treated for "B" (non-incapacitating evident) injuries and released. One passenger [14-year-old, White (non-Hispanic) male; 165 centimeters and 86 kilograms (65 inches, 189 pounds)], who was seated at the left window in the eleventh row of the bus, sustained abrasions and contusions to his right abdomen (flank). The exact nature of the injuries sustained by the other five occupants is unknown; although, it was reported that the injuries to the other five occupants were similarly minor. The case vehicle's driver, a bus monitor [34-year-old, (unknown race or ethnic origin) female], and

the other 29 uninjured student passengers were transported from the scene in another school bus to a local medical facility for precautionary medical examinations. Based on the available information, no additional injuries were discovered.

CASE VEHICLE 11TH ROW–LEFT WINDOW PASSENGER INJURIES

Injury Number	Injury Description (including Aspect)	NASS Injury Code & AIS 90	Injury Source (Mechanism)	Source Confidence	Source of Injury Data
1	Abrasion right flank	590202.1 minor	Right side interior bus surface	Probable	Emergency room records
2	Contusion right flank	590402.1 minor	Right side interior bus surface	Probable	Emergency room records

OTHER VEHICLE

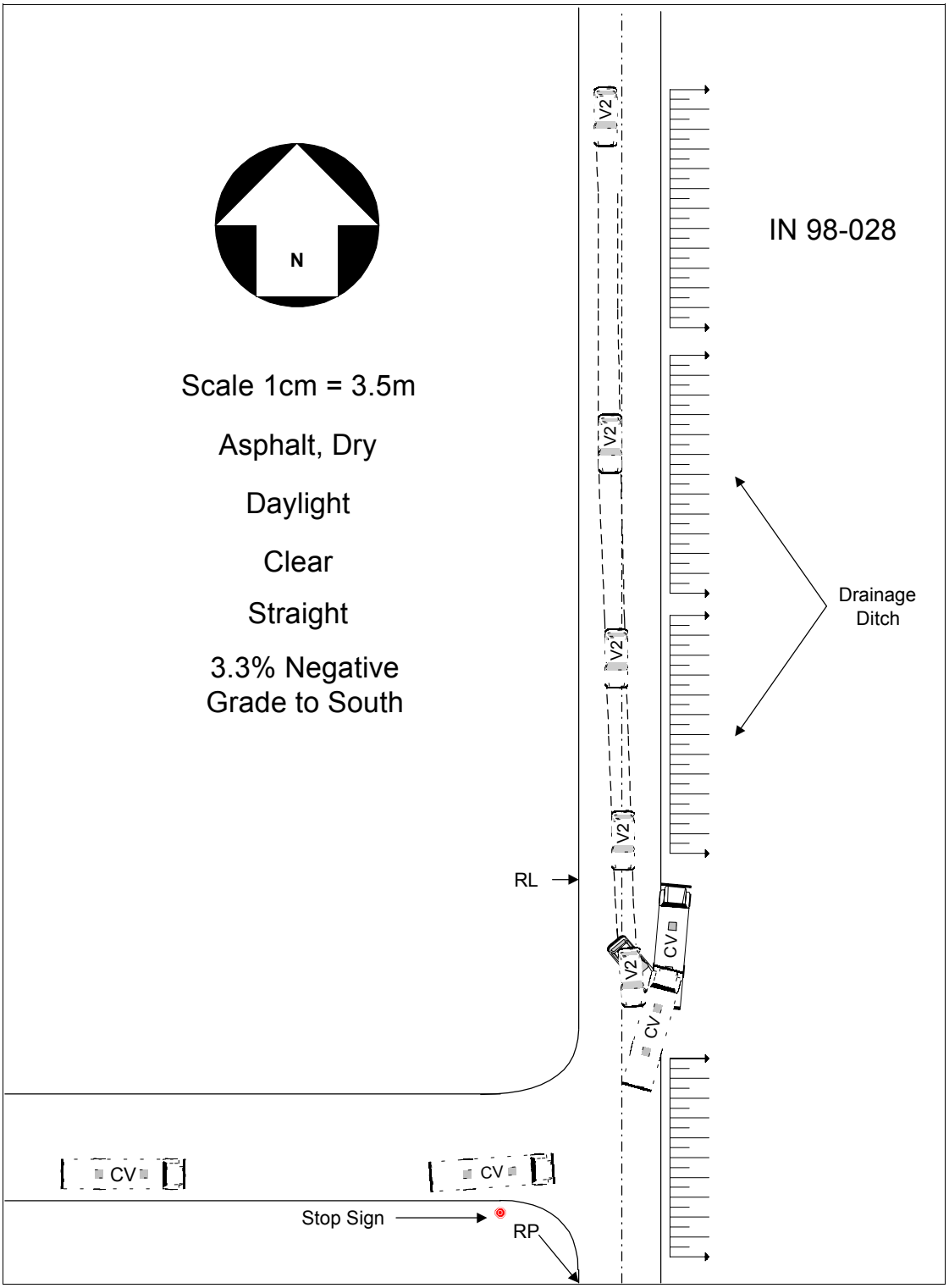
The 1991 Chevrolet Camaro RS was a rear wheel drive, four-passenger, two-door "T"-top, sport coupe (VIN: 1G1FP23T3ML------) equipped with a 3.1L, MFI, V-6 engine and a four-speed automatic transmission. The Chevrolet was not equipped with anti-lock brakes. The case vehicle's wheel base was 257centimeters (101.0 inches), and the odometer reading at inspection was 202,781 kilometers (126,002 miles). The Chevrolet was equipped with a driver supplemental restraint system (air bag) which deployed as a result of its frontal impact. The Chevrolet was towed due to disabling damage.

The front and hood top of the Chevrolet impacted and underrode the left side of the case vehicle. The front bumper, fascia, air dam, grille, and right and left headlamp assemblies; hood; right and left front turn signal assemblies; right and left fenders; windshield; front header; left "A"-pillar; left "T"-top glazing; and left "B"-pillar were all damaged (**Figures 5** and **6** above). The CDC for the Chevrolet was determined to be: **01-FDAW-7** [maximum crush was 44.5 centimeters (17.5 inches)]. The WinSMASH reconstruction program, barrier algorithm, was used on the Chevrolet's highest severity impact. The Total, Longitudinal, and Lateral Delta Vs are, respectively: 39.1 km.p.h. (24.3 m.p.h.), -33.9 km.p.h. (-21.1 m.p.h.), and -19.6 km.p.h. (-12.2 m.p.h.).

The Chevrolet's driver [29-year-old, White (unknown if Hispanic) female; unknown height and weight)] was wearing her available, active, three-point, lap-and-shoulder, safety belt system. The Chevrolet's driver air bag was located in the steering wheel hub and deployed due to crash forces. 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 air bag module was in a symmetrical "H" configuration. The driver's air bag was designed without any tethers and had two vent ports, approximately 2 centimeters (0.8 inches) in diameter, located at the 11 and 1 clock positions. The deployed

driver's air bag was round with a diameter of 50 centimeters (19.7 inches). There were several blood stains noted at the lower vertical midline and the upper right quadrant of the fabric.

The Chevrolet's driver sustained "A" (incapacitating) injuries, one of which was a laceration to the bridge of her nose. She was transported by ambulance to a local medical facility where she was reportedly treated and released.


N
IN 98-028
Scale 1cm = 3.5m
Asphalt, Dry
Daylight
Clear
Straight
3.3% Negative
Grade to South
Drainage
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V2
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V2
V2
V2
RL
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CV
CV
CV
Stop Sign
RP

IN 98-028

Legend:

w=window seat
m=middle seat
a=aisle seat
29y=29 years old
M/F=male/female
*=injured occupant
shaded seat=injured occupant's seat