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TRANSPORTATION SCIENCES
CRASH RESEARCH SECTION

CALSPAN SRL CORPORATION
BUFFALO, NEW YORK 14225

CALSPAN AIR BAG DEPLOYMENT INVESTIGATION

CALSPAN CASE NO. CA98-002

PASSENGER SIDE AIR BAG RELATED FATALITY

LOCATION - STATE OF PENNSYLVANIA

CRASH DATE - SEPTEMBER, 1997

Contract No. DTNH22-94-D-07058

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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 are 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 crash which involved a 1992 Lincoln Continental (Vehicle #1) equipped with dual front air bags occurred during the mid morning hours on a Sunday in the month of September, 1997. The 56 year old male driver was en route to religious services with his 88 year old mother seated in the front right seat and an 82 year old female relative seated in the rear right when he suffered a seizure. Vehicle #1 crossed the opposing travel lane and struck the front of an unoccupied parked 1995 Jeep Cherokee with its right front bumper corner. The Lincoln Continental mounted the adjacent curb, traveled across a grass area and struck several objects which included wrought iron hand railings, concrete stairs, a wood utility pole, and a parked 1995 Saturn. The Supplemental Restraint System (SRS) which was designed with a front left and front right air bags deployed during the impact with the utility pole. The delta V for the pole impact was computed by the SMASH damage algorithm as 28 km/h (17 mph) which was sufficient to initiate the deployment sequence.

The front right occupant was not wearing the manual three point lap and torso belt at the time of the crash. The lower air bag module cover opened in a downward rotation and contacted the upper portion of the front right occupant's neck. As the air bag continued to expand, it rotated her head counterclockwise and back in a hyper-extension movement. This resulted in a gaping laceration of the anterior neck, transection of the trachea (AIS-5), laceration of the neck strap muscles (AIS-2), the fracture dislocation of C1 with transection of the upper spinal cord (AIS-6), the transection of the brainstem (AIS-6), and brain hemorrhage. The air bag then contacted the chest which resulted in contusions of the right chest and fractures of the right 1-2, 4-7 anterior ribs. The occupant was propelled rearward by the expanding air bag where she contacted the seat back support. She came to final rest in a slumped upright position with her back against the seat back support and her legs in front of the seat cushion. She expired at the scene.

The unrestrained driver moved forward during crash sequence and was in contact with the front left driver air bag module cover and air bag during the deployment sequence. He suffered fractures of the right lower ribs (AIS-2), soft tissue abrasions and contusions of the abdominal area, and redness of the sternum area. He was treated and released. The unrestrained rear right occupant sustained contusions in the crash and later suffered a stroke. She expired 3 months later.

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BACKGROUND

The Field Operations Branch (FOB), Crash Investigation Division (CID) of the National Highway Traffic Safety Administration (NHTSA) was notified by a County Coroner's Office from the State of Pennsylvania that a 1992 Lincoln Continental (Vehicle #1) equipped with dual front air bags was involved in a crash where the front right passenger sustained fatal injuries. The Calspan Team was subsequently directed by the FOB to conduct an on-site investigation which began four days later.

SUMMARY

This crash which involved a 1992 Lincoln Continental (Vehicle #1) equipped with dual front air bags occurred during the mid morning hours on a Sunday in the month of September, 1997. The 56 year old male driver was en route to religious services with his 88 year old mother seated in the front right seat and an 82 year old female relative who was seated in the rear right when the driver experienced a seizure and lost control of the vehicle. The vehicle departed the left side of the roadway striking several objects before impacting a utility pole which resulted in the deployment of the dual front air bag system. The unrestrained front seat occupants moved forward and were in contact with the air bag components at the time of deployment. The front right occupant sustained fatal injuries and was pronounced deceased at the scene.

Prior to the crash, Vehicle #1 traveled through a 90 degree left curve and was heading west in a posted speed limit zone of 40 km/h (25 mph). The vehicle traveled approximately 152 m (500') from the curve on a two lane undivided, positive 3.5 percent slope, straight, dry asphalt roadway when it crossed the opposing travel lane and struck the front of an unoccupied 1995 Jeep Cherokee with its right front bumper corner **(Figure 1)**. The Jeep which was parked on the south side of the roadway adjacent to a 10.2 cm

Figure 1 On-scene view of the Lincoln Continental's trajectory prior to impact with the first parked vehicle

Figure 2 View of the Jeep at the final rest position and the Lincoln's continued trajectory onto the adjacent sidewalk

(4.0") barrier curb was pushed rearward 2.4 m (8.0') where it came to the final rest position (FRP) rotated in a counterclockwise direction with the front end angled slightly into the eastbound travel lane **(Figure 2)**.The Lincoln Continental mounted the adjacent south curb, traveled across a 0.9 m (3.0') wide grass area and a 1.8 m (6.0') wide concrete sidewalk before traversing a 38.1 cm (15.0") vertical rise grass lawn **(Figure 3)**. It struck a wrought iron hand railing which was attached to a two step concrete stairway with the left front bumper corner. As the vehicle continued, the left front tire impacted the top step resulting in deformation of the wheel.

Figure 3 Trajectory of the Lincoln which traversed the side walk and continued along the lawn area

Figure 4 View of the Lincoln's trajectory as it returned toward the roadway edge

Vehicle #1 continued across the lawn of a second residence and impacted another wrought iron fence with the frontal plane. It then raked across a second concrete stairway with the engine oil pan and the right front tire. The vehicle's trajectory arced back toward the roadway **(Figure 4)** where on-scene police photographs indicated the left front tire produced an acceleration tire mark in the lawn. Vehicle #1 struck a 23.2 cm (9.2") diameter wood utility pole with the center frontal plane **(Figure 5)** which initiated the deployment sequence of the supplemental restraint system (SRS). The vehicle then rotated in a counterclockwise direction and rebounded 1.2 m (4.0') to the FRP. During the rebound trajectory, it sideswiped the right side of a 1995 Saturn SL which was parked in the road

Figure 5 View of the Lincoln at the final rest position

Figure 6 View of the damage along the right side plane of the Saturn which was parked in the vicinity of the Lincoln's impact with the pole

adjacent to the south curb edge **(Figure 6)**. Vehicle #1 came to the FRP heading in a westerly direction with the right side tires on the roadway surface and the left tires on the sidewalk.

During the impact with the pole, the unrestrained driver moved forward and was in contact with the front left air bag module cover during the air bag expansion sequence. This was noted by the 33.0 cm (13.0") long tear in the bottom rear surface of the air bag which resulted from the air bag being restricted in its normal deployment path and the displacement of the steering column shear plate from the shear capsules. He suffered contusions and abrasions of the abdomen, multiple right lower anterior rib fractures, and redness and pain over the lower sternum which were attributed to contact with the driver side air bag module cover, air bag, and the steering wheel rim. According to medical records, the driver had a controlled seizure disorder and that he may have experienced an episode which lead to the crash events. He was taking Dilantin prior to the crash to control the disorder.

The front right occupant was not using the manual three point lap and torso belt at the time of the crash. She had moved forward during the crash events and was in close proximity to the front right air bag module cover at the time of the air bag expansion sequence. As the air bag expanded, the lower air bag module cover opened in a downward rotation and contacted the upper portion of the front right occupant's neck as noted by a rectangular abrasion pattern which was located just below the chin.

The leading edge of the expanding air bag then contacted the right side of her chin which resulted in a serpentine type laceration pattern (described by the medical examiner as a typical boxer's punch type injury). As the air bag continued to expand, the passenger's head was hyperextended and rotated counterclockwise which resulted in a gaping laceration of the anterior neck, transection of the trachea, shearing of the neck strap muscles, the separation of the skull from C1, the transection of the base of the brain, transection of the spinal cord, and brain hemorrhage. The air bag then contacted the chest which resulted in contusions of the right chest and fractures of the right 1-2, 4-7 anterior ribs.

The front right occupant was propelled rearward and struck the front right seat back support with the her head and upper torso resulting in a fracture of the left 1-2 posterior ribs. She came to final rest in the front right seat with her head bent forward and against the front right door surface and her feet in front of the seat cushion. She was pronounced deceased at the scene by the coroner.

The rear right occupant was not using the restraint belt and moved forward during the crash sequence and contacted the rear surface of the front right seat back support and was found on her knees on the floor behind the front seats at final rest with her head facing the left rear door. She was removed by rescue and transported via ambulance to a nearby medical treatment facility where she was admitted after she suffered a stroke subsequent to the crash.

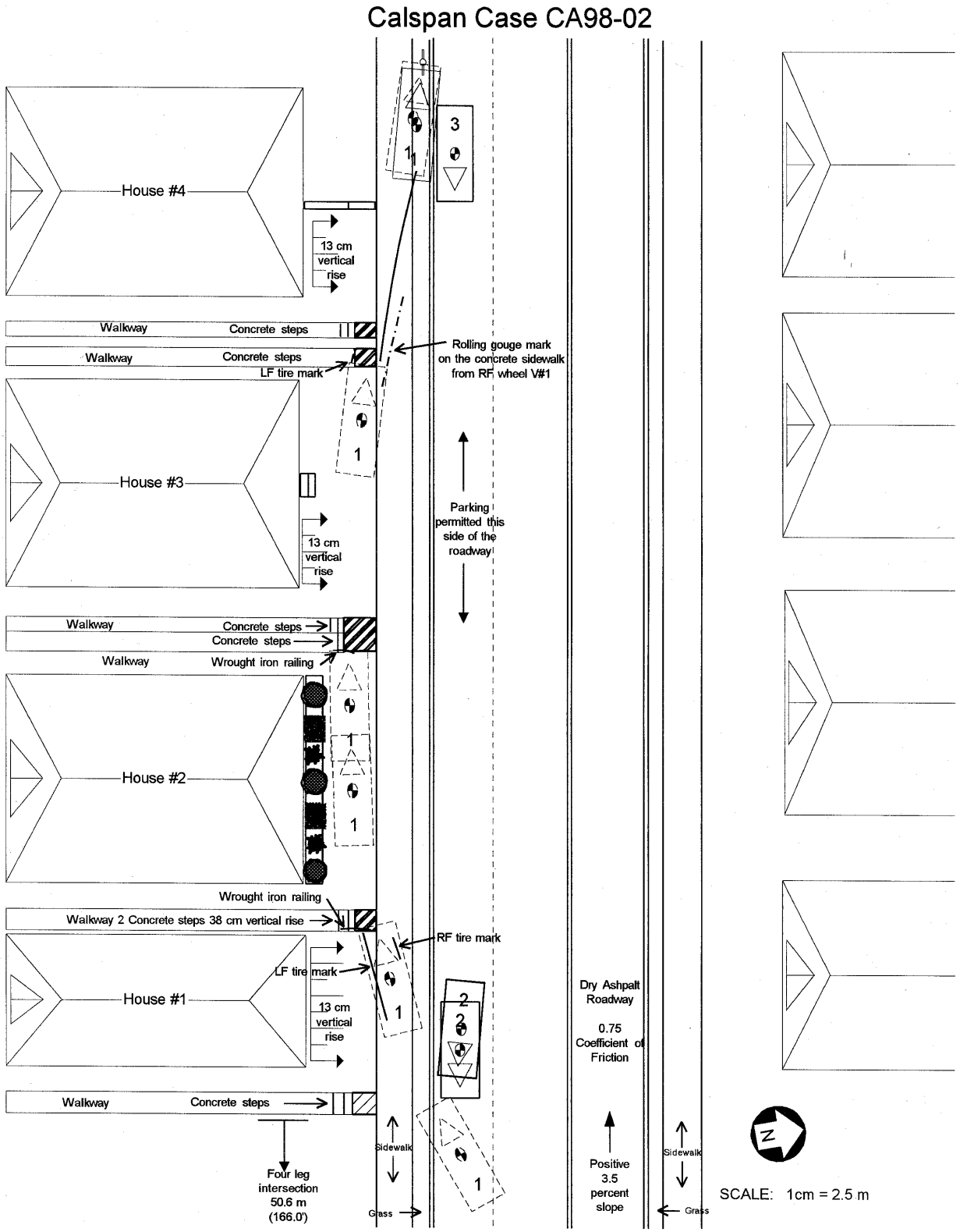

Figure 7. Scaled scene schematic

VEHICLE DATA

Exterior Damage

The 1992 Lincoln Continental was equipped with a dual front Supplemental Restraint System (SRS) which deployed as the result of the impact with the utility pole. The vehicle identification number was: 1LNLM9741NY (production number omitted). Exterior damage to the vehicle involved the front bumper, the grille, the hood, both front fenders, both front wheels, the right front and rear door surfaces, the right rear fender, and the rear axle. The crush profile along the frontal plane that resulted from the impact with the utility pole is listed in the following table:

Vehicle #1 Crush			
Impact with wooden utility pole	C_1 = 0	C_2 = 15.2cm (6.0")	C_3 = 43.2 cm (17.0")
	C_4 = 30.5 cm (12.0")	C_5 = 7.6 cm (3.0")	C_6 = 0

CDC

The vehicle impacted nine objects with the highest delta V impact occurring at the utility pole **(refer to Figures 8&9)** which resulted in a maximum crush of 50.2 cm (19.75"). The crash sequence and the related Collision Deformation Classifications (CDC) are shown in the following table:

Impact Sequence	Object Contacted	Plane of Contact	CDC
#1	1995 Jeep Cherokee (Vehicle #2-parked)	Right Frontal	12-FREE-8
#2	Wrought iron railing	Left Frontal	12-FLEE-1
#3	Wrought iron railing	Frontal	12-FZEW-1
#4	Concrete stairs	Right Front Tire	12-FRWN-3
#5	Concrete stairs	Oil Pan	00-UFCN-2
#6	Concrete stairs	Left Front Tire	12-FLWN-3
#7	Wrought iron railing	Undercarriage Rear Axle	12-FCLW-9
#8	Wood utility pole	Center Frontal	12-FCEN-2
#9	1995 Saturn SL (Vehicle #3-parked)	Right Rear Side	06-RZMS-1

Figure 8 Left front corner view of the Lincoln

Figure 9 Right front corner view

Interior Damage

Interior vehicle damage was attributed to occupant contacts and the deployment of the Supplemental Restraint System (SRS). The lower passenger side air bag module cover flap exhibited an adhesive rectangular area which was attributed to some artifact attached to the surface which may have been dislodged during the crash. The adhesive artifact measured 15.9 x 31.8 mm (0.675" x 1.25") and was located 16.5 cm (6.5") right of the left flap edge.

The passenger side air bag exhibited tissue transfers near the center of the front surface which were attributed to contact with the front right occupant during the deployment cycle. There was a faint yellow/tan transfer along the bottom front surface of the air bag which was attributed to occupant contact. A dark transfer on the right side panel of the air bag was also attributed to occupant contact. A bodily fluid artifact was present on the lower right front panel of the air bag which was associated with the front right occupant's final rest position.

A tissue transfer was noted on the bottom surface of the right sunvisor near the leading edge which was attributed to contact by the front right passenger following the expansion of the passenger side air bag. The front right seat back support had a small area of tissue transfer which was attributed to contact by the front right occupant's head during her rebound trajectory. The right side of the seat cushion and adjacent right sill carpet between the seat and the right front door exhibited bodily fluids which were indicative of the front right occupant's final rest position. A light residue transfer mark was noted along the vertical surface of the instrument panel located 13.3 cm right of the vehicle centerline which was attributed to the passenger side air bag generant residue.

The driver side air bag sustained a 33.0 cm (13.0") lateral tear of the nylon fabric which was located across the lower quadrant along the instrument panel side of the air bag. The tear was the result of loading by the driver against the air bag module cover during the SRS actuation sequence. There was a blue striated pattern on the surface of the air bag below the tear which was attributed to contact with the underside of the air bag module cover. The lower flap traveled beyond the leading edge of the steering rim and became lodged along the instrument panel side of the rim. The steering column shear plate was displaced 6.0 cm (2.4") at the left shear capsule and 4.5 cm (1.75") at the right shear capsule **(Figure 10)**.

The parking brake pedal was deformed laterally by the Driver's left lower leg. There was a scuff mark along the left edge of the lower instrument panel which was attributed to contact by the his left knee.

The rearview mirror was detached from its windshield attachment point by the deploying passenger side air bag and contacted the left side of the windshield 15.9 cm (6.25") left of the vehicle centerline and 19.7 cm (7.75") below the windshield header. This contact resulted in a fracture pattern of the windshield which had a focal origin with an overlaying vinyl transfer from the vinyl mirror housing.

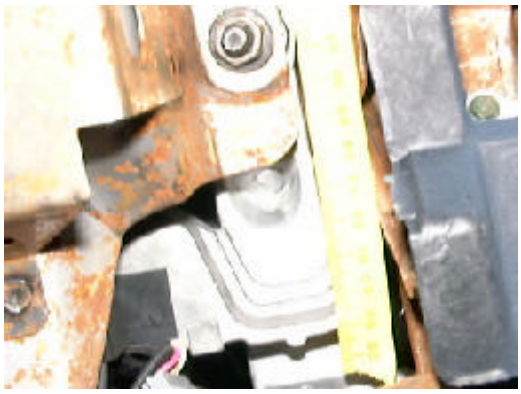

Figure 10 View of the shear capsule displacement

The left rear seat area had multiple areas of fluid deposits which were attributed to the rear right occupant. There was no contact evidence visible to the rear of the front right seat back support from loading by the rear right occupant.

SUPPLEMENTAL RESTRAINT SYSTEM (SRS)

The Supplemental Restraint System (SRS) was designed with a front left driver and a front right passenger air bag system which deployed during the impact with the utility pole. The impact with the utility pole resulted in a SMASH computed delta V of 28 km/h (17 mph) which was sufficient to initiate the deployment sequence.

Front Left Driver Air Bag

The front left driver side air bag had four tethers and two vent ports which measured 2.2 cm (0.875") in diameter. The module cover was a rectangular design which opened in the prescribed asymmetrical pattern **(Figure 11)** where the upper flap measured 12.7 cm (5.0") vertically and the lower flap was 4.4 cm (1.75"). There were no apparent occupant contact points on the cover surface.

Figure 11 View of the front left air bag module cover flap and air bag

The air bag was designed with four tethers which were attached to the front surface and formed a square stitched pattern which measured 17.8 cm (7.0") across. The diameter of the air bag measured 69.9 cm (27.5"). There were two vent ports located in the top rear surface which measured 22.2 mm (0.875") in diameter and were separated by a distance of 18.4 cm (7.25").

A lateral tear along the bottom rear surface of the air bag was attributed to driver loading against the air bag module cover during air bag expansion sequence **(Figure 12)**. The blue transfer mark was noted adjacent to the bottom portion of the tear which was attributed to contact with the inside surface of

the module cover flaps. The rip and transfer were oriented laterally across the air bag and measured 33.0 cm (13.0") in length. There were no visible driver contact evidence on the air bag.

Figure 12 View of the rip in the bottom rear surface of the front left air bag

Front Right Passenger Air Bag

The front right passenger air bag module was a mid mount design which incorporated a top horizontal flap and a bottom vertical flap **(Figure 13)**. The top flap measured 7.9 cm (3.125") longitudinally for the upper flap and 33.3 cm (13.125") laterally along the common separation seam. The vertical measurement for the bottom flap was of 9.5 cm (3.75"). There was no visible occupant contact evidence on either cover flap.

The air bag was nontethered and did not have any visible vent ports. The air bag material was a white course nylon which had a small square weave pattern. The longitudinal excursion of the air bag measured 61.0 cm (24.0") from the air bag module cover toward the seat back rest **(Figure 14)**. The seat back rest measured 72.4 cm (28.5") from the air bag module cover at a height of 43.2 cm (17.0") above the junction of the seat cushion. The lateral dimension of the air bag measured 68.6 cm (27.0").

Figure 13 Angular view of the instrument panel showing the front right air bag module cover

Figure 14 View of the front right air bag manual expanded to illustrate bag excursion

The face of the passenger side air bag exhibited a linear artifact field of small dark brown transfers which were associated with tissue from the front right occupant's neck and facial areas. This area measured 21.6 cm (8.5") in length and 7.6 cm (3.0") in width. It began 15.2 cm (6.0") below the inflator unit and was 22.9 cm (9.0") in-board of the right vertical seam. There was a faint yellow/tan color transfer which measured 26.7 cm (10.5") laterally and 11.4 cm (4.5") vertically and was located 58.4 cm (23.0") below the inflator unit. A 10.2 cm (4.0") dark area on the right side panel of the air bag was located 49.5 cm (19.5") below the inflator unit.

A dark red bodily fluid transfer on the face of the passenger side air bag measured 6.4 cm (2.5") laterally

and 10.2 cm (4.0") vertically. It was located 49.5 cm (19.5") below the inflator unit and 1.9 cm (0.75") in-board from the right vertical seam. This artifact was attributed to contact by the front right occupant at her final rest position.

VELOCITY DATA

The Lincoln Continental experienced nine impacts from the time of its travel lane departure and its final rest position. Many of these impacts involved undercarriage contact with concrete stairs and wrought iron handrails which were considered to be below the threshold for SRS actuation. Additionally, tire mark acceleration marks noted at the scene prior to the impact with the utility pole indicated that the vehicle powered through the impacts thereby theoretically reducing the value of the damage associated delta V. The following table tabulates the output values using the damage and trajectory algorithm of the SMASH program.

Crash Sequence with the Utility Pole	**Vehicle #1**
Impact Speed	29 km/h (18 mph)
Total delta V	28 km/h (17 mph)
Longitudinal	-28 km/h (-17 mph)
Lateral	0 km/h (0 mph)
Energy Dissipated	57,108 joules (42,115 ft-lb)

INJURY DATA

Front Right Occupant

The 88 year old female front right occupant, who was 148 cm (58.3") tall and weighed 63.5 kg (140 lbs), was pronounced deceased at the scene by the medical examiner. An autopsy was performed which documented multiple injuries of the face, brain, neck, spinal cord, and chest as summarized in the following table. The highest Abbreviated Injury Scale (AIS) injury sustained by the front right occupant was an AIS-6 (Maximum).

INJURY	AIS-90 INJURY CODE	INJURY SOURCE
1. Superficial abrasions of the right cheek, right side of chin, and small abrasion of the left cheek	290202.11 290202.18 290202.12	Passenger side air bag
2. 4.5 cm laceration of the lower central chin	290602.18	Passenger side air bag

INJURY	AIS-90 INJURY CODE	INJURY SOURCE
3. Deep laceration of the neck and strap muscles secondary to hyper-extension of the neck	390604.25	Passenger side air bag module cover and air bag
4. Transection of the trachea	442610.54	Passenger side air bag
5. Fracture dislocation of C0, C1 with transection of the upper spinal cord at the level of C1	640276.66	Passenger side air bag
6. Transection of the brainstem between the pons and the medulla	140212.68	Passenger side air bag
7. Subarachnoid hemorrhage over the right temporal lobe and brainstem	140684.31	Passenger side air bag
8. Bruises of the left shoulder	790402.12	Passenger side air bag
9. Abrasions of both shoulders, abrasion of the dorsum aspect of the right hand	790202.13	Passenger side air bag
10. Ecchymosis of the upper chest	490402.13	Passenger side air bag
11. Laceration of the right supra-clavicular area	790602.11	Passenger side air bag
12. Abrasions of the upper chest	490202.13	Passenger side air bag
13. Fracture of the 1-2, 4-7 right anterior ribs	450230.31	Passenger side air bag
14. Fracture of the 1-2 left posterior ribs	450220.22	Front right seat back support
15. Ecchymosis of the right lateral hip	890402.11	Instrument panel
16. Ecchymosis of the left lower leg	890402.12	Front right seat cushion

Driver

Driver #1, a 56 year old male, who was estimated at 180.3 cm (71.0") tall and 90.7 kg (200.0 lbs), was transported from the scene via ambulance to a nearby medical facility where he was treated and released. He sustained contusions and abrasions of the abdomen, multiple right lower anterior rib fractures, and redness and pain over the lower sternum. These injuries were attributed to contact with the driver side air bag module cover, air bag, and the steering wheel rim. Medical findings indicated that the driver had a history of a controlled seizure disorder and that he may have experienced an episode prior to the crash. He was reportedly taking Dilantin prior to the crash to control the disorder. The following table lists the injuries, AIS-90 injury classification, and the injury source.

INJURY	AIS-90 INJURY CODE	INJURY SOURCE
1-2. Abrasion and contusion of the entire upper half of the abdomen and more pronounced contusions on the lower right anterior abdominal wall	590202.1,9 590402.1,0	Front left driver air bag module cover and air bag
3. Redness and pain over the lower sternum	Not codeable	Front left driver air bag module cover and air bag
4. Multiple right lower anterior rib fractures without significant displacement	450220.2,1	Steering wheel rim

Rear Right Occupant

The rear right occupant, an 82 year old female, reportedly sustained soft tissue injuries and was transported to a local medical treatment facility where she reportedly suffered a stroke. She was admitted and subsequently transferred to a long term care facility where she deceased three months after the crash.

OCCUPANT KINEMATICS

Front Right Occupant

The front right occupant was not using the manual three point lap and torso belt at the time of the crash. During the initial impact with the parked 1995 Jeep Cherokee, the front right occupant moved forward and was in contact with the instrument panel. As the vehicle proceeded from this impact to the impact with the utility pole, the vehicle struck several objects with the frontal plane, wheels, and undercarriage which maintained the front right occupant's position against the instrument panel. Upon impact with the utility pole, the SRS actuated with the front right occupant against the passenger side air bag module cover.

The lower air bag module cover opened in a downward rotation and contacted the upper portion of the front right occupant's neck as noted by a rectangular abrasion pattern which was located just below the chin. The leading edge of the expanding air bag contacted the right side of her chin which resulted in a serpentine type laceration pattern (described by the medical examiner as a typical boxer's punch type injury). As the air bag continued to expand, it contacted the right side of the face resulting in a concentrated abrasion pattern of the chin and right cheek. The location of the abrasion indicated that her head was rotated to the left which would be consistent with her attention being focused on the driver who had loss control of the vehicle prior to the crash sequence.

As the air bag continued to expand, it rotated her head counterclockwise and back in a hyper-extension movement. This resulted in a gaping laceration of the anterior neck, transection of the trachea, shearing of the neck strap muscles, the separation of the skull from C1, the transection of the base of the brain, transection of the spinal cord, and brain hemorrhage. The air bag then contacted the chest which resulted in contusions of the right chest and fractures of the right 1-2, 4-7 anterior ribs.

The occupant was subsequently elevated and propelled rearward where her face contacted the bottom surface of the front right sunvisor as noted by a 19.1 mm (0.75") tissue transfer adjacent to the leading edge. She continued rearward and struck the front right seat back support with the her head and upper torso. She sustained a fracture of the left 1-2 posterior ribs which was attributed to this contact mechanism.

She came to rest with her legs forward in front of the front right seat cushion with her upper torso positioned near the front right door surface. Her head was forward and against the front right door surface. Bodily fluid deposits on the air bag surface and the outboard surface at the mid seat location of the front right seat identified this location.

Driver

The driver was not wearing the three point manual lap and torso belt prior to the crash. He moved forward and was against the air bag module cover as the result of the impacts preceding the impact with the utility pole. As the air bag initiated it expansion process, the driver's upper torso impeded the typical opening cycle of the air bag module cover which resulted in displacement of the lower air bag module cover flap beyond the steering wheel rim. The air bag was subsequently pinched between the cover, steering wheel rim, and driver which resulted in a 33.0 cm (13.0") lateral tear of the back surface of the air bag fabric.

The driver then compressed the air bag and loaded the steering column which resulted in the displacement of the steering column shear plate of 6.0 cm (2.4") and 4.6 cm (1.8 ") at the left and right shear capsules, respectively. His left knee contacted the left side of the lower instrument panel adjacent to the left front door as noted by a scuff mark. His lower leg contacted the parking brake foot pedal as noted by the rotation of the pedal stage.

The driver rebounded back against the seat back support where he came to the final rest position. He exited the vehicle under his own power, but was found by arrival of rescue to be in a dazed state.

Rear Right Occupant

The rear right occupant was not wearing the available three point manual lap and torso belt and moved forward during the first impact sequence. She struck the back of the front right seat support and was found on her knees on the floor behind the front seats at final rest with her head facing the left rear door. She was removed by rescue and transported via ambulance to a nearby medical treatment facility.