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SCI/NASS COMBINATION DRIVER AIR BAG-RELATED SERIOUS INJURY INVESTIGATION

CASE NUMBER - 2005-50-175J
LOCATION - Texas
VEHICLE - 2004 VOLVO S60
CRASH DATE - December 2005

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

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

Technical Report Documentation Page

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SCI/NASS combination investigation of an air bag deployment crash involving a 2004 Volvo S60 sedan that was impacted by a tractor-trailer and then ran head-on into a concrete wall

16. *Abstract*
This report covers a SCI/NASS combination investigation of a crash involving a 2004 Volvo S60 sedan (case vehicle) and a 1998 Volvo-GM truck-tractor pulling one van semi-trailer (other vehicle). This crash is of special interest because the case vehicle's driver (66-year-old female), who suffered with an advanced case of osteoporosis, sustained multiple cervical and thoracic vertebrae fractures due to contact with her deploying driver's air bag. Both vehicles were traveling westward in the westbound lanes of a divided urban expressway, with the case vehicle in the outside lane and the tractor-trailer in the adjacent center through lane, abreast of one another. There is no evidence that either vehicle's driver attempted any avoidance maneuver. The crash sequence began in the outside westbound lane. The tractor-trailer moved to its right and the case vehicle's left side was impacted by the tractor's right side. This impact caused the case vehicle's driver to lose control. The case vehicle veered sharply to the right and began to rotate clockwise, crossed the shoulder and the grassy, up-sloping roadside, and its front impacted a concrete wall. The case vehicle bounced off the wall and rotated further clockwise while sliding along the shoulder and came to rest a short distance from the wall impact, on the roadside, heading northeast. The tractor-trailer was brought to controlled stop on the shoulder a short distance further west. The case vehicle driver was hospitalized for three days. The case vehicle's front right passenger (69-year-old male) sustained minor injuries and was treated and released at a hospital emergency department. There were no other occupants in the case vehicle. The case vehicle was towed due to disabling damage and the tractor-trailer was driven away from the scene.

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BACKGROUND

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This SCI/NASS combination investigation was brought to the NHTSA's attention in early January 2006 by NASS-CDS sampling activities and designated for SCI in March 2006. This crash involved a 2004 Volvo S60 sedan (case vehicle) and a 1998 Volvo-GM truck-tractor pulling one van semi-trailer (other vehicle). The crash occurred in December 2005, at 10:24 a.m., in Texas, and was investigated by the applicable municipal police department. This crash is of special interest because the case vehicle's driver (66-year-old female, white, unknown if Hispanic), who suffered with an advanced case of osteoporosis, sustained multiple cervical and thoracic vertebrae fractures due to contact with her deploying driver's air bag. The case vehicle's front right passenger (69-year-old male, race/ethnicity unknown) sustained minor injuries and there were no other occupants in the case vehicle. This report is based on the coded NASS case, a review of the driver's medical records, occupant kinematic principles, and this contractor's evaluation of the available evidence.

CRASH CIRCUMSTANCES

Both vehicles were traveling westward in the westbound lanes of a divided urban expressway (**Figure 1**), with the case vehicle in the outside lane and the tractor-trailer in the adjacent center through lane, abreast of one another. It was daylight, the weather was clear and the road surface was dry and free of defects. The speed limit for both vehicles was 97 km.p.h. [60 m.p.h.]. There is no evidence that either vehicle's driver attempted any avoidance maneuver. The crash sequence began in the outside westbound lane.

Figure 1: Case vehicle's (outside lane) and other vehicle's (center lane) westbound approach

The tractor-trailer moved to its right and the case vehicle's left side was impacted by the tractor's right side. This impact caused the case vehicle's driver to lose control. The case vehicle veered sharply to the right and began to rotate clockwise, crossed the shoulder and the grassy, up-sloping roadside, and its front impacted a concrete wall (**Figure 2**). The case vehicle bounced off the wall and rotated further clockwise while sliding along the shoulder and came to rest a short distance from the wall impact, on the roadside, heading northeast. The tractor-trailer was brought to controlled stop on the shoulder approximately 400 meters [one-quarter of a mile] further west.

Figure 2: Approximate area of case vehicle's impact with wall; note, positive slope from shoulder to base of wall

The case vehicle was a 2004 Volvo S60 front wheel drive, four-door, five-passenger sedan (VIN: YV1RS61TX42------), equipped with a 5-cylinder 2.4 liter gasoline engine and an automatic transmission with a console-mounted selector lever. Four-wheel anti-lock brakes and traction control were standard on this model. The case vehicle was equipped with: manual, three-point, lap-and-shoulder safety belts with retractor pretensioners for the four outboard seat positions; dual-stage frontal air bags; seat back-mounted side impact air bags and active head restraints for the two front seats; roof rail-mounted side curtain air bags that provide inflatable protection for the front and back outboard seat locations; and a tilt-and-telescope steering column.[1] Its wheelbase was 272 centimeters [106.9 inches] and its odometer reading is not known. The case vehicle was towed due to disabling damage.

Figure 3: Case vehicle's front and right side

Figure 4: Case vehicle's front and left side

The case vehicle sustained direct contact damage across its entire front from the impact with the concrete wall (event #2). The ground leading from the roadway to the wall had a positive slope and the case vehicle's bumper was crushed rearward to the leading edges of the front tires while the upper radiator support and the leading edge of the hood had lesser crush, reflecting the up-sloping angle at which the case vehicle engaged the wall (**Figures 3** and **4**). The bumper cover was torn off and the grille and both headlamp/turn signal assemblies were shattered and broken away. The leading edge of the hood had slight direct contact and was bent downward and creased, more so on the right. The leading edges of both fenders were crushed rearward. The right fender was also bent outward and had induced damage extending to the right A-pillar. The rocker panel below the right front door was displaced. The wheelbase was shortened by 9 centimeters [3.5 inches] on the right and lengthened by 5 centimeters [2.0 inches] on the left. The left rear tire was deflated, the right front tire was restricted by deformed body panels and there was no other wheel or tire damage. There was no glazing damage.

[1] For the active head restraints, seat back-mounted side impact air bags, back seat outboard safety belt pretensioners and the telescoping feature of the steering column, the coded NASS case data indicate that these items were not present, but all these items are standard features for this model.

The entire front bumper cover was torn off and the crush profile was measured from the steel bumper. Maximum crush was 46 centimeters [18.1 inches] at C5. The CDC was determined to be **11-FDEW-3 (330 degrees)**. The WinSMASH reconstruction program, barrier algorithm, was used on the case vehicle's most severe (second) impact. The total, longitudinal and lateral delta-Vs are, respectively: 37 km.p.h. [23.0 m.p.h.], -32 km.p.h. [-19.9 m.p.h.] and + 18 km.p.h. [+ 11.2 m.p.h.]. These results appear reasonable. This was an impact of moderate severity (24-40 km.p.h. [15-25 m.p.h.]) for the case vehicle.

The case vehicle's first impact, with the tractor-trailer, involved minor denting and scraping on the left rear door panel. Maximum crush was measured as 5 centimeters [2 inches] at C3, slightly forward of the left rear door handle. The rear bumper cover was torn off, perhaps as a result of snagging on the tractor-trailer's right side components. The CDC was determined to be **09-LPEW-1 (270 degrees)**. This impact is out of scope for the WinSMASH reconstruction program. This was an impact of minor severity (1-13 km.p.h. [1-8 m.p.h.]) for the case vehicle.

Figure 5: Case vehicle's left rear door, showing minor damage from first impact

The manufacturer's recommended tire size is P215/55R16[2] and the case vehicle was fitted with four tires of this size. The tire inspection findings are presented in the following table.

Tire	*Measured Pressure*		*Vehicle Manufacturer's Recommend Pressure*		*Tread Depth*		*Damage*	*Restricted*	*Deflated*
	kPa	psi	kPa	psi	milli-meters	32nd of an inch			
LF	193	28	262	38	7	9	None	No	No
RF	207	30	262	38	6	8	None	Yes	No
LR	flat	flat	262	38	3	4	None	No	Yes
RR	207	30	262	38	4	5	None	No	No

Inspection of the case vehicle's interior revealed that there were no intrusions. Contact

[2] The recommended tire size and pressure were obtained from the *Tire Guide* specifications tables. The case vehicle's tire placard was not accessible and the NASS case data are coded " unknown" for recommended tire size/pressure.

evidence was found on the right side of the center console (scuffing) and on the right front door armrest (cracked), from the front right passenger's left and right legs, respectively. In addition, both the driver's and front right passenger's belt restraint systems showed evidence of loading. The steering wheel was not deformed and there was no contact evidence on the rim or spokes.

AUTOMATIC RESTRAINT SYSTEM

The case vehicle was equipped with: driver and front right passenger frontal air bags with two-stage inflators; retractor safety belt pretensioners for the four outboard seat positions; seat back-mounted side impact air bags for the two front seats; and left and right roof rail-mounted side curtain air bags that provide inflatable protection for the front and back outboard seat positions; and active head restraints for the two front seats (see footnote 1, page 2). The frontal air bags deployed and the front seat pretensioners actuated. The side impact air bags and the curtain air bags did not deploy. It is not known if the back seat pretensioners actuated.

Figure 6: Front of driver's frontal air bag

The driver's air bag was located in the steering wheel hub (**Figure 6**). This air bag had a two-stage inflation system, but, because the case vehicle did not have a downloadable Event Data Recorder, it is not known if this was a first or second stage deployment. The module cover flap opened at the designated tear points and there was no damage to the cover flaps or the adjacent structures. The deployed driver's air bag was round (diameter unknown) with two vent ports located on the back surface, slightly above the horizontal centerline, on either side of the vertical centerline. The air bag fabric was not damaged and there was no obvious evidence of occupant contact.

Figure 7: Front of passenger's frontal air bag

The front right passenger's air bag was located in the top of the instrument panel on the right (**Figure 7**). This air bag had a two-stage inflation system, but, because the case vehicle did not have a downloadable Event Data Recorder, it is not known if this was a one-stage or a two-stage

deployment. The module cover flaps opened at the designated tear points and there was no damage to the cover flaps or the adjacent structures. The deployed front right passenger's air bag was rectangular (dimensions unknown), with two vent ports on the left and right side panels, respectively, of the fabric. The air bag fabric was not damaged and there was no obvious evidence of occupant contact.

Figure 8: Driver's seat area view from right

Figure 9: Driver's seat area; note, safety belt spooled out and locked (pretensioner actuation) and wrinkles/stretching in webbing (occupant loading)

CASE VEHICLE DRIVER'S KINEMATICS

The case vehicle's driver (66-year-old female, white, unknown if Hispanic, 165 centimeters, 77 kilograms [65 inches, 170 pounds]) was restrained by her available manual, three-point, lap-and-shoulder safety belt system, with the retractor pretensioner actuated and the steering wheel air bag deployed (**Figures 8** and **9**). The safety belt webbing was stretched and the driver had chest injuries consistent with safety belt use. The tilt adjustment on the steering wheel was set between the center and full-up positions and the telescoping adjustment was set between the middle and full-forward positions.[3] The active head restraint was not adjustable.[4] The seat track was adjusted at the middle position and the seat back incline was adjusted at the upright position. Her seated posture is not known, but she was operating the foot controls and had at least one hand on the steering wheel.

The driver's medical records indicate that she suffered from advanced osteoporosis in the cervical and thoracic regions of her spinal column. Normal lordotic[5] curvature was preserved in the cervical region but slight kyphotic[5] curvature was evident in the thoracic region and the soft tissue silhouette in the radiographic images showed the outline of a slight " dowager's hump"[5]. With this pre-existing medical condition, her cervical and thoracic spine would be structurally weakened due

[3] The discussion of the steering wheel adjustments is based on this contractor's review of the photographs.

[4] The coded NASS data indicate an adjustable head restraint, but the Volvo active head restraint is not adjustable.

to the reduced density of her vertebrae. In addition, the kyphotic curvature in her thoracic spine would cause her head and neck to be somewhat forward when she was seated with her back against the seat back, as compared to the seated posture of a person who did not suffer from this condition.[5]

The case vehicle's back left door was impacted by the right side of the tractor-trailer (event #1). This was a very minor impact and it probably did not effect the driver's posture, but she probably leaned forward as she attempted to steer away from the tractor-trailer. The case vehicle driver apparently steered hard right and lost control because the case vehicle ran off the right side of the roadway in a clockwise yaw, traversed the shoulder and the grassy roadside, and was heading approximately 90 degrees clockwise from its original path of travel as it slid into the concrete wall. The time interval between the first and second impacts was probably on the order or 2 or 3 seconds.

The case vehicle's front impacted the wall, causing the driver's and front right passenger's air bags to deploy and causing the safety belt pretensioners to actuate. The driver moved forward and upward in response to the frontal impact and encountered the deploying air bag with her face and chest. The expanding air bag caused her head to move rearward, causing hyperextension of her cervical spine, resulting in multiple fractures to the posterior structures of vertebrae C3 - C6 and T3 - T7, with a slight compression fracture of C7 and a major compression fracture of T8. She loaded against the torso portion of the safety belt webbing and sustained a contusion of her left lung. Her left hand struck the instrument panel and she sustained a fracture of the phalanx in her left 4th finger. Her posture at final rest is not known.

CASE VEHICLE DRIVER'S INJURIES

The case vehicle driver was transported via ground ambulance to a trauma center, where she was hospitalized for three days.

Injury Number	Injury Description (including Aspect)	NASS Injury Code & AIS 90	Injury Source (Mechanism)	Source Confidence	Source of Injury Data
1.	Contusion, left lung	serious 441406.3,2	torso portion of safety belt	probable	Emergency Room

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

hump (hump): a rounded eminence; called also gibbus.

dowager's hump: popular name for dorsal *kyphosis* caused by multiple wedge fractures of the thoracic vertebrae seen in *osteoporosis*.

kyphosis (ki-fo´sis): abnormally increased convexity in the curvature of the thoracic spine as viewed from the side; called also *hunchback*. Cf. *lordosis* and *scoliosis*.

kyphotic (ki-fot´ik): affected with or pertaining to kyphosis.

lordosis (lor-do´sis): 1. the anterior concavity in the curvature of the lumbar and cervical spine as viewed from the side. 2. abnormal increase in this curvature; called also *hollow back*, *saddle back*, and *swayback*. Cf. *kyphosis* and *scoliosis*.

lordotic (lor-dot´ik): pertaining to or characterized by lordosis.

osteoporosis (os"te-o-pa-ro´sis): reduction in the amount of bone mass, leading to fractures after minimal trauma.

senile osteoporosis: that occurring in men and women over 70, manifested mainly by hip and vertebral fractures of the painless multiple wedge type leading to dorsal *kyphosis*.

Injury Number	Injury Description (including Aspect)	NASS Injury Code & AIS 90	Injury Source (Mechanism)	Source Confidence	Source of Injury Data
2.	Minor compression of vertebral body (< = 20 %), C7	moderate 650232.2,6	driver's air bag {indirect}	probable	Emergency Room
3.	Fracture, lamina, C6	serious 650224.3,6	driver's air bag {indirect}	probable	Emergency Room
4.	Fracture, lamina, C7	serious 650224.3,6	driver's air bag {indirect}	probable	Emergency Room
5.	Fracture, transverse process, C7	moderate 650220.2,6	driver's air bag {indirect}	probable	Emergency Room
6.	Fracture, transverse process, T3[6]	moderate 650420.2,7	driver's air bag {indirect}	probable	Emergency Room
7.	Fracture, transverse process, T4[6]	moderate 650420.2,7	driver's air bag {indirect}	probable	Emergency Room
8.	Fracture, transverse process, T5[6]	moderate 650420.2,7	driver's air bag {indirect}	probable	Emergency Room
9.	Fracture, transverse process, T6[6]	moderate 650420.2,7	driver's air bag {indirect}	probable	Emergency Room
10.	Fracture, transverse process, T7[6]	moderate 650420.2,7	driver's air bag {indirect}	probable	Emergency Room
11.	Major compression of vertebral body (~ 25 %), T8	serious 650434.3,7	driver's air bag {indirect}	probable	Emergency Room
12.	Left 4th finger, proximal phalanx fracture	minor 752404.1,2	left instrument panel	probable	Emergency Room
13.	Fracture, spinous process, C3[7]	moderate 650218.2,7	driver's air bag {indirect}	probable	Hospitalization Records
14.	Fracture, spinous process, C4[7]	moderate 650218.2,7	driver's air bag {indirect}	probable	Hospitalization Records
15.	Fracture, spinous process, C5[7]	moderate 650218.2,7	driver's air bag {indirect}	probable	Hospitalization Records

CASE VEHICLE FRONT RIGHT PASSENGER'S KINEMATICS

The case vehicle's front right passenger (69-year-old male, race/ethnicity unknown, height and weight unknown) was restrained by his available manual, three-point, lap-and-shoulder safety

[6] The transverse process fractures in the thoracic spine are coded as spinous process fractures in the NASS case data, but further review of the medical records indicate transverse process.

[7] The spinous process fractures at C3, C4 and C5 are not included in the injury coding in the NASS case, but further review of the medical records indicate these injuries.

belt system, with a retractor pretensioner that actuated, and the front right instrument panel air bag deployed. The safety belt webbing was stretched and the front right passenger had chest injuries consistent with safety belt use. The seat track was adjusted at the full-rear position and the seat back incline was adjusted at the upright position. The active head restraint was not adjustable. His seated posture is not known.

The case vehicle's back left door was impacted by the right side of the tractor-trailer (event #1). This was a very minor impact and it probably did not effect the front right passenger's posture. The case vehicle driver apparently steered hard right and lost control because the case vehicle ran off the right side of the roadway in a clockwise yaw, traversed the shoulder and the grassy roadside, and was heading approximately 90 degrees clockwise from its original path of travel as it slid into the concrete wall. The time interval between the first and second impacts was probably on the order of 2 or 3 seconds.

The case vehicle's front impacted the wall, causing the driver's and front right passenger's air bags to deploy and causing the safety belt pretensioners to actuate. The front right passenger moved forward and upward in response to the frontal impact, loading the safety belt webbing and encountering the deploying air bag with his face and chest. He sustained abrasions on his chest from the safety belt and a minor laceration on his forehead, probably from the air bag.[8] His arms flailed and he sustained a fracture of the phalanx in his left thumb, probably from striking the rear view mirror, and a laceration on his right hand, probably from striking the sunvisor/windshield header.

CASE VEHICLE FRONT RIGHT PASSENGER'S INJURIES

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

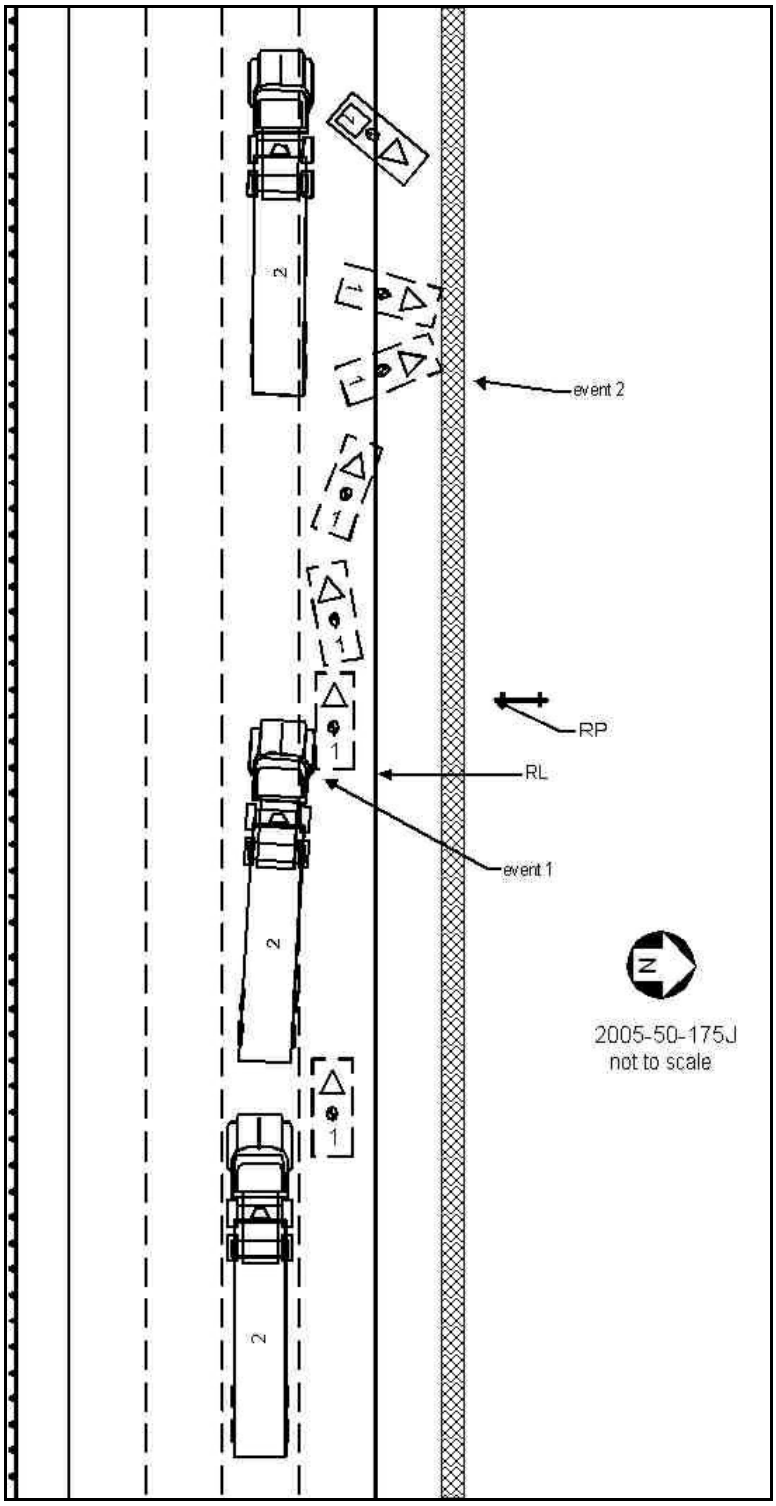
Injury Number	Injury Description (including Aspect)	NASS Injury Code & AIS 90	Injury Source (Mechanism)	Source Confidence	Source of Injury Data
1.	Fracture phalanx, left thumb	minor 752404.1,2	Rear view mirror	probable	Emergency Room
2.	Minor skin laceration, forehead	minor 290602.1,7	Passenger's air bag[8]	probable	Emergency Room
3.	Minor skin laceration, right hand	minor 790602.1,1	Sunvisor	probable	Emergency Room
4.	Abrasion, left chest	minor 490202.1,2	Torso portion of safety belt	certain	Emergency Room

[8] The NASS injury data are coded to indicate that the forehead laceration was due to contact with the instrument panel, but this contractor does not agree.

OTHER VEHICLE: 1998 VOLVO-GM TRUCK TRACTOR 2005-50-175J

The other vehicle was a 1998 Volvo-GM model VN 6-by-4 truck tractor (VIN: 4VG7DAGH0WN------) pulling a single van semi-trailer (VIN unknown). The tractor-trailer was driven from the scene.

The tractor-trailer's driver (36-year-old male) was police-reported as not injured and he was not transported via ambulance.


event 2
RP
RL
event 1
N
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not to scale