TRANSPORTATION SCIENCES
CRASH DATA RESEARCH CENTER

Veridian Engineering
Buffalo, New York 14225

REMOTE NASS/SCI COMBINED ADVANCED OCCUPANT PROTECTION/DRIVER FATALITY INVESTIGATION

VERIDIAN CASE NO. 2002-05-013A

VEHICLE - 2001 VOLVO S40

LOCATION - PENNSYLVANIA

CRASH DATE - JANUARY, 2002

Contract No. DTNH22-01-C-17002

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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 of the involved vehicle(s) or their safety systems.

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17. *Abstract*

This remote investigation focused on the mechanism causing the fatal injuries sustained by the 78 year old female driver of a 2001 Volvo S40 sedan. The Volvo was involved with an offset frontal collision with a 1991 Chevrolet G20 van. The 2001 Volvo S40 was equipped with an Advanced Occupant Protection System (AOPS) that consisted of front seat belt pretensioners, dual stage/dual threshold frontal air bags, front seat side impact air bags and inflatable side curtains. The frontal air bags in the Volvo deployed upon impact. The unrestrained female driver of the Volvo loaded through the deployed driver air bag, deformed the lower half of the steering wheel rim and displaced the steering column from the shear capsules. She sustained multiple blunt thoracic and abdominal trauma as a result of this loading and was pronounced dead at the scene.

This crash was identified by PSU 05 of the National Automotive Sampling System (NASS) during its weekly sampling of police reported crashes. The case was subsequently selected for inclusion in the 2002 NASS CDS and is identified by the case number 2002-05-013A. The Crash Investigations Division of the National Highway Traffic Safety Administration (NHTSA) assigned a remote combined investigation of this crash to the Special Crash Investigations team at Veridian Engineering as part of the Advanced Occupant Protection System Study.

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BACKGROUND

This remote investigation focused on the mechanism causing the fatal injuries sustained by the 78 year old female driver of a 2001 Volvo S40 sedan. The Volvo was involved with an offset frontal collision with a 1991 Chevrolet G20 van. The 2001 Volvo S40 was equipped with an Advanced Occupant Protection System (AOPS) that consisted of front seat belt pretensioners, dual stage/dual threshold frontal air bags, front seat side impact air bags and inflatable side curtains. The frontal air bags in the Volvo deployed upon impact. The unrestrained female driver of the Volvo loaded through the deployed driver air bag, deformed the lower half of the steering wheel rim and displaced the steering column from the shear capsules. She sustained multiple blunt thoracic and abdominal trauma as a result of this loading and was pronounced dead at the scene.

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SUMMARY

Crash Site

This two-vehicle crash occurred during the morning hours of January 29, 2002. At the time of the crash, it was daylight and the weather was not a factor. The road surface was dry. The crash occurred in the southbound lane of a two-lane north/south state highway. The road was straight with a negative two percent grade in the northbound direction**. Figure 1** is a northward view at the crash scene. The respective travel lanes were separated by double yellow center lines. The east road shoulder was comprised of grass and gravel. The shoulder was relatively narrow and tapered into a roadside ditch. A 3.6 m (12 ft) wide

Figure 1: Northward view of the point of impact and the vehicle's final rest positions.

breakdown lane, and a 15 cm (6 in) barrier curb bordered the northbound lane, immediately outboard the white edge line. The speed limit in the area of the crash was 64 km/h (40 mph).

Pre-Crash

The 2001 Volvo S40 was northbound driven by an unrestrained 78 year old female. A non-contact vehicle was traveling north directly ahead of the Volvo at a driver estimated speed of 48 km/h (30 mph). The driver of this non-contact vehicle reported the driver of the Volvo pulled out into the northbound lane in an attempt to pass. As the Volvo was pulling adjacent to the non-contact vehicle, the non-contact driver observed the 1991 Chevrolet G20 van in the southbound lane. The driver of the non-contact vehicle then braked to avoid the impending crash. There was no evidence of pre-crash avoidance maneuvers attributed to either vehicle involved in the impact.

Crash

The crash occurred with the left front of the Volvo impacting the left front of the Chevrolet in an offset frontal impact configuration. The force of the impact caused the Volvo to rotate counterclockwise, as it disengaged from the van. The Volvo rotated approximately 180 degrees and came to rest in-close proximity to (and north of) the point of impact (POI). Two gouge marks in the southbound lane, near the double yellow centerline, identified the point of impact (POI). The Chevrolet van was deflected to its right and into the breakdown lane bordering the southbound lane. The van came to rest against the outboard curb facing south. The velocity changes (delta V's) calculated by the Damage Algorithm of the WINSMASH model were 68.0 km/h (42.3 mph) and 42.0 km/h (26.1 mph) for the Volvo and Chevrolet, respectively. **Figure 2** is a schematic of the crash.

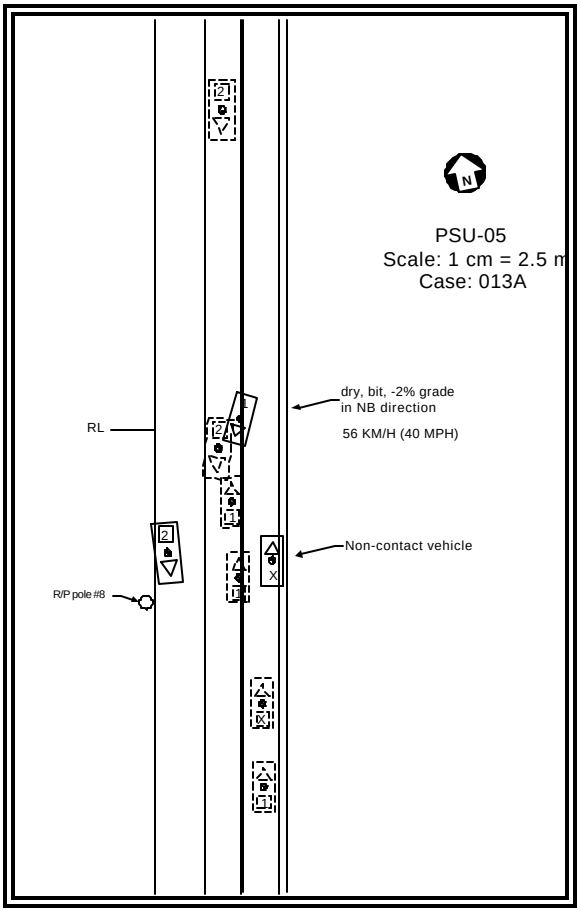

Figure 2: Crash schematic.

Upon impact with the van, the advanced frontal air bag system in the Volvo deployed. The driver exhibited a forward trajectory in response to the 12 o'clock direction of the impact force. She contacted the deployed air bag with her upper torso, loaded through the bag and deformed the lower half of the steering wheel rim with her abdomen. She continued to load the steering column causing the separation of the shear capsules. Coincident to this kinematic pattern, the left aspect of the instrument panel and the components of the steering column intruded into the driver's interior space.

The driver's inertial loading of the air bag and steering wheel/column components resulted in massive blunt thoracic and abdominal trauma. She was pronounced dead at the scene. The 63 year old male driver of the Chevrolet was extricated from the vehicle and was transported for treatment. He sustained multiple left lower extremity fractures and associated minor injuries. He required four days of hospitalization.

2001 VOLVO S40

The 2001 Volvo S40, 4 door sedan, was identified by the Vehicle Identification Number (VIN): YV1VS29571F (production sequence deleted). The Volvo was equipped with a 1.9 liter/I4 engine, a 5-speed automatic transmission, power steering, and 4-wheel power assisted disc brakes with ABS. The manual restraint system consisted of 3-point lap and shoulder belts in the five seat positions. The front seat manual restraints were equipped with retractor pretensioners. The Supplemental Restraint System consisted of dual stage/dual threshold frontal air bags and seat mounted side impact air bags for the front occupants and inflatable side curtains. The vehicle was manufactured in May 2000. The electronic odometer could not be read at the time of the inspection due to a lack of electrical power. **Figures 3 and 4** are the front and left side views of the Volvo.

Figure 3: Front view of the Volvo.

Exterior Damage

The front plane of the Volvo sustained severe contact damage that extended across the entire 150 cm (59 in) end width. The damage pattern was biased to the left side indicative of the off-set impact configuration. The impact force collapsed the left aspect of the engine compartment longitudinally rearward into the left side of the cowl and left A-pillar. The left front aspect of the roof was buckled. The induced damage extended rearward along the left side of the vehicle to the C-pillar and along the right side to the B-pillar locations, respectively. The left front door was jammed shut due to the deformation and removed during the driver's extrication. The left rear door was also jammed. The left wheelbase was foreshortened 24.3 cm (9.5 in). The right doors remained operational. There was no change in the right wheelbase dimension. The crush profile measured along the bumper reinforcement was as follows: C1 = 93 cm (36.6 in), C2 = 67 cm (26.4 in), C3 = 53 cm (20.9 in), C4 = 42 cm (16.5 in), C5 = 18 cm (7.1 in), C6 = 21 cm (8.3 in). The Collision Deformation

Figure 4: Left lateral view.

Classification (CDC) of the Volvo was 12-FDEW-4. The Principle Direction of Force was an estimated +10 degrees. The delta V calculated by the Damage Algorithm of the WINSMASH model was 68 km/h (42.3 mph). The longitudinal and lateral components were -66.9 km/h (-41.6 mph) and -11.7 km/h (-7.3 mph), respectively.

Interior Damage

The interior of the Volvo sustained moderate damage and intrusion consistent with the severity of the exterior impact forces, the deployment of the frontal air bag system, and occupant interior contacts. The left offset configuration and magnitude of the impact resulted in intrusion of the left aspect of the instrument panel and the toe pan. The intrusion of the these components measured 10 cm (3.9 in) and 11 cm (4.3 in), respectively. The magnitude of the intrusion appeared to be underestimated by the NASS researcher, based on a review of the interior photographs.

The seating system consisted of front buckets seats with a split fold rear bench. The driver's seat was adjusted to the forward most track position at the time of the NASS inspection. It was probable this was the at-crash position given the driver's stature. The police report indicated that during the extrication a "throw" pillow was found on the seat cushion under the driver. A family member reported to the investigating officer that the driver used the pillow for additional back support and would have been behind the driver pre-crash. The forward adjustment of the driver's seat, coupled with the use of the pillow pre-positioned the driver in-close proximity to the steering wheel and instrument panel.

Figures 5 and 6 are interior views of the Volvo and depict the deformed steering wheel rim and steering column displacement. The steering wheel rim was deformed throughout its 5 to 9 o'clock sectors. The maximum deformation measured 6.0 cm (2.4 in). The steering wheel was rotated approximately 30 degrees counterclockwise at the time it was loaded by the driver. The location of the upper sector of the steering wheel rim in-close proximity to the brow of the instrument panel indicated there was compression of the steering column.

Lower extremity contacts were noted to the intruding bolster panel consistent with the driver's injuries. Refer to **Figure 7.**

Figure 5: Right lateral interior view.

Figure 6: Deformed steering wheel rim.

Figure 7: Lower extremity contacts to the intruding bolster.

Manual Restraint System

The Volvo S40's manual restraint system consisted of 3-point lap and shoulder belts in the five seat positions. Each belt system utilized an inertial locking retractor. The front seat belt systems were equipped with retractor pretensioners. The first responders on-scene indicated the driver was not conscious and was unrestrained. Upon initial inspection, the driver's belt system was used to retain portions of the damaged left front door with the vehicle (refer to Figure 4). Inspection of the webbing identified no usage marks consistent with this severe impact. The retractor was operational. The fact the retractor was operational indicated its pretensioner did not fire and the belt was not utilized during the crash.

Advanced Occupant Protection System

The Advanced Occupant Protection System in the 2001 Volvo S40 consisted of dual stage/dual threshold frontal air bags and seat mounted side impact air bags for the front occupants and inflatable side curtains which offer protection to both front and rear outboard occupants. The SRS control module was located under the center console. The frontal air bags were designed to tailor their deployment (threshold and staging) dependant on the use of the front manual restraints and the severity of the impact.

The driver air bag, **Figure 8**, deployed as designed from its module located on the center hub of the steering wheel rim. The symmetrical H-configuration cover flaps measured 16 cm by 7 cm (6.3 in by 2.8 in), width by height. There was no evidence of occupant contact to the cover flaps. The air bag measured 55 cm (22 in) in diameter in its deflated state. The air bag was tethered by 4 internal straps sewn to the face of bag and was vented by two ports located in the 11/1 o'clock sectors on the back side of the bag. There was no direct evidence of occupant contact noted during the inspection.

Figure 8: Driver air bag.

Multiple "dicing-type" lacerations were noted within the 12 to 4 o'clock sector on the face of the air bag. These minor lacerations occurred post-deployment as a result of flying glass from the disintegrated front left window.

The front right passenger air bag was a top-mount design located in the right aspect of the instrument panel. The module cover flaps opened as designed during the deployment and measured 32 cm by 8 cm (12.6 in by 3.1 in). The face of the deployed passenger air measured 65 cm by 45 cm (25.6 in by 17.7 in). The air bag was tethered and was vented by two ports located on the side panels of the bag. There was no evidence of occupant contact to the air bag.

1991 CHEVROLET G20 VAN

Exterior Damage

The 1991 Chevrolet G20, **Figure 9**, van was identified by the Vehicle Identification Number (VIN): 1GCEG25H1M7 (production sequence deleted). The 3/4 ton full-size cargo van was manufactured with a 318cm (125 in) wheelbase. The vehicle's gross vehicle weight rating was 2,994 kg (6,600 lb). The power train consisted of a 5.0 liter/V8 engine linked to a 4-speed automatic transmission. The vehicle was equipped with a manual restraint system consisting of 3-point lap and shoulder belts in the front seat positions. The van was not equipped with a Supplemental Restraint System. The odometer read 330,016 km (205,068) miles.

Figure 9: Front view of the Chevrolet.

Exterior Damage

The vehicle's front plane sustained 58 cm (23 in) of direct contact damage that began 25 cm (10 in) left of center and extended to the left corner of the front bumper. The combined width of the direct and induced damage extended across the van's entire 170 cm (67 in) end width. The resultant damage pattern was triangular in shape biased to the left. The impact force collapsed the left side of the engine compartment into the cowl. The left front suspension deformed rearward shortening the left wheelbase approximately 30 cm (12 in). The residual crush profile measured along the front bumper was as follows: C1 = 117 cm (46.0 in), C2 = 63 cm (24.8 in), C3 = 42 cm (16.5 in), C4 = 26 cm (10.2 in), C5 = 12 cm (4.7 in), C6 = 0. The Principle Direction of Force (PDOF) was an estimated -10 degrees. The Collision Deformation Classification (CDC) of the Chevrolet was 12-FLEW-7. The delta V calculated by the Damage Algorithm of the WINSMASH model was 42.0 km/h (26.1 mph). The longitudinal and lateral delta V components were -41.3 km/h (-25.7 mph) and 7.2 km/h (4.5 mph), respectively.

DRIVER DEMOGRAPHICS

	2001 Volvo S40	***1991 Chevrolet G20 van***
Age/Sex:	78 year old/ Female	68 year old/Male
Height:	152 cm (60 in)	178 cm (70 in)
Weight:	44 kg (97 lb)	113 kg (249 lb)
Manual Restraint Use:	None used	None used
Supplemental Restraint:	Advanced Driver Air Bag	None
Usage Source:	First responders, PAR, inspection	Inspection, interview
Medical Treatment:	None, Fatally injured	Hospitalized four days

DRIVER INJURY - 2001 Volvo S40

Injury	***Injury Severity (AIS Update 98)***	***Injury Mechanism***
Major thoracic aorta laceration; 3 cm laceration of the ascending aorta, approx. 1.5 cm above the aortic valve cusp - this laceration is subadjacent to the area of pericardial contusion; complete transection with 2 cm displacement of the proximal descending aorta, just distal to the left subclavian artery - this communicates with the posterior mediastinal hemorrhage and hemorrhage into the left pleural cavity (pleural cavity 1600 cc left and 30 cc right); peritoneal cavity hemorrhage in right upper quadrant; focal retro peritoneal hemorrhage of the left upper quadrant 9 cm x 8 cm	Maximum (420218.6,4)	Steering wheel rim/column assembly
Capsular lacerations of the right anterior and left lobes of the liver and along the insertion of the falciforme ligament; internal fractures deep into the falciforme ligament area	Severe (541826.4,1)	Steering wheel rim/column assembly
Bilateral rib cage fracture - right 2-8 ribs along the anterior axillary line, left 2 and 6-9 ribs along the anterior axillary line, left 3-6 ribs para-sternally	Severe (450240.4,3)	Steering wheel rim/column assembly

Injury	*Injury Severity (AIS Update 98)*	*Injury Mechanism*
Laceration of the renal vein, NFS	Serious (521602.3,2)	Steering wheel rim/column assembly
Open comminuted fracture of the distal left femur, NFS as to site.	Serious (851801.3,2)	Driver's knee bolster
Right lung contusion (upper, middle and lower lobe)	Serious (441406.3,1)	Steering wheel rim/column assembly
Jejunum-ileum laceration perforation - proximal single puncture 1.5 to 2 cm in length	Serious (541424.3,8)	Steering wheel rim/column assembly
Pulmonary artery laceration, NFS	Serious (421004.3,4)	Steering wheel rim/column assembly
Large laceration of the pericardial sac - posterior and to the left; laceration communicates with the posterior mediastinal hemorrhage; pericardial contusion on the upper right	Moderate (441602.2,4)	Steering wheel rim/column assembly
Pancreas contusion, NFS, (focal mid-body peri-pancreatic hemorrhage)	Moderate (542810.2,7)	Steering wheel rim/column assembly
Contusion to the tip of the nose	Minor (290402.1,4)	Deployed driver air bag
Three superficial abrasions to the undersurface of the chin; 1.5 cm , 1 cm and 1 cm in length	Minor (290202.1,8)	Deployed driver air bag
4.5 cm faint rounded contusion to the left forehead	Minor (290402.1,7)	Deployed driver air bag
1 cm linear abrasion to the medial left eye brow	Minor (290202.1.7)	Deployed driver air bag
2 mm right mid abdominal abrasion	Minor (590202.1,1)	Steering wheel rim
4 cm x 2 cm left anterio-lateral abdominal contusion	Minor (590402.1,2)	Steering wheel rim

Injury	*Injury Severity (AIS Update 98)*	*Injury Mechanism*
Multiple small abrasions, contusions, and lacerations predominately over the knuckles and fingers of the dorsal right hand	Minor (790202.1,1) (790402.1,1) (790602.1,1)	Instrument panel
Distal phalanx fracture - right index finger	Minor (752404.1,1)	Instrument panel
2 cm abrasion of the upper pre-tibial aspect of the right lower extremity, multiple linear and curvilinear abrasions overlying the right medial thigh and anterior knee	Minor (890202.1,1)	Driver's knee bolster
12 cm right distal pre-tibial avulsion with partially exposed bone	Minor (890802.1,1)	Driver's knee bolster
Two obliquely oriented lacerations 3.5 cm to 4 cm in length to the left anterior thigh	Minor (890602.1,2)	Driver's knee bolster
Right adrenal gland contusion, NFS (peri-adrenal hemorrhage)	Minor (540210.1,1)	Steering wheel rim/column assembly

Note: the above injuries were identified in the driver's autopsy record.

DRIVER KINEMATICS - 2001 Volvo S40

The 78 year old driver of the Volvo was seated in an upright posture with her seat adjusted to a forward track position. She reportedly drove with a "throw" pillow positioned behind her back for additional back support. The forward track position and the use of the pillow positioned the driver in-close proximity to the steering wheel/column. She was not wearing the available 3-point lap and shoulder belt. The driver initiated a passing maneuver and had crossed into the opposing travel lane at the time of the crash.

Upon impact with the van the advanced frontal air bag system in the Volvo deployed. The deployment of the air bag displaced the driver's hands from the steering wheel. The driver initiated a forward trajectory response to the 12 o'clock direction of the impact force and the impact induced deceleration. She contacted the deployed air bag with her head and upper torso evidenced by the minor facial abrasions. Her right hand struck the instrument panel evidenced by the integumentary injuries and phalanx fracture. The driver loaded through the air bag and deformed the lower half of the steering wheel rim with her abdomen. The rim loading resulted in the multiple blunt abdominal injuries identified above. Coincident to this kinematic pattern, the left aspect of the instrument panel and the components of the steering column intruded into the driver's interior space. The driver continued to load the steering column causing the separation of the shear capsules. Her loading of the steering column caused the multiple rib fractures and the multiple blunt thoracic arterial injuries (AIS 6). She was pronounced deceased at the scene of the crash.