



# INDIANA UNIVERSITY

## TRANSPORTATION RESEARCH CENTER

School of Public and Environmental Affairs  
222 West Second Street  
Bloomington, Indiana 47403-1501  
(812) 855-3908 Fax: (812) 855-3537

## ON-SITE ADVANCED OCCUPANT PROTECTION SYSTEM INVESTIGATION

CASE NUMBER - IN01-012  
LOCATION - MISSOURI  
VEHICLE - 2001 FORD TAURUS SES  
CRASH DATE - April, 2001

Submitted:

September 19, 2002



Contract Number: DTNH22-94-D-17058

Prepared for:

U.S. Department of Transportation  
National Highway Traffic Safety Administration  
National Center for Statistics and Analysis  
Washington, D.C. 20590-0003

## **DISCLAIMERS**

This document is disseminated under the sponsorship of the Department of Transportation in the interest of information exchange. The United States Government assumes no responsibility for the contents or use thereof.

The opinions, findings, and conclusions expressed in this publication are those of the authors and not necessarily those of the National Highway Traffic Safety Administration.

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

<p>1. <i>Report No.</i> IN01-012</p>	<p>2. <i>Government Accession No.</i></p>	<p>3. <i>Recipient's Catalog No.</i></p>	
<p>4. <i>Title and Subtitle</i> On-Site Advanced Occupant Protection Systems Investigation Vehicle - 2001 Ford Taurus SES Location - Missouri</p>		<p>5. <i>Report Date:</i> September 19, 2002</p>	
		<p>6. <i>Performing Organization Code</i></p>	
<p>7. <i>Author(s)</i> Special Crash Investigations Team #2</p>		<p>8. <i>Performing Organization Report No.</i> Task # 0258</p>	
<p>9. <i>Performing Organization Name and Address</i> Transportation Research Center Indiana University 222 West Second Street Bloomington, Indiana 47403-1501</p>		<p>10. <i>Work Unit No. (TRAIS)</i></p>	
		<p>11. <i>Contract or Grant No.</i> DTNH22-94-D-17058</p>	
<p>12. <i>Sponsoring Agency Name and Address</i> U.S. Department of Transportation (NRD-32) National Highway Traffic Safety Administration National Center for Statistics and Analysis Washington, D.C. 20590-0003</p>		<p>13. <i>Type of Report and Period Covered</i> Technical Report Crash Date: April, 2001</p>	
		<p>14. <i>Sponsoring Agency Code</i></p>	
<p>15. <i>Supplementary Notes</i> On-site air bag deployment investigation involving a 2001 Ford Taurus SE, four-door sedan, with manual safety belts and advanced occupant protection systems, and a 1995 Peterbilt truck-tractor and semi-trailer</p>			
<p>16. <i>Abstract</i> This report covers an on-site investigation of an air bag deployment crash that involved a 2001 Ford Taurus SES (case vehicle) and a 1995 Peterbilt truck-tractor with Wabash semi-trailer (other vehicle). This crash is of special interest because the case vehicle was equipped with multiple <b>A</b>dvanced <b>O</b>ccupant <b>P</b>rotection <b>S</b>ystem (AOPS) features and the case vehicle's driver (37-year-old female) sustained serious injuries, resulting in her death. The case vehicle was traveling east in a left-hand curve in the outside eastbound lane of a four-lane, divided, U.S. Interstate trafficway (i.e., both the east and westbound roadways had two through lanes). The other vehicle was stopped and disabled, heading eastward, on the south shoulder of the eastbound roadway of the same, U.S. Interstate trafficway. The crash occurred on the south shoulder of the eastbound roadway. The front of the case vehicle impacted the back left of the Wabash semi-trailer, causing the case vehicle's driver and front right passenger supplemental restraints (air bags) to deploy. The case vehicle's front end initially contacted the trailer's underride guard, bending it under, before continuing under the trailer and impacting the rear tandem wheels. Upon impacting the left rear tandem wheels, the case vehicle rotated approximately 35 degrees clockwise off the trailer and moved in an east-northeasterly direction before coming to rest in the inside eastbound through lane, heading southeastward. The case vehicle's driver was seated with her seat track located between its middle and forward-most positions, and the exact position of the tilt steering wheel could not be determined because of the intrusion and deformation. She was restrained by her available, active, three-point, lap-and-shoulder, safety belt system and sustained, according to her non-invasive, post-mortem examination, serious injuries which included: a left hemothorax; fractures to the frontal bone-involving both the calvarium and the anterior cranial fossa, the left mandible, and an unidentified pubic bone; a pneumocephalus; lacerations to her frontal scalp-near her hair line with disruption of her scalp, left and mid-forehead, and left jaw; abrasions to her whole face, upper neck, right arm and forearm, left forearm, left knee, and left lower leg; and contusions to her chest (multiple), right and left hips, anterior right and left thighs, and right and left lower legs. This occupant's primary brain and skull injuries were caused by the intruding back of the semi-trailer and/or the case vehicle's greenhouse components (i.e., roof, windshield header, etc.).</p>			
<p>17. <i>Key Words</i> Advanced Air Bags Deployment</p>		<p>18. <i>Distribution Statement</i> General Public</p>	
<p>19. <i>Security Classif. (of this report)</i> Unclassified</p>		<p>20. <i>Security Classif. (of this page)</i> Unclassified</p>	
<p>21. <i>No. of Pages</i> 15</p>		<p>22. <i>Price</i> \$9,000</p>	

**TABLE OF CONTENTS**

IN01-012

Page No.

BACKGROUND . . . . . 1

SUMMARY . . . . . 1

CRASH CIRCUMSTANCES . . . . . 4

CASE VEHICLE: 2001 FORD TAURUS SES . . . . . 6

    CASE VEHICLE DAMAGE . . . . . 7

    AUTOMATIC RESTRAINT SYSTEM . . . . . 9

    RESTRAINTS CONTROL MODULE . . . . . 11

    CASE VEHICLE DRIVER KINEMATICS . . . . . 11

    CASE VEHICLE DRIVER INJURIES . . . . . 12

OTHER VEHICLE: 1995 PETERBILT TRUCK-TRACTOR WITH WABASH SEMI-TRAILER . . . . 14

CRASH DIAGRAM . . . . . 15

SELECTED PHOTOGRAPHS

    Figure 1: On-scene westerly view from south shoulder showing case vehicle's pre-crash travel path . . . . . 5

    Figure 2: On-scene view looking southeastward at damage to Wabash semi-trailer . . . . . 5

    Figure 3: Reference line view from right of case vehicle's severe frontal damage and end displacement . . . . . 5

    Figure 4: On-scene view looking east at damage to stopped trailer's back surface and underride guard . . . . . 6

    Figure 5: On-scene view looking northeastward showing distance from case vehicle's impact to final rest position . . . . . 6

    Figure 6: On-scene view of case vehicle at final rest . . . . . 6

    Figure 7: Close-up of case vehicle's severe frontal damage . . . . . 7

    Figure 8: Overhead view of case vehicle's severe frontal and front end displacement . . . . . 7

    Figure 9: Frontal view of damage to case vehicle's front showing narrow Field L because of front end displacement . . . . . 7

SELECTED PHOTOGRAPHS (Continued)

Figure 10:	Overhead view of case vehicle's severe frontal damage and sheared roof taken from atop trunk . . . . .	7
Figure 11:	Intrusion and damage to case vehicle's lower instrument panel and driver knee bolster . . . . .	8
Figure 12:	Case vehicle's front right instrument panel showing evidence of contact . . . . .	9
Figure 13:	Close-up of probable contact to front right instrument panel . . . . .	9
Figure 14:	Close-up of intrusion to case vehicle's left instrument panel . . . . .	9
Figure 15:	Case vehicle's deployed driver air bag . . . . .	10
Figure 16:	Close-up of case vehicle's right instrument panel which was torn off during underride impact with Wabash semi-trailer . . . . .	10
Figure 17:	Front surface of case vehicle's front right passenger air bag showing discolorations . . . . .	10
Figure 18:	Case vehicle's deployed front right passenger air bag and removed air bag module showing tear to vent port . . . . .	11
Figure 19:	Case vehicle's distorted steering wheel and driver air bag . . . . .	11
Figure 20:	On-scene view looking southward at Wabash semi-trailer's under-ride damage and case vehicle's forward penetration . . . . .	12

This on-site investigation was brought to NHTSA's attention on April 19, 2001 via the Missouri Highway Patrol's Crash Report Web site. This crash involved a 2001 Ford Taurus SES (case vehicle) and a 1995 Peterbilt truck-tractor with Wabash semi-trailer (other vehicle). The crash occurred in April, 2001, at 12:25 p.m., in Missouri and was investigated by the applicable police department. This crash is of special interest because the case vehicle was equipped with multiple Advanced Occupant Protection System(AOPS) features and the case vehicle's driver [37-year-old, White (non-Hispanic) female] sustained serious injuries, resulting in her death. This contractor inspected the scene and vehicles on April 25, 2001. Because the case vehicle's only occupant (i.e., the driver) had expired, this contractor was able to interview the investigating police officer on May 14, 2001. This report is based on the Police Crash and Reconstruction Reports, an interview with the investigating police officer, scene and vehicle inspections, occupant kinematic principles, the non-invasive post-mortem examination performed on the driver, and this contractor's evaluation of the evidence.

## SUMMARY

The case vehicle was traveling east in a left-hand curve in the outside eastbound lane of a four-lane, divided, U.S. Interstate trafficway and presumably intended to continue traveling eastbound (i.e., both the east and westbound roadways had two through lanes). The other vehicle was stopped and disabled, heading eastward, on the south shoulder of the eastbound roadway of the same, U.S. Interstate trafficway. The case vehicle's driver made no avoidance maneuvers prior to the crash. The crash occurred on the south shoulder of the eastbound roadway; see **CRASH DIAGRAM** below.

The front of the case vehicle impacted the back left of the Wabash semi-trailer, causing the case vehicle's driver and front right passenger supplemental restraints (air bags) to deploy. The case vehicle's front end initially contacted the trailer's underride guard, bending it under, before continuing under the trailer and impacting the rear tandem wheels. Upon impacting the left rear tandem wheels, the case vehicle rotated approximately 35 degrees clockwise off the trailer and moved in a east-northeasterly direction before coming to rest in the inside eastbound through lane, heading southeastward.

The 2001 Ford Taurus SES was a front wheel drive, four-door sedan (VIN: 1FAFP55S91A-----). The case vehicle was equipped with anti-lock brakes. Based on the vehicle inspection, the CDC for the case vehicle was determined to be: **12-FDAA-7 (0)**. The WinSMASH reconstruction program, barrier algorithm, was used on the case vehicle's highest severity impact. The Total, Longitudinal, and Lateral Delta Vs are, respectively: 132.4 km.p.h. (82.3 m.p.h.), -132.4 km.p.h. (-82.3 m.p.h.), and 0.0 km.p.h. (0.0 m.p.h.). These results should be considered reasonable but most likely higher than expected since the struck object was out of the scope of the reconstruction program and the case vehicle was so radically distorted that the measurement protocol is inadequate. In this contractor's opinion, this crash is beyond the scope of any crush energy-based reconstruction. Based on the police reconstruction, the case vehicle was traveling near the posted 113 km.p.h. (70 m.p.h.) speed limit. The case vehicle was towed due to damage.

The case vehicle's initial contact with the trailer involved approximately the right two-thirds of its front. Direct damage began 34 centimeters (13.4 inches) left of the vehicle's center line (toward driver's side) and extended, a measured distance of 110 centimeters (43.3 inches), to the front right bumper corner (i.e., passenger's side). The case vehicle's off-set impact resulted in the whole front end being displaced to the right approximately 90 degrees. Maximum crush was measured as 214 centimeters (84.3 inches) at C<sub>2</sub>. It should be noted that because of the displacement of the front left bumper, only two C-measurements could be made. The wheelbase on the case vehicle's right side was shortened 147 centimeters (57.9 inches) while the left side was extended 14 centimeters (5.5 inches). The case vehicle's front bumper, bumper fascia, grille, hood, radiator, right fender, and right headlight and turn signal assemblies and were directly damaged and crushed rearward. The direct damage width above the bumper at the roof line was approximately 74 centimeters (29.1 inches). The case vehicle's underride impact with the trailer was so severe, that the entire roof along with the right "A", "B", and "C"-pillars were peeled back from the front windshield header rearward to the case vehicle's right rear bumper corner. The entire right front door and right rear door skins were also pulled off the case vehicle. The case vehicle's left and right front tires were physically restricted with the right front tire being deflated. The right front tire was pushed backwards into the front right occupant seating area. The left headlight and turn signal assemblies sustained induced damage as well as the left fender. Remote buckling was also found on the driver's door and the roof.

The case vehicle's driver air bag was located in the steering wheel hub. An inspection of the air bag module's cover flaps and air bag fabric revealed that the cover flaps opened at the designated tear points, and there was no evidence of damage during the deployment to the air bag or the cover flaps. The driver's air bag was designed with two tethers, each 12 centimeters (4.7 inches) wide, located at the 11-1 and 5-7 o'clock positions. The driver's air bag had two vent ports, approximately 3 centimeters (1.2 inches) in diameter, located at the 11 and 1 o'clock positions. The deployed driver's air bag was round with a diameter 55 centimeters (21.7 inches). An inspection of the driver's air bag revealed a oily area just off the center of the air bag toward the 4 o'clock position. In addition, there were scattered blood spots on the perimeter of the driver's air bag. There were two spots located near the 6 o'clock and a large bloody area between the 4 and 5 o'clock positions.

The front right passenger's air bag was located in the top of the instrument panel. An inspection of the front right air bag module's cover flap and air bag fabric revealed that the top portion of the right instrument panel, including the entire air bag module, had been torn out of the instrument panel as the vehicle underrode the Wabash semi-trailer. The inspection further revealed that the cover flaps opened at the designated tear points, and there was no evidence of damage during the deployment to the cover flap. However, the air bag's fabric showed discoloration, but the origin of the discoloration is unclear (e.g., possibly contact with the under surface of the roof's head liner). Furthermore, the air bag's vent port was torn open an additional 8 centimeters (3.1 inches). The front right passenger air bag was designed without any tethers. The front right air bag had one vent port, approximately 5 centimeters (2.0 inches) in diameter, located at the 2 o'clock position. The deployed front right air bag was rectangular with a height of approximately 41 centimeters (16.1 inches) and a width of approximately 58 centimeters (22.8

inches). An inspection of the front right passenger's air bag fabric reveal that there was no contact evidence readily apparent on the air bag's fabric.

The case vehicle was equipped with multiple **A**dvanced **O**ccupant **P**rotection **S**ystem(AOPS) features which included a **R**estraints **C**ontrol **M**odule (RCM), seat track positioning sensors, dual stage air bag inflators, and a seat belt pretensioner with seat belt load limiter. The case vehicle was not equipped with adjustable foot pedals. The **RCM** was removed and sent to Ford for analysis. According to the analysis, the case vehicle's electrical current was lost during the impact and there was no data recorded in the **RCM** for this crash.

Inspection of the case vehicle's interior revealed two other areas that indicated evidence driver contact. The driver's knee bolster showed scuffs, evidence of contact by the driver's knees, and the right instrument panel revealed blood and skin, most likely from contact with the driver's upper body. Furthermore, there was an area of unknown body fluid splattered on the rear surface of the back seat's back support that was initially suspected to be brain matter; however, the available injury information does not support that possibility. Finally, the intrusion was catastrophic to the majority of the case vehicle's front occupant seating areas, but there was no deformation to the steering wheel rim. The steering wheel's shear capsule and break-away coupling were both completely separated.

The 1995 Peterbilt was a rear wheel drive, 6 x 4, two-door, conventional cab, truck-tractor (VIN: 1XP5DB8X1SN-----) with a Wabash box semi-trailer (VIN: 1JJE532SXVL-----). Based on the vehicle inspection, the TDC for the semi-trailer was determined to be: **06-BLLE-A (180)**. The Peterbilt truck-tractor was driven from the scene, but the Wabash semi-trailer was towed due to damage.

Immediately prior to the crash, the posture of the case vehicle's driver (173 centimeters and 56 kilograms (68 inches, 123 pounds)) is unknown but, presumably, she was seated in an upright posture with her back against the seat back, her left foot on the floor, her right foot on the accelerator, and at least one hand on the steering wheel. Her seat track was located between its middle and forward-most positions, the seat back was upright, and the exact position of the tilt steering wheel could not be determined because of the intrusion and deformation.

The case vehicle's driver was restrained by her available, active, three-point, lap-and-shoulder, safety belt system. Furthermore, the inspection of the driver's seat belt webbing, "D"-ring, and latch plate showed evidence of loading.

Based on the lack of pre-crash scene evidence, the case vehicle's driver made no known pre-crash avoidance maneuvers. As a result and independent of the use of her available safety belts, her pre-impact body position did not change just prior to impact. The case vehicle's impact with the semi-trailer enabled the case vehicle's driver to initially continue forward toward the **0** degree Direction of Principal Force as the case vehicle decelerated. As the case vehicle continued underneath the semi-trailer it began to rotate slightly clockwise because the forward motion of the right side of the case vehicle was being resisted while the left side was attempting to continue at its pre-crash speed. As a result of this impact, the case vehicle's driver moved slightly forward,



loading her safety belts. In this contractor's opinion, based upon the limited injury information, the scalp at the top of the driver's forehead and probably her forehead contacted the back left bottom corner of the semi-trailer, lacerating her scalp and forehead and fracturing her frontal bone. In this contractor's opinion, the penetration of the trailer's corner through the windshield's glazing preceded the collapse of the case vehicle's roof which followed the penetration. As the roof collapsed, the roof, front windshield header, sun visor, and possibly the left "A"-pillar moved downward and backward and also may have contacted the driver's head and scalp as they were being peeled backwards. The driver's impact with the back lower left corner of the semi-trailer most likely knocked the driver backwards into her seat back, where she was at the moment the driver's air bag deployed.

When the case vehicle impacted the back of the trailer's rear tandem wheels, combined with the shearing of the vehicle's right side pillars, the case vehicle reached maximum engagement and rotated rapidly clockwise underneath the semi-trailer. The impact with the semi-trailer was so severe that it caused the left back outside wheel's rim to be deformed. The impact with the back wheels most likely caused the case vehicle's air bags to deploy. As a result of the impact with the back wheels, the driver moved back forward, loading her safety belts and contacting the deploying driver's air bag. In addition, the driver may have moved leftward as the case vehicle rotated underneath her. Likewise, the driver may have moved leftward as a result of contact by the intruding components. Because of the massive intrusion, the case vehicle's driver impacted the knee bolster with her knees and the intruding steering wheel, most likely with the right side of her chest, as the steering column was rotated almost 90 degrees clockwise from its original position. In this contractor's opinion, the separation of the steering column's shear capsules was a result of the intrusion and not a result of occupant loading. Based on the physical evidence, the intruding right instrument panel may have also contacted the driver's face/head or torso, but the exact interaction cannot be determined based on the limited medical information. In any case, the driver was knocked backwards, once again, where, at final rest, the case vehicle's driver was found pinned against the left front door panel by the intruding steering wheel and instrument panel.

The driver was transported by ambulance to the hospital. She sustained serious injuries and was pronounced dead at the hospital by the county medical examiner approximately five hours post-crash. Based upon the non-invasive, post-mortem examination, the injuries sustained by the case vehicle's driver included: a left hemothorax; fractures to the frontal bone—involving both the calvarium and the anterior cranial fossa, the left mandible, and an unidentified pubic bone; a pneumocephalus; lacerations to her frontal scalp—near her hair line with disruption of her scalp, left and mid-forehead, and left jaw; abrasions to her whole face, upper neck, right arm and forearm, left forearm, left knee, and left lower leg; and contusions to her chest (multiple), right and left hips, anterior right and left thighs, and right and left lower legs. This occupant's primary brain and skull injuries were caused by the intruding back of the semi-trailer and/or the case vehicle's greenhouse components (i.e., roof, windshield header, etc.).

## **CRASH CIRCUMSTANCES**

The case vehicle was traveling east in a left-hand curve in the outside eastbound lane of a four-lane, divided, U.S. Interstate trafficway (**Figure 1** below) and presumably intended to

continue traveling eastbound (i.e., both the east and westbound roadways had two through lanes). The other vehicle was stopped and disabled, heading eastward, on the south shoulder of the eastbound roadway of the same, U.S. Interstate trafficway (**Figure 2**). The case vehicle's driver made no avoidance maneuvers prior to the crash. The crash occurred on the south shoulder of the eastbound roadway; see **CRASH DIAGRAM** below.



**Figure 1:** On-scene westerly view from front of where Peterbilt truck-tractor was stopped and disabled showing case vehicle's pre-crash travel path in left-hand curve; Note: evidence indicates that case vehicle's driver failed to negotiate the curve (case photo #51)



**Figure 2:** On-scene view looking southeastward at damage to trailer portion of tractor-trailer that was stopped and disabled along south shoulder; Note: windshield glazing hanging from trailer's left rear door (case photo #42)

The interstate highway was curved to the left for eastbound traffic [i.e., police investigation, using total station technology, determined that the radius of curvature was 805.9 meters (2,644.0 feet)] and level (i.e., actual slope was approximately 1.0%, negative to the east) at the area of impact. The pavement was bituminous, but traveled, and the width of the roadway was approximately 7.3 meters (24 feet). The shoulders were improved (i.e., bituminous), with a 1.1 meter (3.5 foot) wide paved shoulder on the north side, prior to the 10.1 meter (33 foot) wide grassy median, and a 3.0 meter (10 foot) paved shoulder on the south side. The median had a cable barrier along the center to retard vehicle's from crossing the median. Pavement markings for the roadway consisted of a solid yellow edge line on the north side and a solid white edge line on south side. In addition, the through lanes were divided by a dashed white line. The estimated coefficient of friction was 0.72 for the outside eastbound lane and 0.74 for the south shoulder. There were no visible traffic controls in the immediate area of the crash. The posted speed limit was 113 km.p.h. (70 m.p.h.). At the time of the crash the light condition was daylight, the atmospheric condition was cloudy, and the road pavement was dry. Traffic density was light (i.e., given that no one reported seeing the crash occur), and the site of the crash was rural agricultural.



**Figure 3:** Reference line view from right showing case vehicle's severe frontal deformation and rightward end displacement (case photo #11)

The front (**Figure 3** above) of the case vehicle impacted the back left of the Wabash semi-trailer (**Figure 2** above), causing the case vehicle's driver and front right passenger supplemental restraints (air bags) to deploy. The case vehicle's front end initially contacted the trailer's underride guard, bending it under (**Figure 4**), before continuing under the trailer and impacting the rear tandem wheels. Upon impacting the left rear tandem wheels, the case vehicle rotated approximately 35 degrees clockwise off the trailer and moved in a east-northeasterly direction before coming to rest (**Figures 5 and 6**) in the inside eastbound through lane, heading southeastward.



**Figure 4:** On-scene view looking east at damage to stopped trailer's back surface and underride guard (case photo #43)



**Figure 5:** On-scene view looking northeastward showing distance from case vehicle's impact with trailer's back to area of final rest (case photo #44)



**Figure 6:** On-scene view of case vehicle at final rest, straddling the inside eastbound lane heading southeastward; Note: roof peeled back from severe underride damage (case photo #49)

**CASE VEHICLE**

The 2001 Ford Taurus SES was a front wheel drive, five-passenger, four-door sedan (VIN: 1FAFP55S91A-----) equipped with a 3.0L, V-6 engine and a four-speed automatic transmission. Braking was achieved by a power-assisted, front disc and rear drum, four-wheel, anti-lock system. The case vehicle's wheelbase was 276 centimeters (108.5 inches), and the odometer reading at inspection was 1,036 kilometers (644 miles).

Inspection of the vehicle's interior revealed adjustable front bucket seats with adjustable head restraints that were damaged from the collision; a non-adjustable back bench seat without head restraints for the back seating positions; and a continuous loop, three-point, lap-and-shoulder, safety belt systems at the front outboard and all three back seating positions. The front seat belt systems were equipped with manually operated, upper anchorage adjusters for the "D"-rings. The driver upper anchorage adjuster was located in the down-most position. The position of the upper anchorage adjuster for the front right seating position was not determinable because of damage. The vehicle was equipped with knee bolsters for both the driver and front right passenger. There

was contact evidence on the driver's knee bolster both left and right of the steering column. Automatic restraint was provided by a Supplemental Restraint System (SRS) that consisted of a frontal air bag for the driver and front right passenger seating positions. Both frontal air bags deployed as a result of the case vehicle's frontal impact with the Wabash semi-trailer.

**CASE VEHICLE DAMAGE**



**Figure 7:** Close-up of case vehicle's severe frontal damage; Note: tape indicates direct damage width (case photo #05)



**Figure 8:** Overhead view of case vehicle's severe frontal damage with contour gauge present; Note: front has narrow field "L" that faces primarily downward (case photo #09)



**Figure 9:** Frontal view of damage to case vehicle's front with contour gauge present; Note: narrow field "L" because front end was displaced almost 90 degrees to the right (case photo #08)

The case vehicle's initial contact with the trailer involved approximately the right two-thirds of its front (**Figures 7 and 8**). Direct damage began 34 centimeters (13.4 inches) left of the vehicle's center line (toward driver's side) and extended, a measured distance of 110 centimeters (43.3 inches), to the front right bumper corner (i.e., passenger's side—**Figure 7**). The case vehicle's off-set impact resulted in the whole front end being displaced to the right approximately 90



**Figure 10:** Overhead view of case vehicle's severe frontal deformation and intrusion; Note: photo taken while standing on trunk (case photo #40)

degrees (**Figure 9** above). Maximum crush was measured as 214 centimeters (84.3 inches) at C<sub>2</sub>. It should be noted that because of the displacement of the front left bumper, only two C-measurements could be made (**Figures 8** and **9** above). The wheelbase on the case vehicle's right side was shortened 147 centimeters (57.9 inches) while the left side was extended 14 centimeters (5.5 inches). The case vehicle's front bumper, bumper fascia, grille, hood, radiator, right fender, and right headlight and turn signal assemblies and were directly damaged and crushed rearward. The direct damage width above the bumper at the roof line was approximately 74 centimeters (29.1 inches). The case vehicle's underride impact with the trailer was so severe, that the entire roof along with the right "A", "B", and "C"-pillars were peeled back from the front windshield header rearward to the case vehicle's right rear bumper corner (**Figure 10** above). The entire right front door and right rear door skins were also pulled off the case vehicle. The case vehicle's left and right front tires were physically restricted with the right front tire being deflated. The right front tire was pushed backwards into the front right occupant seating area. The left headlight and turn signal assemblies sustained induced damage as well as the left fender. Remote buckling was also found on the driver's door and the roof.

Inspection of the case vehicle's interior revealed two other areas that indicated evidence driver contact. The driver's knee bolster showed scuffs, evidence of contact by the driver's knees (**Figure 11**), and the right instrument panel revealed blood and skin, most likely from contact with the driver's upper body (**Figures 12** and **13** below). Furthermore, there was an area of unknown body fluid splattered on the rear surface of the back seat's back support that was initially suspected to be brain matter; however, the available injury information does not support that possibility. Finally, the intrusion was catastrophic to the majority of the case vehicle's front occupant seating areas (**Figure 14** below), but there was no deformation to the steering wheel rim. The steering wheel's shear capsule and break-away coupling were both completely separated.



**Figure 11:** Intrusion and deformation to case vehicle's lower instrument panel and knee bolster for driver's seating area (case photo #25)

Based on the vehicle inspection, the CDC for the case vehicle was determined to be: **12-FDAA-7 (0)**. The WinSMASH reconstruction program, barrier algorithm, was used on the case vehicle's highest severity impact. The Total, Longitudinal, and Lateral Delta Vs are, respectively: 132.4 km.p.h. (82.3 m.p.h.), -132.4 km.p.h. (-82.3 m.p.h.), and 0.0 km.p.h. (0.0 m.p.h.). These results should be considered reasonable but most likely higher than expected since the struck object was out of the scope of the reconstruction program and the case vehicle was so radically distorted that the measurement protocol is inadequate. In this contractor's opinion, this crash is beyond the scope of any crush energy-based reconstruction. Based on the police reconstruction, the case vehicle was traveling near the posted 113 km.p.h. (70 m.p.h.) speed limit. The case vehicle was towed due to damage.



**Figure 12:** Case vehicle's front right instrument panel showing evidence of contact (circled) by case vehicle's driver (case photo #28)



**Figure 13:** Close-up of contact to front right instrument panel from case vehicle's driver (case photo #29)



**Figure 14:** Close-up of intrusion to case vehicle's driver instrument panel and toe pan areas (case photo #26)

## AUTOMATIC RESTRAINT SYSTEM

The case vehicle was equipped with a Supplemental Restraint System (SRS) that contained frontal air bags at the driver and front right passenger positions. Both frontal air bags deployed as a result of the front right impact with the Wabash semi-trailer. The case vehicle's driver air bag was located in the steering wheel hub. The module cover consisted of asymmetrical, trapezoidal shaped, "H"-configuration cover flaps made of thick vinyl with overall dimensions of 17 centimeters (6.7 inches) at the common horizontal seam and 8 centimeters (3.1 inches) vertically for the upper flap and 5 centimeters (2.0 inches) vertically for the lower flap. Both the upper and lower flaps were trapezoidal in shape and arranged in a mirror image configuration. The width of the upper cover flap's top horizontal seam was 15 centimeters (5.9 inches), and the width of the lower cover flap's bottom horizontal seam was 12 centimeters (4.7 inches). An inspection of the air bag module's cover flaps and air bag fabric revealed that the cover flaps opened at the designated tear points, and there was no evidence of damage during the deployment to the air bag or the cover flaps. The driver's air bag was designed with two tethers, each 12 centimeters (4.7 inches) wide, located at the 11-1 and 5-7 o'clock positions. The driver's air bag had two vent ports, approximately 3 centimeters (1.2 inches) in diameter, located at the 11 and 1 o'clock positions. The deployed driver's air bag was round with a diameter 55 centimeters (21.7 inches). An inspection of the driver's air bag revealed a oily area just off the center of the air bag

toward the 4 o'clock position. In addition, there were scattered blood spots on the perimeter of the driver's air bag. There were two spots located near the 6 o'clock and a large bloody area between the 4 and 5 o'clock positions (**Figure 15**).

The front right passenger's air bag was located in the top of the instrument panel. There was a single, essentially trapezoidal, modular cover flap. The cover flap was made of a thick vinyl over a thick cardboard type frame. The flap's dimensions were: 27.5 centimeters (10.8 inches) at the forward horizontal seam, 13 centimeters (5.1 inches) along the right vertical seam, and 9 centimeters (3.5 inches) along the left vertical seam. The distance along the angled rear (i.e., toward the windshield) horizontally oriented seam was not recorded. The profile of the case vehicle's instrument panel resulted in a 3 centimeter (1.2 inch) setback of the leading edge of the cover flap relative to the protruding right instrument panel. An inspection of the front right air bag module's cover flap and air bag fabric revealed that the top portion of the right instrument panel, including the entire air bag module, had been torn out of the instrument panel (**Figure 16**) as the vehicle underrode the Wabash semi-trailer. The inspection further revealed that the cover flaps opened at the designated tear points, and there was no evidence of damage during the deployment to the cover flap. However, the air bag's fabric showed discoloration (**Figure 17**), but the origin of the discoloration is unclear (e.g., possibly contact with the under surface of the roof's head liner). Furthermore, the air bag's vent port was torn open (**Figure 18** below) an additional 8 centimeters (3.1 inches).



**Figure 15:** Case vehicle's driver air bag showing only a blood transfer on air bag (case photo #32)



**Figure 16:** Close-up of case vehicle's right instrument panel which was torn off during underide of trailer; Note: front right air bag module's cover flap (case photo #38)



**Figure 17:** Front surface of case vehicle's front right passenger air bag showing discoloration to air bag's fabric as a result of crash (case photo #36)

The front right passenger air bag was designed without any tethers. The front right air bag had one vent port, approximately 5 centimeters (2.0 inches) in diameter, located at the 2 o'clock position. The deployed front right air bag was rectangular with a height of approximately 41 centimeters (16.1 inches) and a width of approximately 58 centimeters (22.8 inches). An inspection of the front right passenger's air bag fabric reveal that there was no contact evidence readily apparent on the air bag's fabric.

The case vehicle was equipped with multiple **A**dvanced **O**ccupant **P**rotection **S**ystem(AOPS) features which included a **R**estraints **C**ontrol **M**odule (RCM), seat track positioning sensors, dual stage air bag inflators, and a seat belt pretensioner with seat belt load limiter. The case vehicle was not equipped with adjustable foot pedals. The **RCM** was removed and sent to Ford for analysis. According to the analysis, the case vehicle's electrical current was lost during the impact and there was no data recorded in the **RCM** for this crash.

**CASE VEHICLE DRIVER KINEMATICS**

Immediately prior to the crash, the posture of the case vehicle's driver (173 centimeters and 56 kilograms (68 inches, 123 pounds)) is unknown but, presumably, she was seated in an upright posture with her back against the seat back, her left foot on the floor, her right foot on the accelerator, and at least one hand on the steering wheel. Her seat track was located between its middle and forward-most positions, the seat back was upright, and the exact position of the tilt steering wheel could not be determined because of the intrusion and deformation (**Figure 19**).

The case vehicle's driver was restrained by her available, active, three-point, lap-and-shoulder, safety belt system. Furthermore, there was possible evidence of belt pattern bruising to the driver's body, and the inspection of the driver's seat belt webbing, "D"-ring, and latch plate showed evidence of loading.

Based on the lack of pre-crash scene evidence, the case vehicle's driver made no known pre-crash avoidance maneuvers. As a result and independent of the use of her available safety belts, her pre-impact body position did not change just prior to impact. The case vehicle's impact with the semi-trailer enabled the case vehicle's driver to initially continue forward toward the **0** degree Direction of Principal Force as the case vehicle decelerated. As the case vehicle continued underneath the semi-trailer it began to rotate slightly clockwise because the forward motion of the



**Figure 18:** Case vehicle's deployed front right passenger air bag and removed air bag module showing tear to vent port (case photo #35)



**Figure 19:** Case vehicle's steering wheel and driver air bag viewed while looking rearward down left side of vehicle (case photo #27)



right side of the case vehicle was being resisted while the left side was attempting to continue at its pre-crash speed. As a result of this impact, the case vehicle's driver moved slightly forward, loading her safety belts. In this contractor's opinion, based upon the limited injury information, the scalp at the top of the driver's forehead and probably her forehead contacted the back left bottom corner of the semi-trailer, lacerating her scalp and forehead and fracturing her frontal bone. In this contractor's opinion, the penetration of the trailer's corner through the windshield's glazing preceded the collapse of the case vehicle's roof which followed the penetration (**Figures 2 and Figures 4 and 5** above). As the roof collapsed, the roof, front windshield header, sun visor, and possibly the left "A"-pillar moved downward and backward and also may have contacted the driver's head and scalp as they were being peeled backwards. The driver's impact with the back lower left corner of the semi-trailer most likely knocked the driver backwards into her seat back, where she was at the moment the driver's air bag deployed.

When the case vehicle impacted the back of the trailer's rear tandem wheels, combined with the shearing of the vehicle's right side pillars, the case vehicle reached maximum engagement and rotated rapidly clockwise underneath the semi-trailer. The impact with the semi-trailer was so severe that it caused the left back outside wheel's rim to be deformed (**Figure 20**). The impact with the back wheels most likely caused the case vehicle's air bags to deploy. As a result of the impact with the back wheels, the driver moved back forward, loading her safety belts and contacting the deploying driver's air bag. In addition, the driver may have moved leftward as the case vehicle rotated underneath her. Likewise, the driver may have moved leftward as a result of contact by the intruding components. Because of the massive intrusion, the case vehicle's driver impacted the knee bolster with her knees and the intruding steering wheel, most likely with the right side of her chest, as the steering column was rotated almost 90 degrees clockwise from its original position. In this contractor's opinion, the separation of the steering column's shear capsules was a result of the intrusion and not a result of occupant loading. Based on the physical evidence, the intruding right instrument panel may have also contacted the driver's face/head or torso, but the exact interaction cannot be determined based on the limited medical information. In any case, the driver was knocked backwards, once again, where, at final rest, the case vehicle's driver was found pinned against the left front door panel by the intruding steering wheel and instrument panel.



**Figure 20:** On-scene view looking southward at struck trailer showing trailer's underride damage and case vehicle's forward penetration to left rear tandem wheels; Note: rim damage to trailer's left back outside wheel (case photo #48)

### **CASE VEHICLE DRIVER INJURIES**

The driver was transported by ambulance to the hospital. She sustained serious injuries and was pronounced dead at the hospital by the county medical examiner approximately five hours post-crash. Based upon the non-invasive, post-mortem examination, the injuries sustained by the

**Case Vehicle Front Right Passenger Injuries (Continued)**

IN01-012

case vehicle's driver included: a left hemothorax; fractures to the frontal bone—involving both the calvarium and the anterior cranial fossa, the left mandible, and an unidentified pubic bone; a pneumocephalus; lacerations to her frontal scalp—near her hair line with disruption of her scalp, left and mid-forehead, and left jaw; abrasions to her whole face, upper neck, right arm and forearm, left forearm, left knee, and left lower leg; and contusions to her chest (multiple), right and left hips, anterior right and left thighs, and right and left lower legs. This occupant's primary brain and skull injuries were caused by the intruding back of the semi-trailer and/or the case vehicle's greenhouse components (i.e., roof, windshield header, etc.).

Injury Number	Injury Description (including Aspect)	NASS Injury Code & AIS 90	Injury Source (Mechanism)	Source Confidence	Source of Injury Data
1	Hemothorax left, not further specified	442202.3 serious	Steering wheel rim	Probable	Post-mortem examination
2	Fracture anterior cranial fossa, not further specified	150200.3 serious	Back surface of semi-trailer <sup>1</sup>	Probable	Post-mortem examination
3	Pneumocephalus present (determined by imaging)	140682.3 serious	Back surface of semi-trailer <sup>1</sup>	Probable	Post-mortem examination
4	Fracture frontal bone <sup>2</sup> {calvarium}, not further specified	150400.2 moderate	Back surface of semi-trailer <sup>1</sup>	Probable	Post-mortem examination
5	Fracture left mandible <sup>2</sup> , location not specified	250600.1 minor	Unknown contact mechanism	Unknown	Post-mortem examination
6	Fracture pubic bone, location not specified	852600.2 moderate	Knee bolster, driver's	Possible	Post-mortem examination
7	Lacerations <sup>2</sup> (2) forehead: left forehead, 6 cm (2.4 in), horizontal, extending down to bone mid-forehead, 4 cm (1.6 in), extending down to bone	290602.1 minor	Back surface of semi-trailer <sup>1</sup>	Probable	Post-mortem examination
8	Laceration, 3.5 cm (1.4 in), frontal scalp near hairline, extending down to bone; scalp is undermined	190602.1 minor	Back surface of semi-trailer	Certain	Post-mortem examination
9	Laceration, 3.5 cm (1.4 in), jagged, left chin	290602.1 minor	Unknown contact mechanism	Unknown	Post-mortem examination
10	Abrasions face including right forehead, bilateral cheeks, nose, and left jaw area	290202.1 minor	Front left windshield's glazing	Probable	Post-mortem examination
11	Abrasion midline upper neck	390202.1 minor	Air bag, driver's	Probable	Post-mortem examination

<sup>1</sup> It is possible that this injury resulted from contact with the semi-trailer's underride guard.

<sup>2</sup> These fractures were probably compound. See applicable lacerations; however, no linkage was made by the Medical Examiner.

Injury Number	Injury Description (including Aspect)	NASS Injury Code & AIS 90	Injury Source (Mechanism)	Source Confidence	Source of Injury Data
12	Contusions, multiple, over chest area, not further specified	490402.1 minor	Steering wheel hub and/or spokes and rim	Probable	Post-mortem examination
13	Abrasions right arm and forearm, not further specified	790202.1 minor	Air bag, driver's	Possible	Post-mortem examination
14	Abrasion left forearm	790202.1 minor	Air bag, driver's	Probable	Post-mortem examination
15	Contusion lateral right hip, location not specified	890402.1 minor	Lap portion of safety belt system	Possible	Post-mortem examination
16	Contusion lateral left hip, location not specified	890402.1 minor	Lap portion of safety belt system	Possible	Post-mortem examination
17	Abrasions left knee	890202.1 minor	Knee bolster, driver's, left of steering column	Certain	Post-mortem examination
18	Abrasions left leg {i.e., lower}, location not specified	890202.1 minor	Left instrument panel and below	Probable	Post-mortem examination
19	Contusions, multiple, anterior surface of right thigh and right leg {i.e., lower}, not further specified	890402.1 minor	Center instrument panel and below	Probable	Post-mortem examination
20	Contusions, multiple, anterior surface of left thigh and left leg {i.e., lower}, not further specified	890402.1 minor	Left instrument panel and below	Probable	Post-mortem examination

## OTHER VEHICLE

Based on the VIN and manufacturer's specifications, the 1995 Peterbilt 379 was a rear wheel drive, 6x4, two-door, conventional cab, truck-tractor (VIN: 1XP5DB8X1SN-----) equipped with a 14.6L (893 in<sup>3</sup>), I-6, Caterpillar diesel engine and a nine-speed manual transmission. Braking was achieved by a power-assisted, air brake system. The Peterbilt's wheelbase and odometer reading are unknown because the Peterbilt was not inspected. The Peterbilt was hauling a 16.2 meter (53 foot) long Wabash box (reefer) semi-trailer (VIN: 1JJE532SXVL-----) equipped with two axles that was 259 centimeters (102 inches) wide.

Based on the vehicle inspection, the TDC for the semi-trailer was determined to be: **06-BLLE-A (180)**. The Peterbilt truck-tractor was driven from the scene, but the Wabash semi-trailer was towed due to damage. It should be noted that the semi-trailer's underride guard was completely ineffective in preventing the case vehicle's forward penetration.

