

**TRANSPORTATION SCIENCES  
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**VERIDIAN ON-SITE REDESIGNED AIR BAG DEPLOYMENT INVESTIGATION  
NASS/SCI COMBO CASE NO. 98-05-008K  
VEHICLE - 1998 CADILLAC DEVILLE CONCOURS  
LOCATION - PENNSYLVANIA  
CRASH DATE- FEBRUARY 1998**

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

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

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<p>16. <i>Abstract</i> A 1998 Cadillac DeVille Concours equipped with a redesigned air bag system, was traveling southbound on a two lane undivided roadway with a posted speed limit of 56 km/h (35 mph) when the driver apparently lost consciousness and crossed into the on-coming traffic. The front right area of the Cadillac struck the front right area of a 1987 Plymouth Reliant, that was traveling northbound. The Cadillac rotated in a counterclockwise direction and traveled a short distance in the westbound leg of the intersection and struck the front of a 1996 Saturn with the left front bumper corner. The Saturn was stopped in the right channelized travel lane for the traffic light.</p> <p>The redesigned frontal air bag system in the Cadillac deployed during the crash sequence with the Plymouth. The unrestrained 65 year old male driver of the Cadillac suffered right lower extremity injuries from contact with the brake pedal, lower instrument panel, and knee bolster and injury of the scalp from contact with the roof head liner during the first impact sequence. He exited his vehicle under his own power and walked a short distance. Rescue arrived within ten minutes and transported him via ambulance to a trauma center where he was treated and released for a fracture of the right foot and soft tissue abrasions.</p>			
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**VERIDIAN ON-SITE REDESIGNED AIR BAG DEPLOYMENT INVESTIGATION  
NASS/SCI COMBO CASE NO. 98-05-008K  
VEHICLE - 1998 CADILLAC DEVILLE CONCOURS  
LOCATION - STATE OF PENNSYLVANIA  
CRASH DATE - FEBRUARY, 1998**

***BACKGROUND***

The National Highway Traffic Safety Administration (NHTSA) was notified of a crash involving a redesigned air bag deployment by the NASS PSU 05 in the month of March 1998. The crash was sampled as a CDS Case No. 98-05-008K. The Field Operations Branch of the NHTSA initially assigned this task as a remote investigation to the Veridian SCI team on March 17, but later upgraded it to an on-site effort after the subject vehicle was located at a salvage yard.

***SUMMARY***

An investigation was conducted into a three vehicle crash that occurred in the month of February 1998 during daylight hours in the State of Pennsylvania. The weather at the time of the crash was dry with no adverse conditions. The crash occurred in a three-leg intersection that was regulated by traffic control lights.

A 1998 Cadillac DeVille Concours equipped with a redesigned air bag system, was traveling southbound on a two lane undivided roadway with a posted speed limit of 56 km/h (35 mph) when the driver apparently lost consciousness and crossed into the on-coming traffic. The front right area of the Cadillac struck the front right area of a 1987 Plymouth Reliant, that was traveling northbound. The Cadillac rotated in a counterclockwise direction and traveled a short distance in the westbound leg of the intersection and struck the front of a 1996 Saturn with the left front bumper corner. The Saturn was stopped in the right channelized travel lane for the traffic light.

The redesigned frontal air bag system in the Cadillac deployed during the crash sequence with the Plymouth. The unrestrained 65 year old male driver of the Cadillac suffered right lower extremity injuries from contact with the brake pedal, lower instrument panel, and knee bolster and injury of the scalp from contact with the roof head liner during the first impact sequence. He exited his vehicle under his own power and walked a short distance. Rescue arrived within ten minutes and transported him via ambulance to a trauma center where he was treated and released for a fracture of the right foot and soft tissue abrasions.

The driver of The Plymouth, a 63 year old female was also transported by ambulance to a medical treatment facility where she was admitted for a laceration and contusion of the liver, contusion of the gallbladder, multiple right rib fractures, and multiple soft issue injuries. She was discharged nine days later. The driver of the Saturn, a 46 year old male, and his 11 year old female right front passenger were not injured. The Cadillac and the Plymouth were towed due to damage while the Saturn was driven from the scene.

**VEHICLE DATA- 1998 CADILLAC DEVILLE CONCOURS**

**Exterior**

The 1998 Cadillac DeVille Concours was equipped with a redesigned frontal air bag system and front door mounted side air bags. The frontal driver and right passenger air bags deployed as the result of the impact with the Plymouth. Exterior damage to the vehicle (refer to Figures 1-3) involved the front bumper, the grille, the hood, both front fenders, the radiator, and displacement of the right front axle. Direct contact began at the right front bumper corner and extended 73.7 cm (29.0") toward the left. The maximum crush of 36.8 cm (14.5") was located at the right front bumper corner.



**Figure 1**- Frontal view of the 1998 Cadillac DeVille Concours



**Figure 2** - View of the right front fender showing extent of frontal crush



**Figure 3** - Left front corner view showing contact damage at the left front bumper corner, left front fender, and left rear fender

There was direct contact damage on the front bumper at the left bumper corner which was attributed to the impact with the Saturn. It measured 8.9 cm (3.5") across the frontal plane and continued 71.1 cm (28.0") along the left front fender.

There was a light sideswiping damage pattern noted to the left rear fender area which measured 29.2 cm (11.5") in length. This was attributed to a second impact with the Saturn.

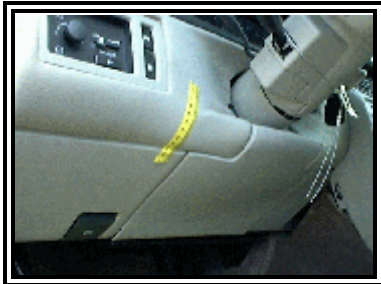
Refer to the following table which categorizes the Cadillac's impacts by the respective Collision Deformation Classification (CDC) codes:

Impact Sequence	Object Contacted	Plane of Contact	CDC
#1	Plymouth Reliant	Front Right	42-FZEW-2
#2	Saturn	Left Frontal	12-FLES-3
#3	Saturn	Left Side Plane	12-LBMS-1

The WinSMASH computed the delta V of 23.1 km/h (14.4 mph) for the Cadillac and 38.8 km/h (24.1 mph) for the Plymouth. These values appeared to be consistent with the vehicle damage profiles.

### ***Interior***

Interior vehicle damage to the 1998 Cadillac DeVille Concours was attributed to occupant contacts and the deployment of the redesigned frontal air bag system. The left side of the driver side knee bolster which was composed of a rigid vinyl material was dislodged from its anchor point from contact by the driver's left knee during the crash sequence. The lower instrument panel adjacent to the dislodged knee bolster panel was also deformed by the driver's left knee contact (**refer to Figure 4**). There was no steering column displacement detected at the left or right shear capsules. The steering wheel was tilted upward in the full up adjusted position at the time of inspection which was 32 degrees above horizontal.



**Figure 4** - View of contact evidence along the lower instrument panel and knee bolster



**Figure 5** - View from rear seat looking forward of contact evidence on the roof head liner and rear surface of the driver seat head restraint

The Cadillac was equipped with redesigned frontal air bags that deployed during the first impact sequence. There was no visible occupant related contact evidence noted on the surfaces of the front left air bag module cover. The front surface of the front left air bag fabric exhibited numerous striated heavy tan transfer marks which were attributed to contact with the underside of the air bag module cover during air bag expansion.

The top portion the driver's head restraint exhibited a light black/gray color transfer which was attributed to contact by the driver during his rebound kinematic pattern following the first impact with the Plymouth Reliant (**refer to Figure 5**). The contact began 3.8 cm (1.5") below the top surface of the head restraint and extended laterally 19.1 cm (7.5"). It continued over the top surface and narrowed to 10.2 cm (4.0") on the back surface and ending 2.5 cm (1.0") below the top surface. The vertical and lateral dimension of the head restraint measured 15.2 cm (6.0") and 30.4 cm (12.0"), respectively.

The roof head liner directly above the driver's head restraint exhibited contact evidence by the driver's head. This was apparent from the black and white hair embedded in the fabric of the roof liner. This contact pattern was located 66.0 cm (26.0") rearward from the windshield header and 22.9 cm (9.0") left of the vehicle centerline. The hair artifact pattern was shaped in an "L" configuration with the longitudinal side measuring 8.3 cm (3.25") long and the lateral side, which extended from the end of the

longitudinal segment toward the left roof side rail, measured 21.6 cm (8.5"). Within this evidence pattern were pronounced dark brown transfer marks were attributed to tissue transfers from the driver's scalp and were correlated with the medically reported scalp abrasions.

A linear gray color transfer mark was also noted along the roof head liner fabric which measured 12.7 cm (5.0") in length. This was attributed to contact by the driver's right arm during the crash sequence. The contact began 96.5 cm (38.0") rearward from the windshield header and 5.1 cm (2.0") right of the vehicle centerline. It ended at the roof mounted courtesy mirror bracket located in the right rear seating area. There were no reported driver injuries associated with this contact pattern.

The front left seat was a six way electric adjustable seat with a separate lumbar support adjustment. It appeared to be adjusted in the mid-to-forward track position. In this position, the seat back support measured 57.2 cm (22.5") rearward from the front left air bag module cover at a height of 41.9 cm (16.5") above the junction of the seat cushion. The seat back support measured 76.2 cm (30.0") vertically (including the height of the adjustable head restraint) and was inclined rearward 24 degrees from vertical. The seat cushion measured 48.3 cm (19.0") longitudinally with the leading edge of the cushion measured 30.4 cm (12.0") above the floor pan. The vertical height behind the driver seat measured 119.4 cm (47.0") from the floor to the roof.

The right side of the windshield was cracked by the expanding front right air bag during the deployment sequence. The area of damage measured 45.7 cm (18.0") wide and 35.6 vertically and was bowed outward. The center of the bowed area was located 33.0 cm (13.0") right of the vehicle centerline and 22.9 cm (9.0") below the windshield header.

The top surface of the instrument panel was displaced vertically by the deploying front right air bag. This was a designed feature of the SRS as the instrument panel served as the deployment cover for the air bag.

The rear view mirror was fractured and rotated in a counterclockwise direction. This damage was attributed to contact by the front right air bag during deployment.

The driver's manual lap and shoulder belt restraint belt did not show signs of usage at the time of the crash. The torso belt height adjustment at the D-ring was in the full up position over an adjustable range of 8.9 cm (3.5"). The torso belt had a spool out distance of 50.8 cm (20.0") which appeared to be less than anticipated. The same dimension was measured for the right front torso belt.

The driver sustained a comminuted fracture of the right calcaneus and fracture of the right medial malleolus which was attributed to contact with the brake pedal and toe pan during the crash. The brake pedal did not exhibit any signs of deformation.



## **VEHICLE DATA- 1987 PLYMOUTH RELIANT**

### **Exterior**

Exterior damage to the 1987 Plymouth Reliant involved the front bumper, the grille, the hood, the radiator, displacement of the right front axle, both front fenders, A-pillar, roof, and right front door. Direct contact began at the right front bumper corner and extended 77.0 cm (30.3") toward the left. The maximum crush of 80.0 cm (31.5") was located at the right front bumper corner. The assigned CDC was: 11-FZEW-3.

## **VEHICLE VELOCITY ESTIMATES**

The outputs from the damage algorithm of the WinSMASH reconstruction program are shown in the following table. The values generated by the program appeared to be consistent with the crush profile of both vehicles.

WinSMASH	1998 Cadillac Concours	1987 Plymouth Reliant
Total delta V	23.1 km/h (14.4 mph)	38.8 km/h (24.1 mph)
Longitudinal delta V	-20.0 km/h (12.4 mph)	-33.6 km/h (20.9 mph)
Lateral delta V	-11.6 km/h (7.2 mph)	19.4 km/h (12.1 mph)
Energy	41,551 joules (30,646 ft-lb.)	117,449 joules (86,626 ft-lb.)

## **REDESIGNED FRONTAL AIR BAG SYSTEM - 1998 CADILLAC DEVILLE CONCOURS**

The redesigned frontal air bag system in the 1998 Cadillac DeVille Concours was designed with a single point sensing system and an event data recorder (EDR). The EDR was not downloaded for this NASS/SCI investigation. The 12 o'clock direction of force to the front right plane resulted in the deployment of the redesigned front left and front right air bags. The three point manual lap and shoulder restraint belt system in the outboard front seat positions were equipped with belt pretensioners which also actuated during the crash sequence.

The front left air bag module cover opened in the prescribed "T" pattern where the left flap measured 9.5 cm (3.75") laterally and the right flap measured 12.1 cm (4.75") which included a 2.5 cm (1.0") semi-circle overlap tab that contained the Cadillac insignia (refer to Figure 6). The vertical height of the flaps measured 10.8 cm (4.25") at the common tear seam line. The flaps measured 12.7 mm (0.5") in thickness and were made of a soft vinyl with the underside constructed of several rows of vinyl. There were no apparent occupant contact points on the cover surface.



**Figure 6** - View of the "T" pattern front left air bag module cover flaps

The front left air bag was nontethered and had two 2.5 cm (1.0") diameter vent ports located in the 3 o'clock and 9 o'clock positions which were 10.2 cm (4.0") inboard from the perimeter of the air bag. The diameter of the air bag measured 66.0 cm (26.0") in its deflated state. The air bag identification number was as follows:

Part No.16758060

Lot No. 14071A3

The front left air bag exhibited tan color striated transfer marks in the upper right quadrant and both lower quadrants which were attributed to contact with the underside of the air bag module cover during the deployment sequence (**refer to Figure 7**). The transfer in the upper right quadrant was heavier in color concentration and measured 35.6 cm (14.0") vertically and 25.4 cm (10.0") laterally. There was no visible driver contact evidence on the air bag.



**Figure 7** - View of the front left non-tethered air bag showing the striated transfer pattern from contact with the air bag module cover



**Figure 8** - View of the front right air bag relocated back under the instrument panel

The front right air bag module was a top mount design which incorporated the top surface of the instrument panel as the air bag module cover (**refer to Figure 8**). The top instrument panel was secured by pressure clips which released as the air bag expanded. There was no damage noted to this panel.

The front right air bag contained two tethers in an upper and lower configuration and were attached across the front surface width of the air bag. The upper tether was located 68.6 cm (27.0") from the inflator unit and the lower tether was located 29.2 cm (11.5") below the upper tether. The excursion of the air bag measured 34.3 cm (13.5") from the instrument panel. The lateral width of the air bag measured 45.7 cm (18.0"). There were two 3.8 cm (1.5") diameter vent ports located on the side surfaces of the air bag and 20.3 cm (8.0") below the inflator unit.

During the SRS deployment cycle, the front right air bag contacted the rearview mirror and the right side of the windshield. The mirror was cracked and the bracket rotated. The windshield was

cracked and a pronounced outward bulge of the glazing was located over the air bag. There was no occupant contact or damage noted on the surface of the air bag.

The front right air bag identification number was as follows:

16823044-00  
E/K98ensan  
TRBP70011118

In addition to the frontal air bags, the Cadillac was equipped with side impact air bags for the front outboard seated positions. The side air bag modules were located in the front door panels above the armrest and rearward of the door release handle. These air bags did not deploy per design parameters during the crash.

### ***INJURY DATA***

The 65 year old male driver of the Cadillac did not recall the events leading to the crash. He was en route to his residence when his vehicle crossed the centerline and struck the Plymouth in an offset head-on impact configuration. The driver was not using the available lap and torso belt prior to the crash.

The driver of the Cadillac exited the vehicle under his own power and was transported via ambulance to a local trauma center where he was treated and released for a fracture of the right foot. The driver indicated that his right calcaneus was fractured and was surgically repaired a week later where screws were attached at the fracture site. A soft removable cast was applied so that it could be removed during nighttime sleep. He was advised not to put any pressure on the foot for a period of 10-12 days.

The driver indicated he sustained a bruise of the right knee and also sustained an injury to the top of his head which he described as “sores” or “burns” which were resolved by washing the effected area. The following table lists the driver reported injuries by AIS-90 classification and by injury source:

<b>INJURY</b>	<b>SEVERITY (AIS-90)</b>	<b>INJURY SOURCE</b>
Fracture of the right calcaneus	Moderate (851400.2,1)	Brake pedal
Contusion of the right knee	Minor (890402.1,1)	Knee bolster
Sores, brush burns top of the head	Minor (190202.1,5)	Roof head liner

## ***OCCUPANT KINEMATICS***

The driver of the Cadillac indicated that he was unaware of the events leading to the crash and that he was uncertain whether he was wearing the manual three point lap and shoulder restraint belt at the time of the crash. Contact evidence on the knee bolster and the roof head liner indicated the driver was not wearing the restraint belt at the time of the crash.

During the crash sequence, the unrestrained driver moved forward and contacted the fully deployed air bag with his upper torso. His lower torso moved forward with his right foot loading against the brake pedal resulting in the fracture of the right calcaneus. His knees contacted the lower instrument panel and knee bolster as noted by the deformation of the instrument panel located left of the steering column and the displacement of the left lower corner of the rigid vinyl panel covering the metal knee bolster. He sustained a contusion of the right knee which was attributed to contact with the knee bolster.

The driver compressed the air bag with his upper torso, but did not displace the steering column as noted by the non-displacement of the steering column shear plate at the shear capsules. He subsequently rebounded rearward from the air bag in an upward motion and contacted the roof head liner directly above the left front seat back support. A longitudinal artifact consisting of black and white hair fibers began 66.0 cm (26.0") rearward of the windshield header measured 8.3 cm (3.25") in length before it moved laterally toward the left side roof rail. The lateral portion was noted by a 21.6 cm (8.5") linear area of black and white hair fibers which appeared to be associated with the 8.3 cm (3.25") linear black and white hair artifact. The change in directions of the head motion may have resulted from the rotation of the vehicle following the impact with the Plymouth and the subsequent impact with the Saturn.

His right arm rotated outward in a rearward motion and contacted the roof head liner. This was apparent from the 12.7 cm (5.0") linear gray color transfer which began 96.5 cm (38.0") rearward from the windshield header and 5.1 cm (2.0") right of the vehicle centerline and ended at the right rear roof mounted vanity mirror bracket. This contact was attributed to contact by his right hand/wrist area.

The driver's upper torso which was positioned over the left front seat back support moved downward and loaded the top surface of the head restraint. This was apparent from the light black/gray color transfer noted along to the top surface of the head restraint which extended 2.5 cm (1.0") below the rear surface and 3.8 cm (1.5") below the front surface.

The driver came to final rest in the driver seat. He exited the vehicle under his own power and walked a short distance. Rescue arrived within ten minutes and transported him to a local trauma hospital.