

**TRANSPORTATION SCIENCES  
CRASH RESEARCH SECTION**

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**ONSITE DEPOWERED DRIVER AIR BAG DEPLOYMENT INVESTIGATION**

**VERIDIAN CASE NO. CA98-029**

**VEHICLE: 1998 TOYOTA AVALON**

**LOCATION - MISSISSIPPI**

**CRASH DATE - APRIL 1998**

**Contract No. DTNH22-94-07058**

**Prepared for:**

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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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**ON-SITE DEPOWERED AIR BAG DEPLOYMENT INVESTIGATION  
VERIDIAN CASE NO: CA98-029**

**VEHICLE: 1998 TOYOTA AVALON  
LOCATION: MISSISSIPPI  
CRASH DATE: APRIL, 1998**

***BACKGROUND***

This investigation focused on a three vehicle crash that involved a 1998 Toyota Avalon, a 1995 Subaru Impreza and a 1991 BMW 750. The Toyota Avalon was equipped with a Supplemental Restraint System (SRS) that consisted of depowered driver and front right passenger air bags, side impact air bags and front seat belt pre-tensioners. The Toyota's depowered driver and front right passenger air bags deployed as a result of an offset frontal crash with the Subaru Impreza. The 49 year old restrained female driver of the Toyota sustained multiple left side injuries as a result of the crash. The Subaru Impreza was equipped with a SRS that consisted of driver and front passenger air bags that also deployed as a result of the crash. The Subaru's 26 year old unrestrained female driver was fatally injured due to a combination of intrusion, sudden deceleration and the lack of seat belt use. The BMW 750il impacted the front of the Toyota Avalon in a second collision. The BMW was equipped with a SRS that consisted of a driver air bag. The air bag system of the BMW deployed as a result of the second collision. The 43 year old male driver of the BMW was not injured.

The Special Crash Investigations Team of Veridian was informed of the crash on April 23, 1998 by the local police jurisdiction during a concurrent SCI on-site investigation. The Crash Investigations Division of the National Highway Traffic Safety Administration was informed of the crash by Veridian and a depowered air bag investigative effort was assigned on May 1, 1998 .

***SUMMARY***

***Crash Site***

This three vehicle crash occurred in the afternoon hours of April, 1998. At the time of the crash, it was daylight and the weather was not a factor. The crash occurred in a rural section of a north/south four lane divided highway. The total width of the respective travel lanes measured 7.3 m (24.0 ft). A 3 m (10 ft) breakdown lane and a 1 m (3 ft) shoulder bordered the outboard and inboard lanes of the interstate, respectively. The opposing traffic lanes were separated by a grass median approximately 17 m (57 ft) wide. The traffic density was described as congested. The speed limit in the area of the crash was 113 km/h (70 mph). **Figure 1** is a view of the northbound lanes of the interstate 61 m (200 ft) south of the point of impact.



**Figure 1:** Northbound trajectory view of the interstate.

### *Pre-Crash*

The 1998 Toyota Avalon was northbound in the in-board lane of the interstate. The 49 year old restrained female driver was the sole occupant of the Toyota. The driver indicated traffic was moving approximately 105 to 113 km/h (65 to 70 mph). The 1991 BMW 750il was northbound in the inboard lane approximately 21 m (70 ft) behind the Toyota. The 43 year old male driver of the BMW was restrained and was the sole occupant of the vehicle. The 1995 Subaru Impreza was driving southbound in the in-board lane of the interstate. There were a total of four occupants in the Subaru. The Subaru was driven by a 26 year old unrestrained female, the right front passenger was a 23 year old unrestrained male, the left rear passenger was a 4 year old unrestrained female and the right rear passenger was a 7 year old unrestrained male.

A witness traveling behind the southbound Subaru reported that prior to the crash the vehicle was in the outboard lane at a speed of approximately 113 km/h (70 mph). The Subaru then moved to the inboard lane to pass slower traffic and drifted off the left side of the road. The vehicle's left wheels dropped off the pavement. The Subaru driver corrected the vehicle's trajectory by steering back to the right, over-corrected and then steered back to the left. The Subaru departed the left side of the southbound interstate in a counterclockwise yaw and traveled through the median to the southeast, **Figure 2**. As the Subaru approached the northbound lanes of the interstate, analysis of the tire marks indicated the vehicle had ceased rotation and had returned to a more tracking trajectory.



**Figure 2:** Southeast trajectory view of the Subaru.

### *Crash*

The Subaru entered the in-board northbound lane directly in the path of the Toyota. The crash occurred with the front plane of the Subaru impacting the front left area of the Toyota in a 1/11 o'clock impact configuration. The force of this impact fired the pre-tensioners in the Toyota's manual restraint system and deployed the vehicle's depowered frontal air bags. The Supplemental Restraint System of the Subaru also deployed.

The front of the Subaru slid along the left side of the Toyota in a protracted engagement, as the northward momentum of the Toyota caused the Subaru to reverse direction. The left side damage on the Toyota extended rearward to the area of the left C-pillar. Both vehicles began to rotate counterclockwise. An area of gouge marks in the in-board lane identified the point of impact. The Subaru rotated counterclockwise approximately 210 degrees and came to rest in the in-board northbound lane approximately 5 m (15 ft) north of the point of impact, facing west. **Figure 3** is an on-scene police photograph of the Subaru at final rest.



**Figure 3:** Final rest position of the Subaru.

Upon separation with the Subaru, the Toyota had rotated counterclockwise approximately 120 degrees and its trajectory was now directed to the northeast. The BMW traveling behind the Toyota in the in-board lane reacted to the initial crash by steering to the right in an avoidance maneuver. The Toyota entered the out-board lane, in the path of the BMW, where it was struck again in the left frontal area. The front of the 1991 BMW 750iL struck the Toyota in a 10/12 o'clock impact configuration approximately 8 m (25 ft) north of the initial point of impact.

The force of this impact caused the SRS of the BMW to deploy. The Toyota and BMW remained in contact and slid off the right side of the interstate, approximately 49 m (160 ft) to the northeast. **Figure 4** is a post-impact trajectory view of the Toyota and BMW. The Toyota came to rest facing southwest, approximately 20 m (65 ft) east of the edge of the shoulder and the BMW came to rest facing northeast approximately 18 m (60 ft) east of the shoulder edge. The police report indicated that the Toyota and BMW were in contact at final rest and were then separated during the extrication process. **Figure 5** is an on-scene police photograph of the Toyota and BMW at final rest (note, the BMW has already been moved.)



**Figure 4:** Post-impact trajectory view of the Toyota and BMW.



**Figure 5:** Final rest positions of the Toyota and BMW.



The front plane of the Toyota Avalon sustained 80.0 cm (31.5 in) of direct contact damage that began 3.8 cm (1.5 in) left of center and extended to the front bumper's left corner as a result of the combined frontal impacts. The crush profile measured along the face of the bumper rebar was as follows: C1=54.6 cm (21.5 in), C2=50.8 cm (20.0 in), C3=21.6 cm (8.5 in), C4=12.7 cm (5.0 in), C5=0, C6=0. **Figures 6 and 7** are the left front and left lateral views of the Toyota respectively. The Subaru's direct contact with the Toyota continued approximately 333 cm (131 in) along the left side of the vehicle to the left rear door. The impact displaced the bumper fascia from the vehicle. The left side wheelbase was foreshortened approximately 36 cm (14 in). There was no measurable change in the right side wheelbase dimension. The lower aspect of the left A-pillar deformed rearward approximately 20 cm (8 in) and 18 cm (7 in) laterally right. The roof was buckled adjacent to the left A-pillar and left B-pillar. The left front window glazing was shattered in the impact. The windshield was removed and the steering column and instrument panel were pulled up in the extrication process. The combined Collision Deformation Classification (CDC) of the Toyota Avalon resultant to the two overlapping impacts was 11-FYEW-3. The barrier equivalent delta V of the Toyota based on the frontal damage as calculated by the barrier model of the WINSMASH program was approximately 33.3 km/h (20.7 mph). The longitudinal and lateral components were 28.8 km/h (-17.9 mph) and 16.7 km/h (10.4 mph), respectively..



**Figure 6:** Left front view of the Toyota Avalon.



**Figure 7:** left lateral view of the Toyota.

The 1995 Subaru Impreza sustained direct contact damage across the full frontal width of the vehicle. The measured crush profile (less assumed free space) at the elevation of the front bumper was as follows: C1=69.9 cm (27.5 in), C2=66.0 cm (26.0 in), C3=57.8 cm (22.8 in), C4=55.2 cm (21.8 in), C5=59.7 cm (23.5 in), C6=50.2 cm (19.8 in). **Figure 8** is the front view of the Subaru. The left front suspension deformed rearward into the lower aspect of the A-pillar. The left side wheelbase was foreshortened approximately 29.7 cm (11.7 in). The right side wheelbase dimensions was unchanged. The left A-pillar



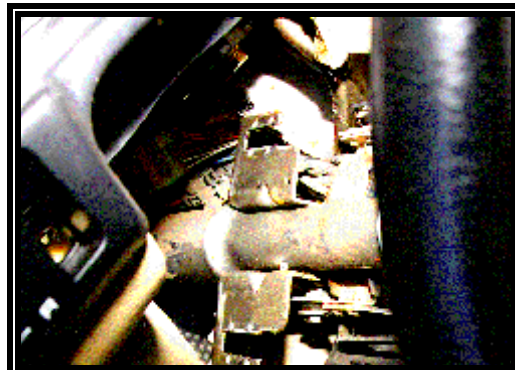
deformed rearward approximately 14.0 cm (5.5 in) causing the roof above the driver to buckle. The left front door buckled and was jammed shut due to deformation. (The left front door was opened in the extrication process.) The left rear door was jammed at the C-pillar latch. The right front door was buckled and jammed at the right B-pillar due to deformation. The right rear door was operational. The steering wheel rim was deformed and the steering column was totally separated from the instrument panel at the shear plate (**Figures 9 and 10**). The CDC of the Subaru was 01-FDEW-3. The barrier equivalent delta V calculated by barrier model the WINSMASH program was approximately 66.1 km/h (41.1 mph).



**Figure 8:** Front view of the Subaru Impreza.



**Figure 9:** Lateral view of the steering wheel.



**Figure 10:** View of the steering column and shear plate.

**Figures 11 and 12** are front and left lateral views of the 1991 BMW 750iL, respectively. The BMW sustained direct contact damage across the full frontal width of the vehicle as a result of its impact with the Toyota. The measured crush profile of the front bumper (less assumed free space) was: C1=17.8 cm (7.0 in), C2=14.0 cm (5.5 in), C3=12.7 cm (5.0 in), C4=11.4 cm (4.5 in), C5=11.4 cm (4.5 in), C6=12.7 cm (5.0 in). The damaged components of the BMW included the front bumper and bumper mounting structures, center grille, head lamp assemblies, left front and right front fenders and the hood. There did not appear to be any damage aft of the radiator support. There was no measurable change in the

respective wheelbase dimensions. The windshield and the glazing of all windows were intact. All the doors opened and closed properly. The CDC of the BMW was 12-FDEW-1. The barrier equivalent delta V calculated by the WINSMASH program was approximately 19.3 km/h (12.0 mph).



**Figure 11:** Front view of the BMW 750iL



**Figure 12:** Left lateral view of the BMW.

### ***Post-Crash***

Police and medical units responded to the crash scene. The 49 year old female driver of the Toyota sustained multiple injuries in the crash and required extrication from the vehicle. Medical information supplied by the investigating police officer indicated she suffered fractures of the left wrist, left elbow and left femur, left rib fractures, collapsed lung, torn bladder, bruised kidney and a cracked/fractured pelvis. All of her injuries were left side. She was reportedly required 13 hours in surgery post-crash and was hospitalized for 12 days. All indications were that her injuries were related to intrusion and interior contact resultant to the forces of the crash. Her injuries were not related to the deployment of the driver air bag.

The 26 year old female driver of the Subaru was pronounced dead at the scene. She reportedly sustained an aortic laceration among the multiple internal injuries resultant to the crash. It was the medical examiner's impression that the driver's injuries were related to the sudden deceleration and intrusion of the crash and not due to involvement with the air bag deployment. The right front male passenger only had a post-crash complaint of pain. The two rear seated child occupants sustained a reported moderate injury. The restrained male driver of the BMW was not injured in the crash and only had a post crash complaint of pain.

### ***AIR BAG VEHICLE - 1998 Toyota Avalon***

The 1998 Toyota Avalon was identified by a vehicle identification number (VIN): 4T1BF18B1WU (production sequence deleted). The vehicle's power train consisted of a 3.0 liter, V-6 engine linked to a 4-speed automatic transmission. Additional safety equipment included a 4-wheel anti-lock braking system. It was not possible to read the electronic odometer due to damage to the vehicle's electrical system.

The vehicle's interior was a high grade vinyl and was tan in color. The 6-way power left front seat was jammed due the lateral deformation. The seat deformation measured 14.0 cm (5.5 in) at mid-cushion. The seat was adjusted to a mid-track position. The adjustable head restraint was in the full down position. There were no seat performance failures.

### ***Interior Damage***

Passenger compartment integrity was lost through the left front and left rear side windows which disintegrated in the impact. Two specific areas of contact were identified on the left knee bolster as a result of the driver contact. The scuffs measured approximately 5 cm x 5 cm (2 in x 2 in). The left scuff was located 2.5 cm (1.0 in) left of the steering column centerline and vertically 5 cm (2 in) below the steering column. The right scuff was located laterally on the right edge of the bolster panel and was vertically located 16.5 cm(6.5 in) below the top edge of the panel.

**Figure 13** is a left interior view of the Toyota. The intrusion of the left A-pillar and left corner of the instrument panel measured approximately 20 cm (8 in) longitudinally rearward and 18 cm (7 in) laterally right. There was approximately 23 cm (9 in) of lateral intrusion at the left B-pillar. **Figure 14** is a view depicting the lateral deformation of the left front seat. The left front, left rear and right rear doors were opened by extrication. The steering column and left side of the instrument panel were pulled up vertically in the extrication process. Identification of interior contacts to the left door were hampered by the post crash extrication.



**Figure 13:** Left interior view of the Toyota.



**Figure 14:** View of the Toyota's left front seat.

### ***Manual Restraint System***

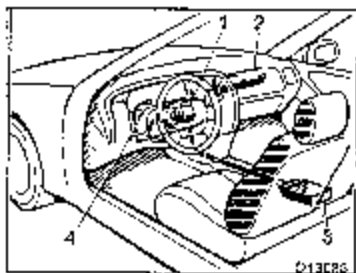
The Toyota was equipped with 3-point lap and shoulder belt systems in the 4 outboard seated positions. The front seat belt systems consisted of a continuous loop lap and shoulder belt webbing with a sliding latch plate. An inertia activated locking retractor was located in the base of each B-pillar. The front restraints were also equipped with pretensioners that were activated as a result of the crash. The restraint's upper anchorages (D-rings) were adjustable. The left front D-ring was adjusted 2.3 cm (0.9 in) above the full

down position. At inspection, the left front restraint webbing was extended and the retractor was locked by the pretensioner. Examination of the latch plate indicated routine usage marks consistent with vehicle age. Examination of the webbing and hardware surfaces revealed witness marks indicative of belt usage in this crash. The left front restraint webbing was cut by EMS personnel in the extrication process. The right front restraint webbing was stowed and taut, locked in place by its pretensioner.

### ***Supplemental Restraint System***

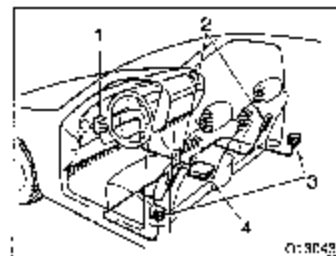
The Toyota was equipped with a Supplemental Restraint System (SRS) that consisted of depowered frontal air bags for the driver and front right passenger. There were no exterior identifiers on the vehicle that indicated the SRS was a depowered system. There also were side impact air bags located in the outboard aspects of the Toyota's front seat backs, refer to **Figure 14**.

The frontal air bag system was controlled by the air bag sensor assembly located in the center console of the Toyota. The sensor assembly consisted of a safing sensor and crash sensor in addition to the air bag diagnostic unit. The sensor assembly also controlled the activation of the seat belt pretensioners. The deployment of the side impact air bags was controlled by the side air bag sensor assembly located under the front seat cushion.



The SRS airbag system mainly consists of the following components and their locations are shown in the illustration.

1. Airbag module for driver (airbag and inflator)
2. Airbag module for passenger (airbag and inflator)
3. Airbag sensor assembly
4. SRS airbag warning light



The SRS side airbag system mainly consists of the following components and their locations are shown in the illustration.

1. SRS airbag warning light
2. Side airbag module (airbag and inflator)
3. Side airbag sensor assembly
4. Airbag sensor assembly

The SRS side airbag system is controlled by the airbag sensor. The airbag sensor assembly consists of a safing sensor and airbag sensor.

The driver air bag module was located in the typical manner in the center hub of the tilt steering wheel. There was no steering wheel rim deformation. The H-configuration air bag module opened as designed at the designated tear points during the deployment sequence. The width of the horizontal seam measured 17.3 cm (6.8 in). The height of the upper and lower flaps measured 7.6 cm (3.0 in) and 7.1 cm (2.8 in) respectively. The following nomenclature was embossed on the interior surface of the upper flap: 45112-07020 and the date code was 3/10/98.

The driver air bag measured 63.5 cm (25.0 in) in diameter in its deflated state. The bag was tethered by two 8.9 cm (3.5 in) wide straps in the 3/9 o'clock sectors of the bag. The bag was vented by two 2.5 cm (1.0 in) diameter ports located on the back side in 11 and 1 o'clock sectors. The back side of the air bag was stamped with the following nomenclature in the 12 o'clock sector:

45165-07010  
 0005539  
 A022 A022  
 30 01 98  
*Assembled in Mexico  
 with USA components  
 A480A7681*

Two blood smears were evident on the upper left quadrant of the face of the air bag. The upper smear was located 15.2 (6.0 in) above the horizontal centerline, began on the vertical centerline and extended 12.7 cm (5.0 in) to the left. The smaller smear measured 3.8 cm (1.5 in) in length and was located 20.3 cm (8 in) left and 3.8 cm (1.5 in) above the center of the air bag.

The passenger air bag was configured as a top-mount design located in the right instrument panel. The air bag module cover flap was a single vinyl flap that hinged on the aft aspect of the top of the instrument panel (refer to Figure 6). The flap was trapezoidal in shape and measured 21.6 cm (8.5 in) in width. The inboard and outboard heights of the flap were 8.6 cm (3.4 in) and 5.8 cm (2.3 in) respectively. The passenger air bag was tethered by a single wide strap sewn to the face of the bag. The bag vented internally back through the air bag module. The air bag extended approximately 61 cm (24 in) from the instrument panel in its deflated state. The face of the deflated bag measured 51 cm (20 in) by 51 cm (20 in) width by height. There was no contact evidence on the air bag.

***DRIVER INJURIES - 1998 Toyota Avalon***

<b>Injury</b>	<b>Injury Severity (AIS 90)</b>	<b>Injury Mechanism</b>
Left elbow fracture - NFS	Moderate (751800.2,2)	Intruding left door/left side
Left wrist fracture - NFS	Moderate (751800.2,2)	Contact with left door panel (air bag related fling injury, probable)
Left ribs fracture w/ pneumothorax - NFS	Serious (450214.3,2)	Intruding left door/left side

Multiple chest contusions - NFS	Minor (490402.1,9)	Intruding left door/left side
Pelvis fracture - NFS	Moderate (852600.2,9)	Intruding left door/left side
Kidney contusion	Moderate (541610.2,2)	Intruding left door/left side
Bladder laceration- NFS	Moderate (540620.2,8)	Intruding left door/left side
Left femur fracture - NFS	Serious (851800.3,2)	Driver knee bolster

*Note: the above referenced injuries were identified in an interview by the investigating police officer. Medical records were not available.*

#### ***DRIVER KINEMATICS - 1998 Toyota Avalon***

Immediately prior to the crash, the 49year old female driver of the Toyota was restrained by the vehicle's manual 3-point lap and shoulder belt system. She was seated with a presumed normal posture with her seat adjusted to a mid-track position. The driver recalled the Subaru approaching her vehicle from the median, but she had no recollection of the impact.

The force of the offset frontal impact was above the threshold required for the activation of the front seat belt pretensioners and the deployment of the vehicle's frontal air bag system. The activation of the seat belt pretensioner minimized any slack in the driver's seat belt and tightened the belt about the driver. The driver and front right passenger air bags deployed as designed from their respective modules.

The driver responded to the 11 o'clock direction by initiating a forward and left trajectory and loading the 3-point restraint. The driver's lower extremities contacted the knee bolster. As a result crash forces and dynamics, the left A-pillar and left aspect of the instrument panel intruded rearward and laterally inboard. The left door also intruded laterally. Intrusion of these components caused the fractures of the left elbow, left femur, ribs and pelvis. These intrusions also resulted in the contusion of the left kidney, laceration of the bladder and the multiple chest contusions. The deployment of the driver air bag resulted in the probable displacement of the driver's left forearm into the door panel. The forearm displacement resulted in the wrist fracture. The driver then rebounded back into the seat.

After disengagement from the initial impact, the Toyota had rotated approximately 120 degrees and was traveling rearward. The vehicle was then struck in the frontal region again by the BMW. Throughout this sequence the driver of the Toyota remained in contact with her seat belt because of the pretensioner activation. The locked seat belt mitigated any potential driver contact with the interior and injury as a result of the second impact.