TRANSPORTATION SCIENCES
CRASH RESEARCH SECTION

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ON-SITE REDESIGNED DRIVER AIR BAG DEPLOYMENT/ FATALITY INVESTIGATION

VEHICLE: 1999 CHEVROLET CAMARO

VERIDIAN CASE NO. CA99-22

LOCATION: DELAWARE

CRASH DATE: JULY, 1999

Contract No. DTNH22-94-07058

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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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This on-site investigation focused on a single vehicle run-off road/fixed object crash. The crash involved a 1999 Chevrolet Camaro equipped with an Automatic Restraint System that consisted of redesigned driver and front right passenger air bags. The 56 year old male driver lost control of the vehicle at high speed, departed the right side of the road, impacted a 152 cm (60 in) diameter tree with the front of the vehicle and rotated into a utility pole. The driver was unrestrained and was out-of-position at impact with the tree. The air bag systems deployed upon impact with the tree, however the cover flaps of the driver module did not open properly due to the driver's forward position. The driver air bag deployed out the top of the module. The driver died of his sustained injuries approximately 3 hours post-crash.

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BACKGROUND

This on-site investigation focused on a single vehicle run-off road/fixed object crash. The crash involved a 1999 Chevrolet Camaro equipped with an Automatic Restraint System that consisted of redesigned driver and front right passenger air bags. The 56 year old male driver lost control of the vehicle at high speed, departed the right side of the road, impacted a 152 cm (60 in) diameter tree with the front of the vehicle and rotated into a utility pole. The driver was unrestrained and was out-of-position at impact with the tree. The air bag systems deployed upon impact with the tree, however the cover flaps of the driver module did not open properly due to the driver's forward position. The driver air bag deployed out the top of the module. The driver died of his sustained injuries approximately 3 hours post-crash.

The Special Crash Investigations (SCI) team at Veridian/Calspan was informed of the crash by the Delaware Fatal Accident Reconstruction Unit on July 9, 1999. The Crash Investigation Division of the National Highway Traffic Safety Administration (NHTSA) subsequently assigned an on-site investigation of the crash to Veridian SCI the same day. Cooperation with the local police authorities was established and the vehicle was placed in the police impound pending SCI inspection. On-site investigation of the crash took place July 13, 1999.

SUMMARY

Crash Site

This single vehicle crash occurred during the evening hours of July 1999. At the time of the crash, it was daylight and the weather was not a factor. The roads were dry. At the crash scene, the roadway was predominately north/south in direction and consisted of two asphalt lanes. There was a 131 m (430 ft) radius left curve for southbound traffic. A two-lane road intersected the primary roadway from the west forming a 3-leg intersection. The primary road widened approximately 46 m (150 ft) north of the intersection to accommodate a turn lane for southbound right turning traffic. The pre-crash road grade was an estimated +3% in the southbound direction and became level in the area of the impact . The speed limit in the area of the crash was 56 km/h (35 mph). **Figure 1** is a southbound trajectory view of the subject vehicle. **Figure 2** is a look back view from the points of impact. Note: the tree was removed prior to SCI inspection.

Figure 1: Southbound trajectory view.

Figure 2: Look back view from the POI.

Pre-crash

The crash occurred in the following manner, refer to **Figure 3**. The 1999 Chevrolet Camaro was driven by a 56 year old male with a reported height and weight of 173 cm (68 in) and 118 kg (260 lb). He was unrestrained and seated in a mid-to-rear seat track position. The driver was operating the vehicle southbound at a high rate of speed and failed to negotiate the left curve. The police investigation identified two yaw marks attributed to the right side tires of the Camaro. The yaw marks indicated the vehicle had initiated a counterclockwise rotation due to the vehicle's speed combined with a late aggressive steering maneuver. The marks began 61 cm (24 in) outboard of the southbound lane edge line, were 33 m (108 ft) long and extended laterally across the right turn lane. The marks departed the roadside immediately prior to the intersection. The yaw mark's radius of curvature measured 184 m (604 ft). A critical speed calculation of the yaw marks indicated a minimum vehicle speed of approximately 130 km/h (81 mph). The Camaro continued its southwestward trajectory and re-entered the roadway in the mouth of the 3-leg intersection. The driver rapidly applied and locked the vehicles brakes. The rotation of the vehicle diminished and it returned to an approximate tracking attitude. The police investigation documented approximately 15m (48 ft) of ABS skid marks attributed to both the left and right side tires across the intersection.

The vehicle decelerated during this trajectory phase to approximately 96 km/h (60 mph).

Crash

The Camaro then traveled into the southwest intersection quadrant, shearing a guy wire, and impacting a 152 cm (60 in) diameter tree with the right aspect of the vehicle's front plane. The Barrier Equivalent Delta V of the frontal impact was 86 km/h (53 mph). The vehicle's redesigned Automatic Restraint System deployed as a result of the 12 o'clock impact force. The driver was out-of-position with his chest against the steering wheel at impact, as a result of the vehicle's pre-crash dynamics and braking. His forward position impeded the deployment of the driver air bag and caused the bag to deploy out of the top of the module. The sudden deceleration of the impact caused inertial loading of the steering column. Refer to the Automatic Restraint System and Driver Kinematics sections that follow. The Camaro then rotated clockwise into a left side impact with a utility pole and came to rest.

Post-crash

The 56 year old male driver was found unrestrained and slumped to the right. He was removed from the vehicle through the right door and transported to a Level 1 Trauma Center located within 16 km (10 miles) of the crash scene. Resussative efforts and subsequent exploratory surgery to control blood loss were unsuccessful. The driver's cause of death was listed as multiple skeletal and visceral injuries with retro-peritoneal soft tissue hemorrhage due to blunt impact. He died 235 minutes post-crash. His Blood Alcohol Content (BAC) was 0.22. An external examination was conducted by the State's Medical Examiner.

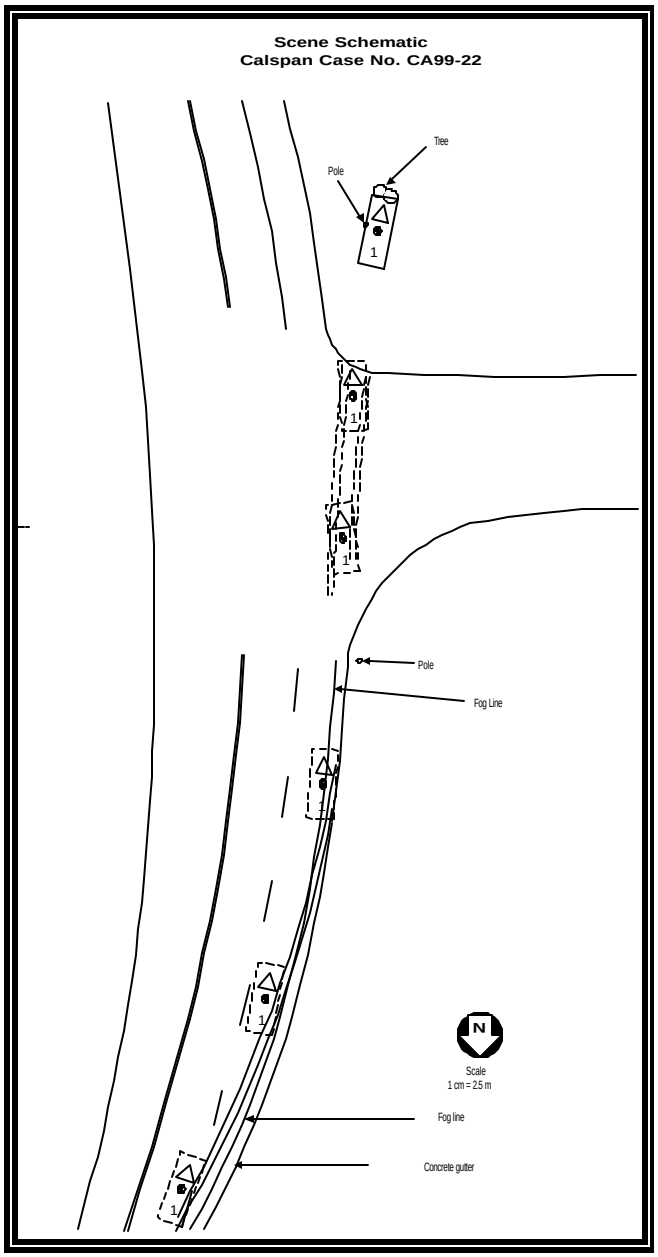

Figure 3: Schematic view of the crash.

AIR BAG VEHICLE DATA

The 1999 Chevrolet Camaro Z28 was identified by a Vehicle Identification Number (VIN): 2G1FP22G6X2 (production sequence deleted). The vehicle was equipped with an Automatic Restraint System that consisted of redesigned driver and front right passenger air bags. The power train consisted of a 5.7 liter, V8 engine linked to a 6-speed manual transmission. The vehicle was equipped with an anti-lock braking system (4-wheel ABS). The investigating police officer indicated the vehicle was issued a new registration in April 1999. The electronic odometer was unreadable due to collision damage.

VEHICLE DAMAGE

Exterior

Figures 4 and 5 are the right front and left side views of the Chevrolet Camaro, respectively. The Camaro sustained 86 cm (34 in) of direct damage to the right and center aspects of the front plane as a result of the impact to the tree. The direct contact began 5 cm (2 in) left of center and extended to the right front bumper corner. The crush profile measured at the elevation of the front bumper was as follows: C1=12.7 cm (5.0 in), C2=68.6 cm (27.0 in), C3=101.6 cm (40.0 in), C4=106.7 cm (42.0 in), C5=99.1 cm (39.0 in), C6=101.6 cm (40.0 in). The 12 o'clock direction of the impact force deformed the frontal structures of vehicle rearward into the engine compartment. The magnitude of the impact force caused buckling of the vehicle's uni-body structure between the A- and C-pillars. The right side wheelbase was foreshortened 41.9 cm (16.5 in). The windshield was fractured and all glazings disintegrated from the impact forces. The Collision Deformation Classification (CDC) of the frontal impact was 12-FDEW-04. The Barrier Equivalent delta V of the frontal impact calculated by the WINSMASH model was 86 km/h (53 mph). The longitudinal and lateral components were -86 km/h (-53 mph) and 0 km/h (0 mph), respectively.

Figure 4: Right front three-quarter view of the Chevrolet Camaro.

Figure 5: Left side view of the Camaro.

Immediately prior to the tree impact, the Camaro's left front fender sideswiped a utility pole. The contact was identified by longitudinal scrapes and scuffing that began 33 cm (13 in) forward of the left front axle and extended 102 cm (40 in) rearward to the approximate A-pillar location (refer to Figure 5). The CDC of this contact was 12-LFES-01. The offset frontal impact with the tree caused the vehicle to rapidly rotate clockwise into direct contact with the pole. The direct left side contact with the pole began 69 cm (27 in) aft of the left front axle and extended 165 cm (65 in) rearward. The left side crush profile measured as follows: C1=10 cm (4.0 in), C2=41.1 cm (16.2 in), C3=40.6 cm (16.0 in), C4=31.8 cm (12.5 in), C5=20.3 cm (8.0 in), C6=6.4 cm (2.5 in). The maximum crush occurred at C2, the B-pillar location. The CDC of the left side impact was 10-LPAW-03. The Barrier Equivalent delta V was 43 km/h (27 mph). The longitudinal and lateral components were -38 km/h (-24 mph) and 22 km/h (14 mph), respectively. The Camaro's impact speed into the fixed objects can be approximated by combining the above Barrier Equivalent speeds. Using the combined sped formula, the impact speed of the Camaro was approximately 95 km/h (59 mph).

Interior Damage

The interior damage to the vehicle was related to the magnitude of the exterior forces of the crash and the unrestrained occupant (driver) contact. The frontal impact caused buckling of the floor pan in the area of the B-pillar and rearward deformation of the right toe pan. The right corner of the instrument panel was displaced rearward approximately 7 cm (3 in). The left side impact and deformation buckled the rear seat back and displaced the left front seat laterally fracturing the center console. Lateral left side intrusion at the B-pillar measured 24.1 cm (9.5 in). Refer to **Figure 6**.

Figure 7: View of the driver's knee bolster.

The driver's forward inertial loading fractured the tilt mechanism of the steering wheel and deformed the 4 to 10 o'clock sectors of the rim longitudinally forward. The maximum displacement in the rim's 6 o'clock sector measured 12.2 cm (4.8 in). Steering column shear capsule displacement was 6 mm (1/4 in) by visual estimate. The driver's knee bolster exhibited two contacts from the driver's lower extremities, **Figure 7**. The left lower extremity contact fractured the bolster. The contact measured 7.1 cm x 14.7 cm (2.8 in x 5.8 in) width by height and was located 19.8 cm (7.8 in) left of the steering column centerline. The driver's right knee contacted the lower edge of the bolster 5.7 cm (2.3 in) right of the steering column centerline. This contact measured 9.7 cm x 5.1 cm (3.8 in x 2.0 in), width by height.

MANUAL RESTRAINT SYSTEM

The manual front restraint system in the 1999 Chevrolet Camaro Z28 consisted of a 3-point lap and shoulder belt. The belt webbing was a continuous loop and spooled from a dual mode locking retractor located in the base of the B-pillar. The latch plate exhibited scratch marks indicative of historical use. The belt webbing was stowed within the retractor and the retractor mechanism was locked upon SCI inspection. Additionally, the webbing was captured between the interior trim panel of the door and the front seat back. The position of the webbing at the inspection confirmed the driver was unrestrained during the crash because the webbing could not have returned to this position post-crash due to the left side deformation.

AUTOMATIC RESTRAINT SYSTEM

The Automatic Restraint System of the 1999 Chevrolet Camaro Z28 consisted of redesigned frontal air bags for the driver and front right passenger. The system was controlled by a single point Sensing and Diagnostic Module (SDM) located within the occupant compartment. Both air bags were deployed as a result of the impact with the tree.

The driver air bag was located in the typical manner in the center hub of the steering wheel, **Figure 8**. The air bag membrane measured 61 cm (24 in) in diameter and was not tethered. The bag was vented by two 2.5 cm (1.0 in) diameter ports located in the 3 and 9 o'clock sectors on the back side of the bag. A bar code label was located in the bag's 12 o'clock sector with the following nomenclature:

PUT11767-01F
TMJ3228Go381

Figure 8: View of the driver air bag.

The I-configuration cover flaps were symmetrical and measured 10.1 cm x 11.4 cm (4.0 in x 4.5 in), width by height. The air bag module was constructed of white sheet vinyl 3 mm (1/8 in thickness) and covered by a black vinyl (type) cloth. All of the interior seams of the module separated during the deployment, however, the cover flaps did not rotate open. The exterior cloth separated along the top seam and partially about the center seam. Refer to **Figure 9.** The driver's chest was positioned against the module and prevented the flap rotation. Expansion of the captured air bag membrane caused pressure to build within the module and membrane. The over-pressure

Figure 9: View of the flap separation.

caused the bag to deploy out of the 12 o'clock sector (top) of the module. As the membrane deployed through the top seam, the jagged edge of the module abraded the membrane evidenced by the patterned vinyl transfers. These abrasions weakened the membrane and the over-pressure caused a 15 cm (6 in) rupture in the 12 o'clock sector on the back side of the bag, **Figure 10**.

Figure 10: View of the ruptured air bag.

The front right passenger air bag module was a top mount design located in the right aspect of the instrument panel. The module cover flap measured 34.3 cm x 22.9 cm (13.5 in x 9.0 in), width by height. The flap was tethered by a single 19.1 cm (7.5 in) wide strap. The face of the passenger air bag measured 41 cm x 61 cm (16 in x 24 in) and extended 38 cm (15 in) from the aft edge of the module, in its deployed state. The bag was tethered by four 8 cm (3 in) wide straps and was vented by two 5 cm (2 in) diameter ports located on the side panels of the bag. Blood spatters were located on the right lower aspect of the bag's face and the lower aspect of the inboard side panel. The blood spatters came from contact with the driver's head at final rest. A bar code label with the following nomenclature identified the air bag:

TRAF80246487
16758402 - 25*

DRIVER DEMOGRAPHICS

Age/Sex:	56 year old/male
Height:	173 cm (68 in)
Weight:	118 kg (260 lb)
Restraint Usage:	Unrestrained
Usage Source:	SCI inspection, occupant kinematics
Medical Treatment:	Transported to a Level 1 Trauma Center
Physical/Psychological condition	0.22 BAC
Trip Plan:	Returning to his home located approximately ½ mile from the crash scene.

DRIVER INJURIES

Injury	*Injury Severity (AIS 90)*	*Injury Mechanism*
Multiple abrasions and lacerations - forehead, not further specified (NFS)	290202.1,7 290600.1,7	Windshield
Multiple abrasions and lacerations - left side of face, NFS	290202.1,2 290600.1,2	Driver air bag (probable) Windshield (possible)
Fracture of the C5 vertebra, NFS	650216.2,6	Driver air bag (probable) Windshield (possible)
Multiple blunt skeletal injuries, NFS	415099.7,0	Steering wheel rim/column
Abrasions and contusions - right chest wall	490202.1,1 490402.1,1	Center aspect of instrument panel
Abrasions and contusions - right flank	590202.1,1 590402.1,1	Center console
Multiple blunt visceral injuries, NFS	515099.7,0	Steering wheel rim/column
Fracture of right acetabulum	852600.2,1	Induced fracture by right knee contact to the driver knee bolster
Open comminuted fracture of right femur	851800.3,1	Induced fracture by right knee contact to the driver knee bolster
Multiple abrasions, contusions and lacerations of lower extremities, NFS	890202.1,3 890402.1,3 890602.1,3	Driver knee bolster

Note: the above injuries were identified in the Delaware State Medical Examiner's Report. Multiple internal chest and abdominal injuries sustained by the driver could not be identified due to medical intervention, prior to examination.

DRIVER KINEMATICS

The 56 year old male driver was operating the vehicle southbound at a reconstructed speed of approximately 129 km/h (80 mph). He was unrestrained and seated in a presumed mid-to-rear track position. The police investigation determined he had just left a bar approximately 3 miles north of the crash scene and was en-route to his home. Due to his intoxication, his perception/reaction and ability to drive were impaired.

Approaching the crash scene, the driver steered late entering a left curve. The driver initiated an abrupt counterclockwise steering input that caused the rear wheels of the vehicle to lose traction. The vehicle then began to yaw counterclockwise off the road. The vehicle yawed a longitudinal distance of approximately 33 m (108 ft). At a travel speed of 129 km/h (80 mph), the Camaro traveled the distance in approximately 1 second. The driver then applied and locked the Camaro's ABS brake system as the vehicle entered the mouth of the intersection. The vehicle's yaw diminished and it began it return to a more tracking attitude and continued to decelerate. The effect of the vehicle's pre-crash dynamics and braking caused the driver to initiate a forward trajectory and move out-of-position. Additionally, the driver may have instinctively moved forward and tightened his grip on the steering wheel rim as he fought to re-gain control of the vehicle.

The vehicle traveled approximately 25 m (83 ft) from the point of ABS locked braking to impact with the tree and pole. During this period the vehicle decelerated from approximately 113 to 120 km/h (70 to 75 mph) to an impact speed of approximately 95 km/h (59 mph). The duration of this trajectory segment was less than 1 second. Throughout this time, the driver exhibited a forward trajectory in response to the vehicle's deceleration.

At impact, the vehicle's SRS deployed. Coincident to the impact, the driver's chest was against the steering wheel rim and driver air bag module. The sudden deceleration of the impact forced the driver into contact with the steering wheel rim. The driver's inertial loading of the steering column prevented the normal rotation of the cover flaps and inflation of the driver air bag. The expansion of the captured air bag caused pressure to build within the air bag module to a point that the over-pressure deployed the air bag out the 12 o'clock sector of the module. As the air bag membrane expanded across the rough vinyl edge of the module, the membrane was abraded. The over-pressure ruptured the membrane. The ruptured air bag and its altered deployment offered little protection to the unrestrained driver.

The driver's chest/abdomen contacted and loaded the steering wheel rim/column. The tilt mechanism was completely fractured. The 4 to 10 o'clock sector of the rim was deformed. The maximum deformation measured 12.2 cm (4.8 in) in the 6 o'clock sector. This loading of the chest and abdomen resulted in unspecified internal injuries. The driver's lower extremities contacted and fractured the knee bolster. This resulted in a right acetabulum fracture, comminuted open fracture of the right femur and multiple abrasions, lacerations and contusions. His face/head contacted the windshield resulting in the above noted abrasions

and lacerations. The vertical expansion of the driver air bag was also a probable source of the facial trauma, as well as a probable source of the cervical fracture.

The offset frontal impact to the tree caused a rapid clockwise rotation of the vehicle into an impact with the utility pole. The driver responded to the 10 'clock direction of the impact by moving to the left and contacting the interior trim panel of the left door. The driver then rebounded to the right and into contact with the center console and center aspect of the instrument panel. This contact caused multiple contusions and abrasions to the right flank and chest wall. The driver was found in this position slumped over the center console.