TRANSPORTATION SCIENCES
CRASH RESEARCH SECTION

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ON-SITE DRIVER AIR BAG NON-DEPLOYMENT/FATALITY INVESTIGATION

VEHICLE: 1995 CHEVROLET S-10 PICK-UP

VERIDIAN CASE NO. CA99-028

LOCATION: NORTH CAROLINA

CRASH DATE: SEPTEMBER 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 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 will focus on a single vehicle run-off road/fixed object crash. The crash involved a 1995 Chevrolet S-10 equipped with a Supplemental Inflatable Restraint (SIR) that consisted of a driver air bag. The 52 year old unrestrained male driver lost control of the vehicle, departed the right side of the road, traveled along a ditch line and struck a concrete culvert with the front of the vehicle. The driver air bag failed to deploy in the above threshold crash. The driver was pronounced dead at the scene. His fatal injuries were described as flail chest.

The Crash Investigation Division of the National Highway Traffic Safety Administration (NHTSA) was informed of the crash by an attorney representing the legal interests of the driver's family. NHTSA assigned an on-site investigation of the crash to the Special Crash Investigation team at Veridian/Calspan on August 16, 1999. Cooperation with the local attorney was established. The vehicle has been in the attorney's possession and was available for inspection. The onsite investigation of the crash was conducted September 1, 1999. Technical representatives for General Motors Corporation were present and took part in the inspection

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BACKGROUND

This on-site investigation focused on a single vehicle run-off road/fixed object crash. The crash involved a 1995 Chevrolet S-10 equipped with a Supplemental Inflatable Restraint (SIR) that consisted of a driver air bag. The 52 year old unrestrained male driver lost control of the vehicle, departed the right side of the road, traveled along a ditch line and struck a concrete culvert with the front of the vehicle. The driver air bag failed to deploy in the above threshold crash. The driver was pronounced dead at the scene. His fatal injuries were described as flail chest.

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SUMMARY

Figure 1: Northbound trajectory view and the point of impact.

This single vehicle crash occurred during the daylight hours in September, 1998. At the time of the crash, it was daylight and the weather was not a factor. The crash occurred off the right shoulder of a two-lane north/south, straight roadway with an asphalt surface, **Figure 1**. The road grade was a negative 3 percent (estimated) in the northbound direction. The right (east) shoulder was grass/sand and measured approximately 1.7 m (5.6 ft) in width. The shoulder then sloped into a 1.5 m (5.0 ft) deep ditch that paralleled the roadway. The ditch's centerline measured approximately 3.8 (12.5 ft) from the road edge. There was a private residence on the east side of the road. Its driveway crossed the ditch line via a culvert and concrete approach that measured approximately 7.3 m x 1.5 m (24 ft x 5 ft), length by height. The concrete approach was the point of

impact. The speed limit in the area of the crash was 89 km/h (55 mph). The 1995 Chevrolet S-10 pickup was driven by a 52 year old male. He was in the process of returning home, after stopping to see a sales customer located approximately 10.3 km (6.4 miles) from the crash site. The vehicle was northbound, in a straight section of the two-lane country road. For unknown reasons the driver lost directional control and gradually departed the right side of the road, **Figure 2**. The police investigation identified tire marks on the shoulder and embankment that led to the vehicle. The tire marks departed the road approximately 28 m (93 ft) south of the point of impact. No other roadway physical evidence was identified by the police investigation. This evidence had eroded from the site prior to this SCI investigation due to the passage of time since the date of the crash.

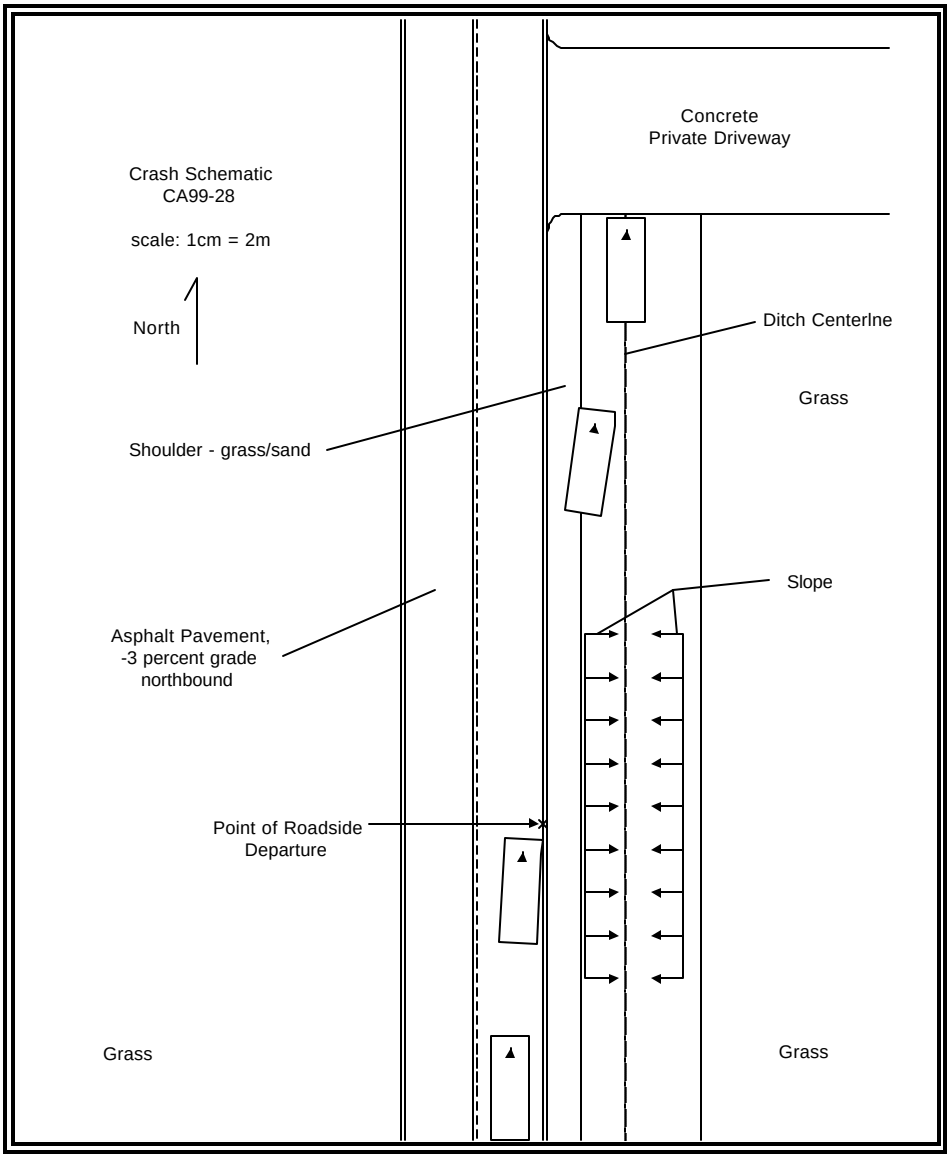

Figure 2: Crash schematic.

The right side wheels of the S-10 traveled across the shoulder and down the side slope and into the 1.5 m (5.0 ft) deep ditch. The vehicle then followed the ditch line and impacted the concrete driveway approach with its frontal plane. Due to the depth of the ditch, the S-10 was rolled approximately 51 degrees to the right. The pick-up came to rest at the point of impact. The Barrier Equivalent delta V of the impact calculated by the WINSMASH model was 56.0 km/h (34.8 mph), longitudinal -56.0 km/h (34.8 mph)/lateral 0 km/h (0 mph). The driver air bag failed to deploy in the above threshold crash. Technical representatives for General Motors participated in the vehicle's inspection and downloaded data that resided in the air bag system's Diagnostic Energy Reserve Module (DERM).

The driver was pronounced dead at the scene of the crash. He was found on the right side of the vehicle, partially out of the window. A full autopsy was performed. The autopsy report indicated that one long horn blast, that ended with the vehicle's impact, was heard. The source of that information was unknown and was not referenced in the police report. The autopsy did not identify any pre-existing medical conditions that would have contributed to the driver's loss of control. Inspection of the manual 3-point lap and shoulder restraint indicated the driver was not restrained. Occupant contacts to the windshield, steering wheel and column and knee bolster were identified. The driver sustained multiple rib fractures and associated thoracic injuries. The cause of death was termed flail chest. The driver's Blood Alcohol Content (BAC) was determined to be 0.07.

1995 CHEVROLET S-10 PICK-UP

The 1995 Chevrolet S-10 pick-up was identified by the Vehicle Identification Number (VIN): 1GCCS144XSK (production sequence deleted). The vehicle was a small conventional cab (2-door), 4x2, ½ ton pick-up. The power train consisted of a 2.2 liter, I4 engine linked to a 5-speed manual transmission. The service brakes were front disc/rear drum, with a rear wheel anti-lock system. The odometer read 63,218 km (39,283 miles). The date of manufacture was 4/95.

Reportedly , the S-10 pick-up was purchased used by the deceased in 9/97 and was his personal vehicle. The vehicle's odometer read 33, 127 km (20,585 miles) at the time of his purchase. A check of the vehicle's service history revealed that no maintenance was required on any of the steering or SIR components. There was reportedly some minor body damage to the right rear that was repaired. At the time of the inspection, the vehicle had been purchased by the family's legal representation and was located on private property. Prior to purchase, the pick-up bed had been removed by the salvage yard. The rear tires/wheels had also been removed. It had been verified that nothing had been altered in the vehicle's interior.

Exterior Damage

The S-10's frontal plane sustained direct contact damage across its entire 142 cm (56 in) end width. **Figures 3 and 4** are the left front and right front three-quarter views of the vehicle, respectively. The vehicular damage was similar in nature and magnitude to that of a NHTSA 56 km/h (35 mph) NCAP test.

The force of the impact compressed the frontal structures rearward into the engine compartment. The crush profile measured as follows: C1=45.7 cm (18,0 in), C2=51.8 cm (20.4 in), C3=62.0 cm (24.4 in), C4=68.1 cm (26.8 in), C5=67.1 cm (26.4 in), C6=45.7 cm (18.0 in). Both front fender's were deformed. The hood buckled in the typical manner and could not be opened. The left door was jammed shut. The right front door was operational, but restricted. The windshield was fractured from both the driver's head contact and the exterior crash force. The side window glazings and backlight disintegrated upon impact. The left and right wheelbase measurements were foreshortened 33.8 cm (13.3 in) and 16.0 cm (6.3 in), respectively. The compressive forces of the crash caused contact between the back of the cab and forward edge of the pick-up bed. The Barrier Equivalent Delta V calculated by the WINSMASH model was 56.0 km/h (34.8 mph). The Collision Deformation Classification (CDC) was 00-FDEW-3. Although the vehicular damage was within the 12 o'clock sector, a non-horizontal impact force (00) was coded due to the orientation of the vehicle at impact.

Figure 3: Left front three-quarter view of the Chevrolet S-10 pick-up.

Figure 4: Right front three-quarter view of the S-10.

Interior Damage

Interior damage to the vehicle identified during the course of the vehicle inspection was associated to both the exterior force of the crash and interior contact from the occupant. The lower aspect of the windshield fractured from the exterior crash force and a star-shaped fracture, inboard of the left A-pillar, resultant to head contact was also identified. The fracture was located 23 cm (9 in) right of the A- pillar and 25 cm (10 in) below the windshield header (measured the plane of the windshield). The fixed steering column was completely displaced from its shear capsules due to driver loading. The shear displacement measured 8.1 cm (3.2 in). There was 5 cm (2 in) of deformation to the lower half of the 4-spoke steering wheel rim as a result of edge loading. The deformation occurred in the plane of the rim and collapsed the spoke in the 8 o'clock sector, **Figure 5**.

The driver's knee bolster fractured as a result of contact from the right knee/lower extremity. The contact measured 6.3 cm x 5.0 cm (2.5 in x 2.0 in) and was located 8.9 cm (3.5 in) right of the steering column centerline, 53 cm (21 in) above the floor. The bolster was abraded by contact from the left knee/lower

extremity. The abrasion measured 5.0 cm x 3.8 cm (2 in x 1.5 in) and was located 23 cm (9 in) left of the steering column centerline, 53 cm (21 in) above the floor. Intrusion of the left toe pan measured approximately 12 cm (5 in).

Figure 5: View of the steering wheel deformation.

Manual Restraint System

The outboard positions of the Chevrolet S-10 were equipped with a manual 3-point lap and shoulder belt with a sliding latch plate. The upper anchorages (D-rings) were fixed. The emergency locking retractor was located in the base of the B-pillar. The driver's belt webbing was found in the stowed position at inspection. The metal surfaces of the latchplate exhibited surface scratches consistent with historical use. However, the plastic surfaces of the guide loop on the latchplate revealed no evidence consistent with belt use during this crash. Similarly, the plastic surfaces of the D-ring were free of any usage evidence. Examination of the belt webbing found the fabric free of defects and abrasions. Given the large magnitude of the vehicle's impact energy, evidence consistent with usage would be expected, if the manual restraint had been properly worn. Inspection of the belt system and the occupant's kinematic pattern indicated the driver was unrestrained in this crash. This conclusion was consistent with the results of the police investigation.

Supplemental Inflatable Restraint (SIR)

The Supplemental Inflatable Restraint (SIR) in the 1995 Chevrolet S10 consisted of a frontal driver air bag. The SIR was controlled by a Diagnostic Energy Reserve Module (DERM) located in the front right passenger's kick panel linked to three external electro-mechanical sensors. A warning lamp, to alert the operator of a fault in the SIR system, was located in the instrument cluster. The two impact sensors were symmetrically mounted to the vertical face of the lower radiator support. The safing sensor was mounted to the left frame rail, approximately 23 cm (9 in) forward of the B-pillar. The following nomenclature identified the DERM and forward left sensor:

DERM	Forward Right Impact Sensor
Service No: 16176557 A13440K250876815 16193440	16182195 AH2195ZE55122

The identification labels for the forward right impact sensor and safing sensor were not accessible.

Figures 6 and 7 are views of the forward left and right impact sensors, respectively. Both sensors were directly involved in the crash damage. The left sensor was displaced free from its mount by the rotation of the steering box during the impact. The rearward crush of the front bumper damaged the sensor. Its phenolic casing was fractured. The electrical wiring was intact. The right sensor was still mounted to the lower radiator support upon inspection, however, it was loose. The sensor was mounted by two rivets. The structural deformation of the support pulled the lower rivet of the sensor free. The vertical orientation of the mounting surface had rotated down approximately 28 degrees (CCW in a left view). The electrical circuitry to the sensor was intact. The sensors' residual positions and damages would not have effected the ability of the SIR system to identify and command deployment. Sensor closure would have occurred early in the "barrier-type" crash experienced by the Chevrolet S-10 and initiated the deployment sequence. The structural deformations and damages to the sensors occurred late in the crash event history. The post-crash condition of the forward impact sensors was not the root cause of the SIR non-deployment.

Figure 6: View of the forward left impact sensor.

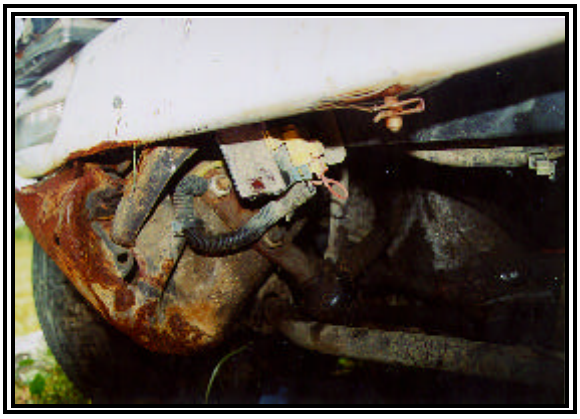

Figure 7: View of the forward right impact sensor.

Technical representatives for General Motors participated in the vehicle's inspection and were specifically asked to download any data stored in SIR DERM. A summary of the download revealed no Diagnostic Trouble Codes (DTC) were stored in the DERM's history. The data list indicated the SIR warning lamp had not been illuminated for at least 125 ignition cycles. The balance of the data list was unremarkable. The Supplemental Inflatable Restraint appears to have been operational at the time of the crash. The root cause of the non-deployment was not determined at the time of this report. The hexa-decimal code

retrieved from the module was sent to GM's Engineering offices for interpretation and analysis.

DRIVER DEMOGRAPHICS

Age/Sex:	52 year old/male
Height:	175 cm (69 in)
Weight:	91 kg (200 lb)
Restraint Usage:	Unrestrained
Usage Source:	SCI and police inspection, occupant kinematics
Medical Treatment:	None
Physical/Psychological condition	0.07 BAC
Trip Plan:	returning to his home after attending a seminar and seeing sales customers

DRIVER INJURY

Injury	***Severity (AIS 90)***	***Injury Mechanism***
Bilateral flail chest - multiple fractures on right, both anteriorly and posteriorly. Fractures of the left superior ribs. Sharp boney fragments projecting into pleural spaces	Critical (450266.5,3)	Inertial loading of the steering wheel/column
Multiple lacerations right lung with bilateral hemo-thoracies	Serious (441430.3,1)	Inertial loading of the steering wheel/column
Multiple lacerations of the liver w/ hemo-peritoneum - largest 15 cm to right lobe	Serious (541826.3,1)	Inertial loading of the steering wheel rim
Cerebral contusion w/ petechial hemorrhage (NFS) and subarachnoid hemorrhage at base of brain (NFS)	Serious (140602.3,9) Serious (140684.3,9)	Windshield (possible)
Open fracture of mid right femur	Serious (851814.3,1)	Driver's knee bolster
7.5 cm x 2 cm forehead laceration - superior to left eyebrow	Minor (290602.1,7)	Windshield
Multiple lacerations to right and left knee	Minor (890602.1,1) Minor (890602.1,2)	Driver's knee bolster
7 cm x 2 cm laceration to left lower leg	Minor (890602.1,2)	Foot controls (probable)

Injury	*Severity (AIS 90)*	*Injury Mechanism*
Superficial abrasions to right forearm	Minor (790602.1,1)	Right window glazing (probable)

The injuries noted above were referenced in the record of the driver's autopsy.

DRIVER KINEMATICS

Immediately prior to the crash, the 52 year old male driver of the 1995 Chevrolet S10 was operating the vehicle northbound within the posted speed limit. He was unrestrained and seated in a presumed normal posture. The seat was probably adjusted to a rear track position consistent with the driver's stature. For unknown reasons, the driver lost directional control and the S10 departed the right side of the road approximately 28 m (93 ft) south of the concrete driveway approach (the point of impact). The right side tires of the vehicle traveled down the embankment and traveled along the centerline of the roadside ditch. The ditch was approximately 1.5 m (5 ft) deep. In this attitude, the vehicle was rolled approximately 51 degrees to the right. A conservative time/distance analysis indicated the vehicle was off the road for less than 2 seconds. Given the short duration of the off-road trajectory, the driver was probably attempting to regain directional control and struggling to maintain his upright posture (considering the vehicle's attitude).

The sudden deceleration of the impact caused a forward weight shift and a negative vehicle pitch. The rear tires of the pick-up probably left the ground. The driver initiated a forward and upward trajectory in response to the 12 o'clock direction of the impact force and negative vehicular pitch. This trajectory displaced the driver forward, upward and slightly to the left of steering column centerline because the vehicle was rolled to the right. The driver's head contacted the windshield evidenced by the fractured laminate and corresponding laceration to his forehead (left aspect). A cerebral contusion was also identified by autopsy and directly linked to this contact. The driver's unrestrained kinematics caused his chest to impact the vehicle's steering wheel/column. His inertial loading completely displaced the column from its shear capsules and resulted in his blunt chest trauma, that included: bilateral flail chest, lacerated right lung and bilateral hemo-thoracies. His abdomen edge loaded and deformed the lower half of the steering wheel rim vertically. This contact caused the multiple liver lacerations and hemo-peritoneum. The driver's forward trajectory displaced his knees and lower extremities into the knee bolster and foot controls. These contacts resulted in the open fracture of the right femur and multiple lacerations to the knees and lower extremities.

The driver rebounded back into the seat and then slid to the vehicle's right side (due to the vehicle's attitude). The driver was found partially out the right window. It was not known if the driver simply fell to this position or may have been trying to exit the vehicle before succumbing to his injuries. He was pronounced dead at the scene.