TRANSPORTATION SCIENCES
CRASH RESEARCH SECTION

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CALSPAN ON-SITE DRIVER AIR BAG DEPLOYMENT/ FATALITY INVESTIGATION

CALSPAN CASE NO. CA98-44

VEHICLE - 1991 DODGE SPIRIT

LOCATION - VIRGINIA

CRASH DATE - JULY, 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 investigation focused on the fatal injury mechanisms of the driver of a 1991 Dodge Spirit that was involved in a single vehicle crash. The Dodge Spirit failed to negotiate a right curve, departed the roadway and struck an embankment and tree. The vehicle was equipped with a frontal Supplemental Restraint System (SRS) that consisted of a driver air bag. The 45 year old male driver was unrestrained in the vehicle and sustained an atlanto-occipital dislocation with cervical spinal cord transection as a result of his involvement with the deploying driver air bag. He was pronounced dead at the crash scene.

The barrier equivalent delta V of the Dodge, as calculated by the barrier model of the WINSMASH program, was 29.3 km/h (18.2 mph). The relatively "soft" nature of the impact with the embankment and tree caused the driver air bag to deploy late in the collision sequence. The late deployment allowed the driver to translate further forward into the deployment zone of the driver air bag. The deploying driver air bag contacted the driver in the anterior neck evidenced by the reported band-like neck abrasions. The forward trajectory of the driver altered the normal deployment path of the air bag upward and left, noted by an air bag fabric transfer on the left aspect of the windshield. The expansion of the air bag hyper-extended the driver's head causing the atlanto-occipital dislocation with spinal cord transection.

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BACKGROUND

This investigation focused on the fatal injury mechanisms of the driver of a 1991 Dodge Spirit that was involved in a single vehicle crash. The Dodge Spirit failed to negotiate a right curve, departed the roadway and struck an embankment and tree. The vehicle was equipped with a frontal Supplemental Restraint System (SRS) that consisted of a driver air bag. The 45 year old male driver was unrestrained in the vehicle and sustained an atlanto-occipital dislocation with cervical spinal cord transection as a result of his involvement with the deploying driver air bag. He was pronounced dead at the crash scene.

Calspan was informed of the crash by Virginia's Multi-Disciplinary Crash Team on August 7, 1998. Calspan in-turn informed the Field Operations Branch of the National Highway Traffic Safety Administration (NHTSA) the same day. An on-site task effort was assigned to Calspan's Special Crash Investigations Team on August 10, 1998. Coordination with the local authorities was immediately initiated and the on-site investigation was conducted on August 12, 1998.

SUMMARY

This single vehicle crash occurred in the early evening hours of July 1998. At the time of the crash, it was daylight and the weather was not a factor. The roads were dry. The crash occurred in the rural section of a narrow two lane north/south asphalt roadway. The width of the road measured 5.7 m (18.8 ft). The asphalt surface of the road was noted to have excess tar. The investigating police officer measured a 0.61 coefficient of friction the evening of the crash. There was a sharp 90 degree right curve at the crash scene. The radius of the curve measured approximately 61 m (200 ft).

Figure 1: Northward trajectory view of the Dodge Spirit 61 m (200 ft) from the POI.

The shoulders of the road were gravel and grass. Parallel to and 4.6 m (15 ft) beyond the west road edge was a 0.6 m (2 ft) deep ditch and a line of trees and brush. The speed limit in the area of the crash was not posted and by state law defaulted to 89 km/h (55 mph). **Figure 1** is a northward view of the crash scene 61 m (200 feet) from the point of impact.

The 1991 Dodge Spirit was operated by an unrestrained 45 year old male with a height/weight of 180 cm (71 in) and 91 kg (200 lb). Immediately prior to the crash, a Virginia State Trooper, operating radar, passed the Dodge Spirit which was traveling at a high rate of speed in the opposite direction. The State Trooper reported, that as she stopped to turn around, the driver of the Dodge attempted to "duck" or loose the Trooper on the adjoining rural roads. Approximately 2 km (1 mile) and several quick turns after passing the radar, the Dodge Spirit was traveling north on the roadway approaching the crash scene. Reconstruction of the crash indicated the vehicle was traveling approximately 80 km/h (50 mph) prior to braking. It is possible the driver may have been distracted looking in his rear view mirror for the Trooper. As the vehicle approached the right curve, the driver locked his brakes when he realized his speed was too high to negotiate the curve. Two parallel skid marks attributed to the front tires of the Dodge were identified at the scene. The skid marks began approximately 43 m (142 ft) from the point of impact. The vehicle skidded an average distance of approximately 35 m (114 ft), 26.6 m (87.2 ft) on the road and 8.2 m (26.8 ft) on the shoulder. The equivalent speed lost due to braking was calculated to be approximately 74 km/h (46 mph). The vehicle departed the left side of the road, crossed the adjacent ditch line and struck the far side embankment and a 15 cm (6 in) diameter pine tree. The pine tree, located 7 m (23 ft) from the road edge, was up-rooted in the process of the impact. **Figure 2** is an on-scene police photograph of the vehicle's final rest position. **Figure 3** is a view of the point of impact (embankment and up-rooted tree).

Figure 2: On-scene police photograph of the Dodge at final rest.

Figure 3: View of the embankment and tree at the POI.

Figure 4 is a front view of the Dodge Spirit. The Dodge sustained 130 cm (51 in) of direct contact damage that extended across the full frontal width of the vehicle from the embankment impact. The width of the direct contact damage from the tree impact measured 15 cm (6 in) and was located on the vehicle's centerline. The crush profile of the combined

Figure 4: Front view of the Dodge Spirit.

damage measured across the width of the bumper was: C_1=10.2 cm (4.0 in), C_2=24.1 cm (9.5 in), C_3=29.7 cm (11.7 in), C_4=37.3 cm (14.7 in), C_5=15.7 cm (6.2 in), C_6=0. The maximum crush of 37.3 cm (14.7 in) was located at C_4, 5.1 cm (2.0 in) right of vehicle centerline. The front center section of the hood buckled as designed. The left front fender was buckled and shifted rearward, slightly restricting the left front door. All of the vehicle's doors were operational and all glass was intact. There was no measurable change in the wheelbase dimensions. The Collision Deformation Classification's (CDC's) of the Dodge were was 12-FDLW-1 and 12-FNEC-2 for the embankment and tree impacts, respectively. The barrier equivalent delta V calculated by the barrier model of the WINSMASH program was 29.3 km/h (18.2 mph).

Upon brake application, immediately prior to the crash, the 45 year old unrestrained driver initiated a forward trajectory in response to the 12 o'clock direction of the braking force. It was probable the driver braced his arms and legs in an effort to restrain his forward motion. Upon impact with the embankment and tree, the driver moved further forward and loaded the steering wheel rim through his arms and fractured the in-board side of the steering wheel's tilt mechanism. The fractured tilt mechanism allowed the steering wheel rim to rotate upward and left.

The relatively "soft" nature of the impact with the embankment and tree caused the driver air bag to deploy late in the collision sequence. The late deployment allowed the driver to translate further forward into the deployment zone of the driver air bag. The deploying driver air bag contacted the driver in the anterior neck evidenced by the reported band-like neck abrasions. A large melanin transfer was noted on the back side of the driver air bag in the 10/2 o'clock sectors. The driver loaded the deploying air bag with his face and chest. This loading was transmitted through the air bag and steering wheel to the steering column denoted by the total displacement of the steering column from the shear plate. The forward trajectory of the driver altered the normal deployment path of the air bag upward and left, noted by an air bag fabric transfer on the left aspect of the windshield. The 10 o'clock sector of the steering wheel rim contacted the instrument panel evidenced by a scuff on the instrument panel near the left vent louver. The expansion of the air bag hyper-extended the driver's head causing the atlanto-occipital dislocation with spinal cord transection. The driver then rebounded into the seat and slumped to the right, where he was found. The driver was pronounced dead at the scene of the crash. An autopsy was performed. The driver's post-mortem blood alcohol content (BAC) was determined to be 0.21.

AIR BAG VEHICLE

The 1991 Dodge Spirit was identified by the Vehicle Identification Number (VIN): 1B3XA4639MF (production sequence deleted). The vehicle was equipped with a 3.0 liter, V-6 engine linked at a four speed automatic transmission. The vehicle's braking system consisted of power-assisted front disc/rear drum; it was not ABS equipped. The vehicle was equipped with a frontal Supplemental Restraint System (SRS) that consisted of a driver air bag. The odometer read 215,361 km (113,823 miles).

The vehicle's front seating positions were cloth covered bucket seats with reclining back rests. The track position of the left front seat measured 1.9 cm (0.8 in) forward of the rearmost position. The total seat

track travel measured 19.1 cm (7.5 in). The seat back was reclined 20 degrees. The anti-submarine angle of the seat cushion measured 15 degrees. There were no seat performance failures.

INTERIOR DAMAGE

The only damage to the interior of the Dodge were those associated to the deployment of the SRS and interaction with the occupant. There was no interior damage or intrusion directly associated to the external forces of the crash. Inspection of the steering column revealed the complete displacement of the shear plate from the shear capsules. In addition, the steering wheel's tilt adjustment was fractured The fracture occurred at the inboard cast adjustment knuckle, **Figure 5**, and allowed the outboard aspect of the rim to pivot upward and left. The damage and deformation to the steering column was a direct result of the driver's forward kinematic pattern and contact.

Figure 5: Fractured tilt mechanism of the steering wheel.

Figure 6 is a view of the left interior contacts as viewed from the rear seat. The left aspect of the instrument panel (near the vent louver) was scuffed by contact from the back side (10 o'clock) of the steering wheel rim. The steering wheel rim was abraded in this area and fibers from that abrasion were identified on the instrument panel. This contact occurred as the driver loaded and displaced the fractured steering wheel.

The trim panel of the left A-pillar was scuffed by a probable contact with the driver's left forearm. The scuff was located 17.3 cm (6.8 in) below the header and measured 2.5 cm x 6.3 mm (1.0 in x 0.3 in). The left aspect of the windshield was fractured from probable contact with the knuckles of the driver's left hand. The elevation of the windshield fracture was consistent with the location of the scuffed A-pillar and was located 17.8 cm (7.0 in) right of the pillar.

Directly below the fracture site was an area of air bag fabric transfer on the interior surface of the windshield, **Figure 7**. The area measured 18 cm x 5 cm (7 in x 2 in) and occurred due to the altered deployment path of the air bag.. This transfer was linked to a scuff located in the 10 o'clock sector on the face of the bag.

Figure 6: Interior contacts.

Figure 7: Air bag transfers to windshield.

A triangular area of fibers was identified on the knee bolster. The area measured 10 cm x 10 cm (4 in x 4 in), width by height , and was located 5 cm (2 in) left of the steering column center line. This contact was linked to the left knee of the driver.

MANUAL RESTRAINT SYSTEM

The manual restraint system in the Dodge Spirit consisted of 3-point lap and shoulder belts for the four outboard seating positions. The center rear position was equipped with a lap belt. 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 restraint's upper anchorages (D-rings) were fixed. The left front restraint was found in the stowed position at inspection. The retractor was not locked. There was no evidence of restraint usage on the webbing or hardware surfaces that could be related to this crash. The first responders to the crash indicated the driver was unrestrained. The driver's kinematic pattern is also indicative that he was unrestrained.

SUPPLEMENTAL RESTRAINT SYSTEM

The Dodge Spirit was equipped with a frontal Supplemental Restraint System (SRS) that consisted of a driver air bag. The driver air bag module was located in the typical manner in the center hub of the steering wheel and deployed as designed from the H-configuration module. The module's upper cover flap was trapezoidal in shape. The cover flap width measured 17.1 cm (6.8 in) at the center seam and tapered to 15.2 cm (6.0 in) over its 7.6 cm (3.0 in) height. The lower cover flap was rectangular and measured 17.1 cm (6.8 in) by 7.6 cm (3.0 in), width by height.

The driver air bag measured 71 cm (28 in) in its deflated state. The air bag was tethered by two 7.6 cm (3.0 in) wide straps sewn to the face of the bag in 3/9 o'clock positions. The bag was vented by two 3.3 cm (1.3 in) diameter ports located in the 11/1 o'clock sectors on the back side of the bag. A large melanin transfer was noted on the back side of the air bag from 10 to 2 o'clock sectors. There also was a region of tissue transfer, located in the 2 o'clock sector on the back side of the bag, that measured approximately 13 cm (5 in). **Figure 8** is a close-up view of the transfers on the back side of the air bag. **Figure 9** is a

view of the face of the air bag. A 1.0 cm x 12.7 cm (0.4 in x 5.0 in) dark colored transfer was identified on the perimeter of the bag, in the 10 o'clock sector. This transfer was linked to the fabric transfer on the left aspect of the windshield previously identified (refer to **Figure 7**).

Figure 8: Close-up view of melanin transfers on the back side of the air bag.

Figure 9: View of the transfer on the face of the air bag.

The following manufacturer's nomenclature was printed in the 12 o'clock sector on the back side of the driver air bag:

UT11179-01B
90 08 21
90 06 42
179-01B
0068851

DRIVER DEMOGRAPHICS

Age/Sex:	45 year old/Male
Height:	180 cm (71 in)
Weight:	91 kg (200 lb)
Manual Restraint Usage:	Unrestrained
Usage Source:	Vehicle inspection/Driver injury pattern/Observations of the first responders to the crash scene
Eyeware:	None

DRIVER INJURIES

Injury	Severity (AIS 90)	Injury Mechanism
Atlanto-occipital dislocation w/ transection of the cervical spinal cord	Critical (640274.6,6)	Deploying driver air bag

Pontine contusions	Critical (140204.5,8)	Deploying driver air bag
Sub-arachnoid hemorrhage involving cerebellum and brain stem	Serious (140466.3,6)	Deploying driver air bag
Mild cerebral edema	Serious (140670.3,9)	Deploying driver air bag
2 band-like anterior neck abrasions	Minor (390202.1,5)	Deploying driver air bag
Dry red flat abrasions -left side of face and behind left ear	Minor (290202.1,2)	Deploying driver air bag
2.5 cm (1.0 in) superficial laceration posterior aspect left arm	Minor (790202.1,2)	Rebound contact with seat back (probable)

NOTE: the above injuries were identified in the autopsy records obtained from the medical examiner.

DRIVER KINEMATICS

The driver of the Dodge Spirit was seated unrestrained in a normal driving position. The left front seat was documented in a rear track position, measured as 1.9 cm (0.8 in) forward of full rear. It was probable, the driver was distracted looking in his center mirror, for the trailing police officer, as he traveled northward approaching the crash scene. Redirecting his attention to straight ahead, the driver realized the vehicle could not negotiate the 90 degree right curve and reacted by applying and locking the vehicle's brakes. The unrestrained driver initiated a forward trajectory and probably braced his arms and legs in an effort to restrain his forward motion.

The vehicle skidded off the left side of the road, traversed a small ditch and struck an embankment and tree. The tree was up-rooted in the process of the crash. The driver responded to the 12 o'clock direction of the impact forces by loading the steering wheel rim through his arms. This loading fractured the inboard side of the steering wheel rim's tilt mechanism. The fractured mechanism allowed the steering wheel rim to rotate upward and left. The impact with the embankment/tree and the process of uprooting the tree created a crash pulse of long duration. This delayed the deployment of the driver air bag to a point late in the collision sequence when the driver became positioned within the deployment path of the air bag.

The air bag deployed and contacted the anterior aspect of the driver's neck evidenced by the band-like abrasions. A large corresponding melanin transfer was noted on the back side of the air bag. The expansion of the air bag hyper-extended the driver's head causing the atlanto-occipital dislocation with transection of the cervical spine, pontine contusions, the sub-arachnoid hemorrhage involving the cerebellum and brain stem and the cerebral edema. The driver's forward trajectory and interaction with the steering column completely displaced the column from the shear plate. The driver's left forearm was displaced from

the rim and contacted the left A-pillar evidenced by the scuffed trim panel. His left knuckles impacted the windshield evidenced by the windshield fracture.

Figure 10: Altered deployment path of the air bag.

The forward position of the driver coupled with the steering wheel's fractured tilt adjustment altered the normal deployment path of the air bag resulting in the fabric transfers to the windshield as the air bag expanded, **Figure 10**. The 10 o'clock sector of the steering wheel rim contacted the left aspect of the instrument panel. The driver then rebounded back into the seat and slumped to the right where he was found.