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ON-SITE SEAT BELT FAILURE INVESTIGATION

VERIDIAN CASE NO. CA01-042

VEHICLE: 1995 GEO TRACKER

LOCATION: SOUTH CAROLINA

CRASH DATE: JULY 2001

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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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17. *Abstract* This investigation focused on the failure of the front left shoulder belt webbing in a 1995 Geo Tracker and the fatal injury mechanisms of the restrained 16 year old female driver. The Geo was involved in a single vehicle rollover crash. The vehicle's restraint system consisted of manual 3-point lap and shoulder belts for the four outboard seat positions. During the rollover sequence, the webbing of the left front restraint tore and separated allowing the driver to be ejected from the vehicle. The driver sustained a fatal cervical spine injury and was pronounced dead at the scene. The local media informed the National Highway Traffic Safety Administration (NHTSA) and the Office of Defects Investigations (ODI) of the crash. The ODI subsequently requested the Crash Investigations Division assign an on-site crash investigation to the Special Crash Investigations team at Veridian Engineering. The vehicle had been impounded by the county coroner pending resolution of the matter and was available for inspection. The on-site portion of the investigation took place on August 14, 2001.			
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BACKGROUND

This investigation focused on the failure of the front left shoulder belt webbing in a 1995 Geo Tracker and the fatal injury mechanisms of the restrained 16 year old female driver. The Geo was involved in a single vehicle rollover crash. The vehicle's restraint system consisted of manual 3-point lap and shoulder belts for the four outboard seat positions. During the rollover sequence, the webbing of the left front restraint tore and separated allowing the driver to be ejected from the vehicle. The driver sustained a fatal cervical spine injury and was pronounced dead at the scene.

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SUMMARY

Crash Site

This single-vehicle crash occurred during the afternoon hours in July, 2001. At the time of the crash, it was daylight and the weather was not a factor. The asphalt road surface was dry. The crash occurred on a two-lane north/south roadway in a rural setting. There was a left curve for southbound traffic at the crash site. The radius of the curve measured approximately 229 m (750 ft) with a five degree super-elevation. The road width measured 6.3 m (20.8 ft). The west shoulder was narrow, approximately 1 m (3 ft) wide, and unimproved. From the road shoulder, the elevation of the off-road terrain dropped approximately 0.8 m (2.5 ft) into an open field that sloped away from the roadway with a negative grade. The average grade measured minus 18 percent. The speed limit in the area of the crash was 72 km/h (45 mph). **Figure 1** is a southbound trajectory view entering the left curve.

Figure 1: Trajectory view of the Geo.

Pre-Crash

The 1995 Geo Tracker was southbound driven by a restrained 16 year old female. The driver's reported height and weight were approximately 165 cm (65 in) and 79 kg (174 lb). Reconstruction of the crash dynamics determined the Geo was probably traveling in the range of 97 to 105 km/h (60 to 65 mph). As the Geo entered the left curve, the driver steered late causing the vehicle's right side tires to travel off the right edge of the pavement. The driver steered left (counterclockwise) to regain the travel lane and correct this errant trajectory. However, in the process of the maneuver, the driver over-corrected and the vehicle crossed the centerline. Realizing her error, the driver steered suddenly back to the right (clockwise). The combination of the vehicle's momentum and the sudden steering maneuver caused the vehicle's rear tires to break traction and the Geo began to yaw clockwise. These sinusoidal steering maneuvers caused a dynamic loading of the vehicle's suspension that was out-of-phase with the vehicle's trajectory.

Inspection of the crash site revealed two yaw marks attributed to the vehicle's left side tires, **Figure 2 and 3**. The length of the left front and left rear marks measured 20.1 m(66.1 ft) and 18.1 m (59.5 ft), respectively. The average radius of curvature of the marks was determined to be approximately 94.4 m (310 ft). This average radius was measured over the first 12 m (40 ft) of the yaw mark. A critical speed calculation for this yawing trajectory was calculated to be approximately 92 km/h (57 mph). (It should be noted that the critical speed calculation is a minimum speed calculation.) This calculation was consistent with the reconstructed vehicle travel speed of approximately 100 km/h (mid 60's mph).

Figure 2: Southbound view along the vehicle's yawing trajectory.

Figure 3: Look back view.

Crash

At the end of the yaw marks, the vehicle's suspension unloaded and the Geo began an untripped left- side leading rollover. There was no rim gouge or touchdown at the end of either yaw mark that could be associated to a tripping condition. The first point of vehicle touchdown was associated to the left side rims of the Geo, (refer to the center of Figure 3) and was located 5.6 m (18.5 ft) from the end of the left front yaw mark. The left rims of the Geo contacted the pavement over a measured length of 5.1 m (16.7 ft). Inspection of the vehicle revealed both left rims to be heavily abraded due to this contact.

The Geo left the roadway and barrel rolled through the open field to rest, **Figure 4**. The vehicle came to rest on its left side approximately 54 m (177 ft) from the point where it left the road. A reconstruction of the roll sequence determined the Geo rolled 13 quarter turns (3-1/4 revolutions). The physical condition of the vehicle indicated roll sequence had an insignificant vertical component. The vertical deformation to the supporting roof structures was minimal. Rather, the physical evidence of the scene and vehicle supported a high velocity roll dynamic with a high roll rate.

Figure 4: View from the roadway to final rest location of the Geo.

During the rollover sequence, the webbing of the left front (driver's) restraint failed and the driver was ejected, probably through the vehicle's left door window opening. (Refer to the manual restraint section below for further discussion regarding the webbing failure.) She was found outside the vehicle approximately 9 m (30 ft) from the vehicle's final rest position (refer to the crash schematic below). It was most likely she was ejected after the vehicle had rolled 10 quarter turns (2-1/2 revolutions). The driver had relatively minor exterior soft tissue injuries indicating she was probably deposited on the ground and rolled a short distance to rest, as the Geo rolled away from her. **Figure 5** is a schematic of the crash.

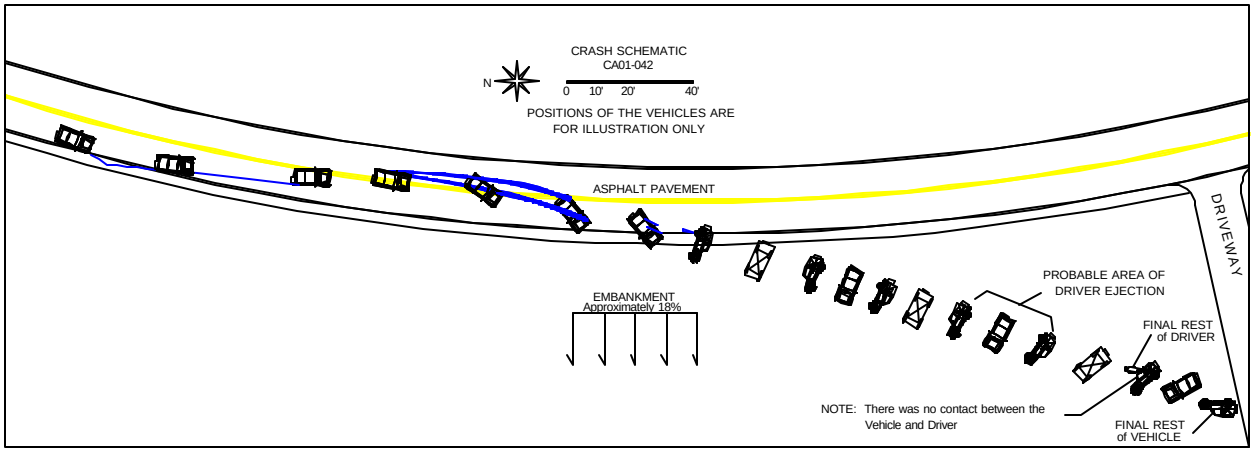

Figure 5: Crash Schematic.

Post-crash

The police and ambulance personnel responded to the crash scene. The driver suffered a cervical spine fracture with a partial spinal cord separation and was dead at the scene. A full autopsy was performed. Post-crash examination of the driver's restraint indicated the webbing had separated under tension, allowing the driver to be ejected. The latch plate remained latched in the buckle post-crash. It was the coroner's opinion, the driver could have survived the crash had the restraint not failed and she had remained within the vehicle.

1995 GEO TRACKER

The 1995 Geo Tracker was identified by the Vehicle Identification Number (VIN): 2CNBE18U2S6 (production sequence deleted). The four passenger utility vehicle was equipped with a soft removable top and was considered a convertible. The power train of the two-door, two-wheel drive vehicle consisted of a 1.6 liter/I-4 engine linked to a 3-speed automatic transmission. The restraint system consisted of manual 3-point lap and shoulder belts. It was not equipped with a Supplemental Restraint System (SRS). The brakes were a hydraulic front disc/rear drum system. Its was not equipped with an Anti-lock braking system (ABS). The odometer indicated 141,263 km (87,779 miles) at the time of the inspection. The date of manufacture was not known. The vehicle had been purchased used for the driver by her parents, as a present for her 16th birthday, therefore the history of the Tracker is unknown.

Exterior Damage

Figures 6 through 8 are left front, left rear and right side exterior views of the Geo, respectively. The vehicle sustained exterior damage consistent with a 3-1/4 revolution (13 quarter turn) left side leading lateral roll. The primary vehicle damage was to the left side roof structures, soft top and right front fender. The upper aspect of the left A-pillar was deformed approximately 5 cm (2 in) longitudinally rearward, 12.5 cm (5 in) laterally right and 5 cm (2 in) vertically down. The soft top was on the vehicle prior to the crash. Inspection of the soft top revealed the front supports were deformed rearward and the rear soft top supports had deformed forward. The left upper door frame and left roof rail were buckled. The left door was bowed outward approximately 13 cm (5 in) from occupant loading. The left door remained closed (jammed by deformation) during the rollover. The left front window was down prior to the crash and was disintegrated. The windshield had fractured. The right glazing was intact and the right door was operational. The right front fender was abraded and deformed leftward during the roll sequence. Dirt and debris was pocketed in the area. The deformed area about the right front fender measured 66 cm (26 in) longitudinally rearward from the front right bumper corner and 41 cm (16 in) laterally across the right front corner of the hood. The Collision Deformation Classification (CDC) of the damage was 00-TDDO-3.

Figure 6: Left front view of the Geo.

Figure 7: Left rear view of the Geo.

Figure 8: Right side view of the Geo.

The vehicle's front and back planes sustained only minor damage indicative that the roll was primarily lateral. The wheelbase dimensions of the vehicle were unchanged. The vehicle's left corner of the windshield header, left side rail and right side plane exhibited scratches and abrasions oriented in three different directions. The primary abrasions to the roof supports were oriented laterally (parallel to the vehicle's pitch axis), however the secondary abrasions were biased both longitudinally and angular to the vehicle. The different orientation of the scratches indicated that the Geo's respective planes contacted the ground at least three times. The nature of the body damage, roll distance, vehicle speed and occupant kinematics were all consistent with a 3-1/4 revolution rollover sequence.

All four tires on the Geo were of the same manufacturer and size and were in good condition. The manufacturer's tire data is identified in the table to the right. The exposed edges of the left front and left rear wheel rims were abraded about their circumference from pavement contact. The left front tire had debeaded and the steering tie rod to the wheel had fractured. The tire was turned approximately 45 degrees clockwise. The left rear tire pressure measured 151 kPa (22 psi). There was dirt, rocks and debris wedged in the tire bead. Debris had also pocketed in the center of the wheel rim. The right rear tire pressure measured 192 kPa (28 psi). There was no noted damage to the wheel rim. Grass debris was wedged in the bead of the right front wheel. The right front tire was turned approximately 30 degrees clockwise. Its tire pressure measured 206 kPa (30 psi).

Tire Data

Ridge Runner Radial APR
P215/75R15 100s M&S
Treadwear 100
Traction A
Temperature B
Made in Canada
R-39704
K-8434
Max. load: 780 kg (1742 lb)
Max. pressure: 240 kPa (35 psi)

Interior Damage

There was no interior damage related to the exterior forces of the crash. The driver's seat was adjusted to a mid-track position. The three-spoke steering wheel rim was undamaged. The fixed steering column was undamaged. There was no movement of the steering column's shear capsules. There were no bolster contacts. The interior panel of the left door, loaded by the driver during the rollover sequence, caused it to bow outward approximately 13 cm (5 in).

Manual Restraint System

The left front (driver's) manual restraint system in the 1995 Geo Tracker consisted of a continuous loop 3-point lap and shoulder belt with an inertial activated locking retractor and a sliding latch plate. The retractor was located in the lower mid B-pillar. The D-ring was not adjustable. The inboard buckle was attached to a 21.6 cm (8.5 in) flexible stalk and was anchored to the floor. The webbing had separated during the rollover sequence allowing the driver to be ejected. The first responders observed the webbing separation and noted the latch plate was still buckled in the receiver. **Figure 9** is an interior view of the belt system with the webbing extended in a reconstruction of its pre-crash position.

Figure 9: Reconstructed belt path for the Geo's driver.

The length of the webbing from the outboard anchor to the separation measured 135 cm (53 in). This measurement indicated the separation would have been initially located approximately between the driver's sternum and left shoulder. This section of webbing would have been stowed in the retractor when the belt was not in-use. Therefore, this section was not subject to deterioration from the elements (sun/weather/chemical) or from being caught in the door. The condition of the webbing was consistent with the age of the vehicle.

Inspection of the vehicle's interior determined there was an absence of a mechanism to cause the webbing separation at this location. There were no sharp metal edges to snag or cut the webbing. Additionally, there was no mechanism for the driver to sufficiently load the belt in this torso section to cause this failure. The driver's loading of the belt in this area would also induce belt loading in the lap portion of the webbing. Load sharing in this manner reduced the localized stress in any particular area of the webbing, given the belt system was extended and worn properly. In this crash, some of the driver's injuries were consistent with proper belt use. These injuries consisted of abrasions to the left neck and shoulder, chest and abdominal abrasions, abraded contusions to the right and left inguinal regions and two moderate spleen lacerations. Refer to the Driver's Injury table later in this report for a complete summary of the injuries.

Figure 10 is a close-up view of the fixed section of webbing near the separation. This section of webbing was across the driver's pelvic region, through the latch plate and directed diagonally across her chest. Examination of the webbing revealed the fibers leading toward the separation were stressed and distorted over a length of 22.4 cm (8.8 in). Additionally, the webbing appeared to have possibly folded over and begun to "rope". This section of the webbing was the only region that appeared stressed. The width of the webbing measured 4.75 cm (1.87 in) at the separation indicating the belting was stretched. The width of the webbing at the out-board anchor measured 5.1 cm (2.0 in).

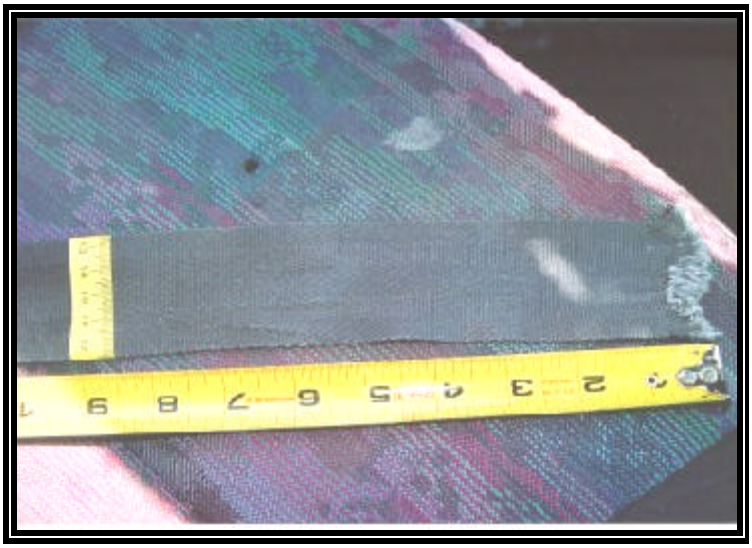

Figure 10: Stressed area of the webbing leading to the separation.

During the rollover sequence, this section of webbing migrated toward the latch plate due to occupant loading in lap portion of the belt system. Apparently the inertial retractor unlocked and allowed webbing to spool or pay-out of the retractor. This mechanism introduced slack into the restraint system. The retractor then locked again in response to the vehicle's inertial change causing the driver to reload the belt system. It was probable that the retractor locked/unlocked/re-locked multiple times during the rollover as the pendulum moved through the neutral position. In this manner, the area of the separation moved from the area of the driver's sternum to the latch plate. There was no debris (glass, metal, dirt, sand) noted on the webbing or embedded in the area of the failure.

Figures 11 and 12 are views of the latch plate and webbing separation. The forward aspect (relative to the vehicle) of the latch plate hardware exhibited obvious evidence of frictional contact. The plastic hardware at the reaction surface was abraded as a result of the contact. The length of this abrasion measured approximately 3.3 cm (1.3 in) and wrapped around the forward corner of the loop, figure 11. This frictional contact, in combination with the possibility the webbing had folded over onto itself (roped) as it passed through the latch plate, induced a stress concentration in the webbing at the latch plate. The webbing probably became jammed as it passed through the plate and then failed under tension as a consequence of driver loading. The fibers at the separation were frayed and width of the webbing splayed consistent with a tensile failure, figure 12.

Figure 11: Close-up view of latch plate deformation.

Figure 12: View of the latch plate and webbing separation.

Figure 13 is an overhead view of the inboard buckle stalks. The lower end of the stalk was attached to the floor anchor by a 9.5 mm (0.375 in) diameter pin. The pin allowed fore/aft movement of the buckle stalk. The floor anchor consisted of a hinge section comprised of a pair of 3.1 mm x 33 mm x 33 mm (1/8 in x 1.3 in x 1.3 in) steel sections. The deformation of the driver's anchor occurred as a result of tension. The buckle stalk was bent leftward at approximately 45 degrees and was in contact with the seat. The deformation occurred at the hinge section.

Figure 13: Overhead view of the inboard buckles.

The seat belt system was manufactured by the Takata Fabrication Corporation. The following manufacturer's nomenclature identified the webbing:

Model: TFC-524-P212
Date: 1994
Lot No: 4189
FL64AC

The following identifiers were stamped on the left retractor: G0139 C2051 P02 7069L

DRIVER DEMOGRAPHICS

Age/Sex: 16 year old/Female
Height: 165 cm (65 in)
Weight: 79 kg (174 lb)
Restraint Usage: 3-point lap and shoulder belt
Usage Source: SCI inspection, occupant kinematics, observation of the first responders
Medical Treatment: None, fatally injured at the scene

DRIVER INJURY

Injury	Severity (AIS 98 Update)	Injury Mechanism
4 cm (10 in) abraded contusion along the right cheek	Minor (290202.1,1) (290402.1,1)	Ground contact
2.3 cm x 9.0 cm (1 in x 3.5 in) abrasion extending across the left neck and mandible and onto the left upper shoulder	Minor (390202.1,2)	Seat belt webbing
1.4 cm (0.6 in) superficial laceration about the angle of the left mandible	Minor (290602.1,2)	Left roof rail
17 cm x 5.5 cm (6.7 in x 2.2 in) left shoulder contusion extending posteriorly and almost to the mid-line	Minor (790402.1,2)	Left roof rail
Vague chest contusions, NFS	Minor (490402.1,9)	Seat belt webbing (possible)
38 cm x 9 cm (15 in x 3.5 in) horizontally oriented abrasion with contusion across the upper chest (consistent with bra imprint)	Minor (490202.1,3) (490402.1,3)	Ground contact
Superficial non-specific abrasions about the upper abdomen	Minor (590202.1,9)	Seat belt webbing (possible)
15 cm x 2 cm (6 in x 1 in) abrasion with contusion to the left inguinal region	Minor (590202.1,2) (590402.1,2)	Seat belt webbing
10 cm x 4.5 cm (4 in x 1.8 in) abrasion with contusion to the right inguinal region	Minor (590202.1,1) (590402.1,1)	Seat belt webbing
Irregular abrasions to the left flank and back extending to the upper border of the scapula	Minor (590202.1,2) (690202.1,2)	Ground contact

11.5 cm x 8.0 cm (4.5 in x 3.1 in) abraded contusion of the left upper extremity from the point of the shoulder to the dorsal mid forearm	Minor (790202.1,2) (790402.1,2)	Ground contact
10.0 cm x 9.0 cm (3.9 in x 3.5 in) abrasion with contusion of the right upper extremity	Minor (790202.1,1) (790402.1,1)	Ground contact
Bilateral knee abrasions	Minor (890202.1,3)	Ground contact
2.5 cm x 1 cm (1 in x 0.5 in) left knee laceration	Minor (890602.1,2)	Ground contact
Vertically oriented abrasions along the back of the lower extremities, bilaterally	Minor (890202.1,3)	Ground contact
Left 2nd rib fractured posteriorly with puncture of parietal pleura with only a minor amount of blood within the left pleural cavity	Minor (450214.3,2)	Left roof rail
Two lacerations of the spleen in the hilar region, NFS	Moderate (544220.2,2)	Seat belt webbing
Mild to moderate hemorrhage in the left parietal region	Minor (190402.1,2)	Ground contact
Bilateral subdural hemorrhage over the convexities of the cerebrum with a small amount in the cerebellar region	Critical (140654.5,3) (140442.4,6)	Ground contact
Subarachnoid hemorrhage with the most severe area in the right Sylvan fissure	Serious (140684.3,1)	Ground contact
Small area of contre coup contusion along the right anterior temporal lobe	Serious (140604.3,1)	Ground contact
Apparent contusion and partial separation of the upper cervical spinal cord at the base of the brain w/ fracture of the upper cervical spine	Maximum (640272.6,6)	Ground contact

DRIVER KINEMATICS

Immediately prior to the crash, the 16 year old female driver was seated in a mid-track position with a presumed normal upright posture. She was proper restrained by the vehicle's 3-point lap and shoulder belt system. The driver lost control of the vehicle due to a combination of driver inexperience, excessive speed and inattention. Her aggressive steering maneuvers caused the vehicle to break traction, yaw and subsequently rollover. It was probable the driver was "fighting" to regain control of the vehicle.

Upon initiation of the left side leading roll and ground contact, the driver exhibited a leftward and upward trajectory. The driver contacted and loaded the belt system evidenced by the abrasions to the neck, shoulder, and respective inguinal regions, and the spleen lacerations. Through the dynamics of the first 1 to 2 revolutions, the inertial retractor apparently unlocked and relocked sequentially allowing slack to be introduced into the restraint system and for the mechanism causing the restraint failure at the latch plate to develop. Stress concentrations developed at the latch plate caused the webbing to failure under tension. It was probable the driver became unrestrained at this point in the roll sequence.

As the vehicle entered the third revolution, the driver contacted and loaded the left door evidenced by the outward door deformation and left flank/arm abrasions. The driver's shoulder and back also contacted the left (side) roof rail, possibly in the area of the rail's buckling. This contact was evidenced by the left posterior 2nd rib fracture and large area of contusion to the left shoulder and back. In this position, it was probable the driver became "captured" with her left arm and shoulder extending out the left window and her head extending out the soft top. As the vehicle rolled inverted the driver sustained the fatal neck fracture and cervical spine damage by ground contact. The unrestrained driver was deposited on the ground through the left front window opening. The vehicle then rolled away from the driver to its final rest. Once ejected, the driver tumbled a short distance along the ground to her final rest position. During this process she sustained the minor abrasions identified above.