

**TRANSPORTATION SCIENCES CENTER
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CALSPAN ON-SITE AIR BAG DEPLOYMENT INVESTIGATION

CALSPAN CASE NO. CA97-012

**VEHICLE #1 - 1997 GEO METRO (DUAL AIR BAG-EQUIPPED)
VEHICLE #2 - 1985 NISSAN KING CAB PICKUP TRUCK
VEHICLE #3 - 1991 FORD TEMPO GL**

LOCATION - STATE OF FLORIDA

CRASH DATE - FEBRUARY, 1997

Contract No. DTNH22-94-D-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 are 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 performance of the involved vehicle(s) or their safety systems.

TECHNICAL REPORT STANDARD TITLE PAGE

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<p>15. <i>Supplementary Notes</i> On-site investigation of a dual air bag deployment crash that resulted in critical injuries to the right front occupant.</p>			
<p>16. <i>Abstract</i> An on-site investigation was conducted into a three vehicle crash involving the front of an air bag equipped 1997 Geo Metro four door hatchback (Vehicle #1), the rear and front planes of a 1985 Nissan King Cab (Vehicle #2), and the rear of a 1988 Ford Tempo GL. The crash occurred in the month of February, 1997 during the early morning hours in the State of Florida. The ambient condition at the time of the crash was sunrise with no adverse weather conditions. Vehicle #1 was traveling south on a two lane, undivided, level, dry, asphalt roadway when it struck the rear end of Vehicle #2 at a CRASH computed impact speed of 57 km/h (36 mph). Vehicle #2 was stopped in the southbound travel lane while waiting in a long line of stopped traffic. This impact resulted in the normal deployment sequence of Vehicle #1's dual air bag system. Vehicle #2 was pushed forward and struck the rear of Vehicle #3. The three year old female right front occupant in the Vehicle #1 who was 106.7 cm (42.0") tall and weighed 13.6 kg (30.0 lbs.) was restrained by the lap portion of the three point lap and shoulder belt. The girl's upper torso moved forward of pre-impact braking and was in close proximity to the passenger side air bag module cover at the time of deployment. The expanding air bag contacted the child's face and head resulting in a well defined significant abrasion injury pattern of her forehead. The child's head was propelled to the left and subsequently contacted the protruding center instrument panel. This contact mechanism resulted in a fracture of the left frontal bone and left orbit. She sustained a contusion of the left frontal temporal lobe, brain swelling, subdural hematoma, and was unconscious for fifteen days. She was transferred to a rehabilitation facility where she made steady recovery progress. Driver #1, a 33 year old male, suffered minor injuries in the crash which included an abrasion of the left shoulder from the torso belt, an abrasion of the left forearm from the driver side air bag, a contusion of the left hand from contact with the upper A-pillar and an abrasion/contusion of the left clavicle from the torso restraint belt. He was treated and released at the local medical facility. Driver #2, a 24 year old male, was stopped in a line of traffic when his vehicle was struck by Vehicle #1. He suffered pain of the ribs, but was not transported to a medical facility from the scene. Driver #3, a fifty-nine year old male, was stopped in front of Vehicle #2 when Vehicle #2 was pushed into the rear of his following the impact with Vehicle #1. The driver was not injured.</p>			
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CALSPAN AIR BAG DEPLOYMENT INVESTIGATION
CALSPAN CASE NO. CA97-012
STATE OF FLORIDA
FEBRUARY, 1997

Background

The NHTSA was notified of the three vehicle crash involving an air bag related injured right front occupant by the General Motors Corporation. Calspan was subsequently notified by the Field Operations Branch of the NHTSA and began the investigation the same day. A Calspan Reconstructionist was on-site four days after notification.

Summary

This crash involved a 1997 Geo Metro equipped with dual front air bags (Vehicle #1), a 1985 Nissan King Cab pick-up truck (Vehicle #2), and a 1991 Ford Tempo GL (Vehicle #3) which were involved in a chain reaction front to rear collision. The crash occurred in the month of February, 1997 at dawn on a straight section of an undivided, two lane, level, dry asphalt roadway which had a posted speed limit of 80 km (50 mph). There was no reported adverse weather conditions present at the time of the crash.

Driver #1, a 33 year old male, was en route to the child day care provider with his three old daughter seated in the right front passenger seat. He was laughing with his daughter which diverted his attention away from the travel lane. Upon returning his focus to the travel lane he observed Vehicle #2 stopped in his travel lane. Driver #1 applied the brakes to full wheel lock-up in an attempt to avoid the crash and skidded 7.0 m (23.0') prior to the point of impact (POI).

Vehicle #1 struck the rear of Vehicle #2 at a CRASH computed impact speed of 57 km/h (36 mph) which resulted in a computed delta V of 34 km/h (21 mph) for Vehicle #1 and 23 km/h (14 mph) for Vehicle #2. This impact resulted in the normal deployment sequence of the dual air bag system. The damage to Vehicle #1 was located primarily above the bumper in a typical bumper override damage pattern. The Collision Deformation Classification (CDC) assigned to Vehicle #1 was 12-FDEW-1 and 06-BDEW-3 for Vehicle #2.

Vehicle #2 was subsequently pushed forward and struck the rear of Vehicle #3 which was also stopped. The assigned CDC for the front of Vehicle #2 was 12-FDEW-1 and 06-BDEW-1 for Vehicle #3. Vehicle #3 sustained minor damage and was driven from the scene. The SMASH program computed a delta V of 17 km/h (10 mph) for Vehicle #2 and 22 km/h (13 mph) for Vehicle #3.

The three year old female who was 106.7 cm (42.0") tall and weighed 13.6 kg (30.0 lbs.) was restrained by the lap belt in the right front seat of Vehicle #1 at the time of the crash as noted by the linear contusion on the child's lower abdomen. Although the driver insisted the child was wearing the torso belt, contact points in the vehicle interior and the injury pattern to the child's forehead indicated that her upper torso was in close proximity to the passenger side air bag module cover at the time of the deployment sequence. This evidence along with the lack of any related soft tissue injuries over the right shoulder/neck area indicated that her upper torso was not restrained by the torso belt at the time of the crash.

During Vehicle #1's pre-crash braking event, the right front occupant moved forward and loaded the lap belt with her hips resulting in a contusion of the abdomen. Her upper torso continued forward in a jackknifing motion and was in close proximity of the top mounted passenger air bag module cover at the time of the crash sequence.

As the Supplemental Inflatable Restraint System (SIR) initiated the deployment sequence, the leading edge of the passenger side air bag contacted the child's forehead resulting in a well defined contusion/abrasion injury pattern. As the air bag continued to expand, the child was then propelled laterally to the left with the left side of her head contacting the protruding center instrument panel. This resulted in a fracture of the left frontal bone, fracture of the left orbit, and brain trauma. The child came to the final rest position in the right front seat leaning toward the right front door and her shoulders rotated slightly toward the driver.

Driver #1 realized immediately that his daughter was unconscious and slid her out of the vehicle through the driver's door after releasing the child's restraint belt. He placed her on the ground and kept her warm while awaiting rescue.

An ambulance traveling six vehicles behind Vehicle #1 responded immediately to the crash and transported Driver #1 and his daughter to a local medical facility where she arrived in a coma. She was evaluated and subsequently transferred via helicopter three hours later to a trauma center located in a major metropolitan area which specialized in pediatric care.

Upon arrival at the trauma center, the child was admitted to the pediatric intensive care unit (PICU) where an intercranial pressure monitor was inserted in the left side of the brain. On the sixth day in the PICU, the child opened her eyes but did not respond to visual stimuli. After eight days in the ICU, the child was transferred to a private room where she regained consciousness eight days later.

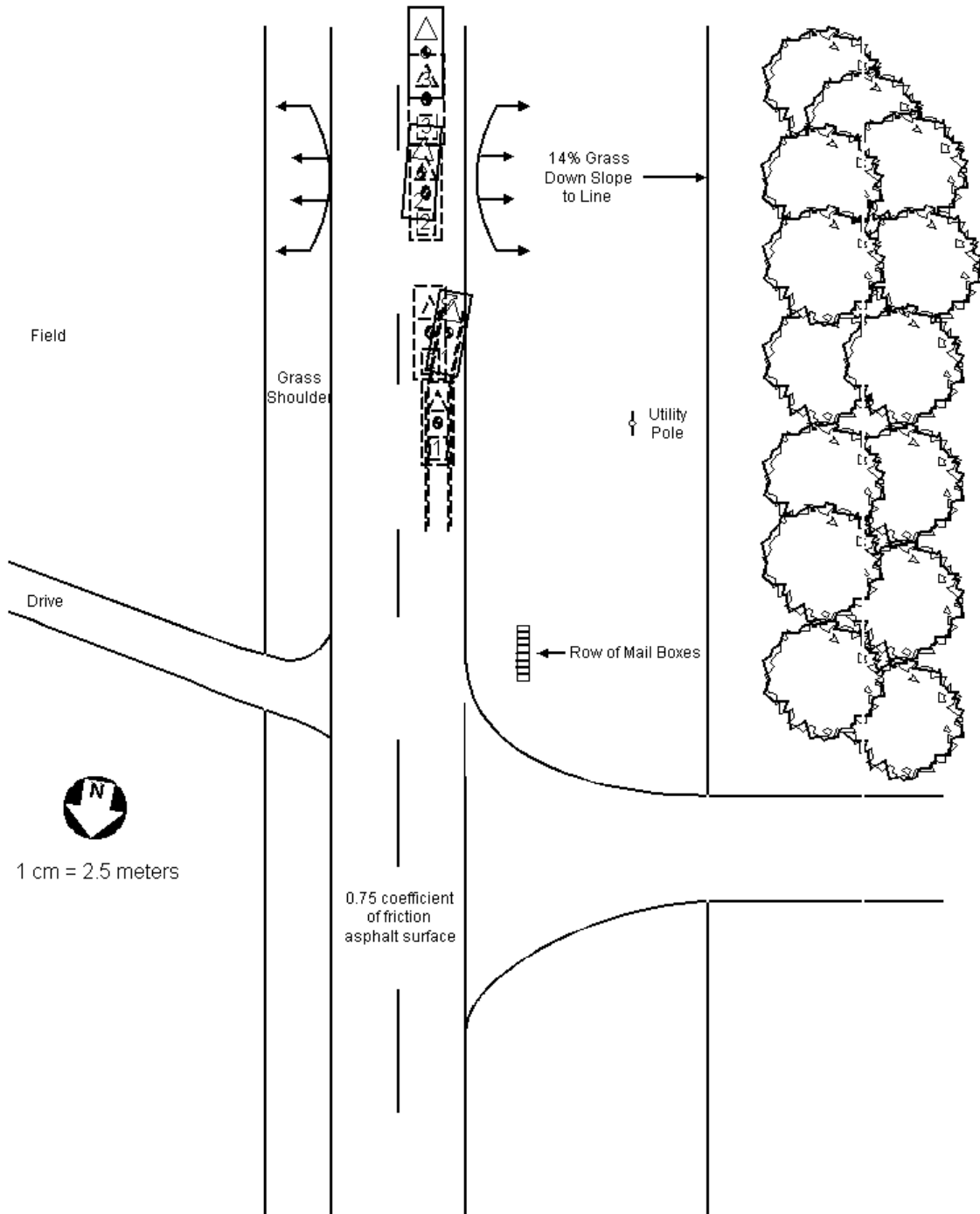
The child was transferred to a rehabilitation center seventeen days after the crash where she stayed approximately one month before being released to home. Her physical and mental condition improved at the rehabilitation center. Four weeks following the crash, the child demonstrated a recognizable speech pattern, a recognition of verbal commands, and mobility of her extremities. However, she was unable to walk and suffered paralysis of the left side of her body.

Driver #1 suffered minor injuries in the crash which included an abrasion and contusion of the left shoulder from the torso belt, an abrasion of the left forearm from contact with the expanding driver side air bag, and an abrasion/contusion of the left hand from contact with the upper A-pillar. He was treated and released at the local medical facility.

Driver #2, a 24 year old male, was stopped in a line of traffic when his vehicle was struck by Vehicle #1. He suffered pain of the ribs, but was not transported from the scene.

Driver #3, a fifty-nine year old male, was stopped in front of Vehicle #2 when Vehicle #2 was pushed into the rear of his vehicle following the impact with Vehicle #1. The driver was not injured.

CRASH SCENE SCHEMATIC
Calspan Case 97-012



SCENE SCHEMATIC

CRASH DEMOGRAPHIC DATA	
Location:	2 lane undivided highway
State:	State of Florida
Area/Type:	Rural residential
Investigating Police Agency:	County Sheriff's Department
Crash Type:	Three vehicle front to rear chain reaction crash
Air Bag Vehicle Right Front Occupant Injury Severity:	Critical (AIS-5)

AMBIENCE	
Viewing Conditions:	Dawn
Weather:	Cloudy
Road Surface:	Dry

HIGHWAY	
Type:	County highway
Number Of Lanes:	Two travel lanes
Roadway Width:	6.8 m (22.3') road edge line to road edge line
Surface:	Asphalt
Median:	None
Edge:	Solid white edge lines in poor condition with an adjacent 14 percent down slope 12.2 m (40.0') wide grass shoulder
Vertical Alignment:	Level
Horizontal Alignment:	Straight
Estimated Coefficient Of Friction:	0.75
Traffic Density:	Moderate to heavy, traffic was stopped 0.4 km (0.25 miles) from signalized four way intersection

TRAFFIC CONTROLS	
Signals:	None
Signs:	None
Markings:	Broken yellow center lines in fair condition and solid white roadway edge lines in poor condition
Speed Limit:	80 km/h (50 mph)

VEHICLE DESCRIPTION	
Vehicle #1	
Description:	1997 Geo Metro, 2 door hatchback
V.I.N.:	2C1MR2297V6(Serial # omitted)
Color:	Red
Odometer:	19,831 km (12,323 miles)
Engine:	1.3 L
Transmission:	3 speed automatic
Steering:	Power
Brakes:	Power assisted front disc and rear drum brakes
Padding:	Upper and mid instrument panel, soft edge steering wheel rim and air bag module cover, door panels, door arm rests, seats, roof liner, and sunvisors
Active Restraints:	3-point lap and shoulder belts in the four outboard seating positions
Passive Restraints:	Driver side and passenger air bags which deployed as designed during the first impact sequence with Vehicle #2
Defects:	None
Tow Status:	Towed due to damage

Vehicle #2	
Description:	1985 Nissan King Cab pickup truck
V.I.N.:	JN6ND06S4FW(Serial # omitted)
Color:	White
Odometer:	315,648 km (196,140 miles)
Engine:	2.4 L
Transmission:	3 speed automatic
Steering:	Power steering
Brakes:	Power assisted front disc and rear drum brakes
Padding:	Upper and mid instrument panel, soft edge steering wheel rim, center console arm rest, door panels, door arm rests, seats, roof liner, and sunvisors
Active Restraints:	3-point lap and shoulder belts in the front seat outboard seat positions, 2-point lap belts in the two rear jump seat positions
Passive Restraints:	None
Defects:	None
Tow Status:	Towed due to damage

VEHICLE DAMAGE

Vehicle #1 - Exterior:

Damage to Vehicle #1 involved the frontal plane. During pre-impact braking, the front of Vehicle #1 pitched downward resulting in a bumper override damage pattern as the result of the impact with the rear of Vehicle #2 (a 1985 Nissan King cab pickup truck). Direct contact damage began at the left front bumper corner/grille area and extended to the right 111.1 cm (43.75"). The total direct and induced length of deformation was 139.1 cm (54.75"). The maximum crush of 12.7 cm (5.0") was located at C₃ [55.6 cm (21.9") right of the left bumper corner]. Crush values for Vehicle #1 are listed below:

Impact #1, Upper radiator support bar	C ₁ = 10.2 cm (4.0")	C ₄ = 10.2 cm (4.0")
	C ₂ = 10.2 cm (4.0")	C ₅ = 10.2 cm (4.0")
	C ₃ = 12.7 cm (5.0")	C ₆ = 0 cm

Impact #1, Front Bumper	C ₁ through C ₆ = 0 cm
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Components damaged in the crash included the front bumper covering, both headlight assemblies, the left front fender, the hood, the upper radiator support bar, the remote crash sensor, and radiator. The measured wheelbase dimensions were equivalent to manufacture specifications which indicated the front wheels were not displaced during the crash. The police estimated vehicle damage at \$8,000.

CDC: The assigned CDC for Vehicle #1 was 12-FDEW-1.

Vehicle #1 - Interior:

Interior damage to the 1997 Geo Metro was associated with the air bag deployment and occupant contacts. The driver side air bag module cover opened along the designed tear seam lines in the typical "I" configuration deployment pattern. There was no driver contact evidence observed on the air bag module flaps.

The driver side air bag was tethered with two 3.8 cm (1.5") diameter vent ports located in the upper left and right quadrants along the instrument panel side of the air bag. There was no driver contact evidence observed on the air bag.

The steering column was fixed with a measured upward angle of 18 degrees from horizontal. There was no displacement of the steering column shear plate noted at the shear capsules.

A 2.5 cm (1.0") long tissue transfer was noted on the mid left upper A-pillar which was attributed to contact by the driver's left hand. A bodily tissue transfer which measured 5.2 cm (2.0") in length was noted at the top of the left upper A-pillar. This was not attributed to occupant contact during the crash.

A series of black transfer marks noted on the roof fabric adjacent to the left sunvisor were not attributed to crash related contact points. Given this was the second day of leasing this vehicle, the transfer marks may have been left during the previous travel day by Driver #1. Driver #1 was a repair person for a copy machine company.

Upon inspection of the vehicle, the driver's seat was noted to be 1.6 cm (0.625") forward of the full rearward setting which was consistent with the placement described by Driver #1. The seat back support angle measured 17 degrees rear of vertical.

The passenger side air bag top mount module cover opened along the designed tear points. A heavy concentration of nylon fibers which were adhered to the underside of the module cover appeared to be part of an air bag protective covering.

There were abraded areas on the surface of the instrument panel adjacent to the bottom left corner of the module cover which were located 16.5 cm (6.5") right of the vehicle centerline and at the transition point between the vertical and horizontal planes of the instrument panel. This was the result of contact by the expanding passenger side air bag.

The right vertical surface of the protruding center instrument panel exhibited a smudge/abrasion mark located 16.5 cm (6.5") right of the vehicle centerline near the leading corner. This artifact was attributed to contact by the right front occupant's head and passenger side air bag during the Supplemental Inflatable Restraint (SIR) system deployment sequence.

There was a narrow lateral abraded area on the right instrument panel just below the passenger side air bag module opening which measured 24.9 cm (11.0") in length. This was attributed to contact by the passenger side air bag during the SIR deployment sequence.

The windshield glazing exhibited a small spider web pattern located 10.2 cm (4.0") left of the vehicle centerline and 7.6 cm (3.0") below the windshield header with two adjoining smudge marks which measured 5.2 cm (2.0") and 3.8 cm (1.5"). These were attributed to contact by the driver's right hand.

There was a 2.05 cm (1.0") diameter light color burnish mark on the glove compartment door located 58.4 cm (23.0") right of the vehicle centerline. This was not attributed to occupant contact during the crash sequence.

There were whitish transfers on the left and right inside vertical edges of the center console. These were not attributable to occupant contact during the crash sequence.

The right front seat was adjusted 2.5 cm (1.0") forward of the full rear position. This was consistent with the description by Driver #1 who indicated the seat was moved one adjustment notch forward from full rear prior to the start of the day's trip due to the placement of his tool box behind the right front seat. The seat back angle measured 20 degrees rearward from vertical. At this setting, the seat back support was 85.1 cm (33.5") rearward from the air bag module cover measured at a height of 45.7 cm (18.0") above the junction with the seat cushion.

The longitudinal dimension of the right front seat cushion measured 49.5 cm (19.5") from the junction with the seat back support to the leading edge of the cushion. The horizontal distance between the leading edge of the seat cushion to the vertical plane of the right instrument panel was 21.6 cm (8.5"). The horizontal distance between the leading edge of the seat cushion to toe pan measured 68.9 cm (27.0").

The vertical height from the top leading edge of the seat cushion to the floor pan was 25.4 cm (10.0"). The vertical distance from the top leading edge of the seat cushion to the passenger side air bag module cover opening was 30.5 cm (12.0"). The vertical dimensional height of the right instrument panel

from the top surface to the lower edge measured 31.8 cm (12.5"). The rake angle of the windshield was 30 degrees from the horizontal plane.

Vehicle #2 - Exterior

The rear plane of Vehicle #2 struck by the front of Vehicle #1 at a CRASH computed impact speed of 57 km/h (36 mph). Vehicle #2 was pushed forward where it contacted the rear plane of Vehicle #3. The direct contact damage length along the rear bumper measured 104.1 cm (41.0") which began at the right rear bumper corner and ended 33.0 cm (13.0") left of the vehicle centerline. The direct and induced damage along the bumper measure 117.5 cm (46.25").

The direct contact damage length for the impact with Vehicle #3 was 109.2 cm (43.0") which began at the right front bumper corner and ended 29.2 cm (11.5") left of the vehicle centerline. The total length of direct and induced damage along the front plane was 149.2 cm (58.8"). Crush values for both impacts are listed below:

Impact #1, Rear bumper	C ₁ = 1.3 cm (0.5") C ₂ = 4.4 cm (1.75") C ₃ = 12.7 cm (5.0")	C ₄ = 15.2 cm (6.0") C ₅ = 14.0 cm (5.5") C ₆ = 21.0 cm (8.25")
Impact #2, Front bumper	C ₁ = 12.7 cm (5.0") C ₂ = 0.5 cm (0.2") C ₃ = 1.3 cm (0.5")	C ₄ = 1.3 cm (0.5") C ₅ = 0.3 cm (0.1") C ₆ = 0 cm (0")

Components damaged in the crash included the rear bumper, the tailgate, the right rear fender, back of the cab, the right front headlight assembly, the right front directional light, the grille, the hood, and the right front fender.

CDC: The CDCs for Vehicle #2 are listed in the following table:

Impact #1	06-BDEW-3
Impact #2	12-FDEW-1

Repair Cost: The insurance company rated the vehicle at a total loss.

Vehicle #2 - Interior

Interior damage to Vehicle #2 was confined to the driver seat back support which was deformed rearward by the driver during the crash.

Vehicle #3 - Exterior

The rear plane of Vehicle #3 struck by the front of Vehicle #2 after Vehicle was struck in the rear by Vehicle #1. The SMASH program computed the delta V for Vehicle #3 as 22.0 km/h (13.0 mph) and 17.0 km/h (10.0 mph) for Vehicle #2. The police estimated vehicle damage at \$100.

CDC: The CDC was 06-BDEW-1.

SUPPLEMENTAL INFLATABLE RESTRAINT SYSTEM (SIR) - VEHICLE #1

The dual air bag Supplemental Inflatable Restraint (SIR) system in the 1997 Geo Metro deployed during the impact with Vehicle #2. The longitudinal component of the delta V value computed by the CRASH speed reconstruction program was -34.0 km/h (-21.0 mph).

The vehicle was equipped with a Sensing Diagnostic Module (SDM) which was located on the floor behind the center console. The SDM had a single remote discriminating sensor installed on the upper radiator support bar mounted 12.7 cm (5.0") right of the vehicle centerline. The protective shield covering the sensor was deformed in the crash.

Driver Side Air Bag

The driver side air bag module cover opened along the designed tear seams in the typical "I" pattern configuration. The vertical seam of the "I" pattern was designed in a serpentine opening pattern. There was no evidence of occupant contact on the module cover flaps. The lateral dimension of each flap measured 7.6 cm (3.0") and the vertical dimension measured 12.7 cm (5.0"). The thickness of the flap measured 3.1 mm (0.125").

The air bag incorporated a two tethered design with the tethers located in the 3 o'clock and 9 o'clock positions. There were two 3.8 cm (1.5") diameter vent ports located at the 1 o'clock and 11 o'clock positions which were 34.3 cm (13.5 cm) apart. The diameter of the air bag measured 69.2 cm (27.25") with a 16.0 cm (6.3") diameter stitched center area. The circumferential edge of the bag was stitched with a finished seam. There was no evidence of occupant contact on the air bag surface. The air bag UPC identification label was stitched into the instrument panel side of the air bag below the vent ports contained the following identification number:

PE5114100-01

TB0S62140266

Passenger Side Air Bag

The passenger side air bag was nontethered and mounted in the top portion of the instrument panel. There were no visible vent ports in the air bag. The asymmetrical module cover measured 35.6 cm (14.0")

along the windshield edge and 34.3 cm (13.5") along the leading edge (i.e., occupant side edge). Both sides of the cover measured 15.2 cm (6.0").

The left side of the cover was located 20.4 cm (8.0") right of the vehicle centerline with the left rear corner located 27.3 cm (10.75") longitudinally from the windshield and the right rear corner 15.2 cm (6.0") from the windshield. The cover thickness measured 4.8 mm (0.1875"). The leading edge of the air bag module compartment was recessed 3.2 cm (1.25") from the leading edge of the instrument panel.

A concentration of nylon fibers was adhered to the undersurface of the cover along the leading edge beginning at the left corner and extending 7.6 cm (3.0") to the right. This concentration was associated with a swatch of nylon fabric located along the bottom of the air bag module housing which was inside of the module overwrap. It was reasoned that the deployment path of the air bag may have been restricted early in the deployment sequence which resulted in the pinching of the fabric swatch between the passenger side air bag and the air bag module cover.

The expanded passenger side air bag measured 54.6 cm (21.5") along a horizontal line that began at the inflator unit and extended rearward to an arbitrary vertical transition point. At a distance of 6.4 cm (2.5") below the transition point was a 22.9 cm (9.0") lateral area of discoloration which measured 11.4 cm (4.5") vertically. The discoloration appeared to be a light brown hue with vertical striation lines. It had a stiffened tactile texture which was different from the supple nature of the adjacent air bag fabric. Additionally, there was a narrow 4.4 cm (1.75") long black transfer mark along the left edge of the discolored area which was attributed to contact with the underside of the module cover during the SIR deployment sequence.

Another narrow 12.7 cm (5.0") long black mark was noted in the vicinity of the left (in-board) vertical seam line which extended onto the side surface of the air bag. This mark was located 34.53 cm (13.5") down from the inflator unit and was attributed to contact with the underside of the air bag module cover. There were no visible signs of occupant transfer marks (e.g., tissue or bodily fluids) on the air bag.

Sensing Diagnostic Module (SDM) Readout

The SIR was designed with a single point Sensing Diagnostic Module (SDM) sensor which was located behind the center console and measured the deceleration values within the occupant compartment. The SDM was equipped with an additional remote discriminating sensor located on the upper radiator support bar 12.7 cm (5.0") right of the vehicle centerline.

The readout of the SDM showed a rapid rise in the algorithm where at ten milliseconds the delta V measured 3.2 km/h (2.0 mph), between 55 and 60 milliseconds it recorded a delta V of 16.1 km/h (10.0 mph), and at 180 milliseconds it registered a 30.0 km/h (18.6 mph) delta V. The crash record was halted at 180 milliseconds due to an electrical interruption.

VEHICLE VELOCITY ESTIMATES

Crash Sequence Impact #1	Vehicle #1	Vehicle #2
Travel Speed:	69.0 km/h (43.0 mph)	0 km/h (stopped)
Impact Speed:	57.0 km/h (36.0 mph)	0 km/h
Total ? V:	34.0 km/h (21.0 mph)	23.0 km/h (14.0 mph)
Longitudinal ? V:	--34.0 km/h (-21.0 mph)	23.0 km/h (14.0 mph)
Lateral ? V:	0 km/h	0 km/h
Energy Absorption:	9,789 joules (7,219 ft-lb)	68,513 joules (50,526 ft-lb)

Crash Sequence Impact #2	Vehicle #2	Vehicle #3
Travel Speed:	0 km/h (stopped)	0 km/h (stopped)
Impact Speed:	Not applicable	0 km/h
Total ? V:	17.0 km/h (10.0 mph)	22.0 km/h (13.0 mph)
Longitudinal ? V:	-17.0 km/h (-10.0 mph)	22.0 km/h (13.0 mph)
Lateral ? V:	0 km/h	0 km/h
Energy Absorption:	30,762 joules (22,686 ft-lb)	9,279 joules (6,843 ft-lb)

The impact speed and velocity changes for the first impact were computed by the damage and trajectory algorithms of the CRASH program. The second impact sequence was computed using the SMASH program

COLLISION SEQUENCE

Pre-Crash:

The driver of the 1997 Geo Metro (Vehicle #1) was transporting his three year old daughter to the day care provider. Driver #1 was familiar with this route as he traveled it on a daily basis. The traffic density on the morning of the crash was described by Driver #1 as unusually heavy with frequent stops along the route.

Driver #1 was not very familiar with this vehicle as this was the second day he had driven it under a short term lease agreement with a rental car company. The driver selected this particular vehicle

(make/model) primarily for its reported high fuel efficiency. His occupation required several local trips per day in connection with the on-site service related industry. His strategy was to evaluate the performance of this vehicle prior to purchasing a similar new vehicle.

Vehicle #1 was traveling at a driver reported speed of 72 km/h (45 mph) with his three old daughter seated in the right front passenger seat. As Vehicle #1 traveled along the straight section of roadway, Driver #1 diverted his attention toward his daughter with whom he was laughing and joking. Upon returning his attention to the travel lane, he observed Vehicle #2 stopped in his travel lane. Driver #1 applied the brakes to full wheel lock-up in an attempt to avoid the crash and skidded 7.0 m (23.0') prior to the point of impact (POI).

Driver #1 moved forward and was restrained by the lap and shoulder restraint belt. The right front occupant moved forward and was restrained by the lap portion of the restraint belt system. Her upper torso continued forward which allowed her head to come in close proximity of the passenger side air bag module cover at the time of the crash.

Crash:

The frontal plane of Vehicle #1 struck the rear of Vehicle #2 at a CRASH computed impact speed of 57.0 km/h (36.0 mph). Due to the downward pitching of Vehicle #1 during pre-impact braking and the relative height of the Nissan pickup truck's (Vehicle #2) rear bumper, the direct contact damage pattern was located primarily above the bumper in a typical override/underride configuration. This impact actuated Vehicle #1's SIR deployment sequence.

The driver loaded the restraint belt which was apparent from the 'D-ring' transfer mark on the torso belt and the corresponding linear contusions of his left shoulder. The driver's right hand was propelled upward by the expanding driver side air bag and contacted the rearview mirror and windshield. His left hand was displaced laterally to the left by the expanding driver side air bag resulting in an abrasion of the medial surface of the wrist. His left hand subsequently contacted the upper A-pillar which resulted in an abrasion/contusion over the dorsal aspect of the left hand.

The child's forehead contacted the expanding passenger side air bag was as noted by the significant abrasion on the right front aspect of her forehead. Her head was deflected laterally to the left and contacted the side of the protruding center instrument panel resulting in a depressed skull fracture of the left side of the frontal bone and a fracture of the left orbit. She rebounded rearward and to the right coming to rest in the seat with her head near the right front door.

The driver in Vehicle #2 was seated in an upright position and moved rearward against the driver seat back support during the crash. The seat back support deformed rearward and contacted the rear wall of the cab with the head rest portion of the seat back. The driver sustained pain of the ribs which was attributed to this contact mechanism.

Vehicle #2 was pushed forward and struck the rear of Vehicle #3 which was stopped behind a line of traffic. The police indicated the Driver #3 was restrained by the lap and torso restraint belt at the time of the crash.

Post Crash:

Final Rest - Vehicle #1 traveled in an angular direction toward the right roadway edge line where it came to the final rest position (FRP) in the southbound travel lane adjacent to the west side road edge line. It was situated with an 11 degree heading angle relative to the road edge line. The vehicle was subsequently towed from the scene and eventually was taken to the rental company's secured storage yard.

Vehicle #2 remained within the southbound travel lane at the FRP. It was towed from the scene and eventually was taken to a vehicle auction salvage yard.

Vehicle # 3 remained in the travel lane at the FRP. By the time police arrived on-scene, the driver had driven the vehicle onto the adjacent grass shoulder.

Driver Activities - Driver #1 located his daughter who was covered by the deployed passenger side air bag and released her restraint belt. After releasing his restraint belt, he exited through the right front door and slid his daughter out of the vehicle through the same door. He carried her a short distance to the adjacent grass shoulder area where he placed her in a supine position on the ground.

Driver #2 and Driver #3 exited their vehicles under their own power. Neither driver was transported to a medical treatment facility from the scene.

Police Activities - The County Sheriffs Department responded and arrived on-scene forty minutes after the reported time of the crash. The investigating officer marked the final rest positions of Vehicle #1 and Vehicle #2 with spray paint, photographically documented the scene, and obtained statements from participants.

Rescue Activities - An ambulance was coincidentally in the line of traffic six vehicles behind Vehicle #1 at the time of the crash. Rescue personnel in the ambulance were alerted to the crash and immediately responded. They transported the child and Driver #1 to a local medical facility and arrived thirty minutes after the police reported time of crash. The child was evaluated and subsequently transferred via helicopter to a trauma center which was equipped with a pediatric care unit. She was admitted for 17 days before being discharged to a rehabilitation center. Driver #1 was treated and released with minor injuries.

Scene Clearance - Vehicle #1 and Vehicle #2 were towed by a local towing service from the scene. Vehicle #3 was driven from the scene. Vehicle #1 was inspected at the lease company's impound lot twenty-eight days after the crash. Vehicle #2 was inspected at an vehicle auction salvage yard.

HUMAN FACTORS/OCCUPANT DATA

Vehicle #1	Driver #1	Right Front Occupant
Age/Sex:	33 year old male	3 year old female
Height:	188.0 cm (74.0"),	106.7 cm (42.0")
Weight:	65.8 kg (145.0 lb.)	13.66 kg (30.0 lb.)
Manual Restraint System Usage:	Three point lap and torso restraint belt	Lap portion of the three point lap and torso restraint belt system
Usage Source:	Vehicle inspection, police report, medical data, photograph	Official medical data, photograph
Eyewear:	None	None
Clothing	Black dress pants, light color pull over shirt	Jump suit which consisted of a shirt attached to shorts with a pink flower pattern
Vehicle Familiarity:	Rental vehicle, second day of usage	
Route Familiarity:	Very familiar	
Trip Plan:	En route to the child care provider	
Type of Medical Treatment:	Treated and released	Admitted

Vehicle #2	
Age/Sex:	24 year old male
Manual Restraint System Usage:	Three point lap and torso restraint belt
Usage Source:	Vehicle inspection, police report
Type of Medical Treatment:	Not transported from the scene

Vehicle #3	
Age/Sex:	59 year old male
Manual Restraint System Usage:	Three point lap and torso restraint belt
Usage Source:	Police report
Type of Medical Treatment:	Not injured

INJURY DATA

Following the crash, Driver #1 and the right front occupant (the three year female) in Vehicle #1 were transported to a medical treatment facility via ambulance and arrived thirty minutes after the police reported time of crash. She arrived in an unconscious state at the emergency room. Computerized tomography revealed a depressed fracture of the left frontal bone with underlying brain swelling. She remained approximately three hours in the medical facility before being transferred via helicopter to a trauma hospital specializing in pediatric care. She arrived approximately one hour later. After arrival, a Camino intercranial pressure monitor (ICP) was inserted over the left fronto-parietal region of the brain. She was subsequently sedated and paralyzed.

Four days after the crash, the ICP was removed. At that time, the patient was listed at a Level 4 on the “The Pediatric Brain Injury Scale” which was adapted from the “Rancho Los Amigos Pediatric Scale”. The Scale ranges from “no response” (Level 5) to “normal” (Level 0). Level 4 was described as: *A generalized response to sensory stimuli. Children blink their eyes to very loud sound and generally grimace to light touch with a feather on the face. Often these children blink to protect their eyes when a toy or hand is passed quickly before their eyes (visual threat).*

Six days after the crash, the child opened her eyes spontaneously and was subsequently transferred out of the intensive care unit into general pediatric care. She remained there for eleven days before being transferred to a rehabilitation facility. Her condition in the rehabilitation center improved to the point where she could vocalize and respond to instructions. She was discharged to home in good condition approximately one month after being admitted to the rehabilitation center.

Driver #1 was sustained minor injuries of his left shoulder and left hand and was treated and released from the first medical facility. Driver #2 complained of pain of the ribs but was not transported from the scene. Driver #3 was not injured in the crash.

The following tables identify the type of injury, the related AIS-90 injury code, and the injury source:

DRIVER #1 INJURIES	INJURY SEVERITY AIS-90	INJURY SOURCE
1-2. Abrasion and ecchymatic area of the mid left clavicle	490202.12 490402.12	Torso restraint belt
3-4. Abrasion/contusion of the dorsal aspect of the left hand	790202.12 790402.12	Upper A-pillar
5. Abrasion of the left forearm	790202.12	Driver side air bag

RIGHT FRONT OCCUPANT OF VEHICLE #1 INJURIES	INJURY SEVERITY AIS-90	INJURY SOURCE
1. Bruise over left eye with significant swelling	297402.12	Center instrument panel
<i>Supplemental Discussion:</i> There was marked peri-orbital ecchymosis extending into the frontal region with near complete closure of the left eye.		
2. Significant abrasion of the right forehead	290202.17	Passenger side air bag
3. Fracture of the left frontal bone with 3-4 mm depression	150404.35	Center instrument panel
4. Fracture of left orbital roof	251200.22	Center instrument panel
5. Edema of the left frontal and left temporal lobe	140668.32	Center instrument panel
6. Cerebral contusion	140602.39	Center instrument panel
7. Minor residual chronic right frontal subdural hemorrhage	140650.41	Passenger side air bag
8. Unconscious >24 hrs.	160824.50	Center instrument panel

RIGHT FRONT OCCUPANT OF VEHICLE #1 INJURIES	INJURY SEVERITY AIS-90	INJURY SOURCE
<i>Supplemental discussion:</i> The patient remained unconscious throughout transportation and has been noted to be posturing with the upper extremities. She does not open her eyes to noxious stimuli. She does not follow commands or attempt any speech or eye contact. She is moving her extremities spontaneously, more so in the lower extremities. Pupils are equal, round and reactive to light, 4 mm down to 2 mm, brisk. Response to pain is extensor in both upper extremities with some intermittent posturing, withdrawal in the lower extremities. The patient had a Glasgow Coma Scale of 4 upon arrival at the first medical treatment facility and rated 7 upon arrival at the second medical treatment facility. Head CT scan revealed a fracture of the left orbital roof which extends into the left frontal bone and was minimally depressed without significant displacement. An Camino ICP transducer monitor for intracranial pressure was placed after arrival at the pediatric intensive care unit at the second medical treatment facility with immediate readings which ranged from 8-16 with good wave form.		
9. Small bruise at the right lower quadrant of the abdomen	590402.11	Lap restraint belt

DRIVER #2 INJURIES	INJURY SEVERITY AIS-90	INJURY SOURCE
Pain of the ribs	Not a codeable injury	Seat back support

DRIVER #3 INJURIES	INJURY SEVERITY AIS-90	INJURY SOURCE
Not injured	N/A	N/A

OCCUPANT KINEMATICS

Vehicle #1

Right Front Occupant

The right front seat was adjusted 2.5 cm (1.0") forward from the full rear position which placed the seat back support 85.1 cm (33.5") rearward from the leading edge of the passenger side air bag cover at a point located 45.7 cm (18.0") above the junction with the seat cushion. The driver was adamant that his daughter was restrained by the three point manual lap and torso belt prior to the crash. This claim was

somewhat qualified by the investigating police officer who traveled to the hospital and obtained a statement from Driver #1 and took photographs of the child. The police officer noted that there was a slight mark on her chest which was right of the breastbone that might have been caused by a shoulder belt.

Given the lack of soft tissue injury noted by medical personnel of the child's right shoulder, neck, and chest area and the presence of a linear contusion along the lower right abdominal area, it appeared that the child was only restrained by the lap belt at the time of the crash. The mark noted on the girl's chest by the police officer was attributed to contact by the expanding passenger side air bag.

Given the short stature of the child [106.7 cm (42.0")] and the fixed position of the D-ring, the torso belt may have been uncomfortable to wear and was probably placed behind the child's back prior to the crash. The child's upper torso moved forward in response to vehicle braking and came in close proximity of the air bag module cover at the time of deployment. Her head was turned slightly toward the driver as the result of the social interaction she had with him prior to the crash.

The right side of the child's forehead was contacted by the expanding passenger side air bag which resulted in a significant well defined abrasion of the right side of the forehead. Her head was then propelled laterally to the left by the air bag where it contacted the right side of the protruding center instrument panel resulting in a depressed fracture of the left frontal bone, fracture of the left orbit, and brain swelling. There was a scuff mark noted on the vinyl surface which was attributed to this contact sequence.

The child rebounded back into the seat and came to rest with her back leaning toward the right front door with her shoulders rotated slightly toward the driver. The driver indicated the passenger side air bag remained inflated and against his daughter at final rest.

Driver #1 released his daughter's restraint belt latch and removed the child from the vehicle through the left front door. He laid her in a supine position on the adjacent shoulder and kept her warm pending the arrival of rescue. A nearby resident rushed over to lend assistance and observed that the child's head was swelling and had the appearance of being battered.

Driver #1

Driver #1 was restrained by the manual three point lap and torso restraint belt at the time of the crash. The driver's hand placement was in the two and ten o'clock positions. His seat was adjusted in the full rear position which placed the seat back support at a measured distance of 62.2 cm (24.5") from the driver side air bag module cover to a point located 44.4 cm (17.5") above the seat cushion. The driver was distracted by the right front occupant and when he returned his attention to the roadway, he observed Vehicle #2 stopped in his travel lane. He applied full brakes and skidded 7.2 m (23.6') prior to the POI.

Driver #1 moved forward during the braking maneuver and loaded the lap and torso belt during the crash sequence. This was apparent from the typical 'D-ring' transfer marks on the torso belt and the

corresponding linear contusions of his left shoulder. His right hand was propelled upward by the expanding driver side air bag and contacted the rearview mirror and windshield. His left hand was displaced laterally to the left by the expanding driver side air bag resulting in an abrasion of the medial surface of the wrist. His left hand subsequently contacted the left front upper A-pillar which resulted in an abrasion/contusion over the dorsal surface of the hand.

Driver #1 came to rest in the driver's seat and released his restraint belt. He initially attempted to locate his daughter who was covered by the passenger side air bag. After determining her body orientation, he released her restraint belt and pulled her out of the vehicle through the left front door. He carried her to the right shoulder of the roadway where he placed her on the ground pending rescue.

Vehicle #2

Driver #2

Driver #2 moved rearward against the seat back support during the crash. The seat back support deformed rearward and contacted the rear wall of the cab. Vehicle #2 traveled forward and struck the rear of Vehicle #3. Driver #2 moved forward in response to the second crash and was restrained by the lap and shoulder belt. The driver exited his vehicle through the driver's door under his own power.