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CALSPAN AIR BAG DEPLOYMENT INVESTIGATION

CALSPAN CASE NO. CA97-006

VEHICLE #1 - 1994 DODGE CARAVAN
VEHICLE #2 - 1989 GMC JIMMY

LOCATION - STATE OF MAINE

CRASH DATE - JANUARY, 1997

Contract No. DTNH22-94-D-07058

Prepared for:

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National Highway Traffic Safety Administration
Washington, D.C. 20590

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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.

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On-site investigation of an air bag deployment crash that resulted in injuries to a three year old male right front passenger.

16. *Abstract*

This crash involved a 1994 Dodge Caravan mini-van equipped with dual front air bags (Vehicle #1) and a 1989 GMC Jimmy four wheel drive utility vehicle (Vehicle #2). The crash occurred during the afternoon hours in the month of January, 1997 in the State of Maine on a straight section of an undivided, two lane, negative 6.1 percent slope southbound, slushy asphalt roadway which had a posted speed limit of 48 km (30 mph). The ambient conditions were daylight with no reported adverse weather conditions present at the time of the crash. Driver #2 initiated a left turn and began to cross the opposing lane when he observed the approach of Vehicle #1. He initially applied the brakes, but decided to accelerate through the intersection.

The right frontal plane of Vehicle #1 struck the right front side plane of Vehicle #2 resulting in a Collision Deformation Classification (CDC) of 11-FZEW-3 for Vehicle #1 and 02-RFEW-3 for Vehicle #2. The damage and trajectory routines of the SMASH program computed the delta V of 17 km/h (11 mph) for Vehicle #1 and 19 km/h (12 mph) for Vehicle #2. This impact resulted in the deployment of Vehicle #1's dual front air bag system. Vehicle #1 rotated in a clockwise direction and side slapped the right side of Vehicle #2.

The right front occupant in Vehicle #1, a three old male who was 104.1 cm (41.0") tall and weighed 15.9 kg (35.0 lbs.), was sitting in a Century Breverra Prestige booster child safety seat which was designed with a five point restraint belt system. The shoulder belts of the safety seat were placed over the child prior to the crash with the two piece comfort clip on the belts engaged. The latch plates on the two piece shield which made-up the fifth point on the harness, however, were not latched into the buckle prior to the crash. During Vehicle #1's pre-crash braking avoidance maneuver, the right front occupant moved forward against the booster seat shoulder belts which resulted in the release of the comfort clip. The child continued forward and came in contact with the deploying passenger side air module cover and air bag. As a result of this contact mechanism, the child sustained heavy abrasions of the forehead, right and left side of the face, fracture of the right parietal bone with corresponding punctate hemorrhage of the posterior aspect of the frontal lobe with some shearing, diffuse axonal brain injury, and subdural hemorrhage. The child was propelled rearward against the booster seat by the expanding air bag where he came to rest against the safety seat back support with his head canted toward the center of the vehicle and his feet angled slightly toward the right. The child was transported via ambulance to a trauma center where he was admitted for 41 days before being transferred to a rehabilitation facility.

Driver #1 complained of pain in the knee. The 8 month old child sitting in a forward facing child safety seat in the second row was not injured. Driver #2 sustained a contusion of the right hip from the seat belt.

17. *Key Words* Supplemental Restraint System (SRS) 3 yr. old male occupant in the right front seat of a dual front air bag vehicle AIS-5 (Critical) injury, 3 yr. old male		18. *Distribution Statement* General Public	
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TABLE OF CONTENTS

January 14, 1998

CALSPAN AIR BAG DEPLOYMENT INVESTIGATION

CALSPAN CASE NO. CA97-006

VEHICLE #1 - 1994 DODGE CARAVAN
VEHICLE #2 - 1989 GMC JIMMY

LOCATION - STATE OF MAINE

CRASH DATE - JANUARY, 1997

BACKGROUND

The Field Operations Branch (FOB) of the National Highway Traffic Safety Administration (NHTSA) was alerted to the crash by the NHTSA Region 1 Office. Calspan was notified of the crash by the FOB and was directed to conduct the investigation as an on-site effort. The investigation began the same day of notification and a Calspan Reconstructionist was on-site the following week.

SUMMARY

This crash involved a 1994 Dodge Caravan mini-van equipped with dual front air bags (Vehicle #1) and a 1989 GMC Jimmy four wheel drive utility vehicle (Vehicle #2). The crash occurred during the afternoon hours in the month of January, 1997 in the State of Maine on a straight section of an undivided, two lane, negative 6.1 percent slope southbound, slushy asphalt roadway which had a posted speed limit of 48 km (30 mph). The ambient conditions were daylight with no reported adverse weather conditions present at the time of the crash.

Driver #1, a 27 year old female, was returning home with her two children after leaving a birthday party at her friend's house which was approximately 3.2 km (2.0 miles) from her residence. After traveling approximately 0.8 km (0.5 mile), Vehicle #1 cleared a hillcrest and proceeded down the hill in a southbound direction when the driver observed Vehicle #2 stopped in the on-coming lane.

Driver #2, an 18 year old male, was proceeding northbound and had planned to make a left turn at an offset four leg intersection en route to a friend's home when he recognized occupants in a non-involved vehicle stopped at the east leg of the intersection to his right. Driver #2 slowed and momentarily stopped while gesturing to this vehicle prior to initiating the left turn.

Driver #2 returned his attention back to the road and proceeded to make the left turn when he observed the approach of Vehicle #1. He initially applied the brakes, but decided to accelerate through the intersection.

Driver #1 observed Vehicle #2 initiate the left turn and applied full brakes and attempted to steer to the left in an effort to go around Vehicle #2. The right frontal plane of Vehicle #1 struck the right front

side plane of Vehicle #2 resulting in a Collision Deformation Classification (CDC) of 11-FZEW-3 for Vehicle #1 and 02-RFEW-3 for Vehicle #2. The damage and trajectory routines of the SMASH program computed the delta V of 17 km/h (11 mph) for Vehicle #1 and 19 km/h (12 mph) for Vehicle #2. This impact resulted in the deployment of Vehicle #1's dual front air bag system.

Vehicle #1 rotated in a clockwise direction and side slapped the right side of Vehicle #2 with the left front fender. The related CDC was 09-LFEW-1 for Vehicle #1 and 03-RYEW-2 for Vehicle #2. Vehicle #1 rotated 139 degrees from its impact heading direction and came to the final rest position (FRP) laterally in the southbound travel lane with the rear portion of the vehicle extending into the northbound lane. Vehicle #2 rotated 89 degrees and came to the FRP on the adjacent snow packed lawn located on the west side of the roadway.

Driver #1 was a 27 year old female who was 154.3 cm (60.75") tall and weighed 47.6 kg (105 lbs.). The driver indicated she was wearing the lap portion of the manual three point lap and shoulder restraint belt at the time of the crash with the torso belt placed behind her back. Reportedly, the driver routinely placed the torso belt behind the back due to discomfort of the belt against her neck.

During the first impact, Driver #1's upper torso moved forward and contacted the deployed driver side air bag. Her torso continued forward resulting in the displacement of the steering column shear plate with measured values of 6.4 mm (0.25") and 12.7 mm (0.5") at the left and right shear capsules, respectively. Her right knee contacted the contoured portion of the knee bolster adjacent to the steering column as observed by the 6.4 cm (2.5") wide fabric transfer mark. She was listed by police as complaining of leg pain, but was not seen by a physician.

The right front occupant in Vehicle #1, a three old male who was 104.1 cm (41.0") tall and weighed 15.9 kg (35.0 lbs.), was sitting in a Century Breverra Prestige booster child safety seat which was designed with a five point restraint belt system. A two piece shoulder belt positioning adjustable comfort clip was located above a two piece safety shield. The safety shield when latched into the buckle located on the forward part of the safety seat formed the fifth point of the restraining harness. The seat was rated for children who weigh between 14 kg - 27 kg (30 lbs.-60 lbs.) and range in height from 89 cm (35") to the physical stature where the top of the child’s ears are below the booster seat headrest.

The vehicle’s three point manual lap and torso belt system was placed over the front of the booster safety seat which secured it to the vehicle. The child was sitting in the booster seat with the two shoulder belts of the safety secured with only the two piece comfort clip. Driver #1 indicated that the two piece safety shield was not latched into the buckle prior to the crash.

During Vehicle #1's pre-crash braking avoidance maneuver, the right front occupant moved forward against the booster seat torso belts resulting in the release of the comfort clip. The child continued forward until his head was within close proximity of the leading edge of the passenger side air bag module flap at the time of the supplemental restraint system (SRS) actuation.

As the SRS began to deploy, the leading edge of the passenger side air bag module cover contacted the child's forehead resulting in a linear type abrasion pattern over the right side of the forehead and a fracture of the right parietal bone. A scuff mark was noted along the leading edge of the module cover which measured 10.8 cm (4.25") in length with the presence of a few short strands of blond hair (reportedly the hew of the child's hair).

The boy's face was subsequently contacted by the expanding air bag which resulted in heavy abrasions of the right side of the face and minor abrasion of the left side of the face which was described by the parents as a rug burn and a fabric weave pattern by rescue. This was consistent with the tissue transfer observed on the passenger side air bag which covered a measured area of 11.4 cm x 22.9 cm (4.5" x 9.0") and was located between the upper and lower air bag tether attachment points.

A red transfer noted along the right vertical seam of the air bag may have been consistent with the color of the boy's jacket. The jacket was described as being dark blue with a broad red stripe on the sleeves. There were no medically diagnosed injuries of the boy's upper extremities.

The child was propelled rearward by the expanding air bag and contacted the booster seat back support. He came to final rest against the booster seat back support with his head angled toward the left side of the vehicle and his feet angled slightly toward the right. The booster seat's torso belts were found by the witness motorist to be away from the child's shoulders.

The right front seat in Vehicle #1 was adjusted in the full rear position which was confirmed by the driver to be the normal seat placement. The booster seat back support measured 73.7 cm (29.0") rearward from the leading edge of the passenger side air bag module cover at a height of 33.0 cm (13.0") above the booster's seat cushion.

The passenger side air bag was constructed with two tethers which limited the excursion of the air bag during expansion. The top tether was located 78.7 cm (31") from the inflator unit. The excursion of the upper tether from the leading edge of the air bag module cover was calculated at 64.8 cm (25.5").

The right front occupant was initially attended to by a witness motorist who was following behind Vehicle #1 prior to the crash. The motorist was a retired emergency medical technician (EMT) who upon observing the child noted that the child was having a hard time breathing with gurgling noise emitting from the boy. The motorist applied pressure to the child's chin in an effort to keep his head up in order to provide a clear airway until the arrival of rescue.

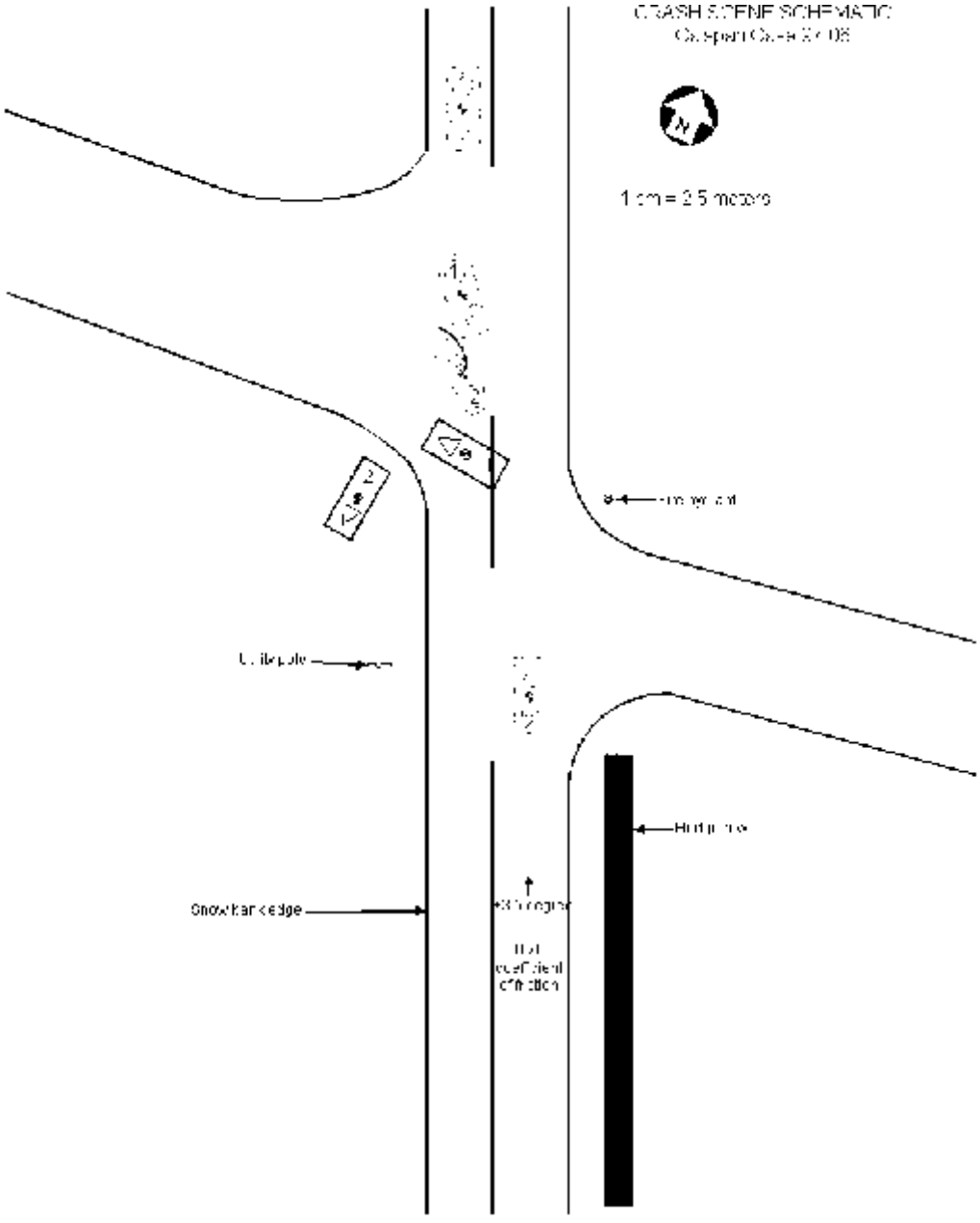
The responding EMTs and police took over from the motorist and placed the child on a backboard. At that time, the child responded only to painful stimuli and began to posture. The rescue team transmitted this information to a physician at a local hospital and requested permission to proceed to a trauma center in another city. The physician directed rescue to swing by the local hospital where the child was evaluated inside the ambulance. The physician agreed with the request and the child was transported to the trauma center which was located approximately forty-five minutes away.

Upon arrival at the trauma center, the child was evaluated and determined to have sustained brain trauma. He was placed on medication to induce a coma in order to manage brain swelling. During the coarse of treatment, an ICP monitor was placed and a ventriculostomy was later performed. The medication was withdrawn on the thirteenth day and the child opened his eyes on the fifteenth day. The medical team was unsure if his eyes were following anything and was given a Glasgow Coma Scale rating of 8 to 9. The child progressed during the course of treatment and was transferred to a rehabilitation facility forty-one days after the crash.

The following summarizes the injuries suffered by the child and the injury source:

- Closed head injury, Glasgow Coma Scale of 5 *(passenger side air bag module cover and air bag)*
- Facial bruising *(passenger side air bag)*
- Ecchymosis around eyes and nose *(passenger side air bag)*
- Facial abrasions *(passenger side air bag)*
- Left subdural tentorium *(passenger side air bag module cover and air bag)*
- Fracture of the right parietal bone with punctate hemorrhage of the posterior aspect of the frontal lobe with some shearing *(passenger side air bag module cover and air bag)*
- Diffuse axonal brain injury *(passenger side air bag module cover and air bag)*
- Diffuse swelling of he left hemisphere *(passenger side air bag module cover and air bag)*
- Intraparenchymal bleed *(passenger side air bag module cover and air bag)*
- Mid brain injury with diffuse hemisphere swelling *(passenger side air bag module cover and air bag)*
- Subconjunctival hemorrhage of the eye *(passenger side air bag)*

SCENE SCHEMATIC



CRASH DEMOGRAPHIC DATA	
Location:	Two lane undivided roadway at a four leg intersection
City/State:	State of Maine
Area/Type:	Rural/Residential
Accident Date/Time:	January, 1997/mid afternoon
Investigating Police Agency:	State Police
Accident type:	Two vehicle, turn across path, front to side crash
Air Bag Vehicle Passenger Injury Severity:	AIS-5 (Critical)
AMBIENCE	
Viewing Conditions:	Daylight
Weather:	Clear
Road Surface:	Slush
HIGHWAY	
Type:	Local route/intersecting local route
Number of Lanes:	2
Width:	7.8 m (25.6 ft)
Surface:	Asphalt
Median:	None
Edge:	Snow
Vertical Alignment:	Negative 6.1 percent slope southbound
Horizontal Alignment:	Straight
Estimated Coefficient of Friction:	0.20F
Traffic Density:	Light
TRAFFIC CONTROLS	

Signals:	None
Signs:	None
Markings:	Solid double yellow centerline
Speed Limit:	48 km/h (30 mph)
VEHICLE #1 DESCRIPTION	
Description:	1994 Dodge Caravan, 4 door mini-van
V.I.N.:	2B4GH2538RR (Serial # omitted)
Color:	Burgundy
Odometer:	42,505 km (26,412 miles)
Engine:	3.0 L V-6 MPI
Transmission:	Automatic
Steering:	FWD
Brakes:	Power assisted front disc and rear drum brakes
Padding:	Upper and mid instrument panel, soft edge steering wheel rim and air bag module covers, door panels, door arm rests, sunvisors, head restraints, center arm rests
Active Restraints:	Three-point continuous lap and shoulder belt webbing through a common latch plate with inertia activated locking retractors, adjustable D-rings in the front outboard seating positions, three-point manual lap and shoulder belts in the two center row seating positions, three-point manual lap and shoulder belts in the third row outboard seating positions, and a 2-point lap belt in center rear
Passive Restraints:	Driver side and passenger side air bags which deployed as a result of the first impact with Vehicle #2
Defects:	None
Tow Status:	Towed due to damage
VEHICLE #2 DESCRIPTION	
Description:	1989 GMC Jimmy 4x4
V.I.N.:	1GKCT18Z8K8 (Serial # omitted)

Color:	Blue
Odometer:	Unknown (electronic display odometer)
Engine:	4.3 L V6 FI
Transmission:	Four speed automatic transmission with a floor mounted manual four wheel drive transfer case shifter
Steering:	Power
Brakes:	Power assisted front disc and rear drum brakes
Padding:	Sunvisors, soft-edged steering wheel rim, door panels, door armrests, center console armrests, head restraints
Active Restraints:	Three point lap and shoulder belts in the front outboard seating positions
Passive Restraints:	None
Defects:	None
Tow Status:	Towed due to damage

VEHICLE DAMAGE

Vehicle #1 Exterior:

The right frontal plane of the 1994 Dodge Caravan (Vehicle #1) struck the right front side plane of the 1989 GMC Jimmy (Vehicle #2). Vehicle #1 sustained direct contact damage to the right frontal area starting 6.4 cm (2.5") right of the vehicle centerline and extending 67.3 cm (26 .5") to the right bumper corner. The front bumper sustained a maximum rearward displacement of 57.2 cm (22.5") located at the right-most bumper bolt.

The left front fender sustained direct contact along the left front fender during the clockwise rotation and subsequent sideslap with the right side of Vehicle #2. The contact began at the left front fender corner and extending 62.9 cm (24.75") rearward.

Front bumper and left front fender crush values are listed in the following tables:

Impact Sequence #1 Front Bumper Crush	C1 = 0 cm	C2 = 3.8 cm (1.5")	C3 = 10.2 cm (4.0")
	C4 = 15.2 cm (6.0")	C5 = 23.5 cm (9.25")	C6 = 55.9 cm (22.0")

Impact Sequence #2 Left Front Fender	C1 = 0.6 cm (0.25")	C2 = 1.3 cm (0.5")	C3 = 0.6 cm (0.25")
	C4 = 0.6 cm (0.25")	C5 = 0.6 cm (0.25")	C6 = 0.6 cm (0.25")

Components damaged in the crash included the front bumper assembly and grille, the radiator support bracket, the hood, the left and right front fenders, the right frontal substructure, the right front suspension, and the windshield.

Vehicle #1 CDC:

Impact #1	11-FZEW-3
Impact #2	09-LFEW-1

Vehicle #1 Interior:

Interior damage to the Dodge Caravan was associated with air bag deployment and occupant contacts. The right front passenger's seat was adjusted to the full rearward position on a seat track which had an adjustment range of 16.5 cm (6.5"). The incline of the seat cushion was 9 degrees. The distance from the leading edge of the seat cushion to the floor was 34.3 cm (13.5").

A Century Breverra Prestige booster child safety seat was secured in the right front passenger seat with the manual lap and shoulder belt. The child's father had moved the seat from the second seat row to the right front seat position the previous day and secured it with the manual three point restraint belt across the front aspect of the child safety seat. In this position, the horizontal distance from the child safety seat back support to the leading edge of the air bag module cover flap was 73.7 cm (29.0") taken 33.0 cm (13.0") above the child safety seat cushion. The adjustable D-ring for the right front manual three point lap and torso restraint belt was in the full up position.

The leading edge of the passenger side air bag module flap was located 2.5 cm (1.0") rearward from the vertical edge the instrument panel. The hinged edge of the air bag module cover was located 20.3 cm (8.0") from the base of the windshield at the right rear corner of the cover and 22.2 cm (8.75") at the left rear corner. The module cover was slightly deformed along the horizontal surface with a rearward displacement of the left rear corner. The leading edge of the passenger side module cover exhibited a 10.7 cm (4.2") scuff mark with a 6.4 mm (0.25") diameter artifact which was attributed to contact by the right front occupant's head during the SRS deployment cycle. A couple of short blond hair fibers were located along the module cover edge right of the artifact.

There were black transfer marks on both the driver and passenger side air bags from contact with the underside of the module cover flaps during the Supplemental Restraint System (SRS) deployment sequence. The passenger side air bag exhibited a red transfer mark along the outboard vertical seam which measured 68.6 cm (27.0") in length. This was attributed to contact with the red sleeves on the child's nylon

jacket. There was a 11.4 cm x 22.9 cm (4.5" x 9.0") area on the front surface of the air bag which exhibited scatter tissue transfers and a light yellow stain along the lower portion of the tissue transfer field. This artifact was attributed to contact with the child's facial area during the deployment sequence. Located to the right of this area was a 3.2 cm (1.25") diameter area which also exhibited tissue transfers and was attributed to facial contact during the air bag expansion event.

The windshield glazing was in place, but was cracked from impact forces. Two air bag transfer marks were located on the upper right surface of the windshield (refer to **Figure 1**). One transfer mark was 3.2 cm (1.25") long and was located 16.5 cm (6.5") right of center and 19.1 cm (7.5") below the windshield header. A second vertically orientated transfer mark was 6.4 cm (2.5") long and located 56.5 cm (22.25") right of the vehicle centerline and 1.3 cm (0.5") below the windshield header. The windshield had a 40 degree rake angle.

Figure 1. Deployed passenger air bag and resulting damage to the windshield.

The leading edge of the center front courtesy light bracket exhibited a 10.2 cm (4.0") smudge mark (refer to **Figure 2**). This contact was not attributed to the crash event.

A 6.4 cm (2.5") scuff from the right knee of the driver was noted on the protruding area of the knee bolster which conformed to the curved surface of the steering column. This contact was located 30.5 cm (12.0") left of the vehicle centerline (refer to **Figure 3**).

Figure 2. Courtesy light smudge mark.

Figure 3. Driver's right knee contact to the bolster.

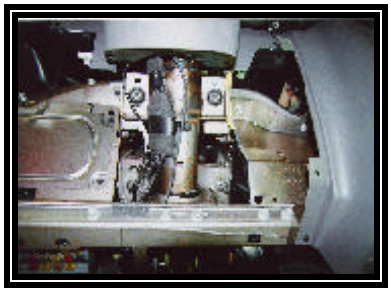


Figure 4. Shear plate displacement.

The steering column shear plate was displaced as a result of driver loading during the crash (refer to **Figure 4**). The displacement at the left shear capsule measured 6.4 mm (0.25") and 12.7 mm (0.5") at the right shear capsule.

At the time of inspection the driver's bucket seat was positioned 5.1 cm (2.0") rearward of the full forward position on a seat track adjustment range of 19.1 cm (7.5"). The adjustable tilt steering column was 41 degrees above horizontal. The seat belt upper anchor D-ring was adjusted to the full up position.

All of the doors of the Dodge Caravan remained closed and operational after the crash except the right front door which was restricted. The driver reportedly attempted to open the door from inside the vehicle following the crash, but was unsuccessful. An uninvolved motorist came forward and was able to open the door.

Repair Cost: Total loss

Vehicle #2 Exterior

The 1989 GMC Jimmy 4X4 (Vehicle #2) sustained direct contact damage along the right front fender during the first impact sequence and continued onto the right front door surface during the subsequent sideslap impact with Vehicle #1. Contact to the right front fender began 212.1 cm (83.5") forward of the right rear axle and extended 86.4 cm (34.0") rearward. The maximum crush measured 21.6 cm (8.5")and was located at the C4 location. Contact damage for the second impact measured 97.8 cm (38.5") which began 125.7 cm (49.5") forward of the right rear axle. The crush values are listed below:

Impact Sequence #1	C1 = 12.4 cm (4.9")	C2 = 13.3 cm (5.2")	C3 = 21.3 cm (8.4")
Right Front Fender	C4 = 21.6 cm (8.5")	C5 = 14.0 cm (5.5")	C6 = 12.1 cm (4.75")

Impact Sequence #2	C1 = 0 cm	C2 = 5.7 cm (2.2")	C3 = 10.5 cm (4.1")
Right Front Door	C4 = 12.1 cm (4.75")		

Components damaged included: the front bumper; the hood; the right front fender; the right headlight; the grille; the right front wheel; the right front door surface, the windshield; and the roof.

CDC:

Impact #1	02-RFEW-3
Impact #2	03-RYEW-2

Vehicle #2 Interior

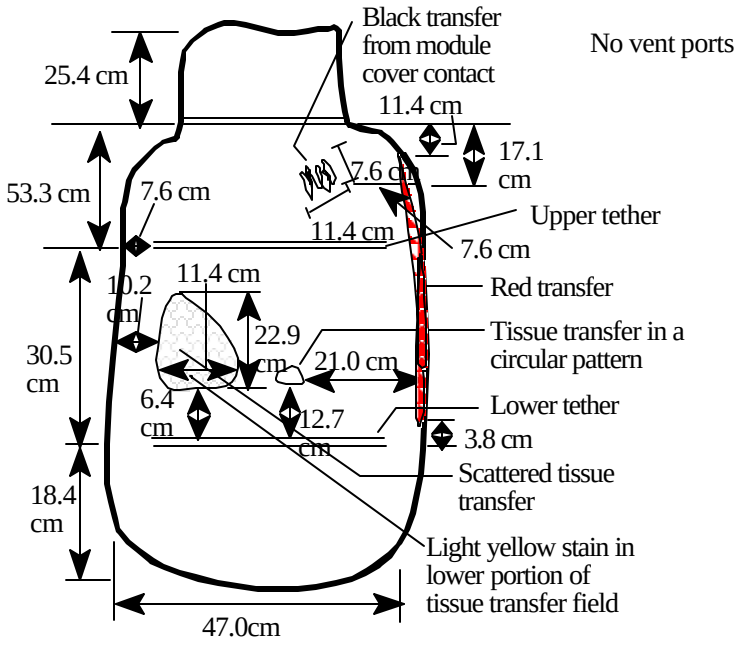
The GMC Jimmy sustained intrusion of the right front floor area where the toe pan intruded 3.8 cm (1.5") longitudinally and the floor intruded 5.1 cm (2.0") vertically. The center console was shifted laterally to the left. The driver was wearing the manual three point lap and torso belt the time of the crash. There were no visible crash related occupant contact points noted in the vehicle interior.

Repair Cost: Vehicle damage was appraised at $9,000 which was rated as a total loss.

SUPPLEMENTAL RESTRAINT SYSTEM (SRS)

Vehicle #1

The 1994 Dodge Caravan (Vehicle #1) was equipped with a Supplemental Restraint System (SRS) that consisted of dual driver and passenger side air bags which deployed as a result of the crash with the 1989 GMC Jimmy. The driver side air bag deployed as designed in an H-configuration symmetrical air bag module cover assembly that was contained within the four-spoke steering wheel. The flaps were hinged at the top and bottom with a horizontal center tear seam and vertical perimeter seams. The driver side air bag was a non-tethered bag. The 68.6 cm (27.0") diameter bag had two 2.9 cm (1.1") diameter vent ports located at 11 and 1 o'clock on the rear surface of the bag. The bag identification number was recorded as follows:



Passenger Side Air Bag

PUT11446-02E
TAC154H11371

A black transfer from the module cover was located on the face of the bag at 2 o'clock. A 14.0 cm (5.5") long light gray transfer mark was located 14.0 cm (5.5") below center and 15.2 cm (6.0") from the left edge.

The passenger side air bag module was a top mount design with a single flap which was hinged along the lateral edge adjacent to the windshield. The vinyl cover flap measured 31.8 cm (12.5") horizontally and 14.0 cm (5.5") along the right (outboard) edge and 14.6 cm (5.75") along the inboard edge. The leading edge of the passenger side air bag module flap was located 2.5 cm (1.0") rearward from the vertical edge the instrument panel. The module cover was slightly deformed along the horizontal surface with a rearward displacement of the left rear corner This deformation was secondary to occupant contact during the air bag expansion activity. The leading edge of the passenger side module cover exhibited a 10.7 cm (4.2") scuff mark with a 6.4 mm (0.25") diameter artifact which was attributed to contact by the right front occupant's head during the SRS deployment cycle.

The passenger air bag contained two tethers which were attached to the top and bottom portion of the air bag at a vertical distance of 78.7 cm (31.0") and 109.2 cm (43.0") from the inflator unit. There

were no vent ports in the air bag fabric. There was a black transfer mark on the passenger side air bag from the interaction of the expanding air bag with the underside of the module cover flap which was located 42.5 cm (16.7") below the inflator module. The right side of the air bag exhibited a red transfer mark along the vertical seam line which measured 68.6 cm (27.0") in length. This was attributed to contact with the right front occupant's jacket which reportedly had a red streak on the sleeves. There was a 11.4 cm x 22.9 cm (4.5" x 9.0") area on the front surface of the air bag which exhibited scatter tissue transfers and a light yellow stain along the lower portion of the tissue transfer field. Located to the right of this area was a 3.2 cm (1.25") diameter area which also exhibited tissue transfers. The tissue transfers were attributed to contact with the child's facial area during the air bag during expansion sequence.

CHILD SAFETY SEATS

The Dodge Caravan contained two child safety seats. A Century Breverra Prestige booster (forward-facing) Model 4885PIX was secured in the right front seat with the manual three point lap and shoulder belt and occupied by a three year old male. The date of manufacture was 3/01/96.

A second child safety seat was secured in the left seat of the middle row by the manual three point lap and shoulder restraint belt. The second safety seat was an Evenflo convertible child safety seat which was forward facing and occupied by an eight month old female occupant.

The Century Breverra Prestige booster child safety seat was designed with a five point restraint belt harness system. The seat was rated for children who weigh between 15 kg - 27 kg (30 lbs. - 60 lbs.) and range in height from 89 cm (35") to the physical stature where the top of the child's ears are below the booster seat headrest. The seat covering was a tweed fabric which was predominately purple in color. A warning label was adhered to the back of the seat with instructions written in English and Spanish which described the two methods for proper installation of the seat in a vehicle. The first method required the vehicle's restraint belt to be routed through the designated slots located in the back of the seat to secure the booster to the vehicle. When used in this configuration, the five point belt safety seat harness was required to properly restrain the child to the booster seat. The second method required only the use of the vehicle's lap and torso belt to restrain the child to the booster seat which in turn secured the booster seat to the vehicle. Following the two methods of installation was a warning (refer to **Figure 5**) which read:

Figure 5. Child safety seat warning label.

> NEVER USE A VEHICLE'S "LAP ONLY" BELT IN FRONT OF CHILD. SERIOUS INJURY OR DEATH MAY OCCUR.

The safety seat, however, was secured to the right front seat with the lap and torso belt being placed across the front surface of the safety seat and behind the child. Rescue personnel indicated the safety seat appeared to be secured with the vehicle lap and torso belt as it did not move during rescue efforts.

The father of the child indicated the seat was normally secured in the second row seat, but was moved forward to the right front seat the previous day. He indicated the child would have had the lap belt across his lap and the torso belt behind his back.

The EMTs were not aware of the child being restrained as they were not encumbered by the presence of the vehicle's lap and torso belt during rescue efforts. The restraint belt was not cut which very often occurs during extrication activities to avoid unnecessary movement of the injured. The witness motorist who immediately came forward and provided first aid noted that the shoulder belts of the safety seat were away from the child's shoulders. He did not see any restraint belts restraining the child.

The five point harness had two torso belts which passed through the back support of the safety seat in the lower of the two vertical height adjustment slots, continued through the two part safety shield, and attached to the seat frame below the seat cushion. The safety shield consisted of two half sections which buckled side-by-side into a common latching mechanism located in the base of the seat to form the fifth attachment point of the harness.

A two piece plastic comfort clip was attached to the shoulder belts above the safety shield that laterally positioned the belts with respect to the centerline of the child so that the shoulder belts would be aligned with the child's shoulders during normal restraint usage. The comfort clip was designed to release under load conditions so that it would not interfere with design of the shoulder belts. The driver only connected the comfort clip and did not latch the two part safety shield into the buckle prior to the crash.

The height of the booster seat back support from the top of the headrest to the top of the seat cushion measured 63.5 cm (25.0"). The width of the seat back support measured 41.9 cm (16.5"). The seat cushion measured 29.2 cm (11.5") from front to the back, 12.7 cm (5.0") vertically, and 43.2 cm (17.0") wide.

The child safety seat exhibited a 0.6 cm (0.25") area of stressed fabric surrounding the seam stitches located 48.3 cm (19.0") above the seat cushion and 4.4 cm (1.75") left of the booster seat centerline which was associated with rebound contact by the child's head during the crash. The adjacent left vehicle torso belt "I" shaped guide exhibited an abrasion and red transfer deposit which was located 10.2 cm (4.0") right of center on the top surface of the clip. The guide dimensional surface measured 7.9 cm x 5.4 cm (3.1" x 2.1").

The child safety seat used by the 8 month old female occupant seated in the left seat of the second row was an Evenflo convertible child safety seat Model 224144, manufactured on 12/11/1992 which was forward facing. The seat was reportedly secured by the lap portion of the three point manual lap and torso belt which was routed through the designated secure points along the back of the safety seat at the time of the crash. The child safety seat was released by a passerby shortly after the crash and removed from the vehicle with the child still restrained in the safety seat. The child was subsequently removed from the seat and the seat placed back inside the vehicle.

The Evenflo child safety seat was equipped with two shoulder belts which were stitched together and attached to a tether secured to a swing down shield. A latch plate at the end of the tether secured the these belts to the a buckle located in the seat cushion. A shoulder belt slack adjustment belt was located along the lower front surface of the seat. The shoulder belts were adjusted to the lowest setting of the three vertical slots in the seat back support. The child was not injured in the crash.

Vehicle Velocity Estimates:

Crash Impact Sequence #1	Vehicle #1	Vehicle #2
Impact Speed	35 km/h (21 mph)	17 km/h (11 mph)
Total delta V	17 km/h (11 mph)	19 km/h (12 mph)
Longitudinal	-16 km/h (-10 mph)	-12 km/h (-7 mph)
Lateral	6 km/h (4 mph)	-14 km/h (-9 mph)
Energy Dissipated	56,509 joules (41,673 ft-lb)	15,414 joules (11,367 ft-lb)

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

COLLISION SEQUENCE

Pre-Crash:

The 27 year old female driver of the 1994 Dodge Caravan mini-van (Vehicle #1) was returning home during the mid afternoon hour from a children's birthday party which was held at a friend's residence. The trip distance was estimated at two miles from door to door. Driver #1 was familiar with the route as she traveled it very often. There were balloons and cake inside the van which were left over from the party.

The 8 month old female child was restrained in a forward facing child safety seat located in the second row directly behind the driver. The safety seat was secured to the vehicle by the vehicle's manual three point lap and shoulder belt.

The three old male child in the right front seat was sitting in a Century Breverra Prestige booster safety seat which was designed for older (larger) children. The two shoulder belts were designed to be secured by a two piece shield to a latching buckle located in the leading area of the seat cushion between the child's legs. Driver #1 indicated she engaged the two piece plastic comfort clip located on the shoulder belts and did not latch the two part shield into the buckle assembly for the trip home.

The child safety seat was secured to the vehicle by the vehicle's three point manual lap and shoulder belt. The father moved the seat from the second row to the front seat the previous day so that his son could ride up front with him to the dealership where the vehicle was taken for a regular maintenance checkup. The exact method used to secured the safety seat was not clear as the father of the child indicated the lap belt would have been across the lap of the child and the torso belt behind his back at the time of the crash.

The safety seat was found to be stable by rescue personnel who indicated that in the course of providing first aid and removing the child from the vehicle, pressure was applied to the safety seat and bumped from time to time. The safety seat, however, remained fixed to the right front seat which indicated to the rescue personnel that it was secured by the vehicle's restraint belt.

Driver #1 was proceeding southbound on an undivided two lane roadway when she crested a hill and saw Vehicle #2 (1989 GMC Jimmy) stopped in the opposite travel lane. As she approached, Driver #2 initiated a left turn across her travel path from her left to right. She applied the brakes to a locked wheel condition and attempted to steer to the left in order to avoid the impending crash.

During the pre-impact braking effort, the right front occupant moved forward and began to load the child safety seat shoulder belts. The comfort clip which held the two belts together released and allowed the child's torso to move forward toward the instrument panel and the right front air bag module cover.

Driver #2 was stopped at the offset four leg intersection and was attempting to make a left turn into a local roadway en route to his friend's home. Prior to the turn, Driver #2 was distracted by friends in another vehicle stopped at the east leg of the intersection. As he proceeded to make the left turn, he noticed the approach of Vehicle #1. He responded by applying the brakes and immediately followed with full application of the accelerator pedal. He indicated that his vehicle had a sluggish response which he believed contributed to the crash.

Crash:

The right frontal area of Vehicle #1 struck the right front fender of Vehicle #2. The impact speed was computed by the SMASH program at 35 km/h (21 mph) for Vehicle #1 and 17 km/h (11 mph) for Vehicle #2. This resulted in a computed delta V of 17 km/h (11 mph) for Vehicle #1 and 19 km/h (12 mph) for Vehicle #2. Vehicle #1 rotated in a clockwise direction and sideslapped the right front door of Vehicle #2 with the left front fender. Vehicle #1 came to the final rest position (FRP) on the roadway. Vehicle #2 rotated in a counterclockwise direction, departed the west side of the roadway, and came to the final rest position (FRP) on the adjacent snow packed lawn.

During the first impact event, the SRS initiated the deployment sequence. The three year old child had moved forward during pre-impact braking and contacted the leading edge of the passenger side air bag module cover as it was opening resulting in a fracture of the right parietal bone and abrasion of the right forehead. His head and facial area were subsequently contacted by the expanding air bag which resulted in brain trauma, facial abrasions, and facial contusions.

The child was propelled rearward by the passenger side air bag and struck the booster seat back support. He came to rest with his torso against the seat back support with his head canted to the inboard side of the seat back support and his buttocks situated near the edge of the safety seat cushion. The first witness to reach the child indicated the two shoulder belts from the safety seat were outboard of the child's shoulders.

Driver #1 was only wearing the lap portion of the manual three point lap and shoulder belt with the shoulder belt placed behind her back. She moved forward and contacted the knee bolster with her right knee which was noted by a scuff mark. She contacted the deployed driver air bag and displaced the steering column 6.4 mm (0.25") and 12.7 mm (0.5") at the left and right shear capsules, respectively.

The 8 month old female restrained in the left seat of the second row in Vehicle #1 was not injured in the crash. The seat remained secured to the vehicle seat at the FRP.

Driver #2 loaded the lap and shoulder belt in response to impact forces. He sustained a bruise of the right hip and pain of the abdomen which was attributed to the restraint belt.

Post Crash:

Final Rest: Vehicle #1 rotated clockwise 139 degrees and traveled 7.2 m (23.6') from the POI to the FRP where it came to the FRP on the roadway with the rear plane of the vehicle over the roadway centerline. Vehicle #2 rotated 89 degrees counterclockwise and traveled 6.8 m (22.3') from the impact to the final rest point.

Driver #1 realized her son in the right front seat was injured. She unbuckled her restraint belt and attempted to ascertain his condition by placing herself between the right front instrument panel and the front of his seat. At that time she attempted to open the right front door, but was unsuccessful. She exited the vehicle through the driver's door and walked around to the right side of the van and was still unsuccessful in opening the door. A motorist traveling behind Vehicle #1 came forward and opened the door.

The motorist, a former EM, observed that the child was making gurgling noises. He elevated the child's head to open the airway and continued to maintain this position until rescue arrived. He was assisted by a police officer who arrived shortly after the crash and entered the vehicle through the sliding right side door and helped by stabilizing the child's head from behind.

When Driver #1 exited her vehicle and walked around the front of her vehicle, she yelled to Driver #2, who had exited his vehicle through the driver's side door, to call 911 for help. Driver #2 ran to a nearby residence and summonsed help. By the time he returned from the residence, the police were on the scene and escorted him to a patrol vehicle.

Police Activities - The local police department arrived on-scene six minutes after being notified. The police provided first aid, documented the final rest positions of both vehicles, obtained on-scene photographs, interviewed participants and witnesses to the crash, and controlled the traffic. They

impounded Vehicle #1 in an enclosed storage facility pending their further review of the crash and to accommodate this investigation.

Rescue Activities - The rescue team arrived within three minutes of notification and took over from the police officer and the motorist witness. They recalled that the child booster safety seat was very stable throughout their rescue efforts and presumed that the seat was secured to the right front seat by the vehicle's restraint belt. However, their concentration was focused on stabilizing the child and preparing him for transportation to a medical treatment. They did not recall removing any restraint belts from the child prior to removing him from the vehicle.

The EMTs placed a board behind the child while he was sitting in the child safety seat. They removed him through the right front door and placed him in the ambulance. They notified a local hospital that the child was seriously injured and requested to transport to a trauma center in another city. The attending physician at the local hospital directed them to first transport the child to the local emergency room where the physician conducted a preliminary evaluation while the child was still in the ambulance. The physician concurred with the EMTs' assessment of the child's condition and directed then to continued to the trauma center where they arrived approximately forty-five minutes later. The child was admitted to the pediatric special care unit where he remained forty-one days before being transferred to a rehabilitation facility.

Scene Clearance - Vehicle #1 and Vehicle #2 were towed by a local towing service from the scene. Vehicle #1 was inspected in an enclosed secured repair facility pending this investigation. Vehicle #2 was inspected at the towing facility's tow yard.

HUMAN FACTORS/OCCUPANT DATA

Vehicle #1

	Driver #1	Right Front Passenger	Left Rear Passenger
Age/Sex:	27 year old female	3 year old male	8 month old female
Height:	154.3 cm (60.75")	104.1 cm (41.0")	63.5 cm (25.0")
Weight:	47.6 kg (105 lbs)	15.9 kg (35.0 lbs)	9.1 kg (20.0 lb)

	Driver #1	Right Front Passenger	Left Rear Passenger
Manual Restraint System Usage:	Wearing the lap portion of the three point manual lap and shoulder belt with the shoulder belt behind her back	Booster child safety seat secured to the right front seat with the manual lap and torso belt across the front of the safety seat, the shoulder belts of the child safety seat were placed over the child with only the belt comfort clip engaged, the two part safety shield was not latched in the five point harness buckle	Forward facing child safety seat secured with the lap portion of the three point manual lap and torso belt which was routed through the rear of the safety seat
Usage Source:	Driver interview, police accident report	Driver interview, witness interviews, EMS interviews, medical, vehicle inspection, police accident report	Driver interview, police accident report
Eyewear:	No glasses	None	None
Jewelry:	Wedding ring on third finger of left hand	None	None
Clothing:	Not described	Brown denim jeans, dark blue light weight jacket with red streak on sleeves, no hat, no gloves, blue/yellow print sweater, socks and boots taken off by child prior to the crash	Not described
Vehicle Familiarity:	Purchased vehicle new, very familiar with operation of vehicle		
Route Familiarity:	Very familiar		
Trip Plan:	Returning home from children's birthday party, 3.2 km (2.0 miles) from door to door		

	Driver #1	Right Front Passenger	Left Rear Passenger
Type of Medical Treatment:	Not treated	Transported via ambulance to a nearby hospital, evaluated, and transferred to a trauma center where he was admitted for 41 days before being transferred to a rehabilitation facility	Not treated

Vehicle #2

	Driver
Age/Sex:	18 year old male
Height:	172.7 cm (68.0")
Weight:	93.0 kg (205.0 lbs)
Manual Restraint System Usage:	Wearing the manual lap and torso belt
Usage Source:	Driver interview, vehicle inspection
Vehicle Familiarity:	New driver, started driving in August, 1996, family vehicle which he used only after school and only on certain days
Route Familiarity:	Very familiar
Trip Plan:	En route to a friend's house
Type of Medical Treatment:	None required

INJURY DATA

The three old right front occupant in Vehicle #1 was transported from the scene to a local hospital via ambulance where a waiting physician directed the ambulance to a trauma medical facility which had a pediatric Special Care Unit (SCU). The child arrived at the trauma center unresponsive to painful stimuli with a Glasgow Coma Scale rating of 5. A Camino ICP monitor was inserted on the first day with little

success in stabilizing his pressure. A Ventriculostomy was subsequently performed on the second day which improved his condition. The child improved over the course of treatment and was transferred to a hospital specializing in child rehabilitation 41 days after the crash. The following table summarizes his injuries and the injury mechanism:

RIGHT FRONT PASSENGER INJURIES	INJURY SEVERITY (AIS-90)	INJURY SOURCE
1. Closed head injury, unresponsive following event, GCS score of 5, non purposeful movement with painful stimuli	160214.50	Passenger side air bag module cover and passenger side air bag
2. Facial bruising	290402.10	Passenger side air bag
3-5. Ecchymosis around eyes, nose	297402.11 297402.12 297402.14	Passenger side air bag
6. Facial abrasions, forehead, cheeks, nose	290202.10	Passenger side air bag
7. Small left subdural tentorium, positive Babinski	140652.42	Passenger side air bag module cover and passenger side air bag
8, 9. Fracture of the right parietal skull with punctate hemorrhage (at junction of gray-white matter) at the posterior portion of bilateral frontal lobes (related to diffuse axonal injury), small amount of right shear injury	150402.21 140628.51	Passenger side air bag module cover and passenger side air bag
10. Diffuse swelling of the left hemisphere	140660.32	Passenger side air bag module cover and passenger side air bag
11. Subconjunctival hemorrhage of the left eye	240416.12	Passenger side air bag
12. Intraparenchymal bleed secondary to shear and some subdural bleed	140638.41	Passenger side air bag module cover and passenger side air bag

RIGHT FRONT PASSENGER INJURIES	INJURY SEVERITY (AIS-90)	INJURY SOURCE
13. Evidence of mid brain injury due to deceleration and diffuse hemisphere swelling	140299.58	Passenger side air bag module cover and passenger side air bag
Supplemental Discussion: The patient arrived a the emergency room unresponsive and was evaluated with a Glasgow Coma Scale (GCS) of 5. A Camino Intracranial Pressure Monitor was placed over the right hemisphere which immediately produced a pressure reading of 35 mm of mercury. On the second day, there was more difficulty controlling the ICP so the patient was given thiopental p.r.n., then placed in a pentobartial coma, and the Camino was switched to a Ventriculostomy which remained until the 20th day when it was removed. The GCS improved to 6 on the 14th day following the crash, increased to 8-9 on the 15th day, and was rated 9-10 on the 16th day. The patient was transferred to a pediatric hospital 41 days after the crash. The abdomen was soft, nondistended, nontender with good bowel sounds. There were no abrasions on the abdomen. No seat belt signs. No other signs of external injury. There was some question of small bowel thickening although there was inadequate amount of GastroGrafin to clarify this. In addition, the mechanism of injury would not support a small bowel wall hematoma and the lack of fluid in the pelvis also would not support this finding.		

Driver #1 complained of pain of the knee, but was not initially seen at the medical treatment facility. Driver #2 was not treated at a medical treatment facility, but experienced pain of the abdomen when lifting weights after the crash and a black and blue area on his right hip which was attributed to loading on the lap restraint belt during the crash.

OCCUPANT KINEMATICS

Vehicle #1

Driver #1

Driver #1, a 27 year old female, who was restrained by the lap portion of the three point manual lap, was applying full brakes when the front of her vehicle struck the right front fender of Vehicle #2. This impact resulted in the deployment of the SRS.

Driver #1 moved forward and contacted the deployed air bag with her upper torso. Her torso continued forward during the impact sequence and compressed the air bag resulting in the displacement of the steering column shear plate a measured distance of 6.4 mm (0.25") at the left shear capsule and 12.7 mm (0.5") at the right shear capsule. A scuff mark on the surface of the knee bolster in the contoured area adjacent to the steering column was attributed to contact by her right knee. She rebounded back into the seat and remained restrained at the final rest position.

Right Front Passenger

The three year old male occupant was improperly restrained in a Century Breverra Prestige child booster safety seat prior to the crash. The booster safety seat was secured to the vehicle by the vehicle lap and shoulder belt system was placed over the front surface of the safety seat. The booster safety seat was designed with a five point restraint belt harness which when used correctly required the two piece shield to be latched to the buckle located forward on the seat cushion. A two piece plastic comfort clip attached to the shoulder belts positioned the respective shoulder belts over the appropriate shoulder area when the clip was engaged. Under loading conditions, the clip was designed to release and allow the shoulder belts to uniformly restrain the occupant.

Upon return from a children's birthday party, Driver #1 indicated that the child was riding in the booster safety seat with only the comfort clip on the shoulder belts attached and the two piece shield not engaged in the buckle. During pre-impact braking, the child moved forward and loaded the shoulder belts. As the slack in the shoulder belts decreased and loading against the comfort clip increased, the comfort clip released. The child continued forward and was in close proximity to the passenger side air bag module cover at the time of the SRS deployment sequence.

The child contacted the leading edge of the passenger side air bag module cover with his forehead as it was opening. A tissue transfer was noted along the leading edge located 8.9 cm (3.5") from the left corner and extending 10.8 cm (4.25") toward the right. The child sustained a fracture of the right parietal skull with punctate hemorrhage at the posterior portion of the bilateral frontal lobes and a linear abrasion of the forehead which were attributed to this contact mechanism. This was immediately followed by the interaction of the expanding air bag against the child's face and head resulting in facial abrasions, facial contusions, and brain trauma.

The child was propelled rearward by the expanding air bag where the posterior aspect of his head contacted the booster seat back support and the left booster seat torso belt guide. This was apparent from the focal stretched stitching located between two panels of fabric on the booster seat back support and the abrasion and transfer noted on the surface of the belt guide. He came to rest with his back against the booster seat back support, his buttocks on the leading edge of the seat cushion, and his head canted toward the center of the vehicle. The shoulder restraint belts of the booster seat were outboard of his shoulders at final rest.

Vehicle #2

Driver #2

Driver #2 was attempting to avoid the crash by accelerating and steering left into an intersection roadway. He was wearing the manual three point la p and torso belt at the time of the crash. During the impact sequence, the driver moved forward and to the right. The restraint belt system limited his trajectory to the immediate area of his seating position. An inspection of the vehicle interior yielded no occupant contact evidence. The steering column was not displaced at the shear capsules. A contusion of the his right hip was attributed to loading the lap restraint belt. He came to rest still restrained in the left front seat.