

Child Safety Seat Investigation / Vehicle to Vehicle
Dynamic Science, Inc. / Case Number: DS05003
1991 Toyota Corolla
California
February, 2005

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The crash investigation process is an inexact science which requires that physical evidence such as skid marks, vehicular damage measurements, and occupant contact points be coupled with the investigator's expert knowledge and experience of vehicle dynamics and occupant kinematics in order to determine the pre-crash, crash, and post-crash movements of involved vehicles and occupants.

Because each crash is a unique sequence of events, generalized conclusions cannot be made concerning the crashworthiness performance of the involved vehicle(s) or their safety systems.

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16. Abstract <p>This on site investigation focused on the performance of a child safety seat that was installed in the second row middle position of a 1991 Toyota Corolla. The Toyota Corolla was occupied by a restrained 28-year-old female driver, an improperly restrained 40-year-old female front right passenger, a restrained 7-year-old male second row left passenger, a 2-year-old female second row middle passenger seated in a child safety seat, and a restrained 11-year-old female second row right passenger. The Toyota Corolla lost control on an interstate highway, departed the roadway, and struck a tree with its left side. The driver of the Corolla sustained a blunt force injury to her head and was fatally injured. The front right occupant sustained head trauma, a pulmonary contusion, rib fractures, and a splenic laceration. The second row left seat occupant sustained lacerations to the left leg and left side of the head, and a fractured right femur. The second row middle occupant sustained a left femur fracture, a neck fracture, a liver laceration and multiple lacerations and abrasions. The second row right side occupant sustained femur and facial fractures.</p>				
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**Dynamic Science, Inc.
Accident Investigation
Case Number: DS05003**

TABLE OF CONTENTS

Background	1
Summary	1
Crash Site	1
Pre Crash	2
Crash	2
Post Crash	3
Vehicle Data - 1991 Toyota Corolla	4
Vehicle Damage	5
Exterior Damage	5
Interior Damage	6
Manual Restraint System	6
Child Safety Seat - Evenflo Horizon	7
Child Seat Damage	7
Occupants	9
Occupant Injuries	11
Occupant Kinematics	14
Attachment 1. Scene Diagram	17

BACKGROUND:

This on site investigation focused on the performance of a child safety seat that was installed in the second row middle position of a 1991 Toyota Corolla. The Toyota Corolla was occupied by a restrained 28-year-old female driver, an improperly restrained 40-year-old female front right passenger, a restrained 7-year-old male second row left passenger, a 2-year-old female second row middle passenger seated in a child safety seat, and a restrained 11-year-old female second row right passenger.



Figure 1. Left side damage to 1991 Toyota Corolla

The Toyota Corolla lost control on an interstate highway, departed the roadway, and struck a tree with its left side (see Figure 1). The driver of the Corolla sustained a blunt force injury to her head and was fatally injured. The front right occupant sustained head trauma, a pulmonary contusion, rib fractures, and a splenic laceration. She was transported by ambulance to a local trauma center for treatment and admitted. The second row left seat occupant sustained lacerations to the left leg and left side of the head, and a fractured right femur. He was transported by ambulance to a local trauma center and admitted for treatment. The second row middle occupant sustained a left femur fracture, a neck fracture, a liver laceration and multiple lacerations and abrasions. She was transported by ambulance to a local trauma center for treatment and was hospitalized. The second row right side occupant sustained femur and facial fractures. She was transported by ambulance to a local trauma center for treatment and was hospitalized.

This child safety seat case was identified by NHTSA from a news report. DSI was notified on February 8, 2005. DSI located the vehicle and child safety seat several days later. The case was assigned to DSI on February 16, 2005. Field work was completed on February 18, 2005.

SUMMARY

Crash Site

This single vehicle, off-road crash occurred in February, 2005 at 0750 hours. The crash occurred near an interstate interchange between a northbound interstate highway and connector ramp to a second interstate highway (see Figure 2). The northbound approach to the interchange is comprised of three northbound travel lanes and a right hand exit lane. The northbound lanes are separated from the southbound lanes by a concrete



Figure 2. Approach to area of road departure (North)

median barrier. The northbound lanes are separated from the exit lane by a solid white line. The northbound roadway is constructed of concrete. The exit ramp, however, is constructed of asphalt as it begins to deviate to the right. There is a negative 1.5% grade. To the right of the exit lane there is a painted solid white line, followed by a small asphalt curb. To the right of the curb is a metal guardrail that terminates 14.5 m (47.6 ft) prior to the impacted tree. The impacted tree is 7.3 m (23.8 ft) east of the curb on a negative 40-45 degree ice-plant covered embankment. The speed limit is 105 km/h (65 mph).



Figure 3. Area of road departure (North)

At the time of the crash, the temperature was 7.2 degrees C (45.0 degrees F), there was 82% humidity, the winds were calm, and there were scattered clouds.

Pre Crash

The case vehicle is a 1991 Toyota Corolla four door sedan driven by a restrained 28-year-old female driver. The front right seat was occupied by an improperly restrained 40-year-old female. This occupant was using the automatic torso belt only. The second row left seat was occupied by a restrained 7-year-old male, the second row middle seat was occupied by a 2-year-old female in an Evenflo Horizon child safety seat, the second row right seat was occupied by a restrained 11-year-old female second row right passenger.

The Toyota Corolla was traveling northbound. It appears that the driver of the Corolla was initially intending to continue straight north, but at the last moment decided to use the connector ramp. The driver lost control and the vehicle began a clockwise rotation. The Corolla left the initial lanes of travel and entered the connector ramp. The vehicle crossed the connector ramp and departed the roadway to the right (see Figure 3). The vehicle continued its left side leading rotation and it began to travel down the embankment.

Crash

The Corolla was at a 40-45 degree roll angle and approximately 80 degree yaw angle when it struck the tree with its left side (see Figure 4). The barrier routine of the WinSmash program computed a total delta V of 28.0 km/h (17.4 mph) based on the Corolla's left side crush profile. The longitudinal and lateral components were -4.9 km/h (-3.0 mph) and 27.6 km/h (17.1 mph), respectively. The Corolla came to rest on the embankment while still in contact with the tree.

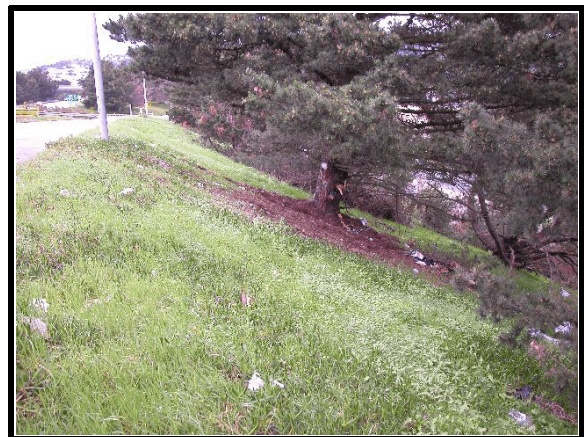


Figure 4. Impact with pine tree

Post Crash

In order to extricate the occupants, the driver's door and the roof were removed. The right side doors may have been pried open. The driver of the Corolla sustained a depressed left side skull fracture and was fatally injured. She was pronounced dead at 0812 hours¹.

The front right occupant sustained head trauma, a pulmonary contusion, rib fractures, and a splenar laceration. She was transported by ambulance to a local trauma center for treatment and admitted. The length of her stay in the hospital is not known.

The second row left seat occupant sustained lacerations to the left leg and left side of the head, and a fractured right femur. He was transported by ambulance to a local trauma center for treatment and admitted. He was hospitalized for several days.

The second row middle occupant sustained a displaced left femur shaft fracture, a right C4 laminar fracture, a right pulmonary contusion, a Grade I liver laceration, facial abrasions, and a right ankle abrasion. She was transported by ambulance to a local trauma center for treatment and was admitted. She was hospitalized for eight days.

The second row right side occupant sustained a left inferior orbit fracture, a laceration of the left levator muscle, an abrasion to the right forehead, a left eyelid laceration and a right mid-shaft femur fracture. She was transported by ambulance to a local trauma center for treatment and was admitted. She was hospitalized for eight days. She was re-admitted several days later with a deep venous thrombosis.

The case vehicle was towed from the scene due to damage.

¹Date on coroner's report is incorrect. Driver was pronounced dead at the scene by the responding paramedic.

VEHICLE DATA - 1991 Toyota Corolla

The 1991 Toyota Corolla four-door, five passenger sedan was identified by its Vehicle Identification number (VIN): JT2AE91A4M3xxxxxx. The vehicle was equipped with a 1.5 liter four cylinder engine, an automatic transmission, front wheel drive, power steering, and a tilt steering wheel.

The Corolla was equipped with Dunlop SDL 80 P155/80R13 tires on the front and Executive steel belted radial P155/80R13 tires on the rear. The specific tire data is as follows:

Tire	Tread	Measured pressure	Manufacturer recommended pressure	Restricted	Damage
LF	3 mm (4/32 in)	200 kPa (29 psi)	352 kPa (51 psi)	No	Rim dented
LR	6 mm (7/32 in)	207 kPa (30 psi)	241 kPa (35 psi)	No	None
RR	6 mm (7/32 in)	221 kPa (32 psi)	241 kPa (35 psi)	No	None
RF	3 mm (4/32 in)	221 kPa (32 psi)	352 kPa (51 psi)	No	None

The seating in the Toyota Corolla was configured with cloth covered bucket seats with adjustable head restraints and a rear bench seat. The driver's seat was adjusted to the full forward seat track position (28.0 cm [11.0 in]) rearward of the A pillar. The driver seat back angle at the time of inspection was 70 degrees from horizontal; the seat bottom measured 30 degrees from horizontal. The driver's seat was deformed due to intrusion. The front right seat back angle was 75 degrees from horizontal; the seat bottom measured 20 degrees from horizontal. The rear bench seat back angle on the right measured 18 degrees from vertical; the seat bottom measured 7 degrees from horizontal.

VEHICLE DAMAGE

Exterior Damage - 1991 Toyota Corolla

The 1991 Toyota Corolla sustained major left side damage as a result of the impact with the tree. The direct damage began 15.0 cm (5.9 in) forward of the left rear axle and extended 271.0 cm (106.7 in) forward along the left side plane and terminated at the front left bumper corner. The maximum lateral crush at the sill level was 30.0 cm (11.8 in) and was located between C2 and C3. Both left side doors were jammed shut. The roll angle at impact was 40-45 degrees. Because of the impact angle and the vehicle roll post impact, the direct damage to the front left door extended upward and included approximately 2/3 of the roof (see Figure 5). There was 46.0 cm (18.1 in) of longitudinal direct contact to the roof that began 36.0 cm (14.2 in) forward of the backlight. It measured 56.0 cm (22.0 in) from the left side rail measured laterally. The left wheelbase was shortened by 17.0 cm (6.7 in). Six crush measurements were documented at the sill level as follows: C1=0 cm (0 in), C2=25.0 cm (9.8 in), C3=28.0 cm (11.0 in), C4=0 cm (0 in), C5=0 cm (0 in), C6=0 cm (0 in).



Figure 5. Roof, front of vehicle is to the left



Figure 6. Left side crush, overhead view



Figure 7. Exterior, driver's door

Interior Damage - 1991 Toyota Corolla

The 1991 Toyota Corolla sustained major interior damage primarily as a result of passenger compartment intrusion. The left side doors, left B pillar, and left roof components sustained lateral intrusion. As a result of the lateral intrusion, the front left seat back intruded into the seating space and was pushed nearly into the front right seating area and the left rear seat bottom was compressed laterally.



Figure 8. Overview of left side intrusion damage

The specific passenger compartment intrusions were documented as follows:

Position	Intruded Component	Magnitude of Intrusion	Direction
LF	Door	30.0 cm (11.8 in) estimated	Lateral
LF	Sill	15.0 cm (5.9 in)	Lateral
LF	Roof	Unknown	Lateral and vertical
LF	B pillar (@ base)	7.0 cm (2.8 in)	Lateral
LF	Seat back	32.0 cm (12.6 in) 33.0 cm (12.9 in)	Vertical Lateral
LR	Door	65.0 cm (25.6 in)	Lateral
LR	Sill	15.0 cm (5.9 in)	Lateral
LR	C pillar	10.0 cm (3.9 in)	Lateral

MANUAL RESTRAINT SYSTEMS - 1991 Toyota Corolla

The 1991 Toyota Corolla was configured with automatic torso belts and manual lap belts for the two front seat positions. The driver was using both belts. The lap belt had been cut off the driver during extrication. The cut section of webbing began 57.0 cm (22.4 in) from the latch and 20.0 cm (7.9 in) from the floor anchor). The lap belt was equipped with a sewn on latch plate. The two outboard rear seats were configured with manual lap and shoulder belts that were equipped with emergency locking retractors and sliding latch plates. Both outboard seats were being used at the time of the crash. The second row right belt had been cut off the occupant during extrication. The cut section of webbing began 16.0 cm (6.3 in) from the C pillar area. The second row middle seat position was configured with a manual lap belt. This seat belt was used to anchor the forward facing child safety seat. There were loading and scuff marks indicating usage during the crash.

CHILD SAFETY SEAT - Evenflo Horizon

The second row middle occupant was seated in an Evenflo Horizon Model #4261D9 convertible child safety seat with a manufacture date of December 6, 1999.

The child seat instruction manual states that this child restraint is designed for use only by children who weigh between 2.3-18 kg (5-40 lbs) and whose height is 66 to 101 cm (19 to 40 in). The manual further states that:

- You **must** use this convertible child restraint **rear facing** if your child weighs between 2.3 and 9 kg (5 and 20 lbs)
- You **must** use this convertible child restraint **forward facing** if your child weighs between 13.6 and 18 kg (30 and 40 lbs)
- You **may** use this convertible child restraint either **rear facing** or **forward facing** if your child is between 9 and 13.6 kg (20 and 30 lbs)



Figure 9. Evenflo Horizon convertible child safety seat

The child in this case weighed 17 kg (37 lbs). Her height is not known.

The seat is equipped with a two-position reclining base (reclining position or upright). The seat was anchored to the case vehicle using the manual lap belt. The belt had been properly routed through the rear slots for the forward facing mode. The child seat harness was being used at the time of the crash, but its slot position is not known. The seat was being used in the forward facing mode and was equipped with a tray shield.

Child Seat Damage

The Evenflo Horizon seat sustained considerable damage during the crash. The tray shield had been broken off at the seat back attachment points. There was a longitudinal fracture that begins at the front left and extends 15.5 cm (6.1 in) rearward into the rear facing belt path guide. The left side of the seat back had moved laterally to the right 3.0 cm (1.2 in). There were blood and hair transfers to the outer edge of the left portion of the tray shield. There was a fracture that ran from the forward facing belt path guide to the rear facing belt path guide. This was in an “L” configuration and measured 12.0 cm (4.7 in) vertically and 13.0 cm (5.1 in) laterally. There was a 14.0 cm (5.5 in) angled fracture in the seat bottom. The reclining base had been crushed

laterally and had broken away from its connection points. There was blood on both the top and bottom of the shield. There was also blood and hair transfers found on the outside portion of the left seat back. The crotch strap had been cut by emergency personnel 12.0 cm (4.7 in) from the attachment point.



Figure 10. Right side, Evenflo child safety seat



Figure 11. Back/bottom, Evenflo child safety seat



Figure 12. Left side, Evenflo child safety seat

Occupants

<u>Case vehicle</u>	Driver		
Age/Sex:	28/Female	40/Female	7/Male
Seated Position:	Front left	Front right	Second row left
Seat Type:	Fabric covered bucket seat, seat adjusted to forward most track position	Fabric covered bucket seat, seat adjusted to forward most track position	Fabric covered bench seat
Height:	165 cm (65 in)	Unknown	Unknown
Weight:	66 kg (146 lbs)	Unknown	Unknown
Occupation:	Unknown	Unknown	NA
Pre-existing Medical Condition:	None noted	None noted	None noted
Alcohol/Drug Involvement:	None	NA	NA
Driving Experience:	Unknown	NA	NA
Body Posture:	Normal, upright	Unknown	Normal, upright
Hand Position:	Unknown, actively steering	Unknown	Unknown
Foot Position:	Right foot on brake, left on floor	Presumed to be on floor	Presumed to be on floor
Restraint Usage:	Manual lap and automatic shoulder belt available, used	Manual lap and automatic shoulder belt available, lap not used	Lap and shoulder belt available, used

Age/Sex:	2/Female	11/Female
Seated Position:	Second row middle	Second row right
Seat Type:	Fabric covered bench seat	Fabric covered bench seat
Height:	Unknown	163 cm (64 in)
Weight:	17 kg (37 lbs)	75 kg (165 lbs)
Occupation:	NA	NA
Pre-existing Medical Condition:	Pneumonia	None noted
Alcohol/Drug Involvement:	NA	NA
Driving Experience:	NA	NA
Body Posture:	Normal, upright	Normal, upright
Hand Position:	Unknown	Unknown
Foot Position:	Unknown	Presumed to be on floor
Restraint Usage:	Lap belt used with child safety seat	Lap and shoulder belt available, used

OCCUPANT INJURIES - 1991 Toyota CorollaDriver: Injuries obtained from Autopsy Report.

<u>Injury</u>	<u>OIC CODE</u>	<u>Injury Mechanism</u>	<u>Confidence Level</u>
Laceration, 10.2 cm (4.0), left side of head, extending from the eyebrow area back into the left temporal area	190604.2,2	Roof side rail	Probable
Skull fracture in the base, the inferior edge of the skull bone in depressed 1.3 cm (0.5 in) into the cranial vault (brain is visible in the base of this fracture)	150406.4,2	Roof side rail	Probable
Dicing-type lacerations, red-brown in color, over the left lateral side of the face below the eye and above the jaw and between the nose and the ear and occupying an area about 12.7 cm (5.0 in) in greatest dimension	290602.1,2	Side glass	Probable
Small lacerations over the left lateral upper arm in its distal two-thirds occupying an area 20.3 cm (8.0 in) in greatest dimension	790602.2,2	Side glass	Probable
Abrasion, 5.0 cm (2.0) posterior left forearm above its mid-portion.	790202.1,2	Door panel	Probable
Abrasion, 0.635 cm (0.25 in), left medial wrist and red abrasion, dorsal wrist.	790202.1,2	Door panel	Probable
Abrasion, 2.5 cm (1.0 in) red-brown, dorsal left hand over the 4 th and 5 th metacarpals.	790202.1,2	Door panel	Probable
Fracture of the tibia and fibular approximately 25.4 cm (10.0 inch) above the right heel.	853420.2,1 851606.2,1	Floor	Possible
Abrasion, 0.9 cm (0.4 in), just below the lower pole of the left scapula.	690202.1,7	Seat back	Probable

Small amount of automobile-type glass laceration are present over the upper part of the torso along with the base of the neck. 490600.1,2 390600.1,2 Flying glass Probable

Front row right occupant: Injuries obtained from police report.

<u>Injury</u>	<u>OIC Code</u>	<u>Injury Mechanism</u>	<u>Confidence Level</u>
Head trauma	115099.7,0	Unknown	Unknown
Pulmonary contusion, left	441402.3,2	Seat back	Possible
Rib fractures, left	450220.2,2	Seat back	Possible
Spleen laceration	544220.2,2	Seat back	Possible

Second row left occupant: Injuries obtained from police report.

<u>Injury</u>	<u>OIC Code</u>	<u>Injury Mechanism</u>	<u>Confidence Level</u>
Lacerations, left side of head	190600.1,2	Side glass	Probable
Lacerations, left leg	890600.1,2	Door side panel	Probable
Right femur fracture	851800.3,1	Child seat	Certain

Second row middle occupant: Injuries obtained form discharge summary, neurosurgery consult, and radiology records.

<u>Injury</u>	<u>OIC Code</u>	<u>Injury Mechanism</u>	<u>Confidence Level</u>
Left femur fracture, shaft / displaced	851814.3,2	Child seat shell	Certain
Right C-4 lamina and articular pillar at junction fracture	650224.3,6	Impact forces	Probable
Small right lobe pulmonary contusion	441406.3,1	Child seat shell (right side)	Probable
Grade I liver laceration	541812.2,1	Child seat shell	Certain
Left temporal head laceration (3-4 cm 11/4 - 11/2 in.)	190602.1,2	Child seat shell	Probable
Left facial abrasion	290202.1,2	Child seat shell	Probable

Right ankle abrasion w/ 1 cm laceration	890202.1,1	Child seat shell	Possible
Forehead abrasion	290202.1,7	Child seat shell	Possible

Second row right occupant: Injuries obtained from discharge summary, in patient progress records, and radiology records.

<u>INJURY</u>	<u>OIC CODE</u>	<u>Injury Mechanism</u>	<u>Confidence Level</u>
Right closed femur mid shaft fracture	851814.3,1	Right door panel	Probable
Left inferior orbital fracture (medial wall blowout fracture with blowout fracture of the left orbit)	251204.3,2	Child seat exterior	Certain
Left periorbital edema and bruising	297402.1,2	Child seat exterior	Certain
Abrasion, right side of forehead	290202.1,7	Unknown	Unknown
Laceration, left eyelid	297602.1,2	Child seat exterior	Probable
Left conjunctival hemorrhage	240416.1,2	Child seat exterior	Certain
Laceration, left levator muscle (assumption: labii superioris / quadratus)	290600.1,2	Unknown	Unknown

OCCUPANT KINEMATICS - 1991 Toyota Corolla

Driver kinematics

The 28-year-old female driver of the case vehicle was seated in a forward facing position. The fabric covered bucket seat was adjusted to the full forward track position, 28.0 cm (11.0 in) rearward of the A pillar. The seat back angle was 70 degree, the seat bottom angle was 30 degrees. The seat was deformed during the crash. The adjustable head restraint was deformed to the right. The driver was wearing the automatic torso belt and the manual lap belt. Prior to impact, the vehicle was in a clockwise rotation. This motion likely brought the driver closer to the left side of the vehicle. As the vehicle left the roadway and proceeded down the embankment, the vehicle was pitching downward and leaning to the left. At impact, the driver initiated a sharp trajectory to the left and engaged the door panel as it intruded into the passenger compartment. Her head likely engaged the roof side rail—resulting in a depressed skull fracture. She was fatally injured, and was transported from the scene by the coroner's office.

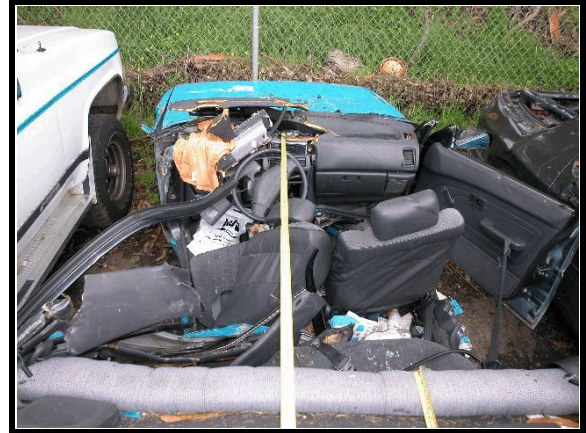


Figure 13. Overview of vehicle interior showing lateral intrusion

Front row right occupant kinematics

The 40-year-old female front right passenger was seated in a forward facing position. The fabric covered bucket seat was adjusted to the full forward track position. This occupant was wearing the automatic torso belt only. Prior to impact, the vehicle was in a clockwise rotation. This motion likely brought this occupant closer to the left side of the vehicle. As the vehicle left the roadway and proceeded down the embankment, the vehicle was pitching downward and leaning to the left. At impact, this occupant initiated a sharp trajectory to the left in response to the 280 degree direction of force and engaged the driver's seat back and possibly driver herself—causing the pulmonary contusion, rib fractures, head trauma, and splenic laceration.

Second row left occupant kinematics

The 7-year-old male second row left occupant was likely seated in a forward facing fashion on the fabric covered bench seat. The non-adjustable seat back had a 72 degree angle and the seat bottom had a 7 degree angle. He was wearing the available lap and shoulder belt. The seat belt was equipped with an emergency locking retractor and a sliding latch plate. Prior to impact, the vehicle was in a clockwise rotation. This motion likely brought this occupant closer to the left side of the vehicle. As the vehicle left the roadway and proceeded down the embankment, the vehicle was pitching downward and leaning to the left. At impact, this occupant initiated a sharp trajectory to the left in response to the 280 degree direction of force and engaged the rear door panel as it intruded into the passenger compartment. He sustained a left leg laceration from contact with the door. As the intrusion continued he was pushed laterally into the middle occupant seat position and engaged the child seat with his torso, hip, and thigh. He sustained right femur fracture as he engaged the child seat. He was removed from the vehicle by rescue personnel and transported to a local trauma center for treatment and admission.



Figure 14. Interior view of left rear door

Second row middle occupant kinematics

The second row middle seat was occupied by a 2-year-old female seated in an Evenflo Horizon convertible child safety seat. The seat was being used in the forward facing mode and was anchored to the vehicle using the available manual lap belt. She was restrained by the child seat's tray shield, 3-point harness. The tray shield was in the down position. Prior to impact, the vehicle was in a clockwise rotation. As the vehicle left the roadway and proceeded down the embankment, the vehicle was pitching downward and leaning to the left. At impact, this occupant initiated a sharp trajectory to the left in response to the 280 degree direction of force. At this same time, the left side of the child seat was being loaded and fractured by the rear left occupant as he moved to the right in response to the left side door intrusion. The lateral crush to the child seat caused the left femur fracture and the liver laceration. This occupant's head moved sharply first to the left and then to the right—causing a C4 laminar fracture. The right side of the child seat was engaged by the right rear occupant in response to the impact and subsequent intrusion. She was transported by ambulance to a local trauma center for treatment and admitted.

Second row right occupant kinematics

The 11-year-old female second row right occupant was likely seated in a forward facing fashion on the fabric covered bench seat. The non-adjustable seat back had a 72 degree angle and the seat bottom had a 7 degree angle. She was wearing the available lap and shoulder belt. The seat belt was equipped with an emergency locking retractor and a sliding latch plate. Prior to impact, the vehicle was in a clockwise rotation. This motion likely brought this occupant closer to the installed child safety seat. As the vehicle left the roadway and proceeded down the embankment, the vehicle was pitching downward and leaning to the left. At impact, this occupant initiated a sharp trajectory to the left in response to the 280 degree direction of force and engaged the child seat with the left part of her face—causing the left orbit fracture and eyelid laceration. As the intrusion continued she was pushed laterally into the right rear door—causing a right femur fracture. She was removed from the vehicle by rescue personnel (seat belt was cut off of her) and transported to a local trauma center where she was admitted.



Figure 15. Second row right seat position

Attachment 1. Scene Diagram

