

Child Safety Seat Investigation  
Dynamic Science, Inc. (DSI), Case Number DS07036  
1996 Jeep Grand Cherokee  
Arizona  
August 2007

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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 single vehicle rollover crash occurred in August 2007. The crash took place in the eastbound lanes of a two-lane divided interstate highway. The subject vehicle was a 1996 Jeep Grand Cherokee Laredo sport utility vehicle that was pulling a trailer. The driver was a restrained 57-year-old female. The front right seat was occupied by a restrained 29-year-old female. The second row left seat was occupied by a 2-year-old female. The second row middle seat was occupied by a 4-year-old male. The second row right seat was occupied by a 1-year-old female. The three second row occupants were seated in child safety seats. The subject vehicle was traveling eastbound on an interstate highway and drifted off the north edge of the roadway. The driver overcorrected to the right and the vehicle began a clockwise rotation across both eastbound travel lanes. The vehicle tripped on the roadway and began rolling with its left side leading. The vehicle departed the roadway on the south side where it came to rest on its wheels and facing west. The driver of the subject vehicle sustained minor injuries to her left arm; she was transported by ground ambulance to a local hospital where she was treated and released. The front right occupant was partially ejected and sustained multiple right hand and spinal injuries; she was transported by ground ambulance to a local hospital where she was admitted. The second row left and middle seat occupants were transported to a local hospital where they were admitted overnight for observation. The second row middle occupant sustained a minor forehead contusion. The second row right seat occupant was ejected during the rollover. She sustained multiple abrasions and was transported by air to a local hospital where she was admitted.</p>			
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**Dynamic Science, Inc.**  
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## Background

This Child Safety Seat Investigation was identified by NHTSA in an on-line news article. This single vehicle crash occurred in August 2007 at 0952 hours. The crash took place in the eastbound lanes of a two-lane divided interstate highway. The subject vehicle was a 1996 Jeep Grand Cherokee Laredo 4x4 sport utility vehicle that was pulling a 2004 Pace Arrow box trailer (**Figure 1**). The driver was a restrained 57-year-old female. The front right seat was occupied by a restrained 29-year-old female. The second row left seat was occupied by a 2-year-old female. The second row middle seat was occupied by a 4-year-old male.



**Figure 1.** 1996 Jeep Grand Cherokee Laredo

The second row right seat was occupied by a 1-year-old female. The three second row occupants were seated in child safety seats (CSS). The subject vehicle was traveling eastbound on the interstate highway at a driver reported speed of 97 km/h (60 mph). The Jeep drifted off the north edge of the roadway. The driver overcorrected to the right and the vehicle began a clockwise rotation across both eastbound travel lanes. The vehicle tripped on the roadway and began rolling with its left side leading. The second row right occupant was ejected during the rollover. The vehicle departed the roadway on the south side where it came to rest on its wheels facing west.

The driver of the case vehicle sustained minor injuries to her left arm; she was transported by ground ambulance to a local hospital where she was treated and released. The front right occupant was partially ejected and sustained multiple right hand and spinal injuries; she was transported by ground ambulance to a local hospital where she was admitted. The second row left and middle seat occupants were transported to a local hospital where they were admitted overnight for observation. The second row middle occupant sustained a minor forehead contusion. The second row right seat occupant was ejected from the vehicle through the right front window opening. She sustained multiple abrasions and was transported by air to a local hospital where she was admitted. The subject vehicle and box trailer were towed from the scene due to damage. The vehicle was later declared to be a total loss by the insurance company and sold to a private party.

DSI was notified on August 14, 2007 with instructions to locate the case vehicle and the child seats. DSI located the vehicle and child seats on August 17, 2007. The police report was obtained on August 20, 2007. DSI was assigned the case on August 20, 2007. The case vehicle and child seats were inspected on August 22, 2007. The Pace Arrow box trailer was not located.

## SUMMARY

### Crash Site

This single vehicle crash occurred on a straight and level section of a two-lane interstate highway. The crash occurred during daylight hours. At the time of the crash, the weather was clear and the asphalt roadway surface was dry. The eastbound roadway was configured with two travel lanes that

were separated by a single broken white stripe. The north roadway edge was separated from a paved shoulder by a single yellow stripe. A rumble strip was present adjacent to the yellow stripe. To the north of the paved shoulder was a depressed dirt median. The south roadway edge was separated from a paved shoulder by a single white fog line. To the south of the paved shoulder was a dirt shoulder and level ground. The posted speed limit for this location was 121 km/h (75 mph).

### Pre Crash

The 1996 Jeep Cherokee was traveling eastbound at a driver reported speed of 97 km/h (60 mph). The Jeep was towing a dual-axle Pace Arrow box trailer. The 57-year-old driver was restrained by the 3-point manual safety belt. The 29-year-old female front right occupant was restrained by the 3-point manual safety belt. The second row was occupied by three children, all seated in child safety seats. The child seats were secured to the vehicle by the vehicle restraints. The children in the second row left and second row middle seat positions were using the CSS internal harnesses. It is not known if the child in the second row right seat was using the harness or not.

The Jeep was traveling in the left lane and drifted off the north edge of the roadway (**Figures 2-3**).

### Crash

The driver overcorrected to the right and the Jeep and trailer began a clockwise rotation across both eastbound lanes of travel. The Jeep tripped on the roadway and began a left side leading rollover (**Figure 4**). The Jeep rolled 8 quarter turns and came to rest on its wheels and facing west. The final rest position of the Jeep was 7.6 m (25.0 ft) south of the south roadway edge. Between the 5<sup>th</sup> and 6<sup>th</sup> quarter turns, the second row right occupant was ejected. The trailer rolled for an unknown number of turns and came to rest on its right side and facing southeast.



**Figure 2.** East approach to area of roadway departure



**Figure 3.** Area of roadside departure



**Figure 4.** Area of rollover

## Post Crash

The driver was able to exit the vehicle without assistance. She sustained abrasions, burns and lacerations to her left arm; she was transported by ground ambulance to a local hospital where she was treated and released. The front right occupant was able to exit the vehicle with assistance from passers-by. She sustained multiple injuries to her right hand/arm, a thoracic compression fracture, and a lumbar compression fracture. She was transported from the scene by air ambulance and hospitalized for 32 days. The second row left and center occupants were removed from their child restraints and exited the vehicle with assistance. They were transported to a local hospital where they were admitted overnight for observation. The second row middle occupant sustained a forehead contusion. The second row right occupant had been ejected from the vehicle. She was located by a witness, who stated that he found her under the right side of the Jeep with her head stuck between the ground and the chassis. He was able to pull her from beneath the Jeep before emergency personnel arrived. He further stated that she had multiple abrasions on her body, but they all appeared to be related to rolling across the ground. He did not see any head related injuries. The child was transported by air ambulance to a local hospital where she was admitted. The Jeep and box trailer were towed from the scene due to damage.

## Vehicle Data - 1996 Jeep Grand Cherokee Laredo

The 1996 Jeep Grand Cherokee Laredo was identified by the Vehicle Identification Number (VIN): 1J4EZ58Y7TCxxxxxx. The Jeep was a 4-door, 5- passenger sport utility vehicle that was equipped with a 5.2 liter, 8-cylinder engine, an automatic transmission, anti-lock brakes, four-wheel drive, and a tilt steering wheel. The Jeep was equipped with Summit GT Radial Trac P255/70R15 tires at all four positions. The vehicle manufacturer's recommended cold pressure was 228 kPa (33psi); the tire manufacturer's maximum pressure was 241 kPa (35 psi). The specific tire information is as follows:

Position	Measured Pressure	Measured Tread Depth	Restricted	Damage
LF	193 kPa (28 psi)	5 mm (6/32 in)	No	None
LR	Tire flat	5 mm (6/32 in)	No	Tire debanded
RR	Tire flat	5 mm (6/32 in)	No	Tire debanded
RF	Tire flat	6 mm (7/32 in)	No	Tire debanded

The first row seating in the Jeep was configured with leather-covered bucket seats with adjustable head restraints. The first row seats had after-market fabric seat covers installed. The second row seating was configured with a leather-covered split bench seat with adjustable head restraints for the outboard positions. There was no head restraint for the middle seat position. The driver's seat back was at a 27degree angle from vertical; the seat cushion angle was 16 degrees from horizontal. The front right passenger seat back was 30 degrees from vertical; the seat cushion was 16 degrees from horizontal. The second row bench seat backs measured 25 degrees from vertical; the seat cushions were 16 degrees from horizontal.



## Vehicle Damage

### Exterior Damage - 1996 Jeep Grand Cherokee

The Jeep sustained moderate damage to the left, right, front, back and top planar surfaces during the rollover (**Figures 5-6**). The front bumper and fascia were detached from the vehicle. The roof and hood were severely buckled. The left front, left rear, and right front doors were jammed shut. The left rear, right rear, and right front tires were flat. The direct damage to the roof began at the right A-pillar and extended laterally 139 cm (54.7 in) to the left. The maximum vertical crush measurement was to the right windshield header. It was located 49 cm (19.3 in) left of the base of the side window and 21 cm (8.3 in) above the base of the side window and measured 27 cm (10.6 in) vertically. The maximum lateral crush measurement was 3 cm (1.2 in). The Collision Deformation Classification (CDC) for the rollover was 00TDDO4.

### Interior Damage -1996 Jeep Grand Cherokee

The 1996 Jeep Cherokee sustained moderate interior damage as a result of passenger compartment intrusion (**Figure 7**). The roof, roof rails and windshield header sustained vertical intrusion. The windshield was cracked and holed from impact forces. The left front, right front and second right rear windows were disintegrated from impact forces.



**Figure 5.** Exterior damage



**Figure 6.** Exterior damage, right side view



**Figure 7.** Overview of interior damage



The specific passenger compartment intrusions were documented as follows:

Row	Position	Intruded Component	Magnitude of Intrusion	Direction
Front seat	Right	Roof	41 cm (16.1 in)	Vertical
Front seat	Right	Windshield header	37 cm (14.5 in)	Vertical
Front seat	Left	Roof	23 cm (9 in)	Vertical
Second seat	Right	Roof	22 cm (8.7 in)	Vertical
Front seat	Right	Roof side rail	13 cm (5.1 in)	Vertical
Front seat	Left	Windshield header	9 cm (3.5 in)	Vertical
Second seat	Left	Roof	8 cm (3.1 in)	Vertical
Second seat	Right	Roof side rail	4 cm (1.6 in)	Vertical

### Manual Restraints -1996 Jeep Grand Cherokee

The Jeep Cherokee was equipped with 3-point manual lap and shoulder belts and adjustable head restraints for the four outboard seat positions. The second row center seat position was equipped with a manual lap belt and no head restraint. The lap and shoulder belts were configured with adjustable D-ring anchorages that were in the full down position. The driver's safety belt was configured with an Emergency Locking Retractor (ELR). The remaining outboard safety belts were configured with light weight locking latch plates and ELR retractors. The second row center safety belt was configured with a locking latch plate. The first row lap and shoulder belts were used to restrain the driver and front right occupant. According to the police, the second row left, middle, and right safety belts were used to secure child safety seats. There were no indications of loading to any of the seat belts.



**Figure 8.** Manual restraints, second row left

## Child Safety Seats

### Child Safety Seat - Second Row Left

A Cosco Safety 1st Vantage Point SE forward facing Child Safety Seat (CSS) was used to restrain the second row left occupant. The model number was 22-561-WAL and the date of manufacture was October 18, 2006. The child seat was configured with a 5-point harness and a 2-piece harness retainer clip. The seat was designed with three harness positions. At the time of the crash, the harness was in the middle set of slots (**Figure 9**). The CSS was designed to be used as a forward facing CSS or a booster seat. The CSS was configured with a top tether and Lower Anchors and Tethers for Children (LATCH) hardware. The child seat was designed to be secured by a lap belt, lap and shoulder belt, or LATCH. When anchored by a safety belt, the belt was to be routed through a set of forward facing slots.

The CSS was found by the investigator secured to the seat by the lap and shoulder belt (**Figure 10**). Measurements were taken of the fore/aft and lateral movement of the anchored child seat. At the time of the inspection there was 15 cm (5.9 in) of fore/aft movement for the top of the child seat, and 6.5 cm (2.6 in) of fore/aft movement at the bottom. There was 30 cm (11.8 in) of lateral movement for the child seat. Both the fore/aft and lateral excursion of the CSS exceeded what was recommended by the manufacturer and by the normal installation conventions.

The Cosco Safety 1<sup>st</sup> instructions specified that the child must be 10.1-18 kg (22-40 lb) in weight, 85.1-110 cm (34-43 in) in height, and greater than 1 year of age. The child in this seat position met the age criteria, but it is not known if she met the height and weight guidelines.



**Figure 9.** Cosco Safety 1<sup>st</sup> child safety seat



**Figure 10.** Cosco child safety seat, as found in vehicle



### Child Safety Seat - Second Row Middle

A Dorel/Cosco convertible CSS was used to restrain the second row middle occupant. There was no model number or date of manufacture found on the CSS. Based on appearance, it was determined that the CSS model was either a Touriva or a Regal Ride. Both of these types are based on identical shells. An instruction label on the CSS indicated that the seat was to be used with children who weighed 9-18 kg (20-40 lbs), whose height was 73-102 cm (29-40 in), and who was greater than 1 year of age. It was not known if the child met the weight or height requirements. The CSS was designed to be rear-facing for children who weighed 2.2-15.8 kg (5-35 lbs) and whose height was 48.2-91.4 cm (19-36 in). The CSS was configured with a three-point harness and a padded tray shield (**Figure 11**). The lower harness strap was attached using a latch plate and buckle style closure. The seat was designed with three harness positions. At the time of the crash, the harness was in the top set of slots. The CSS was designed to be used forward or rear facing. The child seat was not equipped with LATCH hardware. To anchor the child seat, the vehicle's safety belt was to be routed through forward facing slots. At the time of the inspection, the vehicle's lap belt was unbuckled. A locking clip was found stowed on the back of the child seat shell.



**Figure 11.** Dorel/Cosco child safety seat



**Figure 12.** Graco Comfort Sport child safety seat

### Child Safety Seat - Second Row Right

The Graco Comfort Sport convertible CSS was found by the investigator in the cargo area of the Jeep. A locking clip was found stowed on the back of the child seat. The model number was 8C00LNW and the date of manufacture was June 26, 2007. The child seat was configured with a five-point harness and a two-piece harness retainer clip. The lower harness straps were attached using a dual latch plate and buckle style closure. The seat was designed with three harness positions. At the time of the crash, the harness was in the bottom set of slots (**Figure 12**). The Graco was designed to be used rear facing for children weighing 2.2-13.6 kg (5-30 lb), and forward facing for children weighing 9-18 kg (20-40 lb). The Graco was designed for children whose height is 102 cm (40 in) or less. It is not known

if the child met the weight and height requirements. The child seat was configured with a top tether and lower LATCH hardware. The LATCH and tether straps were found stowed in their original positions. When anchored by a seat belt, the belt was to be routed through the rear facing belt paths. The child seat was designed to be secured by a lap belt, lap and shoulder belt, or LATCH. According to one witness, the seat was secured to the vehicle by the vehicle safety belt in the rear-facing orientation. Since the CSS was found in the cargo area of the vehicle, the exact configuration of the CSS placement during the crash could not be determined.

### **Supplemental Restraint Systems -1996 Jeep Grand Cherokee**

The 1996 Jeep Cherokee was equipped with first row frontal air bags for the driver and right passenger. The driver air bag was located in the steering wheel hub. The passenger air bag was located in the top instrument panel. There were no air bag deployments during the crash.

### **Rollover Dynamics**

The 1996 Jeep Cherokee was equipped with an automatic transmission, anti-lock brakes, and four-wheel drive. The Jeep's rollover resistance rating was not known because it was not tested. The Jeep with the trailer in tow was traveling eastbound in the inboard lane and drifted off the north edge of the roadway. The driver overcorrected to the right and the Jeep and trailer began a clockwise rotation. As the rotation increased, the Jeep returned to the roadway while the tires of the trailer were still at the roadway edge. After the Jeep had rotated approximately 120 degrees, the vehicle tripped and began a left side leading rollover along its longitudinal axis. The trailer also rolled at this time. The Jeep rolled 8 quarter turns and came to rest on its wheels and facing west. The trailer separated from the vehicle at some point and rolled for an unknown number of turns before coming to rest off-road on its right side and facing southeast. Based on the scene evidence and police measurements, the estimated roll distance for the Jeep was determined to be approximately 20 m (66.6 ft).

**OCCUPANT DEMOGRAPHICS - 1996 Jeep Grand Cherokee**

	<b>Driver</b>	<b>Front row right</b>		
Age/Sex:	57/Female	29/Female		
Seated Position:	Front left	Front right		
Seat Type:	Bucket	Bucket		
Height:	Unknown	Unknown		
Weight:	Unknown	Unknown		
Alcohol/Drug Involvement:	None	N/A		
Body Posture:	Unknown	Unknown		
Hand Position:	Unknown	Unknown		
Foot Position:	Unknown	Unknown		
Restraint Usage:	Lap and shoulder belt available, used.	Lap and shoulder belt available, used.		
Air bag:	Driver air bag available, did not deploy.	Passenger air bag available, did not deploy.		
	<b>Second row left</b>	<b>Second row center</b>	<b>Second row right</b>	
Age/Sex:	2/Female	4/Male	1/Female	
Seated Position:	Second row left	Second row center	Second row right	
Seat Type:	Bench with folding back	Bench with folding back	Bench with folding back	
Height:	Unknown	Unknown	Unknown	
Weight:	Unknown	Unknown	Unknown	
Alcohol/Drug Involvement:	N/A	N/A	N/A	
Body Posture:	In child seat	In child seat	In child seat	

## **OCCUPANT KINEMATICS**

### **Driver Kinematics**

The 57-year-old female driver was seated in an unknown posture and was restrained by the 3-point manual lap and shoulder belt. The shoulder belt anchorage was in the full down position. The Jeep drifted off the north edge of the roadway. The driver overcorrected to the right and the Jeep began a clockwise rotation back across both eastbound lanes of travel. As the vehicle rotated in a clockwise direction, the driver likely pitched to the left. The vehicle tripped on the roadway and rolled with its left side leading. The driver was probably displaced to the left and right during the rollover. She was partially ejected and sustained abrasions, lacerations, and burns to her left upper arm due to contact with the ground. The Jeep came to rest on its wheels. The driver was able to exit the vehicle under her own power. She was transported by ground ambulance to a local medical center where she was treated and released.

### **First Row Right Occupant Kinematics**

The 29-year-old female occupant was seated in an unknown posture and was restrained by the 3-point manual lap and shoulder belt. The shoulder belt anchorage was in the full down position. As the vehicle rolled over, this occupant likely was displaced in multiple directions, causing thoracic and lumbar compression fractures. During the rollover sequence, probably during the 7<sup>th</sup> quarter turn, her right hand and arm were thrown outside the vehicle. Her hand and arm were then crushed between the exterior of the vehicle and the ground. She sustained a crushing and degloving injury to the hand. She was able to exit the vehicle with assistance from passers-by. She was transported from the scene by air ambulance and hospitalized for 32 days.

### **Second Row Left Occupant Kinematics**

The 2-year-old female occupant was restrained in the forward facing child safety seat by the 5-point harness. The child seat was secured in the Jeep's second row left seat using the 3-point manual lap and shoulder belt. At the time of the vehicle inspection there was 15.0 cm of fore/aft movement for the top of the child seat, and 6.5 cm (2.6 in) of fore/aft movement at the bottom. There was 30 cm (11.8 in) of lateral movement for the child seat. Based on the movement of the CSS, it is probable that the CSS had more slack than is recommended by the manufacturer. As the vehicle rolled, the child and child seat was probably displaced to the left and right. The Jeep came to rest on its wheels. The child exited the vehicle with assistance. There were no reported injuries. She was transported by ambulance to a local medical center where she was admitted overnight for observation.

### **Second Row Center Seat Occupant Kinematics**

The 4-year-old male occupant was restrained in the forward facing child safety seat by the 3-point harness. The child seat was installed in the Jeep's second row middle seat using the manual lap belt. During the rollover, the child and child seat were probably displaced to the left and right. The Jeep came to rest on its wheels. The child exited the vehicle with assistance. He sustained a forehead abrasion from an unknown source and was transported by air ambulance to a local medical center where he was admitted overnight for observation.

## Second Row Right Seat Occupant Kinematics

The 1-year-old female occupant was reportedly seated in the CSS with the child seat in the rear-facing orientation. There were no indications that the child seat's internal harness was being used. As the vehicle rolled, the child came out of the child seat. Based on the number of rolls and the final rest of the child, it is probable that she was ejected from the vehicle between the fifth and sixth quarter turns. The area of ejection was probably the front right window. The vehicle came to rest on top of the child. The child's head was trapped between the vehicle chassis and the ground. She was removed by a witness. She was then transported by air ambulance to a local medical center where she was admitted. The witness reported seeing multiple abrasions on her body that appeared to be related to contact with the ground. He did not see any head related injuries.

## OCCUPANT INJURIES - 1996 Jeep Grand Cherokee

Driver: Injuries obtained from ER Report.

<u>Injury</u>	<u>OIC Code</u>	<u>Injury Mechanism</u>	<u>Confidence Level</u>
Lacerations, minor, upper arm, left	790602.1,2	Ground	Certain
Abrasions, upper arm, left	790202.1,2	Ground	Certain

Front right occupant: Injuries obtained from ER, Operative and Discharge Reports.

<u>Injury</u>	<u>OIC Code</u>	<u>Injury Mechanism</u>	<u>Confidence Level</u>
Abrasion, left forehead	290202.1,7	Unknown	Unknown
Degloving injury, hand, right	794006.3,1	Ground	Certain
Crush injury, massive destruction of bone and cartilage, three fingers	752406.2,1 752406.2,1 752406.2,1	Ground	Certain
Dislocation, Metacarpal-Phalangeal joint, fifth, right hand	750404.1,1	Ground	Certain
Multiple tendon lacerations (rupture, tear) in right hand	740210.1,1	Ground	Certain
Abrasion, right forearm	790202.1,1	Ground	Certain
Compression fracture, thoracic vertebra, T4	650432.2,7	Seat cushion	Probable



Compression fracture, lumbar vertebra, L1	650632.2,8	Seat cushion	Probable
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Second row left occupant: No reported injuries.

Second row center occupant: Injury obtained from Pediatric Emergency Department Record.

<u>Injury</u>	<u>OIC Code</u>	<u>Injury Mechanism</u>	<u>Confidence Level</u>
Abrasion, right forehead	290202.1,7	Unknown	Unknown

Second row right occupant: Injury obtained from police report.

<u>Injury</u>	<u>AIS Code</u>	<u>Injury Mechanism</u>	<u>Confidence Level</u>
Multiple abrasions, whole body	990200.1,0	Ground	Certain

