

Rollover/Child Safety Seat Investigation / Vehicle to Object  
Dynamic Science, Inc. / Case Number: DS07011  
1996 Jeep Grand Cherokee  
Utah  
February 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 This on site investigation focused on the dynamics of a 1996 Jeep Grand Cherokee during a rollover crash, and on the performance of two child safety seats installed in the second row of the Jeep. This single vehicle crash occurred in February 2007 at 1047 hours. The crash occurred on a two lane local roadway, with a posted speed limit of 48 km/h (30 mph). The vehicle was driven by a 22-year-old female, and there were three child occupants in the second row, ages 6 months, 6 years, and 2 years. The 6-month-old was restrained in a rear facing infant seat; the 2-year-old was restrained in a forward facing child safety seat. The case vehicle was traveling westbound when the driver departed the roadway on the right side in a curve. The front of the Jeep struck an outcropping of rocks. The vehicle rotated in a clockwise direction and rolled over onto its roof. All of the occupants were transported to a local hospital where they were treated and released. The vehicle was towed from the scene due to damage.				
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## BACKGROUND

This on site investigation focused on the dynamics of a 1996 Jeep Grand Cherokee during a rollover crash, and on the performance of two child safety seats installed in the rear of the Jeep (**Figure 1**). A forward facing Graco CarGo booster seat was positioned in the second row left of the Jeep Grand Cherokee, and a rear-facing Evenflo Embrace infant seat was positioned in the second row right. This single vehicle crash occurred in February 2007 at 1047 hours. The crash occurred on a two lane local roadway, with a posted speed limit of 48 km/h (30 mph). The vehicle was driven by a 22-year-old female, and there were three child occupants in the second row, ages 6 months, 6 years, and 2 years. The 6-month-old was restrained in a rear facing infant seat; the 2-year-old was restrained in a forward facing child safety seat. The case vehicle was traveling westbound when the driver departed the roadway on the right side in a curve. The front of the Jeep struck an outcropping of rocks. The vehicle rotated in a clockwise direction and rolled over onto its roof. All of the occupants were transported to a local hospital where they were treated and released. The vehicle was towed from the scene due to damage.



**Figure 1.** Case vehicle, 1996 Jeep Grand Cherokee

This Rollover case was identified by NHTSA from an online news article. DSI was emailed the information on February 23, 2007. The police report was obtained on March 12, 2007, and DSI was assigned the case on March 12, 2007. The field work was completed on March 15, 2007. Photos of the child seats were obtained on April 11, 2007.

## SUMMARY

### Crash Site

This single vehicle crash occurred while the vehicle was negotiating a left hand curve in February 2007 (**Figure 2**). At the time of the crash, there were no adverse weather conditions and the asphalt roadway surface was dry. The east/west roadway was configured with a single lane in each direction that were separated by a double-yellow painted centerline. Each travel lane was bordered on the outside by a wide paved shoulder that was marked with a single white fog line. Adjacent to the shoulder was a concrete curb and concrete sidewalk. Adjacent to the sidewalk was an outcropping of rocks. The roadway had a radius of 166 m (544 ft) near the point of departure. The speed limit for this location was 48 km/h (30 mph).



**Figure 2.** Approach to area of roadway departure (west)

### Pre-Crash

The 1996 Jeep Grand Cherokee was traveling westbound at a police estimated speed of 48 km/h (30 mph). There were three child occupants in the second row, ages 6 months, 6 years, and 2 years. The 6-month-old was restrained in a rear facing infant seat that was secured in the second row right seat position. The 2-year-old was restrained in a forward facing child safety seat that was secured in the second row left seat position. The 6-year-old was in the middle seat position and was wearing a manual lap belt.

As the vehicle entered the left hand curve, the 22-year-old driver lost control of the vehicle and the vehicle departed the right side of the roadway (**Figure 3**).

### Crash

The front of the Jeep struck an outcropping of rocks with its front end (**Figure 4**). The impact severity was moderate, and resulted in the deployment of the frontal air bag system in the vehicle. The Damage Only algorithm of the WinSmash program computed a total delta V of 24.0 km/h (14.9 mph), based on the Jeep's front end crush profile. The longitudinal and lateral components were -24.0 km/h (-14.9 mph) and 0 km/h (0 mph), respectively.

It appears that the Jeep rotated clockwise slightly as the vehicle struck the rock outcropping. As the vehicle rotated, it began a left side leading rollover. The Jeep rolled two quarter turns and came to rest on its roof facing west (**Figure 5**).

### Post-Crash

The driver was able to exit the vehicle under her power. The children in the safety seats remained in their respective seats in an upside down position until being extricated by responding private parties and emergency personnel. The second row middle child passenger was also positioned upside down until being extricated. The driver and three children sustained minor injuries and were transported to a local hospital where they were treated



**Figure 3.** Area of roadway departure



**Figure 4.** Impact with rock outcropping



**Figure 5.** Case vehicle at final rest

and released.

The Jeep was towed from the scene due to damage. It was being sold by to the tow agency to pay for lot fees. The owner was uninsured.

### VEHICLE DATA -1996 Jeep Grand Cherokee

The 1996 Jeep Grand Cherokee Limited was identified by the Vehicle Identification Number (VIN): 1J4GZ78Y6TCxxxxxx. The Jeep was a 4-door, 5-passenger wagon that was equipped with a 5.2 liter, 8-cylinder engine, an automatic transmission, 4-wheel drive, and front disc/rear drum brakes. The Jeep was equipped with Mastercraft Courser HTS P225/70R16 tires for the left front, left rear and right rear positions. The right front was equipped with a Radial Trail A/A P225/70R16 tires. The vehicle manufacturer's recommended cold tire pressure was 248 kPa (36 psi). The specific tire information was as follows:

Position	Measured Pressure	Measured Tread Depth	Restricted	Damage
LF	234 kPa (34 psi)	2 mm (3/32 in)	No	None
LR	228 kPa (33 psi)	5 mm (6/32 in)	No	None
RR	Flat	5 mm (6/32 in)	No	Flat
RF	Flat	8 mm (10/32 in)	Yes	Debeaded

The seating in the Jeep Grand Cherokee was configured with leather covered front bucket seats with adjustable head restraints and a second row split bench back seat. The front head restraints had been removed in order to install after-market seat covers. The rear seat head restraints were missing at the time of the inspection. Both front seats were located at the rear most track position. The driver's seat back was at a 22 degree angle from the vertical; the seat bottom angle was 12 degrees from the horizontal. The front right passenger seat back was at a 22 degree angle from the vertical; the seat bottom angle was 12 degrees from the horizontal. The rear seat backs were at a 22 degree angle from the vertical; the seat bottom angles were 13 degrees from the horizontal.



**Figure 6.** Driver's seat back with after market cover removed.

## VEHICLE DAMAGE

### Exterior Damage - 1996 Jeep Grand Cherokee

The 1996 Jeep Grand Cherokee sustained moderate front end damage as a result of the impact with rock outcropping (**Figure 7**). The direct damage began at the front right bumper corner and extended laterally 52 cm (20.5 in). The combined direct and induced damage measured 143 cm (56.3 in). The maximum longitudinal crush was located between C5 and C6 and measured 51 cm (20 in). There was damage into the radiator area and into the lower frame. The right wheelbase was shortened by 3 cm (1.2 in) and the right front tire was flattened. All the doors remained closed and operational. Six crush measurements were documented at the bumper level as follows: C1 = 3 cm (1.2 in), 6 cm (2.4 in), 9 cm (3.5 in), 21 cm (8.3 in), 28 cm (11.0 in), 28 cm (11.0 in). The Collision Deformation Classification (CDC) for the impact with the rocks was 12FREW3.

The Jeep also sustained damage during the rollover (**Figure 8**). The direct damage was 122 cm (48.0 in) wide. It began at the hood line and extended rearward 208 cm (81.9 in) to include the windshield header and the roof area above the front seats. The maximum vertical crush was to the left of the A pillar along the windshield header (**Figure 9**). It was located 34 cm (13.4 in) laterally from the side with a maximum crush of 11 cm (4.3 in). The CDC for the rollover was 00TYDO3.



**Figure 7.** Front impact, Jeep Grand Cherokee



**Figure 8.** Top view of roof damage



**Figure 9.** Front view of roof damage



### Interior Damage - 1996 Jeep Grand Cherokee

The 1996 Jeep Grand Cherokee sustained minor interior damage as a result of passenger compartment intrusion (**Figure 10**). The roof and windshield sustained vertical intrusion. The windshield was cracked from impact damage. All the doors remained closed and operational. The specific passenger compartment intrusions were documented as follows:

Position	Intruded Component	Magnitude of Intrusion	Direction
LF	Roof	9 cm (3.5 in)	Vertical
LF	Header	9 cm (3.5 in)	Vertical
RF	Roof	14 cm (5.5 in)	Vertical
RF	Header	14 cm (5.5 in)	Vertical



**Figure 10.** Overview of roof/windshield header intrusion

## MANUAL RESTRAINT SYSTEMS - 1996 Jeep Grand Cherokee

The 1996 Jeep Grand Cherokee was configured with manual 3-point lap and shoulder belts for the four outboard seat positions. The second row middle seat was configured with a manual lap belt. All four outboard seat safety belts were equipped with adjustable D-rings that were in the full down position. The driver's safety belt was configured with a sliding latch plate and an Emergency Locking Retractor (ELR). The remaining outboard safety belts were configured with lightweight locking latch plates and ELR retractors.

The driver's belt exhibited a 13 cm (5.1 in) area of possible loading that was located approximately 152 cm (59.8 in) from the anchor. The driver reported that she was wearing the safety belt. The second row left safety belt was used to secure a forward facing booster seat (**Figure 11**). There were no indications of seat belt loading. The second row right safety belt was used to secure a rear facing infant seat. The second row right seat belt webbing was cut in two locations by either the responding private parties or emergency personnel (**Figure 12**). The cut section measured 105 cm (41.3 in) in length.



**Figure 11.** Second row left seat belt/latch plate



**Figure 12.** Cut section of second row right seat belt webbing

## Child Safety Seat

### Graco CarGo Booster Seat

A forward facing Graco CarGo booster seat was secured in the second row left seat position of the Jeep Grand Cherokee (**Figures 13-14**). According to the driver, the seat had been secured using the lap and shoulder belt with the belt was routed through the forward facing belt path. According to the driver, the booster seat was tightly anchored to the vehicle. The model number of the seat was 8690CNN and the date of manufacture was February 3, 2006. The child seat was configured with a five-point internal harness system and a two-piece locking harness retainer clip. The seat was designed with three harness positions for the shoulder straps. At the time of the crash, the harness was in the top slot. The CarGo youth booster car seat is designed to be used forward-facing only. It had a depth of 57 cm (22.4 in), a width of 42 cm (16.5 in), and a height of 66 cm (25.9 in).

When using the seat with the internal harness, the manufacturer recommends the seat be used for children who weigh between 9 and 18 kg (20-40 lbs) and are between 69 and 109 cm (27-43 in) in height.

When using the seat without the harness, the manufacturer recommends the seat be used for children who weigh between 14 and 45 kg (30-100 lbs) and are between 89 and 137 cm (35-54 in) in height. In order to use the CarGo youth booster car seat without its harness the child must be able to sit upright unassisted.

In this crash, the child was using the internal harness. The child's height was 94 cm (37 in) and her weight was 16 kg (35 lbs), which was within the manufacturer's recommended height and weight guidelines.



**Figure 13.** Side view, Graco CarGo booster seat



**Figure 14.** Graco CarGo booster seat

### Evenflo Embrace Infant Safety Seat

A rear-facing Evenflo Embrace infant safety seat (ISS) was secured in the second row right seat position of the Jeep Grand Cherokee (**Figures 15-16**). The model number of the seat was 5481586 and the date of manufacture was November 3, 2005. The infant seat was configured with a 5-point internal harness system and a two-piece locking harness retainer clip. The seat was designed with three shoulder harness positions. At the time of the crash, the harness was in the top position. The seat was designed to be used with a stay-in-vehicle base. The base was in use at the time of the crash. The infant seat carrying handle was in the down position. The ISS handle was the subject of a recall in 2007. The recall involved the ISS when it was being carried, and had no impact in this crash. The seat base was designed to be used with a LATCH strap, which was not used. The manufacturer recommends that the seat be used for infants weighing between 2.3-10 kg (5-22 lbs) and between 48-66 cm (19-26 in) in height. The child's weight was 7 kg (15 lbs), which was within the manufacturer's recommended weight guidelines. Her height was 69 cm (27 in), which put her just above the recommended height guideline.

The infant seat was secured in the rear-facing configuration using the vehicle's lap and shoulder belt by the driver. The seat belt was configured with a lightweight/cinching locking latch plate. The seat belt was routed through the rear facing slots of the stay-in-vehicle base. According to the driver, the seat base was installed tightly. The seat belt was cut during the extrication of the child. There were no other indications of usage.



**Figure 15.** Evenflo Embrace infant seat and seat base



**Figure 16.** Evenflo infant seat and seat base (assembled)

## Supplemental Restraint Systems - 1996 Jeep Grand Cherokee

The 1996 Jeep Grand Cherokee was equipped with frontal air bags. The air bags deployed as a result of the longitudinal deceleration of the Cherokee during the impact with the rock outcropping.

The driver's air bag deployed from the center of the steering wheel hub through asymmetrical H-configuration module cover flaps (**Figure 17**). The top flap measured 4 cm (1.6 in) in height and 16 cm (6.3 in) width. The bottom flap measured 8 cm (3.1 in) in height and 16 cm (6.3 in) width. The deployed driver's air bag measured 54 cm (21.3 in) in diameter in its deflated state. The air bag was tethered by a single internal strap. There were no vent ports. There were eight horizontal flaps across the face of the air bag. A stain was found at the top left quadrant. The stain was tested by the SCI investigator and the results were positive for blood<sup>1</sup>.

The front right passenger's air bag deployed from a mid-mount module with a rectangular cover flap that was hinged at the forward aspect (**Figures 18-19**). The module cover flap measured 36 cm (14.2 in) in width and 12 cm (4.7 in) in height. The deployed front right passenger's air bag measured 41 cm (16.1 in) in width seam to seam and 55 cm (21.7 in) in height. There was a light stain on the right side of the air bag face. There was also an orange colored scuff that was approximately 5 cm (2.0 in) wide by 32 cm (12.6 in) high just to the left of the center of the air bag.



**Figure 17.** Driver's air bag (top of air bag at bottom of image)



**Figure 18.** Front right passenger air bag



**Figure 19.** Front right passenger air bag (side view)

<sup>1</sup>Hemident presumptive blood test

**OCCUPANT DEMOGRAPHICS - 1996 Jeep Grand Cherokee**

	Occupant 1	Occupant 2
Age/Sex:	22/Female <sup>2</sup>	2/Female
Seated Position:	Front left	Second row left
Seat Type:	Bucket	Split bench
Height:	Unknown	14.6 cm (37 in)
Weight:	80 kg (176 lbs)	16 kg (35 lbs)
Alcohol/Drug Involvement:	None	NA
Body Posture:	Upright	Sitting in booster seat
Hand Position:	Both hands on steering wheel	Unknown
Foot Position:	Right foot on brake, left on floor	Unknown
Restraint Usage:	Lap and shoulder belt available, used	Lap and shoulder belt used with forward facing booster seat
Air bag:	Steering wheel mounted air bag, deployed	None

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<sup>2</sup>5-6 weeks pregnant

**OCCUPANT DEMOGRAPHICS**

	Occupant 3	Occupant 4
Age/Sex:	6/Female	6 months/Male
Seated Position:	Second row middle	Second row right
Seat Type:	Split bench	Split bench
Height:	Unknown	69 cm (27 in)
Weight:	Approximately 20 kg (45 lbs)	7 kg (15 lbs)
Alcohol/Drug Involvement:	None	None
Driving Experience:	NA	NA
Body Posture:	Upright	Sitting in infant seat
Hand Position:	Unknown	Unknown
Foot Position:	Unknown	Unknown
Restraint Usage:	Lap belt available, used	Lap and shoulder belt used with rear facing infant seat

**OCCUPANT INJURIES - 1996 Jeep Grand Cherokee**

Driver: Injuries obtained from EMS records, admission records, ER records, radiology reports, and discharge records.

<u>Injury</u>	<u>OIC Code</u>	<u>Injury Mechanism</u>	<u>Confidence Level</u>
Cervical strain	640278.1,6	Impact forces	Probable
Chest abrasion	490202.1,4	Seat belt webbing	Certain
Abrasion, right forearm	790202.1,1	Air bag	Probable

Second row left seat occupant: Injuries obtained from EMS records, ER records and discharge records.

<u>Injury</u>	<u>OIC Code</u>	<u>Injury Mechanism</u>	<u>Confidence Level</u>
Contusion, forehead	290402.1,7	Unknown	Unknown
Contused abrasion, neck	390202.1,2	Booster seat webbing	Probable
Contused abrasion, chest	490202.1,9	Booster seat webbing	Probable

An X-ray revealed an ill-defined opacity in the left mid lung the could indicate a pulmonary contusion. There were no indications of a rib fracture or pneumothorax

Second row middle seat occupant: Injuries obtained from EMS records, ER records, radiology reports, Post ER records and discharge records.

<u>Injury</u>	<u>OIC Code</u>	<u>Injury Mechanism</u>	<u>Confidence Level</u>
Contusion, forehead	290402.1,7	Unknown	Unknown
Abrasion, abdomen	590202.1,4	Lap belt webbing	Certain



Second row right seat occupant: Injuries obtained from interviewee, EMS records, ER records and discharge records.

<u>Injury</u>	<u>OIC Code</u>	<u>Injury Mechanism</u>	<u>Confidence Level</u>
Contusion, forehead	290402.1,7	Unknown	Unknown

## **OCCUPANT KINEMATICS - 1996 Jeep Grand Cherokee**

### **Driver Kinematics**

The 22-year-old female driver was seated in an upright posture and was restrained by the 3-point manual lap and shoulder belt. The driver was pregnant, in her 1<sup>st</sup> trimester. The seat was adjusted to the full rearward position. At impact with the rock outcropping, the frontal air bags deployed. The driver initiated a forward trajectory. She loaded the safety belt, causing a neck strain and a chest abrasion. Her right inner forearm sustained an abrasion from the air bag. As the vehicle rotated in a clockwise direction, the driver likely pitched to the left. The vehicle overturned left side leading onto its roof. The driver was able to exit the vehicle under her own power. She was transported by ground ambulance to a local hospital where she was treated and released. No injuries to the fetus were detected.

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

The 2-year-old female child was restrained in the forward facing booster seat by the five-point internal harness. The child seat was installed in the left rear position of the Jeep using the vehicle's 3-point safety belt. According to the driver, the booster seat was tightly anchored to the vehicle. At impact with the rock outcropping, the child and the booster seat initiated a forward trajectory. This occupant sustained a forehead contusion from an unknown source and a contusion/abrasion to the left side of her neck and to her chest from the child seat harness. As the vehicle rotated in a clockwise direction, this occupant was displaced to the left. The vehicle then overturned left side leading onto its roof. This occupant came to rest, upside down, in the booster seat. She was removed from the vehicle by passers-by responding to the crash. She was transported by ground ambulance to a local hospital, where she was treated and then released.

### **Second Row Middle Occupant Kinematics**

The 6-year-old female child was seated in the middle rear seat in an upright posture and was restrained by the 2-point manual lap belt. At impact with the rock outcropping, the child initiated a forward trajectory. This occupant sustained a forehead contusion from an unknown source and an abdominal abrasion from the lap belt. As the vehicle rotated in a clockwise direction and overturned, the child was displaced to the left. This occupant was found hanging upside down in her seat belt according to the medical report. She was transported by ground ambulance to a local hospital. She was treated and then released.

**Second Row Right Occupant Kinematics**

The 6-month-old male child was restrained in the rear-facing infant seat by the internal five-point harness. The infant seat was installed in the rear right position of the Jeep with the vehicle's 3-point safety belt. According to the driver, the infant seat base was tightly anchored to the vehicle. At impact with the rock outcropping, the child and the infant seat initiated a forward trajectory. This occupant sustained a forehead contusion from an unknown source. The child remained within the CSS during the subsequent two quarter turn rollover. This occupant was removed from the vehicle in the infant seat. He was transported by ground ambulance to a local hospital. He was examined and then released.

**Attachment 1. Scene Diagram**

