

On-Site Child Restraint System Investigation  
Dynamic Science, Inc. (DSI), Case Number DS10022  
2001 Toyota Land Cruiser  
Idaho  
September 2010

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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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**Dynamic Science, Inc.**  
**Crash Investigation**  
**Case Number: DS10022**

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## BACKGROUND

The focus of this on-site investigation was the child occupant and Child Restraint System (CRS) in a 2001 Toyota Land Cruiser that was involved in a single-vehicle rollover crash (**Figure 1**). This crash occurred in September 2010 in the southbound lanes of a state highway. The Toyota was being driven by a restrained 36-year-old female and the second row left seat was occupied by a restrained 3-year-old female seated in a high-back booster safety seat (BSS). The driver noticed that the child was attempting to get out of the seat.



**Figure 1.** Subject vehicle, 2001 Toyota Land Cruiser (police photo)

The driver and police stated that she was still secured in the seat when the crash occurred. The driver became distracted by her daughter and the Toyota drifted onto the right shoulder and impacted a metal snow pole. The Toyota continued off-road and traveled up an embankment. The vehicle vaulted, became airborne, and began an end-over-end rollover about its lateral axis. The vehicle completed four quarter-turns and came to rest on the roadside on its wheels.

The driver sustained a fractured left wrist and multiple contusions and abrasions. The second row left occupant sustained multiple contusions and abrasions. Both occupants were transported from the scene by air to a local trauma center where they were treated and released.

The Toyota was towed from the scene due to damage and was later declared a total loss by the insurance company. The BSS was removed from the vehicle by the family of the occupants and was in the possession of the driver.

On September 22, 2010 DSI forwarded a news article to the National Highway Traffic Safety Administration (NHTSA) for review and DSI was then instructed to obtain permission to inspect the vehicle and child seat. On September 29, 2010 DSI obtained permission to and the case was assigned on the same day. Field work was completed on October 5, 2010.

## SUMMARY

### Crash Site

The crash site was the southbound lane of a state highway (**Figure 2**). The highway was configured with single northbound and southbound lanes that were separated by double solid yellow lines painted over a centerline rumble strip. The travel lanes were 3.3 m (11.0 ft) wide and were bordered on either side by white fog lines. The roadway was bordered on the east by an asphalt shoulder and on the west by an asphalt shoulder, a shallow ditch, and an ascending grass-covered embankment. Beyond the west shoulder there were a series of



**Figure 2.** Southbound approach (police photo)

snow poles that paralleled the roadway at 15.2 m (50.0 ft) intervals. The roadway was clear and dry at the time of the crash. The posted speed limit was 89 km/h (55 mph).

### Pre-Crash

The Toyota was traveling southbound at a driver reported speed of 72 km/h (45 mph). The driver looked in her rear view mirror and noticed that her daughter was trying to get out of the BSS. As she turned around to look at her child, the Toyota began drifting onto the right shoulder.

### Crash

The Toyota traveled off the asphalt shoulder and impacted a metal snow pole (Event 1) (**Figure 3**). The Toyota continued off-road and traveled up an embankment. The vehicle vaulted, became airborne, and began an end-over-end rollover about its lateral axis (Event 2). The vehicle completed four quarter-turns and came to rest on the roadside on its wheels (**Figure 4**).

### Post-Crash

The driver remained in the vehicle until being extricated by rescue personnel. She was transported from the scene by air to a local hospital. She arrived with a Glasgow Coma Score (GCS) of 15 and was treated and released. The second row left occupant sustained minor injuries. There was no loss of consciousness but EMS personnel felt the child had a decreased level of consciousness or appeared sleepy and it was determined that she should be airlifted to a local Level 2 trauma center. She was transported to the trauma center where she was treated and released.

The Toyota was towed from the scene due to damage and was later declared a total loss by the insurance company.

### Vehicle Data - 2001 Toyota Land Cruiser

The 2001 Toyota Land Cruiser four-door sport utility vehicle was identified by the Vehicle Identification Number (VIN): JTEHT05J512xxxxxx. The vehicle date of manufacture was August 2000. The Toyota was equipped with a 4.7-liter, 8-cylinder engine, automatic transmission, 4-wheel drive, anti-lock brakes with electronic brake force distribution, active traction control, and vehicle skid control.



**Figure 3.** Impact with snow pole (police photo)



**Figure 4.** Subject vehicle at final rest (police photo)

The vehicle manufacturer recommended P275/70R16 tires for the front and rear with a cold tire pressure of 200 kPa (29 psi) for the front and 221 kPa (32 psi) for the rear. The vehicle was equipped with Trail Mark Max LT285/75R16 tires on the front and rear that were mounted on original equipment aluminum wheels. The specific tire data at the time of the vehicle inspection was as follows:

| Position | Measured Pressure | Measured Tread Depth | Restricted | Damage    |
|----------|-------------------|----------------------|------------|-----------|
| LF       | Tire Flat         | 10 mm (13/32 in)     | No         | De-beaded |
| LR       | 138 kPa (20 psi)  | 10 mm (13/32 in)     | No         | None      |
| RR       | 276 kPa (40 psi)  | 8 mm (10/32 in)      | No         | None      |
| RF       | Tire Flat         | 9 mm (11/32 in)      | No         | De-beaded |

The Toyota's interior was equipped with leather-covered five-passenger seating. The front row outboard bucket seats were separated by a center console and armrest and equipped with height-adjustable head restraints. The driver's seat was located 80.0 cm (31.4 in) aft of the A-pillar and the seat back was slightly reclined. The second row was a 40-20-40 bench seat with folding backs. The vehicle was designed to accommodate a third row bench seat. Four floor anchor points were available but no seat was present during the crash.

## Vehicle Damage - 2001 Toyota Land Cruiser

### Exterior Damage

The Toyota sustained minor front end damage from the impact with the snow pole (**Figure 5**). The direct damage was located 38.0 cm (14.9 in) from the left front bumper corner and measured 2.0 cm (0.8 in) in width and 11.0 cm (4.3 in) in height. The Collision Deformation Classification (CDC) for the impact with the pole was 12FLLN1.



**Figure 5.** Front bumper damage from impact with snow pole

The Toyota sustained moderate front end damage from the impact with the embankment during the end-over-end rollover sequence (**Figure 6**). This was a non-horizontal impact but field measurements were taken for informational purposes. The direct damage began at the front right bumper corner and extended left 125.0 cm (49.2 in). The Field L extended from bumper corner to bumper corner. Six crush measurements were taken along the backing bar as follows:  $C_1 = 6.0$  cm (2.4 in),  $C_2 = 8.0$  cm (3.1 in),  $C_3 = 6.0$  cm (2.4),  $C_4 = 6.0$  cm (2.4 in),  $C_5 = 5.0$  cm (2.0 in),  $C_6 = 12.0$  cm (4.7 in). The maximum crush was

located at C<sub>6</sub>.

The front and rear bumper fasciae and the hood had been displaced during the rollover sequence.

Additionally, the Toyota sustained damage to the hood and roof during the rollover event (**Figure 7**). The direct damage to the top of the vehicle extended laterally from roof side rail to roof side rail and measured 153.0 cm (60.2 in). The damage extended from the hood rearward 403.0 cm (147.2 in) to the backlight. The maximum vertical crush measured 40.0 cm (15.7 in) and was located at the left D-pillar; the maximum lateral crush was located at the same point and measured 20.0 cm (7.9 in) (**Figure 8**). The CDC for Event 2 was 00TDDO4.

### Interior Damage

The Toyota sustained moderate interior damage as a result of intrusions and occupant loading. Vertical intrusions were located at the left side rail, left roof, and left D-pillar. Lateral intrusions were located at the left roof side rail and left D-pillar. Evidence of occupant loading were documented to the driver's safety belt and the BSS.

The left front door and rear hatch were jammed shut; the left door was pried open during EMS extrication efforts. The remaining doors remained closed and operational. All the glazing was either fixed or closed. The windshield was holed and in place. The left second and third row glazing was disintegrated.

The left rear window frame was shifted rearward 20.0 cm (7.8 in) forming a triangular-shaped opening at the B-pillar and deformed laterally outboard 21.0 cm (8.3 in) forming an opening around the entire frame. This may have been result of extrication activities.



**Figure 6.** Frontal damage



**Figure 7.** Overview of rollover damage



**Figure 8.** Maximum lateral and vertical crush at left D-pillar



## Manual Restraints

The Toyota's front row seating was equipped with 3-point manual lap and shoulder safety belts with sliding latch plates and adjustable D-rings. The driver's safety belt was equipped with an Emergency Locking Retractor (ELR) and the front right passenger's safety belt had a switchable ELR/Automatic Locking Retractor (ALR). Both front seats were configured with retractor pretensioners. The second row seating was equipped with lap and shoulder belts with switchable ELR/ALR retractors for all three positions.

The driver's safety belt D-ring anchorage was in the full-down position and the latch plate was scratched indicating historical usage. The safety belt was locked in the spooled out position due to pretensioner actuation and the belt webbing was trapped in the D-ring (**Figure 9**). There was loading on the webbing at the D-ring. Based on the vehicle inspection it was determined that the front left safety belt was used to restrain the driver during the crash.



**Figure 9.** Driver's safety belt webbing at D-ring

The front right safety belt D-ring anchorage was in the full-up position and the latch plate was scratched. The belt was locked in the stowed position due to pretensioner actuation.

The second row left safety belt was being used in combination with an Evenflo high-back BSS. The seat belt webbing had been cut by rescue personnel 113.0 cm (44.4 in) above the stop button. Based on the vehicle inspection and interview it was determined that the second row left safety belt had been used to restrain the child occupant during the crash.

The second row middle and right safety belts were not used in this crash.

## Supplemental Restraint Systems

The Toyota was equipped with redesigned driver and front right passenger air bags and front safety belt pretensioners. The frontal air bags deployed and the pretensioners actuated during the rollover sequence, probably as the vehicle impacted the embankment with its front plane during the first quarter-turn.

The driver's air bag deployed from the steering wheel hub through H-configuration cover flaps (**Figure 10**). It was circular in shape and measured 62.0 cm (24.4 in) in diameter from seam to seam.



**Figure 10.** Driver's frontal air bag

The air bag was configured with two 3.0 cm (1.2 in) diameter vent ports on the back panel and a single internal tether attached to the center of the front panel. The air bag was dirty and scuffed in several locations but this was due to it being in contact with vehicle components that had been placed in the vehicle after the crash.

The right frontal air bag deployed from the top right IP. The air bag measured 70.0 cm (27.5 in) in height and 45.0 cm (17.7 in) in width. The air bag was configured with two vent ports on the side panels. There was no evidence of damage or occupant loading on the air bag.

## Child Restraint System

### Evenflo Big Kid BSS

The Toyota's second row left seat position was occupied by a 3-year-old female seated in an Evenflo Big Kid forward-facing belt positioning BSS (**Figure 11**). The vehicle's lap and shoulder belt was being used in combination with the BSS. The BSS is available with or without a detachable high back support. The seat was being used with the back support in this crash.

The BSS model number was 3381660A and its date of manufacture was February 25, 2007. The BSS was equipped with adjustable armrests that were not being used in this crash, a removable padded seat cushion, a detachable/adjustable high-back support that was in the full-down position, and retractable cup holders on the left and right sides. The total height of the seat was 72.0 cm (28.3 in) and the width was 39.0 cm (15.3 in). Based on the BSS labeling, the seat was intended for children who meet the following requirements.

With back support:

- 13.6-45.3 kg (30-100 lbs) in weight
- Height 145 cm (57 in) or less
- Child's ears are below the top of the vehicle seat head restraints.

Without back support:

- 18-45.3 kg (40-100 lbs) in weight
- Height 145 cm (57 in) or less
- Child's ears are below the top of the vehicle seat head restraints.



**Figure 11.** Evenflo Big Kid BSS

Inspection of the BSS revealed two areas of hazed plastic loading to the high back (**Figure 12**). The first area was located 13.0 cm (5.1 in) below the top of the backrest slide and measured 2.0 cm (0.8 in) in height and 12.0 cm (4.7 in) in width. The second area located at the points where the backrest connects to the seat bottom.

Based on the child's height and weight in this case, it was appropriate to use the BSS with the back support.



**Figure 12.** Loading to BSS back support

### Rollover

The Static Stability Factor (SSF) for the Toyota was not known; the vehicle was not tested. The SSF of a vehicle is an at-rest calculation of its rollover resistance, which is based on its track width and center of gravity.

This vehicle was involved in an end-over-end, four quarter-turn rollover. The Toyota departed the roadway on the right side and traveled in a diagonal up an ascending embankment. As the vehicle reached a point on the embankment where the ground dropped away, the vehicle vaulted and became airborne. The vehicle traveled approximately 12.1 m (40.0 ft) in the air before the front of the vehicle impacted the ground, gouged the ground, and then displaced the hood (**Figure 13**). The vehicle continued the end-over-end movement as it went over on its roof and heavily impacted the area around the left D-pillar. The vehicle continued tumbling until landing on its wheels partially on the roadway. The vehicle then rolled forward a short distance and came to rest on the side of the road (**Figure 14**).



**Figure 13.** Impact with ground after vault (police photo)



**Figure 14.** Final rest (police photo)

**OCCUPANT DEMOGRAPHICS****Driver**

|                            |   |
|----------------------------|---|
| Age/Sex:                   | 36/Female   |
| Height:                    | 157 cm (62 in)  |
| Weight:                    | 91 kg (200 lbs)   |
| Seat track position:       | 80.0 cm (31.4 in) aft of A-pillar                             |
| Manual restraint use:      | Lap and shoulder belt   |
| Restraint use source:      | Vehicle inspection  |
| Air bags:                  | Steering wheel mounted frontal air bag deployed               |
| Alcohol/Drug Involvement:  | None  |
| Body Posture:              | Upright   |
| Hand Position:             | On steering wheel at 11 and 1 o'clock positions               |
| Foot Position:             | Left foot was on the floor, right foot was on the accelerator |
| Type of medical treatment: | Transported and released                                      |

**Second Row Left Occupant (02)**

|                            |                                     |
|----------------------------|-------------------------------------|
| Age/Sex:                   | 3/Female                            |
| Height:                    | 91 cm (36 in)                       |
| Weight:                    | 16 kg (35 lbs)                      |
| Seat track position:       | N/A                                 |
| Manual restraint use:      | Lap and shoulder belt used with BSS |
| Restraint use source:      | Vehicle inspection                  |
| Body Posture:              | Upright                             |
| Hand Position:             | Unknown                             |
| Foot Position:             | Unknown                             |
| Type of medical treatment: | Transported and released            |

## Occupant Injuries

Driver: Injuries obtained from emergency room reports, radiology reports, and the interviewee.

| <u>Injury</u>   | <u>Injury Severity<br/>(AIS 2005)</u> | <u>Injury Mechanism</u>      | <u>Confidence Level</u> |
|---|---------------------------------------|------------------------------|-------------------------|
| Fracture, base of distal radial styloid process. Avulsive fracture. | 752351.2,2                            | Door, forward upper quadrant | Possible                |
| Contusion, left elbow   | 710402.1,2                            | Door, forward upper quadrant | Probable                |
| Abrasion, left elbow  | 710202.1,2                            | Door, forward upper quadrant | Probable                |
| Abrasion, left and anterior neck                                    | 310402.1,2                            | Seat belt webbing            | Certain                 |
| Contusion, left side of head  | 110402.1,2                            | Side glass                   | Probable                |
| Contusion, left chest   | 410402.1,2                            | Seat belt webbing            | Certain                 |
| Contusion, right anterior thigh                                     | 810402.1,1                            | Steering wheel rim           | Possible                |
| Contusion, middle of back   | 410402.1,6                            | Seat back                    | Probable                |
| Bilateral lacerations to backs of hands                             | 710600.1,3                            | Flying glass                 | Possible                |
| Cervical strain   | 640278.1,6                            | Impact forces                | Possible                |

Second Row Left Occupant: Injuries obtained from emergency department, radiological reports, and the interviewee.

| <u>Injury</u>                                 | <u>Injury Severity<br/>(AIS 2005)</u> | <u>Injury Mechanism</u> | <u>Confidence Level</u> |
|---|---------------------------------------|-------------------------|-------------------------|
| Small abrasions, superior portion of the head | 110202.1,7                            | Unknown                 | Unknown                 |
| Buckle abrasion, inside of mouth              | 243099.1,8                            | Impact forces           | Probable                |

|                                   |            |                            |          |
|-----------------------------------|------------|----------------------------|----------|
| Abrasions, right hand and fingers | Not coded  | Probable post-crash injury |          |
| Abrasions, right shoulder         | 710202.1,1 | BSS seat back              | Possible |
| Closed head injury                | 100099.9,0 | Unknown                    | Unknown  |
| Abrasions, left foot              | 810202.1,2 | Driver seat back           | Possible |
| Contusion, left side of head      | 110402.1,2 | BSS seat back              | Possible |
| Abrasions, left shoulder          | 710402.1,2 | Seat belt webbing          | Certain  |

## Occupant Kinematics

### Driver Kinematics

The 36-year-old female driver of the Toyota was seated in an upright posture and was restrained by the lap and shoulder belt. The Toyota was traveling at a driver-reported speed of 72 km/h (45 mph) along a curved right roadway. The driver's hands were on the steering wheel at the 11 and 1 o'clock positions, her left foot was on the floor, and her right foot was on the accelerator. Prior to the crash, the driver was first looking at her child through the rear view mirror and then had turned her head to the right to get a better look at the child. The driver did not report taking any evasive actions as the vehicle drifted off the roadway to the right. As the vehicle ramped up the embankment, the driver was forced downward into the seat cushion. The vehicle began an end-over-end rollover. During the first ground contact the driver was displaced towards the front of the vehicle. The driver loaded the safety belt and probably loaded the deployed frontal air bag. The driver contacted the door with her left arm contusing the elbow and fracturing the wrist and contacted the left side glass with her head causing a minor contusion. As the vehicle landed on its roof the driver was displaced downward and loaded the safety belt causing an abrasion to the anterior and left side of her neck and a contusion on her left breast. The vehicle rolled two more turns and came to rest on its wheels. The driver remained belted in her seated position immediately after the crash. Emergency responders arrived and pried open the driver's door. She was transported to a local trauma center where she was treated and released.

### Second Row Left Occupant Kinematics (02)

The 3-year-old female second row left occupant was seated in an upright posture in a high-back booster seat and was restrained by the lap and shoulder belt. Prior to the crash she was attempting to get out of the lap and shoulder belt. During the initial front end impact she was displaced forward and engaged the lap and shoulder belt. As the vehicle rolled over onto its top she engaged the shoulder belt causing a minor abrasion to the left shoulder. She also contacted the BSS shell causing a right shoulder abrasion and an abrasion to the posterior of her head. The driver reported that the child had self-extricated herself after the crash and had exited the vehicle somehow. The driver also reported that she was confused for several minutes after the crash. Based on the extrication effort

to this seat location it is more likely that the child remained in place in the vehicle and was removed from the vehicle by emergency personnel. She was transported to a local trauma center where she was treated and released.

Attachment 1. Scene Diagram

