

Office of Defects Investigation (ODI)
On-Site Potential Unintended Acceleration Investigation
Dynamic Science, Inc. (DSI), Case Number DS10010
2006 Toyota Highlander
Oregon
February 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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Background

This investigation focused on the alleged unintended acceleration and the crash dynamics surrounding the single vehicle rollover crash of a 2006 Toyota Highlander sport utility vehicle (**Figure 1**). The 57-year-old female driver lost control of the vehicle while backing up on a gravel roadway. Based on an interview with the driver's husband¹, the vehicle initiated an unintended acceleration, the driver braked hard in response, and the vehicle departed the roadway on the right edge.



Figure 1. Subject vehicle, 2006 Toyota Highlander

After departing the roadway, the vehicle traversed a descending embankment resulting in a fall-over type rollover. The Toyota rolled three quarter-turns and came to rest on its right side on level ground at the bottom of the embankment. The driver sustained serious injuries and was transported to a local hospital. She was treated for approximately two weeks and then she died as a result of a pulmonary thromboembolism². The vehicle was towed due to damage and was later declared a total loss by the insurance company.

The National Highway Traffic Safety Administration (NHTSA) Office of Defects Investigation (ODI) was notified of this incident through a Vehicle Owner's Questionnaire (VOQ) Reference Number 10317808 submitted by the attorney representing the deceased driver's family. DSI was forwarded the police report and photographs of the subject vehicle on April 26, 2010 with instructions to obtain cooperation. The Toyota was located at an insurance auction facility. On April 29, 2010, the attorney notified DSI that he had scheduled the vehicle inspection for May 20, 2010. Present at the inspection were the DSI investigator, a NHTSA SCI representative, the attorney, a forensics engineer, and two Toyota representatives.

The inspection included examination of the driver's compartment and foot control pedals. During the vehicle inspection the Toyota's Event Data Recorder (EDR) was imaged and a summary of the data was incorporated into this report. No pre-crash data was available and the reported crash data was associated with the rollover event, hence the EDR did not assist in establishing brake or accelerator pedal status during the crash.

¹ The driver spoke with her husband following the crash.

² Formation in a blood vessel of a clot that breaks loose and is carried by the blood stream to another vessel. Source: www.medterms.com. In this case the clot clogged a vessel in the lung.

Summary

Crash Site

This single vehicle rollover crash occurred during daylight hours in February 2010. At the time of the crash the weather was cloudy and the roadway was dry. The temperature at the nearest reporting station was 11.0° C (51.8° F) and the wind direction was south at 27.8 km/h (17.3 mph) with gusts to 41.2 km/h (25.3 mph). Visibility was 16.0 km (10.0 mi). The crash occurred on an east/west, two-way, one-lane, ascending gravel roadway that began at the driver's residence (**Figure 2**).



Figure 2. Crash site, westbound view

Prior to the crash the Toyota was traveling in reverse in a westbound direction. The crash site description is based on the vehicle's westbound direction of travel and not on the vehicle's heading orientation. The roadway measured 2.7 m (9.0 ft) in width. In the westbound direction, the roadway curved right at a radius of 190.0 m (623.4 ft) as measured from the right road edge. Beginning at the driveway of the driver's residence, the roadway profile had an uphill grade of 14.1 percent; at 15.2 m (50.0 ft) west of the driveway the uphill grade measured 10.5 percent; and at 30.5 m (100.0 ft) west of the driveway the uphill grade measured 9.8 percent. The Toyota departed the roadway on the right side at 29.7 m and 32.3 m (97.6 ft and 106.0 ft) west of the driveway. The area of departure was determined based on ruts deposited in the gravel at the right roadway edge. The ruts each measured approximately 1.5 m (5.0 ft) in length, were oriented 45 degrees relative to the roadway edge, and were spaced 2.56 m (8.4 ft) apart. The angle of the ruts relative to the roadway indicated the vehicle departed the roadway in a slight clockwise yaw and that the driver was probably braking during the roadway departure. The distance separating the tire ruts were consistent with the vehicle's wheelbase and the marks were deposited by the right side tires.

The left edge of the roadway was bordered by a steep ascending embankment. The right edge of the roadway was bordered by an ascending embankment near the driveway and a descending embankment beginning at approximately 24.0 m (80.0 ft) west of the driveway. The descending embankment at the point of the roadway departure had a downhill grade measuring 60.0 percent and the embankment was covered with brush and plants. The lower aspect of the embankment ended at level ground. The distance from the right road edge to the bottom of the descending embankment measured approximately 13.7 m (45.0 ft).

Pre-Crash

All pre-crash information contained under this heading was based on the interview with the driver's husband. The driver related this information to her husband after the crash. Prior to the crash, the driver entered the Toyota and started the vehicle in the usual manner. The vehicle's temperature controls typically were adjusted to automatic settings and due to cold weather conditions, the

vehicle's heater was activated. During the interview, the driver's husband estimated that the driver departed from her parked position 3-5 minutes after she started the engine.

The driver shifted the vehicle's automatic transmission into reverse, exited the driveway, and entered the roadway while traveling in a reverse gear. She negotiated the right curve of the roadway for an unknown distance, then lost control of the vehicle due to an alleged unintended acceleration. According to her statements the driver braked hard with her right foot; it was not known if she pumped the brakes or not. As the driver was actively braking, the vehicle's right side tires deposited two tire ruts in the gravel at the point of departure. **Figure 3** is an image showing a tape measure aligned with the tire rut deposited



Figure 3. Tape measure showing length and orientation of right roadway edge

by the Toyota's right rear tire at the point of the roadway departure. Based on the length of the tire ruts caused by the tires, the grade of the roadway, and the coefficient of friction of the roadway surface, the vehicle's minimum speed at the time of the roadside departure was estimated to be 13.8-17.5 km/h (8.6 - 10.9 mph)³. The vehicle then departed the roadway.

Crash

The crash sequence included one event. The vehicle initiated a fall-over type rollover, rolled approximately three quarter-turns, and came to rest facing east on its right side. The Toyota's roll distance measured 13.7 m (45.0 ft). Based on the roll distance and the grade of the descending embankment, the vehicle's at rest location was 11.9 m (38.9 ft) below the roadway.

Post-Crash

After the vehicle came to rest, the driver exited the vehicle under her own power through the front left window opening. She moved a few feet east of the vehicle and called her husband with her cellular phone. The husband traveled on foot from the residence to the vehicle, which took approximately 2 minutes. After arriving at the vehicle he called 911 for assistance.

The police report stated the notification time was 1027 hours. The next on-scene responders arrived at approximately 1045 hours and treated the driver at the scene. An ambulance arrived at approximately 1115 hours and transported the driver to a local hospital. The time-to-hospital was 15 minutes and she arrived at the emergency department at 1134 hours, 1 hour and 7 minutes post-crash. From 1138-1405 hours she had a Glasgow Coma Score (GCS) of 15. The driver sustained injuries ranging in severity from minor to severe.

³ The coefficient of friction for loose gravel ranges from 0.4 to 0.7.

At 1610 hours she was discharged from the emergency department and transferred to another hospital. She was admitted to the second hospital for seven days and then transferred to a nursing home facility for five days. Twelve days after the crash, the driver died from a pulmonary thromboembolism. The county coroner stated the cause of death was massive pulmonary thromboembolism due to deep leg vein thrombosis occurring during recovery from a motor vehicle crash.

Vehicle Data

The Toyota was identified by the Vehicle Identification Number (VIN): JTEEP21AX60xxxxxx. The vehicle's date of manufacture was November 2005. The odometer reading was 84,099 km (52,258 mi) and was obtained during the vehicle inspection. The vehicle was equipped with a 3.3-liter, 6-cylinder engine, automatic transmission, four-wheel drive, and power steering with tilt column functionality.

The vehicle manufacturer's recommended tire size was P225/65R17 and the recommended cold tire pressure was 207 kPa (30 psi) for the front and rear tires. The vehicle was equipped with Toyo H/T Open Country 225/65R17 tires on the front and the rear. The specific tire information was as follows:

Position	Measured Pressure	Measured Tread Depth	Restricted	Damage
LF	228 kPa (33 psi)	6 mm (8/32 in)	No	None
LR	228 kPa (33 psi)	6 mm (8/32 in)	No	None
RR	214 kPa (31 psi)	6 mm (8/32 in)	No	None
RF	221 kPa (32 psi)	5 mm (6/32 in)	No	None

The Toyota's interior was equipped with three-row seating for seven occupants. The front row seating consisted of outboard bucket seats with adjustable head restraints and the second row seating consisted of a split bench seat with folding backs and adjustable head restraints. The third row seating consisted a bench seat with folding backs that were stowed at the time of the crash.

Based on the interview and a vehicle history report, the vehicle had sustained no damage prior to the crash. No recalls were issued on this vehicle.

Vehicle Damage

Exterior Damage

The Toyota sustained direct damage to the right, top, and left planes consistent with a left side leading three-quarter turn rollover. Each of the three planes exhibited body panel abrasions oriented in a single direction indicating ground contact. The roof rack sustained direct damage to the left and right rails and remained in place. The left and right side mirrors and the front bumper fascia were

displaced from the side doors due to ground contact. The windshield was fractured and had separated from the header on the right side. The left and right side windows of the passenger compartment were disintegrated while in their full closed positions.

Direct damage to the right side began at the right rear bumper corner and extended forward 457.0 cm (179.9 in) to the front right bumper corner. The damage to the right side began at the sill and extended vertically 130.0 cm (51.2 in) to the roof side rail. Maximum lateral crush to the greenhouse was located at the right roof side rail, 77.0 cm (30.3 in) forward of the right rear axle, and measured 11.0 cm (4.3 in). Maximum lateral crush to the right side body panel was located at the front right fender, 37.0 cm (14.6 in) forward of the right front axle, and measured 13.0 cm (5.1 in). Maximum vertical crush to the top plane was located at the right windshield header, 15.0 cm (5.9 in) inboard of the right roof side rail, and measured 9.0 cm (3.5 in) (**Figure 4**). The Collision Deformation Classification (CDC) for the rollover was 00RDAO3.

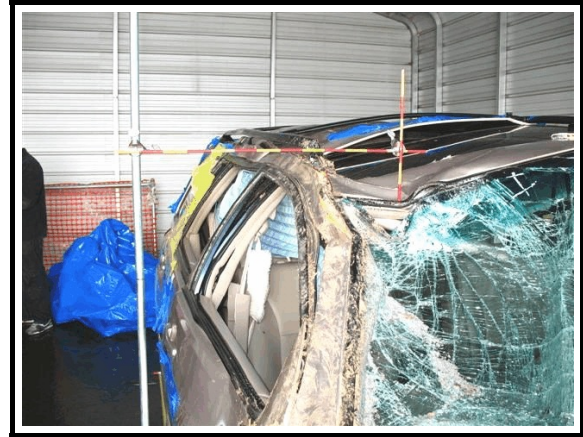


Figure 4. Maximum vertical crush measurement to top plane

Interior Damage

The Toyota sustained moderate interior damage resulting from intrusion, occupant loading, occupant contacts, and post-crash salvage activities. The following components intruded into the occupant compartment: the roof, windshield header, left and right roof side rails, and both left and right door panels. Occupant loading and occupant contact were identified on the left inflatable curtain (IC) air bag and center console. The front row head restraints were removed during post-crash salvage activity to make room for the displaced front bumper fascia.

The tilt steering column was set to middle position. There was no steering wheel rim deformation or sheer capsule displacement.

Foot Controls/Floor Mats

Figure 5 is an interior view of the driver's foot controls and floor mat as it was initially observed during the vehicle inspection. The foot controls were not damaged during the crash and they operated properly. An original equipment manufacturer (OEM) floor mat was installed and held in place by two retaining clips. The floor mat consisted of a carpeted top side and textured rubber underside. The floor mat was flexible and measured 1.0 cm (0.4 in) thick. The overall



Figure 5. Driver foot controls and floor mat

dimensions measured 70.0 cm (27.5 in) in length and 61.0 cm (24.0 in) in width. The floor mat was contoured to fit within the left floor pan. Cutouts at the upper left and right corners of the floor mat yielded space for the dead pedal and accelerator pedal. The floor mat was not damaged; it laid flat and fit closely to the contour of the floor pan. When held in place by the clips, the floor mat did not reach the foot controls or impede their movement.

The engine of the Toyota could not be started during the SCI inspection due to damage. The accelerator pedal was inspected for damage and unusual wear patterns and none was observed. The pedal was manufactured by Denso (**Figure 6**), and the left side of the plastic housing was labeled with the following information: Toyota/78120-48090/198800-3050/11G07/3718A2. The bottom edge of the accelerator pedal was located 14.0 cm (5.5 in) above the floor pan and 4.0 cm (1.6 in) above the brake pedal. It was located 2.5 cm (1.0 in) left of the center console and the lateral separation of the accelerator pedal and brake pedal measured 16.5 cm (6.5 in) (**Figure 7**). Its vertical movement was free of obstruction and the amount of friction appeared normal. Additionally, the accelerator pedal yielded no discernable lateral movement.



Figure 6. Denso accelerator pedal showing housing assembly



Figure 7. View showing brake pedal and accelerator pedal

The lateral center of the brake pedal was offset to the right of the centerline of the driver's seat cushion and the steering column by 1.5 cm (0.6 in). The brake pedal showed slight wear on the right side of the rubber pad. The brake pedal was depressed three times and it returned to its non-depressed position. The brake pedal's movement was normal and the return spring was strong. Additionally, the vehicle's four disc brake rotors were examined and they exhibited no evidence of excessive heat or wear.

During the interview, the driver's husband stated that there were no previous issues with either the accelerator or brake controls.

Manual Restraints

The vehicle's front row seating was equipped with 3-point manual lap and shoulder safety belts with sliding latch plates, adjustable D-rings, and retractor pretensioners. The driver's safety belt was equipped with an Emergency Locking Retractor (ELR) and the front right passenger's safety had a switchable ELR/Automatic Locking Retractor (ALR).

The driver's safety belt D-ring anchorage was in the full-up position and the latch plate was scratched indicating historical usage. The safety belt retractor pretensioner actuated during the rollover and it locked the safety belt webbing in the stowed position on the left B-pillar. The safety belt webbing, latch plate, and D-ring revealed no evidence of occupant loading or other damage. Based on the vehicle inspection, it was determined that the driver's safety belt was not used to restrain the driver during the crash, which was consistent with the interview with the driver's husband.

The front row passenger's safety belt D-ring was in the middle position and the latch plate was scratched indicating historical usage. The safety belt retractor pretensioner actuated during the rollover locking the webbing in the stowed position.

Supplemental Restraint System

The vehicle's Supplemental Restraint System (SRS) included an air bag control module (ACM), driver and passenger frontal air bags, seat-mounted side air bags, combination side impact/rollover IC air bags, and safety belt retractor pretensioners for the front row. Based on the interview and a vehicle history report, the air bags were original to the vehicle and had not been serviced. Based on the vehicle inspection and confirmed by the vehicle's EDR, the left and right IC air bags deployed during the rollover. No other air bags deployed during the crash.

The Toyota was a Certified Advanced 208-Compliant (CAC) vehicle. A CAC vehicle is certified by the manufacturer to be compliant with the Advanced Air Bag portion of Federal Motor Vehicle Safety Standard (FMVSS) No. 208. Advanced frontal air bag systems determine if the frontal air bags will deploy based on sensor inputs that detect occupant size, seat position, seat belt usage, and crash severity. In cases where the occupant is unrestrained and leaning out of position or is too close to the air bag, the system may reduce the risk of an air bag injury by suppressing the frontal air bag.⁴

The left IC air bag deployed from the left roof side rail over the front, second and third rows. The IC air bag measured 200.0 cm (78.7 in) in width and 40.0 cm (15.8 in) in length. The IC air bag extended downward to the bottom of the side glass. The inboard panel of the IC air bag showed two skin oil and makeup transfers measuring 8.0 x 3.0 cm (3.1 x 1.2 in) and 1.0 x 3.0 cm (0.4 x 1.2 in) respectively indicating occupant loading. The left IC air bag was cut at the roof side rail over the front row during post-crash salvage activity.

The right IC air bag deployed during the rollover and exhibited no evidence of occupant loading. The outboard panel showed dirt deposits indicating ground contact during the third quarter-turn and at final rest.

Event Data Recorder

Data in the vehicle's EDR was imaged using the Prototype Toyota Readout Tool and software

⁴ Advanced Air Bags, Accident Reconstruction Newsletter, Vol. 6, Issue 10, October 2004, <http://www.accidentreconstruction.com>

version 1.3.1.2. Pre-Crash Data was not recorded since there was no frontal crash. The EDR had the capacity to record up to three events.

The Data Table was summarized as follows:

- The Rollover Deployment Time was 355 msec.⁵
- The Rollover Roll Angle MAX within 2 sec. from trigger was -106.5 degrees.
- Deployment Stage Driver was Not Fired.
- Deployment Stage Passenger was Not Fired.

Data for the Latest Event was summarized as follows:

- Time from Previous Event was 0 msec.
- Belt Switch Status Driver was Invalid.
- Belt Switch Status Passenger was Invalid.
- Occupant Detection Passenger was Not Implemented.
- Event Counter was 0.
- Writing Flag was Finished Writing.

Data for the Next Most Recent Event was summarized as follows:

- Time from Previous Event was 0 msec.
- Event Counter was 0.
- Writing Flag was Finished Writing.

Data for the Past Event was summarized as follows:

- Time from Previous Event was 0 msec.
- Event Counter was 0.
- Writing Flag was Finished Writing.

Data for the Rollover Roll Angle GWave was summarized as follows:

- The roll angle was recorded for a count of 20 increments. The minimum roll angle measured -11.7 degrees at 0.0 and the maximum roll angle measured -106.7 degrees at count 19.0.

Data for the Rollover Lateral G Gwave was summarized as follows:

- The Rollover Lateral G was recorded for a count of 20 increments. The minimum Rollover Lateral G measured -1.9 at 0.0 and the maximum Rollover Lateral G measured -14.4 at count 9.0.

⁵ Time from trigger event to side air bag deployments

Occupant Demographics

Driver

Age/Sex:	57 years/Female
Height:	183 cm (72 in)
Weight:	88 kg (194 lb)
Seat type:	Bucket with adjustable head restraint
Seat track position:	Mid- to full-rearward track
Manual restraint usage:	Lap and shoulder belt not used
Usage source:	Vehicle inspection
Air bags:	Frontal air bag, seat-mounted side air bag not deployed; left and right IC air bags, deployed
Alcohol, drug involvement:	Positive for alcohol, BAC .039; positive for tetrahydrocannabinol ^{6 7}
Type of medical treatment:	Transported, hospitalized, deceased at nursing care facility

Occupant Kinematics

Driver

The unrestrained 57-year-old female driver was seated in an unknown posture. She was wearing prescription eyeglasses. Her seat track was adjusted between the middle and full-rear track position and her seat back was upright. The driver's seat cushion measured 520 mm (20.5 in) in width and the distance from the leading edge of the driver's seat cushion to the brake pedal measured 550 mm (21.7 in). The vehicle's front row side glass was fully closed. The vehicle's transmission was in reverse and the vehicle was traveling up an ascending gravel roadway at an unknown speed. For an unknown reason the driver lost directional control of the vehicle causing it to depart the roadway on the right side. Based on the interview, the driver braked prior to departing the roadway.

The vehicle immediately traversed a steep, descending embankment and initiated a fall-over type left side leading rollover. During the first quarter-turn, the Toyota's left and right IC air bags deployed

⁶ (THC) The active principal in marijuana. Source: Moseby's Medical Dictionary, 8th Edition

⁷ BAC results were based on a blood test and the THC results were based on a urine drug screen. According to the emergency room report, the draw time for both tests was 78 minutes post-crash.

and the unrestrained driver was displaced from her seated position to the left. Her face loaded the left IC air bag and deposited two skin oil and makeup transfers measuring 8.0 x 3.0 cm (3.1 x 1.2 in) and 1.0 x 3.0 cm (0.4 x 1.2 in) respectively. The vehicle continued to roll and traverse the embankment. During the second quarter-turn the occupant continued to be displaced from her seat and due to not being restrained possibly contacted the roof and the windshield. She sustained a major laceration to her posterior scalp that was consistent with a sharp mechanism. During the third quarter-turn, the driver was displaced to the right. The vehicle's right side impacted the level ground below the embankment and came to rest. At impact with the ground, the driver's right shoulder and thorax contacted the rear upper quadrant of the right door panel and the right IC air bag. She sustained multiple right side rib fractures, scapula fracture, clavicle fracture, lung contusion and shoulder contusion. Additionally, she sustained a minor lip laceration. After the vehicle came to rest, the driver exited the vehicle and was conscious when her husband arrived on-scene a few minutes post-crash.

Driver's Spouse Interview

The VOQ Reference Number 10317808 for this incident was submitted to NHTSA following the death of the driver. The driver's husband was interviewed three days following the vehicle and scene inspections.

The driver purchased the Toyota new in 2006 and had not experienced any mechanical trouble with the vehicle. It had not been involved in any previous crashes and, other than oil changes, the only significant service to the vehicle involved repairs of the power steering system. After the power steering was serviced there were no subsequent issues with that system. The interviewee's wife was the primary driver of the Toyota; she drove the vehicle on a regular basis and she drove the vehicle exclusive of other vehicles owned by the family. On the morning of the crash weather conditions were cloudy and cool and the gravel roadway was dry. The driver was leaving her residence to travel to a doctor's appointment scheduled later that morning. The driver had allowed sufficient travel time and was not rushed or distracted in preparation for her departure.

The driver routinely drove the Toyota in reverse up the ascending roadway when she departed the residence. It was her habit to travel up the ascending roadway in reverse due to the four-wheel drive functionality of the vehicle. The interviewee estimated the driver's speed during these departures were no more than 8.0 km/h (5.0 mph). He stated the driver usually used the vehicle's lap and shoulder belt and the reason she was not restrained on that morning was unknown. The roadway ended at the driver's property and there were no other vehicles on the roadway at the crash site. The vehicle's engine had been running for less than 5 minutes prior to the crash. The vehicle's automatic climate controls were engaged and the heater was operational.

The interviewee stated that within 30.0 m (100.0 ft) from the driver's property the vehicle accelerated and the driver braked hard with her right foot. The driver typically braked with her right foot. The travel distance was based on the location of the two tire ruts located at the point of departure from the roadside. The vehicle subsequently departed the roadway and rolled down the descending embankment.

Occupant Injuries**Driver**

The injury data was obtained from medical records.

<u>Injury</u>	<u>OIC Code</u>	<u>Injury Mechanism</u>	<u>Confidence Level</u>
Laceration, major (15.0 cm/5.9 in, full thickness), posterior scalp	110604.2,6	Windshield	Possible
Fracture, comminuted, right clavicle shaft	750671.2,1	Right door panel, rear upper quadrant	Probable
Fracture NFS, right scapula	750900.2,1	Right door panel, rear upper quadrant	Probable
Fractures, ribs R2-R7, R10-R12, unilateral flail chest NFS, right, postero-lateral	450213.4,1	Right door panel, rear upper quadrant	Probable
Hemopneumothorax NFS, contusion, unilateral NFS, right lung	442205.3,1 441406.2,1	Right door panel, rear upper quadrant	Probable
Laceration, minor, lip	210602.1,8	Unknown	N/A
Contusion, right shoulder (clavicle area)	710402.1,1	Right door panel, rear upper quadrant	Probable

Attachment 1. Scene Diagram

