Side Curtain Air Bag Investigation
Dynamic Science, Inc. (DSI), Case Number DS08033
2006 Toyota Highlander
Oregon
June 2008

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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 side curtain and seat-mounted side air bag deployments in a 2006 Toyota Highlander. The Toyota was involved in a two-vehicle crash with a 2000 Freightliner tractor-trailer that occurred with a four-leg intersection. The Toyota was being driven northbound by an 80-year-old male and the front right seat was occupied by a 76-year-old female. The Freightliner was being driven eastbound by a 32-year-old male. The driver of the Toyota had entered the intersection with a green signal. The driver of the Freightliner reportedly entered the intersection against a red signal. The front end of the Freightliner impacted the left side of the Toyota. The left side curtain and seat-mounted side air bags deployed during the impact. The driver of the Toyota sustained a possible injury and was transported a local hospital. The Toyota's front right passenger was not injured. The Toyota was towed from the scene due to damage and was later declared a total loss by the insurance company. The Freightliner was driven from the scene.

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Dynamic Science, Inc.
Crash Investigation
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BACKGROUND

This on-site investigation focused on the side curtain and seat-mounted side air bag deployments in a 2006 Toyota Highlander (**Figure 1**). The Highlander was involved in a two-vehicle crash with a 2000 Freightliner tractor-trailer that occurred with a four-leg intersection. The Toyota was being driven northbound by an 80-year-old male and the front right seat was occupied by a 76-year-old female. The Freightliner was being driven eastbound by a 32-year-old male. The driver of the Toyota had entered the intersection with a green signal. The driver of the Freightliner reportedly entered the intersection against a red signal. The front end of the Freightliner impacted the left side of the Toyota. The left side curtain and the seat-mounted side air bags deployed at impact. The driver of the Toyota sustained a possible injury and was transported a local hospital. The Toyota's front right passenger was not injured. The Toyota was towed from the scene due to damage and was later declared a total loss by the insurance company. The Freightliner was driven from the scene.

Figure 1. Subject vehicle, 2006 Toyota Highlander

This investigation was initiated by the National Highway Traffic Safety Administration (NHTSA) during a review of vehicles at an insurance salvage facility. On August 21, 2008, DSI was forwarded the notification with instructions to obtain cooperation. DSI obtained permission to inspect the subject vehicle and the vehicle was placed on hold until a police report could be obtained. DSI obtained the police report on September 22, 2008, and the case was assigned on September 23, 2008. The inspection was completed on September 26, 2008.

SUMMARY

Crash Site

The two-vehicle crash occurred within a four-leg intersection controlled by traffic signals for each direction of travel. At the time of the crash, there were no adverse weather conditions and the roadway surface was dry. The south leg of the intersection provided access to a parking lot. The roadway was comprised of a northbound combination through lane and right turn lane, a left turn lane, and a southbound through lane (**Figure 2**). The roadway was of asphalt construction and there was a 2% positive grade. The speed limit was 32 km/h (20 mph). The west leg of the intersection was a state highway that was comprised of an eastbound through lane, a left turn lane, and a westbound through lane (**Figure 3**).

Figure 2. Eastbound approach for Freightliner

There were marked bicycle lanes on the north and south road edges. The speed limit for state highways was 105 km/h (65 mph).

Figure 3. Northbound approach for Toyota

Pre Crash

The Toyota Highlander was being driven northbound at an unknown speed by an 80-year-old male. There was one additional adult female passenger seated in the vehicle's front row right position. The Freightliner was being driven eastbound an unknown speed by a 32-year-old male.

The driver of the Toyota reportedly had entered the intersection with a green signal. The driver of the Freightliner reportedly entered the intersection against a red signal.

Crash

As the vehicles entered the intersection, the front end of the Freightliner impacted the left side of the Toyota. The impact severity was moderate and resulted in the deployment of the left side curtain air bag and the left seat mounted side air bag. The Barrier algorithm of the WinSmash program computed a barrier equivalent speed of 31 km/h (19.5 mph)[1]. The lateral and longitudinal components were 31 km/h (19.0 mph) and -5 km/h (-3 mph), respectively. The Toyota was redirected laterally to the right and rotated in a counterclockwise direction before coming to rest in the intersection facing northwest. The Freightliner was redirected slightly to the left and came to rest in the intersection.

Post Crash

The driver of the Toyota sustained a possible injury and was transported a local hospital. The Toyota's front right passenger was not injured. The driver was extricated from the vehicle by emergency personnel. The front right occupant was able to exit the vehicle unassisted. The Toyota was towed from the scene due to damage and was later declared a total loss by the insurance company. The Freightliner was driven from the scene.

VEHICLE DATA - 2006 Toyota Highlander

The 2006 Toyota Highlander was identified by the Vehicle Identification Number (VIN): JTEEP21A460xxxxxx. The vehicle's odometer could not be read due to the absence of power to the instrument panel. The Highlander was a four-door sport utility vehicle that was equipped with 3.3 liter, 6-cylinder engine, 4-wheel drive, an automatic transmission, ABS and stability control, front/rear disc brakes, rack and pinion steering, and a tilt steering wheel. The Highlander was configured with Goodyear Integrity P225/65R17 tires. The tire manufacturer's maximum pressure

[1]Provided for informational purposes only. Impact was beyond the scope of the WinSmash program.

was 303 kPa (44 psi). The vehicle manufacturer's recommended cold pressure was 303 kPa (44 psi).

The specific tire information is as follows:

Position	Measured Pressure	Measured Tread Depth	Restricted	Damage
LF	221 kPa (32 psi)	7 mm (9/32 in)	No	None
LR	207 kPa (30 psi)	8 mm (10/32 in)	No	None
RR	207 kPa (30 psi)	5 mm (6/32 in)	No	None
RF	Tire flat	5 mm (6/32 in)	No	Tire de-beaded

The seating in the Highlander was configured with front buckets seats, second row split bench seats, and a third row bench seat with a folding back. The front seats were set in the mid-track position. The driver's seat cushion was 12 degrees from the horizontal and the seat back was 21 degrees from the vertical. The front right seat cushion was 12 degrees from the horizontal and the seat back was 23 degrees from vertical. The second row seats were set at the rear most track position. The third row seat was located in the stowed position at the time of the vehicle inspection. There were adjustable head restraints for the front row and second row seating positions.

Vehicle Damage

Exterior Damage

The 2006 Toyota Highlander sustained moderate left side damage as a result of the impact with the large truck (**Figure 4**). The direct damage began 19 cm (7.5 in) forward of the left rear axle, extended 325 cm (127.9 in) forward along the left side plane, and terminated at the left front bumper corner. The maximum crush was located between C2 and C3 and measured 30 cm (11.8 in) at the

mid-door level, 70 cm (27.5 in) above the ground. Both left side doors were deformed and jammed shut due to impact damage. The left side view mirror was knocked off. There was direct contact that extended vertically along the left A-pillar; the damage measured 160 cm (63.0 in) from the ground to the top of the damage. The side glass for both left side doors was disintegrated. There was 57 cm (22.4 in) abrasion damage along the edge of the right front rim due to lateral loading across the road surface (**Figure 5**). The right front tire was flat and de-beaded. The windshield sustained fracture damage from the movement of the A-pillar. Six crush measurements were documented at the mid-door level as follows: C1 = 0 cm, C2 = 29 cm (11.4 in), C3 = 29 cm (11.4 in), C4 = 0 cm, C5 = 0 cm, C6 = 4 cm (1.6 in). The Collision Deformation Classification for the impact with the truck was 09LYAW3.

Figure 4. Left side damage

Figure 5. Damage to right front rim

The damage forward of the A-pillar occurred during vehicle rotation while the two vehicles were in contact with one another. In order to document the pocket of damage formed by the initial impact with the truck, a second set of crush measurements were taken. The field L represented by the pocket measured 195 cm (76.8 in). Six crush measurements were documented at the mid-door level as follows: C1 = 0 cm, C2 = 15 cm (5.9 in), C3 = 30 cm (11.8 in), C4 = 29 cm (11.4 in), C5 = 23 cm (9.0 in), C6 = 0 cm.

Interior Damage

The 2006 Toyota Highlander sustained moderate interior damage as a result of passenger compartment intrusion (**Figures 6-7**). The left side doors and B-pillar sustained lateral intrusion. As a result of the lateral intrusion, the left front seat back and seat cushion, the center console, and the second row seat cushions were displaced laterally to the right. There were scuffs along the forward edge of the first row left door that may have been caused by the driver's left leg. The window control panel was dislodged due to the door movement.

Figure 6. Left door intrusion and instrument panel damage

Figure 7. Second row door intrusion

The specific passenger compartment intrusions were documented as follows:

Position	Intruded Components	Magnitude of Intrusion	Direction
Second row left	Seat cushion	15 cm (5.9 in)	Lateral
Front row left	Door panel	12 cm (4.7 in)	Lateral
Second row left	Door panel	12 cm (4.7 in)	Lateral
Front row left	Lower instrument panel	8 cm (3.1 in)	Longitudinal
Front row left	B-pillar	6 cm (2.4 in)	Lateral
Front row left	Seat back	4 cm (1.6 in)	Lateral
Front row left	Seat cushion	2 cm (0.8 in)	Lateral
First row right	Center console	2 cm (0.8 in)	Lateral

Manual Restraints

The 2008 Toyota Highlander was equipped with 3-point manual lap and shoulder belts for each seating position. Both front seat safety belts were equipped with retractor pretensioners. The driver's safety belt was configured with a sliding latch plate, an Emergency Locking Retractor (ELR), and an adjustable D-ring. At the time of the vehicle inspection, the driver's belt was restricted in the used position as a result of the pretensioner actuation. The driver's latch plate exhibited signs of historical usage. The front right safety belt was located in the stowed position and the pretensioner did not actuate. The belt webbing exhibited a 17 cm (6.7 in) long area of possible loading that was located 3 cm (1.2 in) from the stop button and 60 cm (23.6 in) from the anchor (**Figure 8**).

The second row safety belts were configured with sliding latch plates and switchable ELR/Automatic Locking Retractors (ALR). The third row lap and shoulder belts were configured with two part latch plates.

Supplemental Restraint Systems

The 2006 Toyota Highlander was equipped with dual-stage frontal air bags, seat-mounted side air bags, and first and second row side curtain air bags. The left front side air bag and left side curtain air bag both deployed at impact with the truck.

The left side curtain air bag deployed from the roof side rail (**Figure 9**). The air bag was rectangular in shape and extended from the A-pillar to 14 cm (5.5 in) rearward of the center of the C-pillar. The air bag was attached to the A-pillar by a 2 cm (0.8 in) long tether. There was a 30 cm (11.8 in) sail at the forward aspect of the air bag. The air bag measured 200 cm (78.7 in) in length and 40 cm (15.7 in) in height. An irregularly shaped abrasion that measured 5 cm (1.9 in) in width by 14 cm (5.5 in) in height was present on the outboard aspect of the air bag (**Figure 10**). The abrasion was located 9 cm (3.5 in) rearward of the sail and 8 cm (3.1 in) from the bottom of the air bag. There were no indications of damage or occupant loading to the inboard aspect of the air bag.

The left seat-mounted side air bag deployed from the front left seat back (**Figure 11**). The air bag was D-shaped and measured 26 cm (10.2 in) in height and extended 20 cm (7.9 in) forward. There were no indications of contact or damage.

Figure 8. Possible loading to front right safety belt

Figure 9. Side curtain air bag

Figure 10. Scuff located on outboard side of left side curtain air bag

Figure 11. Side curtain air bag and seat-mounted side air bag

VEHICLE DATA - 2000 Freightliner tractor-trailer

The 2000 Freightliner tractor was a standard Cab Behind Engine (CBE) tractor pulling a single trailer. The vehicle was being driven eastbound by a 32-year-old male when it entered the intersection and struck the left side of the Toyota. The vehicle sustained minor front end damage and was driven from the scene. The driver was not injured.

OCCUPANT DEMOGRAPHICS

	Driver	**Front Right Occupant**
Age/Sex:	80/Male	76/Female
Seated Position:	Front left	Front right
Seat Type:	Bucket	Bucket
Height:	Unknown	Unknown
Weight:	Unknown	Unknown
Alcohol/Drug Involvement:	None	None
Body Posture:	Unknown	Unknown
Hand Position:	Unknown	Unknown
Foot Position:	Right foot presumed to be on accelerator, left on floor.	Unknown
Restraint Usage:	Lap and shoulder belt	Lap and shoulder belt

OCCUPANT KINEMATICS

Driver Kinematics

Driver Kinematics

The 80-year-old male driver was seated in the leather-covered bucket seat and was restrained by the 3-point lap and shoulder belt. The seat was adjusted to the middle track position. The driver was beginning to accelerate through the intersection. At impact, the left side curtain and seat-mounted side air bags deployed. The driver initiated a left lateral and slightly forward trajectory. The driver likely contacted the deployed air bags, but there was no evidence of contact or damage. The driver was extricated from the vehicle by emergency personnel. Police reported that the driver sustained a possible injury. He was transported by ground ambulance to a local hospital for treatment. It was not known if he was admitted. Medical reports were requested and not received. Efforts were made by phone and mail to interview the driver, but were unsuccessful.

Front right passenger kinematics

The 76-year-old female front right passenger was seated in the leather-covered bucket seat and was restrained by the 3-point lap and shoulder belt. The seat was adjusted to the middle track position. At impact, the front right passenger initiated a lateral and slightly forward trajectory to the left. She probably flexed over the center console during the impact. There were no indications of occupant contact. She was able to exit the vehicle under her own power. The police did not report any injuries.

Attachment 1. Scene Diagram