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ON-SITE OTHER INFLATABLE OCCUPANT PROTECTION INVESTIGATION

CASE NUMBER - IN10037
LOCATION - KANSAS
VEHICLE - 2009 TOYOTA PRIUS
CRASH DATE - July 2010

Submitted:

May 2, 2011

Contract Number: DTNH22-07-C-00044

Prepared for:

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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.

Technical Report Documentation Page

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15. *Supplementary Notes* On-site other inflatable occupant protection investigation involving a 2009 Toyota Prius and a 2003 Ford Taurus SE.			
16. *Abstract* The focus of this on-site investigation was the side impact air bag system of a 2009 Toyota Prius. Secondary focus was on the crash performance of the Toyota's Nickel-Metal Hydride (NiMH) propulsion battery. The Toyota was occupied by a 82-year-old female driver. The vehicle was traveling south on a non-divided rural roadway in the southbound lane. A 2003 Ford Taurus SE was traveling west in the inside lane of the intersecting trafficway. The driver of the Toyota attempted to cross over the intersecting trafficway and the front plane of the Ford impacted the left side plane of the Toyota. The force direction on the Toyota was within the 9 o'clock sector and the impact force triggered deployment of the left side impact Inflatable Curtain (IC) air bag and the driver's seat-mounted side impact air bag. The driver of the Toyota was pronounced dead at the scene. The driver and front right passenger of the Ford were not injured and were not transported for medical treatment. Both vehicles were towed from the crash scene due to damage.			
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This on-site investigation focused on the side impact air bag system of a 2009 Toyota Prius (**Figure 1**). Secondary focus was on the crash performance of the Toyota's Nickel-Metal Hydride (NiMH) propulsion battery. This investigation was brought to the National Highway Traffic Safety Administration's attention on September 28, 2010 by Special Crash Investigation Team 2. This investigation was assigned on November 3, 2010. The crash involved the Toyota and a 2003 Ford Taurus SE. The crash occurred in July, 2010, at 1625 hours, in Kansas and was investigated by the Kansas Highway Patrol. The Toyota and crash scene were inspected on November 8 and 10, 2010. The Ford could not be located and was not inspected. This report is based on the police crash report, scene and Toyota inspections, exemplar Toyota inspection, occupant kinematic principles, and evaluation of the evidence.

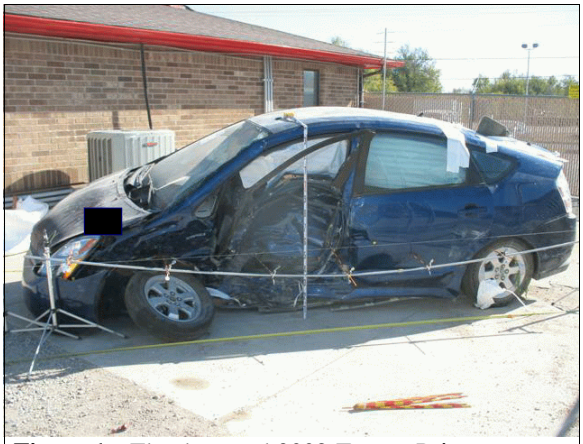


Figure 1: The damaged 2009 Toyota Prius

CRASH CIRCUMSTANCES

Crash Environment: This crash occurred during daylight hours and clear weather conditions at the 4-leg intersection of a 2-lane, undivided rural roadway and a 4-lane, divided, U.S. highway. The U.S. highway traversed in an east-west direction. There were two concrete through lanes in each direction and a left turn lane on the east leg of the intersection. The trafficway was divided by a grass median and bordered by concrete shoulders 1.9 m (6.2 ft) in width. Each lane was approximately 3.6 m (11.8 ft) in width. The roadway was curved slightly and superelevated 3.3% to the north. The rural roadway traversed in a north-south direction and had one bituminous through lane in each direction. Each lane was 4.4 m (14.4 ft) in width and was bordered by grass shoulders 2.2 m (7.2 ft) in width. The roadway was controlled by a stop sign at the intersection. The roadway surfaces were dry and the speed limits were 113 km/h (70 mph) for the U.S. highway and 80 km/h (50 mph) for the rural roadway. The traffic density was moderate and the site of the crash was rural. The Crash Diagram is on page 9 of this report.

Pre-Crash: The Toyota was occupied by a restrained 82-year-old female driver. The Ford was occupied by a restrained 16-year-old male driver and a restrained 14-year-old male front right passenger. The Toyota was traveling south on the rural roadway (**Figure 2**) and was in the process of crossing the U.S. highway. The Ford was traveling west on the U.S. highway in the

Figure 2: Southbound approach of the Toyota to the intersection

second lane from the right (**Figure 3**) and the driver intended to continue westbound. It is not known if the driver of the Toyota attempted any avoidance maneuvers. The driver of the Ford initiated a left steering maneuver in a attempt to avoid the crash.

Figure 3 Westbound approach of the Ford to the intersection

Crash: The left side plane of the Toyota (**Figure 4**) was impacted by the front plane of the Ford (event 1). The force direction on the Toyota was within the 9 o'clock sector and the impact force triggered deployment of the driver's seat-mounted side impact air bag and left Inflatable Curtain (IC) air bag. The impact caused the Toyota to rotate clockwise and the Ford to rotate counterclockwise. The left rear side of the Toyota was impacted by the right side of the Ford (event 2). The Toyota was redirected northwest and rotated clockwise as it separated from the Ford. The Toyota traversed approximately 64 m (210 ft) after impact and came to final rest heading northwest on the north roadside. The Ford departed the south side of the trafficway, into the median. It traversed approximately 19 m (63 ft) after impact and came to final rest heading southwest.

Figure 4: Left side plane damage to the Toyota from the impact with the front of the Ford

Post-Crash: The police, emergency medical personnel, and rescue personnel responded to the crash scene. The driver of the Toyota was pronounced deceased at the crash scene by the coroner. The driver and front right passenger of the Ford refused medical treatment. Both vehicles were towed due to damage.

CASE VEHICLE

The 2009 Toyota Prius was a front wheel drive, 4-door, hatchback (VIN: JTDKB20U297-------) equipped with an 1.5-liter, 4-cylinder gasoline engine with a permanent-magnet AC-synchronous electric motor, a 201 volt sealed NiMH propulsion battery, a continuously variable automatic transmission, and 4-wheel anti-lock disc brakes with electronic brake force distribution, and traction control. The Toyota was also equipped with, multi-stage driver and front right passenger frontal air bags, front seat-mounted side impact air bags, and side impact IC air bags protecting the first and second row outboard passengers. The front row was equipped with bucket seats, adjustable head restraints, lap-and-shoulder safety belts with pretensioners and force limiters. The second row was equipped with a bench seat with folding backs, lap-and-shoulder safety belts, adjustable head restraints, and Lower Anchors and Tethers for Children (LATCH) at the outboard seating positions. The vehicle's specified wheelbase was 281 cm (110.6 in).

Exterior Damage Event 1: The Toyota sustained left side plane damage from the initial impact (event 1) with the Ford. The left fender, left side of the front bumper fascia, left front wheel, and left doors were directly damaged. The direct damage began at the front left bumper corner, 311 cm (122.4 in) forward of the left rear axle, and extended 203 cm (79.9 in) rearward along the left side plane. Since there was front door latch/striker separation, crush measurements were taken at the mid-door and sill levels and averaged based on the crush measurement protocol. The maximum residual crush was 67 cm (26.4 in) and occurred on the door at C_4 (**Figure 5**). The height of the sill and the maximum door crush was 24 cm (9.4 in) and 46 cm (18.1 in), respectively. The door sill differential was 16 cm (6.3 in). The Toyota's left side wheelbase was reduced 23 cm (9.1 in) and the right side wheelbase was reduced 1 cm (0.4 in). There was induced damage to the hood, windshield, and roof. The table below presents the left side crush profile.

Figure 5: Top view of the crush on the left side plane of the Toyota

Units	Event	Direct Damage		Field L	C_1	C_2	C_3	C_4	C_5	C_6	Direct	Field L
		Width CDC	Max Crush								±D	±D
cm	1	203	67	291	0	9	39	58	27	0	86	17
in		79.9	26.4	114.6	0.0	3.5	15.4	22.8	10.6	0.0	33.9	6.7

Damage Classification Event 1: The Collision Deformation Classification (CDC) for the Toyota's left side impact with the Ford was 09LYEW4 (280 degrees). The WinSMASH missing vehicle algorithm calculated the total Delta V for this impact as 46 km/h (28.5 mph). The longitudinal and lateral velocity changes were -8 km/h (-5 mph) and 45 km/h (28 mph), respectively. Based on the damage to the Toyota, the results appeared reasonable.

Exterior Damage Event 2: The Toyota sustained direct damage to the left rear door and left quarter panel during its secondary impact with the Ford. The direct damage began 60 cm (23.6 in) forward of the left rear axle and extended 130 cm (51.2 in) rearward along the left side plane. Crush measurements were taken at the mid door level and maximum crush was 1 cm (0.4 in) at C_5 (**Figure 6**). The table below presents the crush profile.

Figure 6 Secondary impact to left rear of Toyota

Units	Event	Direct Damage		Field L	C_1	C_2	C_3	C_4	C_5	C_6	Direct	Field L
		Width CDC	Max Crush								±D	±D
cm	2	130	1	130	0	0	0	0	1	0	-129	-129
in		51.2	0.4	51.2	0.0	0.0	0.0	0.0	0.4	0.0	-50.8	-50.8

Damage Classification Event 2: The CDC for the Toyota's secondary impact was 09LZEW1 (270 degrees). The WinSMASH missing vehicle algorithm calculated the total Delta V for this impact as 5 km/h (3.1 mph). The longitudinal and lateral velocity changes were 0 km/h and 5 km/h (3.1 mph), respectively. The results appeared reasonable.

The vehicle manufacturer's recommended tire size was P185/65R15. The vehicle was equipped with tires of the recommended size. The Toyota's tire data are shown in the table below.

Tire	*Measured Pressure*		*Vehicle Manufacturer's Recommended Cold Tire Pressure*		*Tread Depth*		*Damage*	*Restricted*	*Deflated*
	kPa	psi	kPa	psi	milli-meters	32nd of an inch			
LF	Flat	Flat	241	35	5	6	None	Yes	Yes
LR	207	30	241	35	5	6	None	No	No
RR	207	30	241	35	4	5	None	No	No
RF	228	33	241	35	4	5	None	No	No

Vehicle Interior: The inspection of the Toyota's revealed no discernable evidence of occupant contact. Based on the intrusion of the left front door, it is certain that the door was contacted by the driver's left leg, thorax, and arm. The center console was also contacted by the driver's right hip. There was no deformation of the steering wheel.

The left front door was jammed shut even though latch and striker separation occurred. The left rear door appeared to have been opened post crash and would not close properly. Both right side doors remained closed and operational. All the window glazing was either closed or fixed. As a result of the crash, the left front window and backlight were disintegrated. The windshield was cracked but in place. The remainder of the vehicle's glazing was not damaged.

Figure 7 Intrusion of the Toyota's left front door

There were numerous intrusions to the passenger compartment. The most significant intrusion occurred at the left front door (**Figure 7**), which intruded laterally through the entirety of the left zone 52 cm (20.5 in), and 22 cm (8.7 in) into the middle zone. The lower A-pillar and side panel forward of the A-pillar intruded laterally 36 cm (14.2 in) and 40 cm (15.7 in), respectively.

CONFORMANCE WITH FMVSS 305, SECTION 571, ELECTRIC POWERED VEHICLES

The Toyota's propulsion battery pack (**Figure 8**) was enclosed in a metal case and rigidly mounted to the cargo area floor pan cross member, immediately behind the second row seat. The battery pack consisted of 28, 7.2 volt NiMH modules connected in series in a water resistant stainless steel case. The battery cells contain an alkaline of potassium and sodium hydroxide, which is absorbed into the battery cell plates and will form a gel. The gel will not normally leak in the event of a crash[1]. Inspection of the propulsion battery revealed no evidence of movement or leakage, nor any disturbance of any surrounding structures. The battery was equipped with a high voltage service disconnect switch, which was located on the back left corner the battery, but not accessible. An electrical isolation test was not conducted. There was no evidence of electrical arching at the visible electrical connections near the battery (**Figure 9**).

Figure 8 The Toyota's propulsion battery pack

Figure 9 Left side of battery and electrical cables

EVENT DATA RECORDER

The Air Bag Control Module (ACM) was accessed in an attempt to image any crash related data that may have been recorded. A direct connection to the ACM was made using the manufacturer's Event Data Recorder (EDR) readout tool with software version 1.4.1.0. Even though the vehicle was indicated as supported in the manufacturer's readout tool documentation, no data was recorded for this crash.

[1] Source: Toyota Prius Emergency Response Guide

The Toyota was equipped with a Certified Advanced 208-Compliant (CAC) frontal air bag system that consisted of multi stage driver and front right passenger frontal air bags, a front passenger weight sensor, and retractor-mounted seat belt pretensioners. The driver's air bag was located within the steering wheel hub. The front right passenger's air bag was located within the top of the instrument panel. Frontal air bag satellite sensors were located in the driver and passenger side inner fenders. Neither of the frontal air bags deployed during the crash.

The Toyota was also equipped with side impact IC air bags and front seat-mounted side impact air bags. The side impact air bag sensors were located in the driver and passenger side lower B- and C-pillars. Both the driver's side impact air bag and IC deployed during the crash. The passenger's side impact air bag and IC did not deploy.

Figure 10 The Toyota's driver's seat-mounted side impact air bag

The Toyota's front seat-mounted side impact air bags were located within the outboard side of the seat back (**Figure 10**) and the driver's air bag deployed through a tear seam. The deployed air bag was oval and measured 22 cm (8.7 in) in width and 40 cm (15.7 in) in height. There were no vent ports and the air bag was sewn together at the lower forward portion. Inspection of the air bag revealed no discernable evidence of occupant contact and the air bag was not damaged.

Figure 11 Driver's IC air bag

The Toyota's side impact IC air bags were located along the roof side rails inside the headliner, and extended from the top of the A-pillar to the C-pillar. The deployed left IC air bag (**Figures 11**) was 156 cm (61.4 in) in width and 39 cm (15.3 in) in height. The bottom edge of the IC extended 8 cm (3.1 in) below the belt line. The air bag was tethered to the A-pillar by a nylon sail panel 17 cm (6.7 in) in width. The air bag was designed with inflation chambers adjacent to the front and second row outboard seat positions. There was a possible blood stain on the lower front portion of the IC air bag. The IC air bag was not damaged.

The Toyota was equipped with lap-and-shoulder safety belts for the front and second row seating positions. The driver's safety belt consisted of continuous loop belt webbing, an Emergency Locking Retractor (ELR), and an adjustable upper anchor that was in the full up position. The front right passenger's safety belt was equipped with a switchable ELR/Automatic Locking Retractor (ALR), a sliding latch plate, and an adjustable upper anchor that was located in the full down position. Actuation of the driver's retractor-mounted pretensioner could not be determined since the safety belt webbing was cut out by rescue personnel. The second row safety belts consisted of continuous loop belt webbing, switchable ELR/ALRs, sliding latch plates and fixed upper anchors.

Inspection of the driver's safety belt assembly revealed evidence that the driver was restrained at the time of the crash. The safety belt webbing had been cut and appeared to be stretched.

CASE VEHICLE DRIVER KINEMATICS

The restrained driver (82-year-old female, unknown height and weight) of the Toyota was seated in an unknown posture. The driver's seat back slightly reclined. The positions of the seat track and steering column adjustment are unknown.

The impact to the left side plane of Toyota displaced the driver leftward opposite the 9 o'clock direction of force. The driver loaded the deployed seat-mounted side impact air bag and IC air bag. The driver probably loaded through the seat-mounted side impact air bag and her thorax contacted the intruding left front door, which caused multiple blunt force trauma to her thorax. Her left leg and left arm also contacted the left front door. She remained restrained in the seat position throughout the crash. Rescue personnel cut the driver's safety belt and extricated her through the right front door.

CASE VEHICLE DRIVER INJURIES

The driver was pronounced deceased at the crash scene. No autopsy or post-mortem examination was conducted. The table below presents the driver's injuries and injury sources.

Injury Number	Injury Description (including Aspect)	NASS Injury Code & AIS 2005	Injury Source	Source Confidence	Source of Injury Data
1	Trauma, multiple blunt force–head	unknown 100999.9,0	unknown injury source	Unknown	Other: interview with doctor who pronounced dead at scene[2]

[2] Only a Death Certificate was created; the doctor made no written record of his examination.

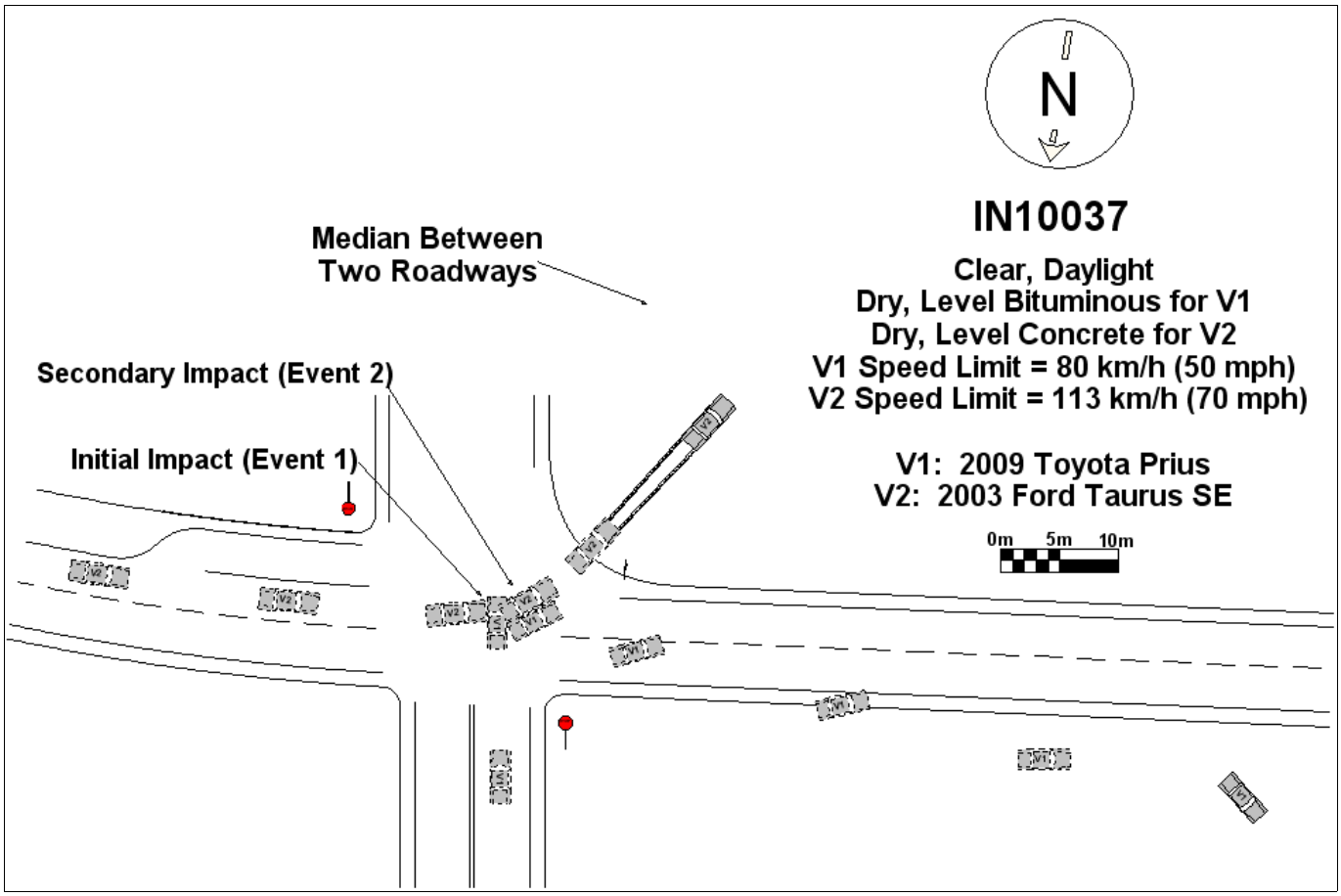
Injury Number	Injury Description (including Aspect)	NASS Injury Code & AIS 2005	Injury Source	Source Confidence	Source of Injury Data
2	Trauma, multiple blunt force– thorax	unknown 400999.9,0	Left front door panel, rear upper quadrant	Certain	Other: interview with doctor who pronounced dead at scene[1]

OTHER VEHICLE

The 2003 Ford Taurus SE was a front wheel drive, 4-door, sedan (VIN: 1FAFP53U03G------) equipped with a 3.0-liter, V6 engine, a 4-speed automatic transmission, dual stage driver and front right passenger frontal air bags, and safety belt pretensioners. The Ford was towed due to damage. The Ford was not inspected since it had been sold at auction.

Damage Classification: The missing vehicle algorithm of the WinSMASH program calculated the Ford's total Delta-V for the initial impact as 37 km/h (23 mph). The longitudinal and lateral velocity changes were -35 km/h (21.7 mph) and -13 km/h (-8.1 mph), respectively. The missing vehicle algorithm calculated the Ford's total Delta-V for the secondary impact as 4 km/h (2.5 mph). The longitudinal and lateral velocity changes were 0 km/h and –4 km/h (-2.5 mph), respectively. The results for both runs should be considered borderline since they are based only on the damage to the Toyota.

Driver and Front Right Passenger: Based on the police crash report, the driver (16-year-old male) and front right passenger (14-year-old, male) of the Ford were both restrained by the lap-and-shoulder safety belt during the crash. Both refused medical treatment and were not transported.


N
IN10037
Median Between
Two Roadways
Clear, Daylight
Dry, Level Bituminous for V1
Dry, Level Concrete for V2
V1 Speed Limit = 80 km/h (50 mph)
V2 Speed Limit = 113 km/h (70 mph)
Secondary Impact (Event 2)
Initial Impact (Event 1)
V1: 2009 Toyota Prius
V2: 2003 Ford Taurus SE
0m 5m 10m