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ON-SITE HYBRID VEHICLE INVESTIGATION

CASE NUMBER - IN09009

LOCATION - LOUISIANA

VEHICLE - 2006 TOYOTA PRIUS

CRASH DATE - October 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.

Technical Report Documentation Page

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16. <i>Abstract</i> This report covers an on-site investigation of a crash that involved a 2006 Toyota Prius, a 2008 Dodge Charger, and a 2000 Toyota Sienna. This investigation focused on the crash performance of the Prius' Nickel-Metal Hydride (NiMH) propulsion battery. The restrained 62-year-old male driver of the Prius was traveling west on a city street. The Sienna was traveling directly behind the Prius. The Dodge was traveling east and the 18-year-old male driver lost control of the vehicle. The Dodge entered the Prius' travel lane and its front plane impacted the Prius' left side plane (event 1) in a sideswiping configuration. The impact triggered the deployment of the Prius' left side impact inflatable curtain air bag and the front left seat-mounted side impact air bag. The Dodge continued and its front plane impacted the Sienna's front plane. The driver of the Prius sustained no police-reported injuries and was not transported for medical treatment. During the SCI interview, he complained of ringing in his left ear, which he believed was possibly due to the deployment sound of the seat-mounted side impact air bag. The inspection of the Prius' NiMH propulsion battery revealed no damage or displacement of the battery pack.					
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This on-site investigation focused on the crash performance of a 2006 Toyota Prius' Nickel-Metal Hydride (NiMH) propulsion battery. This crash was brought to the National Highway Traffic Safety Administration's attention on March 6, 2009 during an on-line review of salvage yard inventories. The investigation was assigned on March 26, 2009. The crash involved the Prius (**Figure 1**), a 2008 Dodge Charger, and a 2000 Toyota Sienna. The crash occurred in October, 2008, at 1750 hours, in Louisiana and was investigated by the city police department. This contractor inspected the Prius and crash scene on March 30-31, 2009. The Dodge could not be located. The Sienna did not contact the Prius and was not inspected. The driver of the Prius was interviewed on March 31, 2009. This report is based on the police crash report, scene and Prius inspections, driver interview, occupant kinematic principles, and this contractor's evaluation of the evidence.



Figure 1: The damaged 2006 Toyota Prius

CRASH CIRCUMSTANCES

Crash Environment: The crash occurred within a transition from a 2-lane, undivided trafficway to a 3-lane divided trafficway. The Prius and the Sienna were traveling west on the 2-lane undivided segment of the trafficway, which had one travel lane in each direction. The west and east travel lanes were 3.4 m (11.2 ft), and 2.9 m (9.5 ft) in width, respectively. The Dodge was traveling east on the 3-lane, divided segment of the trafficway. The division consisted of a painted median. The westbound portion of the roadway had one through lane, which widened to include a right turn lane. Each lane was approximately 4.4 m (14.4 ft) in width. The east lane was 2.9 m (9.5 ft) in width. Roadway pavement markings consisted of solid white edge lines, double yellow center lines for the undivided section, and yellow median lines for the divided section. The turn lane was designated by broken white lines. The speed limit was 64 km/h (40 mph). At the time of the crash the light condition was daylight, the atmospheric condition was clear, and the roadway pavement was dry, level, bituminous. Traffic density was moderate and the site of the crash was suburban commercial. See the Crash Diagram on page 8 of this report.

Pre-Crash: The Prius was occupied by a restrained 62-year-old male driver. The driver stated during the SCI interview that he was traveling west at approximately 40 km/h (25 mph) and was changing lanes to the right turn lane (**Figure 2**) and intended to continue west to the intersection. The Dodge was occupied by a restrained 18-year-old male driver who intended to continue eastbound (**Figure 3**). The Sienna was occupied by a restrained 62-year-old female driver who intended to continue westbound, directly behind the Prius. The Dodge's driver told police that he lost control of his vehicle and entered the west travel lane where the crash occurred. The driver of the Prius driver took no actions to avoid the crash.

Crash: The Dodge's front plane impacted the Prius' left side plane (**Figure 1**, event 1) in a sideswipe configuration. The Prius' direction of force was within the 11 o'clock sector and the impact force was sufficient to trigger deployment of the vehicle's left side impact inflatable curtain (IC) air bag and the front left seat-mounted side impact air bag. The Dodge separated from the Prius and continued east and its front plane impacted the Sienna's front plane (event 2). The Prius came to final rest in the west turn lane heading west. The Dodge and Sienna's front planes remained engaged and they came to final rest in the west lane heading in their respective travel directions.

Post-Crash: The police were notified of the crash at 1750 hours. The police crash report indicated that the investigating officer arrived at the crash scene at 1751 hours. None of the drivers sustained a police reported injury and an ambulance was not called to the scene. The Prius was towed from the crash scene due to damage. The Dodge was left at the scene and the Sienna was driven away.



Figure 2: Prius' approach to the impact area



Figure 3: Dodge's approach to impact area

CASE VEHICLE

Case Vehicle: The 2006 Toyota Prius was a front wheel drive, 4-door hatchback (VIN: JTDKB20U867-----) equipped with a 1.5-liter, 4-cylinder gasoline engine with a permanent-magnet AC-synchronous electric motor, a 201 volt sealed NiMH propulsion battery, and an automatic transmission. The vehicle was also equipped with 4-wheel anti-lock brakes with emergency braking assist and electronic brake force distribution, and traction control. The front row was equipped with bucket seats, adjustable head restraints, lap-and-shoulder safety belts with adjustable upper anchors, dual stage driver and front passenger frontal air bags, seat-mounted side impact air bags, and IC air bags that provided protection for the front and second row outboard seating positions. The second row was equipped with a bench seat with folding backs, adjustable head restraints, lap-and-shoulder belts, and Lower Anchors and Tethers for Children (LATCH) in the outboard seating positions. The vehicle's mileage at the time of the inspection could not be determined since the vehicle had an electronic odometer and was without power. The driver estimated the vehicle's mileage was approximately 28,967 kilometers (18,000 miles). The vehicle's specified wheelbase was 270 cm (106.3 in).

Exterior Damage: The Prius’ impact with the Dodge involved the Prius’ left side plane. The left fender, left front wheel, left side doors, and side view mirror were all directly damaged. The direct damage began 25 cm (9.8 in) forward of the left rear axle and extended 285 cm (112.2 in) along the left side. The crush measurements were taken at the lower door level. The maximum residual crush was 11 cm (4.3 in) occurring at C₄ (**Figure 4**). The height of the vehicle’s sill was 21 cm (8.3 in) and the height of the maximum door crush was 66 cm (26 in). The Door Sill Differential was 4 cm (1.6 in). The left side wheelbase was shortened 10 cm (3.9 in) and the right side wheelbase was extended 1 cm (0.4 in). The induced damage involved the left fender and left rear door. The table below shows the vehicle’s left side plane crush profile.



Figure 4: Top view of the Prius’ left side crush

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	285	11	307	0	4	2	11	6	0	38	39
in		112.2	4.3	120.9	0.0	1.6	0.8	4.3	2.4	0.0	15.0	15.4

Damage Classification: The Prius’ Collision Deformation Classification was **11-LYES-2 (340 degrees)** for the impact with the Dodge. The WinSMASH program could not be used to calculate a Delta-V for the Prius since sideswipe impacts are out of scope for the program. The WinSMASH program was used to calculate a Barrier Equivalent Speed (BES) based on the vehicle’s crush, and the BES was 16.3 km/h (10.2 mph).

The 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	32 nd of an inch			
LF	flat	flat	241	35	6	8	Sidewall Puncture	Yes	Yes
LR	214	31	228	33	6	8	None	No	No
RR	207	30	228	33	5	6	None	No	No
RF	207	30	241	35	5	6	None	No	No

Vehicle Interior: Inspection of the Prius' interior revealed a scuff mark on the inboard side of the left front seat-mounted side impact air bag (**Figure 5**), possibly from contact by the driver's left arm. No other occupant contacts were observed.

The vehicle's left front door was jammed shut, while the other doors and the hatchback remained closed and operational. The pre-crash status of all the window glazings was either closed or fixed. The left front window glazing was disintegrated due to impact forces, while the remaining glazings were undamaged. The vehicle sustained no passenger compartment intrusions.

CONFORMANCE WITH FMVSS 305, SECTION 571, ELECTRIC POWERED VEHICLES

The Prius' NiMH propulsion battery pack was located behind the second row seat (**Figure 6**). It was enclosed in a metal case, which was rigidly mounted to the cargo area floor pan cross member and electrically isolated from high voltage. The 201-volt NiMH battery pack consisted of 28 low voltage modules, each 7.2 volts, connected in series. Each battery module is non-spillable and sealed in a plastic case. The electrolyte used in the battery modules is an alkaline of potassium and sodium hydroxide. The electrolyte is absorbed into the battery cell plates and will form a gel that will not normally leak, even in a collision¹. Inspection of the propulsion battery revealed no evidence of movement and no evidence of arcing or melting of any of the components of the battery pack. The battery was equipped with a high voltage service disconnect plug, which was located on the left side of the battery pack (**Figures 7 and 8**). At the time of the inspection, the plug was in the locked position. The plug was removed and both leads on the battery pack were tested for voltage with a multimeter. The voltage reading was zero volts.

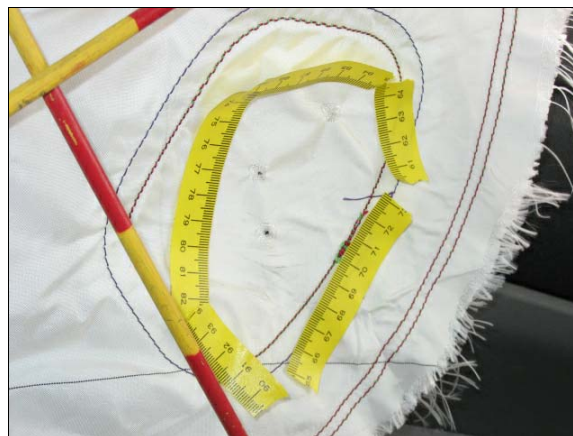


Figure 5: Scuffs on driver's seat-mounted side impact air bag



Figure 6: Prius' NiMH propulsion battery case located immediately behind second row seat

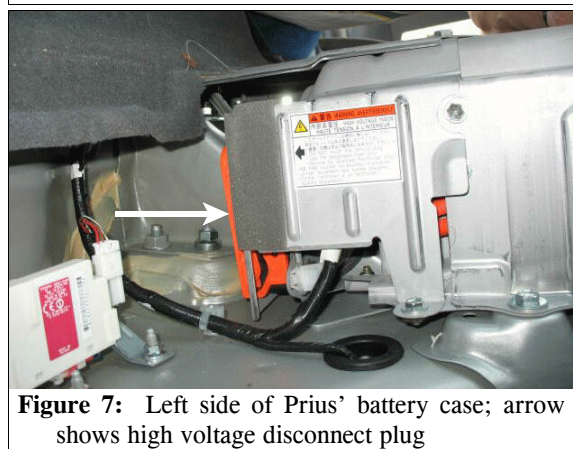


Figure 7: Left side of Prius' battery case; arrow shows high voltage disconnect plug

¹ Toyota Prius Hybrid Emergency Response Guide

The Prius was equipped with a frontal air bag system that was certified by the manufacturer to be compliant to the Advanced Air Bag portion of Federal Motor Vehicle Safety Standard (FMVSS) No. 208. The frontal air bags did not deploy in this crash.

The Prius' side impact air bag system consisted of front seat-mounted side impact air bags and roof side rail-mounted side impact IC air bags. Based on the Holmatro Rescuer's Guide to Vehicle Safety Systems, the vehicle's side impact sensors were located within the lower B- and C-pillars.

The left IC (**Figures 9 and 10**) was 183 cm (72 in) in length and 35 cm (13.8 in) in height. It was not equipped with any visible vent ports. A non-inflatable fabric panel, 22 cm (8.7 inches) in width, connected the IC to the A-pillar. The back of the IC was not attached to the C-pillar by neither fabric nor a tether. Inspection of the IC revealed no damage and no discernable evidence of occupant contact.

The front left seat-mounted side impact air bag (**Figure 11**) was oval-shaped and was 32 cm (12.6 in) in width and 40 cm (15.7 in) in height. Scuffs, possibly due to contact by the driver's left arm, were found on the inboard side of the air bag (**Figure 5**). There was no damage to the air bag.

MANUAL RESTRAINT SYSTEM

The Prius 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), sliding latch plate, and an adjustable upper anchor that was in the middle position. The front right passenger's safety belt was equipped with a switchable ELR/Automatic Locking Retractor (ALR), sliding latch plate, and adjustable upper anchor that was located in the full-up position. The front row retractor-mounted pretensioners did not actuate in this crash. The second row safety belts



Figure 8: High voltage disconnect plug



Figure 9: Front portion of the left IC air bag



Figure 10: Rear portion of the left IC air bag

consisted of continuous loop belt webbing, switchable ELR/ALRs, sliding latch plates and fixed upper anchors.

The inspection of the driver's safety belt system revealed historical usage scratches on the latch plate. The belt webbing also had a slight stretched appearance, but no evidence of significant loading. The evidence was consistent with the driver's interview statement that he was using his safety belt at the time of the crash. The remaining seat positions were unoccupied.



Figure 11: Driver's seat-mounted side impact air bag

CASE VEHICLE DRIVER KINEMATICS

Based on the SCI interview, the driver [62-year-old, male, 175 cm and 84 kg (69 in and 185 lb)] was seated in an upright posture with his back against the seat back and both hands on the steering wheel at the 9 and 3 o'clock positions. The driver's seat track was located between the middle and rear-most positions and the seat back was slightly reclined. The tilt steering column was located in the center position. The driver was wearing glasses at the time of the crash.

The Prius' left side plane impact with the front of the Dodge displaced the driver forward and left, opposite the Prius' 11 o'clock direction force. His left upper arm possibly loaded the seat-mounted side impact air bag. While his head also probably loaded the IC air bag, no discernable evidence of occupant contact was observed. The driver sustained a few small lacerations on the left forearm due to flying glass fragments from the disintegrated left front window glazing. The driver sustained a neck strain, which was probably due to impact force. He also reported ringing in his left ear, which was possibly due to the deployment of the seat-mounted side impact air bag.

CASE VEHICLE DRIVER INJURIES

The driver sustained no police reported injuries and was not transported from the crash scene to a hospital. He visited a private physician 3 days following the crash. The driver lost 2 work days as a result of the crash. The table below shows the driver's reported injuries and the contact sources.

Injury Number	Injury Description (including Aspect)	NASS Injury Code & AIS 90	Injury Source	Source Confidence	Source of Injury Data
1	Tinnitus ² {ringing in} left ear, not further specified	minor 240299.1,2	Seat-mounted air bag	Possible	Interviewee (same person)
	Stiffness in neck, not further specified	not coded	Noncontact injury: impact forces	Probable	Interviewee (same person)
2	Lacerations {cuts}, small, outside left forearm	minor 790602.1,2	Left front window's glazing	Certain	Interviewee (same person)

1ST OTHER VEHICLE

The 2008 Dodge Charger a rear-wheel drive, 4-door sedan (VIN: 2B3KA43R88H-----) equipped with a 2.7-liter, V6 engine. The Dodge was also equipped with dual stage driver and front right passenger frontal air bags and was certified by the manufacturer to be compliant to the advanced air bag portion of the Federal Motor Vehicle Safety Standard (FMVSS) No 208. According to the police crash report, the driver's frontal air bag deployed as a result of the impact with the Prius.

1st Other Vehicle's Driver: The Dodge's driver (18-year-old, male) was restrained by the lap-and-shoulder belt. He was not injured and was not transported for medical treatment.

2ND OTHER VEHICLE

The 2000 Toyota Sienna was a front-wheel, 5-door minivan (VIN: 4T3ZF13C5YU-----), equipped with a 3.0-liter, 4-cylinder engine. The Sienna was also equipped with 4-wheel anti-lock brakes and dual frontal air bags.

2nd Other Vehicle's Driver: The Sienna's driver (43-year, female) was restrained by the lap-and-shoulder belt. She was not injured and was not transported for medical treatment.

² The following term is defined in DORLAND'S ILLUSTRATED MEDICAL DICTIONARY as follows:
tinnitus (*tin'i-tas*) [L. "a ringing"]: a noise in the ears, such as ringing, buzzing, roaring, or clicking. It is usually subjective in type.

