

CRASH DATA RESEARCH CENTER

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CALSPAN ON-SITE ALTERNATIVE FUEL VEHICLE CRASH INVESTIGATION

SCI CASE NUMBER: CA08038

VEHICLE: 2007 TOYOTA PRIUS

LOCATION: PENNSYLVANIA

CRASH DATE: JULY 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 are 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 system.

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16. Abstract This on-site investigation focused on the hybrid power system of a 2007 Toyota Prius. The hybrid system in the Toyota consisted of a 1.5-liter, 4-cylinder gasoline engine linked to a permanent magnetic AC synchronous electric motor. The electric motor was powered by Nickel Metal-Hydride batteries. Additionally, the Toyota was equipped with a Certified Advanced 208-Compliant (CAC) frontal air bag system, front seatback-mounted side impact air bag system, and outboard seating position Inflatable Curtain (IC) air bag system. The Toyota was struck on the left side by a 2007 Mercury Montego at a controlled intersection. As a result of the crash, the left side IC air bag and the left seatback-mounted side impact air bag deployed in the Toyota. None of the four occupants were injured as a result of the crash. Both vehicles were towed from the scene.					
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CALSPAN ON-SITE ALTERNATIVE FUEL VEHICLE CRASH INVESTIGATION
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BACKGROUND

This on-site investigation focused on the hybrid power system of a 2007 Toyota Prius (**Figure 1**). The hybrid system in the Toyota consisted of a 1.5-liter, 4-cylinder gasoline engine linked to a permanent magnetic AC synchronous electric motor. The electric motor was powered by Nickel Metal-Hydrate batteries. Additionally, the Toyota was equipped with a Certified Advanced 208-Compliant (CAC) frontal air bag system, front seatback-mounted side impact air bag system, and outboard seating



Figure 1: Right front oblique view of the Toyota.

position Inflatable Curtain (IC) air bag system. The Toyota was struck on the left side by a 2007 Mercury Montego at a controlled intersection. As a result of the crash, the left side IC air bag and the left seatback-mounted side impact air bag in the Toyota deployed. None of the four occupants were injured as a result of the crash. Both vehicles were towed from the scene.

This crash was identified by the National Highway Traffic Safety Administration (NHTSA), which forwarded the notification to the Calspan Special Crash Investigations (SCI) team for follow-up investigation. Cooperation to inspect the vehicles was received from the vehicles' respective insurance companies. The on-site portion of this investigation took place on Wednesday, August 27, 2008. This SCI investigation involved the inspection and documentation of both vehicles and the crash site. The insurance company of the Toyota would not authorize removal of the Toyota's Event Data Recorder (EDR), thus preventing the imaging of the data by Toyota for analysis.

SUMMARY

Crash Site

The collision occurred at a controlled intersection. The Toyota was traveling southbound in a 2.6 m (7 ft) wide travel lane of the north/south two-lane roadway. The northbound lane was 3.2 m (10 ft) wide and supported by a 1.4 m (5 ft) wide gravel shoulder. The two travel lanes were divided by a single solid yellow center line, which ended 4.4 m (14 ft) longitudinally from the edge of the intersecting roadway. A stop sign for the Toyota's travel lane was located 1 m (3 ft) laterally from the right edge of the roadway and 4.4 m (14 ft) longitudinally from the edge of the intersecting roadway. The posted speed limit was 40 km/h (25 mph).

The Mercury was traveling westbound in the 3 m (10 ft) wide travel lane of the east/west two-lane roadway. The equal width travel lanes were divided by a double solid yellow center line. The posted speed limit was 56 km/h (35 mph).

At the time of the crash, the temperature was 27 degrees Celsius (80 Fahrenheit) and the weather was sunny with scattered clouds. The dry bituminous surface was straight and level in all four directions. A scene diagram is attached at the end of this technical report.



Figure 2: Southbound trajectory view of the travel path of the Toyota.

Vehicle Data

2007 Toyota Prius

The 2007 Toyota Prius was manufactured in Japan and was identified by the Vehicle Identification Number (VIN): JTDKB20U47 (production sequence deleted). The exact odometer reading at the time of the SCI inspection could not be obtained due to vehicle damage and electrical system inoperability. This four-door sedan had a 270 cm (106 in) wheelbase with front-wheel drive (**Figure 3**). The hybrid vehicle was equipped with a 1.5-liter, 4-cylinder gasoline engine linked to a



Figure 3: Left front oblique view of the Toyota.

permanent magnetic AC synchronous electric motor that was powered by Nickel Metal-Hydride batteries. The service brakes included front discs and rear drums with anti-lock and Electric Brake Force Distribution brake assist. The vehicle was also equipped with traction control, power steering, power windows, power locks, and a direct Tire Pressure Monitoring System (TPMS).

The manufacturer’s recommended tire size was P185/65R15 front and rear. All tires were Goodyear Integrity of the recommended size, with matching Tire Identification Number (TIN) VWLX 2KAR 0707. These were mounted on OEM six-spoke alloy wheels with plastic trim. Specific tire data at the time of SCI inspection was as follows:

Position	Measured Pressure	Measured Tread Depth	Restriction	Damage
LF	221 kPa (32 PSI)	5 mm (6/32 in)	No	None
LR	228 kPa (33 PSI)	6 mm (7/32 in)	No	None
RR	Flat	6 mm (7/32 in)	No	None
RF	Flat	4 mm (5/32 in)	No	None

The interior of the Toyota was configured for the seating of five occupants. The vehicle was equipped with front bucket seats that had manual track adjustments. The seatbacks had manual angular adjustments, and were equipped with manually adjustable head restraints. At the time of the SCI inspection, the front left seat track was adjusted to the full-rear position and the front right was adjusted 2 cm (1 in) forward of the full-rear track position. Both head restraints were adjusted 5 cm (2 in) above the seatbacks.

The rear three passenger bench seat was split 60/40, right side wide. All three seat positions incorporated manually adjustable head restraints. The two outboard positions were adjusted 4 cm (1.5 in) upward of full-down at the time of SCI inspection, while the center head restraint was adjusted full-down. All five seating positions were equipped with 3-point lap and shoulder safety belts. For the two front seats, the shoulder D-ring was manually adjustable at the B-pillar.

The Toyota was equipped with the CAC frontal air bag system, front seatback-mounted side impact air bags, and IC air bags for the four outboard seating positions.

2007 Mercury Montego

The 2007 Mercury Montego (**Figure 4**) was identified by the VIN: 1MEHM40167 (production sequence deleted). The odometer reading at the time of SCI inspection was unknown. This four-door sedan had a 286 cm (113 in) wheelbase with front wheel drive. Power was provided by a 3.0 liter, 6-cylinder gasoline engine linked to an automatic transmission. The service brakes were four-wheel power-assisted discs with anti-lock. The Mercury was equipped with power steering, power windows, and power locks.



Figure 4: Left front oblique view of the Mercury.

The vehicle manufacturer’s recommended tire size was P215/60R17, front and rear. All tires were Continental Conti Touring Contact of the recommended size, mounted on 7-spoke OEM alloy wheels. All tires had matching TINs: A3KT 3MT 5006. Specific data at the time of the SCI inspection was as follows:

Position	Measured Pressure	Measured Tread Depth	Restriction	Damage
LF	303 kPa (44 PSI)	7 mm (9/32 in)	No	None
LR	296 kPa (43 PSI)	6 mm (7/32 in)	No	None
RR	318 kPa (46 PSI)	6 mm (7/32 in)	No	None
RF	300 kPa (44 PSI)	6 mm (8/32 in)	No	None

The interior of the Mercury was configured for the seating of five occupants. The vehicle was equipped with front bucket seats and rear three passenger bench seat. All five seating positions were equipped with 3-point lap and shoulder safety belts with manual adjustable head restraints.

The Mercury was equipped with a CAC frontal air bag system, front seatback-mounted side impact air bags, and IC air bags for the four outboard seating positions. The manufacturer of the Mercury has certified that the vehicle's frontal air bags were compliant to the advanced air bag portion of Federal Motor Vehicle Safety Standard (FMVSS) No. 208.

Crash Sequence

Pre-Crash

The 54-year-old male was restrained by the 3-point lap and shoulder safety belt in the driver's seat of the Toyota. He was operating the vehicle southbound on the two lane roadway, approaching the intersection. The 61-year-old male operator of the Mercury was restrained by the vehicle's 3-point lap and shoulder safety belt, traveling westbound approaching the same intersection.

The driver of the Toyota brought the vehicle to a controlled stop at the stop sign. He later reported that he had looked both ways and did not see any other vehicles. He also reported that bushes and other foliage had hindered his line of sight. Subsequently, he proceeded from the stop sign and into the intersection. There was no physical evidence at the scene of any avoidance action by either vehicle.

Crash

The front of the Mercury struck the left side of the Toyota. The 9-o'clock direction of force associated with the impact immediately transitioned the Toyota into a right lateral translation. The left side impact air bag system, including the seatback-mounted and IC air bags in the Toyota, were deployed. Both vehicles came to rest within the roadway, in the west portion of the intersection.

The Damage Algorithm of the WinSMASH model was used to calculate the severity (delta-V) of the crash. The total calculated delta-V of the Toyota was 37 km/h (23 mph). The longitudinal component of the Toyota's calculated delta-V was 36 km/h (22.4 mph), and the lateral component was -6 km/h (-3.7 mph). The total calculated delta-V of the Mercury was 30 km/h (18.6 mph). The longitudinal and lateral components of the Mercury's delta-V were -30 km/h (18.6 mph) and 0 km/h (0 mph), respectively.

Post-Crash

Emergency response to the incident scene was limited to the local police department. All occupants were able to exit the vehicles without assistance and were not injured. Both vehicles were towed from scene due to damage.

Vehicle Damage

2007 Toyota Prius Exterior

The Toyota sustained moderate left side damage from the collision. Damage on this plane included all components from the roof to the wheels forward of the aft edge of the rear passenger door.

Both the driver and rear passenger doors had damage to the exterior skins consisting of abrasions and lateral crush. The left front door was jammed closed and was not operational as a result of the crash. The left rear door was also jammed shut, and although the latch remained operational, door sill deformation prevented its opening. The B-pillar was deformed and displaced right laterally. The windshield was cracked on its left aspect, and the left front glazing was disintegrated.



Figure 5: Damage plane of the Toyota.

The direct damage began 62 cm (24.5 in) forward of the left rear axle and extended 175 cm (69 in) forward. The direct and induced damage (Field L) began 15 cm (6 in) forward of the left rear axle and extended 272 cm (107 in) forward. The accompanying crush profile was measured at six equidistant points at the lower door level with the following results: C1 = 0 cm (0 in), C2 = 13 cm (5 in), C3 = 19 cm (7.5 in), C4 = 32 cm (12.5 in), C5 = 10 cm (4 in), C6 = 0 cm (0 in). Maximum crush was 37 cm (14.5 in), located 198 cm (78 in) forward of the left rear axle. The Door/Sill Differential (DSD) measured 23 cm (9 in), located 191 cm (75 in) forward of the left rear axle. The Collision Deformation Classification (CDC) for this damage pattern was 09LPEW3.

2007 Toyota Prius Interior

Interior intrusion associated with the crash was limited to the left side of the passenger compartment. The left front and left rear door panels were intruded laterally and engaged against the outboard sides of the seat cushions of the corresponding seating positions. The left front polymer door panel was also buckled, with isolated stress loading discoloration. This is depicted in **Figure 6** (note the engagement of the door against the seat).



Figure 6: Interior intrusions of the left front door.

The B-pillar was intruded laterally and in contact with the side of the seatback at the front left occupant position. The left rear polymer door panel had buckled in the middle and yielded along the crease surrounding the door-mounted speaker. No direct occupant contact was found. Measurements of interior left side intrusions were as follows:

POSITION	COMPONENT	MAGNITUDE	DIRECTION
Front Left	Door panel, armrest	10 cm (4 in)	Lateral
	Door panel, aft edge, mid-door level	10 cm (4 in)	Lateral
	Door panel, forward lower quadrant	24 cm (9 in)	Lateral
	B-pillar, forward edge	10 cm (4 in)	Lateral
	Sill	14 cm (5.5 in)	Lateral
Rear Left	Door panel, armrest	8 cm (3 in)	Lateral
	Door panel, forward lower quadrant	12 cm (5 in)	Lateral
	B-pillar, rear edge	10 cm (4 in)	Lateral
	Sill	3 cm (1 in)	Lateral

2007 Mercury Montego

The Mercury sustained minor severity frontal damage from the collision. At the time of the SCI inspection, the front bumper fascia, grille, hood, left fender, headlight assemblies, radiator, and other components had been removed as the vehicle was already in the process of repaired. Therefore, exact damage sustained by the Mercury from the frontal was unknown and a direct contact length could not be obtained.

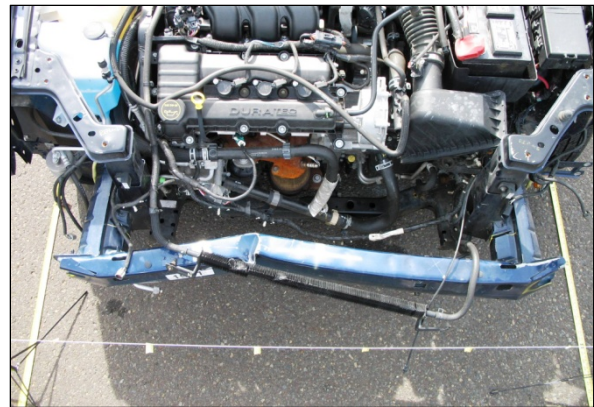


Figure 7: Damage plane of the Mercury.

The induced damage extended the full width of the bumper beam and measured 133 cm (52 in) in width (**Figure 7**). The crush profile was as follows: C1 = 7 cm (3 in), C2 = 9 cm (3.5 in), C3 = 17 cm (7 cm), C4 = 22 cm (9 in), C5 = 12 cm (5 in) and C6 = 7 cm (3 in). Maximum crush was 22 cm (9 in), located at C4. The CDC associated with this damage pattern was 12FDEW1.

Manual Safety Belt Systems - 2007 Toyota Prius

All five seating positions were equipped with 3-point lap and shoulder safety belt systems utilizing continuous loop webbing with sliding latch plates. For the two front seats, the D-ring was manually adjustable at the B-pillar. At the time of SCI inspection, the left D-ring was adjusted to full-down, while the right was full-up. The front left safety belt was equipped with an Emergency Locking Retractor (ELR) with a retractor pretensioner. The right front seating position had an ELR and Automatic Locking Retractor (ALR) with pretensioner. The rear seats were equipped with an ELR/ALR.

The driver and passenger both reported that they were restrained by the 3-point lap and shoulder safety belts at the time of the crash. At the time of SCI inspection there was historical wear on

both of the latch plates, though no loading evidence was present on either webbing. The left pretensioner had actuated as a result of the crash, and the retractor was still locked. The right pretensioner was not actuated.

Frontal Air Bag System – 2007 Toyota Prius

The Toyota was equipped with the CAC frontal air bag system. The manufacturer of the vehicle has certified that the Toyota was compliant to the advanced air bag requirements of FMVSS No. 208.

The Toyota’s frontal air bag system consisted of a steering wheel hub-mounted driver air bag and mid-instrument panel-mounted right front passenger air bag. The system also incorporated dual-stage front seat track position sensors, safety belt buckle switches, and a right front occupant sensor. This frontal air bag system did not deploy.

Side Impact Air Bag System - 2007 Toyota Prius

The Toyota was equipped with a side impact air bag system that consisted of seatback-mounted and IC air bags. The IC air bag was stowed along the length of the roof side rail in an accordion fold, and it had deployed downward through the edge of the headliner. Forces from the collision triggered the deployment of this side air bag system on the left side, as depicted in **Figure 8**.



Figure 8: Side impact air bag system deployed on the left side of the Toyota.

The left IC air bag was rectangular in shape and measured 38 cm (15 in) tall by 155 cm (61 in) long. This bag was available for the front left and rear left seating positions. There was no rear tether. The forward aspect of the air bag was attached to a trapezoidal-shaped sail panel that was 22 cm (8.5 in) tall and 19 cm (7.5 in) wide and covered the forward aspect of the front left seating position at the A-pillar. There was no direct occupant contact evidence found on the IC air bag.

The seatback-mounted side impact air bag was half-oval in shape. It was 29 cm (11.5 in) wide by 38 cm (15 in) tall. It had deployed during the crash sequence through a 27 cm (10.5 in) split in the stitching on the outboard seam edge of the seatback, at thoracic to lumbar level. No direct occupant contact evidence was found on the seatback-mounted air bag.

Alternative Fuel System - 2007 Toyota Prius

The Toyota was equipped with Hybrid Synergy Drive that consisted of an 1.5-liter, 4-cylinder Atkinson-cycle gasoline engine with two electric motors. The gasoline engine was the 1.5-liter, inline 4-cylinder engine. The first of the two electric motors was a permanent magnetic AC synchronous electric motor that provided power to the front wheels. The second electric motor functioned solely as a generator to recharge the Nickel Metal-Hydride battery cell located within the floor of the rear cargo area. A planetary gear-type Continuously Variable Transmission (CVT) seamlessly transferred power between the two engine sources to the front drive wheels.

The standard applied to vehicles that use more than 48 nominal volts of electricity as propulsion and whose speed on a level paved surface is more than 40 km/h (25 mph) is FMVSS No. 305, Electric Powered Vehicles: Electrolyte Spillage and Electrical Shock Protection. This standard specifies performance requirements of electrolyte spillage, retention of propulsion batteries, and electrical isolation of the chassis from the high-voltage system during a crash event. The standard test requirements are summarized as follows:

- Not more than 5.0 liters (1.3 gal) of electrolyte from propulsion batteries shall spill outside the passenger compartment, and none shall spill in the passenger compartment, within 30 minutes after a barrier impact test.
- No propulsion battery system component located inside the passenger compartment shall move from its installed location.
- No propulsion battery system component located outside the passenger compartment shall enter the passenger compartment.
- Electrical isolation shall exist between the propulsion battery system and the vehicle electricity-conducting structure.

The Toyota was visually inspected for compliance with FMVSS No. 305. The left side impact damage did not involve the area of the propulsion battery. There was no intrusion into the battery compartment, nor was there any damage to the battery or battery cover. No leakage was detected during the SCI vehicle inspection. The battery propulsion system components were not displaced or damaged by this impact event.

The insurance salvage facility isolated the Toyota in a protective storage building and instructed the SCI investigator to conduct a non-invasive inspection of the vehicle to retain maximum salvage value. Therefore, 12-volt power could not be applied to the vehicle to check the onboard electrical systems. Additionally, the electrical isolation test was not conducted.

A view of the powertrain in the engine compartment of the Toyota is depicted in **Figure 9**. The battery cell is depicted in **Figure 10**. The integrity of this alternative fuel powertrain was not compromised by the crash.



Figure 9: Alternative fuel powertrain of the Toyota.



Figure 10: Battery cell of the Toyota's hybrid system.

Occupant Data - 2007 Toyota Prius

Driver Demographics

Age / Sex:	54 years / Male
Height:	Unknown
Weight:	Unknown
Seat Type:	Bucket
Seat Track Position:	Full-rear
Manual Restraint Usage:	Restrained by 3-point lap and shoulder safety belt
Usage Source:	SCI vehicle inspection
Air Bags:	Left IC air bag, left front seatback-mounted air bag
Alcohol/Drug Involvement:	None
Egress from Vehicle:	Exited vehicle without assistance
Type of Medical Treatment:	None

Driver Injuries

The driver denied injury and refused treatment at scene and did not seek follow-up medical treatment.

Driver Kinematics

The driver of the Toyota was seated in a full-rear track position with the seat back reclined aft of vertical. The driver was wearing the manual safety belt system. There was no loading evidence on the belt system and the retractor pretensioner did not actuate as a result of the crash.

The driver responded to the side impact by initiating a left lateral trajectory. His left flank and head loaded the deployed seatback-mounted and IC air bags, respectively, as the vehicle was translated laterally by the Mercury. These contacts did not result in injury. He then rebounded right laterally against the safety belt and seat as the vehicle came to rest. Following the crash, the driver exited the vehicle unassisted. He refused medical transport and did not seek medical treatment at a later date.

Front Right Passenger Demographics

Age / Sex:	17-year-old / Female
Height:	Unknown
Weight:	Unknown
Seat Type:	Bucket
Seat Track Position:	Full-rear
Manual Restraint Usage:	Restrained by 3-point lap and shoulder safety belt
Usage Source:	SCI vehicle inspection
Air Bags:	None deployed
Alcohol/Drug Involvement	None
Egress from Vehicle:	Exited unassisted
Type of Medical Treatment:	None

Front Right Passenger Injuries

The front right passenger denied injury and refused medical treatment at scene and did not seek follow-up treatment.

Front Right Passenger Kinematics

The front right passenger of the Toyota was seated in a full-rear track position with the seat back reclined aft of vertical. The front right passenger utilized the manual safety belt system. There was no loading evidence on the belt system, and the retractor pretensioner did not actuate as a result of the crash.

The front right passenger responded to the side impact by initiating a left lateral trajectory. Her torso and left flank loaded the manual 3-point safety belt as the vehicle was translated laterally by the Mercury. This contact did not result in injury. She then rebounded right laterally against the safety belt and seat as the vehicle came to rest. Following the crash, the front right passenger exited the vehicle unassisted. She refused medical transport and did not seek medical treatment at a later date.

SCENE DIAGRAM

