CRASH DATA RESEARCH CENTER

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CALSPAN REMOTE ALTERNATIVE FUEL VEHICLE CRASH INVESTIGATION

CASE NO: 2004-43-141G

VEHICLE: 2002 TOYOTA PRIUS

LOCATION: NORTH CAROLINA

CRASH DATE: MAY 2004

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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 systems.

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16. Abstract This remote investigation focused on the performance of the alternative fuel system that was present in a 2002 Toyota Prius **(Figure 1)**. The Prius was equipped with a hybrid drive train, which consisted of a 1.5-liter gasoline engine coupled with an electric motor. The vehicle was designed to run on battery power, gasoline, or a combination of both dependant on throttle input and desired speed. The 2002 Toyota was involved in a moderate severity intersection crash with a 1992 Nissan SE Club-Cab pickup truck. The Prius was occupied by a 51-year-old male driver, a 15-year-old male seated in the front right position, and a 15-year-old male seated in the rear right position. The three occupants of this vehicle were not restrained. The driver was operating the vehicle in the northbound direction on the inboard lane of a five-lane undivided roadway. A 31-year-old male driver of the 1992 Nissan pickup was exiting a private driveway from the east roadside and was intending to turn left onto the five-lane roadway and enter the southbound lanes. As the Nissan executed the left turn, the front of the Prius contacted the left side of the Nissan. The impact was sufficient to deploy the redesigned frontal air bag system and fire the retractor safety belt pretensioners in the Prius. The occupants of the Prius did not sustain injuries and received no medical treatment. The NASS inspection of the Prius revealed no loose, or severed fuel or electrical lines in the engine compartment or the undercarriage. The fuel gas indicator displayed ½ tank of gasoline. There was a 12-volt battery and a Nickel Metal-Hydride battery located behind the rear seat bight. There were no apparent electrical shorts or leakages in the battery storage area fastened inside the truck. The hybrid power train system is discussed in power train detail later in this report.			
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CALSPAN REMOTE ALTERNATIVE FUEL VEHICLE CRASH INVESTIGATION
NASS/SCI COMBO CASE NO.: 04-43-141G
SUBJECT VEHICLE: 2002 TOYOTA PRIUS
LOCATION: CARY, NC
CRASH DATE: MAY 2004

BACKGROUND

This remote investigation focused on the performance of the alternative fuel system that was present in a 2002 Toyota Prius **(Figure 1)**. The Prius was equipped with a hybrid drive train, which consisted of a 1.5-liter gasoline engine coupled with an electric motor. The vehicle was designed to run on battery power, gasoline, or a combination of both dependant on throttle input and desired speed. The 2002 Toyota was involved in a moderate severity intersection crash with a 1992 Nissan SE Club-Cab pickup truck. The Prius was occupied by a 51-year-old male driver, a 15-year-old male seated in the front right position, and a 15-year-old male seated in the rear right position. The three occupants of this vehicle were not restrained. The driver was operating the vehicle in the northbound direction on the inboard lane of a five-lane undivided roadway. A 31-year-old male driver of the 1992 Nissan pickup was exiting a private driveway from the east roadside and was intending to turn left onto the five-lane roadway and enter the southbound lanes. As the Nissan executed the left turn, the front of the Prius contacted the left side of the Nissan. The impact was sufficient to deploy the redesigned frontal air bag system and fire the retractor safety belt pretensioners in the Prius. The occupants of the Prius did not sustain injuries and received no medical treatment. The NASS inspection of the Prius revealed no loose, or severed fuel or electrical lines in the engine compartment or the undercarriage. The fuel gas indicator displayed ½ tank of gasoline. There was a 12-volt battery and a Nickel Metal-Hydride battery located behind the rear seat bight. There were no apparent electrical shorts or leakages in the battery storage area fastened inside the truck. The hybrid power train system is discussed in power train detail later in this report.

Figure 1 - Subject vehicle 2002 Toyota Prius.

The crash was identified by PSU 43 of the National Automotive Sampling System (NASS) during its weekly sampling of police reported crashes. The case was subsequently selected for inclusion in the NASS CDS data file and assigned case number 2004-43-141G. Due to the alternative fuel system, the Crash Investigations Division of the National Highway Traffic Safety Administration (NHTSA) assigned a remote NASS/SCI Combo investigation to the Calspan SCI team on June 17, 2004.

SUMMARY

Crash Site

Figure 2 - Overall view of north/south roadway.

This crash occurred on a five-lane, north/south roadway in a residential area during daylight hours **(Figure 2)**. The roadway was configured with two northbound and two southbound lanes separated by a center left lane turn bay. The roadway was surfaced with asphalt and was delineated by solid yellow lines contiguous to the turn bay and broken white lines separating the four north/south lanes. The travel lanes were 3.5 m (11.5') in width and the center turn bay was 3.8 m (12.5') wide; paved shoulders that were 0.5 m (1.6') in width bordered the roadway. The driveway that the Nissan was exiting was configured with an entrance to a professional plaza that was 7.6 m (19.3') in width and two exit lanes, each 3.0 m (9.8') wide, and was separated by a raised median containing a landscape design. The environment along the north/south roadway consisted of residential homes and commercial properties. At the time of the crash, the road surface was wet and it was raining. The Prius was traveling in a northerly direction on a straight and level roadway while the Nissan was traveling west and exiting a paved driveway attempting to turn left and travel south. The speed limit for the north/south roadway was posted at 89 km/h (55 mph). The Crash Schematic is included as **Figure 11** at the end of this narrative report.

Vehicle Data

2002 Toyota Prius

The subject vehicle in this two-vehicle crash was a 2002 Toyota Prius, four-door sedan. The Prius was manufactured in 01/2002 and was identified by Vehicle Identification Number (VIN) JT2BK18U520 (production number omitted). At the time of the crash, the odometer reading was 232,026 km (144,178 miles). The Prius was equipped with a 1.5-liter gasoline engine linked to an electric motor. The power was delivered to the front-wheel drive system by a continuously variable transmission. The Prius was equipped with front-wheel disc and rear-wheel drum brakes and an anti-lock breaking system (ABS). The vehicle also contained OEM 8-spoke alloy wheels with varied P175/65R14 tires and a vehicle manufacturer specified pressure of 241 kPa (35 PSI). The specific tire data at the time of the NASS vehicle inspection is identified in the following table:

Position	Tire Make/Model	Measured Tire Pressure	Measured Tread Depth	Damage
Left Front	Goodyear Integrity	214 kPa (31 PSI)	7 mm (9/32")	None
Right Front	Goodyear Integrity	207 kPa (30 PSI)	7 mm (9/32")	None
Left Rear	Dunlop SP20	207 kPa (30 PSI)	6 mm (8/32")	None
Right Rear	Kelly Navigator	172 kPa 25 (PSI)	6 mm (8/32")	None

The interior of the Prius was configured as a five-passenger vehicle with front bucket seats and a fixed rear bench seat. The vehicle's safety system consisted of 3-point lap and shoulder safety belts in all five seating positions, a redesigned frontal air bag system, front row safety belt retractor pretensioners, and side impact seat back-mounted air bags for the two front seating positions.

1992 Nissan SE Club-Cab Pick-Up Truck

The 1992 Nissan pick-up was identified by the VIN 1N6HD16S3NC (production number omitted). A 3.0-liter, V6 engine linked to a four-speed automatic transmission powered the Nissan. The rear-wheel drive vehicle was equipped with Stinger Radial GTS P215/70R14 tires with a manufacture specified pressure of 179 kPa (26 PSI) for the front wheels and 241 kPa (35 PSI) for the rear wheels. The specific tire data at the time of the NASS vehicle inspection is detailed in the table below:

Position	Measured Tire Pressure	Measured Tread Depth	Damage
Left Front	214 kPa (31 PSI)	6 mm (8/32")	None
Right Front	207 kPa (30 PSI)	3 mm (4/32")	None
Left Rear	207 kPa (30 PSI)	3 mm (4/32")	None
Right Rear	207 kPa (30 PSI)	6 mm (8/32")	None

Crash Sequence

Pre-Crash

The 51-year old male driver of the Toyota Prius was traveling in the northbound direction on the inboard lane of a five-lane undivided roadway. The 31-year-old male driver of the 1992 Nissan pick-up initiated a left turn from a driveway on the east roadside with the intent to enter the southbound lanes. As the Nissan executed the left turn, the front of the Prius contacted the left side of the Nissan.

The driver of the Prius related that another uninvolved vehicle was traveling to his right on the outboard northbound lane, but was not involved in the crash.

Crash

The front of the Prius impacted the left door and cargo bed of the Nissan on the inboard northbound lane of the roadway. The direction of force was 1 o'clock for the Prius and 10 o'clock for the Nissan. The maximum crush to the Prius was located at the right front bumper corner and measured 18 cm (7.1"). The maximum crush to the Nissan was located 250 cm (98.4") forward of the left rear axle and measured 20 cm (7.9") in depth. The SCI revised damage algorithm of the WinSMASH program computed the total velocity changes of 19 km/h (11.8 mph) to the Prius and 16 km/h (9.9 mph) to the Nissan. The specific longitudinal and lateral components were –18 km/h (-11.2 mph) and –7 km/h (-4.3 mph) for the Prius and –8 km/h (-5.0 mph) and 14 km/h (8.7 mph) for the Nissan. The impact deployed the frontal air bag system in the Prius.

Following the impact, the Prius traveled forward approximately 3 m (10') in a northwesterly direction and came to rest partially in the center turn bay and was facing a

the same direction. The Nissan rotated in a counterclockwise direction and came to rest predominantly in the center turn bay facing a southwesterly direction.

Post-Crash

The three occupants of the Prius exited the vehicle under their own power and did not sustain any injuries. The driver alerted the rescue personnel of the hybrid engine in the Prius and they cleared the scene as a precaution. The Prius was towed from the crash scene due to the frontal air bag deployment. The Nissan was driven from the scene.

2002 Toyota Prius

Exterior

The 2002 Toyota Prius sustained moderate damage as a result of the impact with the 1992 Nissan pickup truck **(Figure 3)**. The NASS vehicle inspection reported that the maximum crush as at the right front bumper corner and measured 18 cm (7.1"). The SCI revised direct contact damage extended from the left bumper corner to the right bumper corner and measured 145 cm (57.1"). The Field L measurement was also 145 cm (57.1"). The crush profile measured to the bumper was as follows: C1 = 10 cm (3.9"), C2 = 9 cm (3.5"), C3 = 9 cm (3.5"), C4 = 11 cm (4.3"), C5 = 17 cm (6.7"), C6 = 18 cm (7.1"). The SCI revised Collision Deformation Classification (CDC) was 01-FDEW-1.

Figure 3 - Frontal damage to the 2002 Toyota Prius.

Interior

There was no visible interior damage to the 2002 Toyota Prius. No discernable contact points or intrusions were identified during the NASS inspection. The vehicle's knee bolster was rigid plastic and sustained no damage.

1992 Nissan SE Club-Cab Pick Up Truck

Exterior

The 1992 Nissan pickup truck sustained moderate damage as a result of the impact with the 2002 Toyota Prius **(Figure 4)**. The NASS inspection reported that the maximum crush to the Nissan was located 250 cm (98.4") forward of the left rear axle and measured 20 cm (7.9") in depth. The direct contact damage reportedly began 96 cm (37.8") forward of the rear left axle and measured 130 cm (51.1") in width. The Field L measurement was reported to have began 44 cm (17.3") forward of the rear left axle and measured 206 cm (81.1") in width. The crush profile measured at the mid-door level was as follows: C1 = 0 cm, C2 = 2 cm

Figure 4 - Left side damage to 1992 Nissan Pick-Up.

(0.8”), C3 = 17 cm (6.7”), C4 = 20 cm (7.9”), C5 = 18cm (7.1”), C6 = 0 cm. The CDC for this impact was 10-LZEW-2.

Manual Safety Belt Systems – 2002 Toyota Prius

The 2002 Toyota Prius was equipped with 3-point continuous loop safety belt systems for all five seating positions. It should be noted that the NASS investigation determined that the three occupants in the Prius, seated in the front left, front right, and rear right positions, were restrained by the 3-point manual safety belts. The SCI reinvestigation does not support belt use. The driver’s safety belt was configured with a sliding latch plate, Emergency Locking Retractor (ELR), and an adjustable D-ring, which was in the full-down position at the time of the NASS inspection. The front right belt was configured with a sliding latch plate, a switchable ELR/Automatic Locking Retractor (ALR), and an adjustable D-ring, which was in the full-down position. Both frontal safety belts were restricted in an unused position taught along the B-pillar as a result of the retractor pretensioner actuation. It was determined by the SCI reinvestigation as not used during the crash **(Figures 5 and 6)**.

Figure 5 - LF latch plate and restricted belt along the B-pillar.

Figure 6 - Right front seat belt latch plate and restricted belt along the B-

The rear belt systems consisted of sliding latch plates and switchable ELR/ALR configurations in all three positions. There was no evidence of belt usage on the right rear safety belt’s latch plate, webbing, or seatbelt housing and appears to have not been used

Frontal Air Bag System

2002 Toyota Prius

The 2002 Toyota Prius was equipped with redesigned frontal air bags for the driver and front right seating positions. The Prius was also equipped with side impact air bags mounted in the front seat backs. The frontal air bags deployed as a result of the impact with the 1992 Nissan truck The driver’s air bag **(Figure 7)** deployed through a tri-fold module cover flap

Figure 7 - Driver's air bag.

configuration with the one-piece upper flap of trapezoidal shape and the lower flaps triangular in shape and separated by a center vertical seam. The upper flap measured 15 cm (5.9") in width and 18 cm (7.1") in height. The lower flaps were 8 cm (3.1") in width and 8 cm (3.1") in height. The cover flaps opened at the designated tear points. The driver's air bag measured 52 cm (20.0") in its deflated state and contained two internal tether straps. Two ports located at the 11 and 1 o'clock sectors vented the bag. There was no discernable loading evidence to the air bag.

The front right air bag **(Figure 8)** deployed from a top-mount H-configuration module cover flap with the upper flap measuring 20 cm (7.9") in width and 7 cm (2.8") in height and the bottom flap measuring 21 cm (8.3") in width and 8 cm (3.1") in height. The deployed right air bag measured 68 cm (26.8") horizontally and 48 cm (18.9") vertically in its deflated state. The bag was vented by two ports located at the lateral aspects of the bag in the 10 and 2 o'clock positions.

Figure 8 - Right front passenger air bag.

Both front row seating positions were equipped with side impact torso-protection air bags mounted in the outboard lateral aspects of the seat backs. Appropriately, the air bags did not deploy during the crash due to the low lateral velocity change of the frontal impact to the Prius.

Hybrid Engine System – 2002 Toyota Prius

Hybrid System – 2004 Toyota Prius

The Toyota Prius was specifically designed as a hybrid power train vehicle. The hybrid system consisted of a gasoline engine and an electric motor that combined, produced low emissions and high fuel economy without the need to externally charge the battery system.

The Prius was designed with a 1.5 liter, transversely mounted gasoline engine that produced 76 HP. This engine was linked to a permanent magnet AC synchronous electric motor that was capable of producing 67 HP. Both units were conventionally mounted in the front of the vehicle and were linked to an electronically controlled continuously variable transmission (CVT) with front wheel drive. A generator was mounted between the engine and the electric motor that converted the gasoline engine power to electric power to drive the electric motor and recharge the onboard battery system (**Figure 9**). The gasoline engine was positioned on the right side of the engine compartment with the electric motor (**Figure 10**) mounted left of the engine and the CVT transmission mounted left of the electric motor.

The battery system was a Nickel Metal-Hydride battery that was mounted in the rear cargo floor, aft of the second row seat. This high-voltage battery system was mounted lateral to the vehicle and was concealed and protected by an aluminum cover that was

bolted to the rear floor of the vehicle. A protected wiring harness extended along the left side of the Prius, which transferred electrical power to the motor and provided the transfer of power from the generator to recharge the battery system. The Prius was also equipped with a regenerative braking system that utilized the motor to decelerate the vehicle and covert power back into the batteries for recharging purposes.

The battery compartment was vented by an internal duct system. This system provided an exchange of air to ventilate the unit and regulate temperature while the vehicle was in operation. This vent system utilized a duct system with an internal fan that extracted air from the passenger compartment through a vent on the rear deck and exhausted though the lower right quarter panel into the area concealed by the wrap-around rear bumper fascia.

The was no intrusion of the battery pack area or damage to the area of the left side harness. The engine compartment was not damaged. This crash did not expose a risk to the driver. There was no evidence of damage or procedures initiated by the first responders to the crash site.

Figure 9 - Hybrid engine battery.

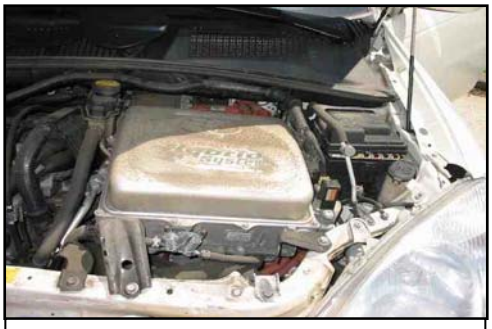

Figure 10 - Electric hybrid motor.

Occupant Demographics

Driver

Age/Sex:	51-year-old/Male
Height:	175 cm
Weight:	91 kg
Seat Track Position:	Full-rear position
Manual restraint Use:	None
Usage Source:	Vehicle inspection images
Eyewear:	None
Type of Medical Treatment:	None

Driver Kinematics

The 51-year-old driver of the Toyota Prius was seated in an upright posture at the time of the crash. The driver was unrestrained and the seat track was adjusted to the full rear position. The driver claimed to have been wearing the 3-point lap and shoulder safety

belt; however, the evidence indicates that he was not restrained. At impact with the Nissan, the driver probably initiated a minimal forward trajectory. It is not known if the driver contacted the frontal air bag. The driver exited the vehicle under his own power. He declined medical treatment and was not transported to a medical facility.

Front Right Passenger

Age/Sex:	15-year-old/Male
Height:	178 cm
Weight:	52 kg
Seat Track Position:	Full-rear position
Manual restraint Use:	None
Usage Source:	Vehicle inspection images
Eyewear:	None
Type of Medical Treatment:	None

Front Right Passenger Kinematics

The 15-year-old front right passenger of the Toyota Prius was seated in an upright posture at the time of the crash. The passenger was unrestrained evidenced by the belt restriction following the firing of the pretensioners. The seat track was adjusted to the full rear position at the time of NASS inspection. The front right passenger was talking on a cellular telephone during the impact. At impact with the Nissan, the passenger probably initiated a minimal forward trajectory. The passenger sustained a nosebleed; however, it is not known if this was from an occupant contact or occurred naturally. During the interview the driver indicated that this occupant experiences nosebleeds frequently. The passenger exited the vehicle under his own power. He declined medical treatment and was not transported to a medical facility.

Rear Right Passenger

Age/Sex:	15-year-old/Male
Height:	178 cm
Weight:	52 kg
Seat Track Position:	Non-adjustable seat track
Manual restraint Use:	None
Usage Source:	Vehicle inspection images
Eyewear:	None
Type of Medical Treatment:	None

Rear Right Passenger Kinematics

The 15-year-old rear right passenger of the Toyota Prius was seated in an upright posture. It was determined that this passenger was unrestrained, evidenced by the lack of physical evidence on the safety belt system. The rear right passenger was playing with a portable video game player during the crash. At impact with the Nissan, the passenger probably initiated a minimal forward trajectory. The passenger did not sustain any injuries during the impact. The passenger exited the vehicle under his own power. He declined medical treatment and was not transported to a medical facility.

Figure 11 – Scene Schematic