CRASH DATA RESEARCH CENTER

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CALSPAN REMOTE ALTERNATIVE FUEL VEHICLE CRASH INVESTIGATION

CASE NO: 2004-11-080F

VEHICLE: 2004 TOYOTA PRIUS

LOCATION: MICHIGAN

CRASH DATE: APRIL 2004

Contract No. DTNH22-01-C-17002

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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 hybrid fuel system that was present in a 2004 Toyota Prius. The Prius was equipped with a gas/electric hybrid drive train, which was configured with a 1.5 liter gasoline engine coupled with an electric drive motor. The vehicle was designed to run on battery power, gasoline, or a combination of both, dependant on the throttle input and desired speed. The 2004 Toyota Pruis was involved in a moderate severity intersection crash with a 2000 Dodge Intrepid. A 53-year-old female driver who was restrained by a manual three-point lap and shoulder safety belt occupied the Prius. The driver was operating the vehicle in an eastbound direction on the outboard lane of a three-lane undivided roadway and was approaching a four-leg intersection that was controlled by three-phase traffic signals. A 17-year-old driver of the Intrepid was traveling westbound on the outboard lane of the same roadway approaching the same intersection. The driver of the Intrepid attempted to initiate a left turn across the path of the Prius. After realizing that a collision was imminent, the driver of the Intrepid counter-steered right in an effort to keep the principal impact off of the right side of the vehicle, thereby protecting the front right passenger. As the driver initiated the correction, the front of the Prius contacted the front of the Intrepid. The impact was sufficient to deploy the redesigned frontal air bag system in the Prius. The driver of the Prius was not injured and was not medically treated. The NASS inspection of the Prius revealed no loose, or severed fuel or electrical lines in the engine compartment or the undercarriage. There was a 12-volt battery and a Nickel-Metal-Hybrid battery located behind the rear seat bight. There were no apparent electrical shorts or leakages in the battery storage area fastened inside the trunk. The hybrid power train system is discussed in greater detail later in this report.			
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NASS/SCI COMBO CASE NO.: 04-11-080F
SUBJECT VEHICLE: 2004 TOYOTA PRIUS
LOCATION: MICHIGAN
CRASH DATE: APRIL 2004

BACKGROUND

Figure 1 – Sunject vehicle 2004 Toyota Prius

This remote investigation focused on the performance of the hybrid fuel system that was present in a 2004 Toyota Prius (**Figure 1)**. The Prius was equipped with a gas/electric hybrid drive train, which was configured with a 1.5 liter gasoline engine coupled with an electric drive motor. The vehicle was designed to run on battery power, gasoline, or a combination of both, dependant on the throttle input and desired speed. The 2004 Toyota Pruis was involved in a moderate severity intersection crash with a 2000 Dodge Intrepid. A 53-year-old female driver who was restrained by a manual three-point lap and shoulder safety belt occupied the Prius. The driver was operating the vehicle in an eastbound direction on the outboard lane of a three-lane undivided roadway and was approaching a four-leg intersection that was controlled by three-phase traffic signals. A 17-year-old driver of the Intrepid was traveling westbound on the outboard lane of the same roadway approaching the same intersection. The driver of the Intrepid attempted to initiate a left turn across the path of the Prius. After realizing that a collision was imminent, the driver of the Intrepid counter-steered right in an effort to keep the principal impact off of the right side of the vehicle, thereby protecting the front right passenger. As the driver initiated the correction, the front of the Prius contacted the front of the Intrepid. The impact was sufficient to deploy the redesigned frontal air bag system in the Prius. The driver of the Prius was not injured and was not medically treated. The NASS inspection of the Prius revealed no loose, or severed fuel or electrical lines in the engine compartment or the undercarriage. There was a 12-volt battery and a Nickel-Metal-Hybrid battery located behind the rear seat bight. There were no apparent electrical shorts or leakages in the battery storage area fastened inside the trunk. The hybrid power train system is discussed in greater detail later in this report.

This crash was identified by the Crash Investigation Division of the National Highway Traffic Safety Administration (NHTSA) The NASS PSU performed the vehicle and scene inspections. Due to the hybrid fuel system, a remote investigation was assigned to the Calspan SCI team on June 17, 2004. The Prius was considered a ‘non-tow’ vehicle for purposes of the CDS case, and the NASS researcher conducted only a partial vehicle inspection. The inspection consisted of a full exterior inspection and an image profile of the interior. The data from the partial inspection was utilized for this SCI narrative report.

SUMMARY

Crash Site

This crash occurred on a three-lane, east/west roadway in a residential area during daylight hours. The roadway was configured with one eastbound and one westbound lane separated by a center left turn lane. The roadway was surfaced with asphalt and was delineated by double-yellow lines contiguous to the turn bay and solid white fog lines. The center turn bay had arrow markings to channel traffic. The travel lanes were 4.0 m (13.1') in width and the center turn bay was 3.5 m (11.5') wide; paved shoulders that were 0.5 m (1.6') in width bordered the roadway. The roadway intersected with a dimensionally similar three-lane road and was controlled by a three-phase traffic control signal. The environment along the roadway consisted of residential homes and natural growth. At the time of the crash, the road surface was dry and there were no adverse atmospheric conditions. Both vehicles were traveling on the east/west roadway; the Prius was intending to continue straight through the green signal while the Intrepid intended to turn left. The speed limit for the straight and level east/west roadway was posted at 72 km/h (45 mph). The Crash Schematic is included as **Figure 10** at the end of this narrative report.

Vehicle Data

2004 Toyota Prius

The subject vehicle in this two-vehicle crash was a 2004 Toyota Prius, five-door hatchback. The Prius was manufactured in 10/03 and was identified by Vehicle Identification Number (VIN) JTDKB20U840 (production sequence omitted). 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 disc and rear drum brakes and an anti-lock breaking system (ABS). The vehicle was equipped with OEM 8-spoke alloy wheels with Goodyear Integrity P185/65R14 tires and a vehicle manufacturer specified pressure of 240 kPa (35 PSI) for the front axle and 230 kPa (33 PSI) for the rear axle. The specific tire data at the time of the NASS vehicle inspection is identified in the following table:

Position	Measure Tire Pressure	Measured Tread Depth	Damage
Left Front	296 kPa (43 PSI)	7 mm (9/32")	None
Right Front	283 kPa (41 PSI)	7 mm (9/32")	None
Left Rear	262 kPa (38 PSI)	7 mm (9/32")	None
Right Rear	269 kPa (39 PSI)	7 mm (9/32")	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.

2000 Dodge Intrepid

The 2000 Dodge Intrepid was identified by the VIN 2B3HD46R9YH (production sequence omitted). At the time of the vehicle inspection, the odometer reading was 78,858 km (49,001 miles). A 2.7-liter, V6 engine linked to a 5-speed automatic transmission powered the Intrepid.

The front-wheel drive vehicle was equipped with Goodyear Eagle G/A P22560/R16 tires with a manufacture specified pressure of 221 kPa (32 PSI). The specific tire data at the time of the NASS vehicle inspection is detailed in the table below:

Position	Measure Tire Pressure	Measured Tread Depth	Damage
Left Front	207 kPa (30 PSI)	5 mm (6/32”)	None
Right Front	207 kPa (30 PSI)	5 mm (6/32”)	None
Left Rear	200 kPa (29 PSI)	5 mm (6/32”)	None
Right Rear	241 kPa (35 PSI)	5 mm (6/32”)	None

Crash Sequence

Pre-Crash

The 53-year-old female driver of the 2004 Toyota Prius was traveling eastbound on the outboard lane of a three-lane undivided roadway (**Figure 2**). The 17-year-old driver of the 2000 Dodge Intrepid was traveling westbound on the outboard lane of the same roadway **(Figure 3**). Both vehicles were approaching an intersection controlled by a three-phase traffic control signal. The driver of the Prius was intending to continue straight through the intersection under the green signal while the driver of the Intrepid was initiating a left turn to travel southbound on a three-lane roadway that intersected this roadway.

Figure 2- Eastboud approach of the 2004 Toyota Prius.

Figure 3 - Westbound approach of the 2000 Dodge Intrepid.

Crash

The front of the Prius impacted the front of the Intrepid on the outboard eastbound lane of the roadway. The SCI revised direction of force for the Prius was 12 o’clock and 1 o’clock for the Intrepid. The maximum crush to the Prius was located 32 cm (12.6”) left of the vehicle’s centerline and measured 30 cm (11.8”). The maximum crush to the Intrepid was located 23 cm (9.1”) right of the vehicle’s centerline and measured 25 cm (9.8”). The maximum crush for the Intrepid was revised by the SCI investigator. Due to revisions to the vehicle damage data, a revised damage algorithm of the WinSMASH program computed the total velocity changes of 32

km/h (19.9 mph) to the Prius and 26 km/h (16.2 mph) to the Intrepid. The specific longitudinal and lateral components were –32 km/h (-19.9 mph) and 6 km/h (3.7mph) to the Prius and –24 km/h (-14.9 mph) and –9 km/h (-5.6 mph) to the Intrepid. The impact deployed the frontal air bag system in the Prius.

Post-Crash

The driver of the Prius and both occupants of the Intrepid exited the vehicle under their own power. The driver of the Intrepid was transported to a medical facility due to multiple fractures. The driver of the Prius and front right occupant of the Intrepid were not injured. Both vehicles were towed from the crash scene due to damage.

2004 Toyota Prius

Exterior

The 2004 Toyota Prius (**Figure 4**) sustained moderate damage as a result of the impact with the 2000 Dodge Intrepid. The crush data was over representative; therefore, the NASS vehicle inspection measurements were revised in the SCI remote investigation. The SCI investigation revealed that the maximum crush was located 32 cm (12.6”) left of the vehicle’s centerline and measured 29 cm (11.4”) in depth. The direct contact began at left front reinforcement bar corner and extended 100 cm (39.4”) to the right. The Field L measurement began at the front left reinforcement bar corner and extended across the entire front end and measured 108 cm (42.5”). The crush profile measured to the reinforcement bar and adjusted for missing components was as follows: C1 = 28 cm (11.0”), C2 = 29 cm (11.4”), C3 = 27 cm (10.6”), C4 = 20 cm (7.9”), C5 = 9 cm (3.5”) and C6 = 0 cm. The Collision Deformation Classification (CDC) was 12-FYEW-2.

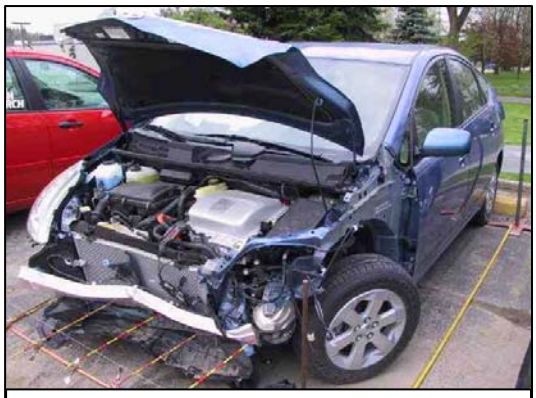

Figure 4 - Damaged 2004 Toyota Prius.

Interior

The NASS investigation did not complete an interior inspection as this vehicle was considered a non-towed vehicle according to their sampling conventions. The NASS team did provide images, which showed no occupant contact points or passenger compartment intrusion.

2000 Dodge Intrepid

Exterior

The 2000 Dodge Intrepid (**Figure 5**) sustained moderate damage as a result of the impact with the 2004 Toyota Prius. The NASS vehicle inspection measurements were revised in the SCI remote investigation, due to the over estimation of the crush. The SCI investigation revealed that the maximum crush was located 24 cm (9.4”) right of the vehicle’s

Figure 5 - Damaged 2000 Dodge Intrepid.

centerline and measured 25 cm (9.8”) in depth. The direct contact damage began at the right front bumper corner and extended 80 cm (31.5”) to the left across the front plane. The Field L measurement began at the right front corner and extended across the entire front measuring 108 cm (42.5”). The crush profile measured to the reinforcement bar and adjusted for missing components was as follows: C1 = 0 cm, C2 = 12 cm (4.7”), C3 = 14 cm (5.5”), C4 = 23 cm (9.1”), C5 = 15 cm (5.9”) and C6 = 0 cm. The SCI revised CDC is 01-FZEW- 1.

Manual Safety Belt Systems – 2004 Toyota Prius

The 2004 Toyota Prius was equipped with 3-point continuous loop safety belt systems for all five seating positions. 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-up position. Both frontal seating positions were equipped with retractor pretensioners, neither of which appear to have actuated. It should be noted that the NASS investigation did not make a determination on belt usage for the driver of the Prius.

The rear belt systems consisted of sliding latch plates and switchable ELR/ALR configurations in all three positions.

Frontal Air Bag System

2004 Toyota Prius

The 2004 Toyota Prius was equipped with redesigned frontal air bags for the driver and front right seating positions. The frontal air bags deployed as a result of the impact with the 2000 Dodge Intrepid. Both frontal air bags **(Figure 6 and 7)** deployed through H-configuration module cover flaps with the one-piece upper and lower flaps separated by a center vertical seam. No air bag dimensions were recorded during the NASS vehicle inspection.

Figure 6 - Driver's air bag.

Figure 7 - Right front passenger air bag.

The Prius was also equipped with side impact 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 impact to the Prius.

Hybrid Engine System – 2004 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 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 8**). The gasoline engine was positioned on the right side of the engine compartment with the electric motor (**Figure 9**) mounted left of the engine and the CVT transmission mounted left of the electric motor.

Figure 8 - Onboard battery system.

Figure 9 - Engine Components.

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 through the lower right quarter panel into the area concealed by the wrap-around rear bumper fascia.

There was no intrusion of the battery pack area or damage to the area of the left side harness. The engine compartment was only minimally damaged missing the hybrid components completely. This crash did not expose a risk to the driver.

Occupant Demographics

Driver

Age/Sex:	53-year-old/Female
Height:	Unknown
Weight:	Unknown
Seat Track Position:	Unknown
Manual restraint Use:	None
Usage Source:	Vehicle inspection images
Eyewear:	Unknown
Type of Medical Treatment:	Not injured

Driver Kinematics

The 53-year-old female 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 in an unknown position. At impact with the Intrepid, 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 her own power. She was not injured and declined medical treatment.

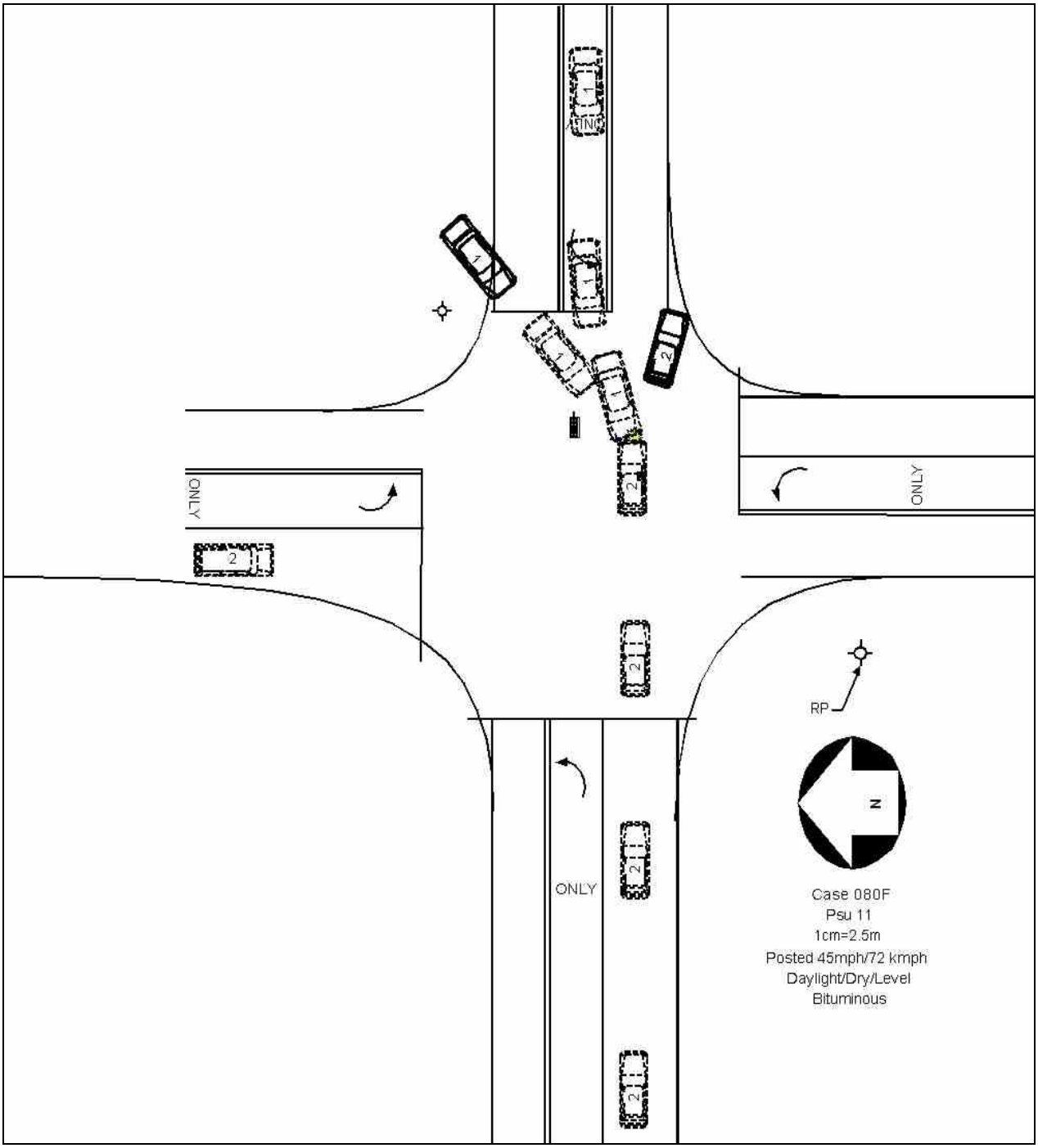

Figure 10 - NASS Scene Schematic