CRASH DATA RESEARCH CENTER

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CALSPAN ON-SITE ALTERNATIVE FUEL VEHICLE CRASH INVESTIGATION

CALSPAN CASE NO: CA05-041

VEHICLE: 2004 TOYOTA PRIUS

LOCATION: NORTH CAROLINA

CRASH DATE: MAY 2005

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 on-site investigation focused on the crashworthiness of the hybrid power system of a 2004 Toyota Prius. The hybrid system in the Toyota consisted of a 1.5-liter gasoline engine linked to a permanent magnet AC synchronous motor powered by Nickel Metal-Hydride batteries. Additionally, the Prius was equipped with a dual stage frontal air bag system; seatback mounted side impact air bags for the front seating positions, and curtain air bags for the four outboard seating positions. The Toyota was occupied by a restrained 32-year-old male driver and was involved in an intersection collision with a 2000 Nissan Altima. The front plane of the Nissan impacted the right side of the Toyota. This collision resulted in the deployment of the right side seatback mounted side impact air right side curtain air bags. Reportedly, the driver of the Toyota was injured and was transported to a local hospital where he was treated and released.			
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TABLE OF CONTENTS

CALSPAN ON-SITE ALTERNATIVE FUEL VEHICLE CRASH INVESTIGATION
SCI CASE NO. – CA05-041
SUBJECT VEHICLE – 2004 TOYOTA PRIUS
LOCATION - STATE OF NORTH CAROLINA
CRASH DATE – MAY 2005

BACKGROUND

This on-site investigation focused on the crashworthiness of the hybrid power system of a 2004 Toyota Prius **(Figure 1)**. The hybrid system in the Toyota consisted of a 1.5-liter gasoline engine linked to a permanent magnet AC synchronous motor powered by Nickel Metal-Hydride batteries. Additionally, the Prius was equipped with a dual stage frontal air bag system; seatback mounted side impact air bags for the front seating positions, and curtain air bags for the four outboard seating positions. The Toyota was occupied by a restrained 32-year-old male driver and was involved in an intersection collision with a 2000 Nissan Altima. The front plane of the Nissan impacted the right side of the Toyota. This collision resulted in the deployment of the right side seatback mounted side impact air bag and the right side curtain air bags. Reportedly, the driver of the Toyota was injured and was transported to a local hospital where he was treated and released.

Figure 1. Subject vehicle 2004 Toyota Prius.

The Police Accident Report (PAR) was identified by the routine sampling activities of the NASS PSU-43. Due to the hybrid vehicle involvement, the PAR was forwarded to the Calspan Special Crash Investigations team and was forwarded to the Crash Investigations Division of NHTSA where it was assigned for an on-site investigation. The SCI team located both vehicles at an insurance auto auction facility and cooperation to inspect the vehicles was granted by the insurance claims representative. The field aspects of the case were completed on Friday, June 24.

SUMMARY

Crash Site

This intersection crash occurred during the daylight hours of May 2005. At the time of the crash, the weather was clear with no adverse conditions. The crash occurred at an intersection of two local roadways. Additionally, a business driveway was located at the east road edge forming a four-leg intersection. The north and south legs of the intersection were configured with three through traffic lanes and a center left turn lane. The travel lanes of the north/south legs were separated by double yellow centerlines. Furthermore, the northbound lanes curved slightly right. The east leg of the intersection was configured with one through traffic lane in each direction. The travel lanes of the

east leg were separated by double yellow centerlines. The roadways were surfaced with asphalt and were bordered by concrete barrier curbs. Traffic through the intersection was controlled by overhead three-phase traffic lights. The posted speed limit for the north/south roadway was 72 km/h (45 mph). The scene schematic is included as **Figure 12** of this report.

Vehicle Data – 2004 Toyota Prius

The 2004 Toyota Prius was identified by the Vehicle Identification Number (VIN): JTDKB20U94 (production sequence omitted). The odometer reading at the time of the inspection was unknown due to the expended vehicle battery. However, based on an oil change reminder label that was posted on the windshield, the odometer was approximately 18,000 kilometers (11,200 miles). The vehicle was a four-door hatchback that was equipped with a 1.5-liter four-cylinder engine linked to a permanent magnet AC synchronous motor powered by Nickel Metal-Hydride batteries, an electronically control continuously variable transmission, front-wheel drive, power front disc and rear drum brakes, OEM alloy wheels, power steering, and a tilt steering wheel. The Toyota was configured with Goodyear Integrity tires, size P185/65R15. The manufacturer recommended front and rear tire pressure was 241 kPa (35 PSI) and 228 kPa (33 PSI), respectively. The specific tire data was as follows:

Tire	Measured Pressure	Tread Depth	Restricted	Damage
LF	262 kPa (38 PSI)	6 mm (8/32)	No	No
LR	255 kPa (37 PSI)	6 mm (8/32)	No	No
RF	255 kPa (37 PSI)	6 mm (8/32)	No	No
RR	248 kPa (36 PSI)	6 mm (8/32)	No	No

The seating positions in the Toyota were configured with cloth upholstered front bucket seats with height adjustable head restraints. The front seat head restraints were adjusted between the mid to full-down positions at the time of the vehicle inspection. The second row was configured with a cloth upholstered three-passenger split bench seat (60/40). The seats, headliner, and right side interior panels were removed from the Prius prior to the SCI inspection. These components were removed during the vehicle damage estimate process by a repair facility.

2000 Nissan Altima

The 2000 Nissan Altima was identified by the VIN: 1N4DL01D4Y (production sequence deleted). The vehicle was a four-door sedan that was equipped with a 2.4-liter, four-cylinder engine, 4-speed automatic transmission, and front-wheel drive. The front tires on the Nissan were Firestone FR690 tires, size P195/65R15. The right rear was a General XP2000 and the left rear was a Futura Touring HR, size P205/60R15. The tire data at time of the SCI inspection was as follows:

Tire	Measured Pressure	Tread Depth	Restricted	Damage
LF	186 kPa (27 PSI)	6 mm (7/32)	No	No
LR	241 kPa (35 PSI)	8 mm (10/32)	No	No
RF	186 kPa (27 PSI)	6 mm (8/32)	No	No
RR	145 kPa (21 PSI)	5 mm (5/32)	No	No

Crash Sequence

Pre-Crash

The restrained 32-year-old male driver of the 2004 Toyota Prius was operating the vehicle northbound on the four-lane roadway approaching the four-leg intersection where he intended to turn left **(Figure 2)**. A 35-year-old female driver was operating the 2000 Nissan Altima southbound approaching the same intersection **(Figure 3)**. The driver of the Prius failed to detect the southbound Nissan and turned left at the intersection, crossing the path of the Altima.

Figure 2. Pre-crash travel for the Toyota.

Figure 3. Southbound travel of the Nissan.

Crash

The front of the Nissan impacted the right side of the Toyota within the intersection. The resulting directions of force were within the 2 o'clock sector for the Toyota and 11 o'clock sector for the Nissan. The WINSMASH program was used to calculate a delta-V for this impact. The total delta-V for the Toyota was 14.0 km/h (8.7 mph). The longitudinal and lateral components were -7.0 (-4.3 mph) and -12.1 km/h (-7.5 mph), respectively. The total delta-V for the Nissan was 14.0 km/h (8.7 mph) with longitudinal and lateral components of -13.2 km/h (-8.2) and 4.8 km/h (3.0 mph), respectively. The Toyota's right seatback mounted side impact air bag and right side curtain air bag deployed as result of the intersection crash.

The Toyota initiated a clockwise rotation from the lateral force applied rearward of the vehicle's center gravity. The Prius traveled approximately 4 meters (13 feet) in a northwest direction prior to coming to final rest within the intersection facing a northwest

direction. The Nissan continued its forward trajectory approximately 10 meters (33 feet) from impact and came to rest facing a southerly direction.

Post-Crash

Police and emergency medical personnel responded to the crash site. The driver of the Toyota sustained evident injury and was transported by ambulance to a local hospital where he was treated and released. The driver of the Nissan was police reported as not injured or transported. The Toyota and Nissan sustained minor severity damage and were towed from the crash site. Both vehicles were subsequently deemed a total loss by their respective insurance companies.

Vehicle Damage

Exterior Damage – 2004 Toyota Prius

The 2004 Toyota Prius sustained minor right side damage as a result of the intersection collision with the Nissan **(Figure 4)**. The damage consisted of lateral deformation to the right side doors and forward aspect of the right quarter panel. At the time of the SCI inspection, the rear right door was removed and placed in the rear seat of the vehicle. The SCI investigator repositioned the door and secured it in position for documentation of the damage. The direct contact damage began 10 cm forward of right rear axle and extended forward 137 cm (54.0") terminating 23 cm (9.0") forward of the rear edge of the right front door. The maximum crush measured 11 cm (4.3") and was located on the right rear door. The crush profile was documented utilizing six equidistant points along the mid-door level and were as follows: C1 = 0 cm, C2 = 5 cm (1.9"), C3 = 11 cm (4.3"), C4 = 9 cm (3.5"), C5 = 1 cm (0.4"), C6 = 0 cm. The Collision Deformation Classification (CDC) for this impact was 02-RZEW-2.

Figure 4. Resultant right damage to the Prius.

Exterior – 2000 Nissan Altima

The 2000 Nissan Altima sustained minor damage as result of the impact with the Toyota **(Figure 5)**. The damage consisted of longitudinal crush to the front bumper beam, hood, and to the right fender. The direct contact damage began 8 cm (3.0") right of the centerline and extended 65 cm (25.5") to the front right bumper corner. The maximum crush was located the right end of the bumper beam and measured 22 cm (8.7"). Six crush measurements were

Figure 5. Nissan's minor frontal damage.

documented along the full width of the front beam of 140 cm (55.0”), and were as follows: C1 = 0 cm, C2 = 0 cm, C3 = 3 cm (1.2”), C4 = 9 cm (3.5”), C5 = 15 cm (5.9”), C6 = 22 cm (8.7”). The CDC for the impact was 11-FZEW-1.

Interior Damage – 2004 Toyota Prius

The 2004 Toyota Prius sustained minor interior damage as a result of passenger compartment intrusion. The intrusion was located at the right C-pillar at the junction of sill and measured 3 cm (1.0). A possible occupant contact point was noted on the lower aspect of the center instrument panel, which was evidenced by a scuffmark. In order to obtain a repair estimate the repair facility, disassembled the interior, which consisted of the removal of all the seats, headliner, carpeting, center console, and all of the right side plastic trim panels.

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.

Figure 6. Electric motor located in the left of the engine bay.

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. The gasoline engine was positioned on the right side of the engine compartment with the electric motor mounted left of the engine and the CVT transmission mounted left of the electric motor. **Figure 6** is an overall view of the engine compartment.

Figure 7. Nickel metal-hydride battery pack.

The battery system was a Nickel Metal-Hydride battery that was mounted in the rear cargo floor, aft of the second row seat **(Figure 7)**. 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.

This minor severity crash was isolated to the right C-pillar area. There 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.

Frontal Air Bag System – 2004 Toyota Prius

The 2004 Toyota Prius was equipped with a dual stage frontal air bag system for the driver and front right passenger positions. The subject crash did not produce a significant deceleration; therefore, the frontal air bags did not deploy. Both front safety belt systems were equipped with retractor pretensioners. The pretensioners did not fire in this side impact crash.

Side Impact Air Bags – 2004 Toyota Prius

The 2004 Toyota Prius was equipped with seatback mounted side impact air bags for the front seating positions. In the subject crash, the right side impact air bag deployed **(Figure 8)**. The air bag membrane was semi-circular in shape and measured 33.0 cm (13.0”) in height and 33 cm (13.0”) in width from the seatback. An additional 3 cm (1.0”) of air bag fabric extended beyond the outer edge peripheral seam of the expandable portion of the air bag. The entire perimeter of the side impact air bag was frayed. The air bag membrane contained two circular stitch patterns that created tethers between the front and rear panels. The outer stitching measured 15 cm (6.0”) in diameter and the inner stitching measured 13 cm (5.”). Two 1 cm (0.4”) diameter holes were located within the stitching. No occupant contacts or damage were noted to the air bag. The following nomenclature was printed on the inboard aspect of the air bag membrane:

Figure 8. Deployed right seatback mounted side impact air bag.

GA320-00810 1U3510654

Curtain Air Bags – 2004 Toyota Prius

The 2004 Toyota Prius was equipped Inflatable Curtain (IC) air bags for the four outboard seating positions. As a result of the right side impact the right side IC deployed **(Figure 9 and 10)**. The IC deployed downward from the right roof side rail and extended from the right A-pillar to the right C-pillar. Five clips attached the IC membrane to the roof side rail. The IC inflator canister was mounted on the side rail between the B- and C-pillars. The inflator canister measured 36 cm (14.3") in length and 3 cm (1.0") in diameter. The deployed IC was removed from the side rail during the estimate process and was temporarily reinstalled during the SCI inspection. The IC was free of occupant contct points or damage. A bar code noted with the following information was noted on the right IC:

300317203Q42

Figure 9. Front seat portion of the IC.

Figure 10. Rear seat portion of the right IC.

The repair facility removed the headliner and roof side rail trim panels, which allowed access to the non-deployed left IC **(Figure 11)**. The following nomenclature was identified on the left IC:

300308003Q43
L62B3013513

Figure 11. Non-deployed left IC.

The side impact air bag system was designed to deploy based solely on impact. There was no occupant presence sensor in this vehicle. The right side impact air bag and right IC deployed into unoccupied positions during the crash.

Manual Restraint Systems – 2004 Toyota Prius

The 2004 Toyota Prius was equipped with manual continuous loop 3-point lap and shoulder safety belts for the five seating positions. The driver safety belt was configured with a sliding latch plate, Emergency Locking Retractor (ELR), height adjustable D-ring that was in the full-up position, and a retractor pretensioner. The driver utilized his safety belt in the crash; however, due to the minor crash forces, the safety belt and hardware did not exhibit loading evidence or frictional abrasions. Furthermore, the retractor pretensioner did not fired during the subject crash.

The safety belts for the remaining four seating positions were configured with continuous loop webbing with sliding latch plates that retracted onto switchable ELR/Automatic Locking Retractors (ALR). The front right safety belt was equipped with a retractor pretesnioner that did not fire.

Occupant Demographics – 2005 Toyota Prius

Driver

Age/Sex:	32-year-old/Male
Height:	Not available
Weight:	Not available
Seat Track Position:	Unknown
Manual Restraint Use:	Manual 3-point lap and shoulder safety belt
Usage Source:	Vehicle inspection
Eyewear:	Not available
Type of Medical Treatment:	Transported to a hospital, treated and released.

Driver Kinematics

The 32-year-old male driver of the 2004 Toyota Prius was seated in a presumed upright posture and was restrained by the manual 3-point lap and shoulder safety belt. The driver's seat was removed at a repair facility prior to the SCI inspection and was not reinstalled in the vehicle; therefore, the seat track position was unknown.

At impact with the Nissan, the right seatback mounted side impact air bag and the right IC deployed. The driver initiated a right and slight forward trajectory in response to the 2 o'clock direction of force. The interior of the Prius was disassembled; however, none of the available components exhibited evidence of occupant contact. The driver of the Toyota sustained evident injury and was transported by ambulance to a local hospital where he was treated and released.

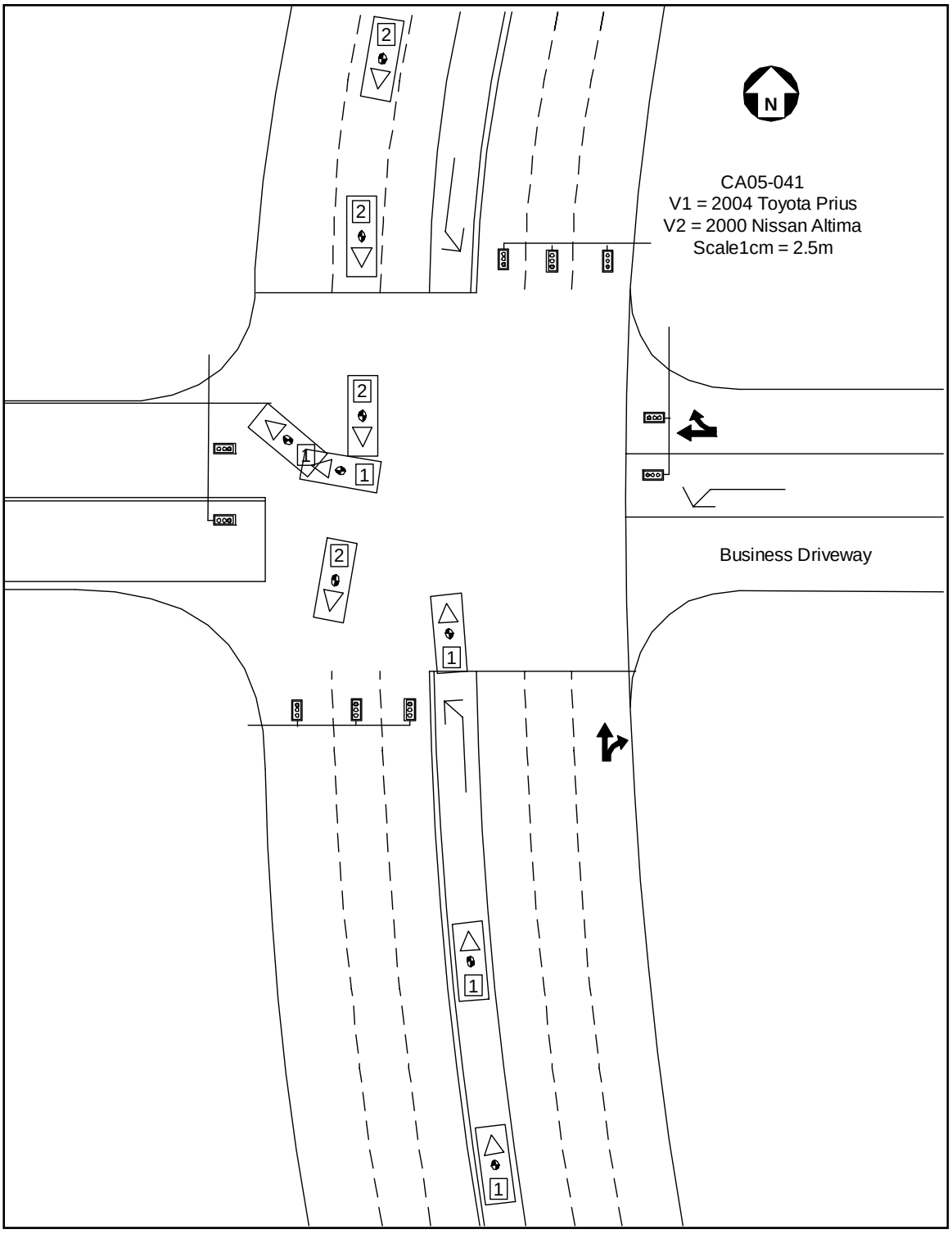

Figure 12. Scene schematic