

On-scene Investigation / Vehicle to Vehicle
Dynamic Science, Inc. / Case Number: DS02019
2002 Toyota Prius four-door
California
August, 2002

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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

1. Report No. DS02019		2. Government Accession No.		3. Recipient Catalog No.	
4. Title and Subtitle In-Depth Accident Investigation				5. Report Date	
				6. Performing Organization Report No.	
7. Author(s) Dynamic Science, Inc.				8. Performing Organization Report No.	
9. Performing Organization name and Address Dynamic Science, Inc. 530 College Parkway, Ste. K Annapolis, MD 21401				10. Work Unit No. (TRAIS)	
				11. Contract or Grant no. DTNH22-94-D-27058	
12. Sponsoring Agency Name and Address U.S. Dept. of Transportation (NRD-32) National Highway Traffic Safety Administration 400 7th Street, SW Washington, DC 20590				13. Type of report and period Covered [Report Month, Year]	
				14. Sponsoring Agency Code	
15. Supplemental Notes					
16. Abstract <p>This hybrid vehicle crash took place on a two-lane, undivided roadway. There is a nearly vertical dirt embankment on the east side of the roadway and a -77% downhill embankment on the west side of the roadway. At the bottom of the embankment there is a private residence. The speed limit is 24 km/h (15 mph) for both travel directions.</p> <p>The case vehicle, a 2002 Toyota Prius hybrid vehicle driven by a 75-year-old woman, was traveling downhill. The driver of the case vehicle was wearing the available lap and shoulder belt. The other vehicle, a 1988 Ford E-series Club Wagon driven by a 35-year-old male, was traveling uphill. As the other vehicle entered the right turn to continue east it encountered the case vehicle. The roadway is narrow at this location. It appears that the other vehicle crossed into the path of travel for the case vehicle. The front of the other vehicle struck the left front of the case vehicle. Both frontal air bags in the case vehicle deployed at this time, as did both front seatbelt pretensioners. The case vehicle was pushed to the right and began overturning down the embankment. The other vehicle also departed the roadway and began overturning down the embankment. The other vehicle continued overturning until striking a tree with its right side. The case vehicle rolled until striking the side of the private residence with its undercarriage.</p> <p>The driver of the case vehicle required extrication by EMS personnel. Her seat belt was cut by EMS personnel. She sustained a fractured left ulna, a left knee laceration, and a chest contusion. She was transported to a local trauma center by ground ambulance for treatment. The driver of the other vehicle sustained a head laceration but refused any treatment. The case vehicle was towed from the scene due to damage and was later declared a total loss. The other vehicle was towed from the scene due to damage.</p>					
17. Key Words Air bag, deployment, hybrid, electric, injury, driver			18. Distribution Statement		
19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No of pages	22. Price		

Dynamic Science, Inc.
Accident Investigation
Case Number: DS02019

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BACKGROUND:

Description: This electric hybrid vehicle case took place in the morning hours of August, 2002. This case was identified by DSI using on-line resources. NHTSA was notified on September 4, 2002. DSI was assigned the case on September 5, 2002. This was an on-scene investigation. All field work was conducted and completed on September 12, 2002.

Investigation Type: On-scene
 Crash Location: California
 Crash Date: August, 2002
 Notification Date: September 4, 2002
 Field Work Completed: September 12, 2002

SUMMARY:

The crash took place on a two-lane, undivided roadway. The asphalt roadway was dry and free of defects. There is a -8.8% downgrade at this location for southbound traffic. There is a nearly vertical dirt embankment on the east side of the roadway and a -77% downhill embankment on the west side of the roadway. The downhill embankment is grass and tree covered. Approximately halfway down the embankment there is a wooden walk that parallels the roadway and a set of stairs that are perpendicular to the roadway. At the bottom of the embankment there is a private residence.

The speed limit is 24 km/h (15 mph) for both travel directions.



Figure 1. Approach to area of impact–case vehicle

The case vehicle, a 2002 Toyota Prius hybrid vehicle driven by a 75-year-old (160 cm/63 in, 73 kg/160 lbs) woman, was traveling downhill. The driver of the case vehicle was wearing the available lap and shoulder belt. The other vehicle, a 1988 Ford E-series Club Wagon driven by a 35-year-old male, was traveling uphill. As the other vehicle entered the right hand turn to continue east it encountered the case vehicle. The roadway is narrow at this location. It appears that the other vehicle crossed into the path of travel for the case vehicle. The front of the other vehicle (12FYEW1) struck the left front of the case vehicle (11FDEW2).

The total velocity change for the case vehicle calculated by the WinSmash collision model was 22.0 km/h (13.7 mph)¹. The longitudinal and lateral delta v components were -19.1 km/h (-11.8 mph) and 11.0 km/h (6.8 mph), respectively.

Both frontal air bags in the case vehicle deployed at this time, as did both front seatbelt pretensioners.

The total velocity change for the other vehicle was 13.0 km/h (8.1 mph). The longitudinal and lateral delta v components were -12.8 km/h (-8.0 mph) and 2.3 km/h (1.4 mph), respectively.

The case vehicle was pushed to the right and began overturning down the embankment. The other vehicle also departed the roadway and began overturning about its longitudinal axis down the embankment (five quarter turns, 180 degree rotation). The other vehicle continued overturning until striking a tree with its right side. The case vehicle rolled until striking the side of the private residence with its undercarriage.

The driver of the case vehicle required extrication by EMS personnel. Her seat belt was cut by EMS personnel. She sustained a fractured left ulna, a left knee laceration, and a chest contusion. She was transported to a local trauma center by ground ambulance for treatment. The driver of the other vehicle sustained a head laceration but refused any treatment.

The case vehicle was towed from the scene due to damage and was later declared a total loss. The



Figure 2. Final rest (looking south). Case vehicle to right side, other vehicle in upper left of image.



Figure 3. Final rest, other vehicle, looking south

¹Calculated using WinSmash version 2.06, stiffness values calculated from NCAP test results.

other vehicle was towed from the scene due to damage.



Figure 4. Area of final rest–facing west

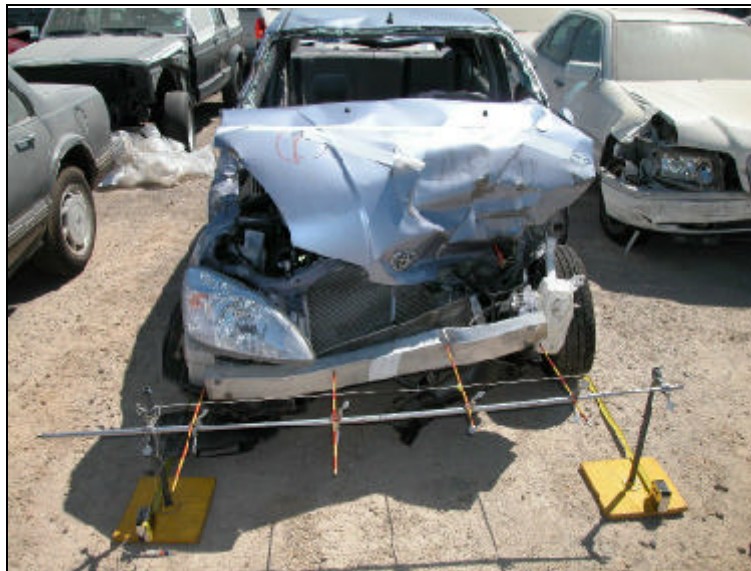


Figure 5. Front, case vehicle

Scene Diagram

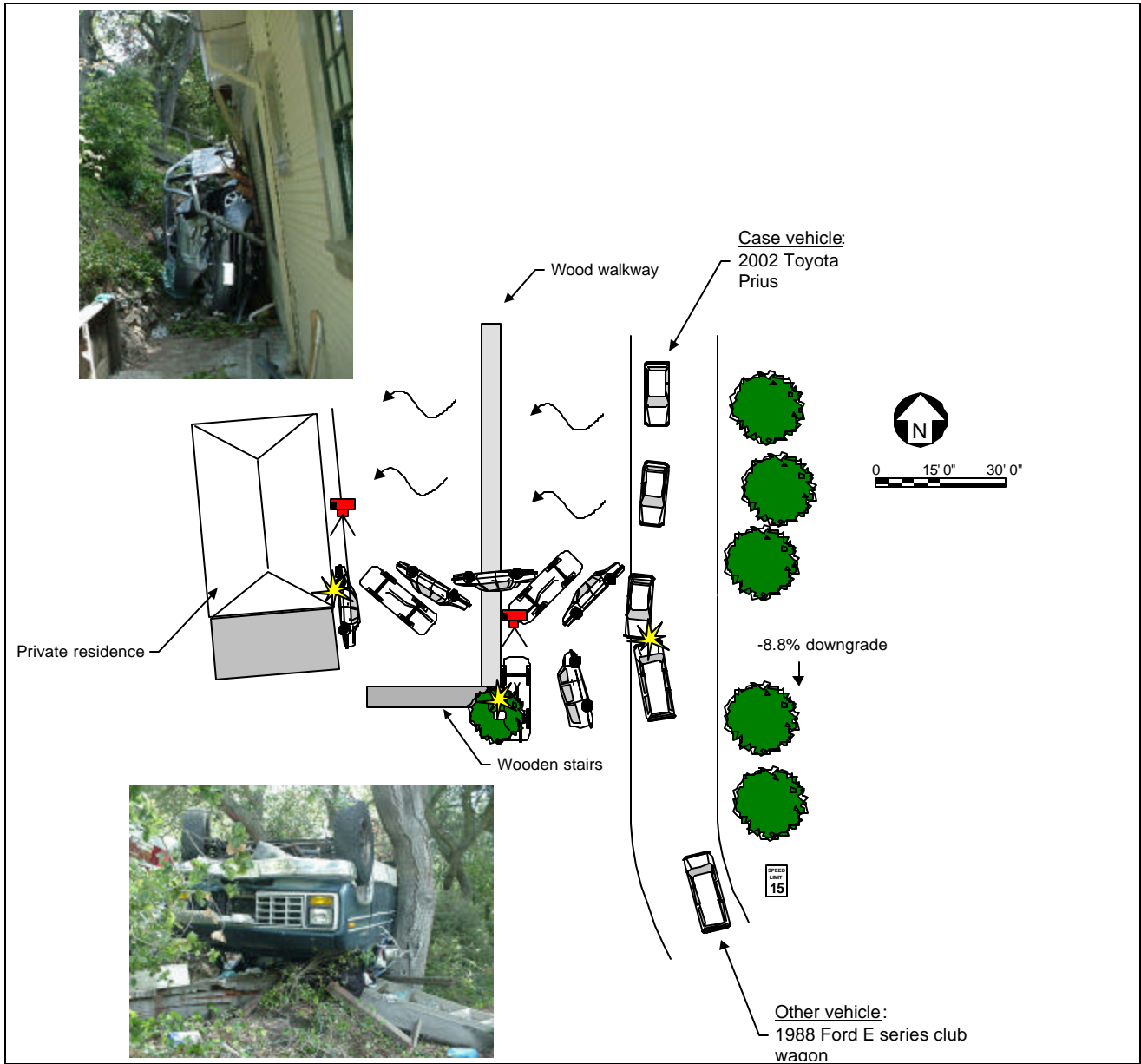


Figure 6. Scene diagram

DETAILED INFORMATION**Vehicles**Case vehicle

Description:	2002 Toyota Prius four-door	
VIN:	JT2BK18UXZ0xxxxx	
Odometer:	Unknown	
Engine:	1.5 L, 4 cylinder	
Reported Defects:	None noted	
Cargo:	None	
Damage Description:	Moderate frontal crush beginning at left. Roof, left side, and right side damage. Towed from the scene due to damage.	
CDC:	Impact 1: 11FDEW2 Impact 2 (rollover): 00TDDO2 Impact 3 (house impact): 00UDDW2	
Delta V (Impact 1):	Total	22.0 km/h (13.7 mph)
	Longitudinal	-19.1 km/h (-11.8 mph)
	Latitudinal	11.0 km/h (6.8 mph)
	Energy	25,763 joules (19,002 ft-lbs)

**Figure 7.** Front view, case vehicle

The case vehicle sustained 92.0 cm (36.2 in) of direct contact damage across the front end beginning at the left front bumper corner. The residual crush measured along the bumper reinforcement bar was as follows: C1=24.0 cm (9.4 in), C2=17 cm (6.7 in), C3=6 cm (2.4 in), C4=2.0 cm (0.8 in). The maximum crush was located at C1. The principle direction of force was within the 11 o'clock sector and was an estimated 340 degrees. The impact energy was managed by the forward structures of the vehicle. The damaged components for this impact included the bumper fascia and reinforcement bar, upper and lower radiator supports, and hood. The vehicle also sustained damage to the roof, left side, and right side as a result of the rollover and a non-horizontal impact with a private residence. The wheelbase was shortened by 5 cm (1.9 in) on the left side. The left rear door was jammed shut. The windshield was fractured and was likely removed by EMS personnel. The glazing at the left front, left rear, backlight, and right rear locations was disintegrated.



Figure 8. Right rear, case vehicle

Safety features discussion

The driver's manual restraint system consisted of a continuous loop 3-point lap and shoulder belt with a sliding latch. The emergency locking retractor was located in the B-pillar. The front seat belts were equipped with pretensioners and force limiters, in addition to adjustable shoulder anchors. Both pretensioners fired during the crash. The driver's seatbelt was locked in the used position and had been cut off the driver. The front right passenger seatbelt was locked in the stowed position. The front right seat and all rear seat positions were equipped with lap and shoulder belts using switchable emergency/automatic locking retractors.



Figure 9. Steering column deformation/air bag

The case vehicle was equipped with driver and front right passenger air bags, a driver's seat mounted side air bag, and a front right passenger seat mounted side air bag.

Both front air bags deployed during the crash. The circular driver's front air bag was mounted in the steering wheel hub and measured 52 cm (20.5 in) in diameter. The air bag was equipped with two vents ports--located at the 10 and 2 o'clock positions-- and one tether. The "Y" type module cover opened at the designed tear points and there was no damage to the cover.



Figure 10. Front right passenger's air bag

There was no damage to the air bag nor any occupant contacts found. The rectangular front right air bag was mounted in the top of the instrument panel and measured 45 cm (17.7 in) wide seam to seam. The air bag was equipped with two vents--located at the 3 and 9 o'clock positions. The single module cover flap opened at the designed tear point and there was no damage to the cover. There was no damage to the air bag nor any occupant contacts found.

Prius Hybrid Discussion²

The Prius' hybrid powertrain consists of a 70 horsepower 1.5 litre four cylinder gasoline-fueled internal combustion engine, a 33 KW (44 horsepower) permanent magnet electric motor, a generator, a 274 volt nickel metal-hydride battery, an electronic controller, and a 'power split device' which functions as a continuously variable (automatic) transmission. The Prius operates on both the engine and electric motor/battery - one or both of these power sources can drive the Prius depending on load and road conditions - the electronic controller makes that decision with no input from the driver.

The Prius system works in six main modes:

1. When accelerating from a stop, the Prius is powered by the battery/electric motor only.
2. As more acceleration is needed, the engine will turn on automatically and run by itself or in conjunction with the electric motor and the battery.
3. Under full acceleration, the electric motor is supplemented by power from the battery. At high speeds the gas engine is the primary source of power. The electric motor will assist to varying degrees.
4. When the engine is running it uses a generator to charge the battery, and when braking, a regenerative braking system also charges the battery, so there is never a need to recharge the battery separately. When the vehicle is coasting or the brakes are applied, the motor is turned into a generator, capturing energy that would normally be lost as heat or kinetic energy and transforming it into electricity to recharge the batteries.
5. The battery is regulated to maintain a constant charge. When the charge is low, the electric generator routes power to charge the battery.
6. During coasting or braking, the electric motor functions as a generator to charge the battery. When the vehicle is stopped, the gas engine shuts off automatically and the electric motor stands ready to power up the Prius. This conserves fuel and eliminates exhaust emissions caused by idling.

Specifications

Prius' primary power is provided by an all-aluminum 1.5-liter 4 cylinder gasoline engine with a peak 70 horsepower at 4,500 rpm and peak torque of 82 lb./ft. at 4,200 rpm. The electric drive motor is a permanent-magnet design. It produces its maximum power of 33 kW (44 horsepower) from 1,040-5,600 rpm, and maximum torque of 350 N-m (258 lb./ft.) from 0-400 rpm.

Prius' battery pack is comprised of 38 sealed Nickel-Metal Hydride modules with a nominal voltage of

²Prius specifications and system modes data obtained from the Internet @ http://www.toyota.com/shop/vehicles/prius/technology/prius_technology.html

274 volts. It is sealed in a carbon composite case and positioned behind the rear seat within the unibody of the car.

Compliance with Sec.571.305 Standard No.305; Electric-powered vehicles: electrolyte spillage and electrical shock protection

The case vehicle was examined to determine compliance with the 305 standards.

1. There were no indications of electrolyte spillage from the propulsion battery.
2. There was no movement of the battery module.
3. The electrical isolation test was attempted; however, there was no power present in the traction battery. It was physically possible to conduct the isolation tests for the service plug found in the rear trunk area (Item A in Attachment 1) and the battery power cable (Item B), and the results were understandably positive for isolation. The isolation test for Items C and D could not be conducted because the crush to the front of the vehicle had pushed the converter/inverter module into a location that could not be accessed. There were no indications of any arcing, fire, or component meltdown.

An overview of the electrical isolation test is included as Attachment 1.



Figure 11. Service plug (located in trunk)



Figure 12. Battery power cable (behind rear seat)



Figure 13. Converter/inverter assembly

Other vehicle

Description: 1988 Ford E series club wagon

VIN: Unknown

Odometer: Unknown

Engine: Unknown

Reported Defects: None reported by police. Police photos, however, reveal that several tire rims were improperly secured to the vehicle axles. Nuts missing and/or not tightened.

Cargo: Unknown

Damage Description: Towed from the scene due to damage.

CDC: Impact 1: 12FYEW1
Impact 2 (rollover): 00TDDO2
Impact 3 (impact with tree): 00RPAN2

Delta V:

Total	13.0 km/h (8.1 mph)
Longitudinal	-12.8 km/h (-8.0 mph)
Latitudinal	2.3 km/h (1.4 mph)
Energy	20,777 joules (15,324 ft-lbs)



Figure 14. Front right, other vehicle

The other vehicle sustained direct contact damage beginning at the left front bumper corner and extending 2/3 the way across the bumper. The principle direction of force was within the 12 o'clock sector and was an estimated 355 degrees. The impact energy was managed by the forward structures of the vehicle. The damaged components for this impact included the bumper, grille, and likely the lower radiator support. The vehicle also sustained damage to the left, right, and top side of the vehicle due to the rollover. There was additional damage to the right side due to contact with a tree as it came to final rest. There was substantial intrusion to the roof and windshield header on the left side. The windshield glazing was out of place. The side glass at the front left, front right, and rear right was disintegrated.



Figure 15. Final rest, other vehicle



Figure 16. Left front rim (loose and missing lug nuts)



Figure 17. Front right rim (missing and loose lug nuts)

Occupants

<u>Case vehicle</u>	Occupant 1
Age/Sex:	75/Female
Seated Position:	Front left
Seat Type:	Fabric covered bucket seat, seat adjusted to forward most track position.
Height:	160 cm (63 in)
Weight:	73 kg (160 lbs)
Occupation:	NA
Pre-existing Medical Condition:	Unkonwn
Alcohol/Drug Involvement:	None
Driving Experience:	> 20 years
Body Posture:	Normal, upright
Hand Position:	Unknown
Foot Position:	Right foot initially on accelerator.
Restraint Usage:	Lap and shoulder belt available, used
Air bag:	Steering wheel mounted air bag, deployed

Other vehicle

Age/Sex:	35/Male
Seated Position:	Front left
Seat Type:	Unknown
Height:	178 cm (70 in)
Weight:	79 kg (175 lbs)
Occupation:	Unknown
Pre-existing Medical Condition:	None noted
Alcohol/Drug Involvement:	None
Driving Experience:	Unknown
Body Posture:	Unknown
Hand Position:	Unknown
Foot Position:	Unknown
Restraint Usage:	Lap and shoulder belt used, per police report

Injuries and Injury Mechanisms**Case vehicle**

	<u>INJURY</u>	<u>OIC CODE</u>	<u>ICD-9</u>	<u>SOURCE</u>
Driver:	Fracture, left ulna	753202.2,2	813.2	Air bag
	Contusion, across chest	490402.1,0	922.1	Seat belt webbing
	Laceration, left knee (required eight stitches)	890600.1,2	891.0	Lower instrument panel

Other vehicle

	<u>INJURY</u>	<u>OIC CODE</u>	<u>ICD-9</u>	<u>SOURCE</u>
Driver:	Head laceration	190600.1,9	873.00	Unknown

Occupant Kinematics

The 75-year-old female driver (160 cm/63 in, 73 kg/160 lbs) of the case vehicle was seated in a normal, upright fashion. The fabric covered bucket seat was adjusted to the forward most track position. The driver was wearing the available lap and shoulder belt. The manual shoulder belt upper anchorage was in the full down position. She had turned the steering wheel to the right so her left hand was above her right (10 and 5 o'clock positions). Her right foot was on the brake and her left on the floorboard. She was not wearing eyeglasses or contacts. She was attired in black Levi-type jeans and a blue shirt.

At impact, the driver's pretensioner fired and the frontal air bags deployed. The driver responded to the 11 o'clock direction of force by exhibiting a forward trajectory and loading the pretensioned and locked manual restraint system—causing the chest contusion. Her upper torso contacted the deployed air bag and both her knees struck the lower instrument panel. The driver sustained a laceration to her left knee from this contact. At impact, it is believed that her left hand was tightly gripping the steering wheel rim. As the air bag deployed, it struck her arm—causing the ulna fracture.

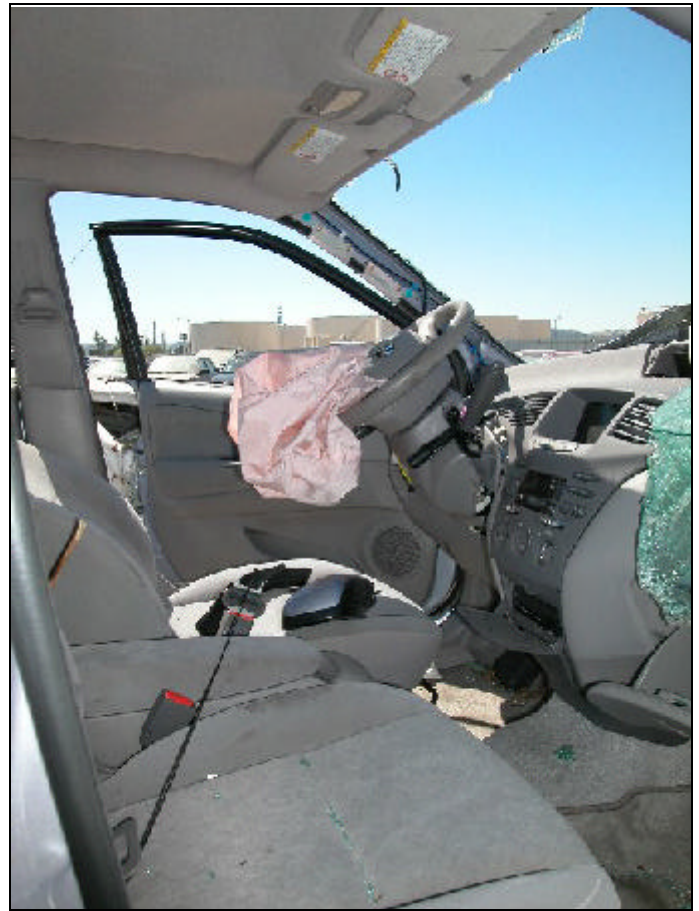


Figure 18. Driver's seated area—note upward loading to steering column (possibly due to extrication)

The case vehicle was redirected to the right after the initial impact and began overturning as it traveled down the embankment. The vehicle overturned five quarter turns before striking a private residence and coming to rest on its right side. During the second quarter turn onto the roof, the driver may have loaded the steering wheel to some degree and assisted in moving it upward. However, a more likely explanation is that the movement was as a result of extrication activities by EMS personnel.

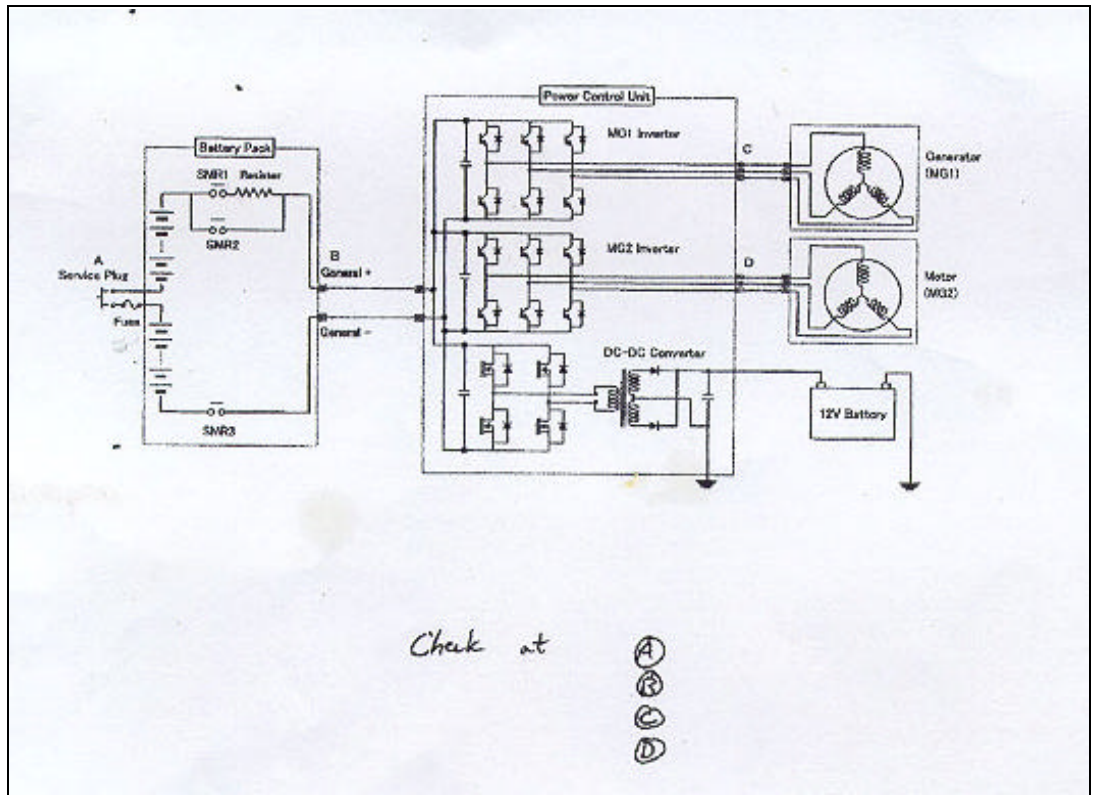


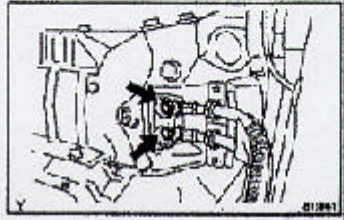
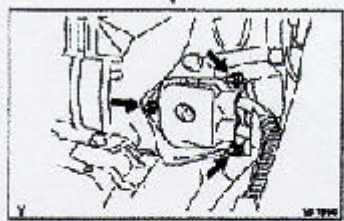
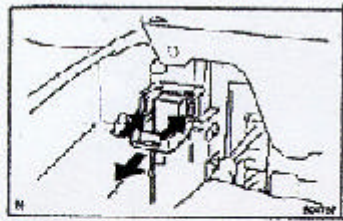
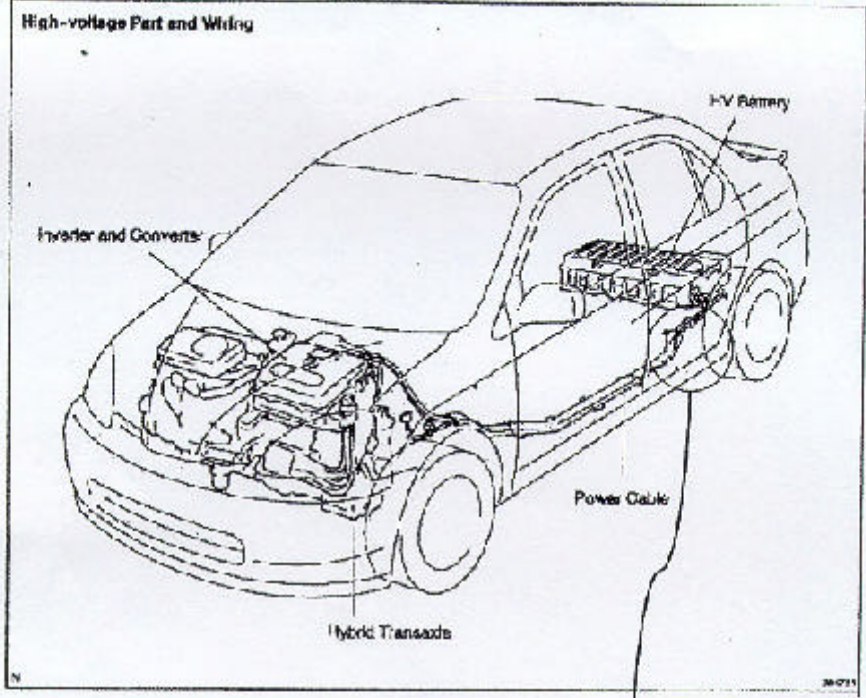
Figure 19. Damage and contact to left side of steering column



Figure 20. Right knee contact to lower instrument panel

Attachment 1. Electrical Isolation Test





Page: HV-1 of repair manual

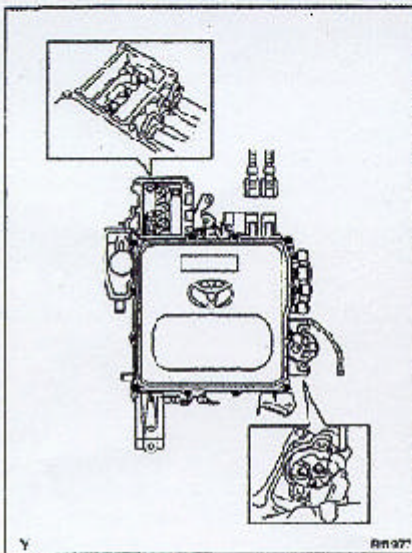
HV-10

HYBRID VEHICLE CONTROL - CONVERTER AND INVERTER ASSEMBLY

REMOVAL

*You do not need to conduct
2. and 3 just to reach
to the MG terminals.*

1. REMOVE SERVICE PLUG (See page HV-1)
2. DRAIN HV COOLANT (See page HT-6)
3. REMOVE COWL TOP PANEL (See page BO-27)



4. VERIFY 0 V

NOTICE:

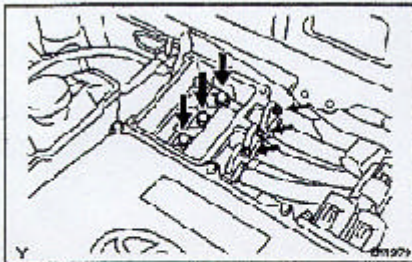
- Before starting step (a), 5 minutes or more should be passed after removing the service plug.
- Be careful to prevent foreign matter from entering the inside of connector cover.

- (a) Disconnect the connector of the battery power cable and insulate it with packaging tape.
- (b) Using a torx socket wrench (T30), remove the 4 screws and inverter terminal cover.
- (c) Using a torx socket wrench (T40), remove the 2 screws, circuit breaker sensor and connector cover.

HINT:

Slide the connector cover to disconnect the circuit breaker sensor connector.

- (d) Using a voltmeter, measure the voltage between terminals of 3 phases (U-V, V-W, U-W) and each terminal and body ground to verify them to be approx. 0 V.

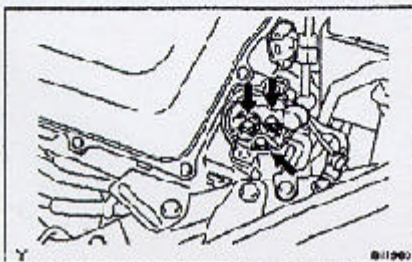


5. REMOVE CONVERTER & INVERTER ASSEMBLY

- (a) Remove the 6 bolts and 3 power cables for MG2.

NOTICE:

Be careful to prevent foreign matter from entering the inside of connector cover.



- (b) Remove the 3 bolts and power cable for MG1.

NOTICE:

- Remove the power cable for MG1 together with converter & inverter assembly.
- Be careful to prevent foreign matter from entering the inside of connector cover.

- (c) Remove the bolt and ground cable.

