INDIANA UNIVERSITY

TRANSPORTATION RESEARCH CENTER
School of Public and Environmental Affairs
501 S. Madison Street–Suite 105
Bloomington, Indiana 47403-2452
(812) 855-3908 Fax: (812) 855-3537

ON-SITE HYBRID VEHICLE INVESTIGATION

CASE NUMBER - IN08029
LOCATION - INDIANA
VEHICLE - 2008 FORD ESCAPE HYBRID
CRASH DATE - August 2008

Submitted:

January 21, 2009

Contract Number: DTNH22-07-C-00044

Prepared for:

U.S. Department of Transportation
National Highway Traffic Safety Administration
National Center for Statistics and Analysis
Washington, D.C. 20590-0003

DISCLAIMERS

This document is disseminated under the sponsorship of the Department of Transportation in the interest of information exchange. The United States Government assumes no responsibility for the contents or use thereof.

The opinions, findings, and conclusions expressed in this publication are those of the authors and not necessarily those of the National Highway Traffic Safety Administration.

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.* IN08029	2. *Government Accession No.*	3. *Recipient's Catalog No.*
4. *Title and Subtitle* On-Site Hybrid Vehicle Investigation Vehicle - 2008 Ford Escape Hybrid Location - Indiana		5. *Report Date:* January 21, 2009 6. *Performing Organization Code*
7. *Author(s)* Special Crash Investigations Team #2		8. *Performing Organization Report No.*
9. *Performing Organization Name and Address* Transportation Research Center Indiana University 501 South Madison Street, Suite 105 Bloomington, Indiana 47403-1501		10. *Work Unit No. (TRAIS)* 11. *Contract or Grant No.* DTNH22-07-C-00044
12. *Sponsoring Agency Name and Address* U.S. Department of Transportation (NVS-411) National Highway Traffic Safety Administration National Center for Statistics and Analysis Washington, D.C. 20590-0003		13. *Type of Report and Period Covered* Technical Report Crash Date: August 2008 14. *Sponsoring Agency Code*

15. *Supplementary Notes*
On-site hybrid vehicle investigation involving a 2008 Ford Escape Hybrid.

16. *Abstract*

This report covers an on-site investigation of a crash that involved a 2008 Ford Escape Hybrid and a 1992 Oldsmobile Custom Cruiser station wagon. The focus of this on-site investigation was on the crash performance of the Ford's Nickel-Metal Hydride (NiMH) propulsion battery. The Ford was traveling east and the Oldsmobile was traveling north. The Oldsmobile entered a 4-leg intersection and the front of the vehicle impacted the Ford's right side plane. The Ford rotated clockwise and rolled over one quarter turn onto its left side. The vehicle's side curtain air bags deployed during the rollover and the driver was not injured. The Ford's NiMH propulsion battery sustained no damaged during the crash.

17. *Key Words* Hybrid Vehicle Rollover Motor Vehicle Traffic Crash Injury Severity		18. *Distribution Statement* General Public	
19 *Security Classif. (of this report)* Unclassified	20. *Security Classif. (of this page)* Unclassified	21. *No. of Pages* 12	22. *Price*

Form DOT 1700.7 (8-72) Reproduction of completed page authorized

TABLE OF CONTENTS

Page No.

This crash was brought to the National Highway Traffic Safety Administration's attention on August 4, 2008 by a news article. This on-site investigation was assigned on August 4, 2008. The crash involved a 2008 Ford Escape Hybrid (**Figure 1**) and a 1992 Oldsmobile Custom Cruiser station wagon. The crash occurred in August, 2008 at 1554 hours in Indiana and was investigated by the applicable police department. The focus of this on-site investigation was on the crash performance of the Ford's Nickel-Metal Hydride (NiMH) propulsion battery. This contractor inspected the Ford and scene on August 4 and 5, 2008 and interviewed the Ford's driver on October 16, 2008. The Oldsmobile could not be located for an inspection. This report is based on the police crash report, police on-scene photographs, a Ford Escape Hybrid/Mariner Hybrid Emergency Response Guide, inspections of the Ford and the crash scene, occupant kinematic principles, and this contractor's evaluation of the evidence.

Figure 1: The 2008 Ford Escape Hybrid and damage on the left side from the rollover

CRASH CIRCUMSTANCES

Crash Environment: The trafficway on which the Ford was traveling was one way city street and the Ford was traveling east approaching a 4-leg intersection. The trafficway on which the Oldsmobile was traveling was also a one way city street and the Oldsmobile was traveling north approaching the same intersection. The Ford's roadway had two through lanes and a left turn channel, and was bordered by 13 cm (5 in) high curbs. Each travel lane was 3.7 m (12 ft) in width and pavement markings consisted of a broken white center line. The Oldsmobile's roadway had two through lanes and was bordered by 15 cm (6 in) high curbs. Each travel lane was 2.8 m (9.2 ft) in width and pavement markings consisted of a faded broken white center line, a white through arrow for the left lane, a white right turn/through arrow for the right lane, and a white stop bar. The Ford's roadway had a positive 3.3% grade and was uncontrolled. The Oldsmobile's roadway was level and controlled by two stop signs. The speed limit for the Ford was 40 km/h (25 mph) and the speed limit for the Oldsmobile was 48 km/h (30 mph). At the time of the crash the light condition was daylight, the atmospheric condition was clear, and the roadway pavement was dry bituminous. The traffic density was moderate and the site of the crash was urban university campus and residential. See the Crash Diagram on page 10 of this report.

Pre-Crash: The Ford was occupied by a restrained 51-year-old female driver and she was traveling in the outside lane negotiating a left curve (**Figure 2**) as she approached the intersection. She stated during the interview that she was traveling 40 km\h (25 mph) and intended to continue east. The Oldsmobile was occupied by a restrained 21-year-old male driver and he was traveling in the right lane (**Figure 3**) and intended to continue north. The Oldsmobile's driver told police

that he did not stop for the stop sign and entered the intersection. The Ford's driver steered left in an attempt to avoid the crash, which occurred within the intersection.

Crash: The front of the Oldsmobile (**Figure 4**) impacted the right side of the Ford (**Figure 5**, event 1). The Ford rotated clockwise and was redirected northeast and entered the east quadrant of the intersection (**Figure 6**). It rotated 55 degrees as it traversed 12 m (39.4 ft) and rolled over on the roadway one quarter turn onto its left side (**Figure 7**, event 2). The Ford was equipped with a rollover sensor, which triggered deployment of the vehicle's side curtain air bags. The vehicle traversed approximately 11.5 m (37.7 ft) from the trip point of the rollover to the final rest position, which was on the roadway heading southeast (**Figure 8**). The Oldsmobile rotated clockwise and the driver drove it to its final rest position east of the Ford straddling the south curb.

Figure 2: Approach of the Ford traveling east in the right lane; arrow shows the approach of the Oldsmobile

Figure 3: Approach of the Oldsmobile traveling north in the right lane

Figure 4: Damage to the front of the Oldsmobile from the impact with the Ford

Figure 5: Damage to right side of Ford from impact by front of Oldsmobile

Figure 6: Police photograph showing Ford's left rear and left front yaw marks and scratches on the pavement from the rollover

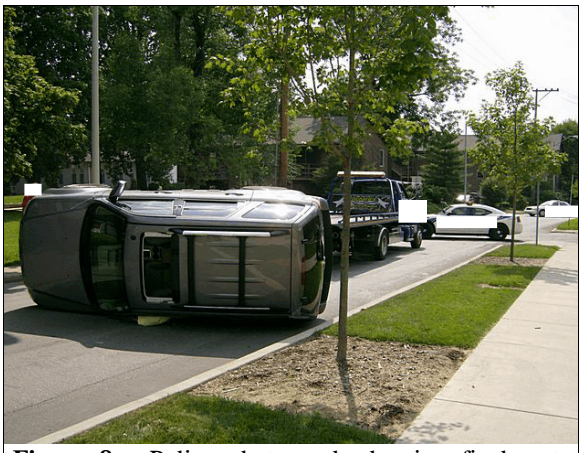


Figure 8: Police photograph showing final rest position of the Ford

Figure 7: Damage to Ford's left side from the rollover

Post-Crash: The police, emergency medical and rescue services responded to the scene. The police were notified of the crash at 1555 hours and arrived on scene at 1557 hours. The Ford's driver exited the vehicle through the sun roof. She refused transport to a hospital and left the scene in a taxi cab. The Oldsmobile's driver was not injured and he drove the Oldsmobile from the scene. The Ford was towed due to damage.

CASE VEHICLE

Case Vehicle: The 2008 Ford Escape Hybrid was a front wheel drive, 4-door, sport utility vehicle (VIN: 1FMCU49H68K------) equipped with a 2.3L, 4-cylinder gasoline engine with permanent-magnet AC-synchronous electric motor, a 330 volt sealed NiMH propulsion battery, and a continuously variable automatic transmission. The vehicle was also equipped with 4-wheel anti-lock disc brakes, rollover sensor, electronic stability control, driver and front right passenger frontal air bags, side curtain air bags, seat back-mounted side impact air bags, and a tire pressure monitoring system. The front row was equipped with

bucket seats with adjustable head restraints and lap-and-shoulder belts. The second row was equipped with lap-and-shoulder belts, a bench seat with folding back, adjustable head restraints, and Lower Anchors and Tethers for Children (LATCH) in the outboard seating positions. The vehicle's mileage was 21,120 kilometers (13,124 miles) and the specified wheelbase was 262 cm (103.1 in).

CASE VEHICLE DAMAGE

Exterior Damage: The Ford's impact with the Oldsmobile involved the right side plane. The right front and rear doors and the sill were directly damaged. The direct damage began 38 cm (14.9 in) rear of the right front axle and extended 142 cm (55.9 in) rearward on the side of the vehicle. The crush measurements were taken at the lower door level and the residual maximum crush was 6 cm (2.4 in) occurring 107 cm (42.1 in) rear of the right front axle. The table below shows the vehicle's right side crush profile.

Units	Event	Direct Damage		Field L	C_1	C_2	C_3	C_4	C_5	C_6	Direct	Field L
		Width CDC	Max Crush								±D	±D
cm	1	142	6	142	0	2	5	5	3	0	-18	-18
in		55.9	2.4	55.9	0.0	0.8	2.0	2.0	1.2	0.0	-7.1	-7.1

The damage from the rollover involved the entire left side of the vehicle. The direct damage began 53 cm (20.9 in) forward of the left front axle and extended 385 cm (151.6 in) rearward along the left side. The maximum lateral crush was 4 cm (1.6 in) and occurred at the belt line near the left A-pillar. It was the result of contact from the left side view mirror when the vehicle rolled onto its left side. There was no vertical crush to the left roof side rail. The Ford's wheelbase was unchanged and the induced damage involved the right front and rear doors.

Damage Classification: The Ford's Collision Deformation Classifications (CDCs) were: **01-RPEW-1** (**30** degrees) for the right side impact with the front of the Oldsmobile and **00-LDAO-2** for the rollover. The Missing Vehicle algorithm of the WinSMASH program calculated the Ford's Delta V for the right side impact as 7.0 km/h (4.3 mph). The longitudinal and lateral components were -6 km/h (-3.7 mph) and -4 km/h (2.1 mph), respectively. The results are borderline because they are based only on the crush to the Ford. The severity of the rollover event was moderate based on the damage to the Ford's left side.

The vehicle manufacturer's recommended tire size was P235/70R16 and the vehicle was equipped with tires of this size. The Ford's tire data are shown in the table below.

Tire	*Measured Pressure*		*Vehicle Manufacturer's Recommended Cold Tire Pressure*		*Tread Depth*		*Damage*	*Restricted*	*Deflated*
	kPa	psi	kPa	psi	milli-meters	32nd of an inch			
LF	241	35	241	35	6	8	None	No	No
LR	248	36	241	35	9	11	Sidewall abraded	No	No
RR	241	35	241	35	8	10	None	No	No
RF	241	35	241	35	6	8	None	No	No

Vehicle Interior: The inspection of the Ford's interior revealed a small possible occupant contact scuff from the driver's right knee on the knee bolster. A small blood stain was present at the bottom of the left side curtain air bag adjacent to the driver's seat back. This appeared to be a blood drop and not an occupant contact mark. The rearview mirror was displaced upward, possibly due to contact by the driver's right hand during the crash. The forward upper quadrant of the left front door intruded 4 cm (1.6 in) laterally into the left front occupant space. There were no other intrusions. There was no evidence of steering rim deformation or compression of the energy absorbing steering column. The left front door was jammed closed while the other doors remained closed and operational, and all the window glazing was either fixed or closed. The left front window glazing was disintegrated from impact forces and there was no damage to the remaining glazing.

CONFORMANCE WITH FMVSS 305, SECTION 571, ELECTRIC POWERED VEHICLES

The Ford's propulsion battery was located in the cargo area under the carpet (**Figure 9**). The battery pack consisted of 50 battery modules, each comprised of five, 1.3 volt NiMH batteries sealed in a water resistant stainless steel case. The battery cells contained a base electrolyte consisting of potassium hydroxide as the dominant active ingredient, which is absorbed in a special paper. The electrolyte will not leak from the battery under most conditions; however, if the battery is crushed, it is possible for a small amount of electrolyte to leak[1]. Inspection of the propulsion battery revealed no evidence of movement or damage. The battery was equipped with a high voltage service disconnect switch, which was located on the top right of the battery pack (**Figure 10**). At inspection, the switch was in the locked position. The high voltage wiring connector was located on the front right of the battery (**Figure 11**). It was undamaged and exhibited no evidence of displacement within the socket. Examination of the DC/DC converter (**Figure 12**) and the associated wiring and connectors (that were accessible) revealed no evidence of electrical arcing or melting of components. The vehicle was equipped with an inertia activated high voltage shut off switch, which was located in the jack storage compartment within the passenger side cargo area (**Figure 13**). The switch opened in the crash and disabled the high

[1] Source: Ford Escape Hybrid/Mariner Hybrid Emergency Response Guide

voltage system. See the attachment at the end of this report, which illustrates the location and identification of the Ford's hybrid components.

Figure 9: The Ford's propulsion battery pack

Figure 10: The high voltage service disconnect switch; switch in the locked position at the inspection

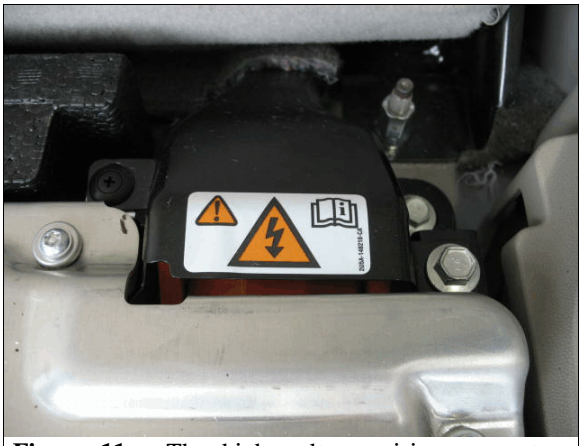


Figure 11: The high voltage wiring connector located at front right corner of the propulsion battery

Figure 12: Arrow shows the DC/DC converter located on the right side of the engine compartment

AUTOMATIC RESTRAINT SYSTEM

The Ford was equipped with a Certified Advanced 208-Compliant (CAC) frontal air bag system that consisted of dual stage driver and front right passenger air bags, seat position sensors, seat belt usage sensors, retractor and seat belt buckle mounted pretensioners and a front right passenger presence sensor. The frontal air bag sensor was located on the center radiator support. The manufacturer has certified that the vehicle is compliant to the Advanced Air Bag portion of the Federal Motor Vehicle Safety Standard (FMVSS) No. 208.

The Ford's driver air bag was located within the steering wheel hub and the front right passenger air bag was located within the middle of the right instrument panel. The vehicle did not sustain a frontal impact and neither of these air bags deployed in this crash.

The vehicle was also equipped with a safety canopy side curtain air bag system with rollover sensor and seat back-mounted side impact air bags. Based on the Holmatro Rescuer's Guide to Vehicle Safety Systems, the side impact sensors were located within the lower B-pillar and mid C-pillar. The rollover sensor was located within the vehicle's Restraint Control Module (RCM).

The Ford's side curtain air bags were located along the roof side rails inside the headliner, and extended along the each side of the vehicle from the A-pillar to the C-pillar (**Figure 14**). Each deployed air bag was 145 cm (57.1 in) in length and 45 cm (17.7 in) in height. Each air bag was anchored to the A-pillar by a cloth cord 37 cm (14.6 in) in length and to the C-pillar by a cloth cord 7 cm (2.8 in) in length. There was a 30 cm (11.8 in) wide gap between the leading edge of each air bag and the A-pillar (**Figure 15**). The side curtain air bags were designed with inflation chambers adjacent to each outboard seat position and did not have external vent ports. The left side curtain air bag had a few small abrasions on its outboard surface due to flying glass fragments when the left front window glazing disintegrated during the rollover. The right side curtain air bag was unremarkable.

The seat back-mounted side impact air bags were located within the outboard side of the front seat backs. These air bags did not deploy in this crash.

Figure 13: Arrow shows the inertia activated high voltage shut off switch located in the jack compartment

Figure 14: The left side curtain air bag

MANUAL RESTRAINT SYSTEM

The Ford was equipped with lap-and-shoulder belts in the two front and three second row seating positions. The driver's seat belt consisted of continuous loop belt webbing, an adjustable upper anchor, retractor-mounted and seat belt buckle-mounted pretensioners, sliding latch plate, an Emergency Locking Retractor (ELR), and an adjustable upper anchor that was located in the full up position. The front right seat belt was similarly equipped but had a switchable ELR/Automatic Locking Retractor (ALR). The three second row seat belts consisted of continuous loop belt webbing, sliding latch plates, switchable ELR/ALRs, and fixed upper anchors.

Inspection of the left front seat belt assembly revealed evidence of occupant loading, which consisted of minor abrasions on the D-ring and plastic transfer on the belt webbing (**Figure 16**). The transfer was located 54 cm (21.3 in) above the stop button, which indicated the source of the transfer was the sliding latch plate. Both pretensioner's actuated and the buckle-mounted pretensioner was reduced 3 cm (1.2 in). The evidence indicated that the driver was restrained by the lap-and-shoulder belt at the time of the crash. The remaining seat positions were unoccupied.

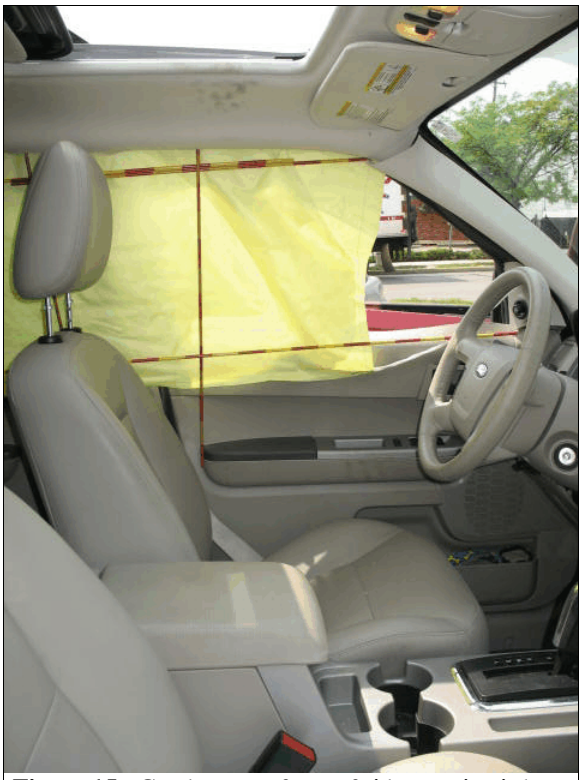


Figure 15: Gap between front of side curtain air bag and left A-pillar

Figure 16: Plastic transfer from the sliding latch plate on the driver's seat belt webbing

CASE VEHICLE DRIVER KINEMATICS

The Ford's driver [54-year-old, female; 163 cm and 68 kg (64 in, 150 lbs)] was seated in an upright posture with her back against the seat back. She had both hands on the steering wheel at the 10 and 2 clock positions and her right foot on the accelerator. The driver's seat track was located between the middle and full rear position and the seat back was slightly reclined. The head restraint was adjusted one detent (of four) below the full up position. The tilt steering wheel was located in its full up position. The driver was wearing glasses at the time of the crash.

The Ford's right side impact with the Oldsmobile displaced the driver forward and to the right opposite the 1 o'clock direction of principal force. The driver loaded the seat belt and her right knee possibly contacted and scuffed the knee bolster. As the vehicle rotated clockwise and began to roll over left side leading, the driver was redirected to the left. Although there was no occupant contact evidence on the left side curtain air bag, the left side of her torso and head probably contacted it when the vehicle rolled onto its left side. The driver's right hand also possibly contacted the rear view mirror during the crash.

CASE VEHICLE DRIVER INJURIES

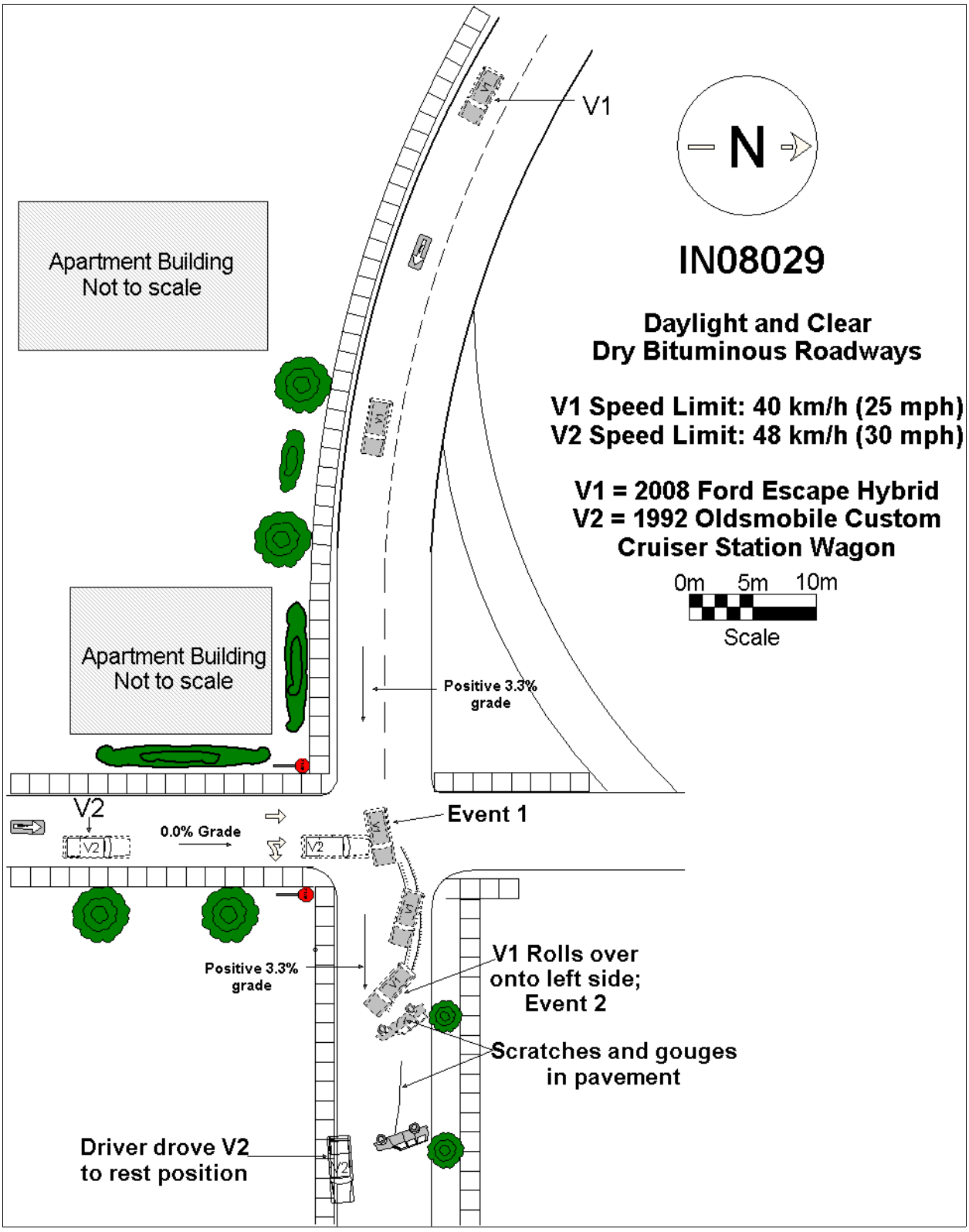
The police crash report indicated that the driver complained of pain to her neck, but she refused medical assistance at the scene.

The 1992 Oldsmobile Custom Cruiser was a rear wheel drive, 4-door station wagon equipped with a 5.7L, V8 engine and four-speed automatic transmission. The vehicle identification number was not listed on the police crash report.

Exterior Damage: The Oldsmobile's impact with the Ford involved the front plane. The front bumper, end of the left fender, hood, and left headlamp/turn signal assembly were directly damaged (**Figure 4**). The induced damage involved the left fender, hood and the grille.

Damage Classification: Based on the police photographs, the Oldsmobile's CDC was estimated to be **10-FYEW-1** (**290** degrees). The Missing Vehicle algorithm of the WinSMASH program calculated the Oldsmobile's Delta V as 6 km/h (3.7 mph). The longitudinal and lateral components were -2 km/h (-1.2 mph) and 6 km/h (3.7 mph), respectively. The results are borderline because they are based only on the crush to the Ford.

Oldsmobile's Driver: According to the police crash report, the Oldsmobile's driver [37-year-old, male] was restrained by the lap-and-shoulder seat belt.


V1
N
Apartment Building
Not to scale
IN08029
Daylight and Clear
Dry Bituminous Roadways
V1 Speed Limit: 40 km/h (25 mph)
V2 Speed Limit: 48 km/h (30 mph)
V1 = 2008 Ford Escape Hybrid
V2 = 1992 Oldsmobile Custom
Cruiser Station Wagon
0m 5m 10m
Scale
Apartment Building
Not to scale
Positive 3.3%
grade
V2
0.0% Grade
Event 1
Positive 3.3%
grade
V1 Rolls over
onto left side;
Event 2
Scratches and gouges
in pavement
Driver drove V2
to rest position

HYBRID COMPONENT LOCATION AND IDENTIFICATION

This chart provides the location, description and basic function of the Hybrid system components. Refer to the Hybrid Component Location illustration on the following page.

	COMPONENT	LOCATION / DESCRIPTION	FUNCTION
1	High-Voltage Shut-Off Switch	• Located in the jack stowage compartment, passenger side in the cargo area.	Disconnects high-voltage battery in the event of a collision.
2	High-Voltage Service Disconnect Switch	• Located on top of the high-voltage battery, passenger side in the cargo area under carpet. • Orange in color with molded plastic handle, about 100 mm (4 inch) in diameter.	Provides means to disconnect high-voltage battery for safely servicing vehicle.
3	High-Voltage Battery — 300+ Volts	• Located in the cargo area under carpet. • Sealed nickel-metal hydride.	Provides high-voltage storage (300+ V) for vehicle propulsion requirements.
4	High-Voltage Wiring	• Runs along underside of vehicles cab floor from high-voltage battery to electronically controlled continuously variable transaxle (eCVT) then to DC-to-DC converter. • All high-voltage wiring has orange-colored insulation.	Provides physical path for high-voltage circuitry.
5	12-Volt Battery	• Located under the hood on driver side of the vehicle. • Typical automotive 6-cell lead/acid design.	Provides 12-volt power for vehicle accessories.
6	Electronically Controlled Continuously Variable Transaxle (eCVT)	• Transverse-mounted design similar to the non-Hybrid Escape/Mariner vehicles. • Contains the traction motor, generator motor and Hybrid electronics.	Provides delivery of power to wheels for vehicle propulsion, generates electricity to recharge the batteries during braking and coasting, and contains certain Hybrid electronics.
7	DC/DC Converter	• Located under the hood on the passenger side forward of the strut tower.	Provides 12 volts of power to charge the 12-volt battery and run vehicle accessories.
8	Fuel Shut-Off Inertia Switch	• Located behind the flip-up panel in the passenger front foot well.	Disables power supply to the gasoline fuel pump and the HV shut-off switch in the event of a collision.

NOTE: All high-voltage wires and harnesses are wrapped in orange-colored insulation.

Hybrid Component Location