INDIANA UNIVERSITY

TRANSPORTATION RESEARCH CENTER
School of Public and Environmental Affairs
222 West Second Street Suite A
Bloomington, Indiana 47403-1501
(812) 855-3908 Fax: (812) 855-3537

ON-SITE ROLLOVER INVESTIGATION

CASE NUMBER - IN08018
LOCATION - MICHIGAN
VEHICLE - 2007 SUBARU FORESTER
CRASH DATE - January 2008

Submitted:

July 29, 2008
Revised: August 15, 2008

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.* IN08018	2. *Government Accession No.*	3. *Recipient's Catalog No.*	
4. *Title and Subtitle* On-Site Rollover Investigation Vehicle - 2007 Subaru Forester Location - Michigan		5. *Report Date:* August 15, 2008 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: January 2008 14. *Sponsoring Agency Code*	
15. *Supplementary Notes* On-site rollover investigation involving a 2007 Subaru Forester.			
16. *Abstract* This report covers an on-site rollover investigation that involved a 2007 Subaru Forester. This crash is of special interest because the Subaru was involved in a rollover event. The Subaru was traveling west on a two lane county roadway and was negotiating a left curve. It contacted a patch of ice and began to rotate counterclockwise. The driver steered right and the vehicle rotated clockwise and departed the north side of the road. The vehicle entered a ditch and the front plane impacted a culvert. The left front wheel loaded into the embankment and tripped the vehicle, and it rolled over six quarter turns with the left side leading. As the vehicle was on it's top, the back end impacted an evergreen tree and it came to final rest heading southeast. The restrained driver was not ejected and was not injured.			
17. *Key Words* Rollover Ejection 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* 7	22. *Price*

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

TABLE OF CONTENTS

IN08018

This crash was brought to the National Highway Traffic Safety Administration's attention on or before March 7, 2008 through the sampling activities of the National Automotive Sampling System. The crash involved a 2007 Subaru Forester (**Figure 1**) that ran off the road, impacted a culvert, and rolled over. The crash occurred in January, 2008, at 19:15 hours, in Michigan and was investigated by the applicable county sheriff's department. This crash is of special interest because the Subaru was involved in a rollover event. This contractor inspected the vehicle and scene on May 6 and 7, 2008. The driver interview was completed on May 20, 2008. This report is based on the police crash report, scene and vehicle inspections, inspection of an exemplar vehicle, driver interview, occupant kinematic principles and this contractor's evaluation of the evidence.

Figure 1: The 2007 Subaru Forester

SUMMARY

The crash occurred during dark evening hours under conditions of light snow and dry pavement with patches of ice. The Subaru was traveling west on a two lane county roadway and was negotiating a left curve. It contacted a patch of ice and began to rotate counterclockwise. The driver steered right and the vehicle rotated clockwise and departed the north side of the road. The vehicle entered a ditch and the front plane impacted a culvert. The left front wheel loaded into the embankment and tripped the vehicle, and it rolled over six quarter turns with the left side leading. As the vehicle was on it's top, the back end impacted an evergreen tree and it came to final rest heading southeast. The Delta V for the front impact was 14.0 km/h (8.7 mph) and the severity of the rollover damage was moderate based on the extent of the crush to the roof. The restrained driver was not ejected and was not injured.

CRASH CIRCUMSTANCES

Crash Environment: The trafficway on which the Subaru was traveling was a curved, two-lane, undivided, rural roadway, traversing in a nominal east-west direction. Each travel lane was 3.5 meters (11.5 feet) in width and was bordered by gravel shoulders. The south shoulder was 0.9 meters (3 feet) in width and the north shoulder was 1.2 meters (4 feet) in width. The roadway pavement markings consisted of double yellow solid no passing lines and solid white edge lines. A curve warning sign was posted for each travel direction, and the posted speed limit was 88 km/h (55 mph). At the time of the crash, it was dawn, the atmospheric condition was light snow, the roadway pavement was dry bituminous with patches of ice and a negative 1.5% grade. Given the rural location and time of day, there was presumably little or no other traffic. See the Crash Diagram at the end of this report.

Pre-Crash: The Subaru was traveling west (**Figure 2**) at a driver estimated speed of 88 to 97 km/h (55 to 60 mph). The driver was intending to continue westbound and was negotiating a left curve. The driver stated during the interview that as the vehicle exited the curve, it contacted a patch of ice and began to rotate counterclockwise. The driver steered right and the vehicle began rotating clockwise and departed the north side of the road (**Figure 3**) where the crash occurred.

Figure 2: Subaru's approach to crash scene; number on roadway indicates meters to impact area

Crash: The Subaru entered a ditch and the front plane (**Figure 4**) impacted a culvert. The left front wheel loaded into the embankment and tripped the vehicle, and it rolled over six quarter turns with the left side leading. As the vehicle was on it's top, the back plane (**Figure 5**) impacted an evergreen tree and it came to final rest heading southeast with the back end against the evergreen tree (**Figure 6**). The vehicle traversed a distance of 11 meters (36.1 feet) from the area of rollover initiation to final rest.

Figure 3: Arrow shows location of initial impact with culvert and area of rollover initiation

Figure 4: Damage to front of Subaru from impact with the culvert; scale numbers in tenths of meter

Figure 5: Back end damage from impact with tree (shown by arrows)

Figure 6: Area of initial impact (left arrow) and final rest (right arrow)

Post-Crash: A passer-by opened the left front door and the driver exited the vehicle. The sheriff's department was notified of the crash and a deputy responded to the scene. No emergency medical personnel responded to the scene and the driver was not transported to a hospital. The Subaru was towed from the scene due to damage.

CASE VEHICLE

The 2007 Subaru Forester was an all wheel drive, 4-door, station wagon (VIN: JF1SG63677G------), equipped with a 2.5L, 4-cylinder engine and 5-speed manual transmission. The vehicle was also equipped with 4-wheel anti-lock brakes, dual stage frontal air bags, front seat back-mounted side impact air bags and driver and front right passenger retractor mounted seat belt pretensioners and active head restraints. The front right passenger seat was equipped with an occupant weight detection system. The vehicle's supplemental restraint system was certified by the manufacturer to be compliant to the Advanced Air Bag portion of the Federal Motor Vehicle Safety Standard (FMVSS) No. 208.

CASE VEHICLE DAMAGE

Exterior Damage: The Subaru's impact with the culvert involved the front plane. The vehicle's plastic bumper cover sustained the direct damage and the underlying bumper bar was crushed rearward. The direct damage began at the left corner of the bumper cover and extended 149 centimeters (58.7 inches) across the lower portion of the bumper cover. The crush measurements were taken on the bumper bar (this is the reason the field L is less than the damage width) and the residual maximum crush was 4 centimeters (1.8 inches) occurring at C_3. The table below presents the vehicle's front 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	149	4	126	0	3	4	2	3	0	0	0
in		58.7	1.6	49.6	0.0	1.2	1.6	0.8	1.2	0.0	0.0	0.0

The damage from the rollover involved the top plane and both side planes of the Subaru (**Figures 7** and **8**). The direct damage on the left side included scratches on the A-pillar, front and back doors, quarter panel and deformation of the left rear wheel and suspension (Figure **9**). The direct damage on the right side involved the right fender, A and B-pillars, and the front and back doors. Both left and right side view mirrors were broken off the vehicle and the roof, roof side rails, luggage rack, windshield header, and windshield were also directly damaged. The maximum vertical crush occurred at the right windshield header (**Figures 10**), and based on the vehicle inspection and measurements from an exemplar vehicle, the crush was 12 centimeters (4.7 inches, **Figure 11**). There was no measurable lateral crush to the roof side rails or A pillars. The vehicle's left wheelbase was reduced 25 centimeters (9.8 inches) and the right wheelbase was extended 2 centimeters (0.79 inch).

Figure 7: Front right view of the front damage and damage from the rollover

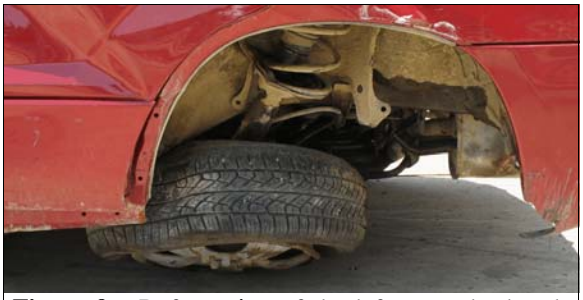


Figure 9: Deformation of the left rear wheel and suspension from the rollover

Figure 8: Damage to the left side from the rollover

Figure 10: Crush to the windshield header and roof from the rollover

Figure 11: The maximum vertical crush to the windshield header; each increment on rods is 5 cm (2 in)

The Subaru's impact with the evergreen tree involved the back plane. The direct damage began 24 centimeters (9.4 inches) right of the left rear bumper corner and extended 21 centimeters (8.3 inches) across the back bumper. The maximum residual crush was 2 centimeters occurring at C_2. Only the bumper cover and upper spoiler (above the backlight) were directly damaged. The induced damage involved the back bumper and hatch. The table below presents the back 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	3	21	2	150	0	2	0	0	0	0	-46	0
in		8.3	0.8	59.1	0.0	0.8	0.0	0.0	0.0	0.0	-18.1	0.0

Damage Classification: The Collision Deformation Classifications (CDCs) for the Subaru were **12-FDLW-1** (**0** degrees) for the front impact with the culvert, **00-TDDO-3** for the rollover, and **00-BLAN-1** for the back end impact with the evergreen tree. The WinSMASH reconstruction program, Barrier Algorithm was used to reconstruct the Subaru's Delta V for the front impact. The total Delta V was 14.0 km/h (8.7 mph), and the longitudinal and lateral components were

-14.0 km/h (-8.7 mph) and 0 km/h, respectively. The severity of the rollover damage was moderate based on the extent of the crush to the roof. Non-horizontal impacts are out of the scope of the WINSMASH reconstruction program and no Delta V could be calculated for the back impact.

The vehicle manufacturer's recommended tire size was P215/60R16 and the vehicle was equipped with the recommended size tires. The vehicle's tire data are shown in the table below.

Tire	*Measured Pressure*		*Vehicle Manufacturer's Recommended Pressure*		*Tread Depth*		*Damage*	*Restricted*	*Deflated*
	kPa	psi	kPa	psi	milli-meters	32nd of an inch			
LF	221	32	200	29	6	8	None	No	No
LR	Flat	Flat	200	29	6	8	Bead separation	Yes	Yes
RR	228	33	193	28	6	8	None	No	No
RF	234	34	193	28	6	7	None	No	No

Vehicle Interior: Evidence of occupant contact was found on the wiper control lever, which was broken off the steering column, probably as a result of contact with the driver's right hand. There were several intrusions of the passenger compartment. The most severe intrusion involved the roof mounted console, which intruded 26 centimeters (10.2 inches) vertically into the front center sector (**Figure 12**). The interior roof structure also intruded vertically 14 centimeters (5.5 inches) into the front left sector, 15 centimeters (5.9 inches) into the front center sector and 16 centimeters (6.3 inches) into the front right sector. There was no evidence of steering rim deformation or compression of the energy absorbing steering column.

Figure 12: Driver's seating area and intrusion of the roof mounted console and roof

AUTOMATIC RESTRAINT SYSTEM

The Subaru's driver air bag was located in the steering wheel hub and the front right passenger air bag was located in the middle of the right instrument panel. Neither air bag deployed in the crash.

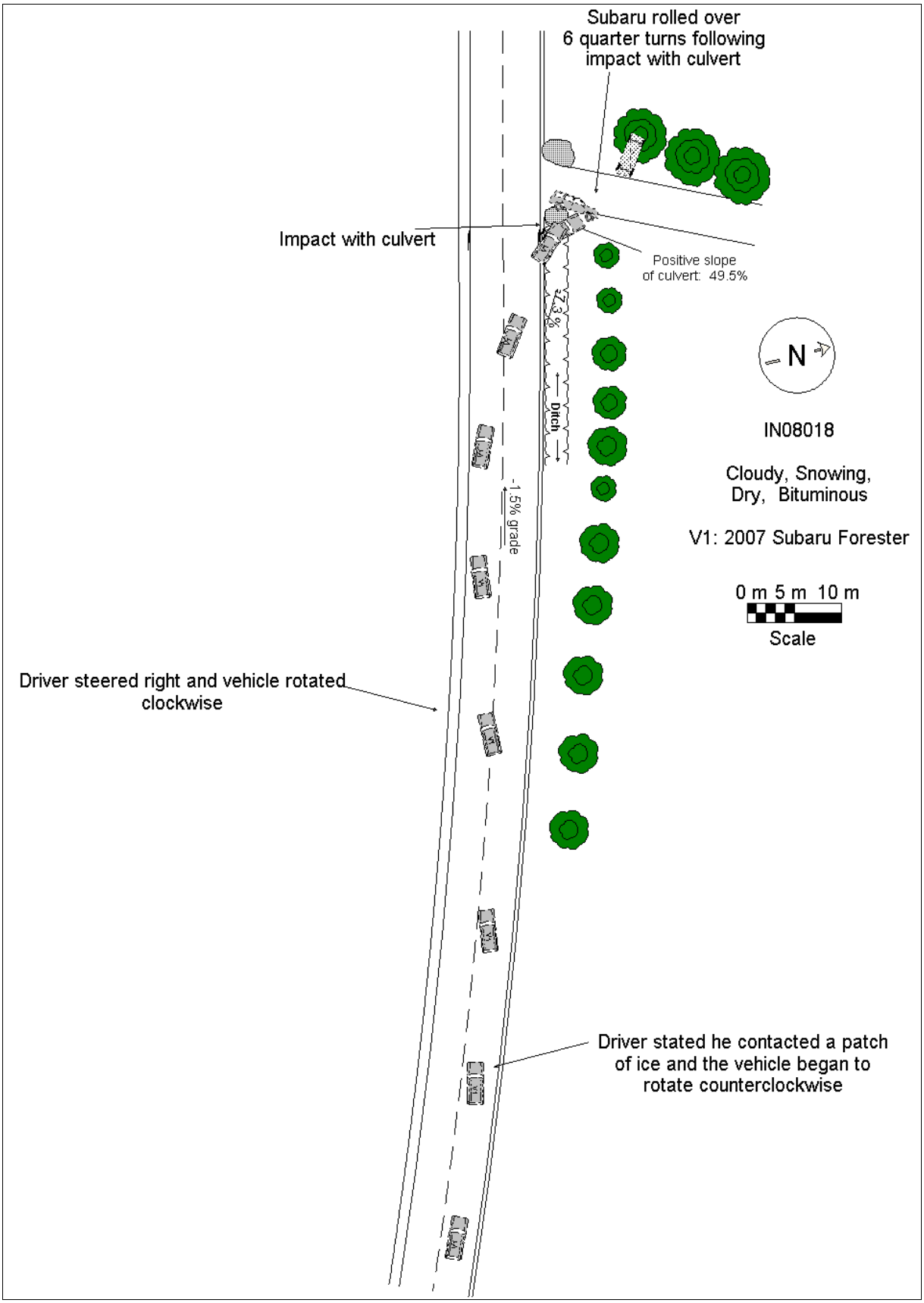
The driver [57-year-old, male; 175 centimeters and 73 kilograms (69 inches and 160 pounds)] stated during the interview that he was seated in an upright posture with his hands on the steering wheel, but in an unknown position. His right foot was on the brake and his left foot was on the floor. The seat track was adjusted to between the middle and rear most position, the seat back was slightly reclined, and the tilt steering wheel was located between the middle and full up position. The driver was not wearing glasses or contact lenses at the time of the crash.

The driver was wearing the lap belt low on his hips and the shoulder belt over his left shoulder across the collarbone and was suspended upside down by the seat belt following the crash. The seat belt usage could not be independently verified because inspection of the seat belt assembly revealed no evidence of loading.

The Subaru's front impact with the culvert displaced the driver forward opposite the 0 degree direction of principal force. As the Subaru rolled over, the driver was displaced to the left and toward the roof within the seat belt. During the rollover his right hand or arm probably contacted the turn signal lever and broke it off the steering column.

CASE VEHICLE DRIVER INJURIES

The driver sustained no injuries as a result of the crash.


Subaru rolled over
6 quarter turns following
impact with culvert
Impact with culvert
Positive slope
of culvert: 49.5%
2.3 %
Ditch
-1.5% grade
N
IN08018
Cloudy, Snowing,
Dry, Bituminous
V1: 2007 Subaru Forester
0 m 5 m 10 m
Scale
Driver steered right and vehicle rotated
clockwise
Driver stated he contacted a patch
of ice and the vehicle began to
rotate counterclockwise