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ON-SITE ROLLOVER INVESTIGATION

CASE NUMBER - IN08041
LOCATION - MISSOURI
VEHICLE - 2007 CHEVROLET UPLANDER LS
CRASH DATE - October 2008

Submitted:

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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

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16. <i>Abstract</i> This report covers an On-Site Rollover Investigation that involved a 2007 Chevrolet Uplander LS, which departed the roadway and rolled over. The focus of this on-site investigation was the Chevrolet's rollover. The Chevrolet's unrestrained 26-year-old female driver was traveling south negotiating a left curve. The right side tires departed the right side of the roadway and the driver initiated a left steering maneuver. The vehicle reentered the roadway and began rotating counterclockwise (CCW). The vehicle departed the left side of the roadway and the frontal plane impacted an embankment. The vehicle continued to rotate CCW as it traveled up the embankment and it tripped and rolled over, right side leading. During the rollover, the left front window glazing disintegrated and the driver was completely ejected through the left front window opening. The driver sustained moderate injuries and was transported by ambulance and hospitalized for one day.					
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The focus of this on-site investigation was the rollover of a 2007 Chevrolet Uplander LS. This crash was brought to the National Highway Traffic Safety Administration's attention on October 17, 2008 by this contractor following a review of the Missouri State Highway Patrol Online Traffic Crash Reports website. This investigation was assigned on November 10, 2008. The crash involved a 2007 Chevrolet Uplander LS (**Figure 1**), which departed the roadway, impacted an embankment, and rolled over. The crash occurred in October 2008 at 1450 hours, in Missouri and was investigated by the Missouri State Highway Patrol. This contractor inspected the crash scene and the vehicle, and interviewed the driver on November 11, 13, and 16, 2008. This report is based on the police crash report, scene and vehicle inspections, exemplar vehicle inspection, an interview with the Chevrolet's driver, occupant kinematic principles, and this contractor's evaluation of the evidence.



Figure 1: The damaged 2007 Chevrolet Uplander LS

CRASH CIRCUMSTANCES

Crash Environment: The trafficway on which the Chevrolet was traveling was a 2-lane, undivided state highway that traversed in a north-south direction. The trafficway had one travel lane in each direction and was curved left on the Chevrolet's southerly travel direction. The south lane was 3.1 m (10.2 ft) in width and the north lane was 3.4 m (11.2 ft) in width. The roadway was bordered by grass shoulders 1.6 m (5.3 ft) in width. The roadway had a positive 3% grade 92 m (301.8 ft) prior to the area of the Chevrolet's final roadway departure, which became a negative 1% grade 15 m (49.2 ft) prior to the area of final roadway departure. The roadway's radius of curvature was 225 m (738 ft) and the curve had a positive 3% superelevation to the west. The roadway pavement markings consisted of solid white edge lines and double yellow center lines. The posted speed limit was 80 km/h (50 mph). At the time of the crash the light condition was daylight, the atmospheric condition was cloudy, and the roadway was wet bituminous. The traffic density was light and the site of the crash was rural. See the Crash Diagram on page 9 of this report.

Pre-Crash: The Chevrolet's unrestrained 26-year-old female driver was traveling south negotiating a left curve (**Figure 2**) at the driver's estimated speed of 64-80 km/h (45-50 mph). The driver stated during the SCI interview that the right side tires departed the right (west) side of the roadway and she initiated a left steer maneuver. She had no recollection of applying the brakes. The driver



Figure 2: Southbound approach of the Chevrolet; number on pavement shows feet to area roadway departure to the rollover (arrow)

stated that as the vehicle reentered the roadway, the right front axle broke causing her to lose control of the vehicle. She had no memory of what occurred next. There was no evidence to support the right front axle breaking on the roadway. The inspection of the Chevrolet revealed a broken right front steering arm; however, this damage occurred during the rollover. The dirt embedded in the right front wheel and a wheel-shaped divot on the ground in the path of the rollover indicated that the steering arm broke when the right front wheel impacted the ground during the rollover. The tire mark evidence in the grass (**Figure 3**) just prior to the area of rollover initiation indicated that the vehicle was in a counterclockwise (CCW) yaw when it departed the left (east) side of the roadway just prior to the rollover.

Crash: After the Chevrolet departed the left side of the roadway, it continued to rotate CCW and traveled 6 m (19.7 ft) down a 20% grade into a ditch. The vehicle had rotated CCW approximately 40 degrees from its initial southerly heading on the roadway when the front plane (**Figure 4**) impacted an embankment (**Figure 5**, event 1). The vehicle continued to rotate CCW as it traveled up the embankment and it tripped and rolled over, right side leading (event 2). The left front window glazing was disintegrated during the rollover and the driver was fully ejected out of the left front window opening. She was thrown clear of the vehicle in a southerly direction. The vehicle rolled over a total of 6 quarter turns across a distance of approximately 16 m (52.5 ft) and came to final rest on its top heading northeast (**Figure 6**). The driver came to final rest on top of the embankment (**Figure 6**) 9.5 m (31 ft) south of the final rest position of the vehicle. She was oriented parallel to the roadway with her head toward the south.

Post-Crash: A passer-by called 911 and the Missouri State Highway Patrol was notified of the crash at 1452 hours and arrived on scene at 1510 hours. Emergency medical personnel also



Figure 3: Chevrolet's approach to departure of east side of roadway with arrows (left to right) showing left front tire mark, right front tire mark, and right rear tire mark



Figure 4: Damage to lower portion of Chevrolet's front bumper from impact with the embankment

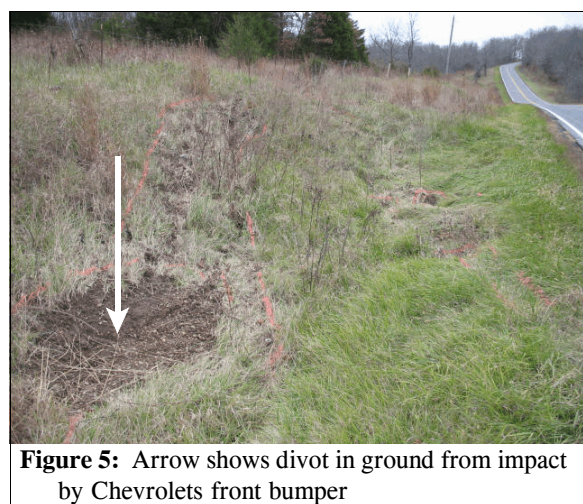


Figure 5: Arrow shows divot in ground from impact by Chevrolet's front bumper

responded to the scene. The driver was transported by ambulance to a hospital and the Chevrolet was towed from the scene due to damage.

ROLLOVER DISCUSSION

The Chevrolet was not equipped with Electronic Stability Control (ESC), a rollover sensor, or side curtain air bags. No rollover rating information was available for this vehicle.

Following the frontal impact with the embankment, the vehicle continued to rotate CCW as it traveled approximately 10 m (32.8 ft) up the embankment's positive 25% grade. The force between the ground and the right side wheels was sufficient to induce a rollover and the vehicle tripped and rolled over, right side leading. The vehicle landed on the left portion of the roof and left roof side rail (Figure 1) during the second quarter turn. This ground impact (Figure 7) disintegrated the left front and left rear window glazing and displaced the unrestrained driver to the left and toward the top of the left front door. A deposit of hair on the top of the left front window frame indicated that the driver's head contacted the top of the left front window frame. She was completely ejected out of the left front window opening as the vehicle continued to roll over. The scene evidence and damage to the vehicle indicated that it rolled over a total of 6 quarter turns across a distance of approximately 16 m (52.5 ft) and came to final rest on its top heading northeast.

CASE VEHICLE

The 2007 Chevrolet Uplander LS was manufactured in December 2006 and was a front wheel drive, 4-door, all purpose vehicle (VIN: 1GNDV231X7D-----) equipped with a 3.9L, V6 engine, automatic transmission, and 4-wheel anti-lock disc brakes. The front row was equipped with box-mounted bucket seats with folding backs, adjustable head restraints, dual stage driver and front right passenger frontal air bags, and lap-and-shoulder belts. The second row was equipped with two removable modular bucket seats with folding backs, adjustable head restraints, and lap-and-shoulder belts. The third row was equipped with a 50/50 split bench with folding backs, fixed head restraints in the outboard seating positions and lap-and-shoulder belts. The vehicle was also



Figure 6: Final rest position of Chevrolet; arrow on right shows deposit of tinted, tempered glass fragments from the backlight; arrow on left shows area where driver came to rest



Figure 7: Impression on the ground where left portion of roof and left roof side rail touched down during second quarter turn; left arrow shows area of tempered glass fragments from left front window; right arrow shows area of tinted, tempered glass fragments from left rear window

equipped with Lower Anchors and Tethers for Children (LATCH) in the second row seating positions and an Event Data Recorder (EDR). The vehicle was not equipped with seat back-mounted side impact air bags, side curtain air bags, traction control, a rollover sensor, or ESC. The vehicle’s mileage at the time of the inspection could not be determined because the vehicle was without power and equipped with an electronic odometer. The driver estimated the vehicle’s mileage was approximately 56,326 kilometers (35,000 mile). The vehicle’s specified wheelbase was 307 cm (121 in).

CASE VEHICLE DAMAGE

Exterior Damage: The damage from the impact with the embankment involved the full width of the front bumper (Figures 8 and 9). The lower portion of the front bumper was directly damaged and grass and mud were embedded in the lower frame and coils of the radiator. The direct damage began at the front left bumper corner and extended 146 cm (57.4 in) across the bumper. The residual maximum crush was 2 cm (0.8 in) and occurred at C₆. The table below shows 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	146	2	146	0	0	0	0	1	2	0	0
in		57.5	0.8	57.5	0.0	0.0	0.0	0.0	0.4	0.8	0.0	0.0

The damage from the rollover involved the top plane, both side planes (Figures 1 and 8), and the undercarriage of the vehicle. The direct damage on the top plane began 74 cm (29.1 in) forward of the left front axle and extended 381 cm (150 in) rearward, and involved the full width of the top, 116 cm (45.7 in). The direct damage on the right side plane began 94 cm (37 in) rear of the right rear axle and extended 478 cm (188.2 in) forward along the right side. The direct damage on the left side plane began at the left front axle and extended 400 cm (157.5 in) rearward along the left side. The maximum residual vertical and lateral crush occurred on the left roof side rail (Figures 9 and 10) and was located 200 cm (78.7 in) rear of the left front axle. The maximum vertical crush was 20 cm (7.9 in) while the maximum lateral crush was 26 cm (10.2 in).



Figure 8: Front right view of damage to the Chevrolet from the rollover and embankment impact

The vehicle’s right side wheelbase was reduced 6 cm (2.4 in) while the left side wheelbase was extended 1 cm (0.4 in). The induced damage involved the both fenders, both front doors, the rear hatch, and back bumper.

Damage Classification: The Chevrolet’s Collision Deformation Classifications were **01-FDEW-1** (40 degrees) for the front impact with the embankment (event 1), and **00-TDDO-3** for the rollover (event 2). The Barrier algorithm of the WinSMASH program calculated the Total Delta V for the frontal impact as 9 km\h (5.6 mph). The longitudinal and lateral velocity changes were -7 km\h (-4.3 mph) and -6 km\h (-3.7 mph), respectively. The severity of the rollover damage was moderate based on the extent of the crush to the top plane.

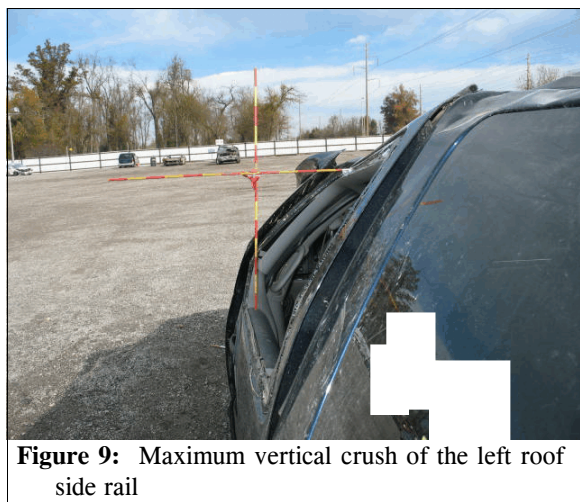


Figure 9: Maximum vertical crush of the left roof side rail

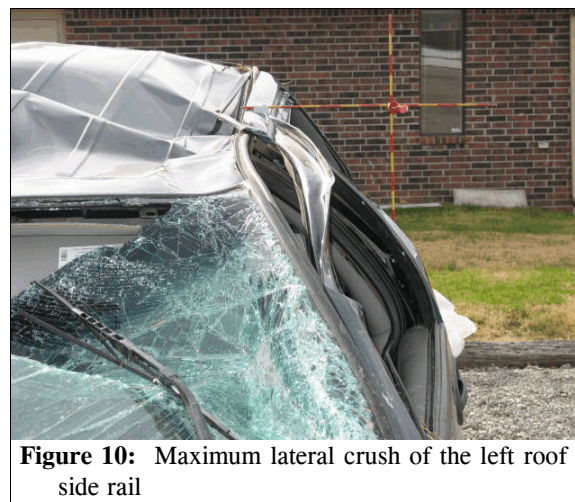


Figure 10: Maximum lateral crush of the left roof side rail

The vehicle manufacturer’s recommended tire size was P225/60R17. The Chevrolet was equipped with tires of the recommended size. The vehicle’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	32 nd of an inch			
LF	214	31	241	35	6	8	None	No	No
LR	207	30	241	35	5	6	None	No	No
RR	207	30	241	35	6	7	None	No	No
RF	Flat	Flat	241	35	6	7	Bead separated	Yes	Yes

Vehicle Interior: The inspection of the Chevrolet’s interior revealed a deposit of hair embedded in the top of the left front window frame. The evidence indicated that the driver contacted her head on the window frame during the rollover, and supported the disintegrated left front window as the driver’s path of ejection. No other discernable evidence of occupant contact was located within the vehicle.

The vehicle’s passenger compartment sustained 19 intrusions. The most severe intrusion occurred in the second row left and involved the left roof side rail, which intruded laterally 26 cm

(10.2 in) and vertically 20 cm (7.9 in). The most severe intrusion in the driver's occupant space also involved the left roof side rail, which intruded laterally 17 cm (6.7 in) and vertically 11 cm (4.3 in).

The left front and right rear doors remained closed and operational, while the right front, left rear and tailgate were jammed shut. The pre-crash condition of all of the window glazing was either closed or fixed. The left front, left rear, second right rear, and backlight glazing were disintegrated. The windshield glazing was in place and cracked from impact forces, although it had sagged and separated along the windshield header due to weathering.

EVENT DATA RECORDER

The Chevrolet's EDR was not downloaded. When permission to inspect the vehicle was obtained from the insurance company representative, he stipulated that the imaging of the EDR was not permitted.

AUTOMATIC RESTRAINT SYSTEM

The Chevrolet was equipped with a Certified Advanced 208-Compliant (CAC) frontal air bag system that was certified by the manufacturer to be compliant to the Advanced Air Bag portion of the Federal Motor Vehicle Safety Standard (FMVSS) No. 208. The driver air bag was located within the steering wheel hub and the front right passenger air bag was located within the top of the instrument panel.

MANUAL RESTRAINT SYSTEM

The Chevrolet was equipped with lap-and-shoulder belts for all the seating positions. The driver's seat belt consisted of continuous loop belt webbing, an Emergency Locking Retractor (ELR), a sliding latch plate, and an adjustable upper anchor that was located in the middle position. The front right seat belt was equipped with continuous loop belt webbing, a switchable ELR/Automatic Locking Retractor (ALR), a sliding latch plate, and an adjustable upper anchor that was located in the full-down position. The seat belts in the remaining seating positions were equipped with continuous loop belt webbing, switchable ELR/ALRs, sliding latch plates, and fixed upper anchors. The driver and front right passenger seat belts were equipped with retractor-mounted pretensioners, which did not actuate in the crash.

Inspection of the driver's seat belt assembly revealed some historic usage scratches on the latch plate but no evidence of loading was found on the seat belt webbing, D-ring or latch plate belt guide. Deposits of lint, dust, and hair were present on the D-ring under the belt webbing (**Figure 11**). This



Figure 11: Lint, dust, and hair on driver's D-ring

evidence indicated that the belt had not been pulled across the D-ring for some time and also indicated that the seat belt was not in use at the time of the crash. The remaining seat positions were unoccupied.

CASE VEHICLE DRIVER KINEMATICS

The Chevrolet's driver [26-year-old, female; 158 cm and 64 kg (62 in, 140 lbs)] was seated in an upright posture with her back against the seat back, both hands on the steering wheel and her right foot on the accelerator. The seat track was adjusted to the full-forward position, which was measured as 17 cm (6.7 in) forward of the full-rear position, and the seat back was upright. The tilt steering column was located one notch above the full-down position.

While there was no discernable occupant contact evidence on the steering wheel or instrument panel, occupant kinematic principles suggest that the driver was probably displaced forward and to the right to some degree opposite the 1 o'clock direction of force during the embankment impact. When the vehicle rolled over, right side leading, and landed on the left portion of the roof and left roof side rail, the left front window glazing was disintegrated and the unrestrained driver was redirected to the left and toward the top of the left front door. A deposit of hair embedded in the top of the left front window frame (Figures 12 and 13) indicated that the driver's head loaded the window frame prior to her complete ejection through the left front window opening. She sustained a nonanatomic brain injury with amnesia and a neck strain, probably from this contact. She also sustained contusions on the left thigh and flank, probably due to loading the rear upper quadrant of the left front door. The driver sustained a non-displaced fracture of the right radial styloid process, abrasions on the right hand, and a contusion on the right lower leg, probably due to contact with the ground following her ejection from the vehicle.

CASE VEHICLE DRIVER INJURIES

The driver sustained moderate injuries and was transported by ambulance to a hospital where she was admitted for treatment of her injuries. She was hospitalized for one day and had five follow-up visits to her physician. The table below shows the driver's injuries and injury sources.



Figure 12: Driver was ejected out of left front window; yellow tape shows location of hair deposited in the window track

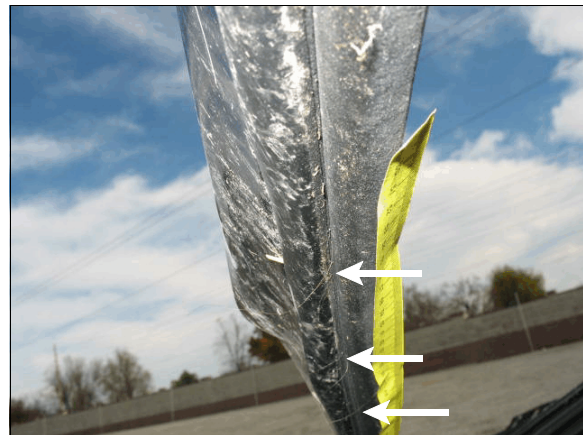


Figure 13: Arrows show hair embedded in top of left front window track

Injury Number	Injury Description (including Aspect)	NASS Injury Code & AIS 90	Injury Source	Source Confidence	Source of Injury Data
1	Nonanatomic brain injury with amnesia to event	moderate 160410.2,0	Left front window frame	Probable	Hospitalization records
2	Fracture right radial styloid process, non-displaced	moderate 752802.2,1	Ground	Probable	Hospitalization records
3	Abrasion left flank, not further specified	minor 690202.1,2	Left front door panel, rear upper quadrant	Probable	Emergency room records
4	Strain {whiplash}, acute cervical ¹	minor 640278.1,6	Left front window frame {Indirect injury}	Probable	Interviewee (same person)
5	Abrasion right hand/finger, not further specified	minor 790202.1,1	Ground	Probable	Emergency room records
6	Contusion left thigh, not further specified	minor 890402.1,2	Left front door panel, rear upper quadrant	Probable	Interviewee (same person)
7	Contusion right lower leg, not further specified	minor 890402.1,1	Ground	Probable	Interviewee (same person)

¹ This patient's medical records did not rule out this interviewee-reported lesion. In fact, straightening of the cervical lordosis was noted, but no conclusion was drawn.

