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## ON-SITE ROLLOVER INVESTIGATION

CASE NUMBER - IN09040

LOCATION - MISSOURI

VEHICLE - 2008 MAZDA CX-7

CRASH DATE - October 2009

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 on-site investigation focused on the rollover of a 2008 Mazda CX-7 and the sources of the driver's injuries. The Mazda was occupied by an unrestrained 42-year-old male driver. He was traveling west on a 2-lane city street approaching a 3-leg intersection. A 2002 Jeep Grand Cherokee Laredo was stopped heading north at the intersection. The driver of the Jeep initiated a left turn and the front plane of the Mazda impacted the right side plane of the Jeep (event 1). The impact redirected the Mazda northwest and the right front and right rear wheels impacted a curb (events 2 and 3). The curb impacts tripped the Mazda and it rolled over (event 4) right side leading 3 quarter turns across a sidewalk and onto a residential driveway. The Mazda's rollover inflatable curtain air bags deployed during the rollover. The driver of the Mazda sustained a neck strain from contact with the intruded roof. He was treated at the crash scene by emergency medical responders and refused transport to a hospital. The driver of the Jeep was not injured.			
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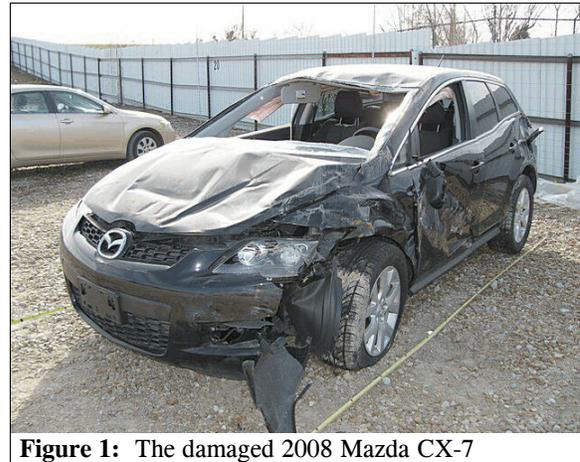
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This on-site investigation focused on the rollover of a 2008 Mazda CX-7 (**Figure 1**) and the sources of the driver's injuries. This crash was brought to our attention by the National Highway Traffic Safety Administration (NHTSA) on November 20, 2009, through the sampling activities of the National Automotive Sampling System-General Estimates System (NASS-GES). This investigation was assigned on November 30, 2009. The crash involved the Mazda and a 2002 Jeep Grand Cherokee Laredo. The crash occurred in October, 2009, at 1242 hours, in Missouri and was investigated by the city police department. The crash scene and the Mazda were inspected on December 1, 2009. The driver was interviewed on December 12, 2009. The Jeep was not inspected since it had been salvaged. This report is based on the police crash report, vehicle and crash scene inspections, driver interview, occupant kinematic principles, and evaluation of the evidence.



**Figure 1:** The damaged 2008 Mazda CX-7

## CRASH CIRCUMSTANCES

**Crash Environment:** The trafficway that the Mazda was traveling on was a 2-lane, undivided city street that traversed in an east-west direction and approached a 3-leg intersection. The roadway had one through lane in each direction bordered by 15 cm (6 in) curbs. A sidewalk was located on the north side of the roadway. Each travel lane was approximately 4.5 m (14.8 ft) in width, and the roadway pavement markings consisted of double solid yellow center lines. The roadway had a negative 6.7% grade and the intersection was uncontrolled. The trafficway that the Jeep was traveling on was a 2-lane, undivided city street that traversed in a north-south direction and formed the 3-leg intersection with the Mazda's trafficway. The Jeep's roadway was straight and level and was controlled by a stop sign. The roadway pavement markings consisted of a solid white stop bar. There were no lane designations. At the time of the crash, the light condition was daylight, the atmospheric condition was cloudy, and the roadway was dry bituminous. The speed limit was 40 km/h (25 mph) for both vehicles. The traffic density at the time of the crash was light and the site of the crash was urban residential. The Crash Diagram is on page 10 of this report.

**Pre-Crash:** The Mazda was occupied by an unrestrained 42-year-old male driver. He was traveling west approaching the 3-leg intersection (**Figure 2**) and intended to continue west. The



**Figure 2:** Approach of the Mazda; arrow on left shows approach of the Jeep; arrow in center shows area of impact with the Jeep; arrow on right shows location of the Mazda's rollover

Jeep was occupied by a restrained 68-year-old male driver. The Jeep was stopped at the intersection heading north (**Figure 3**) and the driver intended to turn left. Based on the SCI interview, the driver of the Mazda initiated a right steering maneuver immediately prior to the impact. The crash occurred in the Mazda's travel lane.

**Crash:** The driver of the Jeep accelerated into the intersection and initiated a left turn. The front plane of the Mazda (**Figure 4**) impacted the right side plane of the Jeep (event 1). The impact on the Mazda was within the 11 o'clock sector and the impact force was not sufficient to trigger deployment of the driver's frontal air bag. The impact redirected the Mazda northwest and the right front and right rear wheels (**Figure 5**) impacted a curb (events 2 and 3, **Figure 6**). The curb impacts tripped the Mazda and it rolled over (event 4, **Figure 7**) right side leading across the sidewalk and onto a residential driveway. The Mazda's rollover inflatable curtain (IC) air bags deployed during the rollover. The Mazda came to final rest on the driveway (**Figure 6**) on its left side heading southwest. The driver of the Jeep pulled his vehicle over to the north curb approximately 30.5 m (100 ft) west of the Mazda.

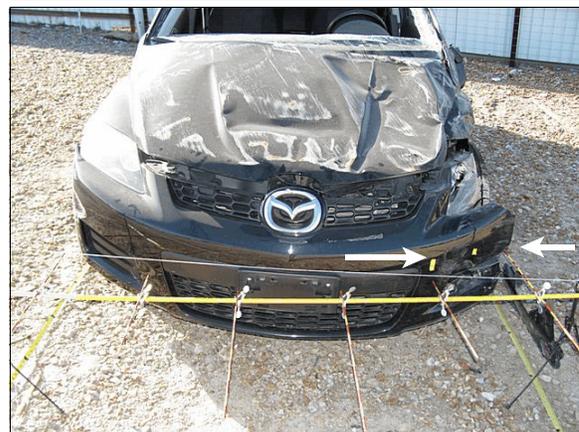
**Post-Crash:** The police were notified of the crash at 1243 hours and arrived at the crash scene at 1245 hours. Rescue personnel cut the windshield out of the Mazda and the driver exited the vehicle through the windshield opening. The driver was treated by emergency medical personnel and refused transport to a hospital. The driver of the Jeep was not injured. The Mazda was towed due to damage, while the Jeep was driven from the scene by the driver.

## ROLLOVER DISCUSSION

**Rollover Discussion:** The Mazda's rollover mitigation features consisted of rollover sensing and Electronic Stability Control (ESC). The vehicle has been given a four star rollover rating on a five



**Figure 3:** Approach of the Jeep to the intersection; arrow on right shows the approach of the Mazda; arrow on left shows the area of impact



**Figure 4:** Arrows show the damage on the front bumper from the impact with the Jeep



**Figure 5:** Arrows show the damage on the right front and right rear wheels from the curb impacts

star scale by the NHTSA and a Static Stability Factor of 1.28<sup>1</sup>. A four star rating indicates that the vehicle has a 10%-20% chance of a rollover when involved in a single vehicle crash. The specific chance of rollover for this vehicle model was given as 14%. The Static Stability Factor (SSF) is a calculation based on the vehicle's track width and height of its center of gravity. The result of the calculation is a measure of a vehicle's resistance to a rollover. A higher SSF indicates a more stable vehicle. The majority of passenger vehicles have an SSF of 1.30 to 1.50<sup>2</sup>. An exemplar vehicle did not tip-up during a dynamic steering maneuver test in which the test vehicle was put through a fish-hook shaped steering maneuver (i.e., hard left and hard right steer) at between 56 km/h-80km/h (35-50 mph).

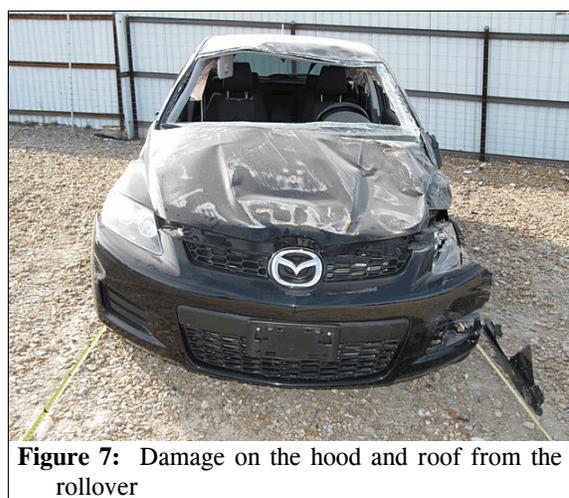
The rollover of the Mazda (event 4) was initiated when the Mazda's right side wheels impacted the curb. The curb impacts occurred near a storm water drain (**Figure 6**) and the curb was higher in this area due to the grade to the drain. The curb was 28 cm (11 in) high in the area where the right front wheel impacted and 18 cm (7.1 in) high where the right rear wheel impacted. The curb impacts tripped the vehicle and it rolled over right side leading 3 quarter turns across a distance of approximately 12 m (39.4 ft). The vehicle came to final rest on its left side heading southwest.

## CASE VEHICLE

2008 Mazda CX-7 was a front-wheel drive, 4-door, multi-purpose station wagon (VIN: JM3ER293780-----). It was equipped with a 2.3-liter, 6-cylinder engine, 6-speed automatic transmission, 4-wheel anti-lock disc brakes with electronic brake force distribution, traction control, ESC, and rollover sensing. The front row was equipped with bucket seats, adjustable head restraints, lap-and-shoulder safety belts, dual stage driver and front passenger frontal air bags, seat-mounted side impact air bags, and rollover/side impact IC air bags that provided protection for the front and second rows. The second row was equipped with a split bench seat with split folding backs, adjustable head restraints, lap-and-shoulder safety belts, and Lower



**Figure 6:** Arrows in foreground show marks on the curb from the impacts by the right front and right rear wheels of the Mazda; arrow in background show final rest position of the Mazda



**Figure 7:** Damage on the hood and roof from the rollover

<sup>1</sup> [www.safercar.gov](http://www.safercar.gov), 11/29/09

<sup>2</sup> "Trends in the Static Stability Factor of Passenger Cars, Light Trucks, and Vans", NHTSA Technical Report, DOT HS 809 868, June 2005

Anchors and Tethers for Children (LATCH) in the outboard seating positions. The mileage at the time of the inspection could not be determined since the vehicle was without power. The driver estimated the vehicle’s mileage at approximately 39,000 miles ( 62,765 kilometers). The specified wheelbase was 275 cm (108.3 in).

**CASE VEHICLE DAMAGE**

**Exterior Damage:** The impact with the Jeep (event 1) involved the front plane of the Mazda. The direct damage involved the left corner of the front bumper, left headlamp/turn signal assembly, and the left fender (**Figure 8**). The direct damage began at the front left bumper corner and extended 36 cm (14.2 in) across the bumper fascia. The crush measurements were taken on the bumper bar. The bumper bar did not extend beyond the left frame member (**Figure 9**) and due to the narrow end engagement, the only components of the bumper structure that were damaged were the plastic bumper fascia and a metal bracket on the outboard side of the left frame rail (**Figure 9**). The maximum crush was 3 cm (1.2 in) occurring at C<sub>1</sub>, which was measured on the metal bracket. The left fender was crushed rearward 8 cm (3.1 in). The left front wheel was also engaged during this impact and displaced rearward 14 cm (5.5 in). The induced damage involved the bumper fascia and the hood. The table below shows the vehicle’s front crush profile.



**Figure 8:** Left side view of the impact area on the left portion of the front bumper



**Figure 9:** Close view of the left end of the bumper bar and left frame member; arrow shows the deformed metal bracket where C<sub>1</sub> was measured

Units	Event	Direct Damage		Field L	C <sub>1</sub>	C <sub>2</sub>	C <sub>3</sub>	C <sub>4</sub>	C <sub>5</sub>	C <sub>6</sub>	Direct	Field L
		Width CDC	Max Crush								±D	±D
cm	1	36	3	170	3	0	0	0	0	0	-69	0
in		14.2	1.2	66.9	1.2	0.0	0.0	0.0	0.0	0.0	-27.2	0.0

The curb impacts (events 2 and 3) involved the right front and right rear wheels. The right front rim and tire were damaged (**Figure 10**) and a piece of the rim 9 cm (3.5 in) in length was broken off. The sidewall of the tire was also cut and abraded. A heavy abrasion 53 cm (20.5 in) in length was present on the right rear wheel rim (**Figure 11**).

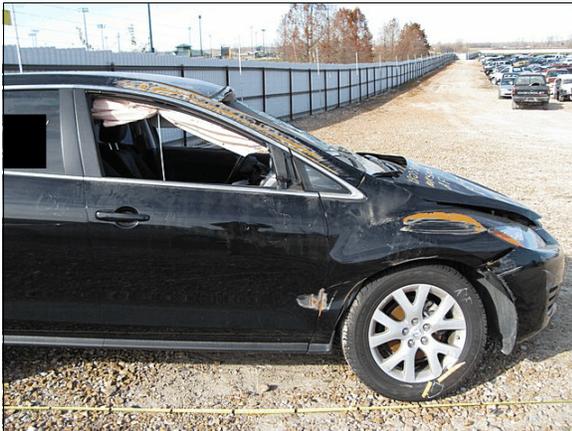
The rollover (event 4) involved the top and both side planes of the Mazda. The primary area of direct damage on the right side plane began on the right roof side rail 122 cm (48 in) forward of the right rear axle. The direct damage extended from the roof side rail 211 cm (83.1 in) forward and involved the right A-pillar, front portion of the right front door, right fender, and the right side of the front bumper fascia (**Figure 12**). The direct damage on the left side plane extended from the back of the left quarter panel forward onto the fender (**Figure 13**) and involved both left side doors, roof side rail, and the A-pillar. The direct damage on the top plane began 137 cm (53.9 in) forward of the left rear axle and extended 200 cm (78.7 in) forward to the front of the hood. The direct damage involved the full width of the roof, 115 cm (45.3 in). The maximum vertical crush was 6 cm (2.4 in) located 26 cm (10.2 in) inboard of the left A-pillar (**Figure 14**). There was no lateral crush of the roof structure.



**Figure 10:** Damage to the right front rim and tire from the curb impact



**Figure 11:** Damage on the right rear rim from the curb impact



**Figure 12:** The primary areas of direct damage on the right side plane



**Figure 13:** Damage from the rollover on the left side plane

**Damage Classification:** The Collision Deformation Classifications were **11-FLEE-3 (340 degrees)** for the front plane impact with the Jeep (event 1), **02-RFWN-1 (60 degrees)** for the right front wheel impact with the curb (event 2), **02-RBWN-1 (60 degrees)** for the right rear wheel impact with the curb (event 3), and **00-TYDO-2** for the rollover. The Missing Vehicle algorithm of the WinSMASH program calculated the Mazda's total Delta-V for the front plane impact as 17.0 km/h (10.6 mph). The longitudinal and lateral velocity changes were -16.0 km/h (-9.9 mph)

and 5.8 km/h (3.6 mph), respectively. Based on the damage on the vehicle, the results appeared to be reasonable. The severity of the damage for the right side wheel impacts was minor. The severity of the damage due to the rollover was minor based on the extent of the crush on the roof.

The vehicle manufacturer’s recommended tire size was P235/60R18. The Mazda was equipped with P255/55R18 size tires. The vehicle’s tire data are shown in the table below.



Figure 14: The maximum vertical crush occurred on the windshield header

Tire	Measured Pressure		Vehicle Manufacturer’s Recommended Cold Tire Pressure		Tread Depth		Damage	Restricted	Deflated
	kPa	psi	kPa	psi	milli-meters	32 <sup>nd</sup> of an inch			
LF	Flat	Flat	221	32	10	13	None	No	Yes
LR	207	30	221	32	9	11	None	No	No
RR	214	31	221	32	9	11	None	No	No
RF	214	31	221	32	10	13	Sidewall cut and abraded	No	No

**Vehicle Interior:** The inspection of the Mazda’s interior revealed several areas of occupant contact evidence within the driver’s seating area. The lower middle and lower left instrument panel were scuffed due to knee contact (Figure 15). The left roof side rail and adjacent roof were lightly scuffed with a few hair transfers from head contact (Figure 16). The left front door arm rest (Figure 17) and the forward lower quadrant of the left front door were scuffed from contact by the driver’s left thigh and left lower leg. There was no deformation of the steering wheel and no compression of the energy absorbing steering column.



Figure 15: Scuff marks on the lower instrument panel of the Mazda

All the vehicle’s doors remained closed and operational. The pre-crash status of all the window glazings was either closed or fixed. The left front and right front window glazings were disintegrated by impact forces. The windshield had been cut out of the vehicle by rescue

personnel. Based on the damage on the roof and windshield header, the windshield glazing was probably in place and cracked from impact forces. The remaining glazings were undamaged.

The vehicle's passenger compartment sustained several minor intrusions due to the rollover. The most severe intrusions occurred in the driver's seating area and involved the roof and windshield header, which both intruded vertically 6 cm (2.4 in).

#### AUTOMATIC RESTRAINT SYSTEM

The Mazda was equipped with a Certified Advanced 208-Compliant (CAC) frontal air bag system that consisted of dual stage driver and front passenger air bags, driver seat position sensor, seat belt usage sensors, retractor-mounted pretensioners, and a front passenger weight sensor. Based on the Holmatro Rescuer's Guide to Vehicle Safety Systems, the frontal air bag impact sensor was located on the back of the front bumper in the center. 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. Neither frontal air bag deployed in this crash.

The Mazda was also equipped with rollover/side impact IC air bags and front seat-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-pillars and quarter panels. The inflators for the IC air bags were located within the roof side rail forward of the D-pillars. Both IC air bags deployed in this crash. The seat-mounted side impact air bags did not deploy.

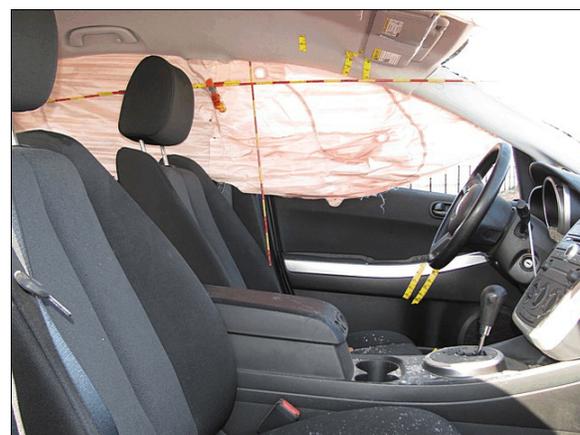
The IC air bags were located along the roof side rails inside the headliner (**Figure 18**) and extended from the A-pillar to the D-pillar. They were designed with inflation chambers adjacent to the outboard seat positions. The creases in the IC air bags indicated that they were folded accordion style within the module. Each deployed IC air bag was 206 cm (81.1 in) in width and 42 cm (16.5 inches) in height. There were no visible tethers that attached the IC air bag to the A-



**Figure 16:** Scuff marks and a few hair transfers on the left roof side rail and adjacent roof



**Figure 17:** Scuff mark on the left front door arm rest



**Figure 18:** The front portion of the left rollover/side impact IC air bag

or D-pillar and no visible vent ports. Each IC air bag extended 5 cm (2 in) below the beltline in the second row and 8 cm (3.1 in) in the front row. The gap between the front of the IC air bag and the front of the window frame at the beltline was 11 cm (4.3 in). Inspection of the IC air bags revealed no discernable evidence of occupant contact and no damage.

## **MANUAL RESTRAINT SYSTEM**

The Mazda was equipped with lap-and-shoulder safety belts for all seating positions. The driver's safety belt consisted of continuous loop belt webbing, an Emergency Locking Retractor (ELR), a sliding latch plate, and an adjustable upper anchor that was in the full-down position. The front passenger safety belt consisted of 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-up position. The driver and front right passenger safety belts were equipped with retractor-mounted pretensioners. The second row lap-and-shoulder safety belts were similar to the front passenger safety belt but had fixed upper anchors and the outboard restraints were integrated within the seat back. The second row safety belts were not equipped with pretensioners.

Inspection of the driver's safety belt assembly revealed that the belt webbing was retracted tightly in the retractor due to actuation of the pretensioner. Only a few usage scratches were present on the latch plate. These findings supported non-usage of the safety belt in this crash. The remaining seat positions were unoccupied.

## **CASE VEHICLE DRIVER KINEMATICS**

Based on the SCI interview, the driver of the Mazda [42-year-old, male; 188 cm (74 in) and 132 kg (290 lbs)] was seated in an upright posture with his back against the seat back. He had both hands on the steering wheel at the 10 and 2 o'clock positions and his right foot was over but not on the accelerator pedal. The seat track was adjusted to between the middle and rear positions and the seat back was reclined 20 degrees. The distance from the top of the seat back to the top of the head restraint was 27 cm (10.6 in). The tilt steering column was located in the center position. The driver was not wearing glasses at the time of the crash.

The Mazda's impact with the Jeep displaced the driver forward and left opposite the 11 o'clock direction of force and his knees contacted the lower instrument panel. As the vehicle's right side wheels impacted the curb and the vehicle rolled over right side leading, occupant kinematics principles suggest that the driver was redirected to the right and toward the roof. The driver stated that he was not displaced out of his seating area during the rollover. Occupant contact evidence indicated that the driver contacted his head on the left roof side rail and roof during the rollover. The driver sustained a neck strain during the crash, probably from this contact. He also contacted his left thigh and lower left leg on the left front door arm rest and lower forward quadrant of the left front door, respectively. The driver reported no injuries from these contacts. Rescue personnel removed the windshield from the vehicle and the driver exited through the windshield opening.

The driver sustained a minor injury and was treated at the scene by emergency medical personnel. He refused to be transported to a hospital. He lost two work days as a result of the crash and sought no follow-up medical treatment. The table below presents the driver's injury and injury source.

Injury Number	Injury Description (including Aspect)	NASS Injury Code & AIS 90	Injury Source	Source Confidence	Source of Injury Data
1	Strain, cervical, not further specified	minor 640278.1,6	Roof	Probable	Interviewee (same person)

#### OTHER VEHICLE

The 2002 Jeep Grand Cherokee was a 4-wheel drive, 5-passenger, 4-door sport utility vehicle (VIN: 1J4GW48S62C-----) equipped with a 4.6L, 6-cylinder engine, 4-speed automatic transmission, 4-wheel anti-lock disc brakes with electronic brake force distribution, and dual stage driver and front passenger frontal air bags.

**Exterior Damage:** The Jeep was not inspected. The driver of the Jeep was contacted and he stated that the Jeep had been salvaged.

The Missing Vehicle algorithm of the WinSMASH program calculated the Jeeps's total Delta V for the impact with the Mazda as 16.0 km/h (9.9 mph). The longitudinal and lateral velocity changes were 12.3 km/h (7.6 mph) and -10.3 km/h (-6.4), respectively. The results were based only on the Mazda's crush profile and should be considered as a borderline reconstruction of the Jeep's Delta V.

**Other Vehicle's Driver:** The police crash report indicated that the driver of the Jeep (68-year-old, male) was restrained by the lap-and-shoulder safety belt. He was not injured.

