

Inflatable Side Air Curtain Investigation / Vehicle to Object
Dynamic Science, Inc. / Case Number: DS03030
2003 Mini Cooper S three-door hatchback
Colorado
August, 2003

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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 crash-worthiness performance of the involved vehicle(s) or their safety systems.

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16. Abstract This Inflatable Side Air Curtain two-vehicle rollover crash occurred in a rural area of Colorado in August, 2003 at 2130 hours. The crash occurred near a three leg Y-shaped intersection. The two lane northbound roadway—which comprises the base and right side of the Y—initially begins as a straight roadway that transitions into a right hand curve. The speed limit is 64 km/h (40 mph). The two lane southbound roadway—which comprises the left side of the Y—is straight and it controlled by a stop sign. The roadway is gravel covered and essentially straight and level. The speed limit is 32 km/h (20 mph). It was dark at the time of the crash and there were no streetlights available The case vehicle is a 2003 Mini Cooper S three-door hatchback that was being driven northbound by a restrained 53-year-old male. The front right seat was occupied by a restrained 52-year-old male. The other vehicle is a 2001 Toyota Highlander four-door sport utility vehicle that was being driven by a 61-year-old male. The case vehicle was initially traveling straight on the northbound roadway. The driver indicated that he had been blinded by the bright lights of an oncoming vehicle. As the case vehicle entered the curve the driver failed to make the turn. The case vehicle departed the roadway on the left. There were no skid marks or indications of braking. The case vehicle struck a large rock with its right front end. The driver and front right passenger air bags likely deployed at this point. Both front seat belt pretensioners actuated. The vehicle ramped when engaging the rock and began to both pitch to the left and to rotate clockwise. The vehicle pitched over and overturned two quarter rolls—impacting the ground with the right roof rail and roof area. The right side air curtain and right seat back mounted side air bag deployed at this time. The right side of the case vehicle then struck the left side of the other vehicle. The case vehicle continued overturning until it had completed one full roll and came to rest on its wheels. The driver of the case vehicle sustained lacerations to his left elbow, left thumb, and the left side of his scalp. He was able to exit the vehicle on his own. He was treated at the scene by paramedics and was not transported. The front right occupant did not sustain any apparent injuries. He was able to exit the vehicle on his own. He was treated at the scene by paramedics and was not transported.					
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**Dynamic Science, Inc.
Accident Investigation
Case Number: DS03030**

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BACKGROUND:

Description: This Inflatable Side Air Curtain case was identified by the local National Automotive Sampling System (NASS) team. The National Highway Traffic Safety Administration (NHTSA) was notified on September 16, 2003. DSI was assigned the case on September 25, 2003. Field work was completed on September 29, 2003.

Investigation Type: On-scene
Crash Location: Colorado
Crash Date: August, 2003
Notification Date: September 16, 2003
Field Work Completed: September 29, 2003

SUMMARY:

This two-vehicle rollover crash occurred in a rural area of Colorado in August, 2003 at 2130 hours. The crash occurred near a three leg Y-shaped intersection. The two lane northbound roadway—which comprises the base and right side of the Y—initially begins as a straight roadway that transitions into a right hand curve. The speed limit is 64 km/h (40 mph). There is a +3.5 positive grade and a +6.9% superelevation. The approach had a radius of curvature of 78 m (257 ft) and a critical speed (maximum possible velocity at which this curve can be taken) of 86 km/h (54 mph).



Figure 1. Approach, case vehicle (north)

The two lane southbound roadway—which comprises the left side of the Y—is straight and is controlled by a stop sign. The roadway is gravel covered and essentially straight and level. The speed limit is 32 km/h (20 mph). It was dark at the time of the crash and there were no streetlights available.

The case vehicle is a 2003 Mini Cooper S three-door hatchback that was being driven northbound by a restrained 53-year-old male (178 cm/70 in, 82 kg/180 lbs). This was the driver's first time driving this particular vehicle and he was unfamiliar with how the vehicle handled. He was wearing prescription glasses. The case vehicle was equipped with the following safety features: dual stage driver and front right passenger air bags, driver and front passenger seat-mounted side air bags, an advanced head protection system (inflatable curtains for both front and rear outboard occupants), and side-impact door beams with interlocking

anchoring system. The front right seat was occupied by a restrained 52-year-old male (185 cm/73 in, 95 kg/210 lbs). He was wearing prescription glasses. The front right occupant was also the owner of the vehicle. The other vehicle is a 2001 Toyota Highlander four-door sport utility vehicle that was being driven by a 61-year-old male. The front right seat was occupied by a 58-year-old female. The rear right seat was occupied by a 49-year-old male. This vehicle was stopped at the intersection on the southbound roadway.

The case vehicle was initially traveling straight on the northbound roadway. The driver indicated that he had been blinded by the bright lights of an oncoming vehicle. As the case vehicle entered the curve the driver failed to make the turn. The case vehicle departed the roadway on the left. There were no skid marks or indications of braking. The case vehicle struck a large rock with its right front end (12FRLE2). The right portion of the bumper reinforcement bar rotated rearward and the vehicle engaged the rock with its front right tire/rim. The rock cracked and was displaced. The case vehicle wheelbase was shortened by 23.0 cm (9.0 in). The driver and front right passenger air bags likely deployed at this point. Both front seat belt pretensioners actuated. The vehicle ramped when engaging the rock and began to both pitch to the left and to rotate clockwise. The vehicle pitched over and overturned two quarter rolls—impacting the ground with the right roof rail and roof area (00TDZO2). The right side air curtain and front right seat back mounted side air bag deployed at this time. The right side of the case vehicle then struck the left side of the other vehicle (00RBEW1). The case vehicle continued overturning until it had completed one full roll and came to rest on its wheels 52 m (172 ft) south of the intersection area.



Figure 2. Rock(s) struck by case vehicle



Figure 3. Overview of southbound approach to area of impact

The driver of the case vehicle sustained lacerations to his left elbow, left thumb, and the left side of his scalp. He was able to exit the vehicle on his own. He was treated at the scene by paramedics and was not transported.

The front right occupant did not sustain any apparent injuries. He was able to exit the vehicle on his own. He was treated at the scene by paramedics and was not transported. His glasses came off during the crash. They were found intact outside the vehicle.

None of the occupants of the other vehicle reported any injuries.

The case vehicle sustained major damage and was towed from the scene. It was declared a total loss by the insurance company.



Figure 4. Front right, case vehicle

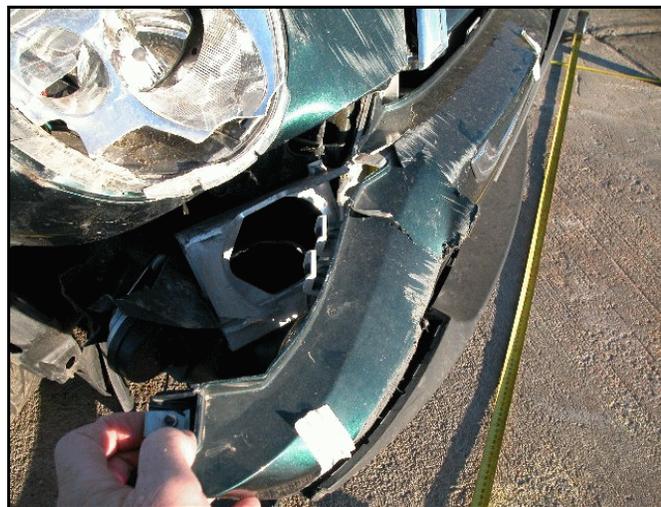


Figure 5. Close up view of reinforcement bar movement

Scene Diagram

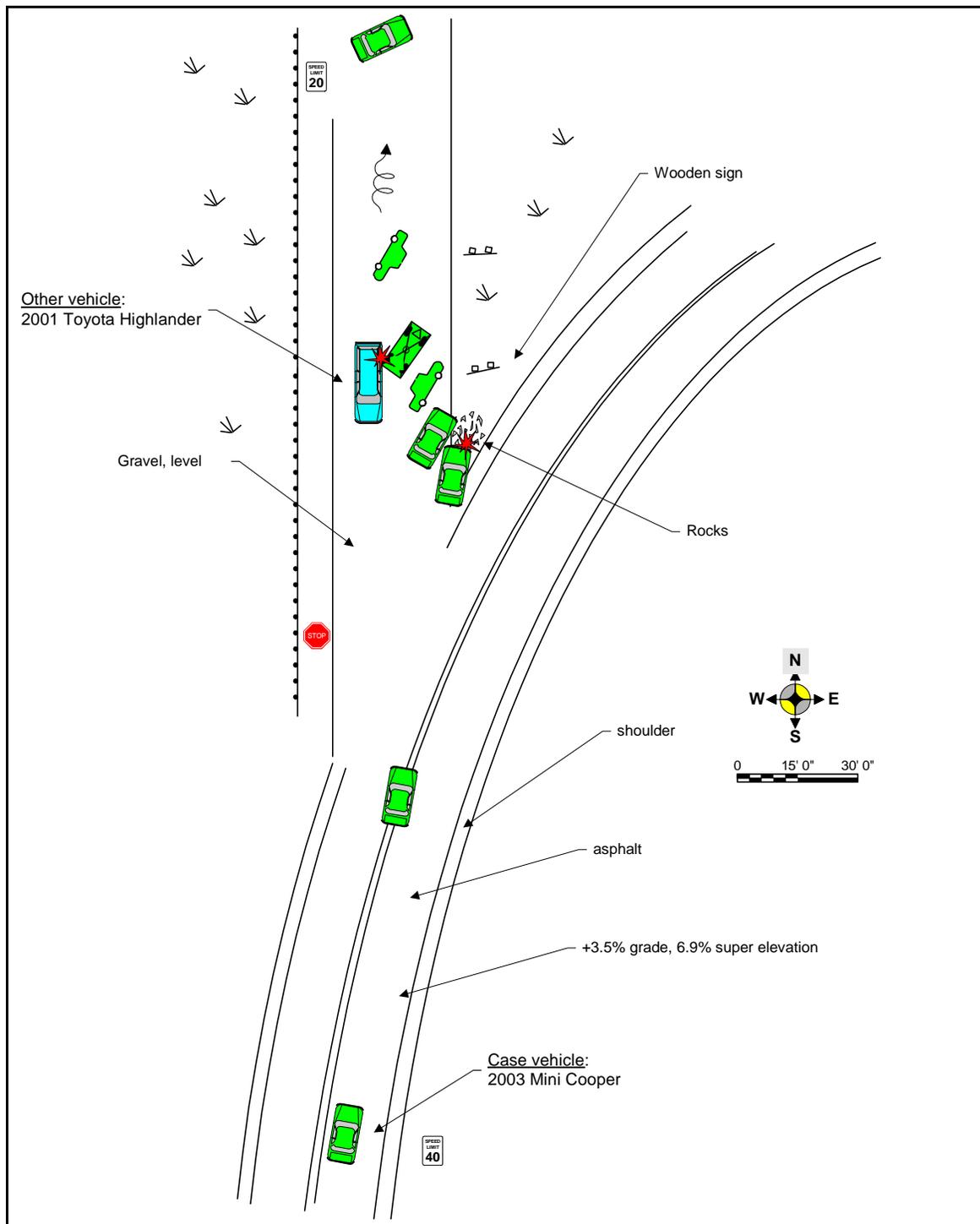


Figure 6. Scene diagram

DETAILED INFORMATION**Vehicles**Case vehicle

Description:	2003 Mini Cooper S three-door hatchback. Manual transmission.	
VIN:	WMWRE33453TDxxxxx	
Odometer:	10,666 km (6,628 miles).	
Engine:	1.6 L, 4 cylinder	
Reported Defects:	None	
Cargo:	None	
Damage Description:	Moderate frontal damage from impact with rock. Wheelbase shortened. Damage on all planes from rollover. Integrity loss to side glass, roof glass, and backlight.	
CDC:	Impact 1: 12FRLE2 Impact 2: 00TDZO2 Impact 3: 00RBEW1	
Delta V:	Total	Unknown
	Longitudinal	Unknown
	Latitudinal	Unknown
	Energy	Unknown

The case vehicle sustained 31.0 cm (12.2 in) of direct contact to the front bumper from the initial impact. The residual crush measured along the bumper was as follows: C1=0 cm (0 in), C2=0 cm (0 in), C3=0 cm (0 in), C4=0 cm (0 in), C5=2.0 cm (0.8 in), C6=9.0 cm (3.5 in). The maximum crush was at C6. The principle direction of force was within the 12 o'clock sector and was an estimated 0 degrees. The damaged components included the bumper fascia and reinforcement bar. The wheelbase was shortened by 23.0 cm (9.0 in).

During the subsequent rollover the vehicle sustained direct contact damage to the hood, roof, and both sides. The maximum crush was at the right A pillar and measured 22.0 cm (8.7 in) vertically. All the side windows, roof windows, and the backlight glass disintegrated during the crash. The latch failed on the rear hatch and the hatch came open at some point.

The vehicle sustained 59.0 cm (23.2 in) of direct contact to the right side from the impact with the other vehicle. The case vehicle was essentially upside down when this damage occurred.



Figure 7. Right rear view showing rollover damage and contact to other vehicle



Figure 8. Rock damage to right bumper corner



Figure 9. Rear latch failure

Occupant Protection Systems

The case vehicle was equipped with a dual stage driver's air bag, a dual stage front right passenger's air bag, driver and front right passenger seat back mounted side air bags, left and right side air curtains¹, and latch mounted seat belt pretensioners with force limiters for the front seats. The front right passenger air bag has a cutoff sensor that is activated by seat belt engagement and passenger weight. In this crash, the driver's air bag, the front right passenger's air bag, the right passenger side air bag, and right side air curtain all deployed. Both front seat pretensioners actuated.



Figure 10. Overview of air bag locations



Figure 11. Driver's air bag



Figure 12. Front right passenger air bag

The driver's air bag was mounted in the steering column. It measured 50.0 cm (19.7 in) in diameter in its deflated state. It was equipped with one vent port at the 9 o'clock position. It was equipped with 10 force limiting type tethers. The tethers were arranged in a fan shape along the top half of the air bag. They ranged in length from 6.0 cm (2.4 in) at the 9 o'clock position to 14.0 cm (5.5 in) at the 12 o'clock position. The air bag module cover was 11.0 cm (4.3 in) in diameter. It was held in place by two 9.0 cm (3.5 in) long tethers. There was no damage to the cover.

¹Described as Front and Rear Advanced Head Protection System (AHPS II) Side Head Curtain Airbags by Mini

The front right passenger air bag had a mid mount installation. It measured 43.0 cm (16.9 in) wide seam to seam and 70.0 cm (27.5 in) high. There were two “X” cut vent ports at the 3 and 9 o’clock positions. The module cover was generally rectangular in shape and measured 25.0 cm (9.8 in) wide by 17.0 cm (6.7 in) high. There were no indications of any damage or contact to either the air bag or the module cover.

The right side air curtain measured 140.0 cm (55.1 in) end to end. The inflatable portion of the curtain is sheathed by a 22.0 cm (8.7 in) high covering. The front end is secured to the A pillar by a 32.0 cm (12.6 in) long tether. The rear end is secured to the C pillar by an 11.0 cm (4.3 in) tether on the top and a 16.0 cm (6.3 in) tether on the bottom. The inflator is in the C pillar. Prior to deployment, the entire curtain in enclosed in the roof rail cladding. The right side air curtain deployed during the rollover sequence of this crash. There was no damage to the curtain. The front right occupant contacted the curtain with his face—leaving a skin transfer.

The seat back mounted side air bag measured 32.0 cm (12.6 in) long by 22.0 cm (8.7 in) high. The right side air bag deployed during the rollover sequence. There was no damage to the air bag or to the 9.0 cm (3.5 in) high cover flap.

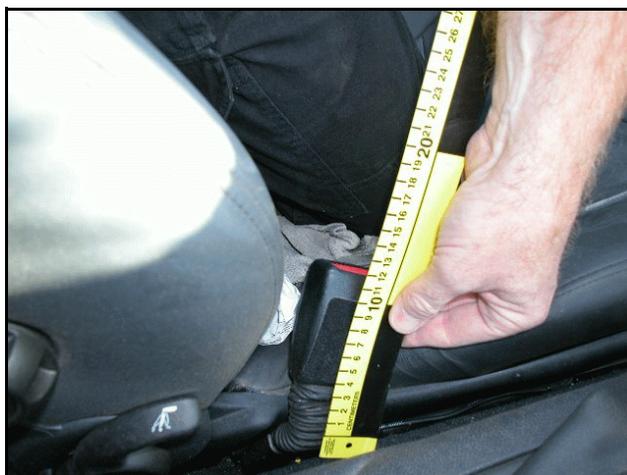


Figure 13. Driver’s buckle mounted seat belt pretensioner



Figure 14. Seat back mounted right side air bag



Figure 15. Right side air curtain

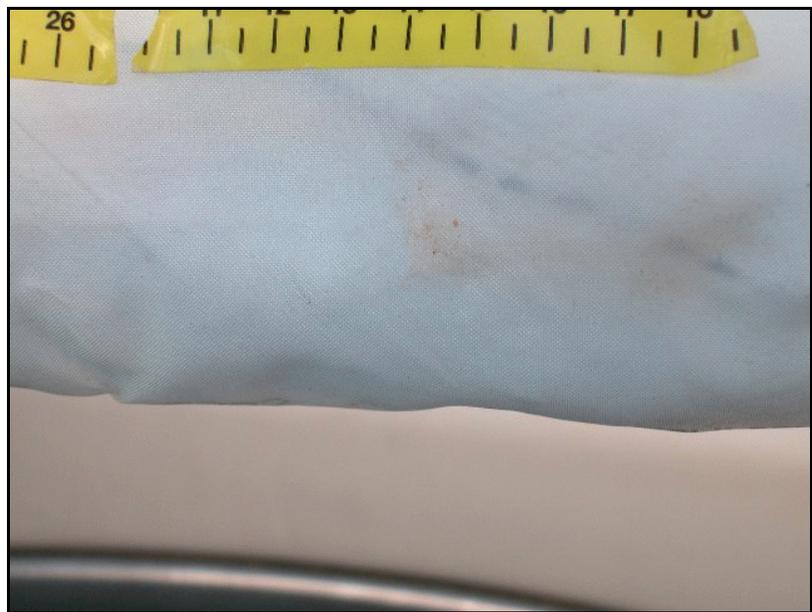


Figure 16. Skin contact to side air curtain

Tire Safety Discussion

The case vehicle was equipped with Dunlop P205/45R17 tires that use Dunlop's Self-Supporting Technology (DSST). This is a tire technology that allows driving to continue under certain conditions, even after a loss of tire pressure. DSST tires incorporate special reinforcements into the tire, which allows the tire to support the weight of the vehicle for up to 80 kilometers (50 miles) at speeds up to 89 km/h (55 mph).

Because of these capabilities, if a DSST tire loses its inflation pressure, the driver may not be aware of such a loss and may continue driving for extended distances at high speeds. The vehicle is equipped with sensors that will warn the driver if inflation has been lost. In this case the front right tire sustained a complete air out due to the impact, but appears to have retained some measure of vehicle support.

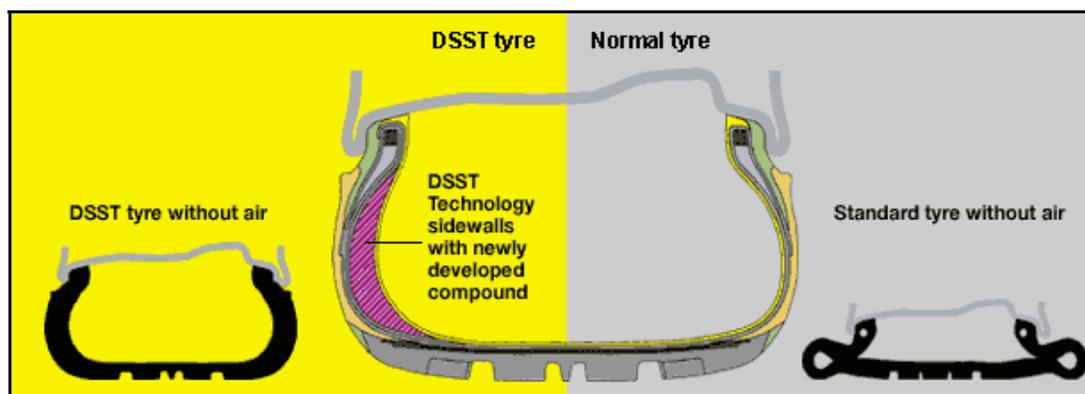


Figure 18. DSST overview

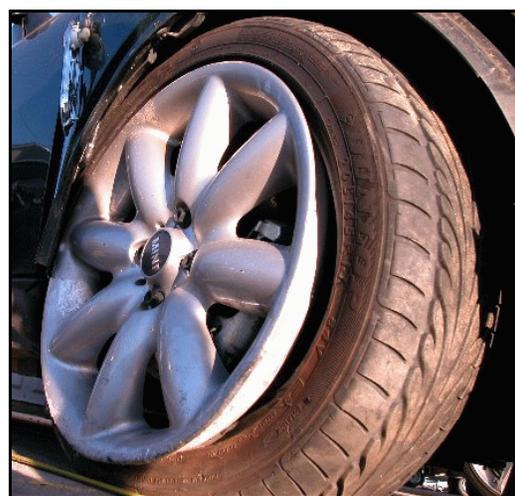


Figure 17. Front right tire, case vehicle

Other vehicle

Description:	2001 Toyota Highlander sport utility vehicle, four door, four-wheel drive	
VIN:	JTEHF21A610xxxxxx	
Odometer:	Unknown	
Engine:	3.0L V6	
Reported Defects:	None noted	
Cargo:	Unknown	
Damage Description:	Moderate contact damage to left front door area, left door area, and left rear—per police report. Driven from crash.	
CDC:	Unknown	
Delta V:	Total	Unknown
	Longitudinal	Unknown
	Latitudinal	Unknown
	Energy	Unknown

Occupants

<u>Case vehicle</u>	Occupant 1	Occupant 2
Age/Sex:	53/Male	52/Male
Seated Position:	Front left	Front right
Seat Type:	Fabric covered bucket seat with folding back. Seat adjusted to rear most track position. Seat back slightly reclined.	Fabric covered bucket seat with folding back. Seat adjusted to rear most track position. Seat back slightly reclined.
Height:	178 cm (70 in)	185 cm (73 in)
Weight:	82 kg (180 lbs)	95 kg (210 lbs)
Occupation:	Unknown	Unknown
Pre-existing Medical Condition:	None noted	None noted
Alcohol/Drug Involvement:	None	None
Driving Experience:	> 20 years	NA
Body Posture:	Normal, upright	Normal, upright
Hand Position:	Both hands on steering wheel, 3 and 9 o'clock positions	In lap
Foot Position:	Right on accelerator, left on floorboard.	Both feet on floorboard.
Restraint Usage:	Lap and shoulder belt available, used. Latch pretensioner available, actuated. Shoulder belt upper anchorage adjusted to full up position.	Lap and shoulder belt available, used. Latch pretensioner available, actuated. Shoulder belt upper anchorage adjusted to full down position.
Air bag:	Steering wheel mounted front air bag available, deployed. Seat back mounted side air bag, did not deploy. Roof rail mounted side air cushion, did not deploy.	Instrument panel mounted front air bag available, deployed. Seat back mounted side air bag, deployed. Roof rail mounted side air cushion, deployed.

Other vehicle

Age/Sex:	61/Male	58/Male	49/Male
Seated Position:	Front left	Front right	Rear right
Seat Type:	Bucket	Bucket	Unknown
Height:	Unknown	Unknown	Unknown
Weight:	Unknown	Unknown	Unknown
Occupation:	Unknown	Unknown	Unknown
Pre-existing Medical Condition:	None noted	None noted	None noted
Alcohol/Drug Involvement:	None	NA	NA
Driving Experience:	Presumed to be > 20 years	NA	NA
Body Posture:	Unknown	Unknown	Unknown
Hand Position:	Unknown	Unknown	Unknown
Foot Position:	Right foot presumed to be on brake, left on floor	Unknown	Unknown
Restraint Usage:	Unknown type restraint used, per police report	Unknown type restraint used, per police report	Unknown type restraint 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:	Minor lacerations, left elbow	790600.1,2	881.01	Side glass
	Minor laceration, left thumb	790600.1,2	883.0	Side glass
	Minor lacerations, left side of scalp	190602.1,2	873.0	Side glass
Front right occupant:	Not injured.			

Other vehicle

	<u>INJURY</u>	<u>OIC CODE</u>	<u>ICD-9</u>	<u>SOURCE</u>
Driver:	Not injured.			
Front right occupant:	Not injured.			
Rear right occupant:	Not injured.			

Occupant Kinematics

The 53-year-old male driver of the case vehicle was seated in a normal, upright fashion in a fabric covered bucket seat with a folding back. The seat had been adjusted to the rear most track position. The seat back was slightly reclined. He was wearing the available type 2 lap and shoulder belt. The shoulder belt upper anchorage was adjusted to the full up position. Both of his hands were on the steering wheel and were position at the 3 and 9 o'clock positions. His right foot was on the accelerator, his left was on the floor. He was wearing prescription glasses with metal frames and plastic lenses at the time of the crash.

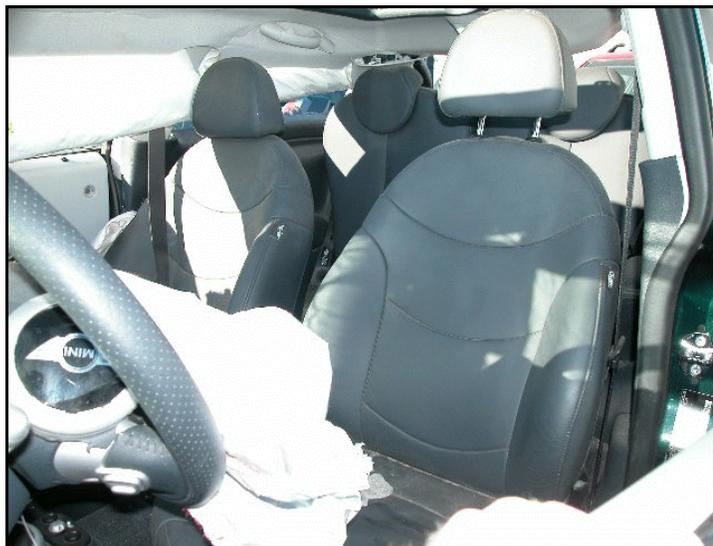


Figure 19. Driver's seated area

During the first impact (with rock), the driver's air bag deployed and the driver's lap and shoulder belt pretensioner actuated. The driver pitched forward and engaged the locked lap and shoulder belt. His face and torso likely engaged the deployed air bag. He did not sustain any injuries during this initial impact. His glasses remained on and were undamaged. The case vehicle ramped while engaging the rock and began to both overturn to the left to rotated clockwise. This motion forced the driver to the left. The vehicle tripped and went over onto its left side—causing both left side windows



Figure 20. Front right seat area—shows contacted side air curtain

to disintegrate. The driver sustained lacerations to the left elbow, left thumb, and left side of the scalp that were likely related to contact with the side window glass after it had been broken. The vehicle continued overturning and landed on the right roof rail/right side. Both sun roofs disintegrated at this time. The right side air curtain and right seat back mounted air bag deployed at this time. The vehicle continued overturning and came into contact with the other vehicle. This appears to have been a minor impact that had little effect on the occupants. The overturning continued until coming to rest on its wheels. The driver remained locked into place during the rollover and did not sustain any additional injuries.

The 52-year-old male front right occupant of the case vehicle was seated in a normal, upright fashion in a fabric covered bucket seat with a folding back. The seat had been adjusted to the rear most track position. The seat back was slightly reclined. He was wearing the available type 2 lap and shoulder belt. The shoulder belt upper anchorage adjusted to the full down position. He was wearing prescription glasses with metal frames and plastic lenses at the time of the crash.

During the first impact (with rock), the front right passenger's air bag deployed and the lap and shoulder belt pretensioner actuated. The front right occupant pitched forward and engaged the locked lap and shoulder belt. His face and torso likely engaged the deployed air bag. He did not sustain any injuries during this initial impact. His glasses came off during the crash and were later found undamaged outside the vehicle. The case vehicle ramped while engaging the rock and began to both overturn to the left to rotated clockwise. This motion forced the front right occupant to the left. The vehicle continued overturning and landed on the right roof rail/right side. Both sun roofs disintegrated at this time. The right side air curtain and right seat back mounted air bag deployed at this time. The right side of this occupant's face contacted the deployed side air curtain, but there were no related injuries. The vehicle continued overturning and came into contact with the other vehicle. This appears to have been a minor impact that had little effect on the occupants. The overturning continued until coming to rest on its wheels. The front right occupant remained locked into place during the rollover and did not sustain any injuries.

Attachment 1. Calculations

CASE NUMBER : DS03030			
Comments: radius of curve			
**RADIUS FORMULA **			
$R = \frac{C^2}{8 \times M} + \frac{M}{2}$		$R = \frac{75.00^2}{8 \times 2.75} + \frac{2.75}{2}$	
		$R = \frac{5625.00}{22.00} + \frac{2.75}{2}$	
		$R = 255.68 + 1.37$	
		$R = 257.05$	
AR = (R ± C ntr of Mass Adjustment)		AR = The Adjusted Radius in Feet.	R = The Radius in Feet.
AR = 257.05 + 0.00			
AR = 257.05			
INPUTS:		RESULTS:	
The Chord in Feet is:	75.00	The Radius in Feet is:	257.05
The Middle Ordinate in Feet is:	2.75	The Adjusted Radius in Feet is:	257.05
AR Pro, Ver. 7.06: © Since 1994, Maine Computer Group.			

CASE NUMBER: DS03030

Comments: critical speed

**** CRITICAL SPEED W/ COEFF. OF FRICTION AND RADIUS ****

$$S = 3.86 \times \sqrt{R \times (\mu \pm e)}$$

$$S = 3.86 \times \sqrt{257.05 \times (0.70 + 0.07)}$$

$$S = 3.86 \times \sqrt{257.05 \times 0.77}$$

$$S = 3.86 \times \sqrt{197.92}$$

$$S = 3.86 \times 14.06$$

$$S = 54.27$$

S =The Speed in MPH.

3.86 =A Constant.

R =The Radius in Feet.

μ =The Coeff. of Friction, Level Surface.

e =The Superelevation.

INPUTS:	
The Level Surface Coeff. of Friction is	0.70
The Radius in Feet is:	257.05
The Percentage of Superelevation is	0.07

RESULTS:	
The Speed in MPH is:	54.27
The Velocity in FPS is:	79.55