290262

Memorandum

U.S. Department
of Transportation

**National Highway
Traffic Safety
Administration**

Subject: ACTION: Submittal Roof Crush Analysis Using 1997-2001 NASS Case Review Report, by the Department of Applied Research, to Docket No. NHTSA-1999-5572 - 95

Date: JUL 27 2004

From: Joseph N. Kanianthra, Ph.D.
Associate Administrator for
Applied Research

To: The Docket

Thru: Jacqueline Glassman
Chief Counsel

The attached report, Roof Crush Analysis Using 1997-2001 NASS Case Review, is the report of the work accomplished under Task Order Agreement Contract No. DTNH22-97-C-07003 and prepared by the Office of Applied Research. This report discusses observations made by three reviewers on sever National Automotive Sampling System Crashworthiness Data System (NASS) rollover crashes to see if previously identified roof deformation patterns from an earlier study in1992 are still valid for more recent vehicle roof designs. The observed damage patterns were compared to the results of Federal Motor Vehicle Safety Standard FMVSS No. 216, "Roof crush resistance," testing with extended crush limits and to the results of testing to the Society of Automotive Engineers (SAE) J996, "Inverted Vehicle Drop Test. Vehicle Safety Research requests that the report be placed in the public docket. This report has been reviewed by the agency and the comments have been incorporated into the reports.

Attachment

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Roof Crush Analysis Using 1997-2001 NASS Case Review

Authors: Ron Pack, Steve Summers and Maurice Hicks.

1.0. INTRODUCTION

1.1. Background

In 1992, the National Highway Traffic Safety Administration (NHTSA) conducted a study to examine full-scale rollover test data and to review cases from the National Automotive Sampling System Crashworthiness Data System (NASS) involving rollover[1]. This study was intended to compare the roof damage from the full-scale rollover tests to real world crashes in NASS. Using photographs and recorded information on the crash event, it was concluded that full-scale rollover tests produced similar roof crush damage patterns to those seen in real world crashes. There was some indication that NASS crashes tended to produce more severe roof deformation. From the photos, general types of roof deformation patterns were also identified. It was noted that the roof damage patterns were consistent among different vehicle classes and that most frequent roof deformation pattern involved the A and B pillars remaining virtually straight but bending primarily at the pillar-to-vehicle body interfaces and at the pillar-to-roof interfaces. Generally, it was also found that roof deformation was most severe on the side of the vehicle opposite the side that makes first roof contact with the ground. Additionally, the study noted that typical roof damage patterns were common among vehicle classes.

1.2. Objective

The objective of this study was to review severe NASS rollover crashes to see if previously identified roof deformation patterns from the 1992 study are still valid for more recent vehicle roof designs. Additionally, the NASS cases were reviewed to determine a frequency of roof deformation patterns and to assess whether there are differences among various vehicle classes. The observed damage patterns were compared to the results of Federal Motor Vehicle Safety Standard (FMVSS) No. 216, "Roof crush resistance," testing with extended crush limits and to the results of testing to the Society of Automotive Engineers (SAE) J996, "Inverted Vehicle Drop Test."[2] Finally, recent interest has developed in assessing the extent of roof support provided by the front windshield in rollover crashes. Therefore, observations were made on the extent of front windshield damage in the cases, and used to assess whether the windshield was able to provide roof support throughout the rollover crash event.

1.3. NASS Case Analysis

This study analyzed a sample of 273 rollover crashes reported in the 1997-2000 NASS. The cases were selected using the following criteria:

1. Vehicle weight less than 4536 kg (10,000 pounds)
2. Rollover crashes reported with at least two quarter turns
3. Reported at least 15.24 cm (6 inches) of vertical intrusion to the roof, side rail, roof header, A or B-pillar
4. No trailing unit (i.e. vehicles without anything in tow)
5. No post manufacturer modifications to the vehicle
6. Vehicles manufactured between 1995-2001

The case selections included 95 passenger cars, 101 sport utility vehicles, 66 pickup, and 11 minivans. The analysis procedure consisted of examining the case summary, crash diagrams, and photographic documentation to observe general roof damage patterns. Each case was evaluated against the deformation patterns observed from the previous analysis:

1. A and B-pillars tended to remain virtually straight. The pillars primarily bent at the pillar body interfaces and at the pillar / roof interfaces.
2. The most significant roof deformation occurs on the side opposite of the first roof contact with the ground.
3. There was some variation in roof deformation patterns by vehicle types.

This study will review these previous conclusions using NASS cases involving more recent vehicles and reevaluate the observed trends as appropriate.

2.0. General Findings

2.1. Rollover Conditions of the Sampled Cases

The rollover cases represented 273 very severe rollover crashes of late model year vehicles from 1995 to 2001, as shown in Table 1. The rollover crashes experienced from 2 to 17 quarter turns, as shown in Table 2. The maximum vertical roof intrusion, recorded in NASS, ranged from 16 to 130 cm with an average of 30.8 cm. While the cases had substantial roof crush, only 25 of the cases were considered catastrophic. This is a subjective classification by the reviewers, intended to reflect the complete loss of occupant survival space, and not the injury outcome of the crash. The majority of the vehicles predominantly had damage to the front of the roof, i.e. 69 percent of the cases. The rear of the roof was damaged in only 29 percent of the cases, many of these being pickup trucks. There were no set boundary lines defining roof sections. Reviewers determined independently where they believed the damage occurred. The observed cases are listed in Appendix A.

Table 1: Distribution of Model Years

Model Year	Frequency
1995	49
1996	51
1997	77
1998	47
1999	32
2000	15
2001	2

Table 2: Distribution of Quarter Turns

Number of 1/4 Turns	Frequency
2	87
3	14
4	55
5	10
6	47
>=7	60

2.2. General Damage Patterns

Overall, the roof damage patterns were similar to what was reported in the previous study, with no substantial difference in damage patterns between vehicle classes. However, several cases were observed to have unique damage patterns. Typical damage patterns were identified as follows:

1) Predominately, A-pillar(s) largely remained straight with bending (laterally, longitudinally or a combination of both) occurring at or near both ends, although in few cases, the A-pillar(s) bent along its/their length.
2) B-pillars largely remained straight with bending occurring at or near both ends, but there were also a large number of cases with bending at the midpoint of the B-pillar between the body and roof.
3) C and D-pillars largely were straight with bending occurring at or near both ends.
4) Front and rear roof headers bent upward or downward. There was a significant minority of cases that experienced a pure "matchboxing" type of damage where the roof and headers remained relatively planar.
5) Roof damage frequently included a deformed area, usually near to the A-pillar to roof junction, which was planar and bent at a compound angle to the level or undamaged portion of the roof. In a small number of cases, the roof experienced multiple bends or crumpling along the front roof rail. However, crumpling type damage primarily occurred in cases where the pillars bent along their length, and did not remain primarily straight.
6) More damage occurred on the side opposite of the first vehicle to ground contact.
7) This post crash roof support determination does not necessarily reflect the amount of support the windshield may have provided during the crash event. That could not be determined in this analysis.

Table 3 illustrates the varying nature of the observed vehicle windshields. Their damage was indiscriminate with the vehicle roof damage. A conclusion could not be drawn linking a roof damage pattern with a windshield damage pattern. Post crash windshields varied across the sample cases from being completely intact and non-cracked to being completely removed. Although it was concluded that 24 percent of the cases had intact non-cracked windshields, it was determined that less than half of those windshields were capable of providing post crash roof support. This post crash roof support determination does not necessarily reflect the amount of

support the windshield may have provided during the crash event. That could not be determined in this analysis. This was a subjective observation by the reviewers due to the roof damage regardless of the intact windshield. Each reviwer viewed photographs of the vehicle post crash and determined the feasibilty of the post crash windshield providing support. It could not be determined how much if any support the non-intact windshields provided during the crash event.

Table3: Windshield Status

Windshield Status	Frequency
Cracked, partially separated	20
Holed	98
Intact	66
Intact, but Cracked	56
Missing	33

2.2.1. Single Sided Rollover Damage

Crash cases were classified as single sided whenever the roof damage was predominantly on one side of the vehicle. This included cases where the roof deformation involved lateral, longitudinal or a combination of bending of the vehicle pillars. In certain cases, the pillars tended to remain straight with the bending localized near the ends of the pillars. The roof and roof headers bent along vehicle width and tended to form a significant planar region that formed a compound longitudinal and lateral angle with the undeformed roof. There was also a substantial minority of these cases where the A and B pillars did not remain straight, but bent at or near the midsection. The next section references examples of these deformation patterns.

2.2.2. Selected Cases with Single Sided Rollover Damage

In this section, a few cases were selected that clearly illustrate the types of roof deformation occurring in rollovers with single side damage. Particularly, Cases 1 through 11 involve single side rollover damage to the roof, side rail, header and pillars. These cases include a variety of vehicle types and show the similarities in roof damage patterns. Cases 1 through 6 show crashes with roof deformation involving the pillars bending at or near their intersections with the roof or vehicle body. Cases 7 through 12 show crashes with roof deformation involving the pillars bending along their length. Roof deformation in these cases involved the roof structures experiencing a crumpling effect. Also, illustrated in Case 1 is the possibility for the pillars to experience a combination of damage patterns. More specifically, Case 1 involved the A-pillar bending at the body intersection (remaining straight), B-pillar bending near its middle, the roof bending transversely. The cases also show that the windshield experiences far more damage in crashes where the A-pillar collapses laterally as opposed to longitudinally. In addition, a lateral collapse of the pillars typically caused more damage along the longitudinal length of the roof structure.

Case #1

Crash Year: 1998
PSU: 72
Case Number: 150
Vehicle Make/Model: 1996 Saturn SL
Rollover Cause: Single Vehicle Rollover (Left Roadside Departure)

Crash Summary:

The case vehicle, a 1996 Saturn SL, was traveling northbound on a five lane divided expressway in the second travel lane. The vehicle lost control and departed the road to the left, impacting the left side concrete barrier with its front plane. The vehicle then rotated counterclockwise and impacted the wall again with its back plane. The vehicle then rolled onto its left side and came to rest on its roof. The vehicle was towed from the scene.

Roof Damage Summary:

Damage to the hood and roof structure occurred after the vehicle left the roadway and began to roll. The roof was creased laterally across its front and mid sections. The passenger side A and B-pillars were bent. The passenger side A-pillar bent longitudinally at both ends where it connects to the vehicle body and roof. Figure 1 shows a post-crash photo of the A-pillar damage, where it can be seen that the pillar remains almost straight. Figure 2 shows another post-crash photo highlighting the damage to the B-pillar and roof structure. In the photo, the B-pillar is shown experiencing bending near the middle, whereas the A-pillar bent at the ends. The roof bent laterally just behind the A-pillar and B-pillar intersections. The windshield cracked but remained intact and could provide some support to the roof structure.

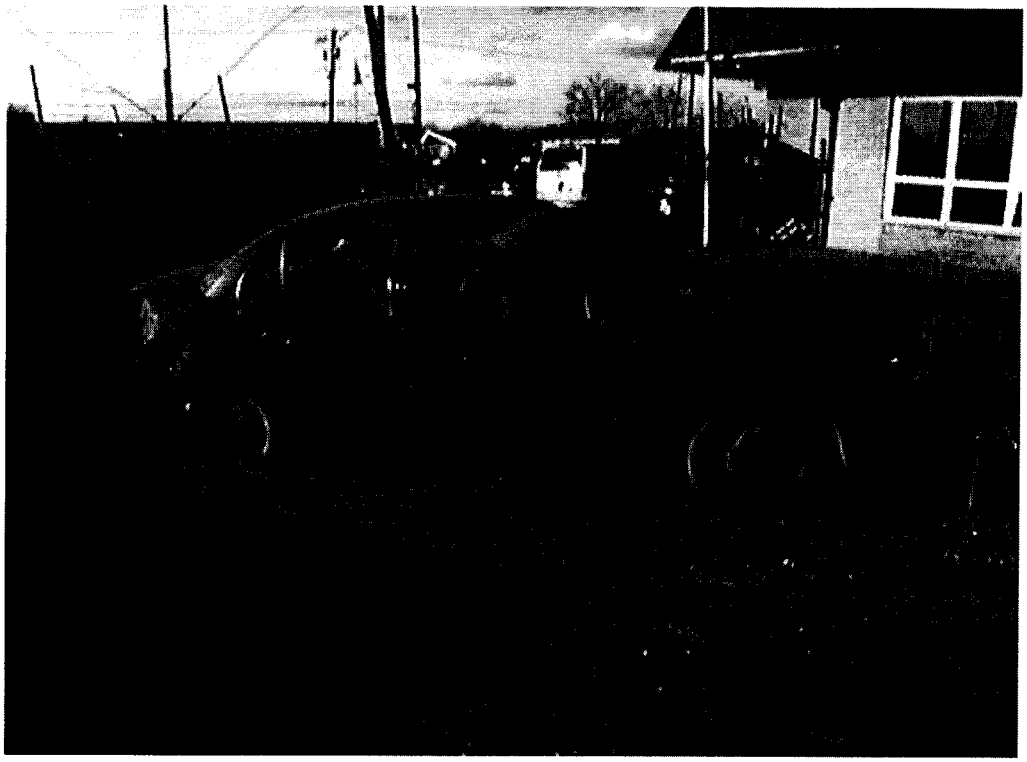


Figure 1. 1998-72-150, Longitudinal A-pillar Bending (Side View)

Figure 2. 1998-72-150, Longitudinal A-pillar Bending (Oblique View)

Case #2

Crash Year: 1999
PSU: 48
Case Number: 24
Vehicle Make/Model: 1999 Mitsubishi Galant
Rollover Cause: Passenger Car to Passenger Car Collision

Crash Summary:

The case vehicle, a 1999 Mitsubishi Galant, was traveling east on a 3-laned, dry bituminous roadway. Another vehicle was traveling west on a 5-laned dry bituminous roadway in the third lane to turn left. The front of the case vehicle impacted the front of the other vehicle. The case vehicle rolled over left onto its top in the roadway and came to rest on its top facing south along the north road edge.

Roof Damage Summary:

The left side of the vehicle contacted the ground, with damage to the front and mid portion of the roof. Both A-pillars bent inwardly at compound angles but remained fairly straight. The B-pillars remained mostly undamaged. The windshield was holed.

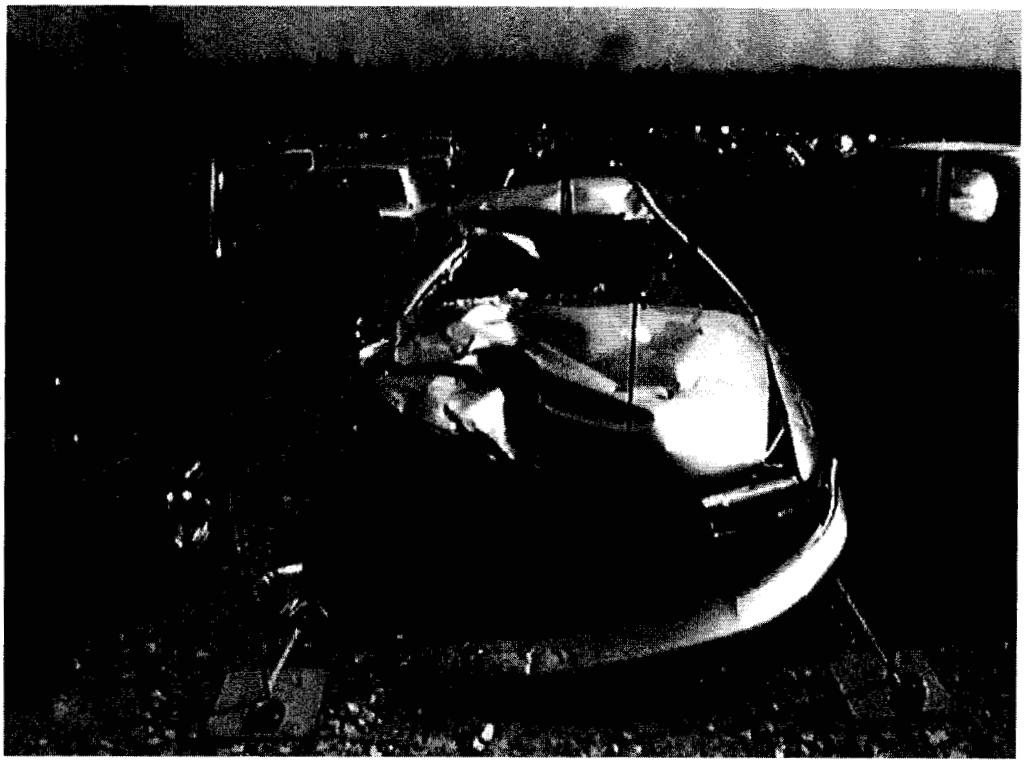


Figure 3. 1999-048-024, Compound A-pillar Bending (Front View)

Case #3

Crash Year: 1999
PSU: 4
Case Number: 14
Vehicle Make/Model: 1998 Nissan Pathfinder
Rollover Cause: Sideswipe/Rollover

Crash Summary:

The case vehicle, a 1998 Nissan Pathfinder, was traveling behind a second vehicle (a passenger car) heading east on a two lane roadway approaching a driveway. The second vehicle attempted to turn left at the same time the case vehicle was passing on the left of the second vehicle. The left front of the case vehicle contacted the right rear wheel of the second vehicle, causing the case vehicle to rotate clockwise. The case vehicle then had a left rear blow out, causing the rim to gouge and initiate a rollover (left leading). The case vehicle rolled three quarter turns, coming to rest facing west on a lawn on the south side of the road. The case vehicle was towed due to damage.

Roof Damage Summary:

The right side of the vehicle contacted the ground with damage to the A and B-pillars, the roof and roof rail. The A and B-pillar both bent laterally and remained fairly straight. The roof side rail was severely distorted. The roof bent downwards at approximately ¾ of the vehicle width. The deformed portion of the roof was planar, deforming at a lateral angle to the undamaged portion of the roof. The damage to the roof extended from the front to the rear of the vehicle.

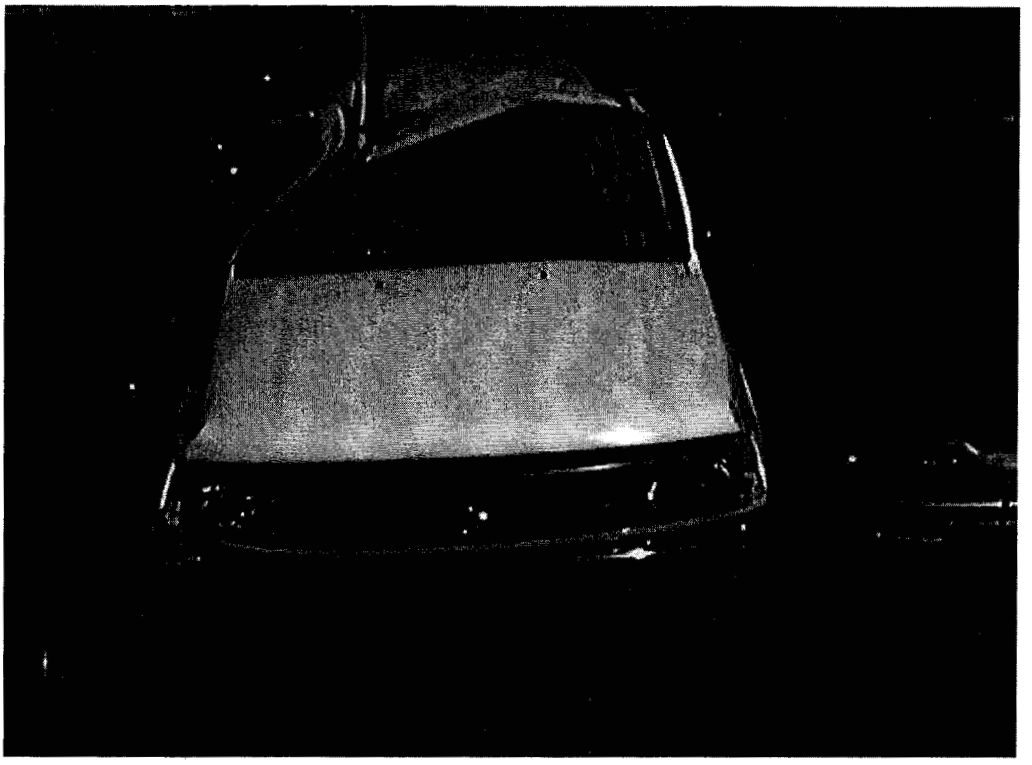


Figure 4. 1999-4-14, Lateral A-pillar Bending (Front View)

Figure 5. 1999-4-14, Lateral A-pillar Bending (Oblique View)

Case #4

Crash Year: 1998
PSU: 43
Case Number: 303
Vehicle Make/Model: 1995 Jeep Cherokee
Rollover Cause: Rear End Collision

Crash Summary:
The case vehicle, a 1995 Jeep Cherokee, was traveling east on a dry, two-lane, bituminous roadway at night without streetlights. The case vehicle was traveling in front of another vehicle, negotiating a curve to the left. The case vehicle slowed and began to turn right into a side street just past the end of the curve. The other vehicle's front collided with the rear of the case vehicle. The case vehicle subsequently rotated 180 degrees while rolling 2 quarter turns to the left, coming to rest on its top in the middle of the side street. Both vehicles were towed due to damage.

Roof Damage Summary:

The case vehicle rolled at an angle (caused by lateral and longitudinal sliding) damaging the top of the front passenger side door, A-pillar and roof structure. The roof bent at a compound angle (both laterally and longitudinally). It remained planar sloping downward toward its intersection with the A-pillar. The A-pillar, side roof rail and front header remained fairly straight with the A-pillar bending longitudinally. The B-pillar was undamaged although the side door window frame closest to the B-pillar received minor damage.

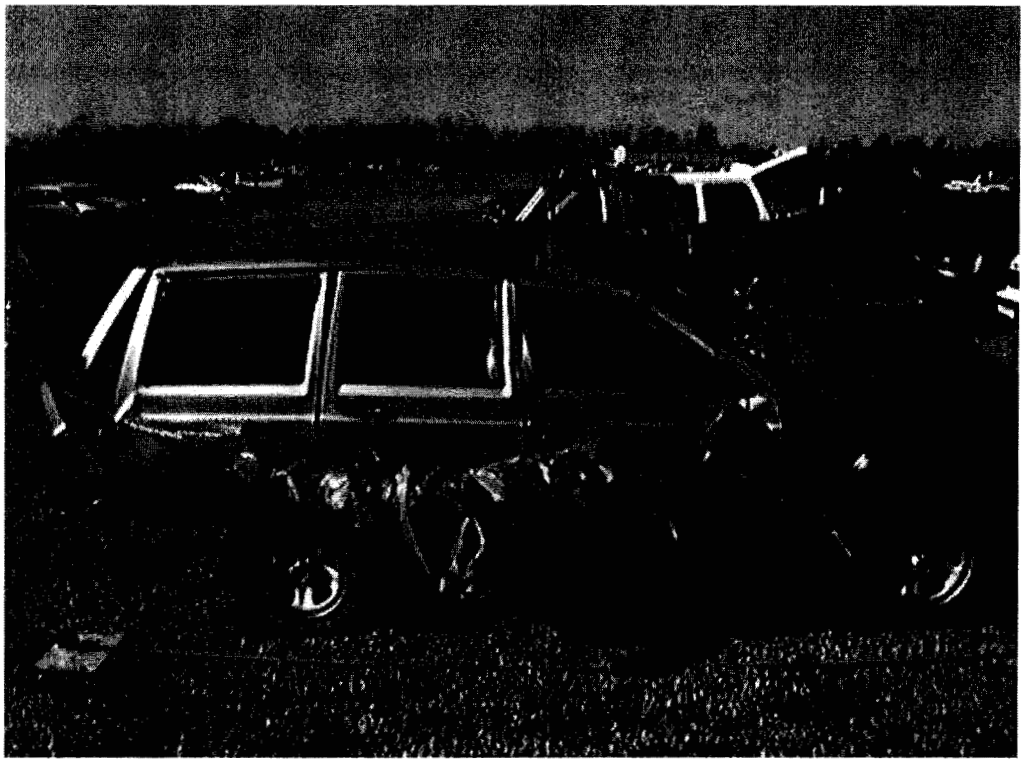


Figure 6. 1998-043-303, Combination A-pillar Bending (Side View)

Figure 7. 1998-043-303, Combination A-pillar Bending (Front View)

Figure 8. 1998-043-303, Combination A-pillar Bending (Oblique View)

Case #5

Crash Year: 1999
PSU: 11
Case Number: 88
Vehicle Make/Model: 1997 Ford Ranger
Rollover Cause: Single Vehicle Rollover

Crash Summary:

The case vehicle, a 1997 Ford Ranger, was traveling eastbound in lane one of a two way undivided roadway. At the time of the accident the roads were wet and it was raining outside. The case vehicle approached a sharp bend in the roadway. The driver lost control while rounding the curve and exited the roadway on the right side (heading south). The vehicle rolled over approximately three quarter turns coming to rest in a ditch on the south side of the roadway. The vehicle at final rest was lying on the driver's side. The driver of vehicle was ejected during the rollover out of the left front window, which was broken during the crash. The vehicle was towed due to vehicle damage.

Roof Damage Summary:

The vehicle exited the roadway from the right and began to rotate clockwise. Ground contact to the A-pillar caused the structure to bend at a compound angle. The A-pillar deformed slightly but remained relatively straight. The roof was damaged with multiple bends; there were no planar areas of damage on the roof (uncommon for composite bending at the A-pillar). The roof rail was also damaged but still remained relatively straight. The windshield was cracked but remained intact.

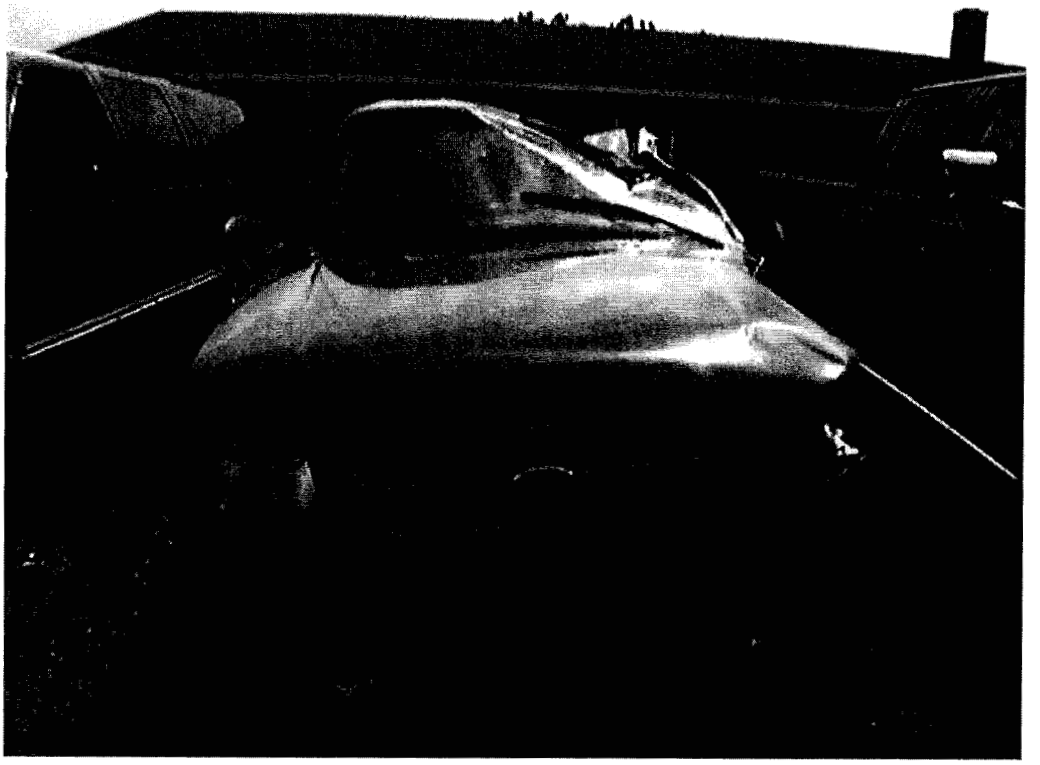


Figure 9. 1999-11-88, Combination A-pillar Bending (Front View)

Figure 10. 1999-11-88, Combination A-pillar Bending (Oblique View)

Case #6

Crash Year: 1999
PSU: 12
Case Number: 60
Vehicle Make/Model: 1996 Ford Mustang
Rollover Cause: Single Vehicle Rollover

Crash Summary:

The case vehicle, a 1996 Ford Mustang, was northbound on a two lane, concrete roadway with icy conditions. The vehicle lost control, went off road to the left, tripped on large piles of snow in the center median, the vehicle rotated two quarter turns, and slid on its top. The occupant cockpit area was filled with snow. The vehicle stopped in the center of the median resting on its roof. The vehicle was towed from the scene of the crash.

Roof Damage Summary:

The rollover event initiated from the passenger side of the vehicle (the right side). The vehicle's momentum allowed it to rotate two quarter turns without contacting the ground. On the third quarter turn, the vehicle contacted the roof at the driver side A-pillar juncture. Contact with the ground caused the roof to experience bending over its entire surface, especially near the A-pillar juncture. The contact with the roof caused the roof rail and the A-pillar to both bend. The roof side rail and front header bent downward but remained planar. The A-pillar bent at a composite angle (laterally and longitudinally), although the pillar remained straight. The windshield was holed during the rollover with only the periphery attached.

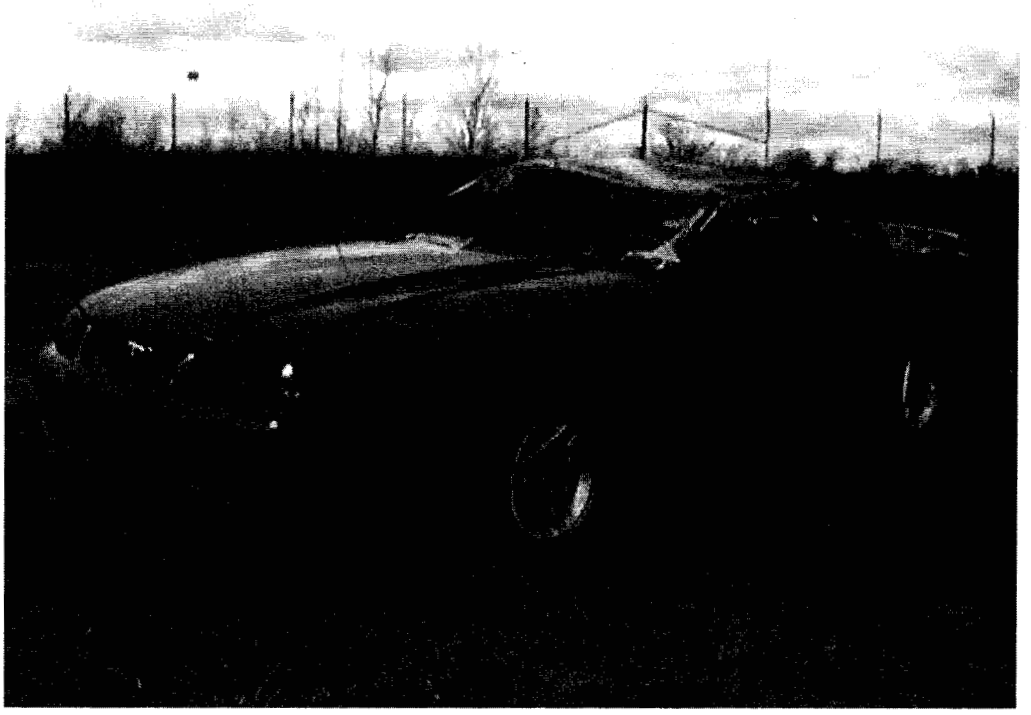


Figure 11. 1999-12-60, Combination A-pillar Bending (Oblique View)

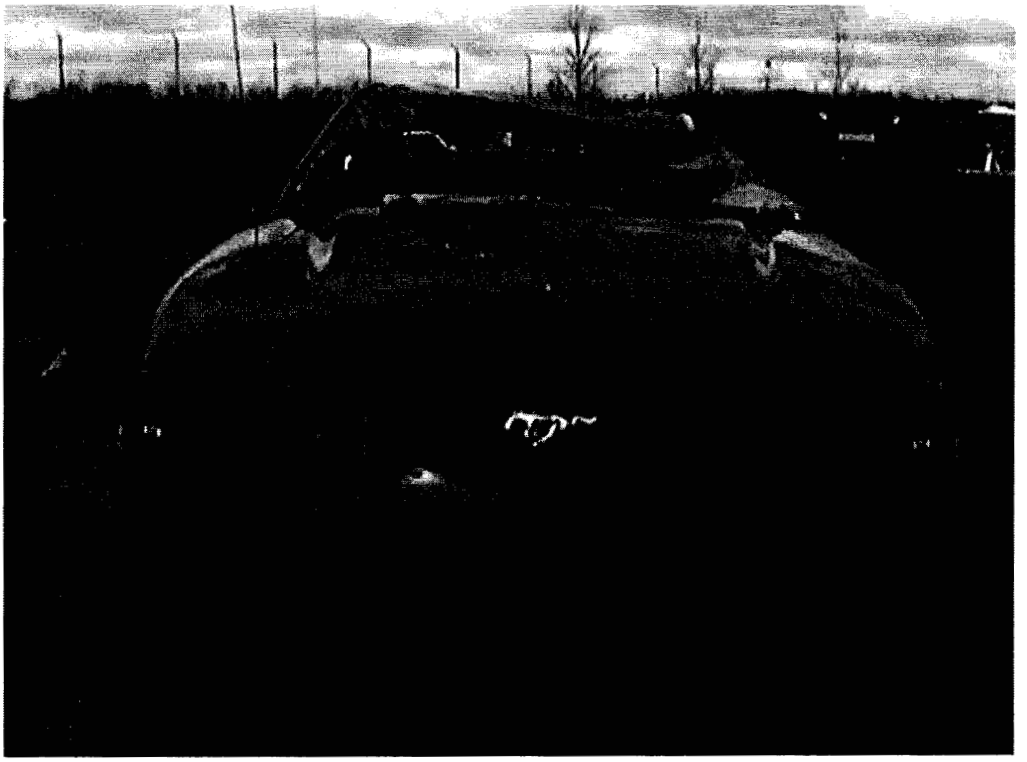


Figure 12. 1999-12-60, Combination A-pillar Bending (Front View)

Case #7

Crash Year: 1999
PSU: 78
Case Number: 34
Vehicle Make/Model: 1998 Chevrolet S-10/T-10
Rollover Cause: Single Vehicle Rollover

Crash Summary:

The case vehicle was eastbound on a rural, 2-lane, dry, level, bituminous roadway with no traffic controls present. The case vehicle gradually exited the roadway on the right side and then re-entered the roadway in a counterclockwise rotation. The right side tires dug into the asphalt and the vehicle then overturned on the roadway, overturning a total of (6) quarter turns. The case vehicle came to final rest partially on the pavement, partially off the left side on the gravel. The vehicle was on the roof facing generally northwest.

Roof Damage Summary:

The vehicle initiated its rollover from the passenger side of the vehicle (the right side). The rollover caused damage to the right side quarter panels (front and rear), A-pillar, roof rail, side rail and front header. The quarter panels were dented severely. The right A-pillar was bent at a longitudinal angle. The roof experienced multiple bends. The front windshield was missing.

Figure 13. 1999-078-034, A-pillar Bending along its length (Driver Side View)

Figure 14. 1999-078-034, Roof Damage (Top View)

Case #8

Crash Year: 1999
PSU: 12
Case Number: 22
Vehicle Make/Model: 1998 Ford Ranger
Rollover Cause: Single Vehicle Rollover

Crash Summary:

The case vehicle, a 1998 Ford Ranger, was traveling southbound on a three lane, one way asphalt expressway in icy environmental conditions. The vehicle lost control on the ice and veered to the right leaving the roadway, entering a ditch and climbing an embankment. The front of the vehicle struck a pine tree and rolled over to come to final rest on its wheels. Both redesigned air bags deployed during the impact to the front. The vehicle was towed from the scene of the crash due to damage.

Roof Damage Summary:

The vehicle sustained damage to the front end and hood from a tree impact. It is believed that the rollover event began on the driver's side of the vehicle (the left side). The rollover damaged the left side A-pillar and the entire roof structure, including the side rail and front header. The A-pillar bent longitudinally along its length. The B-pillar remained undamaged. The roof rail and front header bent along their lengths. The roof bent upwards and crumpled over its entire structure. The front windshield cracked but remained intact. The windshield could provide minimal roof support after the crash, do to it remaining intact but structural integrity is diminished due to it being cracked.

Figure 15. 1999-12-22, A-pillar Bending along its length (Oblique View)

Figure 16. 1999-12-22, A-pillar Bending along its length (Side View)

Case #9

Crash Year: 1998
PSU: 11
Case Number: 193
Vehicle Make/Model: 1995 Plymouth Voyager (Minivan)
Rollover Cause: Single Vehicle Rollover

Crash Summary:

The case vehicle, a 1995 Plymouth Voyager minivan, had been parked in a residential driveway with the engine running. When the intended driver and other occupants exited the residence they realized that the van had been stolen. The minivan was reportedly traveling East on a rural, two lane asphalt roadway with a statutory speed limit of 55 MPH. Marked police cars were pursuing the van. The police ceased pursuit as the van departed the roadway on the right in excess of 90 MPH. The driver abruptly turned the steering wheel to the left, which caused the vehicle to cross the travel lanes and depart the left side of the roadway in a counter-clockwise yaw. The van struck trees as it was rolling onto its roof with the right side leading. The van rolled 6-quarter turns before coming to rest on its roof. The van was towed from the scene.
Roof Damage Summary:

The vehicle initiated the rollover event from the passenger side (the right side). The vehicle avoided damaging the passenger side of the vehicle. Damage was sustained on the driver's side. This included the roof, side rail, front header, A/B/C pillars, front left side quarter panel and hood. The roof sustained crumpling type damage from the front of the vehicle to the rear. The A-pillar bent at a compound angle near its intersect to the roof. The B and C-pillars bent but remained straight. The roof side and front header were severely bent, without any planar segments. The front windshield cracked but remained attached without any holes.

Figure 17. 1998-11-193, A-pillar Bending along it length (Front View)

Figure 18. 1998-11-193, A-pillar Bending along its length (Oblique View)

Case #10

Crash Year: 1998
PSU: 48
Case Number: 4
Vehicle Make/Model: 1996 Mercury Mystique
Rollover Cause: Single Vehicle Rollover

Crash Summary:

The case vehicle, a 1996 Mercury Mystique, was traveling north on a two lane state roadway in a heavy rainstorm. The vehicle hydroplaned on the wet pavement and traveled off the right side of the road in a counterclockwise yaw. As the vehicle traveled over the steep embankment, it went airborne and struck several trees during a four quarter rollover. The vehicle came to rest on its wheels facing west. The vehicle was towed due to disabling damage.

Roof Damage Summary:

The vehicle initiated its rollover from the passenger side (the right side). The vehicle hit several trees as it rolled, causing an uncommon damage pattern to the driver's side of the vehicle. This included damage to the roof, side rail, door and side window frame, front header and A-pillar. Because the severity of the impact caused by the trees, the level of bending at the roof front left corner was almost catastrophic. The A-pillar bent at a composite angle just about at its middle. The top of the pillar bent almost to the vehicle's body. The side rail and front header bent downward to the same level. None of these components remained planar, except the roof, which bent downwards at a planar angle. The front windshield was holed but remained attached.

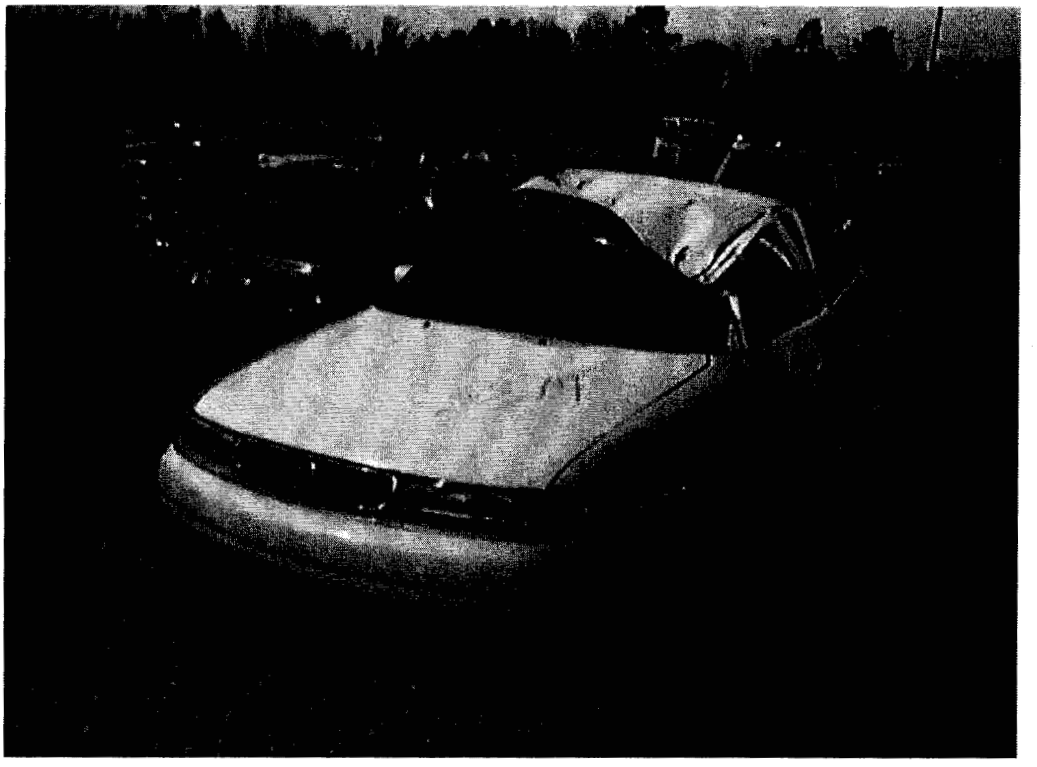


Figure 19. 1998-48-4, A-pillar Bending along its length (Oblique View)

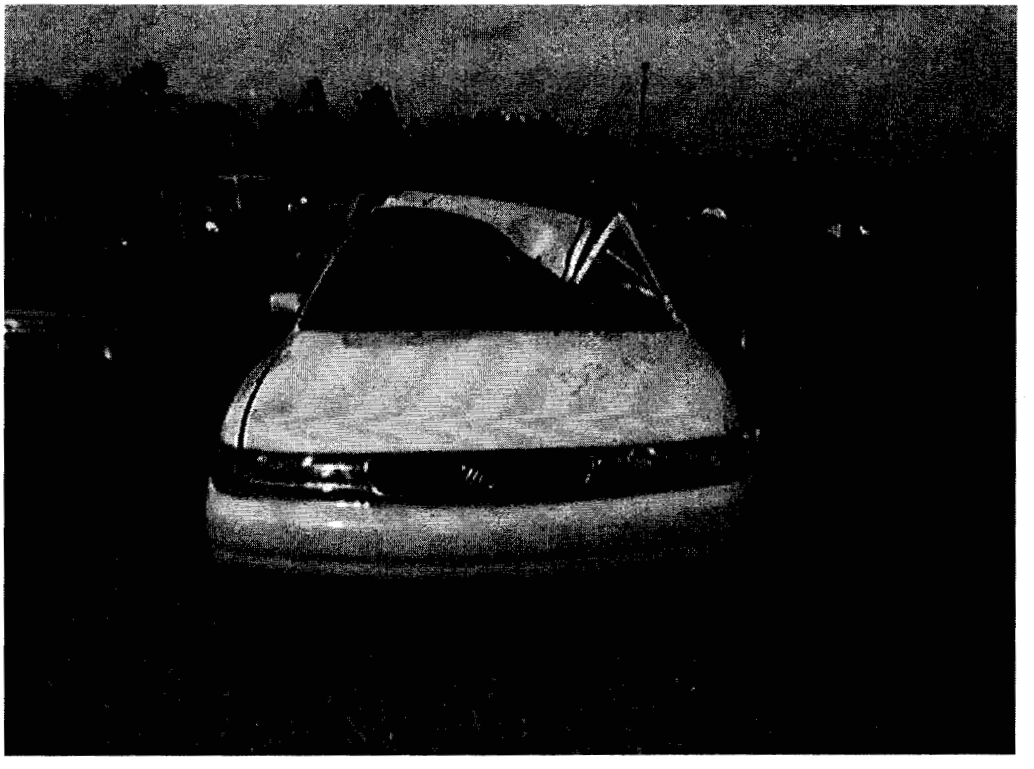


Figure 20. Figure 19. 1998-48-4, A-pillar Bending along its length

Case #11

Crash Year: 1999
PSU: 12
Case Number: 114
Vehicle Make/Model: 1998 Chevrolet S-10 Blazer
Rollover Cause: Tractor Trailer to SUV Collision

Crash Summary:

The case vehicle was northbound traveling on a 5 lane, 2 way, asphalt roadway. Another vehicle was westbound traveling on a 2 lane, asphalt urban roadway under dry, daylight environmental conditions. Entering an intersection, the two vehicles contacted their front to right sides, and the case vehicle then rolled over and was towed from the scene of the crash due to damage. The number of quarter turns and the initial contact point for roll initiation is unknown.

Roof Damage Summary:

Damage was sustained to the roof, side rail, header, and A-pillar. The A-pillar bent at a compound angle. The roof remained planar but sloped at a compound angle. The front windshield was cracked and partially holed.

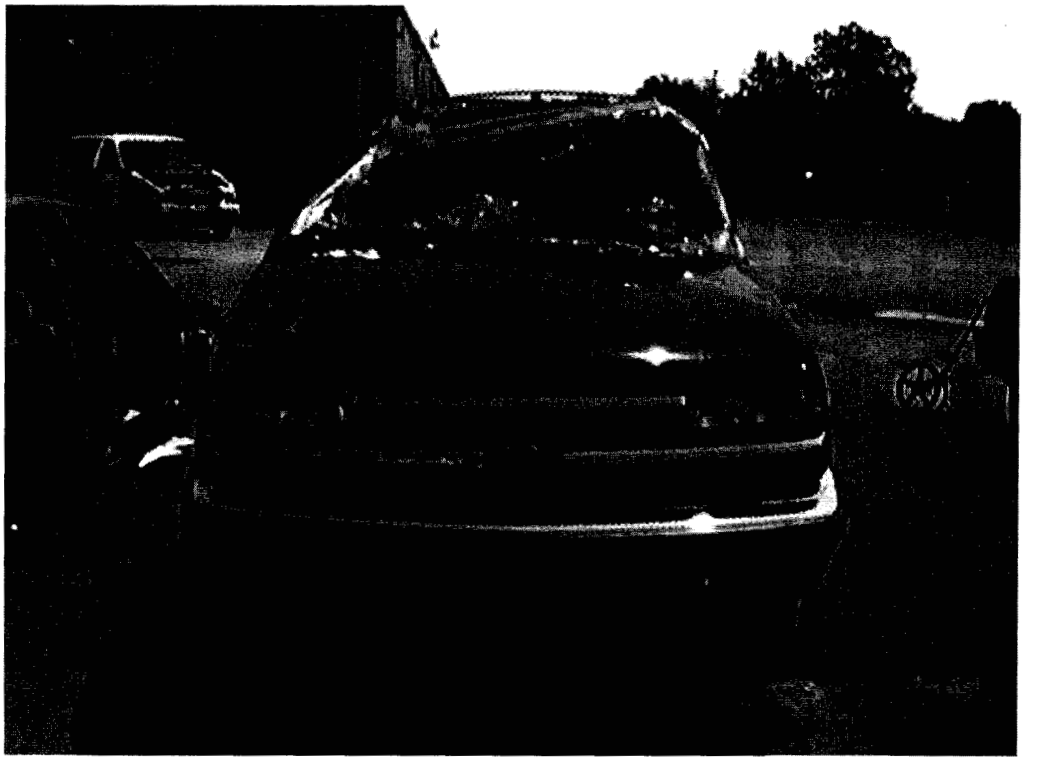


Figure 21. 1999-012-114, Compound Bending (Front View)

Figure 22. 1999-012-114, Compound Bending (Close-Up View)

2.2.3. Dual Sided Rollover Damage

Cases were classified as experiencing dual sided rollover damage when both left and right side pillars were substantially damaged. These cases include examples where both sides of the roof were damaged due to ground contact and cases where damage to one side of the roof caused damage to the opposite side. Notably, the dual sided damage cases include damage where pillars on both sides of the vehicle bend in the same direction, creating a "matchbox" or parallelogram damage pattern. In these cases, the roof had little bending. In contrast, there were also cases where the pillars on both sides bent inwards, causing the roof to bend upwards along a longitudinal crease.

2.2.4. Selected Cases with Dual Sided Rollover Damage

Sample cases are shown to illustrate the types of two-sided damage. Cases 12 through 14 show the typical types of roof patterns associated with bending of the pillars and Case 15 shows a crash where the roof experienced catastrophic roof damage.

Case #12

Crash Year: 1997
PSU: 73
Case Number: 26
Vehicle Make/Model: 1995 Ford Explorer
Rollover Cause: SUV to Passenger Car Collision

Crash Summary:
The case vehicle, a 1995 Ford Explorer, was traveling east on a two lane, two-way state road in the eastbound lane. A second vehicle was traveling in the same direction on the same roadway behind the case vehicle. The second vehicle struck the case vehicle in the rear end with the front end of its vehicle. The case vehicle was forced off the roadway to the right striking a stop sign post, a large rock, and a wooden fence post. The case vehicle entered a farm field and rolled over numerous times before coming to final rest in the field right side up facing back west. Both of the vehicles involved in the accident were towed from the scene due to damage sustained in the accident.

Roof Damage Summary:

The case vehicle started its roll on the passenger side of the vehicle (the right side). The vehicle experienced almost a pure lateral rotation. During the rollover event, the vehicle contacted the ground on both sides of the vehicle. Ground contact caused damage to the A, B, and C-pillars, the roof, side rails, and the front header. Damage to the pillars involved bending with all of the pillars remaining straight. Similarly, the front header bent at its middle but remained planar on both sides of the bend. The roof also bent at its middle, longitudinally down the center of the vehicle, forming an upward "V." The front windshield was holed but remained attached to the vehicle.

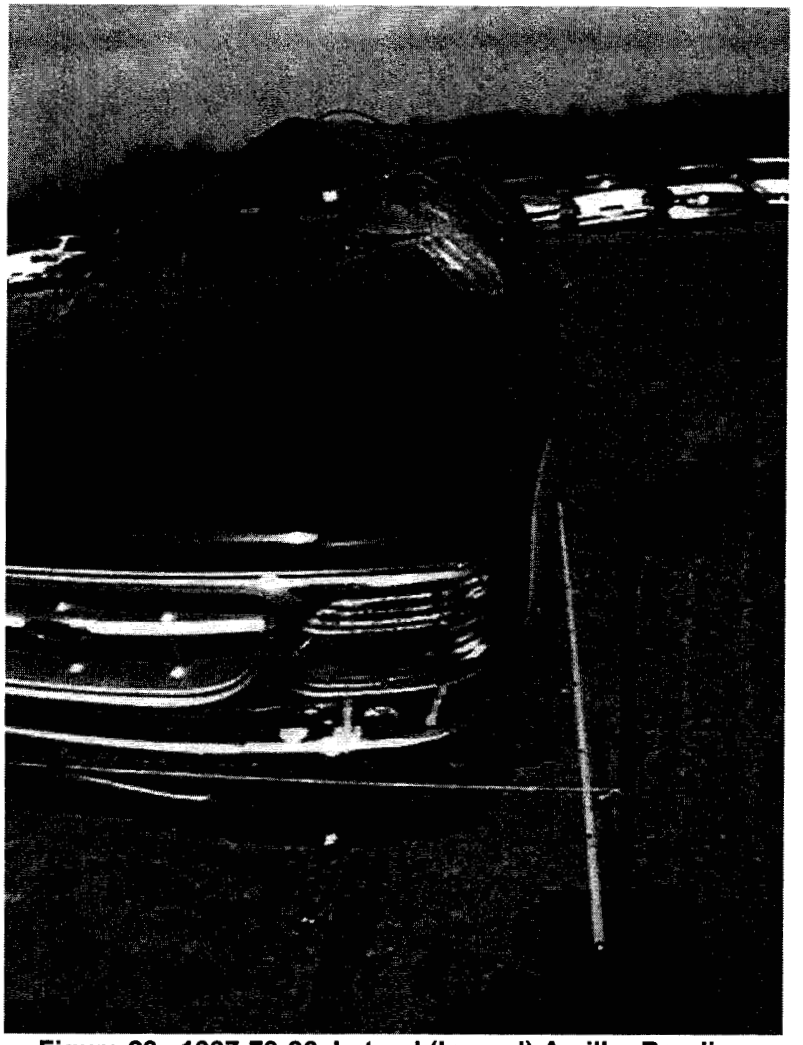


Figure 23. 1997-73-26, Lateral (Inward) A-pillar Bending

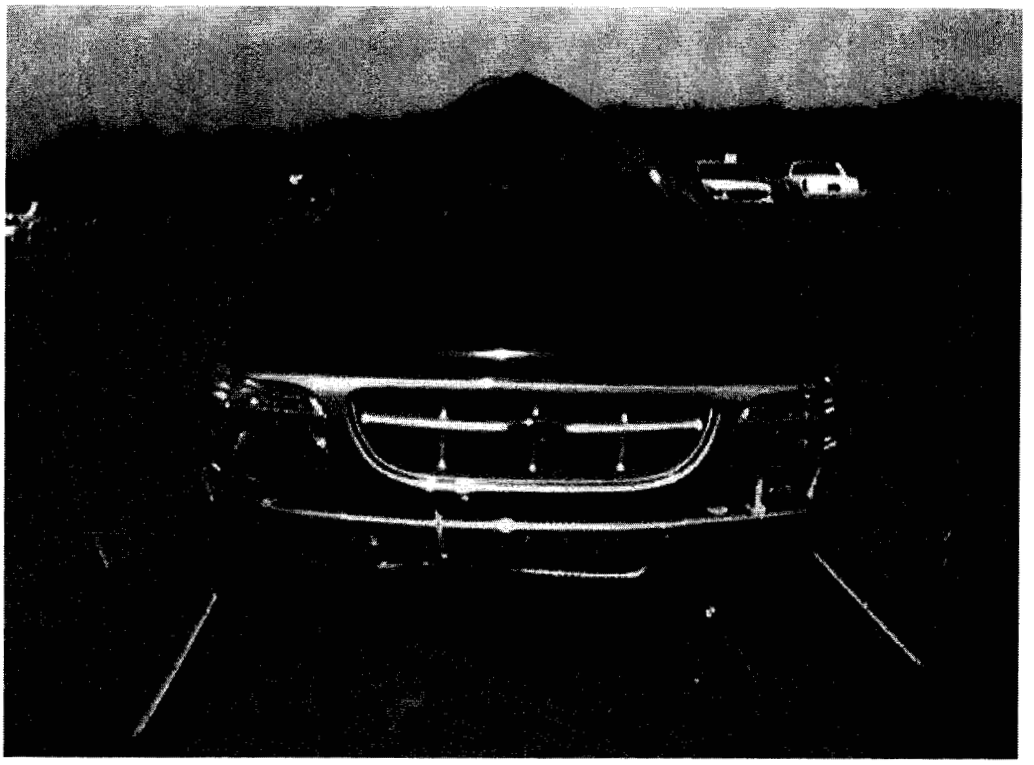


Figure 24. 1997-73-26, Lateral (Inwards) A-pillar Bending

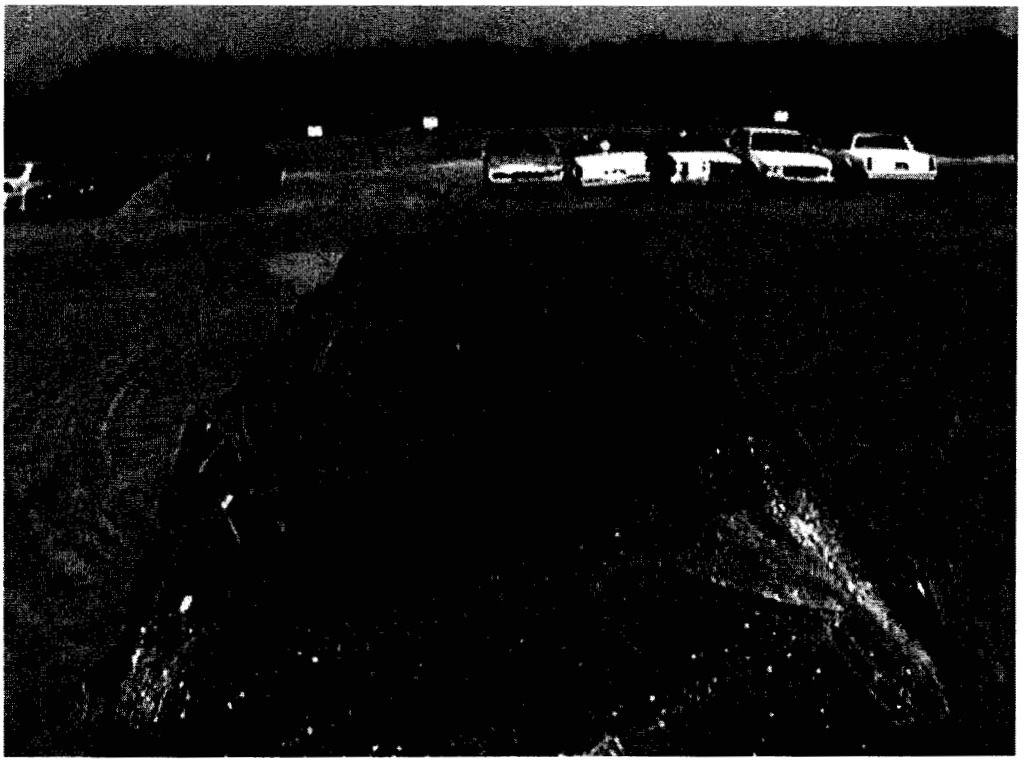


Figure 25. 1997-73-26, Lateral (Inwards) A-pillar Bending

Case # 13

Crash Year: 1998
PSU: 73
Case Number: 149
Vehicle Make/Model: 1998 Ford Explorer
Rollover Cause: Single Vehicle Rollover

Crash Summary:

The case vehicle, a 1998 Ford Explorer, was southbound on a four-lane two-way divided interstate. The vehicle was in the inside lane next to the grass median. The vehicle lost control on the icy road and departed the roadway on the right side. The vehicle went down the embankment and up the other side rotating in a clockwise direction. The left wheel of the vehicle dug into the ground causing it to roll. The vehicle went through some brush finally coming to rest in a field on its roof facing north. The vehicle was towed from the scene.

Roof Damage Summary:

The vehicle initiated its rollover from the driver's side of the vehicle (the left side). The vehicle rolled on the left side of the roof structure. The A and B-pillars bent but remained mostly straight. Additionally the roof, side rails and front header remained mostly straight, forming a parallelogram or "matchboxing" damage pattern. The front windshield was cracked and detached from the vehicle.

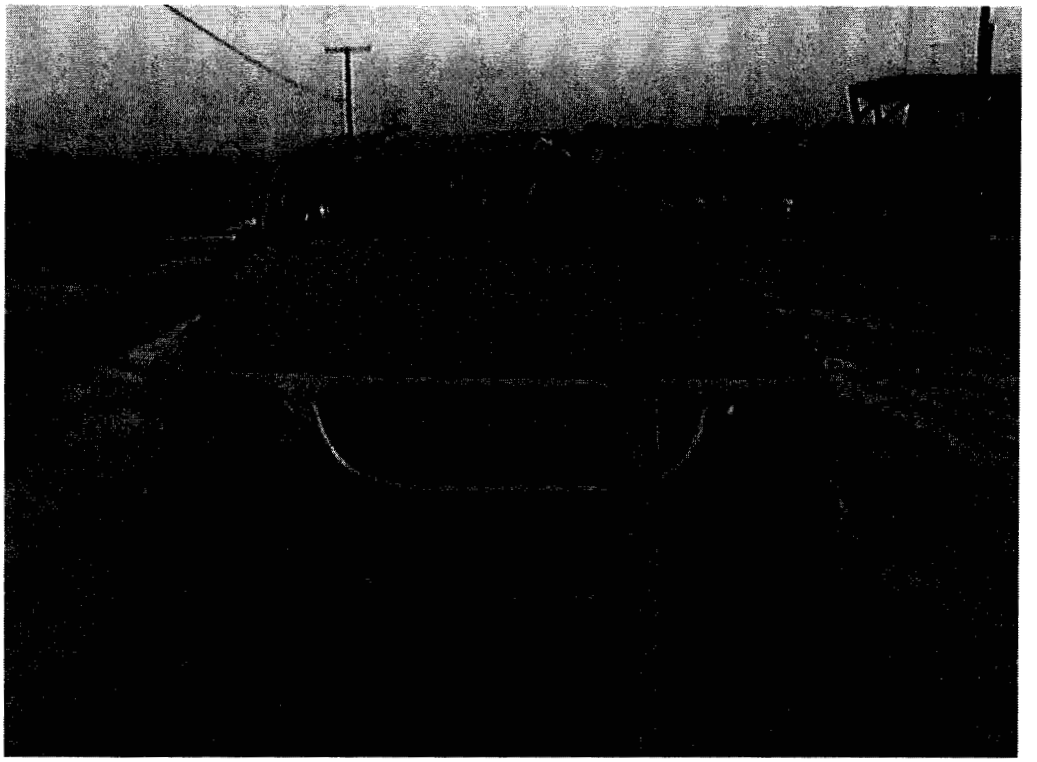


Figure 26. 1998-73-149, Lateral A-pillar Bending (Matchboxing)

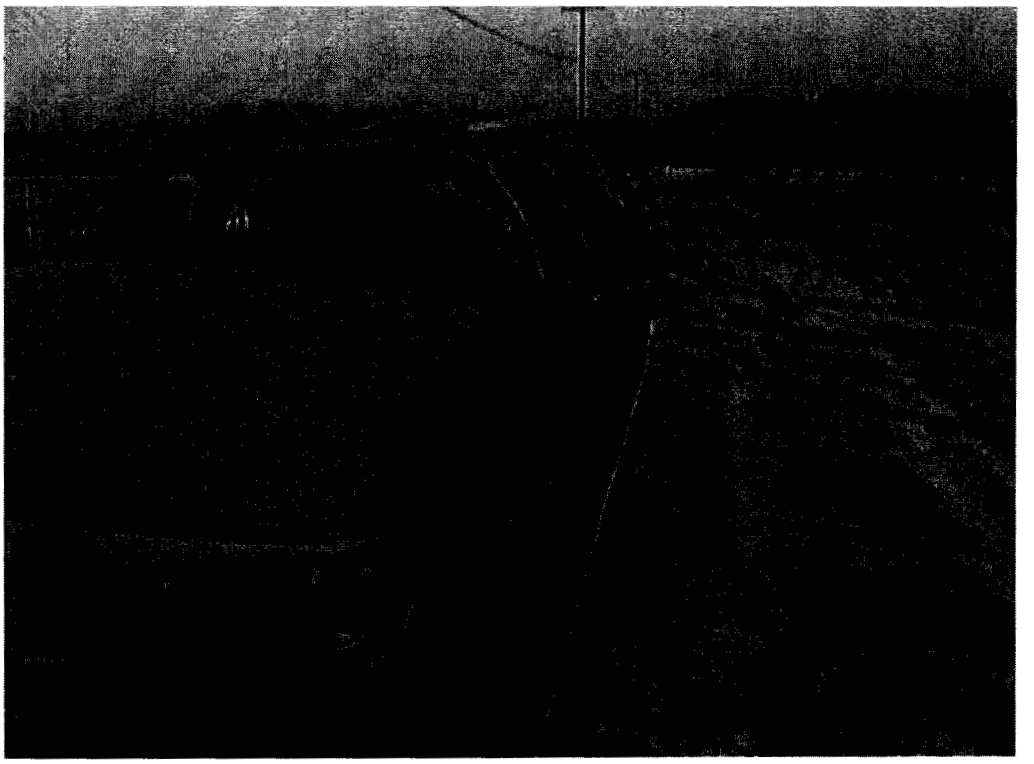


Figure 27. 1998-73-149, Lateral A-pillar Bending (Matchboxing)

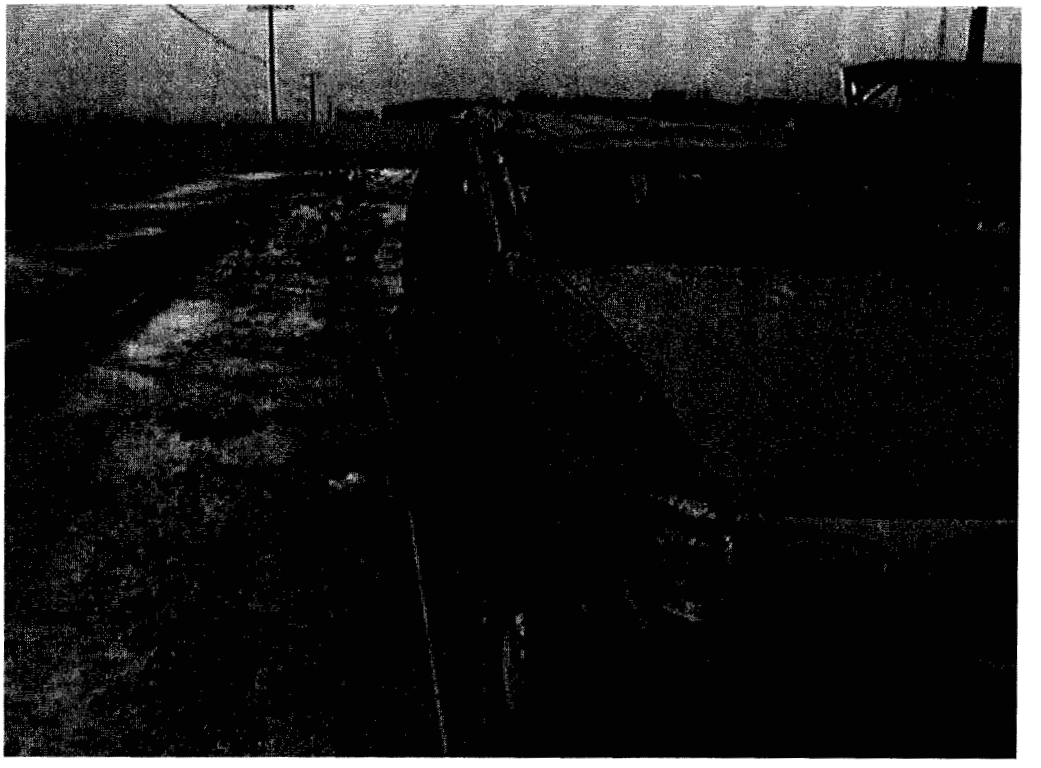


Figure 28. 1998-73-149, Lateral A-pillar Bending (Matchboxing)

Case #14

Crash Year: 1999
PSU: 49
Case Number: 140
Vehicle Make/Model: 1995 Mazda 626
Rollover Cause: Angle Impact with Minivan

Crash Summary:

A minivan was traveling east, merging from right to left from an expressway on ramp to a two lane divided expressway. The case vehicle, a 1995 Mazda 626, was traveling east in the first lane of the same expressway. As the minivan merged onto the expressway, the case vehicle was forced out of its lane to the left. At that point, the case vehicle ran slightly off the shoulder and lost control, rotating clockwise. The left side of minivan contacted the left side of the case vehicle. This contact sent both vehicles off the roadway to the right. Both vehicles began to rollover and both vehicles collided with a fence. The minivan ended up back on its wheels while the case vehicle ended on its top on an adjacent service road. Both vehicles were towed.

Roof Damage Summary:

The case vehicle initiated the rollover event from the driver's side of the vehicle. As the vehicle rolled, contact was made with the driver's side of the vehicle and then the passenger side. During the rollover, the A-pillars on both sides of the vehicle bent midway along the length at a compound angle. The front header bent downward at both ends causing the roof to deform inward, although the roof side rails still remained straight. The windshield separated along the front header but remained attached along the other three sides.

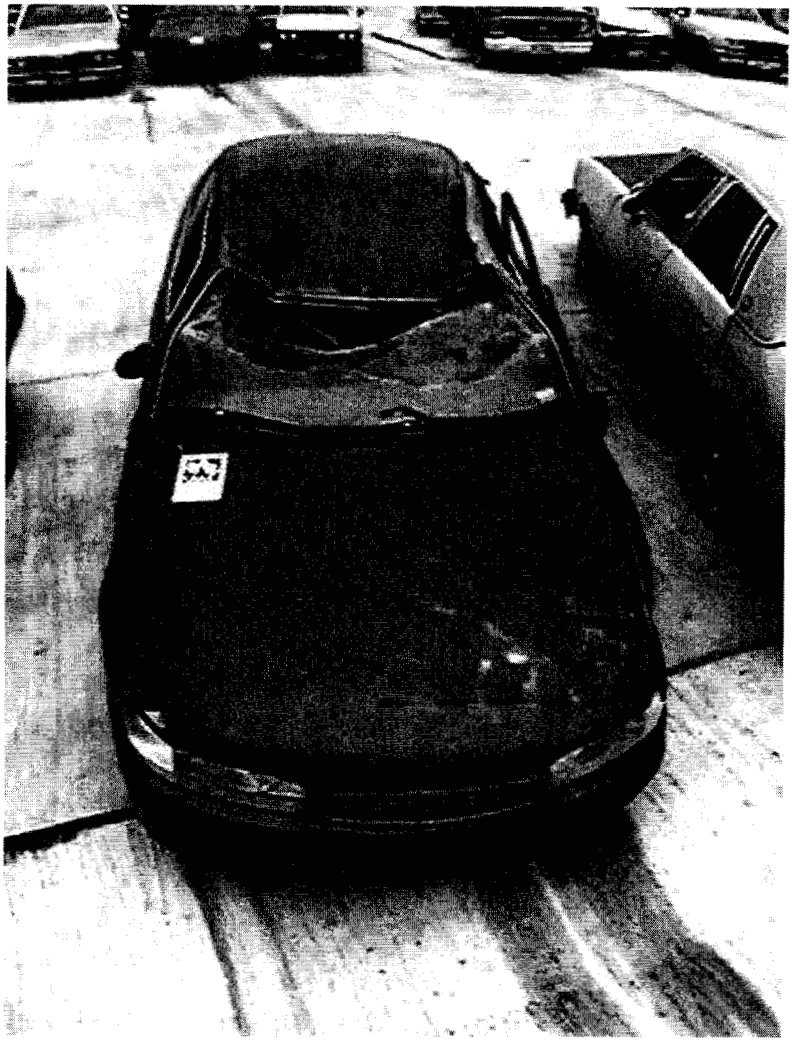


Figure 29. 1999-49-140, Combination A-pillars Bending

Case #15

Crash Year: 1997
PSU: 79
Case Number: 49
Vehicle Make/Model: 1996 Volkswagon Jetta III
Rollover Cause: Single Vehicle Collision with Object

Crash Summary:

The case vehicle was travelling south in the #1 lane of a multi-lane, dry, divided concrete highway with a left curve. As the case vehicle entered the curve, it began a counter clockwise rotation subsequently exiting the left pavement edge. The vehicle's lateral motion against the soft soil initiated a right side "trip over" resulting in severe roof damage. The vehicle rolled approximately onequarter turn before impacting a pole (and pole base - non-horizontal to the right plane) resulting in severe top (overlapping) damage. At this point, the pole was knocked over as the vehicle continued to roll 9 more quarter turns before coming to rest (on its roof) partially on the east shoulder facing southeast.

Roof Damage Summary:

All six pillars bent inwards, with the degree of damage decreasing towards the rear of the occupant compartment. The B and C-pillars were bent along their length on both sides of the vehicle. The roof damage was considered catastrophic.

Figure 30. 1997-79-049, Catastrophic Roof Damage

2.2.5 Frequency of Identified Roof Deformation Patterns

This study was intended to be an evaluation of general roof damage patterns in severe NASS crashes. The frequencies of the observed damage patterns are not representative of general rollover crashes, and these numbers do not reflect the NASS weighting factors for each case. For the 273 cases in this study, the following trends were noted:

99 cases, 36 percent, had damage primarily to one side of the vehicle
189 cases, 69 percent, had damage to front of the roof
116 cases, 42 percent, had damage to the middle of the roof
79 cases, 29 percent, had damage to the rear of the roof
32 cases, 12 percent, had a parallelogram or "matchbox" damage pattern
53 cases, 19 percent, had A-pillar bending along its length
32 cases, 12 percent, had B-pillar bending along its length
21 cases, 8 percent, had the A-pillar bending at a lateral angle
20 cases, 7 percent, had the A-pillar bending at a longitudinal angle
89 cases, 33 percent, had the A-pillar bending at a compound angle

The case reviewers independently judged from the descriptive and photographic evidence whether the post crash windshield was capable of providing some roof support. Post crash support was considered evident in 10 percent of the cases. I reiterate that this does not determine what support the windshield gave to the roof structure during the crash event. The roof damage was predominantly to the front of the vehicle with the A-pillar bending at a compound angle. For the most part only one side of the vehicle had damage to the A-pillar, yet the roof damage was seen across the entire front of the roof in most cases. The middle of the roof experienced damage close to half the time although the B-pillar was damaged just over 10 percent of the time. This middle of the roof damage was usually a reaction to the main frontal damage that the roof encountered.

The vehicles were divided into two categories, above and below 25 cm of maximum vertical intrusion. Approximately the same number of vehicles had ≤ 25 cm and > 25 cm of vertical roof intrusion. The frequency of the observed damage patterns showed remarkable consistency. The ≤ 25 cm group had significantly more vehicles with undamaged B-pillars and the >25 cm group had twice the frequency of two sided matchboxing.

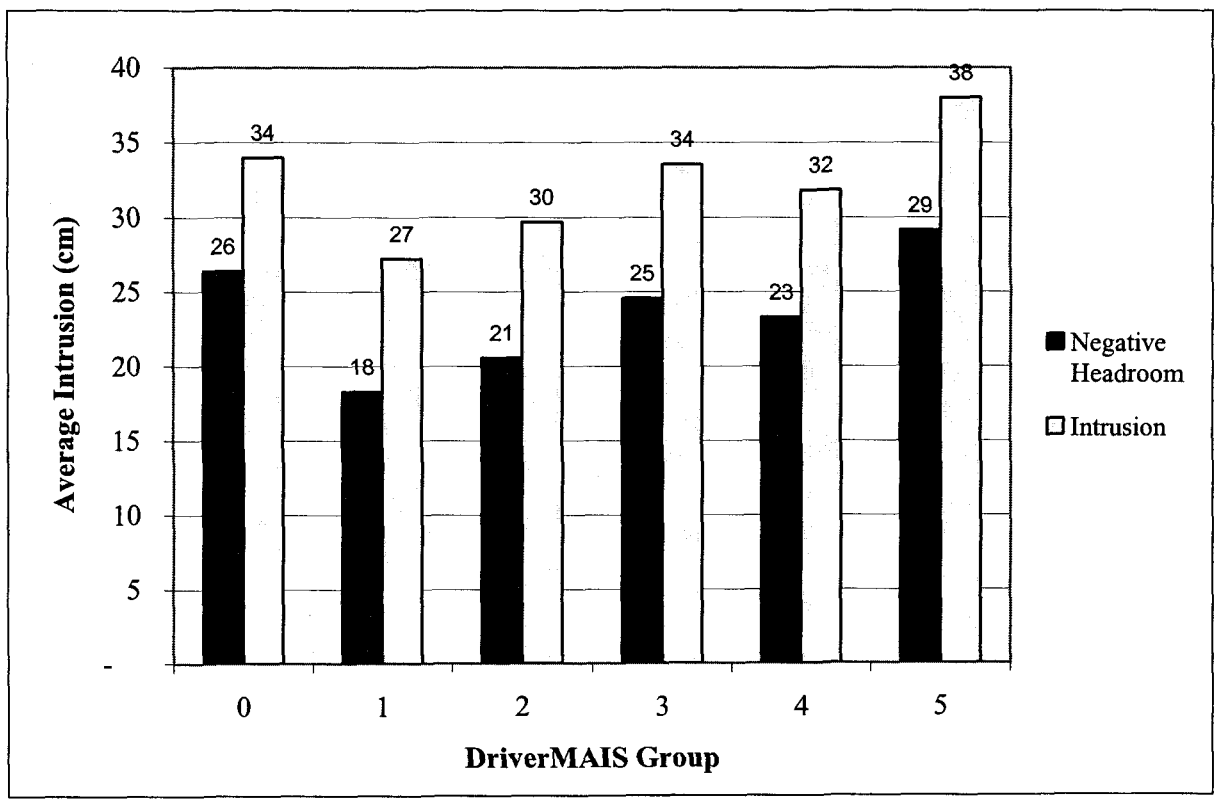
2.2.6 Comparison of Roof Damage Patterns and Occupant Injury Severity

Maximum Abbreviated Injury Scale (MAIS) levels for belted occupants were used to divide the NASS cases. The average vertical roof intrusion for the 273 cases was found to be 30.8 cm. There were 78 occupants with less than average roof crush and MAIS 3+ injuries (57 drivers and 21 right front passengers). There were 45 occupants with above average roof crush and MAIS 3+ injuries (35 drivers and 10 right front passengers). Since there were more occupants with MAIS 3+ injuries in the cases with less than the average roof crush, it is observed that something besides roof crush may be associated with the occupant's injuries. This emphasizes the

importance of accounting for other measurements such as pre and post crash headroom measurements. When considering only roof intrusion, this data set supports that more occupants had higher MAIS levels of injury with less roof intrusion. This contradicts the generalized conclusion that higher MAIS injury levels correlate with more intrusion. This study did not account for occupant seating position, what the nature of the MAIS 3+ injuries were, or if their was partial ejection. The vehicles in this data set do not represent a national sample due to the vehicle criteria of having at least six inches of roof crush. Therefore to understand this properly, more than roof intrusion must be considered.

In order to analyze this contradiction, we first added mean headroom for each car group to the dataset and then subtracted the mean headroom from the total intrusion. This calculation is defined as negative headroom[1]. The negative headroom allows us to see if the problem lies in the variable measured. The original dataset contained 273 cases. When we matched the 273 cases with the car groups, we eliminated 71 cases since they did not match with a car group, thereby leaving us with 202 cases. Figure 31 shows both intrusion and negative headroom for each MAIS group.

Figure 31: Intrusion and Negative Headroom vs. Driver MAIS Group

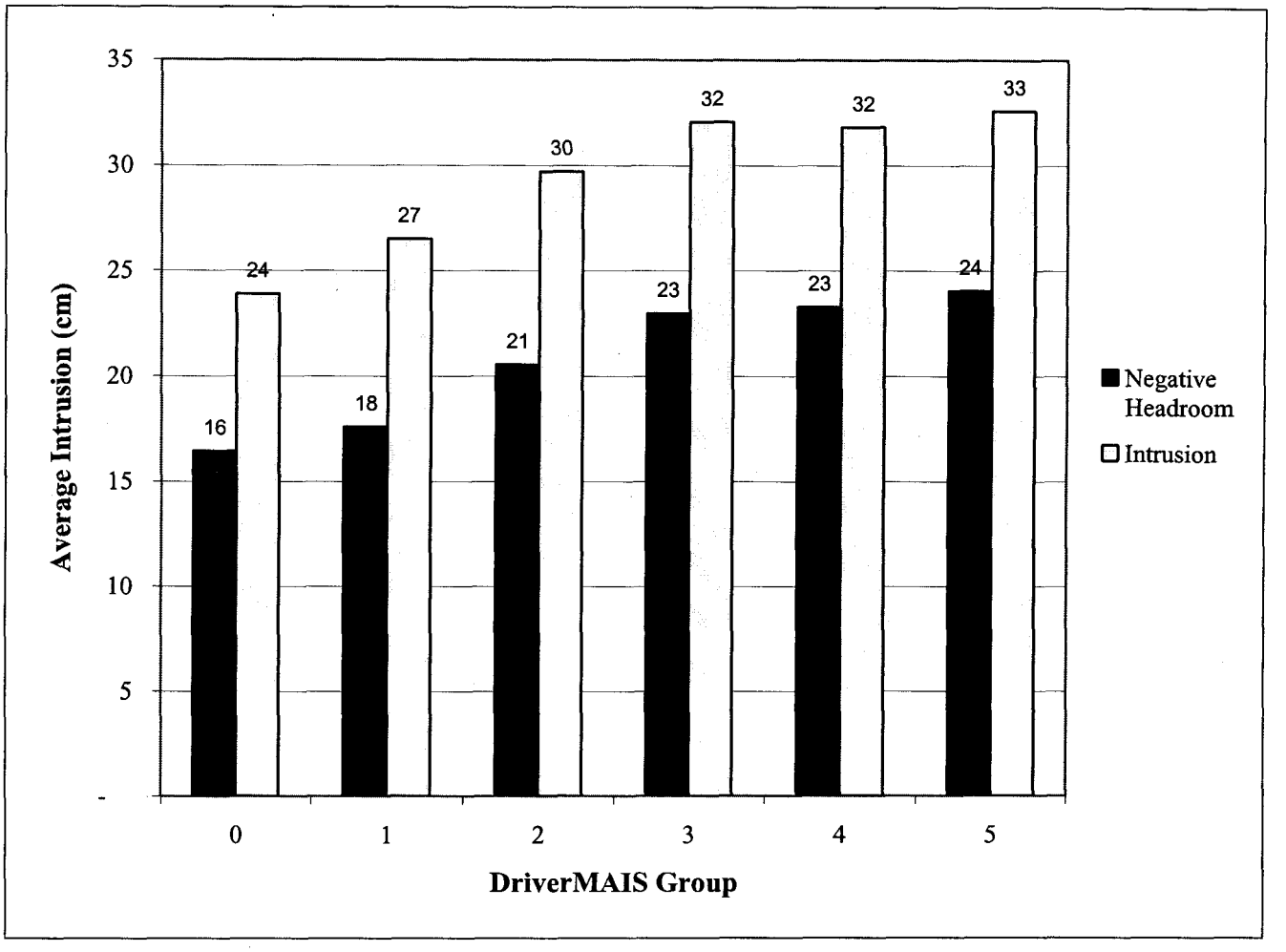


[1] We didn't use intrusion as a percent of initial available space because the scale would be different for each observation. For example, a car with 5 cm headroom and 10 cm intrusion would have intrusion as 200% initial available space and a car with 10 cm headroom and 20 cm intrusion would also have intrusion as 200% initial available space.

The above result shows that even when redefining the variable from intrusion to negative headroom there is still no change in the conclusion that higher MAIS injury levels do not correlate with more intrusion. This result led us to look at the photographs from all 202 remaining cases in the dataset to determine if there was improper reporting on the amount of total intrusion. There were 6 cases removed from the dataset due to improper reporting of intrusion levels, leaving 196 cases available for the analysis. This was based on the engineering review regarding intrusion levels from the data set photographs.

Once we eliminated cases with improper reporting on intrusion, we got more intuitive results. Figure 32 shows both intrusion and negative headroom for each MAIS group from the remaining data. As predicted, lower intrusion levels correspond to less injury. For instance, the average negative headroom for MAIS group 0 is 16 cm while the average negative headroom for MAIS group 5 is 24 cm.

Figure 32: Intrusion and Negative Headroom vs. Driver MAIS Group



2.2.7 Comparison of Damage Patterns by Vehicle Class

No major distinctions were identified between the damage incurred by the different vehicle classes. There were too few cases involving vans to develop a good understanding of any typical damage patterns for that class of vehicles. It is possible that given additional crash cases that the vans may display roof damage different from the passenger cars, SUVs, and pickup trucks. The pickup trucks seemed to experience the most significant roof damage. The damage to the sport utility vehicles was similar to the passenger car category, though the SUVs had more damage to the rear of the roof, C and D-pillars. A comparison between vehicles weighing over 6,000 lbs. and those weighing below 6,000 lbs. was not made in this study. The observations from this study are generally consistent with the previous report.

2.2.8 Comparisons to Extended FMVSS 216 and Roof Drop Testing

Both the FMVSS No. 216 test methodology and the roof drop testing conducted at the FMVSS 216 angles produce similar deformation patterns. However, the baseline FMVSS 216 test does not produce damage levels comparable to the crashes in this study, so the comparisons are made in reference to the extended FMVSS testing and corresponding drop tests for the 10 and 15 inch crush levels, as reported in Reference 2. In both of these test procedures, the vehicle is oriented to load the A-pillar at a compound angle. The tests produce significant lateral and longitudinal bending of the A-pillar and tend to develop a significant planar region at a compound angle to the undeformed roof. These damage patterns are generally consistent with the observations from the NASS cases. The only notable exception would be the cases that experience a bending at the middle of the A and B-pillars. Additionally, neither of these test procedures provide dual side damage or loading to the rear of the roof structure

2.2.9 Summary and Conclusions

The results of this study are generally consistent with the previous report and do not show any newly emerging trends due to the newer vehicle designs. The roof support pillars tend to remain straight with bending occurring near the pillar / body interface and the pillar / roof interface. Bending at the A-pillar is almost always present with the deformation angle dependent upon the specific crash conditions. Roof damage primarily occurs to the side of the vehicle opposite that which contacts the ground first. It is common to see a significant planar region of the roof that forms a compound angle with the undeformed roof. Based on the subjective post-crash observations made in this report, the post crash windshield does not appear to be capable of providing any significant roof support. The post crash roof support determination does not necessarily reflect the amount of support the windshield may have provided during the crash event. That could not be determined in this analysis. These general roof damage patterns were observed for all of the vehicle categories studied and the relative frequency of the damage patterns did not change significantly between the vehicle types.

2.2.10 References

1. Michael Leigh, Donald Willke, "Upgraded Rollover Roof Crush Protection: Rollover Test and NASS Case Analysis", Event Report VRTC-81-0197, June 1992
2. Glen Rains, Mike Van Voorhis, "Quasi Static and Dynamic Roof Crush Testing", June 1998

Appendix A: NASS Case Listing

Year	Case	PSU	MAKE	MODEL	MODELYR
1997	108	78	FORD	F-SERIES PICKUP	1997
1997	98	5	CHRYSLER	CONCORDE	1996
1997	15	8	DODGE	INTREPID	1995
1997	52	75	GMC	JIMMY/TYPHOON/ENVOY	1997
1997	158	11	FORD	BRONCO ii/BRONCO (-77)/EXPLORER	1996
1997	87	78	DODGE	NEON	1995
1997	81	41	FORD	BRONCO ii/BRONCO (-77)/EXPLORER	1996
1997	151	12	GMC	FULLSIZE JIMMY/YUKON	1997
1997	55	78	FORD	BRONCO ii/BRONCO (-77)/EXPLORER	1995
1997	26	73	FORD	BRONCO ii/BRONCO (-77)/EXPLORER	1995
1997	9	13	CHEVROLET	C, K, R, V-SERIES PICKUP	1996
1997	59	2	VOLKSWAGEN	GOLF/CABRIOLET	1997
1997	125	12	GMC	S15/T15/SONOMA	1997
1997	49	45	FORD	RANGER	1995
1997	92	41	KIA	SEPHIA	1996
1997	67	74	CHEVROLET	GEO METRO	1996
1997	169	75	AUDI	A4	1997
1997	122	78	TOYOTA	COROLLA	1995
1997	30	11	FORD	BRONCO ii/BRONCO (-77)/EXPLORER	1995
1997	172	13	JEEP / KAISER-JEEP	CHEROKEE (1984 ON)	1997
1997	180	43	TOYOTA	TACOMA	1995
1997	68	75	TOYOTA	LANDCRUISER	1996
1997	51	9	FORD	ESCORT/EXP	1997
1997	79	48	OLDSMOBILE	CUTLASS (FWD)	1997
1997	47	79	VOLKSWAGEN	JETTA III	1996
1997	52	82	DODGE	NEON	1995
1997	37	78	CHEVROLET	GEO METRO	1996
1997	3	41	BUICK	SOMERSET(85-87)/SKYLARK(86-ON)	1996
1997	39	74	MERCURY	COUGAR/XR7	1995
1997	124	11	JEEP / KAISER-JEEP	CHEROKEE (1984 ON)	1997
1997	121	78	HONDA	CIVIC/CRX/DEL SOL	1996
1997	71	12	CHEVROLET	S-10 BLAZER, BLAZER	1996
1997	31	12	FORD	TAURUS	1996
1997	69	11	FORD	BRONCO ii/BRONCO (-77)/EXPLORER	1997
1997	68	72	CHEVROLET	S-10 BLAZER, BLAZER	1995
1997	144	48	FORD	E-SERIES VANS	1997
1997	133	78	FORD	RANGER	1995
1997	162	43	FORD	F-SERIES PICKUP	1996
1997	53	76	FORD	F-SERIES PICKUP	1995
1997	187	75	CHEVROLET	S-10/T-10	1997
1997	21	76	GMC	S15/T15/SONOMA	1996
1997	63	43	FORD	BRONCO ii/BRONCO (-77)/EXPLORER	1997
1997	120	41	CHEVROLET	S-10 BLAZER, BLAZER	1995
1997	80	6	FORD	RANGER	1996
1997	63	13	CHEVROLET	C, K, R, V-SERIES PICKUP	1997
1997	90	9	DODGE	B-SERIES VANS	1997

Year	Case	PSU	MAKE	MODEL	MODELYR
1997	111	8	JEEP / KAISER-JEEP	CHEROKEE (1963 - 1983)	1997
1998	42	73	CHEVROLET	S-10/T-10	1997
1998	100	75	INFINITI	I30	1996
1998	46	75	PLYMOUTH	NEON	1995
1998	176	49	FORD	MUSTANG/MUSTANG II	1998
1998	142	11	CHEVROLET	CAVALIER	1995
1998	44	9	CHEVROLET	S-10 BLAZER, BLAZER	1996
1998	165	13	DODGE	D, W-SERIES PICKUP, W100-W350	1995
1998	76	72	TOYOTA	TERCEL	1995
1998	143	45	NISSAN / DATSUN	ALTIMA	1998
1998	153	11	DODGE	AVENGER	1995
1998	59	48	NISSAN / DATSUN	DATSUN/NISSAN PU/FRONTIER	1998
1998	4	6	BMW	3 SERIES	1998
1998	108	41	GMC	S15/T15/SONOMA	1996
1998	113	45	JEEP / KAISER-JEEP	CHEROKEE (1984 ON)	1995
1998	146	48	TOYOTA	4-RUNNER	1998
1998	102	78	CHEVROLET	S-10 BLAZER, BLAZER	1998
1998	127	41	MERCURY	MOUNTAINEER	1998
1998	218	75	JEEP / KAISER-JEEP	CHEROKEE (1984 ON)	1996
1998	133	45	TOYOTA	LANDCRUISER	1996
1998	204	75	TOYOTA	4-RUNNER	1997
1998	45	11	FORD	WINDSTAR	1996
1998	3	81	FORD	RANGER	1998
1998	117	12	CHEVROLET	C, K, R, V-SERIES PICKUP	1997
1998	18	13	FORD	F-SERIES PICKUP	1995
1998	166	72	FORD	E-SERIES VANS	1998
1998	69	9	TOYOTA	PICKUP	1995
1998	16	9	FORD	BRONCO ii/BRONCO (-77)/EXPLORER	1996
1998	40	79	CHEVROLET	SUBURBAN	1996
1998	31	78	SUBARU	LEGACY	1996
1998	70	72	CHEVROLET	MONTE CARLO (1995+) (FWD ONLY)	1997
1998	6	11	FORD	ESCORT/EXP	1997
1998	29	12	CHRYSLER	CONCORDE	1997
1998	186	75	TOYOTA	TERCEL	1997
1998	80	76	HONDA	ACCORD	1998
1998	137	48	HYUNDAI	SONATA	1997
1998	33	75	AUDI	CABRIOLET	1996
1998	148	72	HONDA	ACCORD	1995
1998	50	43	CHEVROLET	CORVETTE	1995
1998	32	73	CHEVROLET	CAVALIER	1995
1998	95	78	PONTIAC	GRAND AM	1995
1998	46	12	GMC	C, K, R, V-SERIES PICKUP	1995
1998	51	74	CHEVROLET	S-10 BLAZER, BLAZER	1997
1998	120	75	FORD	F-SERIES PICKUP	1997
1998	204	13	HONDA	CR-V	1997
1998	40	75	CHEVROLET	SUBURBAN	1998
1998	12	41	TOYOTA	RAV-4	1997
1998	6	81	JEEP / KAISER-JEEP	CHEROKEE (1984 ON)	1997
1998	174	43	KIA	SPORTAGE	1996

Year	Case	PSU	MAKE	MODEL	MODELYR
1998	64	74	JEEP / KAISER-JEEP	CHEROKEE (1984 ON)	1996
1998	88	12	CHEVROLET	GEO TRACKER	1998
1998	143	72	CHEVROLET	S-10 BLAZER, BLAZER	1995
1998	93	11	MERCURY	MOUNTAINEER	1998
1998	303	43	JEEP / KAISER-JEEP	CHEROKEE (1984 ON)	1995
1998	131	78	FORD	RANGER	1997
1998	6	76	DODGE	RAM	1995
1998	130	11	HONDA	PASSPORT	1998
1998	115	78	FORD	ESCORT/EXP	1995
1998	196	13	CHEVROLET	CHEVELLE/MALIBU (83-)	1997
1998	103	2	NISSAN / DATSUN	810/MAXIMA	1997
1998	63	3	BMW	5 SERIES	1998
1998	149	73	FORD	BRONCO ii/BRONCO (-77)/EXPLORER	1998
1998	275	43	CHEVROLET	S-10 BLAZER, BLAZER	1995
1998	139	78	FORD	BRONCO ii/BRONCO (-77)/EXPLORER	1998
1998	119	9	LAND ROVER	DISCOVERY (LR)	1998
1998	224	12	CHEVROLET	S-10 BLAZER, BLAZER	1997
1998	192	12	PONTIAC	FIREBIRD/TRANS AM	1995
1998	4	48	MERCURY	MYSTIQUE	1996
1998	151	49	FORD	ESCORT/EXP	1995
1998	150	72	SATURN	SL	1996
1998	67	12	CHEVROLET	ASTRO VAN	1998
1998	193	11	PLYMOUTH	VOYAGER (MINIVAN)	1995
1998	28	74	DODGE	AVENGER	1996
1998	125	11	CHEVROLET	C, K, R, V-SERIES PICKUP	1997
1999	103	78	NISSAN / DATSUN	DATSUN/NISSAN PU/FRONTIER	1995
1999	14	4	NISSAN / DATSUN	PATHFINDER	1998
1999	152	8	CHEVROLET	LUMINA	1997
1999	48	13	JEEP / KAISER-JEEP	CHEROKEE (1984 ON)	1995
1999	22	12	FORD	RANGER	1998
1999	114	12	CHEVROLET	S-10 BLAZER, BLAZER	1998
1999	124	12	CHEVROLET	LUMINA APV/VENTURE	1997
1999	96	82	KIA	SEPHIA	1998
1999	121	11	DODGE	RAM	1999
1999	126	48	FORD	CROWN VICTORIA	1995
1999	15	45	CHEVROLET	S-10/T-10	1997
1999	99	76	CHEVROLET	C, K, R, V-SERIES PICKUP	1996
1999	192	11	FORD	BRONCO ii/BRONCO (-77)/EXPLORER	1997
1999	42	75	CHEVROLET	S-10/T-10	1996
1999	114	41	ISUZU	RODEO	1999
1999	60	12	FORD	MUSTANG/MUSTANG II	1996
1999	34	78	CHEVROLET	S-10/T-10	1998
1999	123	48	MITSUBISHI	MIRAGE	1995
1999	128	48	HONDA	ACCORD	1996
1999	162	48	HONDA	PASSPORT	1997
1999	207	8	DODGE	NEON	1998
1999	8	79	HONDA	CIVIC/CRX/DEL SOL	1997
1999	24	41	CHRYSLER	300M	1999
1999	141	12	SATURN	SL	1999

Year	Case	PSU	MAKE	MODEL	MODELYR
1999	10	72	DODGE	INTREPID	1999
1999	16	41	MAZDA	MILLENIA	1995
1999	84	12	MAZDA	MILLENIA	1996
1999	110	2	SAAB	99/99E/900	1997
1999	7	45	CHEVROLET	CAVALIER	1997
1999	81	82	JEEP / KAISER-JEEP	CHEROKEE (1984 ON)	1996
1999	24	48	MITSUBISHI	GALANT	1999
1999	97	75	JEEP / KAISER-JEEP	CJ-5/CJ-6/CH-7/CH-8	1997
1999	11	75	FORD	BRONCO ii/BRONCO (-77)/EXPLORER	1999
1999	76	12	PONTIAC	J2000/SUNBIRD/SUNFIRE	1997
1999	75	9	CHEVROLET	S-10 BLAZER, BLAZER	1999
1999	84	9	CHEVROLET	LUMINA	1998
1999	193	13	CHEVROLET	MONTE CARLO ('70-'88) (RWD ONLY)	1996
1999	215	13	CHRYSLER	SEBRING	1997
1999	177	43	CHEVROLET	GEO TRACKER	1996
1999	89	48	FORD	ESCORT/EXP	1998
1999	8	75	TOYOTA	4-RUNNER	1997
1999	188	11	JEEP / KAISER-JEEP	CHEROKEE (1963 - 1983)	1998
1999	142	74	CHEVROLET	S-10 BLAZER, BLAZER	1997
1999	59	41	ISUZU	TROOPER/TROOPER II	1996
1999	137	12	GMC	JIMMY/TYPHOON/ENVOY	1999
1999	101	8	CHEVROLET	S-10 BLAZER, BLAZER	1996
1999	150	12	FORD	EXPEDITION	2000
1999	71	5	ISUZU	RODEO	1997
1999	20	41	FORD	EXPEDITION	1996
1999	51	78	TOYOTA	4-RUNNER	1997
1999	131	79	FORD	BRONCO ii/BRONCO (-77)/EXPLORER	1997
1999	133	75	LINCOLN	CONTINENTAL/TOWN CAR	1998
1999	140	49	MAZDA	626	1995
1999	101	11	JEEP / KAISER-JEEP	CHEROKEE (1984 ON)	1996
1999	67	78	NISSAN / DATSUN	DATSUN/NISSAN PU/FRONTIER	1997
1999	45	75	JEEP / KAISER-JEEP	CHEROKEE (1984 ON)	1997
1999	138	75	TOYOTA	TACOMA	1998
1999	44	76	DODGE	RAM	1999
1999	155	49	CHEVROLET	CAMARO	1995
1999	106	12	CHEVROLET	MONTE CARLO (1995+) (FWD ONLY)	1998
1999	5	75	HONDA	PASSPORT	1997
1999	34	41	ISUZU	RODEO	1997
1999	59	8	CHEVROLET	C, K, R, V-SERIES PICKUP	1998
1999	88	11	FORD	RANGER	1997
1999	109	12	CHEVROLET	S-10/T-10	1998
1999	147	13	FORD	RANGER	1998
1999	44	78	FORD	F-SERIES PICKUP	1997
1999	3	78	FORD	CONTOUR	1998
1999	58	81	SUBARU	LEGACY	1995
1999	75	49	CHEVROLET	C, K, R, V-SERIES PICKUP	1999
1999	73	78	FORD	CROWN VICTORIA	1997
1999	95	81	FORD	TAURUS	1998
1999	10	78	NISSAN / DATSUN	PATHFINDER	1995

Year	Case	PSU	MAKE	MODEL	MODELYR
1999	50	78	FORD	F-SERIES PICKUP	1997
1999	111	5	ISUZU	RODEO	1998
1999	66	12	FORD	EXPEDITION	1998
1999	193	48	JEEP / KAISER-JEEP	CHEROKEE (1984 ON)	1995
2000	64	2	MERCURY	SABLE	1997
2000	65	78	DODGE	INTREPID	2000
2000	64	78	GMC	SAFARI (MINIVAN)	1997
2000	233	43	GMC	JIMMY/TYPHOON/ENVOY	1999
2000	19	4	FORD	BRONCO ii/BRONCO (-77)/EXPLORER	1999
2000	65	12	DODGE	NEON	1996
2000	46	8	CHEVROLET	S-10 BLAZER, BLAZER	1997
2000	71	74	CHEVROLET	S-10 BLAZER, BLAZER	1999
2000	181	41	CHEVROLET	S-10 BLAZER, BLAZER	1998
2000	68	13	CHEVROLET	S-10 BLAZER, BLAZER	1995
2000	150	11	CHEVROLET	LUMINA APV/VENTURE	2001
2000	96	41	FORD	F-SERIES PICKUP	1999
2000	182	45	FORD	F-SERIES PICKUP	2000
2000	126	79	FORD	BRONCO ii/BRONCO (-77)/EXPLORER	1998
2000	211	74	GMC	C, K, R, V-SERIES PICKUP	1996
2000	22	75	LEXUS	LX 450/470	1999
2000	190	8	HYUNDAI	ACCENT	1999
2000	28	8	DODGE	NEON	1999
2000	204	45	HONDA	CR-V	1997
2000	172	12	BMW	5 SERIES	1999
2000	71	11	CADILLAC	CATERA	1998
2000	73	11	FORD	F-SERIES PICKUP	1999
2000	98	41	FORD	BRONCO ii/BRONCO (-77)/EXPLORER	1999
2000	119	11	FORD	BRONCO ii/BRONCO (-77)/EXPLORER	2000
2000	78	13	CHEVROLET	MONTE CARLO (1995+) (FWD ONLY)	1995
2000	118	72	FORD	ESCORT/EXP	1999
2000	167	9	TOYOTA	4-RUNNER	1997
2000	124	13	PONTIAC	J2000/SUNBIRD/SUNFIRE	1997
2000	107	41	DODGE	NEON	2000
2000	164	45	CHEVROLET	S-10/T-10	2000
2000	32	49	MERCEDES BENZ	220/280 C	1996
2000	162	11	FORD	RANGER	1999
2000	167	12	GMC	JIMMY/TYPHOON/ENVOY	1998
2000	78	8	FORD	BRONCO ii/BRONCO (-77)/EXPLORER	1998
2000	53	45	FORD	F-SERIES PICKUP	1997
2000	50	13	CHEVROLET	C, K, R, V-SERIES PICKUP	1996
2000	41	12	CHEVROLET	C, K, R, V-SERIES PICKUP	1997
2000	153	48	DODGE	RAM	1999
2000	118	81	DODGE	RAM	1999
2000	55	76	MAZDA	MAZDA PICKUP	1996
2000	61	41	KIA	SPORTAGE	2000
2000	70	11	FORD	F-SERIES PICKUP	2000
2000	49	75	FORD	F-SERIES PICKUP	1998
2000	170	11	FORD	WINDSTAR	2000
2000	77	76	FORD	F-SERIES PICKUP	1997

Year	Case	PSU	MAKE	MODEL	MODELYR
2000	97	78	TOYOTA	COROLLA	2001
2000	159	11	TOYOTA	CAMRY	1997
2000	214	43	ACURA	INTEGRA	1995
2000	124	74	HYUNDAI	ACCENT	1998
2000	57	78	FORD	TAURUS	2000
2000	199	74	CHEVROLET	BERETTA/CORSICA	1996
2000	73	41	VOLKSWAGEN	JETTA	1999
2000	174	11	FORD	F-SERIES PICKUP	1997
2000	207	13	FORD	F-SERIES PICKUP	1999
2000	67	41	CHEVROLET	S-10 BLAZER, BLAZER	2000
2000	225	8	FORD	BRONCO ii/BRONCO (-77)/EXPLORER	1997
2000	163	48	FORD	F-SERIES PICKUP	1997
2000	122	13	CHEVROLET	S-10 BLAZER, BLAZER	1997
2000	46	12	FORD	RANGER	1999
2000	75	9	MITSUBISHI	MONTERO	2000
2000	119	12	CHEVROLET	S-10/T-10	2000
2000	111	81	FORD	BRONCO ii/BRONCO (-77)/EXPLORER	1998
2000	44	75	TOYOTA	4-RUNNER	1997
2000	59	45	FORD	F-SERIES PICKUP	1999
2000	68	48	ISUZU	RODEO	1998
2000	80	75	CHEVROLET	CAMARO	2000
2000	143	76	DODGE	DURANGO	2000
2000	125	12	OLDSMOBILE	BRAVADA	1999
2000	85	74	CHEVROLET	C, K, R, V-SERIES PICKUP	1999
2000	76	11	FORD	F-SERIES PICKUP	1997
2000	98	2	CHEVROLET	G-SERIES VAN	1996
2000	8	43	FORD	E-SERIES VANS	1995
2000	19	74	MERCURY	MOUNTAINEER	1997
2000	149	43	MITSUBISHI	MONTERO	1999
2000	7	13	FORD	BRONCO-FULLSIZE	1996
2000	77	49	FORD	EXPEDITION	1997