Center for Auto Safety
1346 Connecticut Ave., NW
Washington, D.C. 20009
(202) 328-7700

December 12, 2006

The Honorable Nicole R. Nason, Administrator
National Highway Traffic Safety Administration
400 7th Street SW
Washington DC 20590

Dear Ms. Nason:

This letter is to report recent findings from our research and testing that demonstrate the high level of rollover occupant protection currently offered in at least one production vehicle; and the availability of a highly repeatable, controlled dynamic test to objectively demonstrate such performance.

From its inception, the National Highway Traffic Safety Administration (NHTSA) recognized two fundamental principles necessary for protecting motor vehicle occupants: (1) keep the occupant compartment intact to protect its occupants from intrusion from the front, side, rear and top; and to contain them,[1] and (2) dynamic performance standards can ensure better occupant protection in the real world than quasi-static standards.[2]

Rollover Occupant Protection: Theory and Policy

More specifically, NHTSA correctly understood the key hazards of a vehicle rollover in 1970 and applied these principles of occupant protection when it proposed two Federal motor vehicle safety standards: the roof crush standard, FMVSS 216, *Roof*

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[1] Federal Highway Administration [National Highway Safety Bureau], 32 F.R. 14280, Advanced Notice of Proposed Rulemaking, *Intrusion – Passenger Cars, Multipurpose Passenger Vehicles, Trucks, and Buses*, October 14, 1967.

[2] National Highway Safety Bureau, 35 F.R. 7187, Notice of Proposed Rulemaking, *Occupant Crash Protection; Passenger Cars, multipurpose Passenger Vehicles, Trucks and Buses*, May 7, 1970, "The performance requirements are stated primarily in terms of crash tests that are destructive. These requirements, as in all the standards, are simply methods of expressing necessary characteristics of each vehicle produced." NHSB proposed dynamic frontal and side impact crash tests which were ultimately implemented in the late 1980s and early 1990s. At that time, NHTSA proposed a dynamic dolly rollover test ". . . which provides that test dummies shall be contained by the outer surfaces of the passenger compartment." That test was included in the final rule, but was made optional if the manufacturer complied with the roof crush requirements of FMVSS 216.

Intrusion Protection, and the dolly rollover requirements of FMVSS 208, *Occupant Crash Protection*.[3]

These proposals address occupant head and neck protection from injuries due to roof intrusion and with occupant ejection. The purpose of the roof crush requirement was ". . . to reduce the likelihood of roof collapse in a rollover accident."[4,5] The purpose of the dolly rollover requirement was to reduce occupant ejection in rollovers, which was particularly important given the low rate of safety belt use at the time.[6]

In issuing FMVSS 216, NHTSA recognized that a strong roof was critical to controlling ejection. It noted that "The roof crush standard will provide protection in rollover accidents by improving the integrity of the door, side window, and windshield retention areas. Preserving the overall structure of the vehicle in a crash decreases the likelihood of occupant ejection, reduces the hazard of occupant interior impacts, and enhances occupant egress after the accident."[7]

In issuing a substantially weakened version of FMVSS 216 in its final rule, NHTSA recognized that the dynamic, dolly rollover test requirement was planned that would obviate the need for FMVSS 216.[8] Unfortunately, that did not happen.

In 1989, NHTSA evaluated whether the weak FMVSS 216 had improved rollover occupant protection.[9] This report (hereinafter 1989 NHTSA Roof Crush Report)

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[3] National Highway Safety Bureau, 35 F.R. 16927, Rules and Regulations, *Occupant Crash Protection; Passenger Cars, multipurpose Passenger Vehicles, Trucks and Buses [S4.3, Rollover]* 36 F.R. 166, *Roof Intrusion Protection – Passenger Cars.*

[4] The notice states, "When applied to 1969 accident data, the analysis developed in a recent study indicates that approximately 1,400 motor vehicle occupants were killed in that year by impact with roof structure in rollover accidents. Roof intrusion would have been sufficient in many of the cases for the roof to have struck the head of a properly restrained occupant. The benefits of occupant restraint are negated if the passenger compartment collapses in this fashion, and it is therefore important that minimum roof strength requirements by established."

[5] It was unfortunate that the agency watered down FMVSS 216 by reducing the pitch angle from º10 (which realistically puts a substantial part of the roof crush loading on the A pillar) to 5º (which permits the B pillar to resist a substantial part of the load) and by requiring that only one side of the roof be tested.

[6] It is interesting that on July 8, 1968, a Ford Engineer, J.R. Weaver wrote a memorandum to J.R. Weaver, *Roof Strength Study*, in which he noted, "It is obvious that occupants that are restrained in upright positions are more susceptible to injury from a collapsing roof than unrestrained occupants who are free to tumble about the interior of the vehicle. It seems unjust to penalize people wearing effective restraint systems by exposing them to more severe rollover injuries than they might expect with no restraints."

[7] National Highway Traffic Safety Administration, 36 F.R. 23299, *Motor Vehicle Safety Standards*.

[8] Op. Cit., "(3) After August 15, 1977, Standard 216 will no longer be a substitute for the Standard 208 [dynamic dolly] rollover tests. It is expected that as of that date, Standard 216 will be revoked, at least with respect to its application to passenger cars."

[9] Kahane, Charles J., "An Evaluation of Door Locks and Roof Crush Resistance of Passenger Cars – Federal Motor Vehicle Safety Standards 206 and 216," National Highway Traffic Safety Administration, Washington, D.C.: November 1989, DOT HS 807 489.

concluded, "Vehicles other than true hardtops, such as sedans, coupes, station wagons or hatchbacks experienced little change in roof crush strength throughout 1966-85." It attributed no rollover life savings to the new standard except that it contributed to the "curtailed production of true hardtops – 110 lives."[10] The evaluation actually found that in general, roofs became less crush resistant after the standard took effect: "Cars of the mid 1960s actually had the strongest roofs in the test . . ." NHTSA found that the 1964 Dodge Dart had the strongest roof of all vehicles tested.

Since the 1989 NHTSA Roof Crush Report and the steadily growing number of rollover casualties, both Congress and NHTSA have recognized that rollover casualties are the greatest unsolved auto safety problem. Congress has repeatedly directed NHTSA to conduct rulemaking on rollover and roof crush.[11] In response, NHTSA has issued a dynamic rollover susceptibility rating system and initiated rulemaking on roof crush. However, in 2005 Congress directed NHTSA to more comprehensively address the issue.

A New Policy: Dynamic Testing

Today, a substantially more controlled, repeatable test, the Jordan Rollover System (JRS), is available to dynamically test roof strength (this system is described in detail in Attachment 1). If applied in Federal Motor Vehicle Safety Standards and New Car Assessment Program crash ratings, JRS testing will significantly reduce occupant injury in rollover crashes.

Our Research and Testing Program

Under a grant from the Santos Family Foundation and with vehicle donations from the State Farm Mutual Auto Insurance Company, we have conducted research and testing that makes a major contribution to resolving these questions. First, we have conducted a major study of recent National Accident Sampling System rollover data that quantifies the losses in contemporary vehicles that shows the exceptional opportunities for reducing rollover casualties.

The benefits are so large that even if ESC is successful in substantially cutting the number of vehicle rollovers, a high level of roof crush resistance would still be justified using methodology and data developed by NHTSA. This is especially true for light trucks such as SUVs and pickups.

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[10] The report pointed out the change to pillared hardtops from true hardtops "may have been due to styling or manufacturing considerations … Thus, the relationship between the standard and the shift from hardtop to pillared vehicles is loose . . ." (Id. at 8.)

[11] In the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA), Congress directed NHTSA to initiate rulemaking to provide "[p]rotection against the unreasonable risk of rollovers." Pub. L. No. 102-240, Sec. 2503 (Dec. 18, 1991). In the Transportation Recall Enhancement, Accountability, and Documentation (TREAD) Act of 2000, Congress required NHTSA to adopt a dynamic rollover rating system, Pub. L. No. Congress (in the 2005 highway authorization bill, SAFETEA-LU Public Law No. 109-59 (Aug. 10, 2005) directed NHTSA is issue an upgraded roof crush standard which may consider dynamic crash testing..

More importantly, we have conducted dynamic roof crush tests of the Volvo XC90, a vehicle that has gained a reputation for a high level of rollover occupant protection already. Our tests demonstrate that this vehicle defines the state-of-the-art in rollover occupant protection. These tests also show that a feasible, objective, low cost dynamic test is available that differentiates critical performance differences between the XC90 and other contemporary vehicles that do a poor job of protecting occupants in rollovers. Although Volvo has conducted its own internal dynamic roof crush tests, its parent company Ford has obtained Protective Orders in 24 courts to conceal them from the public and NHTSA has agreed to keep them confidential.[12]

Roof strength is critical to rollover occupant protection for two reasons.

- A roof that does not intrude significantly into the occupant survival space cannot inflict serious head or neck injuries on occupants.
- A strong roof is necessary to protect side windows from breakage and their frames from distortion which is critical to controlling both partial and complete ejection.

Our tests also demonstrate, yet again, that the "diving" theory of rollover head and neck injury, also known as "torso augmentation," has no scientific basis.[13]

Volvo XC90 Test Results

Our tests have confirmed that the Volvo engineers achieved their goal. The Volvo XC90's roof crush is limited in both extent and velocity so that it is unlikely to injure a restrained occupant even in a multiple rollover. Furthermore, when we tested the Volvo equipped with the optional laminated side windows, the roof protected the windows from breakage. However, even if they had broken, they would have continued to provide a

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[12] In denying a CAS FOIA request for release of the Volvo documents, NHTSA Acting Chief Counsel Stephen P Wood wrote: "Ford provided copies of 23 protective orders from courts in various other jurisdictions [besides Duncan v. Ford] that subject these [Volvo roof crush] documents to confidential treatment. . . . In light of the protective orders and Ford's ongoing actions to maintain the documents' confidentiality, it is evident that continuing efforts are being expended to protect the contents of the documents. . . . I am withholding the Volvo documents for which confidentiality was granted." (October 18, 2005).

[13] The diving theory of occupant neck injury, promoted for decades by Edward Moffatt and his colleagues, is that in a rollover the head and neck provide occupant restraint arresting the body when the roof strikes the ground. Under this theory, several auto manufacturers, in effect, argue that they use an occupant's head and neck, rather than the safety belts, to restraint the body during a rollover. That theory has long since been discredited by data from his Malibu test program at General Motors conducted in the 1980s that shows the head impact speed in a flat ground rollover to be too low to cause severe neck injury even when the safety belts do not properly restraint the occupant.

The final definitive blow to this theory comes from the Volvo engineers who developed the XC90. They theorized that if the roof does not crush substantially and if the occupant restraints hold the occupants firmly in their seats, there can be no significant contact between the occupant's head and the roof of the vehicle. Even if the occupant is diving into the roof, his or her motion is arrested or restrained by the safety belts, not the occupant's head and neck.

barrier to ejection because of the plastic inner liner of the glass. This shows the other major advantage of a strong roof: its contribution to ejection control.

In our tests, we showed that the Jordan Rollover System can measure the dramatic improvement in rollover occupant protection and control of roof crush. In more than twenty tests, the Center for Injury Research and Xprts–LLC have found that all of the other tested production vehicles sustained substantial roof buckling and in some cases dramatic collapse in the JRS test. The damage occurs on the initially trailing side of the roof and sometimes extends back to the C pillar area. The extent and speed of the roof crush can be measured at a number of points where an occupant's head may be in a rollover, providing a critical measure of the potential for injury.

Quasi-static Test. We conducted an M216 test on a baseline Volvo XC90. This test is similar to the originally proposed FMVSS 216 test in that the pitch angle of the test is 10º rather than the 5º used in FMVSS 216, and we test both side of the roof sequentially. The major difference beyond testing just the first side is that we test the second side at a roll angle of 40º rather than the 25º that was proposed by NHTSA in 1970.

These test conditions were designed to more realistically simulate the conditions imposed in an actual rollover. For example, in most rollovers that result in serious injury, both sides of the roof strike the ground. Furthermore, National Accident Sampling System (NASS) data show that in at least two-thirds of all rollovers there is contact with the one or both front fenders which can only happen if the vehicle is pitched approximately 10º.

In this test, no contemporary vehicle tested in an M216 test has sustained significantly more than its own weight in roof crush force, a strength-to-weight ratio of one. By comparison, the XC90 had roof crush resistance of more than twice its weight. Furthermore, structural damage was minor in this test.

This experience indicates that had NHTSA adopted its originally proposed test for FMVSS 216 with a 10° pitch and two sided testing, vehicle roofs in the last 30 years would have been substantially more crush resistant and tens of thousands fewer people would have been seriously injured or killed in crashes.

Dynamic Test. We conducted two sequential JRS tests of the XC90 under the same conditions as previous JRS tests. We found that the structure of the XC90 performed well in resisting intrusion, limiting the speed of intrusion, and not compromising the structural integrity of the vehicle.[14] The JRS also measure the force of the roof on the road surface, showing the crush resistance during roof impact throughout roof contact with the ground. The results of these tests are shown in Table 1.

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[14] It is important that the structural integrity not be compromised in this test because that leaves the vehicle capable of providing full protection on subsequent rolls of a multiple rollover.

The maximum intrusion of the roof into the interior of the vehicle in either test was only 2.6 inches and the maximum peak intrusion velocity was only 5.4 ft/sec (less than 4 mph, about walking speed). Even for an occupant who was not restrained, this intrusion would not inflict significant injury, particularly since the roof in this vehicle has padding to ameliorate the impact. However, the Volvo XC90 has rollover triggered safety belt pretensioners that hold the occupant away from the roof so that head contact is even less likely.

There were no structural failures in these tests, so that the vehicle would have been capable of sustaining further rollover roof impacts while protecting the occupants. Figure 1 shows the XC90 following the second JRS test while Figure 2 shows a Ford Explorer following the same tests.

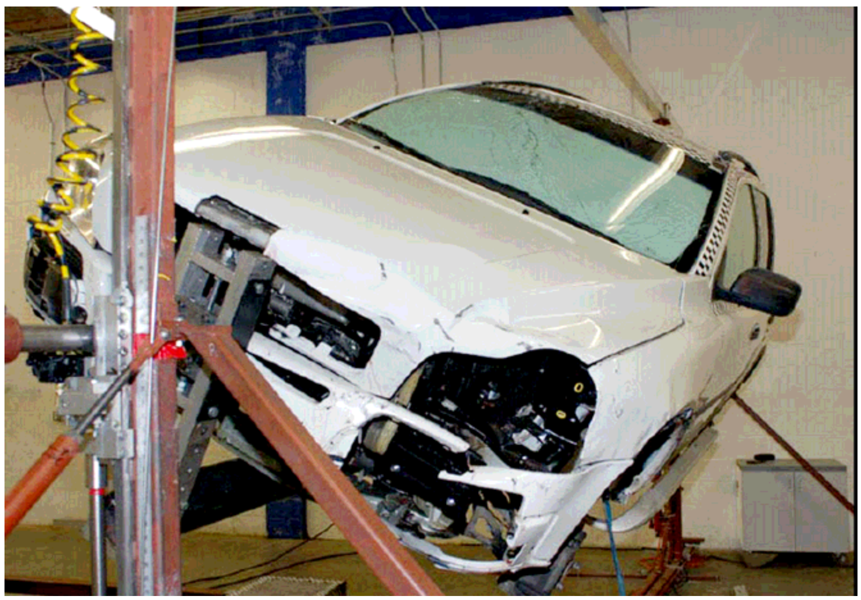


Figure 1. A 2004 Volvo XC90 following the second JRS test of its rollover roof strength.

Figure 2. A 1995-2001 Ford Explorer following the second JRS test.

Note that the impact forces between the road and roof hit a maximum of more than 21,000 pounds – more than ten tons. This shows that the Volvo XC90 roof can sustain substantially more force than was demonstrated in the M216 test for the short durations of an actual rollover without compromise of its structural integrity.

These tests show that a reliable, repeatable dynamic test is available that provides detailed information on a vehicle's performance in a rollover.

2004 Volvo XC90	Intrusion (inches)				Peak Intrusion Velocity (ft/sec)	
	Peak		Residual			
Location	1st Test	2nd Test	1st Test	2nd test	1st Test	2nd Test
A-Pillar	1.0	1.9	0.1	0.5	2.3	2.9
Mid-Point Between A & B Pillars	1.5	2.6	0.3	0.7	3.2	4.3
B Pillar	1.2	2.6	0.1	0.7	2.8	4.4
Header Inboard of A Pillar	0.6	1.2	0.0	0.3	1.8	2.0
Front of Sunroof	1.1	1.6	0.4	0.5	2.7	3.0
Side of Sunroof	1.5	2.5	0.3	0.7	3.4	4.2
Near Side A Pillar	2.1	0.3	0.9	0.2	4.8	1.6
Near Side B Pillar	3.2	0.9	1.1	0.3	5.4	2.6
	1st Test			2nd Test		
Maximum Roof Crush Force – Near Side	21,208 pounds			8,101 pounds		
Maximum Roof Crush Force – Far Side	13,590 pounds			15,461 pounds		

Table 1. Roof intrusion and intrusion velocity at eight key points over the interior of the roof.

Performance Comparisons and Rollovers on Public Road

There has been only one spontaneous rollover of a Volvo XC90 that has been fully investigated: NASS Case 2003-79-57 (see Figure 3, below; and Attachment 2). In that case, the rollover occurred because an initial collision sent the Volvo out of control so that it subsequently rolled one and a half rolls landing on its roof. The vehicle in question did not have the optional laminated side glazing. The two women front seat passengers were uninjured except for some glass cuts from the failed side windows. Although the roof sustained substantial superficial damage, its structure protected the occupant survival space very well. This is similar to the results we obtained in our JRS tests of this vehicle.

Figure 3. A Volvo XC90 involved in a rollover of 1½ rolls (NASS Case 2003-79-57).

To provide a comparison, Xprts-LLC has tested several common mid-sized and larger SUVs including Ford Explorers, Chevrolet Blazers and Chevrolet Suburbans (see Attachment 3). All did poorly in the JRS tests with near complete roof collapse on the initially trailing side of the roof. These results are shown in Table 1.

We looked for examples of flat ground rollovers of these vehicles in recent NASS files and found several. In all cases there was serious structural buckling and roof intrusion into the occupant survival space where there was a restrained occupant who suffered serious to fatal head or neck injury. These cases are shown in the attachments and in the photographs (Figures 4 through 7).

Figure 4. A 2001 Chevrolet Blazer following a one roll rollover. The right front passenger, who was wearing a lap/shoulder belt, suffered a serious cervical spine injury.

Figure 5. A 1997 Chevrolet Suburban that rolled over. The lap/shoulder belted driver suffered fatal head injuries.

Figure 6. A 1993 Ford Explorer after a three roll rollover. The right front passenger died of brainstem injuries.

Figure 7. A 1999 Chevrolet Suburban that rolled over. The right front passenger died of critical head injuries.

Model Years	Mid-sized SUV Models	216 SWR	Max Crush (Inches)	Max Speed (mph)	Injury in On-Road Rollover
2002-2006	Volvo XC90	3.6	3.2	3.7	Minor Cuts
1995-2005	Chevrolet Blazer (Reinforced Roof)	5.6	3.6	4.9	NA
2003-2006	Kia Sorrento	1.9	6.9	9	Quadriplegia
1995-2001	GMC Jimmy	2.4	6.7	9.8	Quadriplegia
1995-2005	Chevrolet Blazer	2.4	9.6	10.1	Quadriplegia
1999-2001	Isuzu VehiCross		6.8	11.1	Brain Injury
1995-2001	Ford Explorer	1.6	11.5	11.9	Quadriplegia

Table 2. A comparison of the Jordan Rollover System test results on a number of production SUVs and one with a reinforced roof. The injured occupants were seated on the initially trailing side of the vehicle under the part of the roof with maximum crush. The case that is shaded is a Chevrolet Blazer that was modified by having its roof strengthened to demonstrate that a vehicle could be built with a roof that would not collapse or buckle in a rollover.

Conclusions

From our tests we conclude:

- The Volvo XC90 defines the state-of-the art in rollover roof crush resistance performance. It shows that a competitive, mid-priced production vehicle can have good performance without compromising *any* other characteristics including the price of the vehicle.
- The JRS gives definitive, dynamic measures of roof crush performance that can easily differentiate between vehicles that provide good and poor rollover occupant protection.

The JRS test equipment is relatively inexpensive, and tests on this equipment cost substantially less than the cost of a new vehicle being tested. The JRS test meets the requirements of the National Traffic and Motor Vehicle Safety Act that Federal motor vehicle safety standards be performance based and objective. Furthermore, the changes that ensure a vehicle will perform well on the JRS are practicable and such vehicles meet the need for motor vehicle safety.

Our analysis of NASS rollover cases, described in Attachment 4, also shows that particularly for vehicles with high rollover rates such as SUVs and pickups, a strong roof is highly cost-beneficial even if the vehicle is equipped with electronic stability control. We have separately submitted a complete set of Reports and Videos on the Volvo XC90 M216 and JRS testing to the agency.

Our research and test programs provide fresh evidence of the need and justification for a strong roof crush standard and the existence of equipment that can provide highly repeatable dynamic test results that can discriminate between vehicles that provide good and poor rollover occupant protection. NHTSA's proposal for a very modest increase in roof crush resistance in its standard does not even begin to address the question of rollover occupant protection because the test specified in the standard is not a realistic dynamic test and it does not stress a vehicle roof adequately. NHTSA has also not addressed the other problems in rollover occupant protection such as ejection.

Our tests confirm that the Volvo XC90 sets a standard for rollover occupant protection that shows the practicability of such protection. NHTSA has ignored this critical safety challenge for far too long and must now take action not only to protect the public, but to meet the requirements of the 2005 motor vehicle safety legislation.

Sincerely,

Clarence M. Ditlow
Executive Director

Carl E. Nash, Ph.D.
Technical Advisor

Attachment 1: Description of the JRS

Attachment 2: NASS Cases 2003-79-57, 2003 Volvo XC90

Attachment 3: NASS Cases 2002-11-48, 1993 Ford Explorer
2002-75-58, 1997 GMC Suburban
2002-81-62, 2000 Cadillac Escalade (Suburban)
2003-5-17, 1999 Chevrolet Suburban
2003-12-45, 2000 Chevrolet Blazer
2003-41-102, 2001 Chevrolet Blazer
2004-75-39, 1996 Ford Explorer

Attachment 4: Nash Paper on NASS Rollover Cases

Attachment 1

CENTER FOR INJURY RESEARCH, LLC

510 South Fairview Avenue
Goleta, California 93117

The Jordan Rollover System (JRS) was designed and built by Acen Jordan for the Center for Injury Research (CFIR). Mr. Jordan is a leading designer of test devices for the auto industry including crash pulse sleds used by many auto companies.

The JRS is designed for dynamic testing to evaluate roof crush in rollovers. It consists of:

- A linear track supporting a moving roadbed platform.
- A rotating carriage supporting the test vehicle.
- A mechanism and vertical linear track to enable the rotating vehicle to drop onto the moving roadbed under carefully controlled conditions.

The vehicle being tested is supported by drop towers that straddle the linear track. The test is initiated by propelling the roadbed forward which begins the vehicle rotation. The vehicle is released at a certain point so that it strikes the moving roadbed at a designed roll angle. JRS tests are staged to enable a single roll with impacts on the leading and trailing sides. Multiple rolls on the same vehicle can be carried out by resetting the JRS and conducting further tests.

The JRS design provides convenient adjustments to set the roadbed velocity, vehicle roll rate, vehicle drop height, and vehicle roll, pitch and yaw impact orientations relative to the roadbed. Additional important features include:

- Test staging – The user can easily set various speed and impact orientations. Ballast weights may be used to adjust the vehicle's weight and center of gravity.
- Reliability – The JRS has a minimum of moving parts. Adjustments of setup parameters, propulsion rate and coordination triggers are all mechanically linked.
- Compact– The JRS test facility requires a laboratory area of less than 5,000 ft^2 to comfortably set up and conduct tests.
- Since it is recommended that the JRS be installed indoors, tests can be conducted under various weather and lighting conditions.
- Safety – The JRS equipment includes appropriate controls and sensors to ensure the safety of operators and the equipment.

A JRS test provides several unique and compelling benefits for better understanding the effects of roof crush due to rollover:

- Repeatability – the JRS provides consistent, controlled test conditions.
- Event simulation – linear and rotational speed, mass, drop height and roof impact orientation with the roadbed can be set to simulate actual rollover conditions.
- Roll by roll evaluation – roof intrusion distances and rates, deformation effects on vehicle structure, occupant dynamics and glazing integrity can be carefully observed within each roll test sequence.

Data instrumentation incorporated in the JRS include string potentiometers to measure roof intrusion displacement and velocity across the roof's interior. Load cells and accelerometers mounted on the vehicle and the roadbed measure impact forces and vehicle deceleration.

Attachment 2

Occupant: 2003-79-57-3-1




Rollover Characteristics

Number of Events	3
Rollover Initiation Type	COLLISION W/VEH
Location of Rollover Initiation	ON ROADWAY
Rollover Initiation Object Contacted	VEHICLE NO. 1
Location on Vehicle where Principal Tripping Force was Applied	END PLANE
Direction of Initial Roll	ROLL LEFT

Crash Severity

Nr. Quarter Turns	6 QUARTER TURNS
Impact Speed	999
Total, Longitudal, and Lateral δV	999 999 999
Est. δV with sequence number	MODERATE 2
CDC	0 T D D O 3
Damage (C1-C6)	0 0 0 0 0 0
Crush (L and D)	0 0
Object Contacted 1	ROLLOVER-OVERTRN
Object Contacted 2	VEHICLE NO. 1

Pre-Crash Environment

Traffic Flow	DVDED/W/BARRIER
Number of Travel Lanes	SIX
Roadway Alignment	STRAIGHT
Roadway Profile	LEVEL
Roadway Surface Type	CONCRETE
Roadway Surface Condition	DRY
Light Conditions	DAYLIGHT
Atmospheric Conditions	No ADVERSE COND
Relation to Intersection	NONINTER/NONJUNC
Traffic Control Device	
Police Reported Alcohol Presence	No ALCOHOL
Alcohol Test (< 95 indicates BAC 0.xx)	99

Vehicle Factors

Make-Model	Volvo XC90
Year	2003
Class	TRUCK
Body Type	COMPACT UTILITY
Weight	208

NASS Weighting Factor

Weighting factor	42.872

Pre-Crash Driver Data

Accident Type	25
Pre-event Movement	GOING STRAIGHT
Critical Pre-crash Event	Same DIR-OV RGHT
Attempted Avoidance Maneuver	99
Pre-impact Stability	TRACKING
Pre-impact Location	STAYED IN LANE

DRIVER Factors

Age	45	Height	157	Weight	54

Gender	FEMALE-NOT PREG
Ejection	No EJECTION
Ejection Area	No EJECTION
Entrapment	Not ENTRAPPED

Restraint Factors

Restrain	Lap and shoulder
AOPS	YES-RES DET
Airbag Deployment	NONDEPLOYED
Airbag Deployment - 1st Seat	NONDEPLOYED
Airbag Deployment - Oth Seat	BAG DEPLOYED

Injuries

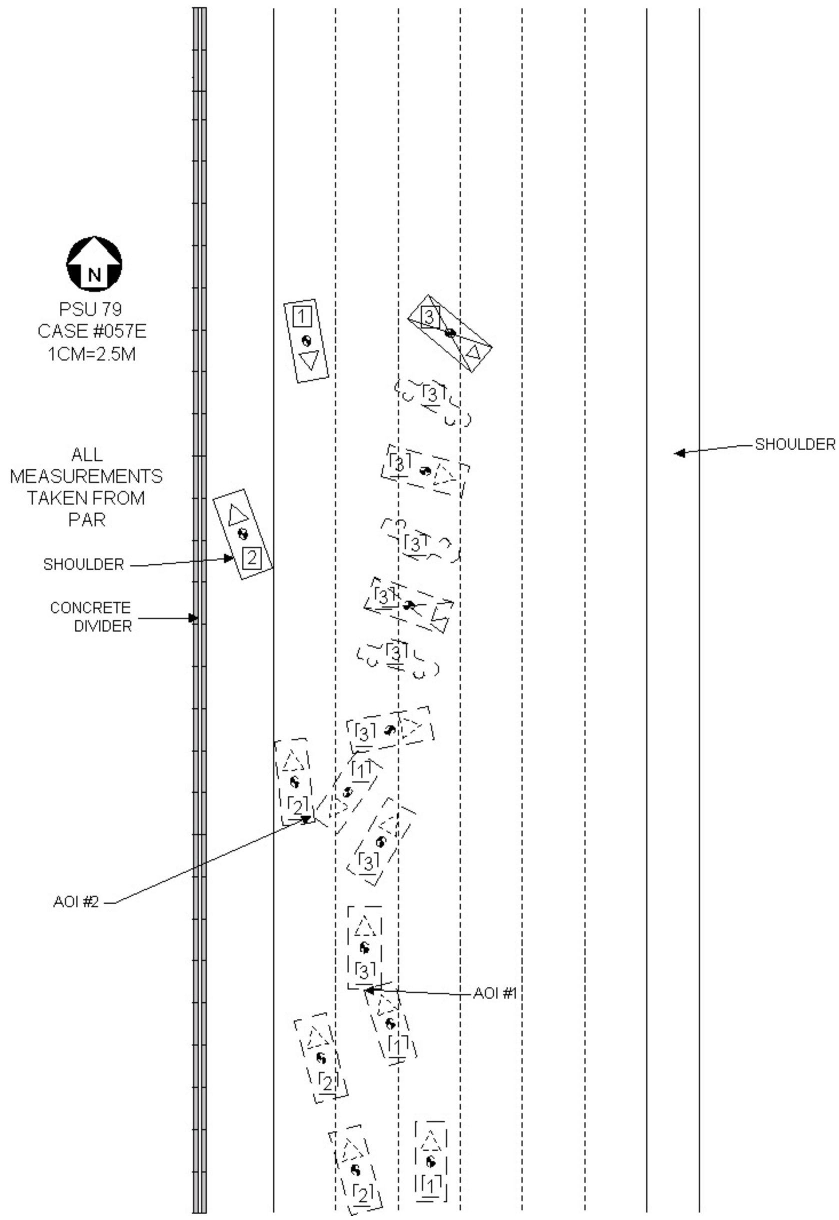
Occupant	2003-79-57-3-1
MAIS	1=Minor
Seat Position	Front left side

AIS Level	Injury Description	Contacts
1=Minor	Upper extremity skin abrasion	Flying glass

Case Number: 2003-79-57

Summary:

Vehicle one, a 1998 Ford Mustang, was traveling north in the number four lane of a six lane, physically divided, concrete, level, dry highway. Vehicle two, a 1995 Chevy Camaro, was traveling north in the number five lane of the same highway. Vehicle three, a 2003 Volvo XC90, was traveling north in the number five lane of the same highway. As vehicle one negotiated a lane change, from number five to number six, its left front plane contacted the right rear plane of vehicle three. Vehicle one spun counter clockwise then it's right rear contacted the right plane of vehicle two as vehicle two veered to the left to attempt to avoid the crash. Vehicle three, after being contacted by vehicle one on its right rear plane then spun clockwise and rolled over about six quarter turns, landing on its roof. Vehicle one was towed with moderate damage. Vehicle two was driven from scene with moderate damage. Vehicle three was towed with rollover damage and had deployed side curtain air bags. Driver of vehicle one was not reported as injured. Driver of vehicle two was not reported as injured. Driver of vehicle three received visible injuries and was transported. Occupant two of vehicle three received visible injuries and was transported.)

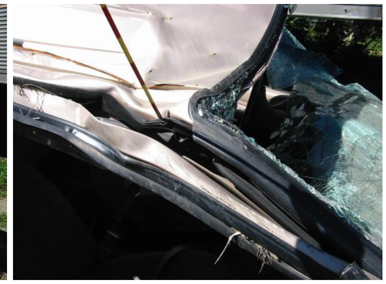


Vehicle	Body type	Make	Model	Year	Occ. #	Age	Occupant's sex	Maximum known occupant ais
1	Unk AUTO TYPE	Ford	Mustang/Mustang II	1998	1	56	MALE	0=None
3	COMPACT UTILITY	Volvo	XC90	2003	1	45	FEMALE-NOT PREG	1=Minor
3	COMPACT UTILITY	Volvo	XC90	2003	2	9	MALE	1=Minor

Attachment 3

Occupant: 2002-11-148-1-2



Rollover Characteristics

Number of Events	1
Rollover Initiation Type	99
Location of Rollover Initiation	9
Rollover Initiation Object Contacted	99
Location on Vehicle where Principal Tripping Force was Applied	9
Direction of Initial Roll	9

Crash Severity

Nr. Quarter Turns	99
Impact Speed	999
Total, Longitudal, and Lateral δV	999 999 999
Est. δV with sequence number	MODERATE 1
CDC	0 T D D O 3
Damage (C1-C6)	0 0 0 0 0 0
Crush (L and D)	0 0
Object Contacted 1	ROLLOVER-OVERTRN
Object Contacted 2	0

Pre-Crash Environment

Traffic Flow	DVDED/W/BARRIER
Number of Travel Lanes	TWO
Roadway Alignment	CURVE RIGHT
Roadway Profile	LEVEL
Roadway Surface Type	ASPHALT
Roadway Surface Condition	DRY
Light Conditions	DAYLIGHT
Atmospheric Conditions	No ADVERSE COND
Relation to Intersection	NONINTER/NONJUNC
Traffic Control Device	
Police Reported Alcohol Presence	No ALCOHOL
Alcohol Test (< 95 indicates BAC 0.xx)	96

Vehicle Factors

Make-Model	Ford Bronco II
Year	1993
Class	TRUCK
Body Type	COMPACT UTILITY
Weight	175

NASS Weighting Factor

Weighting factor	41.873

Pre-Crash Driver Data

Accident Type	6
Pre-event Movement	NEGOTIATE CURVE
Critical Pre-crash Event	OFF EDGE-LEFT
Attempted Avoidance Maneuver	STEERING RIGHT
Pre-impact Stability	LATERAL SKID-CLK
Pre-impact Location	DEPARTED ROADWAY

PASSENGER Factors

Age	15	Height	173	Weight	83
Gender			MALE		
Ejection			No EJECTION		
Ejection Area			No EJECTION		
Entrapment			Not ENTRAPPED		

Restraint Factors

Restrain	Lap and shoulder
AOPS	NO
Airbag Deployment	Not EQUIP/AVAIL
Airbag Deployment - 1^{st} Seat	Not EQUIP/AVAIL
Airbag Deployment - Oth Seat	Not EQUIP W/ OTH

Injuries

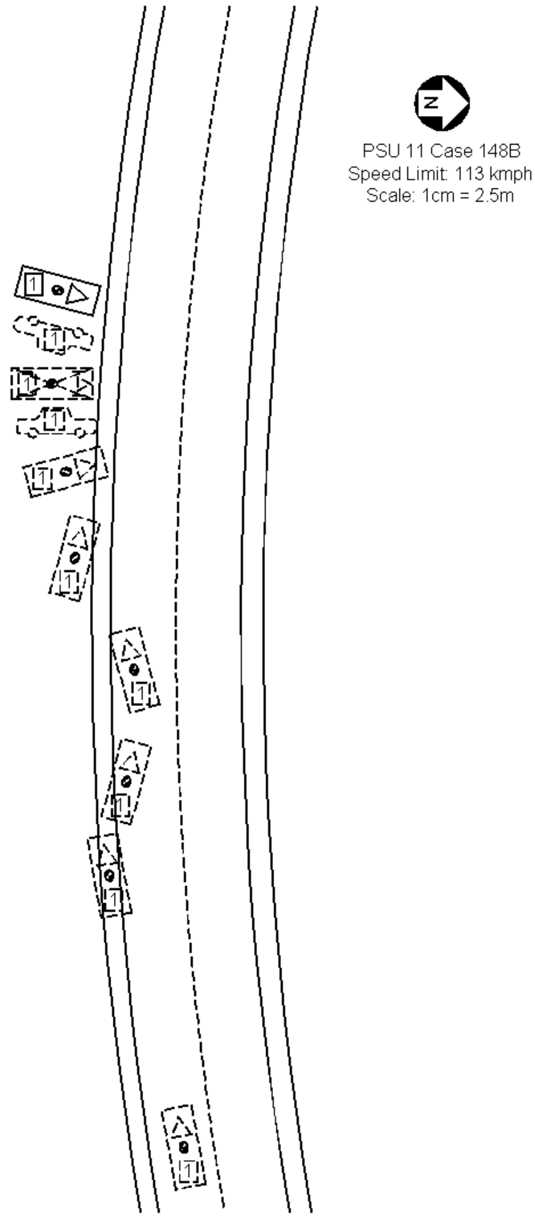
Occupant	2002-11-148-1-2
MAIS	5=Critical
Seat Position	Front right side

AIS Level	Injury Description	Contacts
4=Severe	Incomplete cervical cord syndrome with fracture	Other noncontact
4=Severe	Lung contusion, bilateral	Right interior
1=Minor	Upper extremity skin laceration, minor	Right interior
1=Minor	Facial skin laceration NFS	Flying glass
2=Moderate	Cervical transverse process fracture, no cord injury	Other noncontact
2=Moderate	Thoracic spine fracture, no cord injury, NFS	Right B pillar
3=Serious	Cervical pedicle fracture, no cord injury	Other noncontact
3=Serious	Cervical pedicle fracture, no cord injury	Other noncontact
2=Moderate	Thoracic spine fracture, no cord injury, NFS	Right B pillar
2=Moderate	2-3 rib fractures with stable chest	Right interior
1=Minor	Upper extremity skin contusion	Right interior
5=Critical	Brainstem compression (includes herniation)	Other noncontact
1=Minor	Upper extremity skin contusion	Seat, back

Case Number: 2002-11-148

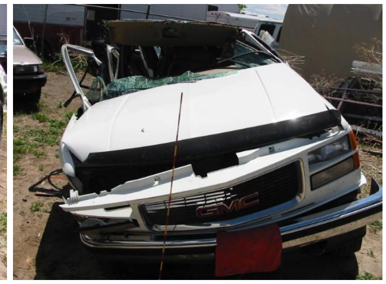
Summary:

V1 was traveling westbound in the #2 lane on a two lane, one way roadway, negotiating a curve. V1 began drifting off the roadway to the left. The driver of V1 swerved to the right, overcorrected and swerved back left. The vehicle departed the roadway and began rolling on the unpaved shoulder, rolling 3 complete turns and coming to rest on it wheels. Both occupants of V1 were transported due to injuries. The driver was released the same day. Occupant 2 remained in the hospital for nine days, then died due to injuries.)



Vehicle	Body type	Make	Model	Year	Occ. #	Age	Occupant's sex	Maximum known occupant ais
1	COMPACT UTILITY	Ford	Bronco II	1993	1	16	MALE	1=Minor
1	COMPACT UTILITY	Ford	Bronco II	1993	2	15	MALE	5=Critical

Occupant: 2002-75-58-1-1

Rollover Characteristics

Number of Events	6
Rollover Initiation Type	99
Location of Rollover Initiation	9
Rollover Initiation Object Contacted	99
Location on Vehicle where Principal Tripping Force was Applied	9
Direction of Initial Roll	9

Crash Severity

Nr. Quarter Turns	99
Impact Speed	999
Total, Longitudal, and Lateral δV	999 999 999
Est. δV with sequence number	SEVERE 3
CDC	0 R D A W 4
Damage (C1-C6)	0 0 0 0 0 0
Crush (L and D)	0 0
Object Contacted 1	VEHICLE NO. 3
Object Contacted 2	ROLLOVER-OVERTRN

Pre-Crash Environment

Traffic Flow	DVDED/NO BARRIER
Number of Travel Lanes	THREE
Roadway Alignment	CURVE RIGHT
Roadway Profile	DOWNHILL GRADE
Roadway Surface Type	ASPHALT
Roadway Surface Condition	DRY
Light Conditions	DAYLIGHT
Atmospheric Conditions	No ADVERSE COND
Relation to Intersection	NONINTER/NONJUNC
Traffic Control Device	
Police Reported Alcohol Presence	No ALCOHOL
Alcohol Test (< 95 indicates BAC 0.xx)	0

Vehicle Factors

Make-Model	GMC Suburban
Year	1997
Class	TRUCK
Body Type	UTILITY STAWAGON
Weight	240

NASS Weighting Factor

Weighting factor	41.703

Pre-Crash Driver Data

Accident Type	6
Pre-event Movement	NEGOTIATE CURVE
Critical Pre-crash Event	Unk CONTROL LOSS
Attempted Avoidance Maneuver	99
Pre-impact Stability	LAT SKID-CTR CLK
Pre-impact Location	DEPARTED ROADWAY

DRIVER Factors

Age	51	Height	183	Weight	109
Gender			MALE		
Ejection			No EJECTION		
Ejection Area			No EJECTION		
Entrapment			ENTRAPPED		

Restraint Factors

Restrain	Lap and shoulder
AOPS	YES-RES DET
Airbag Deployment	NONDEPLOYED
Airbag Deployment - 1^{st} Seat	NONDEPLOYED
Airbag Deployment - Oth Seat	Not EQUIP W/ OTH

Injuries

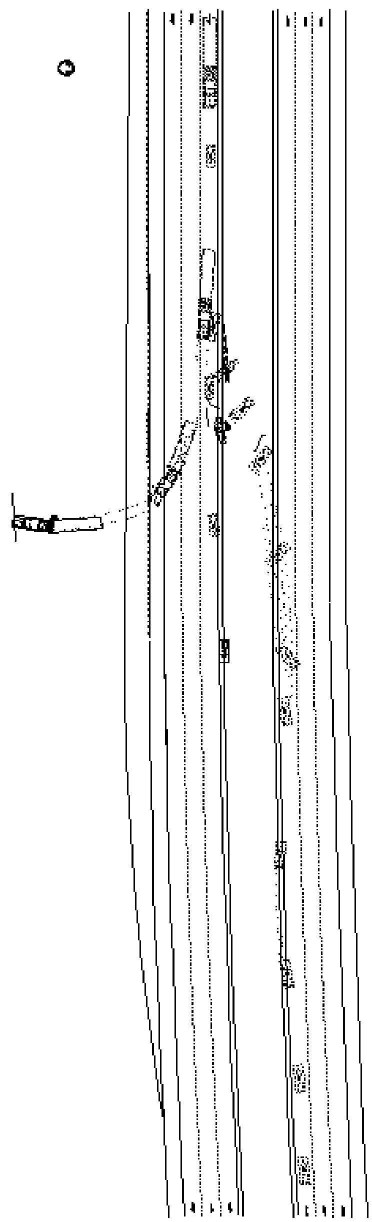
Occupant	2002-75-58-1-1
MAIS	7=Unk. sev.
Seat Position	Front left side

AIS Level	Injury Description	Contacts
7=Unk. sev.	Head injury, closed, NFS	Roof
7=Unk. sev.	Blunt chest trauma NFS	Unknown SOURCE

Case Number: 2002-75-58

Summary:

This crash occurred at 1320 hours in daylight with no adverse weather conditions. Vehicle one, a 1997 GMC Suburban was eastbound in the #3 through lane on a divided six-lane interstate highway. The eastbound side of the highway consists of three through lanes and vehicle one's precrash roadway was curved to the right. The westbound side of the highway also has three lanes but was straight. Vehicle two, a 1998 Jeep Cherokee was westbound on the same interstate highway in the #3 through lane. Vehicle three, a 2002 Volvo conventional cab tractor pulling one trailer that was empty, was also westbound on the same interstate highway in the #3 through lane following vehicle two. Vehicle two was some distance in front of vehicle three. Vehicle one departed the road to the left onto the left shoulder and into a grassy center median. Driver of vehicle one over corrected by steering right and re-entered the interstate into the #3 lane. He again steered left and then lost control. Vehicle one started to rotate counter clockwise and ran off the left side of the road into the grassy median. Vehicle one rolled to its right an unknown number of times and towards the #3 westbound lane. Flying debris from the rollover of vehicle one hit vehicle two on the left side and broke the left front window of the Jeep Cherokee. Vehicle one continued to roll as it entered the westbound lane and the right side of vehicle one impacted with the left side of vehicle three, the Volvo tractor. The right side of vehicle one came to rest on its right side in the center median shoulder facing west. Vehicle two drove to final rest on the left shoulder after the impact. Vehicle three ran off the right side of the road hitting the guardrail with it's front. Vehicle three continued through the guardrail down a steep embankment and hit a tree and an embankment with it's front. Vehicle three came to rest facing north at the bottom of the embankment. All vehicles were equipped with dual frontal air bags. Only the air bags in vehicle three deployed. The driver of vehicle one was pronounced dead at the scene with unspecified head and internal injuries. The driver and occupant of vehicle two were not injured. The driver of vehicle three was transported and released to a trauma center with cuts and scrapes.)



Vehicle	Body type	Make	Model	Year	Occ. #	Age	Occupant's sex	Maximum known occupant ais
1	UTILITY STAWAGON	GMC	Suburban	1997	1	51	MALE	7=Unk. sev.

Occupant: 2002-81-62-1-2




Rollover Characteristics

Number of Events	2
Rollover Initiation Type	99
Location of Rollover Initiation	9
Rollover Initiation Object Contacted	99
Location on Vehicle where Principal Tripping Force was Applied	9
Direction of Initial Roll	9

Crash Severity

Nr. Quarter Turns	99
Impact Speed	999
Total, Longitudal, and Lateral δV	999 999 999
Est. δV with sequence number	SEVERE 1
CDC	0 T D D O 5
Damage (C1-C6)	0 0 0 0 0 0
Crush (L and D)	0 0
Object Contacted 1	ROLLOVER-OVERTRN
Object Contacted 2	SMALL TREE

Pre-Crash Environment

Traffic Flow	Not DIVIDED
Number of Travel Lanes	TWO
Roadway Alignment	CURVE RIGHT
Roadway Profile	LEVEL
Roadway Surface Type	ASPHALT
Roadway Surface Condition	DRY
Light Conditions	DAYLIGHT
Atmospheric Conditions	No ADVERSE COND
Relation to Intersection	NONINTER/NONJUNC
Traffic Control Device	
Police Reported Alcohol Presence	9
Alcohol Test (< 95 indicates BAC 0.xx)	99

Vehicle Factors

Make-Model	Cadillac Escalade
Year	2000
Class	TRUCK
Body Type	LARGE UTILITY
Weight	257

NASS Weighting Factor

Weighting factor	18.895

Pre-Crash Driver Data

Accident Type	6
Pre-event Movement	NEGOTIATE CURVE
Critical Pre-crash Event	OFF EDGE-LEFT
Attempted Avoidance Maneuver	No AVOIDANCE
Pre-impact Stability	TRACKING
Pre-impact Location	DEPARTED ROADWAY

PASSENGER Factors

Age	10	Height	157	Weight	41

Gender	FEMALE-NOT PREG
Ejection	No EJECTION
Ejection Area	No EJECTION
Entrapment	Not ENTRAPPED

Restraint Factors

Restrain	Lap and shoulder
AOPS	YES-RES DET
Airbag Deployment	NONDEPLOYED
Airbag Deployment - 1^{st} Seat	NONDEPLOYED
Airbag Deployment - Oth Seat	Not EQUIP W/ OTH

Injuries

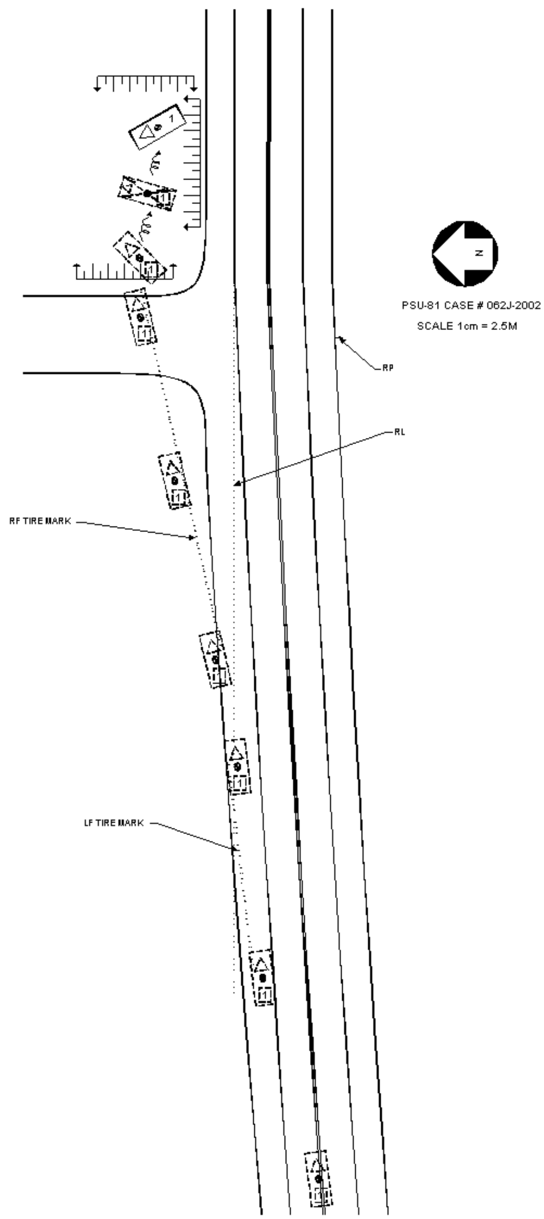
Occupant	2002-81-62-1-2
MAIS	5=Critical
Seat Position	Front right side

AIS Level	Injury Description	Contacts
2=Moderate	Awake on admission, never unconscious & neuro deficit	Roof
3=Serious	Cerebral contusion, single, small (<30ccs)	Roof
5=Critical	Cerebral diffuse axonal injury	Roof
3=Serious	Cerebral brain swelling, mild	Roof
3=Serious	Cerebral brain swelling, mild	Roof
1=Minor	Neck skin abrasion	Belt webb/buckle
1=Minor	Neck skin contusion (hematoma)	Belt webb/buckle
1=Minor	Neck skin laceration, minor	Belt webb/buckle
1=Minor	Facial skin laceration, minor	Flying glass
1=Minor	Upper extremity skin abrasion	Belt webb/buckle
1=Minor	Upper extremity skin laceration, minor	Roof right rail
1=Minor	Thoracic skin abrasion	Belt webb/buckle
1=Minor	Thoracic skin contusion	Belt webb/buckle

Case Number: 2002-81-62

Summary:

Vehicle 1, a 2000 Cadillac Escalade, was traveling eastbound on a 2-lane, 2-way, bituminous roadway. Vehicle 1 was approaching a right curve. Vehicle 1 traveled straight through the curve and departed the left side of the road. Vehicle 1 entered a ditch and travelled approximately 26 meters then crossed a private road. After crossing the north/south road, vehicle 1 went down an embankment and rolled four quarter turns, leading with its right side.During the rollover the vehicle struck a tree with the top plane. Vehicle 1 came to rest on it's wheels. The driver was treated and released with neck strain and minor scalp contusion. The front seat passenger was hospitalized for brain injuries and minor lacerations. The left rear seat passenger was treated and released with minor arm lacerations and shoulder strain. The right rear seat passenger was restrained in a child safety seat and was treated and released with minor facial abrasion and contusion. Vehicle 1 is equipped with driver and passenger front airbags that did not deploy. Vehicle 1 is also equipped with an EDR. The near deployment data was recovered by the police and a copy was submitted with this case.)



Vehicle	Body type	Make	Model	Year	Occ. #	Age	Occupant's sex	Maximum known occupant ais
1	LARGE UTILITY	Cadillac	Escalade	2000	1	31	MALE	1=Minor
1	LARGE UTILITY	Cadillac	Escalade	2000	2	10	FEMALE-NOT PREG	5=Critical
1	LARGE UTILITY	Cadillac	Escalade	2000	3	18	MALE	1=Minor
1	LARGE UTILITY	Cadillac	Escalade	2000	4	2	MALE	1=Minor

Occupant: 2003-5-17-1-2



Rollover Characteristics

Number of Events	2
Rollover Initiation Type	TRIP-OVER
Location of Rollover Initiation	ON SHLDER-UNPAVE
Rollover Initiation Object Contacted	GROUND
Location on Vehicle where Principal Tripping Force was Applied	WHEELS/TIRES
Direction of Initial Roll	ROLL LEFT

Crash Severity

Nr. Quarter Turns	2 QUARTER TURNS
Impact Speed	999
Total, Longitudal, and Lateral δV	999 999 999
Est. δV with sequence number	SEVERE 2
CDC	0 T D D O 4
Damage (C1-C6)	0 0 0 0 0 0
Crush (L and D)	0 0
Object Contacted 1	ROLLOVER-OVERTRN
Object Contacted 2	FIRE HYDRANT

Pre-Crash Environment

Traffic Flow	Not DIVIDED
Number of Travel Lanes	TWO
Roadway Alignment	CURVE RIGHT
Roadway Profile	DOWNHILL GRADE
Roadway Surface Type	ASPHALT
Roadway Surface Condition	Other
Light Conditions	DAYLIGHT
Atmospheric Conditions	No ADVERSE COND
Relation to Intersection	NONINTER/NONJUNC
Traffic Control Device	
Police Reported Alcohol Presence	No ALCOHOL
Alcohol Test (< 95 indicates BAC 0.xx)	96

Vehicle Factors

Make-Model	Chevrolet Suburban
Year	1999
Class	TRUCK
Body Type	UTILITY STAWAGON
Weight	240

NASS Weighting Factor

Weighting factor	252.221

Pre-Crash Driver Data

Accident Type	2
Pre-event Movement	NEGOTIATE CURVE
Critical Pre-crash Event	TRAVEL TOO FAST
Attempted Avoidance Maneuver	99
Pre-impact Stability	9
Pre-impact Location	DEPARTED ROADWAY

PASSENGER Factors

Age	45	Height	180	Weight	111

Gender	MALE
Ejection	No EJECTION
Ejection Area	No EJECTION
Entrapment	ENTRAPPED

Restraint Factors

Restrain	Lap and shoulder
AOPS	YES-RES DET
Airbag Deployment	NONDEPLOYED
Airbag Deployment - 1^{st} Seat	NONDEPLOYED
Airbag Deployment - Oth Seat	Not EQUIP W/ OTH

Injuries

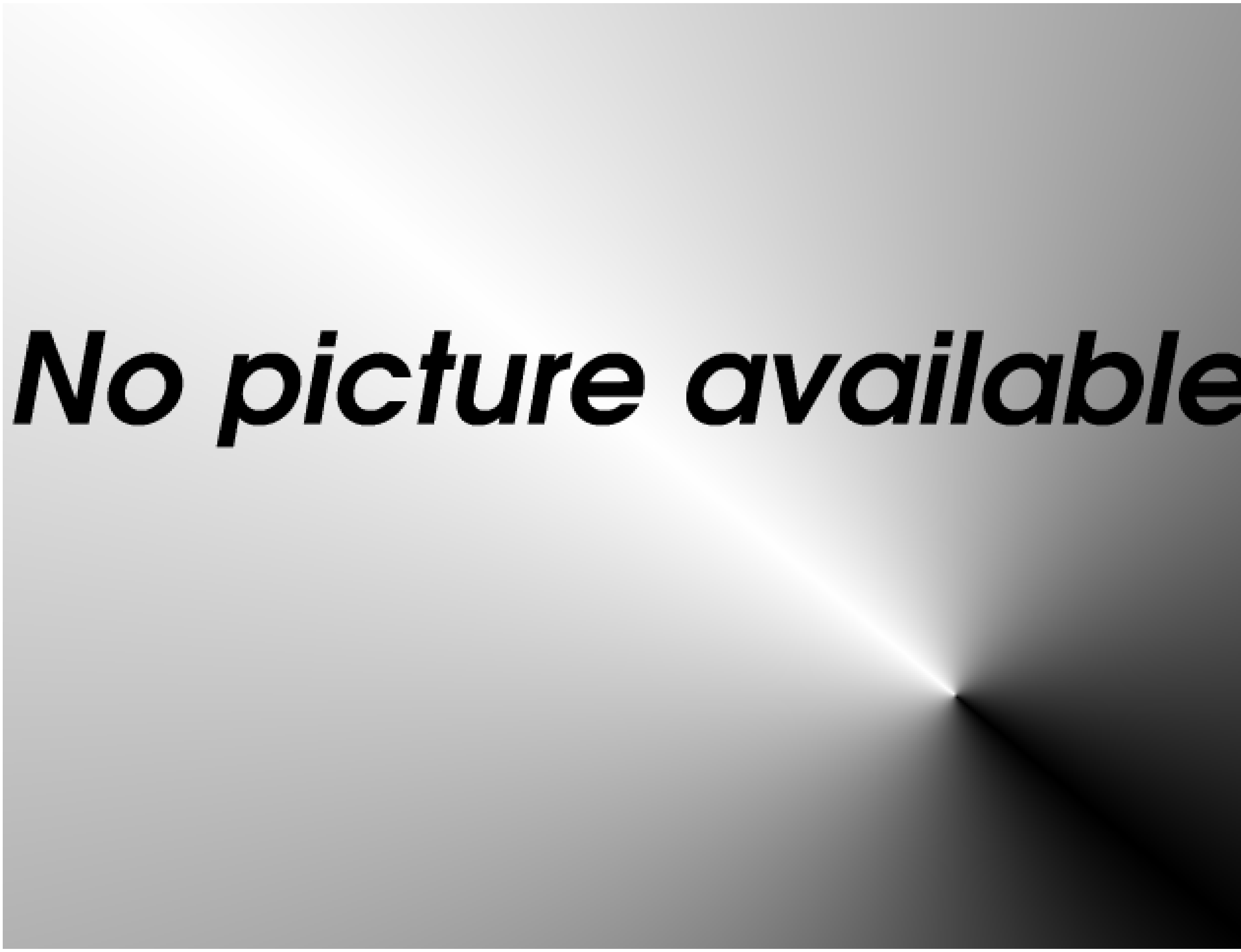
Occupant	2003-5-17-1-2
MAIS	2=Moderate
Seat Position	Front right side

AIS Level	Injury Description	Contacts
1=Minor	Scalp laceration, NFS	573
1=Minor	Leg skin laceration, minor	Glove door
1=Minor	Facial skin abrasion	206
1=Minor	Facial skin contusion	206
1=Minor	Facial skin abrasion	206
1=Minor	Facial skin contusion	206
1=Minor	Facial skin abrasion	206
1=Minor	Facial skin contusion	206
2=Moderate	2-3 rib fractures with stable chest	Right interior
1=Minor	Upper extremity skin contusion	Belt webb/buckle
1=Minor	Leg skin contusion (hematoma)	Glove door
1=Minor	Leg skin contusion (hematoma)	Seat, back
1=Minor	Upper extremity skin abrasion	Windshield

Case Number: 2003-5-17

Summary:

V1 was traveling eastbound on a two-lane, two-way, not physically divided, snow-covered roadway. V1 began negotiating a curve in the roadway and lost control and the front right tire left the roadway and traveled up a steep embankment. The front left tire then left the roadway and traveled in a southeasterly direction along the base of the embankment. The left rear tire was separated from the rim at the bead and lost air pressure, causing the rim to gouge the roadway. V1 continued to travel in a southeasterly direction until the front of V1 contacted a fire hydrant. Upon impact with the fire hydrant V1 began to rollover and to rest on its roof. The driver of V1 exited the vehicle with some assistance and the passenger was extracted from the vehicle due to serious injuries. Both the driver and passenger were transported to a hospital for injuries. The driver sustained a cut from a piece of broken glass. The passenger was pronounced dead on arrival, due to multiple head injuries. V1 was towed from the scene.)



Vehicle	Body type	Make	Model	Year	Occ. #	Age	Occupant's sex	Maximum known occupant ais
1	UTILITY STAWAGON	Chevrolet	Suburban	1999	1	18	MALE	0=None
1	UTILITY STAWAGON	Chevrolet	Suburban	1999	2	45	MALE	2=Moderate

Occupant: 2003-12-45-1-2

Rollover Characteristics

Number of Events	2
Rollover Initiation Type	TRIP-OVER
Location of Rollover Initiation	ROADSIDE/MEDIAN
Rollover Initiation Object Contacted	Oth FIXED OBJECT
Location on Vehicle where Principal Tripping Force was Applied	WHEELS/TIRES
Direction of Initial Roll	ROLL LEFT

Crash Severity

Nr. Quarter Turns	4 QUARTER TURNS
Impact Speed	999
Total, Longitudal, and Lateral δV	999 999 999
Est. δV with sequence number	SEVERE 1
CDC	0 T D D O 5
Damage (C1-C6)	0 0 0 0 0 0
Crush (L and D)	0 0
Object Contacted 1	ROLLOVER-OVERTRN
Object Contacted 2	SMALL POLE

Pre-Crash Environment

Traffic Flow	Not DIVIDED
Number of Travel Lanes	TWO
Roadway Alignment	STRAIGHT
Roadway Profile	LEVEL
Roadway Surface Type	SLAG/GRAVL/STONE
Roadway Surface Condition	WET
Light Conditions	DARK
Atmospheric Conditions	No ADVERSE COND
Relation to Intersection	INTERSECTION REL
Traffic Control Device	
Police Reported Alcohol Presence	No ALCOHOL
Alcohol Test (< 95 indicates BAC 0.xx)	0

Vehicle Factors

Make-Model	Chevrolet S-10 Blazer
Year	2000
Class	TRUCK
Body Type	COMPACT UTILITY
Weight	176

NASS Weighting Factor

Weighting factor	30.110

Pre-Crash Driver Data

Accident Type	2
Pre-event Movement	GOING STRAIGHT
Critical Pre-crash Event	POOR ROAD CONDIT
Attempted Avoidance Maneuver	BRAKE+STEER RT
Pre-impact Stability	LATERAL SKID-CLK
Pre-impact Location	DEPARTED ROADWAY

PASSENGER Factors

Age	21	Height	157	Weight	57

Gender	FEMALE-NOT PREG
Ejection	No EJECTION
Ejection Area	No EJECTION
Entrapment	Not ENTRAPPED

Restraint Factors

Restrain	Lap and shoulder
AOPS	YES-RES DET
Airbag Deployment	NONDEPLOYED
Airbag Deployment - 1^{st} Seat	NONDEPLOYED
Airbag Deployment - Oth Seat	Not EQUIP W/ OTH

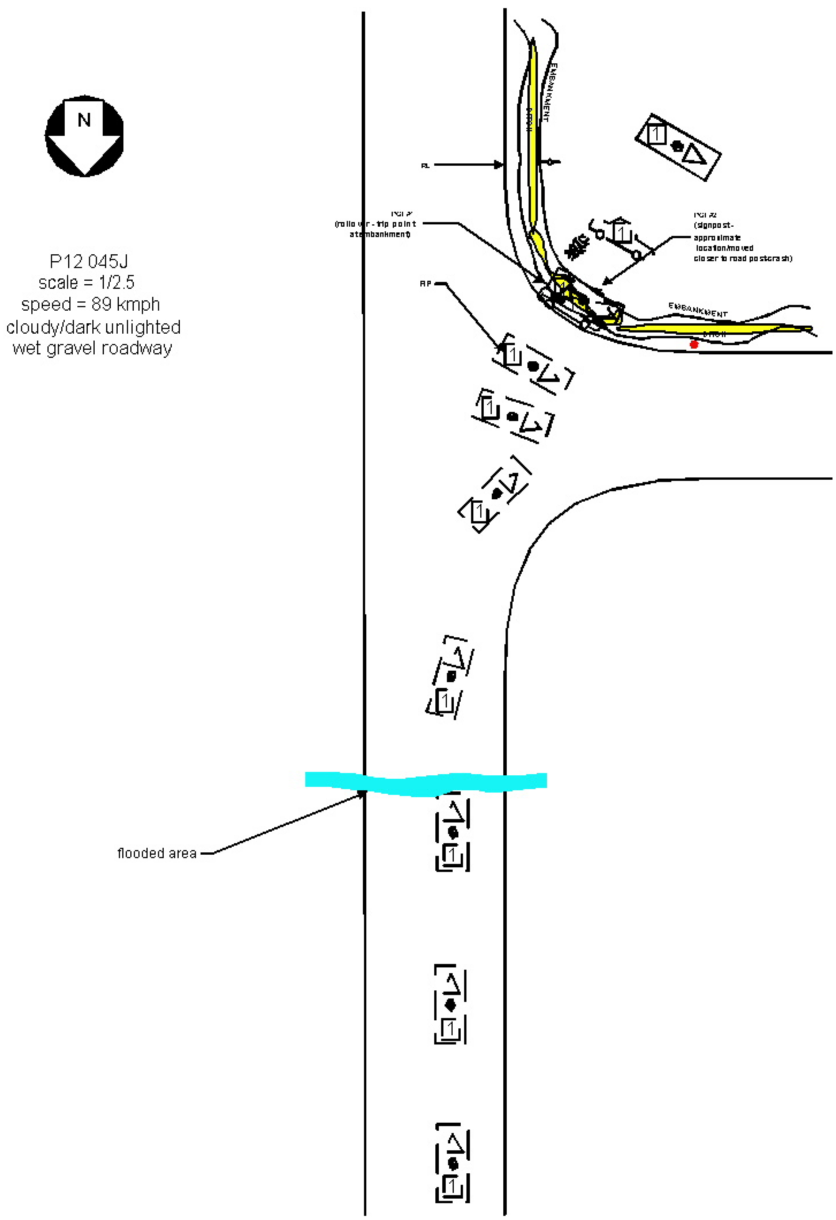
Injuries

Occupant	2003-12-45-1-2
MAIS	3=Serious
Seat Position	Front right side

Case Number: 2003-12-45

Summary:

Vehicle 1 was heading south on a 2 lane, 2-way wet, gravel roadway during cloudy, dark, unlighted conditions, on approach to a 3-leg rural intersection. The 3-leg intersection was bordered to the southwest by a shallow ditch with an embankment at the corner apex. The roadway had water flowing over the road. As the vehicle went through the water the driver lost control of the vehicle. Rotating in a clockwise pattern, the vehicle continued in a southwesterly direction and exited the forward (south) edge of the intersecting roadway (broadside to the embankment). As the vehicle departed the south roadedge, the left side wheels came into contact with the embankment which initiated a 4-quarter turn left side rollover (tripover). Traveling up the embankment, and into its second quarter turn, the vehicle right side surface struck/sheared a small diameter (U-channel) signpost, resulting in minor (non-horizontal) damage. At this point, the vehicle continued into an open field, while rolling the two remaining quarter turns. The vehicle came to rest on its wheels at final rest facing northwest (in the open field). The vehicle was towed due to damage. All 4 occupants were transported to a local trauma center for treatment of their injuries. The front seat occupants were wearing their lap & shoulder belts, the back occupants were also wearing their safety belts. Occupant 4 was partially ejected out of the right rear window. The rear tailgate on the vehicle did come open during the crash but was held closed by the spare tire mount.)



Vehicle	Body type	Make	Model	Year	Occ. #	Age	Occupant's sex	Maximum known occupant ais
1	COMPACT UTILITY	Chevrolet	S-10 Blazer	2000	1	21	MALE	1=Minor
1	COMPACT UTILITY	Chevrolet	S-10 Blazer	2000	2	21	FEMALE-NOT PREG	3=Serious
1	COMPACT UTILITY	Chevrolet	S-10 Blazer	2000	3	18	FEMALE-NOT PREG	1=Minor
1	COMPACT UTILITY	Chevrolet	S-10 Blazer	2000	4	20	FEMALE-NOT PREG	1=Minor

AIS Level	Injury Description	Contacts
1=Minor	Facial skin laceration, minor	Flying glass
1=Minor	Scalp laceration, minor	Flying glass
1=Minor	Upper extremity skin contusion	Roof
1=Minor	Facial skin abrasion	Roof
1=Minor	Upper extremity skin abrasion	Roof
2=Moderate	Thoracic vertebral body fracture without cord injury NFS	Seat, back
3=Serious	Thoracic facet fracture without cord injury	Right B pillar
2=Moderate	Unconsciousness <1 hour	Roof
7=Unk. sev.	Abdominal injury, blunt	Belt webb/buckle
7=Unk. sev.	Blunt chest trauma NFS	Belt webb/buckle
3=Serious	Cervical lamina fracture, no cord injury	Right B pillar
2=Moderate	Cervical nerve root injury NFS	Right B pillar
3=Serious	Cervical cord contusion, transient neuro signs with fx	Right B pillar

Occupant: 2003-41-102-1-1

Rollover Characteristics

Number of Events	1
Rollover Initiation Type	TRIP-OVER
Location of Rollover Initiation	ON ROADWAY
Rollover Initiation Object Contacted	GROUND
Location on Vehicle where Principal Tripping Force was Applied	WHEELS/TIRES
Direction of Initial Roll	ROLL RIGHT

Crash Severity

Nr. Quarter Turns	4 QUARTER TURNS
Impact Speed	999
Total, Longitudal, and Lateral δV	999 999 999
Est. δV with sequence number	SEVERE 1
CDC	0 T D Y O 4
Damage (C1-C6)	0 0 0 0 0 0
Crush (L and D)	0 0
Object Contacted 1	ROLLOVER-OVERTRN
Object Contacted 2	0

Pre-Crash Environment

Traffic Flow	DVDED/W/BARRIER
Number of Travel Lanes	SIX
Roadway Alignment	STRAIGHT
Roadway Profile	LEVEL
Roadway Surface Type	ASPHALT
Roadway Surface Condition	WET
Light Conditions	DAYLIGHT
Atmospheric Conditions	RAIN
Relation to Intersection	NONINTER/NONJUNC
Traffic Control Device	
Police Reported Alcohol Presence	No ALCOHOL
Alcohol Test (< 95 indicates BAC 0.xx)	0

Vehicle Factors

Make-Model	Chevrolet S-10 Blazer
Year	2001
Class	TRUCK
Body Type	COMPACT UTILITY
Weight	182

NASS Weighting Factor

Weighting factor	20.087

Pre-Crash Driver Data

Accident Type	98
Pre-event Movement	GOING STRAIGHT
Critical Pre-crash Event	TRAVEL TOO FAST
Attempted Avoidance Maneuver	99
Pre-impact Stability	LAT SKID-CTR CLK
Pre-impact Location	Left TRAVEL LANE

DRIVER Factors

Age	35	Height	183	Weight	130

Gender	MALE
Ejection	No EJECTION
Ejection Area	No EJECTION
Entrapment	Not ENTRAPPED

Restraint Factors

Restrain	Lap and shoulder
AOPS	YES-RES DET
Airbag Deployment	NONDEPLOYED
Airbag Deployment - 1st Seat	NONDEPLOYED
Airbag Deployment - Oth Seat	Not EQUIP W/ OTH

Injuries

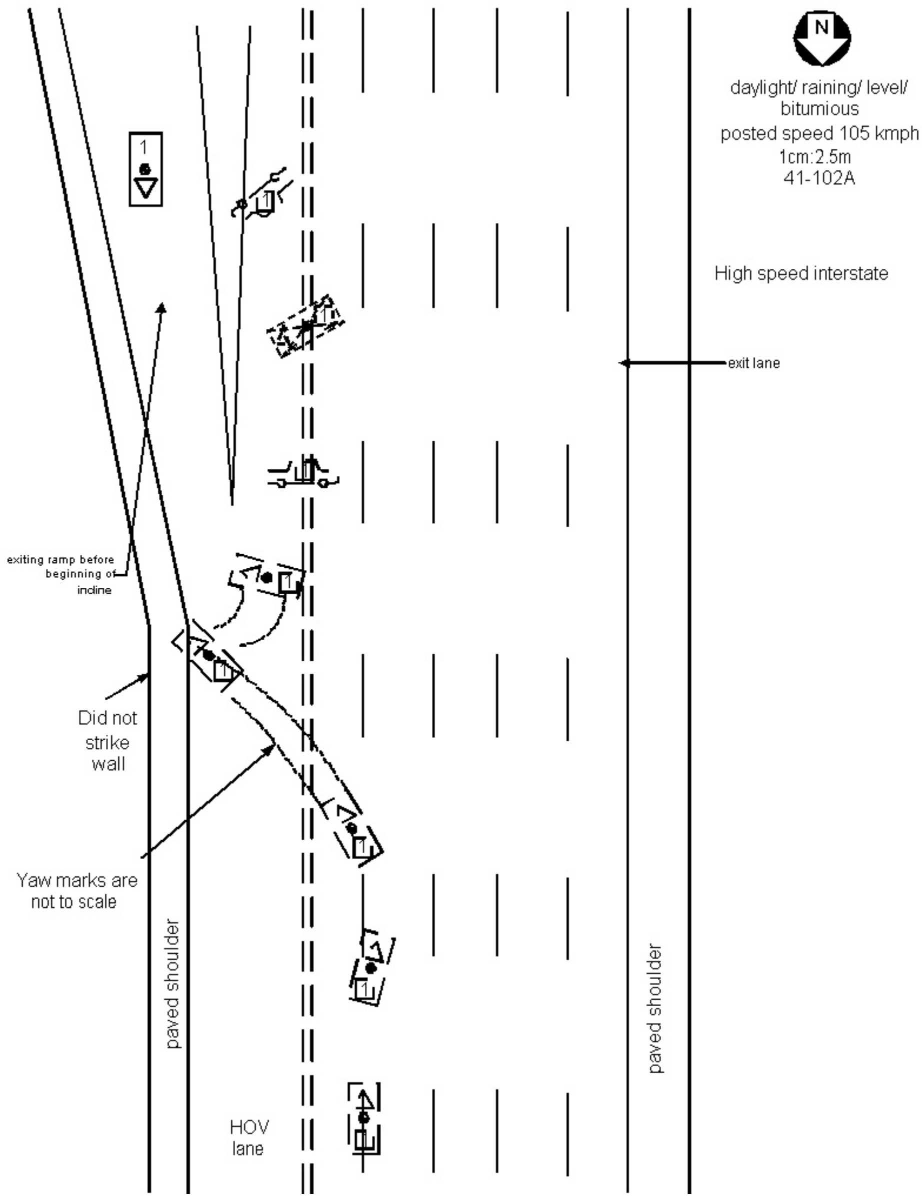
Occupant	2003-41-102-1-1
MAIS	4=Severe
Seat Position	Front left side

AIS Level	Injury Description	Contacts
1=Minor	Facial skin contusion	Roof
1=Minor	Scalp contusion	Roof left rail
1=Minor	Scalp avulsion, superficial (<100 cms2)	206
1=Minor	Scalp abrasion	Roof
1=Minor	Scalp contusion	Roof
1=Minor	Scalp abrasion	Roof left rail
3=Serious	Cerebral subarachnoid hemorrhage	206
3=Serious	Cerebral subarachnoid hemorrhage	Roof left rail
3=Serious	Cerebral contusions, multiple, bilateral, small	206
2=Moderate	Skull fracture, vault, closed (simple, undisplaced)	206
4=Severe	Basilar skull fracture, open, with brain tissue loss.	Roof
1=Minor	Neck skin contusion (hematoma)	Belt webb/buckle
1=Minor	Neck skin abrasion	Belt webb/buckle
1=Minor	Upper extremity skin abrasion	Roof
1=Minor	Thoracic skin abrasion	Belt webb/buckle
1=Minor	Thoracic skin contusion	Belt webb/buckle
1=Minor	690402	Seat, back
1=Minor	690202	Seat, back
2=Moderate	Sternal fracture	Belt webb/buckle
1=Minor	Upper extremity skin contusion	Roof
1=Minor	Upper extremity skin abrasion	Belt webb/buckle
1=Minor	Upper extremity skin contusion	Belt webb/buckle

Case Number: 2003-41-102

Summary:

V1, a 2001 Chevrolet Blazer, was traveling southbound on a major interstate in lane four, next to the HOV lane. The roadway was wet, due to rain, bitumious and level. The vehicle veered to the left and then back to the right from lane four to lane five and back before tripping and rolling four quarter turns and landing on its wheels. The driver was transported to a trama center after sustaining incapacitating injuries. The vehicle was towed due to damage.)



Vehicle	Body type	Make	Model	Year	Occ. #	Age	Occupant's sex	Maximum known occupant ais
1	COMPACT UTILITY	Chevrolet	S-10 Blazer	2001	1	35	MALE	4=Severe

Occupant: 2004-75-39-1-1




Rollover Characteristics

Number of Events	3
Rollover Initiation Type	FLIP-OVER
Location of Rollover Initiation	ROADSIDE/MEDIAN
Rollover Initiation Object Contacted	Oth FIXED OBJECT
Location on Vehicle where Principal Tripping Force was Applied	UNDERCARRIAGE
Direction of Initial Roll	ROLL RIGHT

Crash Severity

Nr. Quarter Turns	2 QUARTER TURNS
Impact Speed	999
Total, Longitudal, and Lateral δV	999 999 999
Est. δV with sequence number	MODERATE 1
CDC	1 F R E W 1
Damage (C1-C6)	0 0 0 0 0 0
Crush (L and D)	0 0
Object Contacted 1	Other BARRIER
Object Contacted 2	Other BARRIER

Pre-Crash Environment

Traffic Flow	DVDED/NO BARRIER
Number of Travel Lanes	THREE
Roadway Alignment	CURVE LEFT
Roadway Profile	LEVEL
Roadway Surface Type	ASPHALT
Roadway Surface Condition	SNOW OR SLUSH
Light Conditions	DARK/LIGHTED
Atmospheric Conditions	SNOW
Relation to Intersection	NONINTER/NONJUNC
Traffic Control Device	
Police Reported Alcohol Presence	ALCOHOL PRESENT
Alcohol Test (< 95 indicates BAC 0.xx)	23

Vehicle Factors

Make-Model	Ford Bronco II
Year	1996
Class	TRUCK
Body Type	COMPACT UTILITY
Weight	185

NASS Weighting Factor

Weighting factor	52.520

Pre-Crash Driver Data

Accident Type	7
Pre-event Movement	NEGOTIATE CURVE
Critical Pre-crash Event	POOR ROAD CONDIT
Attempted Avoidance Maneuver	99
Pre-impact Stability	LAT SKID-CTR CLK
Pre-impact Location	DEPARTED ROADWAY

DRIVER Factors

Age 30 Height 168 Weight 58

Gender	FEMALE-NOT PREG
Ejection	No EJECTION
Ejection Area	No EJECTION
Entrapment	Not ENTRAPPED

Restraint Factors

Restrain	Lap and shoulder
AOPS	YES-RES DET
Airbag Deployment	BAG DEPLOYED
Airbag Deployment - 1^{st} Seat	DR&PAS BAG DEPLY
Airbag Deployment - Oth Seat	Not EQUIP W/ OTH

Injuries

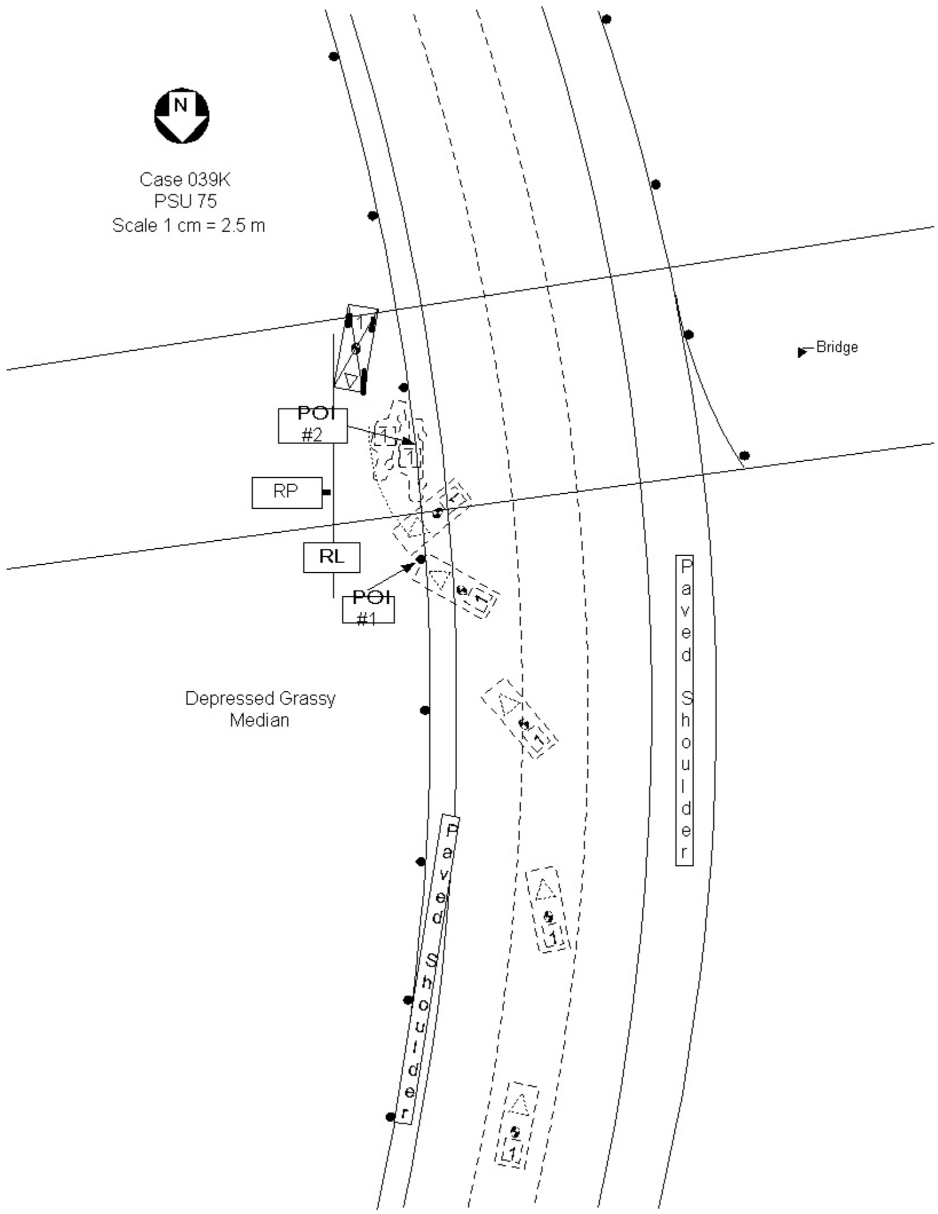
Occupant	2004-75-39-1-1
MAIS	4=Severe
Seat Position	Front left side

AIS Level	Injury Description	Contacts
4=Severe	Rib fxs (=>1), open/displaced/comminuted,& hemo-/pneumo thx	Left interior
4=Severe	Lung contusion, bilateral	Left interior
3=Serious	Splenic laceration, moderate (>3 cms deep, no hilar injury)	Left hardware
2=Moderate	Splenic contusion, minor (<50% surface, <2cms, nonexpanding)	Left hardware
3=Serious	Cerebral subarachnoid hemorrhage	Roof
2=Moderate	Thoracic transverse process fracture without cord injury	Left interior
2=Moderate	Thoracic transverse process fracture without cord injury	Left interior
2=Moderate	Thoracic spinous process fracture without cord injury	Left interior
2=Moderate	Lumbar fracture of transverse process without cord injury	Left hardware
2=Moderate	Lumbar fracture of transverse process without cord injury	Left hardware
2=Moderate	Lumbar fracture of transverse process without cord injury	Left hardware
2=Moderate	Lumbar fracture of spinous process without cord injury	Left hardware
2=Moderate	Lumbar fracture of spinous process without cord injury	Left hardware
1=Minor	297402	Left A pillar

Case Number: 2004-75-39

Summary:

V1, a 1996 Ford Explorer, was traveling westbound on a divided, left curve, wet, six-lane, interstate highway at night during a snowstorm. Westbound traffic had three lanes. V1 was traveling in the number 2 lane; the driver lost control and rotated counterclockwise traveling across lane number 3 and then exited the left edge of the interstate. The front of V1 collided with the edge of a guardrail and rolled right onto and over the guardrail as it continued to rotate. V1 came to rest on its roof in the median facing generally north after having rollied a total of 2 quarter-turns and having cleared the guardrail. V1 was equipped with deployed driver and passenger-side front airbags. V1 was towed due to moderate rollover damage to the top and side planes. The restrained V1 driver was hospitalized with multiple back and rib fractures as well as a spleen laceration and lung contusion.)



Vehicle	Body type	Make	Model	Year	Occ. #	Age	Occupant's sex	Maximum known occupant ais
1	COMPACT UTILITY	Ford	Bronco II	1996	1	30	FEMALE-NOT PREG	4=Severe

Attachment 4

What NASS Rollover Cases Tell Us

Carl E. Nash, Ph.D.
National Crash Analysis Center, the George Washington University

The National Accident Sampling System (NASS),[15] initiated by the National Highway Traffic Safety Administration (NHTSA) more than 25 years ago, is a rich source of data on motor vehicle crashes. Most analysts use only its electronic files and therefore miss the value that is contained in the crash descriptions, scene diagrams, and photographs of the vehicles and scenes that are in the NASS files.

For this work, we examined the details of more than 500 case files from accident years 2002-2004 to determine the critical conditions of rollover crashes. Based on that data, we estimated the effectiveness of countermeasures that are designed to reduce casualties in rollovers.

Specifically, we looked at *all* NASS rollover cases involving passenger cars, utility vehicles (SUVs), pickups, and minivans that were ten years old or less in which there was at least an AIS 3 injury to an occupant of the vehicle that rolled over. NASS is currently between one fourth and one third of its original design size and rollover cases typically have more serious consequences than other types of crashes. Thus, we assumed that we would get reasonably representative results by combining three years of recent data.

Each rollover vehicle *occupant* who sustained an AIS 3+ injury was considered as a unit for this work. There were more than one such occupants in relatively few rollovers, and in most of those, it was because at least one of the occupants was ejected. In only about 2 percent of the cases did we find more than one occupant who remained completely in the vehicle who sustained an AIS 3+ injury unless there was a major impact either before or during the rollover.

Classes of Rollovers

In looking at the NASS cases, a natural classification of rollovers suggested itself for quantitative study. The traditional taxonomies were of little use in analyzing rollover injuries. The number of rolls is a valid measure of severity only in the sense that each vehicle roof impact offers additional opportunity to damage a weak roof or to eject an occupant through a failed window. The classification of initiation of the rollover (trip over, flip over, climb over, bounce over, etc.) are poorly defined, often incorrectly coded, and of little practical use. Thus, we divided the rollovers into the following classes:

1. Cases where the rollover was the most serious event and an occupant with AIS 3+ injuries was unbelted and ejected.

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[15] Now that a politically correct NHTSA Administrator is gone, the more accurately descriptive original names of the National Accident Sampling System, the Fatal Accident Reporting System, and the Experimental Safety Vehicle Conference should be restored.

2. Cases where the rollover was the most serious event and where any occupants were belted and received at least an AIS 3 injury to the head or spinal column.
3. All other cases where the rollover was the most serious event and an occupant had an AIS 3+ injury.
    a. A subclass of these cases are cases where the rollover was the most serious event and where any occupants were belted and received at least an AIS 3 arm or hand injury (the maximum AIS coding for an upper extremity injury) that was due to a partial ejection of the hand or arm.
4. Cases where an initial collision was the most serious event (and the one that probably caused the most serious injury) but where there was subsequent rollover.
    a. A subclass of this group includes cases where there were serious collisions both before and during the rollover.
5. Cases where a rollover was the initial event, but where the most serious event was a collision or a substantial change in elevation as the vehicle was rolling over (where the collision probably caused the most serious injury).

Figure 1. An example of a Class 4 NASS case where an initial collision (with a large tree) was the most serious event.

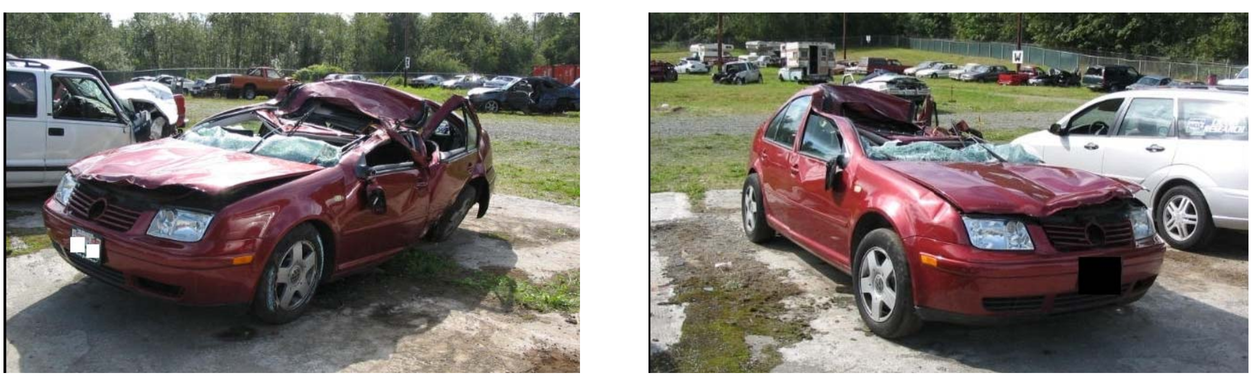

Figure 2. An example of a Class 5 NASS case where a collision (with a large tree) during a rollover was the most serious event.

There was one case (NASS 2002-75-110) where 5 people riding in the bed of a pickup each received at least AIS 3 injuries (one was a fatal) when the pickup rolled over. We did not include this case in the analysis.

The justification for this classification is not only that rollover crashes divide into roughly equal sets among, at least for passenger cars, but that each class suggests a unique set of countermeasures as will be discussed later.

Economic Consequences of Injuries: a Harm Metric

Next, using the NHTSA estimates of the economic consequences of injury, we assigned a dollar value to each of the injuries. These values are shown in Table 1. They were determined by taking the direct economic cost of injuries to specific body areas from Appendix H in the NHTSA report, *the Economic Impact of Motor Vehicle Crashes 2000*,[16] multiplying the results by the factors in Appendix A for injury severity in that report to get the specific economic consequences. These results were updated for inflation by multiplying by a factor of 1.15 (roughly 3 percent inflation per year).

These are the essentially values that NHTSA would use in assessing the economic consequences of new motor vehicle safety standards. They include the actual medical costs associated with the injury,[17] the lost wages, and intangible consequences of injury and death which were determined from studies of people's "willingness to pay" to avoid injury or death based on "wages for high-risk occupations and purchases of safety improvement products."

Cases Studied

We studied all rollovers involving passenger cars, SUVs (utility vehicles), pickups, and minivans that were less than 11 years old. (That is, for accident year 2004 we included all vehicles of model year 1995 and later that rolled over and had an AIS 3 or greater injury to an occupant.) Each unit of study was an occupant who received an injury of AIS 3 or greater or who died as a consequence of the accident. A very substantial majority of these were front seat occupants. Virtually all occupants who received such AIS 3 or greater injuries who were not in front seats were not restrained. Once the cases were identified, they were classified as noted above. Because of the limitations on vehicles and injuries, our data underestimates the total harm in rollovers by a factor of 1.5 to 2. We will attempt to better quantify the total harm from rollovers in follow-up work.

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[16] Blincoe, Lawrence J., et al., "the Economic Impact of Motor Vehicle Crashes 2000," National Highway Traffic Safety Administration, Washington, D.C. May 2002, DOT HS 809 446

[17] It was suggested by NHTSA staff in a private communication that the assessment of medical costs contained in this work significantly underestimated the cost of rehabilitation following injury.

AIS	Body Part	Cost		AIS	Body Part	Cost
1	SCI	N.A.		4	SCI	$ 7,296,260
	Brain	$ 124,459			Brain	$ 2,939,047
	Lower Extremity	$ 13,820			Lower Extremity	$ 1,161,530
	Upper Extremity	$ 5,548			Upper Extremity	N.A.
	Trunk, Abdomen	$ 10,133			Trunk, Abdomen	$ 480,459
	Face, Head, Neck	$ 9,734			Face, Head, Neck	$ 869,853
2	SCI	N.A.		5	SCI	10,210,387
	Brain	$ 686,992			Brain	$ 6,826,032
	Lower Extremity	$ 277,275			Lower Extremity	$ 2,056,783
	Upper Extremity	$ 117,739			Upper Extremity	N.A.
	Trunk, Abdomen	$ 204,573			Trunk, Abdomen	$ 860,798
	Face, Head, Neck	$ 144,749			Face, Head, Neck	$ 1,805,288
3	SCI	$ 1,506,961		6	All	$ 3,623,787
	Brain	$ 1,306,647				
	Lower Extremity	$ 530,725				
	Upper Extremity	$ 235,160				
	Trunk, Abdomen	$ 266,856				
	Face, Head, Neck	$ 325,650				

Table 1. Cost of injury by severity level and body part from *The Economic Impact of Motor Vehicle Crashes 2000.*

Harm in Rollovers

The results of this investigation are shown graphically in Figures 3 and 4. These graphics clearly shows the dramatic difference between passenger cars on one hand, and light trucks on the other. The total annual economic consequence of AIS 3+ injuries in light vehicles in the first ten years of operation is approximately $36 billion.[18] Because of their total number, the largest total cost is from passenger car rollovers. However, the highest cost per registered vehicle, by a substantial margin, is for SUVs. Their comprehensive cost for AIS 3+ injuries in rollovers is nearly three times as high as for passenger cars. Pickups have about twice the comprehensive cost of passenger cars.

By dollar volume of harm, the largest numbers by far were in Class 1 rollovers of SUVs. This is partly because of the higher rollover rates of these vehicles and the lower safety belt use in them, but those factors do not fully account for the excessive ejections.

[18] It is worth noting that NHTSA estimates that the total direct economic cost of injury today is more than $260 billion and the economic consequences would therefore be on the order of $350 billion. Rollovers account for roughly one quarter of the total loss, or nearly $90 billion annually. Thus, our estimate of the comprehensive cost of rollover casualties is conservative even if one assumes that counting AIS 1 and 2 injuries and counting injuries in vehicles more than ten years old would double our estimate.

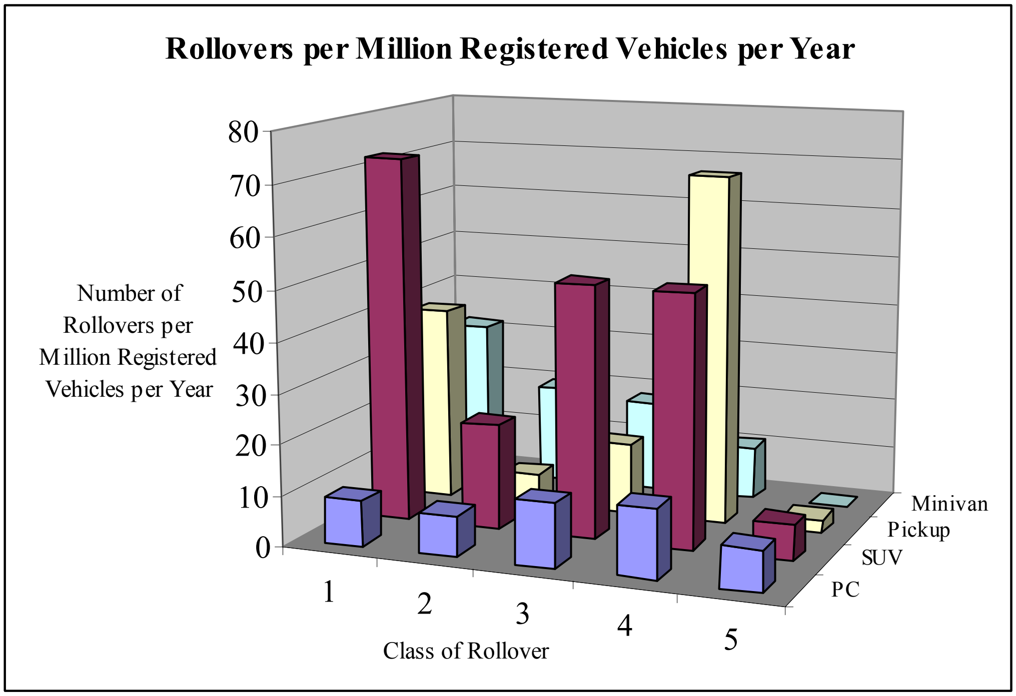

Figure 3. Estimated annual number of rollovers with AIS 3+ injuries by class and vehicle type.

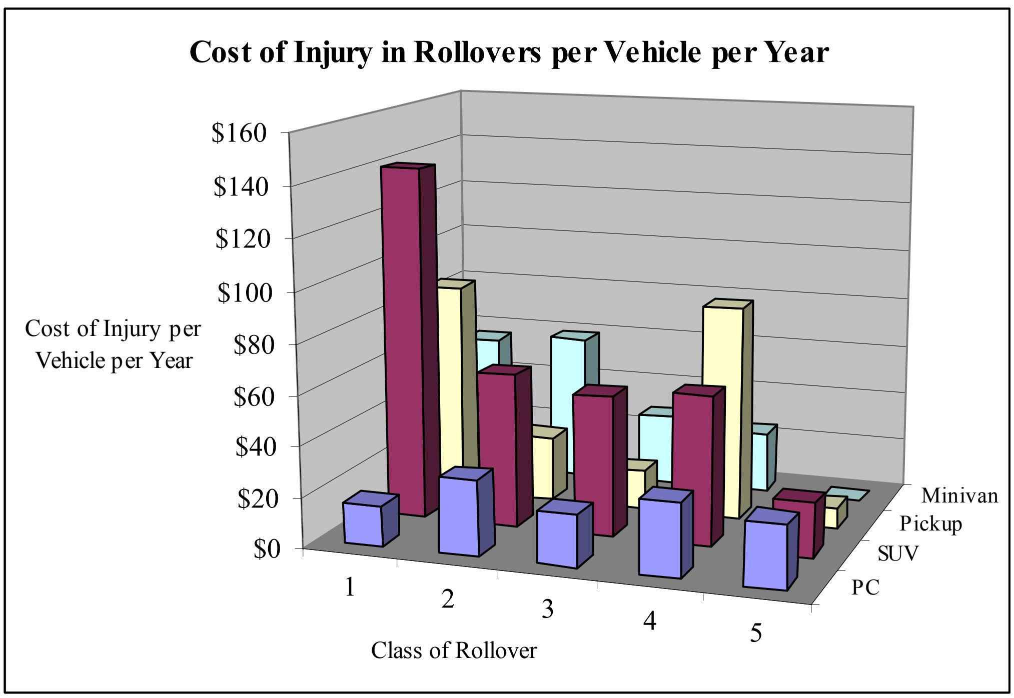

Figure 4. Cost of injury per registered vehicle by type of vehicle and type of injury.

Light trucks are also overrepresented in cases where a rollover is a secondary consequence of a serious collision (class 4 rollovers). This suggests that loss of control is a greater problem for light trucks than for passenger cars. Since the rollovers in these cases were almost incidental, for this class of crashes the traditional countermeasures applied to frontal and side crashes are much more likely to be effective. The same is not necessarily true for Class 5 crashes since a significantly stronger occupant compartment and roof will help to reduce roof crush and injuries in these cases.

It is interesting to compare the proportional relations among the five classes of rollovers for specific vehicle types. For example, because of the high cost of head and cervical spine injuries, Class 2 rollovers have a proportionally larger economic impact.

These data show that *each new* SUV comes loaded with an average of at least $3,500 in discounted economic consequence costs for the rollovers they will have during their lifetime. For pickups, the added liability is at least $2,200 and for passenger cars and minivans it is at least $1,200 and $1,700 respectively. Few if any purchasers of these vehicles are aware of this liability when they purchase a new vehicle. Furthermore, because first and third party auto insurance together pay only a trivial part of the cost of the most serious injuries and fatalities, fewer still are aware that they will bear most of these costs either directly or through non-automobile insurance systems if they are actually seriously injured in a rollover.[19] In fact, Medicaid picks up a significant part of these costs and families themselves must suffer the lost income (and the consequently reduced standard of living) and the extra personal services that are a major consequence of AIS 3+ injuries to a family member.

Figures 3 and 4 show that the spectrum of passenger car rollovers is quite different than the spectrum of SUV and pickup rollovers. The minivan figures are not as reliable because of the small number of minivan cases in the study (in the three years studied, there were only 20 rollovers involving 45 occupants with AIS 3+ injuries). It is nevertheless clear that as a class, minivans have rollover harm that is higher, per vehicle, than for passenger cars. Part of the reason for the relatively low rate of rollover harm in minivans is the demographics of those who own and use them (they are often the family station wagon for people who do not need the image of driving an SUV), not that they are inherently particularly safe in rollovers.

- About forty-five percent of passenger car and pickup truck rollover harm is either preceded by a collision that is the most serious event, or involve a collision or other complication during the rollover that is the most serious event (Class 4 and 5 rollovers). For SUVs, only a quarter of the rollovers met those conditions.

This result strongly suggests that about one-third of the harm attributed to rollovers should be reconsidered from the standpoint of appropriate countermeasures. That is, for cases with major collisions before or during a rollover, the traditional assumption that rollover casualties come primarily from ejection that is a consequence of the rollover or from roof crush (the justifications for the dolly rollover test in FMVSS 208 and for the roof crush requirements of FMVSS 216) should be reconsidered. However, it should be

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[19] Nash, Carl E., "A Market Approach to Motor Vehicle Safety . . . That Also Addresses Tort Reform," Product Safety and Liability Reporter, Bureau of National Affairs, Vol. 34, No. 8: Washington, D.C. February 27, 2006, p. 202-212.

noted that some countermeasures – particularly occupant restraint – protect in both circumstances.

- By far the greatest disparity is in complete ejections of occupants in rollovers. The rate of such rollover ejections where the rollover is the most serious event is nearly 9 times as high in SUVs, and 5 times as high in pickups as in passenger cars.

This dramatic difference comes partly from the much higher rollover rates and lower belt use rates in light trucks but those factors do not completely explain the difference. The only other major factor that might account for the higher unrestrained occupant ejection rates is the larger side window openings in SUVs and pickups. It is clear that SUVs and pickups in particular should be a major target of further research and programs to reduce ejection.

The NASS photographs reviewed for this study showed that the roofs in most contemporary vehicles crush extensively in a majority of rollovers where there are serious to fatal injuries. While it is clear that an occupant is safer in a rollover with a safety belt than without, public policy that increases belt use without addressing the problem of roof crush would be irresponsible (see comments below and footnote #7). This situation would be analogous to ignoring the unintended injuries that were inflicted by the first generation of air bags.

- Rollovers where a restrained occupant receives an AIS 3+ head or neck (cervical spine) injury are common in all vehicle types but are about twice as high in SUVs and minivans as in passenger cars and pickups.

This finding strongly suggests that a major increase in roof strength would have a substantial benefit in reducing these injuries to people who are taking the responsibility of wearing the available lap and shoulder belts.

Restraint Use

The major disparity in complete ejections between passenger cars and light trucks initially suggested that belt use in the latter was much lower than in the former, and figure 2 confirmed that suspicion. One might expect that when looked at from the standpoint of the proportion restrained by the economic consequences of the injury, only SUVs and pickups show a significant difference which probably results in the exceptional ejection rate in these light trucks.

	Restrained	Unrestrained	Unknown
Passenger Car	52%	46%	2%
SUV	30%	61%	9%
Pickup	27%	70%	3%

Table 2. Restraint use among occupants with AIS 3+ injuries from light vehicle rollovers.

	Restrained	Unrestrained	Unknown
Passenger Car	46%	48%	6%
SUV	43%	49%	8%
Pickup	26%	70%	4%

Table 3. Proportion of harm in rollovers where there was at least one AIS 3+ injury by belt use.

Rollover Countermeasures

Next, we looked at the potential savings from obvious, well tested, inexpensive and effective rollover occupant protection countermeasures. The primary countermeasures we considered were the following:

1. Safety belt use which could be substantially increased by installation of a highly effective safety belt use reminder.[20] (Most critical for classes 1,3 and 4)
2. Side windows that do no fail in rollovers (such as laminated glass that is retained in its opening so that even if it breaks it continues to provide a barrier to ejection – see Figure 5). (Class 1)
3. A strong roof that is resistant to crushing during a rollover (such as has been demonstrated by the Volvo XC90 – see Figure 6). (Classes 1,2,3 and 5)

The secondary countermeasures were:

4. Padding in the head impact area as now required by amendments to FMVSS 201. (Class 2 and 3)
5. Improving safety belt performance. Safety belts are notorious for developing excessive slack in rollovers and many belts have rather poor geometry to hold occupants effectively in rollovers. The best solution would probably be a seat mounted safety belt with a rollover-triggered pretensioner. However, less expensive approaches, such as cinching latch plates that keep lap belts snug, would have some benefit. (Class 2)
6. Changes to interior design (particularly in the door and foot well areas) to reduce torso and limb injuries from contact with the interior. (Class 3 and 4)

[20] See Committee for the Safety Belt Technology Study, "Buckling Up – Technologies to Increase Seat Belt Use," Special Report 278, Transportation Research Board, Washington, D.C. 2003.

In addition to these elements, two advanced technologies that are currently being commercialized are:

7. Electronic stability systems that will primarily reduce the probability of some of the Class 1, 2, and 3 rollovers. These systems generally reduce the oversteer of vehicles so that even though the driver cannot fully control a vehicle, at least it will not yaw so that a rollover is likely. (Classes 1, 2, 3 and 5)
8. Rollover-triggered side curtain air bags. These systems deploy as a vehicle begins to roll (triggered by a combination of the roll angle of the vehicle and its roll rate) and cover the window openings so that the potential for ejection is substantially reduced. (Class 1, 3, 4 and 5

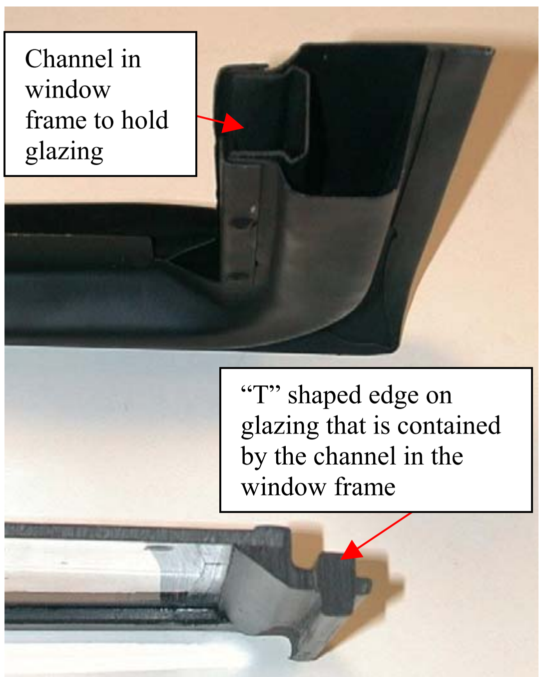

Figure 5. Side window glazing designed with channels and tracks for ejection mitigation.

Figure 6. A Volvo XC90 with a strong roof after a rollover (NASS Case 2003-79-57).

It is important to note that the effectiveness of these elements may be interrelated. For example, as was pointed out by a Ford engineer in the late 1960s, "It is obvious that occupants that are restrained in upright positions are more susceptible to injury from a collapsing roof than unrestrained occupants who are free to tumble about the interior of the vehicle. It seems unjust to penalize people wearing effective restraint systems by exposing them to more severe rollover injuries than they might expect with no restraints."[21] It is also the case that even window glazing that is designed to reduce

[21] Memorandum from J.R. Weaver to H.G. Brilmyer, "Roof Strength Study," Ford Automotive Safety Research Office, July 8, 1968.

ejection will do so only if the window openings and frames are reasonably protected from distortion by a strong roof. Conversely, if the roof does not significantly distort in a rollover, it can generally protect even tempered side glazing.

Occupant ejection could be reasonably addressed by either substantially increased belt use, the use of side window glazing that will contain occupants, or rollover-triggered window curtain air bags. Belt use is the most cost-effective means, but it would not fully address partial ejections. On the other hand, belt use has major benefit in virtually all other crash modes.

The cost and weight of the three primary countermeasures would be modest:

- Effective safety belt use reminders would add less than $25 to the retail cost of a vehicle. The added weight would be trivial.

An effective belt use reminder must go well beyond the Ford Belt Minder® system which was shown to raise belt use rates by only about 5 percentage points.[22] Effective systems have been developed in Europe and are recognized there in the European New Car Assessment Program. Highly effective belt use reminders might come about without regulatory pressure if insurance companies worked with auto makers by offering significant medical payment insurance discounts for vehicles that were equipped with them. Such discounts could easily offset the original cost of these systems.

Although belt use is critical to reducing injuries in rollovers, it must be accompanied by other countermeasures.

- Front side glazing that retains occupants (laminated glass with edge holding systems) would, according to NHTSA, have added approximately $50 to the retail price of a vehicle in 1997. Inflation would increase this to less than $65 today.

The cost-effectiveness of this technology would be greatest if it were used only in the front doors because by far the majority of occupants are ejected through these windows. If advanced glazing were used in all side windows, it would increase the retail price of a vehicle by about $140 per vehicle on average. The agency estimated that there would be no weight penalty for any of the alternative side window materials.[23,24] We have used a compromise figure of $100 as the average increase in the retail price per vehicle for ejection control glazing.

This technology is fully developed and available for production. In its simplest form, it consists of laminated glass that has "T" shaped material glued on to the side edges that fit into channels such that the glass can move up and down, but even if the glass is broken, it cannot pull out of the channels (see Figure 5). NHTSA conducted

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22 Insurance Institute for Highway Safety

23 The Advanced Glazing Research Team, "Ejection Mitigation Using Advanced Glazing, a Status Report," National Highway Traffic Safety Administration, Washington, D.C.: November 1995.

24 Willke, Donald, Stephen Summers, Jing Wang, John Lee, Susan Partyka, and Stephen Duffy, "Ejection Mitigation Using Advanced Glazing: Status Report II, National Highway Traffic Safety Administration, Washington, D.C.: August 1999.

extensive research into this product in the 1990s. The effectiveness of this countermeasure depends on the vehicle having a strong roof so that the window opening is not substantially distorted from roof impacts.

NHTSA has estimated that the effectiveness of advanced ejection-mitigating glazing in reducing rollover ejection injuries is in excess of 80 percent. It noted that the benefit would be particularly high for light trucks.[25] The 2005 Transportation legislation[26] requires that NTHSA specifically address the problem of occupant ejection.

- A strong roof would, on average, cost less than $100/vehicle.

Research has shown that the addition of well under than 100 pounds of structural material can be added to an existing vehicle to ensure very good roof crush resistance – well beyond that called for even in NHTSA's proposed amendment to FMVSS 216.[27] The use of high strength steels and plastic inserts at buckling points would ensure only minor weight increase for an adequately strong roof.[28]

If a roof is designed to provide a high level of crush resistance in the first place, the added material and cost would be substantially less than 100 pounds and $100. Volvo has demonstrated the mass production practicability of strong roof construction.

Electronic stability systems and rollover-triggered side curtain air bags each has the potential to substantially reduce rollover casualties, but their cost in full production is substantially higher than the cost of the three basic countermeasures. Their benefit was not estimated in this work. The added retail cost of either of these technologies has been estimated to be around $250 in large scale production. The extra cost of rollover triggering of side curtain air bags that are already in a vehicle would be $25 to $50. The cost of electronic stability systems assumes that the vehicle already has anti-lock brakes.

Benefits of Rollover Countermeasures

The effectiveness of each primary countermeasure was assessed against the specific conditions of the crash. In no case was it assumed that the effectiveness would be above 80 percent because of uncertainties about the cases and outcomes and the fact that there might be residual, although less serious injuries even with the countermeasures. However, where there was a complete ejection in an otherwise simple rollover (without complications such as significant collisions or major changes in elevation during the rollover) it was assumed that the combination of a strong safety belt use reminder and

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[25] Winnicki, John, "Estimating the Injury-Reducing Benefits of Ejection-Mitigating Glazing," National Highway Traffic Safety Administration, Washington, DC. February 1996, DOT HS 808 369.

[26] Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU), enacted August 10, 2005, as Public Law 109-59. SAFETEA-LU authorizes the Federal surface transportation programs for highways, highway safety, and transit for the 5-year period 2005-2009.

[27] See, for example, Brian Herbst, Stephen Forrest, Steven E. Meyer, Davis Hock "Alternative Roof Crush Resistance Testing with Production and Reinforced Roof Structures" SAFE, LLC, Golita: SAE 2002-01-2076

[28] In its Regulatory Analysis, NHTSA estimated that increasing roof strength from 1.5 to 2.5 in the FMVSS 216 test would cost $___ per car and result in a weight increase of ____.

retained side window glazing would have an 80 percent effectiveness in reducing the injury below the AIS 3 level, conservatively based on the NHTSA estimate, for example. Thus, the benefits of safety belt use and improved side glazing was high for the first class of rollovers. The benefits of a strong roof were major for the second class.

There has been considerable reluctance to require (or for manufacturers to voluntarily offer) strong belt use reminders because of the experience with ignition interlocks in the early 1970s. We believe that manufacturers and insurance companies could develop a voluntary program, encouraged by changes in the NCAP rating system and insurance premium reductions, to offer and encourage effective belt use reminder systems in new vehicles. Such systems would have benefits well beyond rollovers. However, even in the absence of such systems, improved side glazing or rollover-triggered side curtain air bags would very substantially reduce ejections from vehicles that rollover.

It was assumed that the effectiveness of the three basic countermeasures considered here for the fourth and fifth classes of rollovers, where collisions were the primary source of injury, would be low. Exceptions would be for unrestrained and ejected occupants who were not subject to direct trauma from the collisions.

The results, which are a total saving of half of the comprehensive cost of rollover AIS 3+ injuries, are shown in Figure 5.

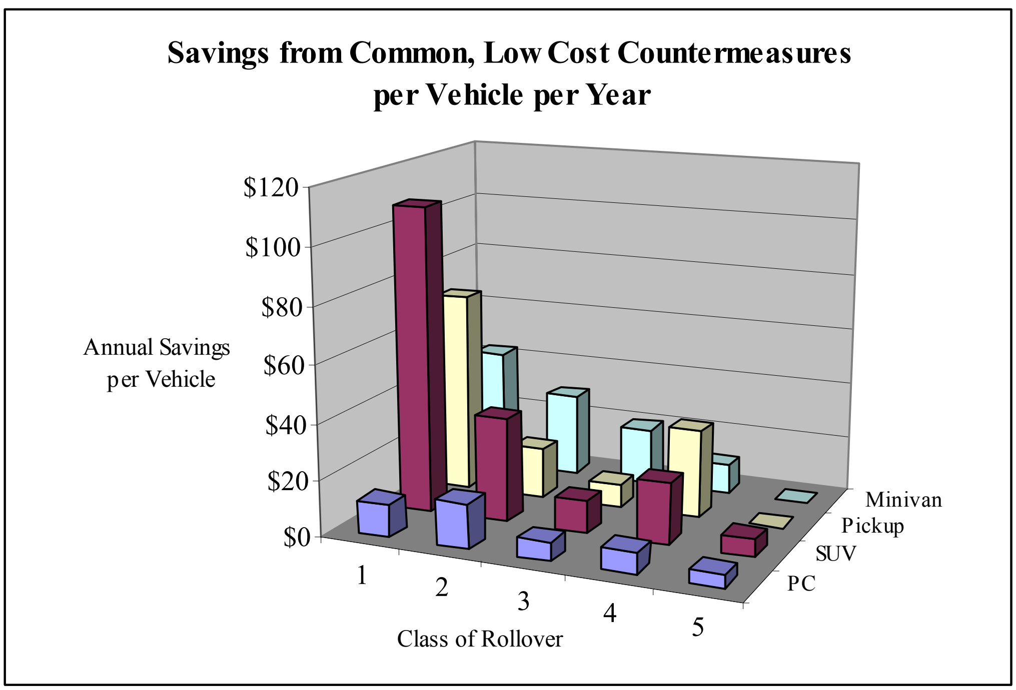

Figure 7. Benefits of basic countermeasures – a strong roof, side glazing designed to contain occupants, and effective safety belt use reminders – from the reduction of rollover AIS 3 or greater injuries. These results should be compared with Figure 4 showing the total economic consequences of AIS 3+ injuries rollovers. It does not include reductions in AIS 1 and 2 injuries.

Overall Costs and Benefits

In doing this analysis, we found that making conservative assessments of the benefits yielded very high potential savings (over $17 billion per year) from the three simple countermeasures discussed above.

The cost of these three would be around $3.5 billion per year for all new light vehicles, light trucks and vans; so that their benefits would be at least five times the cost. If these were applied only to SUVs and pickups, these countermeasures would yield a benefit more than eight times the cost because of the much higher rate of rollover casualties in them. However, these countermeasures would be cost beneficial even for passenger cars and minivans. Responsible manufacturers have a particular obligation to adopt these countermeasures, even in the absence of regulatory requirements, for SUVs and pickups because of their excessive rollover casualties in comparison with the passenger cars they have typically replaced.

This analysis does not account for the savings of AIS 1 and 2 injuries in rollovers, for vehicles more than ten years old, or for the reduction in injuries in non-rollovers. Thus, these countermeasures would have even greater cost effectiveness than is calculated here. The belt use reminder would improve safety in all crash modes while improved occupant compartment integrity and glazing would improve side impact protection.

Class of Rollover	Passenger Car	SUV	Pickup	Minivan
1. Unbelted Occupant Fully Ejected	$ 2,177	$3,658	$3,359	$ 1,004
2. Belted Occupant w/Head, SC Injury	$ 4,061	$1,600	$1,016	$ 1,062
3. Other Primary Rollovers	$ 2,768	$1,461	$ 612	$ 511
4. Collision Before Rollover	$ 3,925	$1,546	$3,340	$ 439
5. Collision During Rollover	$ 3,399	$ 561	$ 311	$ 0
Total	$16,330	$8,826	$8,638	$ 3,016

Table 2. Total annual economic consequences of rollovers by type of vehicle and class of rollover (in millions). The sum for all light vehicles is $36.8 billion per year.

The total cost of AIS 3 and greater injuries in rollovers of vehicles no more than ten years old – $36.8 billion – is shown in Table 2. Note that only $13.5 billion (just over one-third) is in cases involving a collision as the most serious event, either before or during the rollover. This table does not include any losses from AIS 1 or 2 injuries nor does it include losses in vehicles more than ten years old.

Class of Rollover	**Passenger Car**	**SUV**	**Pickup**	**Minivan**
1. Unbelted Occupant Fully Ejected	$1,572	$2,822	$2,770	$ 773
2. Belted Occupant w/Head, SC Injury	$2,118	$ 961	$ 688	$ 530
3. Other Primary Rollovers	$ 902	$ 303	$ 329	$ 363
4. Collision Before Rollover	$1,015	$ 560	$1,220	$ 188
5. Collision During Rollover	$ 602	$ 163	$ 8	$ 0
Total	$6,209	$4,809	$5,014	$1,855

Table 3. Total Savings by Type of Vehicle and of Rollover (in millions) from primary countermeasures. The total for all light vehicles is $17.9 billion.

The savings from the countermeasures described in this paper are provided in Table 3. Note that the savings from reducing ejection of unbelted occupants (primarily from improved belt use reminders, improved side glazing, or both) amounts to nearly $8 billion. This counts neither the savings in AIS 1 and 2 injuries, the other savings in non-rollover crashes from these countermeasures, or savings from vehicles more than ten years old. Those savings would probably more than double the benefits. The savings from a reduction in head and spinal column injuries to belted occupants would be over $4 billion, and would come primarily from stronger roofs and the interior padding that is now standard in all new light vehicles.

Estimates of the upper bound costs of these countermeasures, assuming that 16 million light motor vehicles are sold in the U.S. annually, are shown in Table 4.

Countermeasure	Cost per Vehicle	Total Cost (billions)
Safety Belt Use Reminders	$25	$0.4
Improved Side Window Glazing	$100	$1.6
Strong Roof	$100	$1.6
Total	$225	$3.6

Table 4. Upper limit of the cost of countermeasures to reduce rollover injuries.

It can be seen from Table 4 that even considering only the benefits from reductions in AIS 3+ injuries in rollovers of vehicles less than eleven years old, these countermeasures are highly cost-beneficial. Their value would be higher if one considered AIS 1 and 2 injuries, injuries from rollovers of vehicles more than ten years old, and the ancillary benefits in non-rollovers of these countermeasures. It is clear that priority should be given to making these improvements in light trucks where the losses are greatest.

Further Thoughts: History and Policy

This research shows the value of the National Accident Sampling System and the NHTSA's estimates of the economic consequences of motor vehicle crashes. This work derives directly from the important work from the 1970s of the late Dr. Anthanasios

Malliaris, who developed the harm concept; and Barbara Faigin who produced the first analysis of the cost of injury and Laurence Blincoe who produced the current edition. It is unfortunate that NHTSA did not carry out this type of analysis of rollover injury years ago when it could have saved thousands of lives and serious injuries in rollovers.

Based on refinements of this work and on more realistic dynamic testing of vehicle rollover performance and the requirements of the SAFETY-LU legislation, we look forward to major advancements in rollover occupant protection in the near future.

We believe that NHTSA could achieve much of the benefit discussed in this paper by instituting a rollover occupant protection rating in the New Car Assessment Program that gave increasing ratings (number of stars) to vehicles that had stronger roofs and that incorporated other features that improved rollover occupant protection. A proposal has been made to NHTSA for such a rating system (see Appendix A).

When NHTSA proposed the amendment to FMVSS 216 last August, it made the very controversial comment, ". . . if the proposal were adopted as a final rule, it would preempt all conflicting State common law requirements, including rules of tort law." This comment conflicts with the statement in the National Traffic and Motor Vehicle Safety Act of 1966 which says, "Compliance with any Federal motor Vehicle safety standard issued under this title does not exempt any person from any liability under common law." NHTSA's view was based on the Supreme Court decision in *Geier v. Honda*,[29] in which the court held that NHTSA's ability to use more creative means of implementing motor vehicle safety standards involving new technologies and uncertain public acceptance would be compromised by permitting product liability claims against manufacturers that did not implement the most effective safety technology.

An alternative that addresses the highly controversial question of manufacturer liability is discussed in another of this author's publications on how automobile insurance can become a much more effective regulator of motor vehicle safety.[30] The use of consumer information under the New Car Assessment Program could also obviate this controversy.

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[29] *Geier v. Honda*, Supreme Court . . .

[30] Nash, *op cit.*