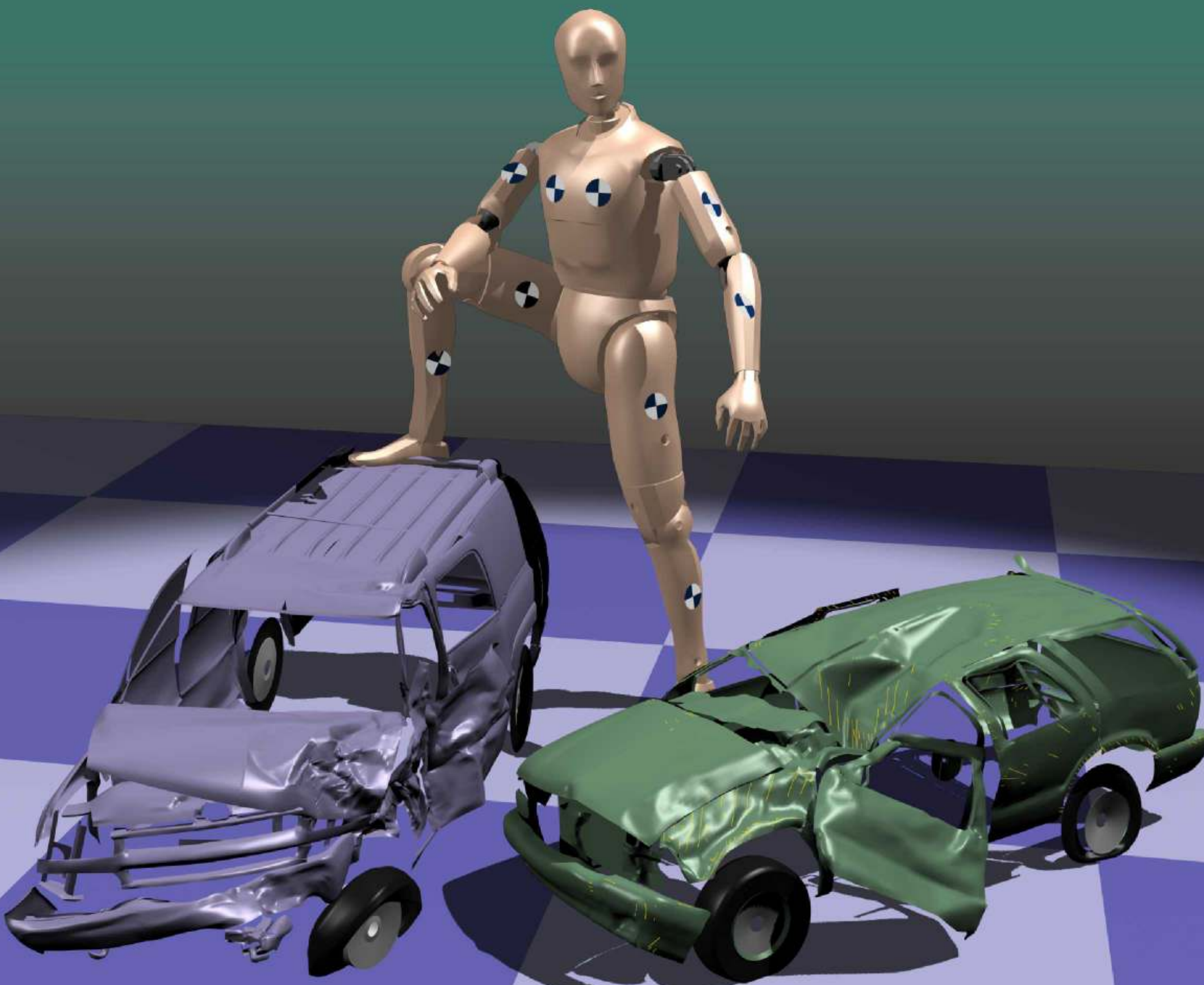
# Vehicle Crashworthiness

## Identifying If Vehicle Safety Defects Exist

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# Vehicle Crashworthiness

When trying to identify whether a vehicle contains potential safety related defects, a vehicle crashworthiness analysis must be conducted. Crashworthiness is the science of minimizing the risk of serious injuries and fatalities in motor vehicle collisions. There are five basic principles involved in reducing injury producing hazards following a motor vehicle accident:

## Crashworthiness:

- Control Crush - Maintain Survival Space
- Restrain the Occupants
- Prevent Ejection
- Control Energy / Transfer Energy
- Prevent Fire

To provide adequate crashworthiness in a motor vehicle accident, the vehicle's safety systems must work together. Yet, vehicle safety systems routinely fail. Seatbelt buckles unlatch. Airbags deploy in minor impacts causing more harm than they prevent, and fail to deploy in high speed collisions. Doors fly open. Roofs crush. Seats collapse. Vehicles catch on fire. This brochure will hopefully assist your office in identifying vehicle safety system defects.

the TRACY firm
Attorneys at Law

*"The chairman of the board commented that it would be desirable to reduce costs related to items designed to achieve or exceed compliance with regulatory requirements to as low a level as possible, to maximize our future pricing flexibility vis-a-vis competition."*

**Vehicle manufacturers maximize profit at the expense of safety.**

*"Value analysis of auto fuel fed fire related fatalities, each fatality has a value of $200,000."*

**Vehicle manufacturers perform cost benefit analysis to determine if it is cheaper to pay claims or fix design issues.**

*"Our objective is to bring together and categorize all pertinent documents and add comments where appropriate."*

**Vehicle manufacturers sanitize engineering documents before a single vehicle is sold to get the story straight to help with litigation.**

*"Our recommendation is to conduct a 20 mph side impact test...with production fuel system removed and the non-impacted door removed so as not to create any embarrassing information."*

**Vehicle manufacturers are cognizant that test failures create potential litigation concerns so instead of conducting whole vehicle tests, they focus on a single safety component rather than the complete safety system.**

*"While cost is a reality in the decisions we must make, cost arguments are certain to be questioned by some when the safety content of our European affiliates and our competition is examined. If they can do it on entry level cars, shouldn't we? Safety advocates and trial attorneys may be asking the same question in the near future."*

**Vehicle manufacturers routinely use safety advances in Europe on their cheaper, lower entry vehicles but not on any of its US bound vehicles.**

*"A corporate position as to rear seat restraint safety has been requested. It is stay with the pack."*

**Vehicle manufacturers rarely take the initiative to implement state-of-the-art safety advances.**

# Control Crush - Maintain Survival Space

## Crashworthiness:

- **Control Crush - Maintain Survival Space**

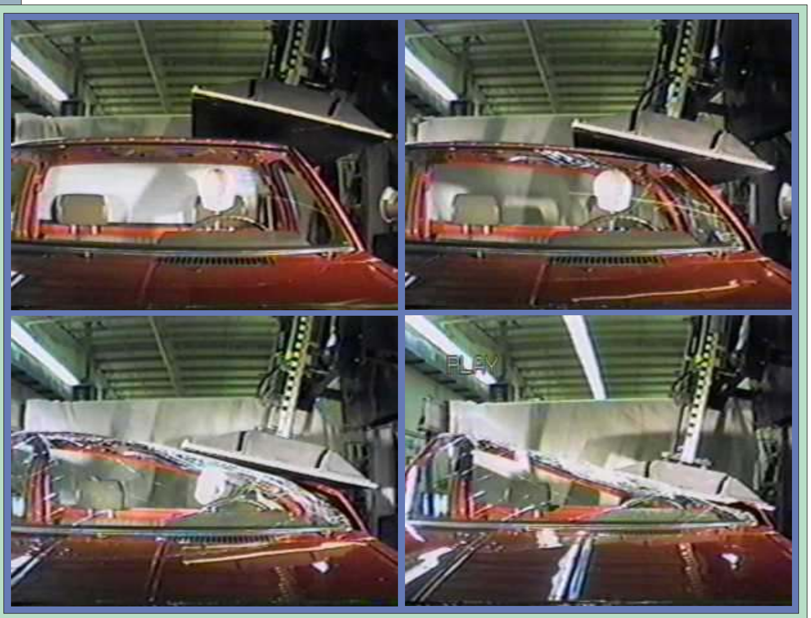
If a vehicle's restraint system (seat belts, doors, seats and glass) and interior padding are to meet the manufacturer's design goal to protect the occupant, the passenger compartment area must maintain adequate survival space. No matter how effective the seat belt, airbag, door latch and seat system is in a vehicle, if the vehicle structure is inadequate, occupant protection is compromised. Unfortunately, consumers are being misled by advertising slogans that tout how vehicles contain "built-in safety cages" and "steel reinforced crush zones." Every vehicle has a reinforced area that surrounds the passenger compartment. However, it is the structure in the front, side, top, and rear of the passenger compartment that determines occupant protection. In most vehicles, the structural integrity that surrounds the "built-in safety cage" and the "steel reinforced crush zone" is inadequate.

A good test of a vehicle's ability to maintain its survival space can be seen during a rollover. Manufacturers routinely receive failing grades even though their roofs pass all of the applicable standards. Roof structures are simply too weak. Roofs are designed to pass a static (FMVSS 216) test where a rectangular platen that is 30 inches by 70 inches is pushed at a controlled rate near the A-pillar/roof header junction. The test can take up to two minutes to apply the designated force. If the vehicle crushes less than 5 inches before the load reaches 1 ½ times the unloaded vehicle weight of the vehicle, or 5,000 lbs, whichever is less, then the vehicle passes.

## FMVSS 216 Realities

1. **216 is a minimum standard.**
2. **216 is not a dynamic test.**
3. **216 applies constant load for 120 seconds.**
4. **216 does not evaluate how the vehicle's safety systems will perform in a rollover.**

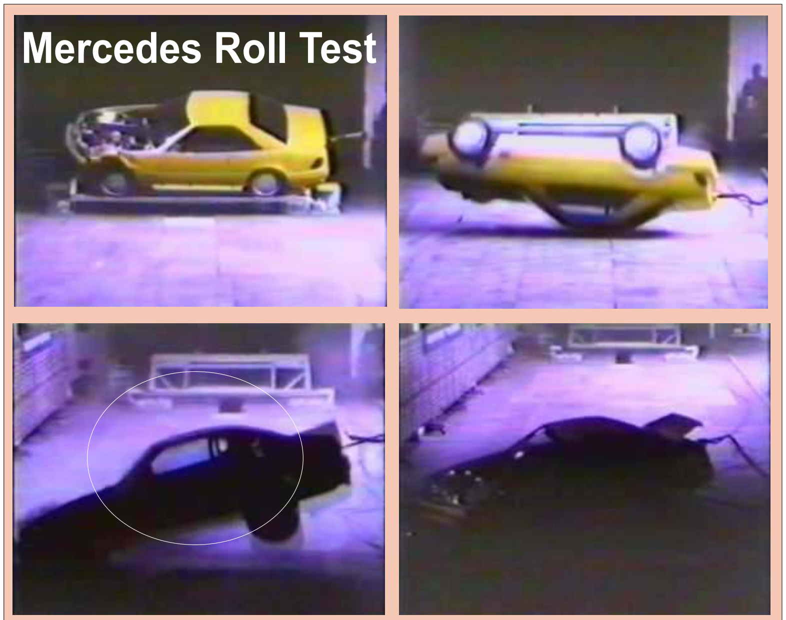
However, the static 216 test is unrealistic for a number of reasons. First, rollovers are not controlled load bearing events. There has never been a rollover in the history of motor vehicle accidents where the A-pillar/roof header junction was loaded at a constant rate over 120 seconds. Second, the area of the vehicle that is tested takes into consideration the strength that the laminated windshield provides to the roof. The automotive glazing industry has documented that the windshield provides up to 30% of the roof resistance in a 216 test. Yet, during the roll phase, the windshield routinely shatters thus causing the roof to immediately



FMVSS 216 Test

lose up to 30% of its strength. Third, rollovers are not static events. Instead, rollovers are dynamic events that involve directional changes of loading throughout the roll sequence. Fourth, the 216 test does not evaluate how the B-pillar or C-pillar will perform unless the roof is extremely weak. Fifth, the 216 test does not even consider how an occupant will be protected since no test dummy is used.

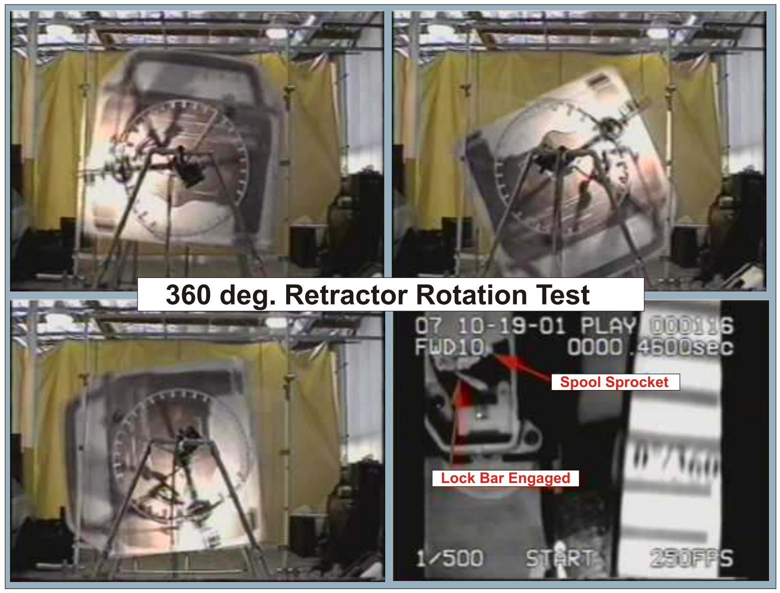
It is disingenuous for a vehicle manufacturer to say that its vehicle safety systems will protect occupants in the event of a rollover accident, when they themselves do not know how their safety systems will perform in such accidents. No domestic vehicle manufacturer (with the exception of their European subsidiaries) regularly performs rollover and drop testing. Instead, these vehicle manufacturers conduct only frontal, side and rear impact testing. These tests involve a single impact scenario. A rollover is a series of impacts that can involve the front, side, roof and rear of the vehicle.


Mercedes Roll Test

This much is known about how vehicles perform in rollover accidents. During a rollover, the glass behind the windshield typically shatters because it is tempered glass (except for Mercedes Benz, BMW, Volvo) rather than laminated/bi-layer/plastic glass. Once the tempered glass is gone, a huge ejection portal is created. Hence, seat belts become critically important during rollovers. However seat belt use in rollovers is not a guaranteed survival tool.


Ejection Portals

During a rollover, seat belt retractors are supposed to lock and stay locked when the vehicle decelerates rapidly, when webbing is withdrawn rapidly, or when the vehicle reaches a certain angle tip. However, during every rollover event, there are periods when the locking mechanisms of some retractor designs will actually disengage. The retractor will actually unlock and then lock up again. This scenario has been tested by placing the retractor on a spinning device that replicates an accident's roll rate. Certain retractors fail to remain locked throughout the rotational sequence because the retractor's locking bar will disengage.



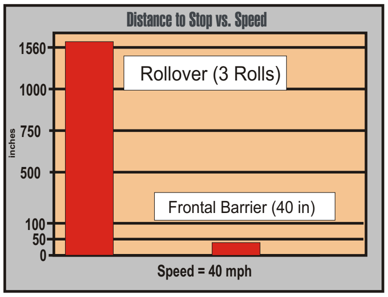
360 deg. Retractor Rotation Test

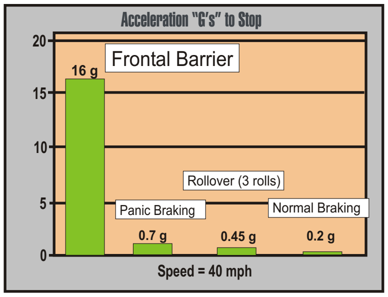
Doors can also open during rollover accident because the standard that governs doors fails to consider the effect that vertical loading has on a door latch assembly. Instead, FMVSS 206 deals only with longitudinal and transverse loads under static, not dynamic conditions. Also, 206 fails to consider what effect, if any, the hinges have on the door opening in a rollover. In fact, the door could separate from the vehicle and still pass the side door protection standard even if the hinges failed but the door latch remained locked.

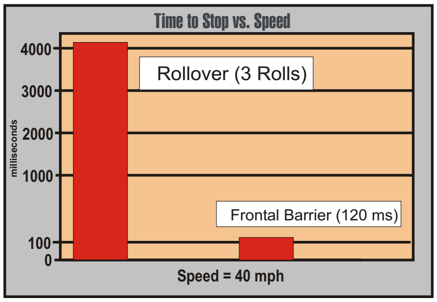
Seats can also fail during a rollover because the recliner, frame and seat tracks are not designed to withstand significant loading because the seat safety standard is too weak. Specifically, FMVSS 207 mandates that a seat withstand 20 G's. However, the standard does not include the weight of an occupant. Consequently, once a seat withstands 400 lbs., the seat can collapse. There is no dynamic test, much less a rollover test requirement to evaluate seat integrity.

Rollovers should be one of the easiest accidents to provide adequate protection because time and distance are on the occupants' side. Consider this example. In a 40 mph frontal impact into an immovable barrier, the vehicle goes from 40 mph to 0 mph in 120 milliseconds over 40 inches. In a 40 mph rollover accident, the vehicle goes from 40 mph to 0 mph in 4000 milliseconds over 130 feet.

# Control Crush - Maintain Survival Space




Speed is also on the occupants' side during a rollover. Manufacturers are required by law to protect against serious injuries in 30 mph frontal and rear accidents and 20 mph side impacts. However, in the vast majority of all rollover events, the vertical drop height velocity is rarely over 8 mph. Yet, manufacturers claim they cannot protect people against impacting the roof.

Despite having time, distance and speed advantages, rollovers account for 16 percent of serious injuries to passenger car occupants and 42 percent of serious injuries to light truck occupants even though rollovers are only 3 percent of all accidents.

Manufacturers routinely argue in roof crush cases that strengthening the roof or securing the occupant more rigidly to the seat with a better performing seat belt will provide little added benefit. However, the average juror has seen at least one rollover accident involving a race car, where the driver climbed out of his vehicle and waved to the crowd. The racer survived because his vehicle met the five principles of vehicle crashworthiness. The bottom line therefore remains-consumers should be more aware and concerned about how their vehicle will perform during a rollover since rollovers will continue to occur, especially considering the number of SUV's that are now sold.

Tests are available to vehicle manufacturers that would confirm the occupant protection capabilities of the roof structure during a rollover. Manufacturers have been conducting dolly rollover tests for over 30 years. There is an SAE J996 drop test procedure that is routinely used by both manufacturers and crash victims to study roof performance. Even though the test procedure was cancelled in 1991 and manufacturers claim the tests are not repeatable or reliable, manufacturers like Mercedes Benz continue to use the drop test. The NHTSA (National Highway Traffic Safety Administration) routinely conducts dolly rollover testing.


Nissan Roll Test - *Conducted by NHTSA*

Mercedes Benz Drop Test

There are also some technologically and economically feasible design alternatives that could be used to increase the strength of roof structures. These include using foam filled material in the pillars, header and roof panel. Drop testing has revealed that foam, along with other minor structural modifications, can increase the roof strength by 300%. Using a double panel roof panel or thicker material for the pillars has proven to increase roof strength by at least half. Weld access holes in the pillars, roof rails, header and roof bows should be moved away from locations of maximum bending moment. Also, production vehicles should be tested, not just prototypes. The roof strength of a production vehicle is 20 to 40 percent lower than that of a prototype vehicle. However, manufacturers routinely certify their vehicles with prototype vehicles, not production vehicles.

Production Roof Structure - *NISSAN*


Modified Roof Structure - *NISSAN*


This car rolled five times - *No Injury*

# Crashworthiness:

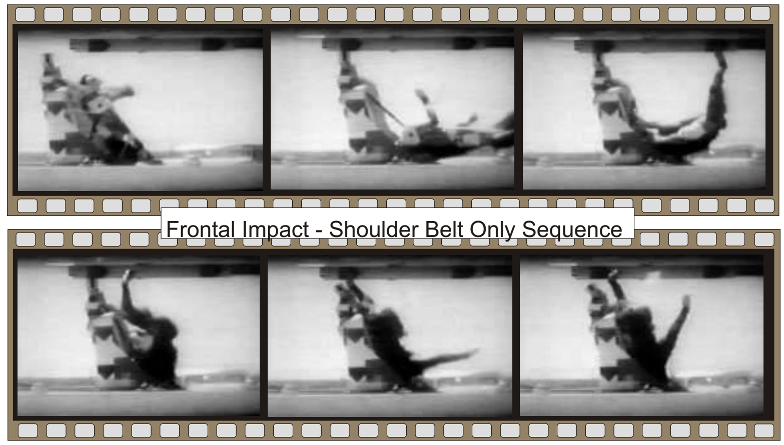
## Restrain the Occupant

### Seat Belt Types

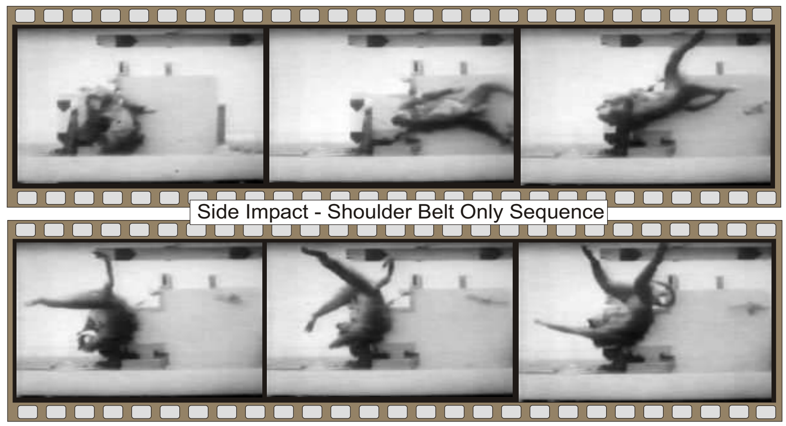
Seat belt cases are the most frequent crashworthiness cases you will see because of mandatory use laws. Besides, as a society, we are told by talking anthropomorphic dummies to "Buckle up, don't be a dummy." Unfortunately, seatbelts do not work properly 100% of the time.

There are six types of seat belt systems that are found on vehicles even though some are no longer used. The first type of seat belt system is the 2-point shoulder belt with no lap belt. This design was used by Hyundai, VW and the Mitsubishi Precis. The second system is a 2-point passive (automatic) shoulder belt with manual lap belt. Some vehicles had door mounted shoulder belts like Nissan and Kia. Others had a motorized shoulder belt that was track mounted like Toyota, Ford and Mazda. The third type is a 3-point door mounted belt where the lap and shoulder belt were attached to the door. This design was used by GM and some Honda designs. The fourth system is the 3-point B-pillar mounted design. It is the most widely used seat belt system in the world. In fact, this design has been used since the 1970's. The fifth system is the integrated ABTS *(All Belts To Seat)* design, where the seatbelt is mounted to the seat. This design is used by Mercedes, BMW, Chrysler Sebring, Dodge Ram pickup, Buick Roadmaster, Chevrolet Suburban, and Cadillac. The last type of seat belt system is the lap belt only. This is typically seen in the center seat position of vehicles that have bench type seats, in the rear center seat position or for jump seats.

As for design problems associated with each seat belt system, the 2-point passive shoulder belt designs were inherently flawed because in rollovers, there was no passive lap belt to prevent ejection. Also, in the event the door opened, the occupant could be swept out of the vehicle. Moreover, in frontal and side impacts, the lack of passive lap restraint allowed the occupant to submarine under the shoulder belt. This resulted in decapitation type injuries and cervical/hangman's fractures. The most common injury pattern with this design was internal organ injuries since the belt was so stiff and the belt geometry (fit) so inadequate that the internal organs were overloaded due to the placement of the belt. These same two-point belt related injuries in the 1950's and 1960's resulted in the two-point being banned worldwide. In the US, a loophole in the FMVSS permitted their re-introduction.



Frontal Impact - Shoulder Belt Only Sequence

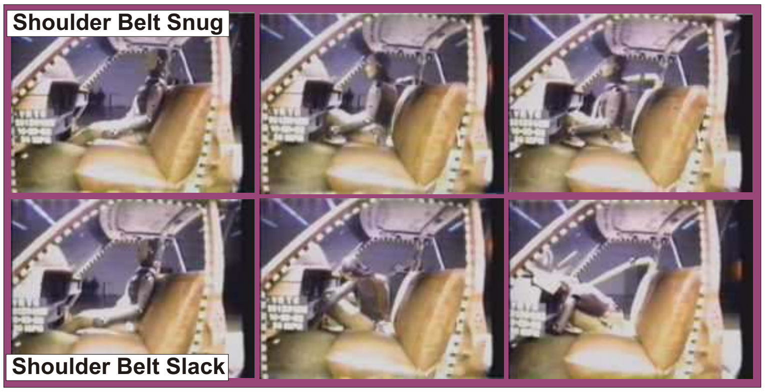


Side Impact - Shoulder Belt Only Sequence

The 3-point door mounted belt design was flawed in a number of ways as well. Specifically, GM vehicles whose doors would open because they contained a Type III door latch rendered the door mounted belt useless. The door mounted belt also caused a phenomena known as occupant rebound where the restrained occupant would sling- shot rearward with a significant velocity. As a result, restrained dummies impacted the mounting bracket with their head. Another frequent problem with this system involved the loss of restraint effectiveness if the door side rail collapsed since the seat belt was attached to the door.

Side Rail Collapse

Occupant Rebound



Shoulder Belt Snug

Shoulder Belt Slack

The 3-point B-pillar mounted belt design has had a checkered past but has saved many lives. A frequent complaint with this design is that the retractor locking device does not lock up timely. An entire book could be written on the various types of retractors. The most prevalent problems with retractors include skip locking, unlocking during rollovers, non-actuation of the deadman/pendulum sensing mechanism and retractor housings actually cutting the webbing. Other design problems included the use of slack inducing devices and failure to install secondary locking devices such as web grabbers/web lockers or pre-tensioners to limit loading on the occupant.

The integrated ABTS seat belt that is mounted to the seat is arguably the best seat belt design in the world because the occupant is tied to the seat not the vehicle. This design encompasses engineering technology developed in the aerospace industry and proven safe in the racing industry. The ABTS design requires a stronger seat base and frame which in turn helps keep the occupant upright during an accident. In non-ABTS vehicles, the seatback frequently deforms rearward in relatively minor

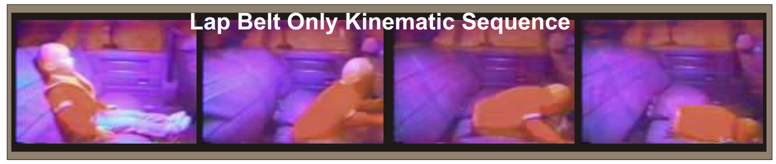
ABTS - Seat Track Failure

rear impact accidents. Since the seat belt is attached to the vehicle body (i.e. door, B-pillar), the restraint system in a non-ABTS vehicle is virtually useless once the seat back is deformed. In ABTS vehicles, even if the seat collapses rearward, the belt is functional since it is mounted to the seat. In side impact cases, the ABTS design helps keep the occupant's head from penetrating the breach of the vehicle. However, the ABTS must be designed properly, or it too is dangerous. Certain ABTS designs

ABTS - Side Impact Benefits

have a tendency to have its seat mounted retractors pull completely free from the seat. Also, these same vehicles' seat tracks are prone to disengage due to the added stress associated with having the occupant tied to the seat.

The lap belt only is an extremely treacherous design because the occupant, typically a child, hyperflexes forward so violently that his spine is severely fractured or his internal organs are ripped and lacerated. It is believed by some that children are better off without any type of seat belt than if they are only restrained by a lap belt.



Lap Belt Only Kinematic Sequence

### Seat Belt-Small Occupant Protection

A small occupant is technically referred to as a 5th percentile female, which is defined by the NHTSA as a female five feet tall and 110 pounds. According to anthropomorphic studies conducted by the United States Department of Transportation, (USDOT) 10.6 percent of the adult male and female population in 1998 (16 years old and greater) is comparable in size to the 5th percentile test dummy. Yet, no vehicle manufacturer that I have found has ever conducted and then reported a barrier crash test where a 5th percentile female dummy's crash protection was evaluated. The failure to test is compounded with the knowledge that 5th percentile persons are at a significantly greater risk of serious injury than a 50th or 95th percentile occupant when exposed to the same crash forces. In fact, the USDOT reported in 1976 that a 5th percentile female can withstand 900 pounds of shoulder belt load before bone fractures; a 50th percentile male can withstand 1,360 pounds; and a 95th percentile male can withstand 1,625 pounds.

5th percentile Submarine Sequence

In 1977, GM determined that the average occupant in the right front passenger seat was typically the size of a 5th percentile female. However, GM waited fourteen years after it developed a Hybrid III 50th percentile male dummy to develop a Hybrid III 5th percentile female dummy. GM does not conduct crash tests with 5th percentile female dummies; it only runs sled test. Unfortunately, GM is merely staying with the pack.

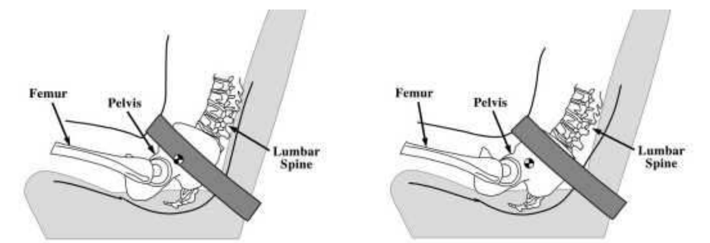
Failing to crash test with small occupants has left a large segment of the smaller population unprotected. In 1985, Ford wrote "there is no known feasible fix for 5th percentile females in full rear seat position. 120 small occupants will be killed each year using our motorized belt." In 1987, GM created a Small Occupant Kinematics Control Committee. This group concluded "GM's door mounted belt geometry does not provide optimum placement on the small dummy pelvis." This came as no surprise to GM engineers since they wrote in 1969 that "5th percentile dummies submarine more frequently than 50th percentile dummies." Despite knowing that its door mounted belts exposed small occupants to submarining injuries, GM concluded in 1988 that there will be only "22 significant belt related abdominal injuries to small occupants per million car years." According to GM, no design fix was needed as this was an acceptable morbidity/mortality ratio.

Refusing to conduct barrier crash tests with 5th percentile female sized occupants is at odds with good engineering design practice since the restraint system's belt geometry (fit) is so much different on a small occupant than a 50th or 95th percentile male. GM has written in response to USDOT comment requests that "GM should test at high severity other size occupants in [all] expected position[s]." This is called due care testing.

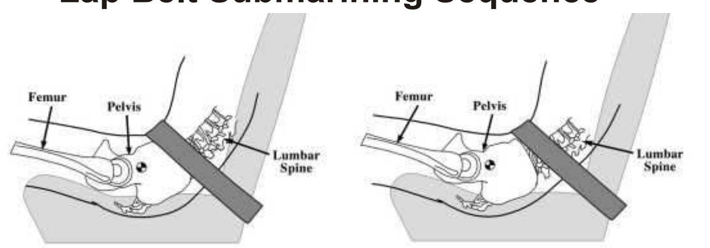
Even the NHTSA has been slow to conduct barrier tests with 5th percentile females. As of March 1, 2005, the NHTSA reported having only 151 barrier tests with 5th percentile females. Of the 151 tests, the Canadian government had conducted 142 of the tests.

## Seat Belt-Submarining

The concept of an occupant submarining under a lap belt has been known by vehicle manufacturers since the 1960's. Submarining occurs when an occupant's pelvis rotates down and forward and allows the lap belt to slide over the pelvic bones into the soft abdominal tissue. Horrific intra-abdominal injuries, lumbar spinal fractures and lower leg fractures are suffered when an occupant submarines under a lap belt.




**Lap Belt Submarining Sequence**




**Several design flaws can lead to submarining:**

1. Rigid buckle stalk raises belt above pelvis;
2. Buckle stalk is too tall and raises belt above pelvis;
3. Ineffective seat ramp or cushion design;
4. Belt anchorage location too far aft or forward;
5. Belt anchorage angle too steep or shallow; and
6. Too much slack in the belt.

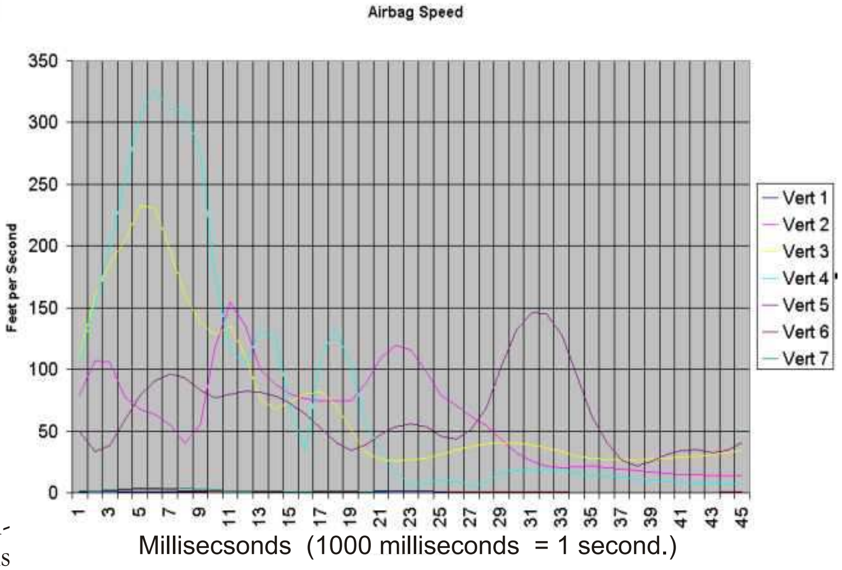
Each of these design flaws has one component in common—they affect belt fit or belt geometry. Alternative designs that will prevent or minimize the risk of submarining range from using a shorter, more flexible buckle stalk to incorporating an anti-submarining seat. More elaborate design fixes include pyrotechnic pre-tensioners, vehicles with ABTS and vehicles with seat mounted lap belt buckles. These help reduce belt slack and help secure the occupant closer to his pre-accident seated position. Submarining also occurs if the seat bottom cushion slides forward due to improper attachment. When a seat slides forward, the anti-submarining seat ramp is rendered useless.

Submarining has been observed in lap belt only, 3-point continuous loop, and 2-point motorized/automatic shoulder belt configurations. FMVSS 209 previously mandated that a lap belt should remain below the pelvis under all accident conditions, however this provision was dropped in 2002.

**Submarining Sequences**

## Airbags

During a frontal impact, front airbags deploy at speeds approaching 225 mph; in less time than it takes to blink an eye. The majority of all crash speeds are below a 20 mph Delta Velocity. Therefore, since airbag deployment thresholds are 8-12 mph Delta Velocity, there are far too many unnecessary deployments.

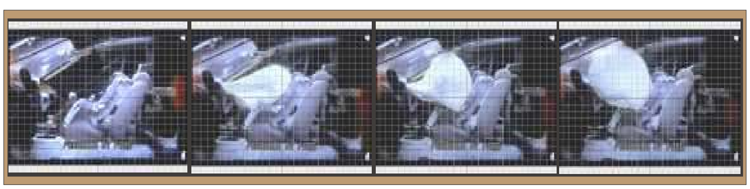



**Airbag Deployment Velocity Chart**

In the 1970's, the federal government proposed a "no fire" deployment threshold of 15 mph Delta Velocity. Every automobile manufacturer resisted the proposal. Current vehicles sold in the U.S. have a much lower deployment threshold than 15 mph Delta Velocity. In fact, airbags in some vehicles sold in the United States "can fire" at less than 8 mph Delta Velocity and "must fire" at Delta Velocities of only 12 mph. This is drastically too low and is inconsistent with the premise behind airbags – supplemental restraint system secondary to a seat belt. A seat belt by itself is designed to minimize injuries in 30 mph Delta Velocity accidents. Most new vehicles provide reasonable protection to even unrestrained occupants up to 25 mph Delta Velocity without an airbag. With airbags deploying at such low crash speeds, many people whom otherwise would not be injured had the airbag not deployed are being catastrophically injured because it did deploy.

There has been widespread publicity about never placing rear facing child seats in front of a passenger side airbag. However, millions of vehicles contain instructions that advise parents it is proper to place a forward facing child seat in front of an airbag if the seat belt is adjusted properly (by setting the ALR or by using the locking clip) and the seat moved completely rearward. Stronger legislation to curb the catastrophic effects of airbag induced injuries should be adopted. Consider the following.

A child sitting in a front facing child seat will almost inevitably be killed or seriously injured by an airbag because when the airbag deploys, the child is impacted by a device that is the power equivalent of dozens of exploding shotgun shells.



Airbag Deployment Sequence - Forward Facing Child Seat

Manufacturers have known for 30 years that forward facing child seats and airbags are a deadly combination. During piglet testing and child-size dummy testing at Holliman Air Force Base and the Southwest Research Institute, airbags literally blew the piglets and child-size dummies out of the vehicle. The conclusions reached were startling:

1. *out-of-position children are at risk for head and neck injuries;*
2. *airbag deployment speeds are too high;*
3. *airbag deployment angles expose children to head and neck injuries; and*
4. *airbags can kill children.*

Airbag Deployment Sequences - Restrained Child

Knowing that children could be injured or killed by an airbag, GM invented a dual stage airbag system in the early 1970's. The GM two-stage system used dual inflators. Only one inflator would fire in low speed crashes. Both inflators would fire in high speed crashes. Unfortunately GM's design was not implemented until the late 1990's. Consequently, more than 140 children have been killed by airbags. The NHTSA has even set up a Special Crash Investigation unit for airbag injuries/fatalities to children.

Why do children and airbags make such a deadly combination?

There are several reasons:

1. *airbags are designed to protect a 5' 10," 165 lb. male;*
2. *airbags that are mid-mounted deploy with full deployment force into a child;*
3. *most passenger side airbags are not tethered (restricted);*
4. *airbags deploy at crash speeds as low as 4 mph Delta Velocity;*
5. *airbags are too aggressive; and*
6. *passenger side airbags are too big – they take up too much passenger volume.*

What can be done to protect children against airbags? The easiest solution is to place children under 12 in the rear seat, as recommended since November, 1996, by the federal government. Unfortunately, this is a band-aid fix because the rear seat poses serious restraint fit problems for small occupants. Besides, many vehicles do not contain a rear seat. Also, some parents or caregivers have more than three children under age 12 in the vehicle at the same time. The safest design alternative is to use "smart bag" technology. Smart bag technology is based on the 1973 GM dual stage airbag design and uses the following principles:

1. *airbag deploys at certain levels of power based on crash severity;*
2. *airbag deploys at certain levels of power based on weight of occupant in seat;*
3. *airbag deploys at certain levels of power based on belted status of occupant; and*
4. *airbag will not deploy if child seat placed on seat.*

Airbag risks could also be reduced by using the air pillow design patented by GM. Several vehicle manufacturers use this design on many of their passenger airbags today.

Here are the reasons why airbags are not the safety panacea the automotive industry would have us believe:

1. *Out of 96 airbag deaths, 54 deaths were children 10 or younger;*
2. *Airbags increase the overall risk of fatal injuries among children in below 12 mph Delta Velocity accidents by some 21%;*
3. *In 96 airbag deployment deaths, the average accident speed was 12 mph Delta Velocity;*
4. *In 27 airbag deployment deaths, the average accident speed was 10 mph Delta Velocity;*
5. *In 2 airbag deployment deaths, the average accident speed was 5 mph Delta Velocity ;*
6. *Passenger side airbags are killing more children (in these low speed crashes) than they are saving; and*
7. *Children have experienced a 63% net increase in the risk of death attributable to the installation of airbags .*

Vehicle manufacturers defend their airbag designs by claiming that some 93% of all airbag deaths occurred because the children or small adults were out-of-position. This argument should fall on deaf ears for the following reasons:

Out-of-Position Child when Airbag Deploys

1. *Parents make innocent mistakes sometimes with their children as it relates to child seat placement, buckling children with the 3-point belt, etc. However, they should not be punished for having made a mistake by having an airbag deploy unnecessarily;*
2. *Vehicle manufacturers know that parents make mistakes and that is why the safety designs they use must consider human error; and*
3. *Honda, Mercedes Benz and BMW designed their airbag systems with the worst possible out-of-position scenario in mind. To date, no child airbag deaths have occurred in low speed accidents in these vehicles.*

Another commonly used defense is that the low accident speed threshold of 8-14 mph Delta Velocity is necessary to meet the federal occupant crash protection standards for unbelted occupants. Yet, FMVSS 208 has had the same unbelted occupant protection standards in place since 1980. Accordingly, the manufacturers had to meet the same standard <u>without</u> airbags as they now have to meet <u>with</u> airbags.

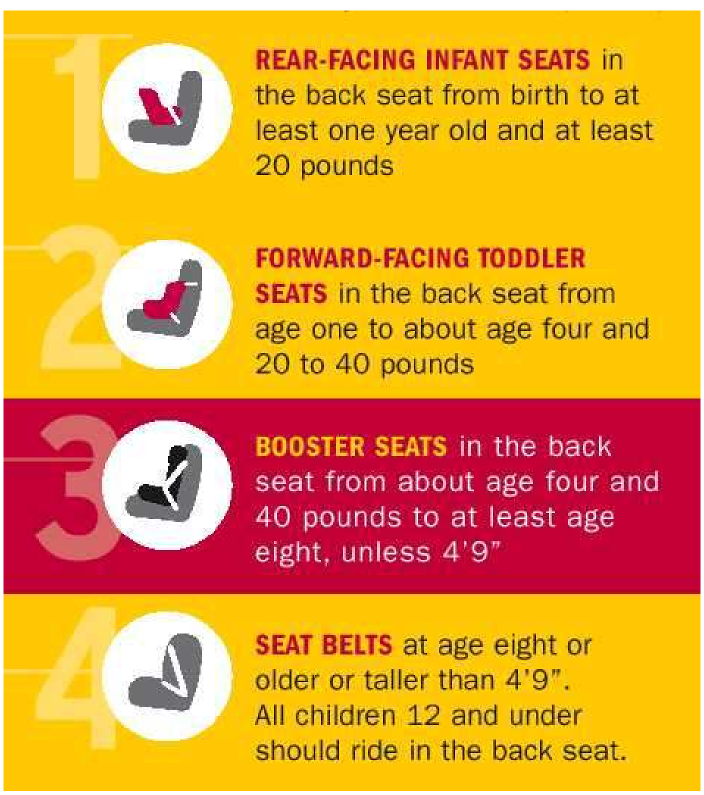
Furthermore, in the early 1980's, GM told the NHTSA that vehicle manufacturers could meet the occupant crash protection standards with better designed interiors, not with airbags. The GM project was called VSIP (Vehicle Safety Improvement Program) and focused on recessing instrument panels, rounding off and smoothing surfaces, eliminating protruding knobs and incorporating padding on areas that were likely to be impacted by an unbelted occupant. GM reported that its VSIP plan reduced injury potential by 45% without increasing belt use, or using airbags.

The bottom line remains - airbags deploy in low speed accidents, when by definition, airbags are a supplemental restraint system. Statistics maintained by two government databases, the NASS (National Accident Sampling System) and FARS (Fatal Accident Reporting Service), indicate that 60% of all airbag deployments are occurring at accident speeds below a Delta Velocity of 15 mph. Yet, in accidents below 15 mph Delta Velocity, the likelihood of minor injury, even to unbelted occupants, is miniscule. However, once the airbag deploys in these 15 mph Delta Velocity or lower accidents, the risk of injury is increased several times by the very device that is meant to protect.

Airbags can and do save lives. However, airbags are a high speed accident safety device. Airbag Delta Velocity threshold levels should be increased from the present 8-14 mph Delta Velocity (can fire at 8, must fire at 14), to a Delta Velocity level that is closer to 18 mph like they are in Europe and Australia. If manufacturers refuse to change the airbag sensor calibration and algorithm diagnostics that determine accident speed fire or no fire, then the deployment angle of the leading edge of the airbag should be changed to deploying vertically rather than horizontally. Honda has had incredible success with the vertically deploying airbag design. Honda's airbag design is based on GM's air cushion restraint system which was first evaluated by GM in the early 1970's.

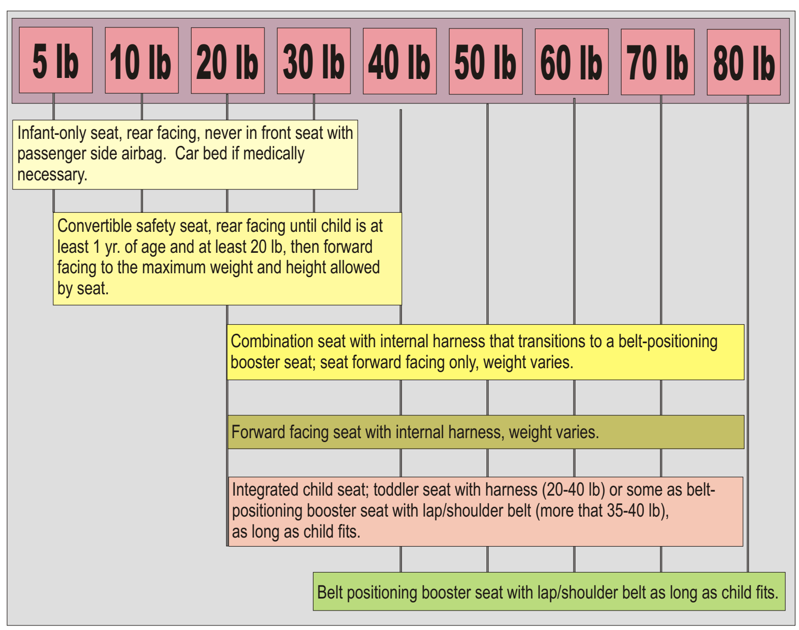
## Child Seats - Overview

According to the NHTSA, "child restraints are highly effective in reducing the likelihood of death or serious injury in motor vehicle crashes." However, statistics contained in a recent Notice of Proposed Rule Making (NPRM) Change 2002-11707-20 indicate that child restraint effectiveness for children ages 1-4 is cited as 54 percent in passenger cars and 59 percent in light trucks. One commentator in responding to this NPRM queried "assuming that these data represent survivable crashes, what other business can survive, much less prosper, with an apparent 40% failure rate?"


Why are child seats so ineffective? The answer to this question is fivefold. First, parents simply do not realize that children need something other than an adult seat belt up to 80 lbs. Second, child seat inadequacy can be traced to the federal standard that governs child seat safety. Prior to 2002, FMVSS 213 was an antiquated regulation that did not insure that child seats would perform properly in real world type tests. (For the record, 213 has been improved, but it remains woefully inadequate). For example, there was no requirement for angled or offset frontal impacts, side impacts, rear impacts or rollovers. The standard also allowed for 32 inches of forward head excursion despite the fact that oftentimes there was not 32 inches of rear seat space due to downsized vehicle interiors. Also, there was no lateral head excursion provision. Third, the child seat manufacturers themselves have historically been unsophisticated and under-funded entities that had little to no biomechanical expertise. Fourth, vehicle manufacturers are not testing child seats in their own vehicles to determine child seat effectiveness. Lastly, until the LATCH system there was not any requirement that mandated child seat compatibility with the vehicle. Hence, you might have the safest child seat ever built but since it does not fit in your vehicle properly, it is rendered dangerous.

Too many parents and caregivers rush children out of child seats and into the vehicle's 3-point seat belt. The chart below was proposed by the American Academy of Pediatrics. Notice that weight, not age, is the determining factor.



## Child Seats - Potential Safety Related Issues

**Angle of recline -** for a rear facing seat, the seat should be reclined so that the angle of the back surface is not more than 45 degrees from vertical. As the baby grows, the angle should be decreased. For a forward facing seat, the most upright position is the safest in terms of load distribution. Newer model child seats have a level, which advises users the correct angle of recline. Some manufacturers mislabeled their instructions which allowed for excessive reclination.

**Chest clip** holds the shoulder straps together. If not spring loaded, the clip could slide down under load allowing the child's shoulders to slip out which could lead to complete or partial ejection. The clips that are not spring loaded also have a tendency to be flimsy and one of the teeth can shear or displace (bend) rendering the shoulder straps ineffective.


**Shoulder harness slots -** two common problems. Mislabeling which slot to put the shoulder belt through is most common. For rear facing child seats, the shoulder straps should be at or just <u>below</u> the child's shoulders. For forward facing child seats, put the shoulder strap in the slot at or <u>above</u> the child's shoulders. The slots also have a tendency to be weak and un-reinforced such that the slots tear out under load ejecting the child.


Shoulder slot cracks due to weak and un-reinforced design

**Harness strap tightness-** this is a major problem because users will wrap the child in bulky clothing or a blanket then the harness is not tight enough. However, nothing advises parents about swaddling a child in a blanket. Also, some manuals differ in how they define tightness. Some say one finger between the straps. Some say two. Others say three fingers.

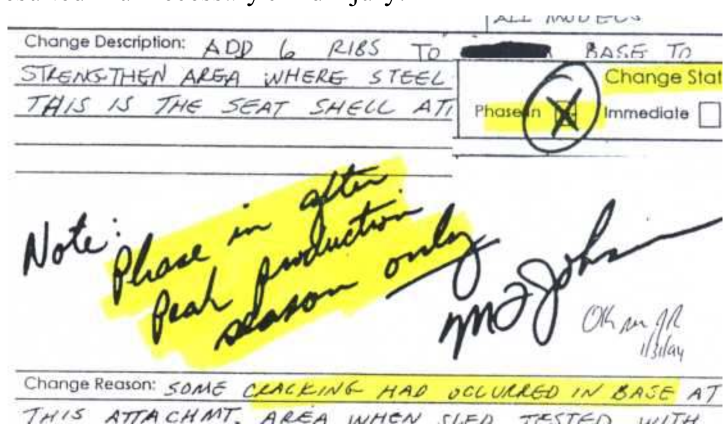
**3-point harness-** this harness configuration has two straps over the shoulders and a single crotch strap. A child is susceptible to ejection or submarining with this design because there is no pelvic support across the child's thighs..

**Tray shield-** located on a convertible child seat. The tray breaks off and impacts the child or the child impacts the tray and suffers injury because the tray was not adequately padded. Testing has shown that tray shields result in 35% higher head peak acceleration forces than 5-point harnesses.

Fractured tray shield

**T-shields-** shoulder straps are attached to a flat, plastic pad on a fairly rigid stalk that buckles into the child seat shell between the child's legs. Testing has revealed that a child's throat can impact the top of the T-shield. Also, neck forces are 40% higher on T-shields compared to 5-point harnesses.

**Plastic shell fracturing -** over the years, shell deformation has resulted in unnecessary child injury.



ALL MODELS
Change Description: ADD 6 RIBS TO [redacted] BASE TO STRENGTHEN AREA WHERE STEEL THIS IS THE SEAT SHELL AT
Change Stat
Phase in
Immediate
Note: Phase in after Peak production season only
OK
Change Reason: SOME CRACKING HAD OCCURRED IN BASE AT THIS ATTACHMT. AREA WHEN SLED TESTED WITH

**Head excursion-** before September 1999, the forward head excursion was 32 inches forward of a point located 5 inches rearward of the seat bight. After September 1999, the head excursion was reduced to 28 inches but with a tether device. There is still no lateral head excursion requirement.

**Lateral child seat excursion-** Vehicle safety belts are not properly designed to laterally restrain a child seat. Lateral movement places the child in harm's way from intruding components. The top tether and LATCH system have minimized this problem.

> **Safe Passage Brochure:**
> "You must also use a top tether strap if you can pull the top of the child restraint more than one inch forward or one to two inches to the side".

**Lateral head excursion-** focuses on the failure to use a winged seat design to help minimize lateral head excursion in side impacts.

**Twisted harness belt-** the load carrying capacity of the straps is decreased to the point the harness can separate under otherwise survivable accidents.

**Low shield booster seats-** these were first introduced in the US in 1979 and problems quickly followed because there is no harness to restrain the upper torso. As a result, children in shield boosters can be ejected or injured due to head contact or abdominal loading. One company recommended to its US customers that it was safe to use a shield booster seat for children under 40 lbs. This was contrary to the message it gave its Canadian customers. In 1991, the NHTSA wrote that "shield boosters may not provide adequate protection because they don't offer adequate upper body restraint and children can be ejected from them."

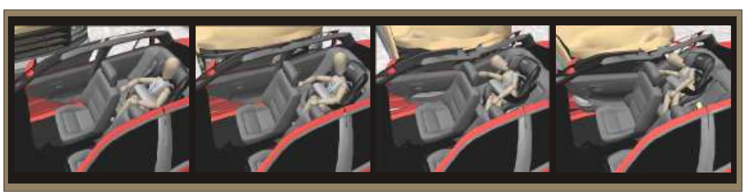
US Version

Shield booster for children 30 and 40 pounds, (13.6-18 kg.)

Canadian Version

Shield booster for children 40 and 60 pounds, (18-27 kg.)

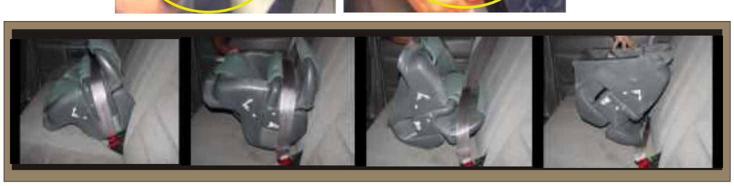
**Unstable base-** a narrow or unstable base that allows the child seat to move excessively sideways due to the vehicle seat belt placement can allow a child to impact the striking object or vehicle interior.



**No positive belt capture feature-** this has been seen primarily on no-back booster seats. The vehicle's seat belt routes around the booster but is not captured or locked in place. As such, the booster seat could slip out from under the vehicle's belt allowing the child to be ejected. On more conventional child seats, the vehicle's belt is routinely not capable of being locked to the child seat. This lack of retention can allow excessive lateral movement.

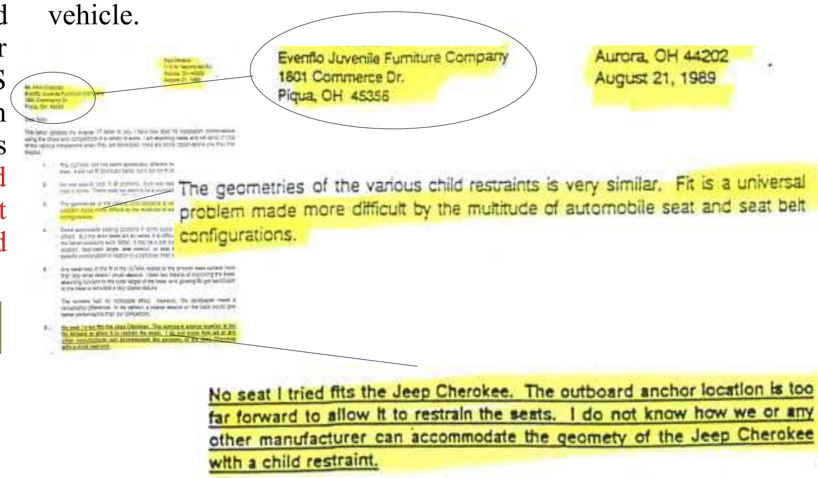
Rear Facing

Front Facing



Booster seat rolls out from under belt

**Vehicle seat incompatibility-** due to the angle of the seat rake and seat bight location, the child seat cannot be placed securely to the vehicle.


Evenflo Juvenile Furniture Company
1801 Commerce Dr.
Piqua, OH 45356

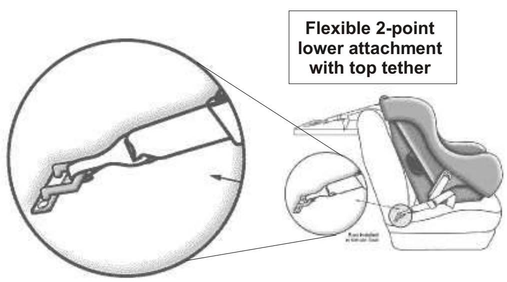
Aurora, OH 44202
August 21, 1989

The geometries of the various child restraints is very similar. Fit is a universal problem made more difficult by the multitude of automobile seat and seat belt configurations.

No seat I tried fits the Jeep Cherokee. The outboard anchor location is too far forward to allow it to restrain the seats. I do not know how we or any other manufacturer can accommodate the geomety of the Jeep Cherokee with a child restraint.

## Design Fixes

**Top Tethers-** A top tether is a strap that connects the top of the child seat to an anchor mounted in the vehicle at a location behind the child seat. It is designed to prevent the forward or lateral excursion of the child seat. Most vehicles sold since 1989, have factory locations for the installation of a tether anchor. In comparison sled testing, child seats with top tethers have reduced head excursion. More importantly, tethered child seats tend to reduce head accelerations and neck loads.





**LATCH-** this stands for Lower Anchors and Tethers for Children. LATCH became mandatory on new cars September 1, 2002. With the LATCH system, there is no need to use the vehicle belts. The goal behind the LATCH system was to eliminate misuse through loose seats and misrouted belts. LATCH has not been the panacea however. Multiple configurations of how to affix child seats have been produced which have lead to confusion in how to affix the child seat to the latch in the vehicle.

## Children In Adult Seat Belt Dangers

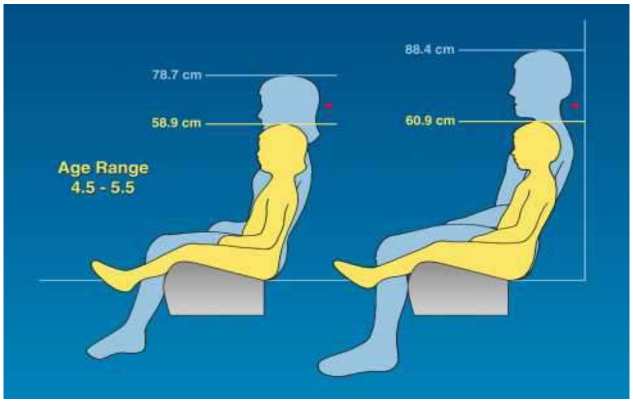
Over 500 children a year are killed because they are either unrestrained or effectively unrestrained because of poor belt fit and improper restraint.

Most parents allow their children to stop using any form of child seat after age four. These parents are making a potentially life altering mistake. Unless a child can meet the following criteria, they need to stay away from adult seat belts:

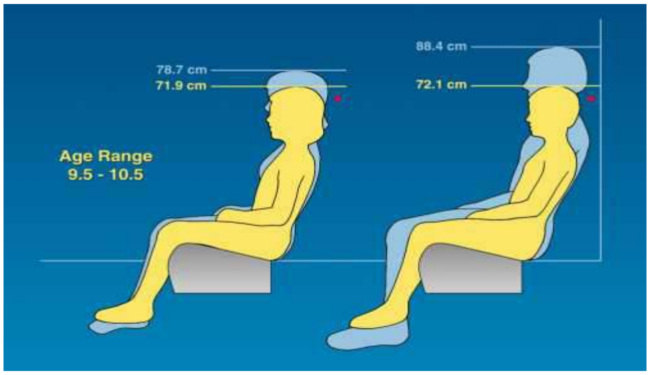
- They are tall enough so that their legs bend at the knees at the edge of the vehicle's seat when seated;
- They are mature enough to remain seated with their backs flat against the back of the seat (no slouching);
- The lap belt sits high on the thighs or low on the hips;
- The shoulder belt crosses the shoulder and chest;
- The latch plate is as far as possible from the occupant center line;
- The child weighs at least 80 lbs; and
- The buckle is close to the child's hip.

Children between the ages of four to eight are typically less than 48 inches tall and under 80 lbs. A child this size is exposed to a high risk of severe injury or death because they are strapped into adult safety belts that are designed to protect adults, not small children.

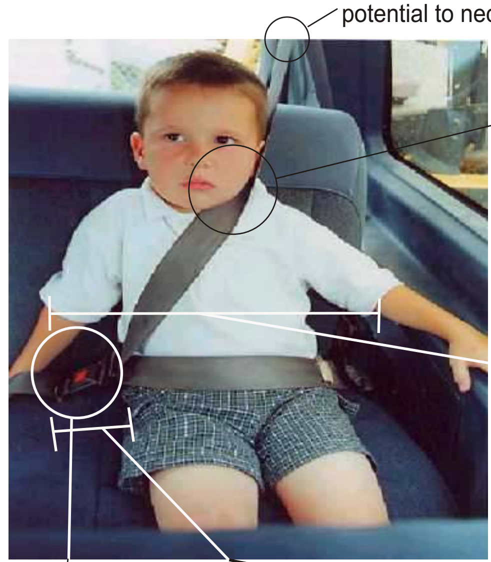
**Comparison of a 4.5 to 5.5 yr old 50th percentile girl & boy anthropometry to the 5th percentile female & 50th percentile male adult.**




**Comparison of a 9.5 to 10.5 yr old 50th percentile girl & boy anthropometry to the 5th percentile female & 50th percentile male adult.**



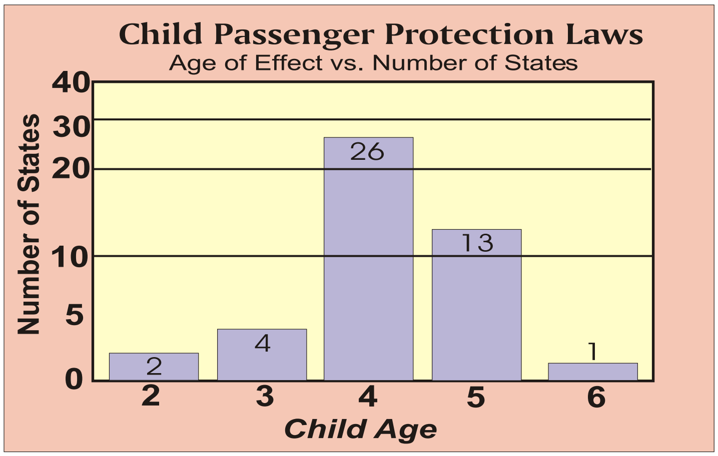

In what ways does an adult seat belt not fit a child properly? What injuries can occur because of this improper belt fit?




Due to improper belt fit, children are also susceptible to rolling out of the shoulder belt. This exposes the child to potential head, internal organ and spinal injuries.

Shoulder belt rollout sequence of a child.

A 1996 NHTSA study showed that only 6.1 percent of the children who were weight eligible were actually restrained in a booster seat. This small percentage could be explained by state seat belt laws. As of 2002, 26 states allowed parents to place children in an adult seat belt after the child reached age four. Four states allowed children to use an adult seat belt after age three. Two states allowed children to use an adult seat belt after age two.




Knowing that 32 states allow parents and caregivers to place four year old and younger children in adult seat belts, some vehicle manufacturers have advocated the use of booster seats for children ages four to eight. In April 2000, former Ford CEO Jacques Nasser touted the safety benefits of booster seats in announcing Ford's Boost America Campaign:

" We have made great progress in protecting infants in car crashes, but now we need to focus on older children between the ages of 4 to 8. They are too big for a regular child safety seat and too small for adult safety belts. The child safety gap must and will be closed."

A year later in front of a Senate Subcommittee hearing, Ford's Director of Automotive Safety testified about the safety benefits of booster seats:

"We have increased our focus recently on the need to improve the effectiveness of restraint systems for children aged 4 to 8. In a crash, poor belt fit can reduce the protection that the safety belts should provide against the risk of serious or fatal injuries."

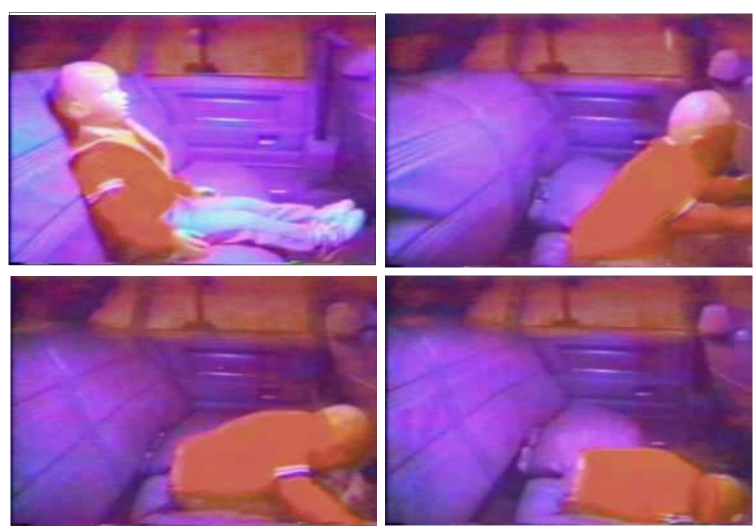
However, when faced with litigation, this same vehicle manufacturer argued in court that booster seats were not safety related items at all but were used merely to improve comfort. In fact, Ford's retained experts argued in a Florida trial that booster seats are a matter of comfort and convenience, not safety. CEO Nasser testified, contrary to his Boost America Campaign comments, that booster seats were intended to increase seat belt use based on comfort, not safety.


So, are four to eight year old children adequately protected by adult seat belts or do they need booster seats? Vehicle manufacturers for years have recommended that the shoulder portion of the seat belt be placed behind the back of a child if the seat belt did not fit properly. In short, they encouraged belt mis-positioning.

**For children having a seated height greater than 28 inches (71 centimeters), which is the maximum height for use of the Tot-Guard, use the belts provided with the vehicle. However, the shoulder belt portion of the lap-shoulder belts should not be used if it contacts the child's face, chin, neck or throat.**

**WARNING - If the shoulder belt portion contacts or remains in front of the child's face, chin, neck or throat, move the child to a seat with a lap belt only, if available. Otherwise, place the shoulder belt portion behind the child's back.**

Once the shoulder portion of the seat belt system is defeated, the seat belt is rendered dangerous since the upper torso is no longer restrained. Without the upper torso belt, the child will hyperflex over the lap belt and sustain paralyzing injuries or catastrophic internal organ injuries because the 3-point belt has become a lap belt only design.



**Lap Belt Only Kinematic Sequence**

Further, by placing the shoulder belt behind the back, the injury producing consequences of submarining are increased.

In September 1996, the National Transportation Safety Board (NTSB) issued a safety report recommending that the NHTSA revise FMVSS 213 to create a performance standard for child seats for children up to 80 lbs. Until 2002, the only safety standard designed to protect children limited its protection to children up to 50 lbs. By June 2003, the revised FMVSS 213 extended protection to children who weigh up to 65 lbs. However, the NHTSA acknowledged that "children must weigh approximately 80 lbs. to fit properly in a safety belt without a booster seat." Why not protect children between 65-80 lbs.? Don't they deserve protection?

Knowing that vehicle manufacturers were taking inconsistent positions on the need to protect four to eight year old children and knowing that the safety of four to eight year old children remained ignored, Public Citizen, in April, 2002, urged the vehicle industry, NHTSA and Congress to require integrated, built-in child restraints for children four to eight.

Public Citizen's request is well-founded. Various integrated child seats have been available since the 1980's. In fact, Ford has indicated in internal engineering notes that for children between ages four to eight, the integrated child seat with 5-point harness is the "safest form" of restraint system to use because it is both "safe" and "convenient."

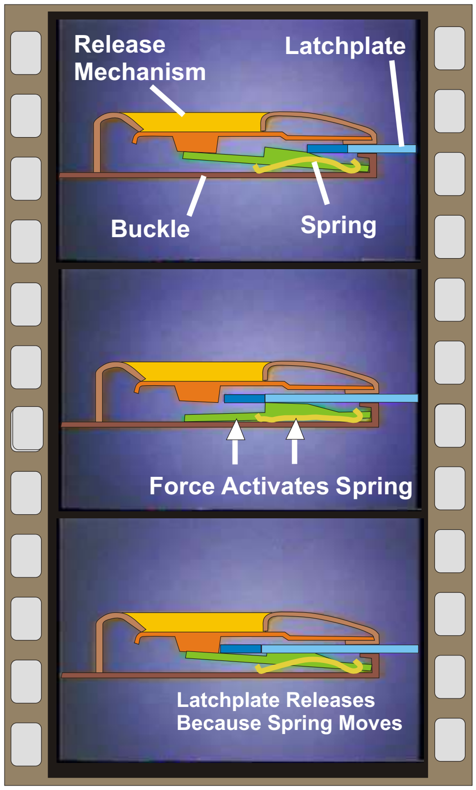
Despite decades of research that demonstrate that four to eight year old children are not adequately protected by adult seat belts, only a handful of vehicle manufacturers have provided integrated child seats.

The time is now to protect children ages four to eight from the ill-fitting consequences of adult seat belts. Four to eight year old children who are using adult seat belts are being maimed and killed at a staggering rate. In 1997 alone, over 10 times the number of children who were ever killed by airbags were killed while using an adult seat belt. Adult seat belts and children age four to eight are a deadly combination. As long as four to eight year old children remain a forgotten priority, deaths and catastrophic injuries will continue to rise at epidemic proportions.

Hope may be on the horizon however. In 2002, the NHTSA announced its 2003-2006 Rulemaking Priorities and Supporting Research. One of the special populations the NHTSA intends to focus on is the protection of children. This is certainly well overdue. Unfortunately, it could be another 10 years before any meaningful required legislation is adopted. In the meanwhile, safety advocates will have to keep encouraging manufacturers to implement safety features even before legislation requires them to do so. Alternatively, states should enact laws that require children to use booster seats until they weigh 80 lbs., regardless of age.

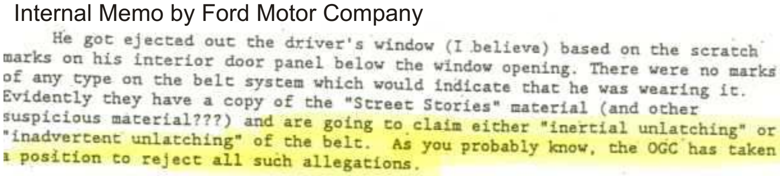
Conventional Child Seat vs. Integrated Booster Seat

## Ejection -Buckle Release




There are two types of buckles used by vehicle manufacturers: side release and end release. Unfortunately, both can release during accidents. The side release buckle was widely used prior to the early 1990's by most manufacturers. The side release buckle is susceptible to a phenomenon known as inertial buckle unlatching. This is seen when the backside of the buckle is impacted by a hard surface such as the iliac crest, which in turn shock loads the spring which controls the tension on the metal insert called the latch-plate. As the spring vibrates ever so slightly, the buckle inertially releases because the spring has been tricked into believing the depressor button has been pushed. Manufacturers used to say this was merely a "parlor trick". However, General Motors has recalled the C/K series truck advising owners that their seatbelt buckle could inertially release. Internal memoranda sent to the NHTSA from other vehicle manufacturers have acknowledged that they too have had buckles inertially release when the buckle is dynamically loaded. Vehicle manufacturers have also commented in test incident reports that they have had buckles release during crash testing due to inertial loading. Yet, vehicle

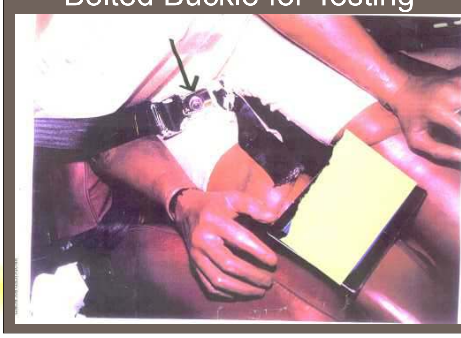
Internal Memo by Ford Motor Company


He got ejected out the driver's window (I believe) based on the scratch marks on his interior door panel below the window opening. There were no marks of any type on the belt system which would indicate that he was wearing it. Evidently they have a copy of the "Street Stories" material (and other suspicious material???) and are going to claim either "inertial unlatching" or "inadvertent unlatching" of the belt. As you probably know, the OGC has taken a position to reject all such allegations.

manufacturers have taken a position to deny all claims of inertial release. Even though inertial release allegations are routinely denied as being unrealistic by the vehicle manufacturers, one vehicle manufacturer had to bolt its side release buckle so it would stay latched rather than open during testing.

The design fix for the side release buckle was supposed to be the end release buckle. Yet, it too has had problems with unwanted unlatching. The depress button on many of these systems is not recessed sufficiently inside the buckle so that during an accident an occupant's arm, hand, purse or elbow could contact the buckle and release the latch-plate. An example of a buckle whose release button is not sufficiently recessed is the Gen 3 buckle. A second design flaw with the end release buckle stems from the way the buckle stalk allows the buckle to be elevated so that the buckle is no longer flus with the seat trim. Another dangerous aspect o the end release buckle is the button release force By law, the push button is required to withstan 1DaN (4.6 lbs.) before disengagement. Testin has revealed that most end release buckles do no meet this requirement. A fourth design flaw wit many end release buckles is the inability of th buckle to withstand a vertical load as would b experienced in a rollover. Since the buckle i oftentimes secured to the seat with a rigid stalk the buckle can receive a shock load that i transmitted through the underbody of the vehicl as the vehicle rolls.


Bolted Buckle for Testing



NHTSA Barrier Testing

Unwanted buckle release is not impossible to prove. Sometimes there will be a number of telltale signs left on the restraint system such as blood or dirt on the webbing, D-Ring striations, webbing transfer, belt elongation, stalk/anchorage distortion, fabric burns and latch-plate transfers. When there are no belt marks, look for the lack of other witness marks to support belt use. In a rollover, look for the lack of marks consistent with the occupant flailing around the vehicle like a cat in a dryer. When a person is unbelted, the center console is moved, the gearshift lever is distorted, the lower instrument panel and steering rim are deformed and the rear view mirror may be knocked off. Also, look at the medical. Injuries consistent with belt use include bruised or fractured clavicle, bruised or separated sternum, dislocated or separated pubic symphosis. When there are no classic seat belt marks, look for the lack of injury. For example, in a rollover, if the occupant has no compression fracture of the cervical spine, this is evidence that the occupant did not dive into the roof or header. When there are multiple occupants in the vehicle, look to see if the occupants slammed together. When they have not, ask why, because if they were allegedly unbelted they should have slammed into each other. Lastly, look at the ejection point of rest versus the vehicle's point of rest. If the ejection happened late in the sequence, something had to keep the occupant in the vehicle, perhaps it was the seat belt.




## Ejection-Door Failure

When the door opens in an accident, the occupant is exposed to the risk of ejection or partial ejection even if the individual is wearing a seat belt. Ejection remains one of the greatest risks, hazards and dangers facing vehicle occupants today because the door systems that are used by some vehicle manufacturers simply do not perform adequately during a crash event. When a vehicle's door opens during an accident, a large ejection portal is created. When an occupant is ejected from a vehicle, there is a 13 times greater risk of injury to the ejected individual when compared to the people that remain inside the vehicle. Here are a few ways that doors fail during accidents.

This model T's door opened in testing conducted almost 80 years ago.

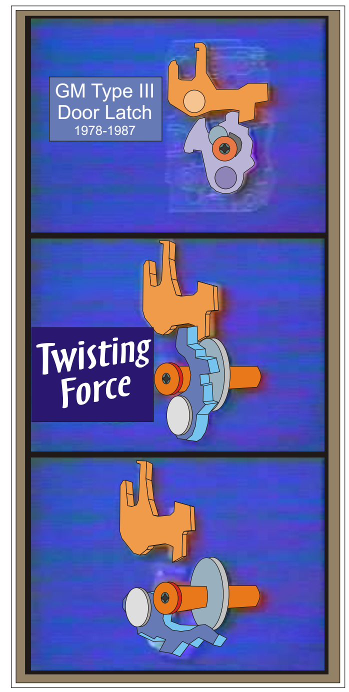
***Linkage Actuation-*** *the tension compression rod linkage that activates the interior and exterior handle is bent inward or outward. When the rod bends, the handle is actuated. This failure mode is seen when the outer door panel of the door is deformed inward, or the occupant contacts the inner door panel. The rod linkage can also deform when the door crushes longitudinally. The rigid rod linkage design is presently used on 93% of all vehicles. The design fix is a flexible cable that connects the inner handle to the outer handle and is called a bowden cable. This design was patented in 1969. Yet, the flexible cable is only used on 7% of 2004 model year vehicles.*

***Handle Actuation**-the outside handle actuates as the vehicle scrapes along the ground during a rollover. This failure mode is resolved by using automatic door locks, a vertically oriented handle, a recessed handle, or a box handle/latch combination.*


***Inertial Actuation-** no obvious latch, striker or linkage damage is noted. However, due to shock loading, the locking pawl bypasses the striker. This failure mode exists due to the lackluster door performance standard that has been unchanged since 1968. FMVSS 206 contains an inertial calculation performance requirement rather than a dynamic or static performance requirement. The inertial calculation allows for door components to be designed for 30G's of load. In real world crashes, these same components experience 300G's.*

***Composite Material Failure**- some hatchbacks and lift gates are made from a composite material called sheet-molding compound. This material can vary in strength from one batch to the next by as much as 300%. The fundamental problem with using a composite material is that once it shatters it offers no energy absorption. Moreover, the material has a tendency to shatter around the latch that remains locked.*

***GM Type III-** The Type III was used on almost every GMC vehicle between 1978-1987. The failure mode occurs because the latch was not designed to withstand compressive or twist-out loads. Consequently, the latch bypassed the striker. The design fix was a support plate that prevented bypass which was ultimately used by GM.*




***Sliding Door Assemblies-** on all Ford Aerostar minivans and 1984-1996 Chrysler minivans, the sliding door has no front latch. Instead, there is a pocket where a nipple is inserted that helps stabilize the door. On vehicles with sliding doors, the attachment brackets are manufactured out of very brittle low carbon steel or cast aluminum. If these brackets fail, the sliding door can separate from the vehicle.*

***Vertical Loading-** FMVSS 206 requires testing and performance in the longitudinal and transverse direction. There is no vertical direction testing. However in every accident there is vertical loading.*


Vertical load unlatches sliding door

GM Type III Latch Openings

***Chrysler minivan 1984-1996**- the fundamental problem with the 1984-1988 minivans focused on Chrysler's failure to install an upset head on the striker. Consequently, during any direction of load, the latch assembly had nothing to prevent the locked assembly from sliding off of the striker. This problem was corrected in 1988. After 1988, the mounting bracket for the striker was too flimsy. As such, the striker would twist out or move away from the upset head. Every 1984-1996 Chrysler, Plymouth and Dodge minivan only had one lift gate latch instead of two latches positioned on the rear pillars. Even more basic, none of these minivans contained a secondary locking latch.*

Ejection Sequence Out Liftgate

Liftgate Opens - Side Impact

## Ejection- Seat Failure

In a rear impact accident, the primary restraint system is the seat back. However, the seat rarely stays upright in rear impact accidents. As a result, even restrained people can be ejected. Seats routinely fail in accidents because the standard that governs seat strength was adopted in 1968 and has never been strengthened despite repeated attempts by the government. The problem with FMVSS 207 arises from the fact that the standard fails to take into account the weight of an occupant involved in an accident using the seat. Hence, in a parking lot accident, the seat can fail rearward. Further, there is no crash test requirement to evaluate seat strength. One test that does demonstrate how seats perform when a vehicle is impacted from the rear is a test that evaluates the fuel system (FMVSS 301). In most 301 tests, the front seated dummies are thrown into the rear seat when the seat back fails. Yet, as long as there is no fuel leakage, the failed seatback is of no consequence.

Seat Back Collapse Sequence - Rear Impact

In 1968, a GMC engineer acknowledged that a seat that was no longer upright could pose safety problems to pedestrians since the driver was no longer seated upright and could injure the driver and occupants sitting behind the driver. Yet, GMC and other vehicle manufacturers did nothing. Knowing that its seats would allow the driver to be deposited into the rear seat once the seat failed, manufacturers in the early 1970's began testing seats that had seat belts attached to the seat (see ABTS discussed earlier). This design concept had been utilized for years by the military with life-saving results. Manufacturer testing revealed that using an ABTS system improved rear impact safety performance considerably. However, Land Rover was the only manufacturer to use the ABTS design in the 1970's. By 1990, Mercedes Benz and BMW were the only other manufacturers that used the ABTS design. Today, only a handful of manufacturers use this superior restraint design.

Manufacturers routinely contend that when a seat back fails, the occupant benefits. They argue that with controlled seat deflection/yielding, the occupant actually benefits since they cannot ramp up the seat and impact the roof. They argue that any seat that remains upright is dangerous because the occupant does not get to ride down the crash event. However, they forget that most trucks that are not extended cab models and most sports cars have seats that cannot recline because the rigid structure is located behind the seat. Further, they forget that any vehicle that has a rear seat is incapable of having its rear seat yield rearward.

The defense to these cases started unraveling about nine years ago when a GMC seat litigation study surfaced. In the study, GMC lawyers and engineers expressed how seat back cases were not defensible. GMC's chief biomechanical engineer has also testified and written in a book that he knew in the early 1980's that GM's seat performance was inadequate. Documents also surfaced that indicated that for less than $5.00, seats could be strengthened sufficiently to make them safe. Perhaps the most damning evidence came from the children that were being crushed by their parents or caregiver's seats.

## Ejection- Reclined Seat

The hazards of reclining one's seat while a vehicle is in motion have been well known in the automotive safety community for decades. Reclining one's seat while the vehicle is in motion is dangerous, since it alters the seat belt's restraint capability. If your vehicle's seat is reclined, it does not matter if you are in a frontal, rear or rollover accident. The effect is the same, your seat belt will not work.

GM acknowledged the dangers of reclined seats in a 1968 memo: "The fact that our competitors .....market reclining seats with adjustments greater than 20 degrees does not justify us doing so." Yet, vehicle manufacturers have used seat recliner devices as optional and now standard comfort features for years. There is no known data from any public record furnished by any vehicle manufacturer where it was determined how vehicle occupant users would likely use the seatback recline feature built into their vehicles. The ordinary passenger vehicle occupant, with no specialized knowledge or crash test equipment, and no guidance from the manufacturer, is not typically aware of the extreme hazards of reclining one's seat with the vehicle in motion.

The NTSB in a May 10, 1998 Safety Recommendation, requested a more effective warning from vehicle manufacturers:

*".....some advertisments for cars equipped with reclining seats show a right front passenger reclined in a seat while wearing a three-point belt with the vehicle obviously in motion."*

The NHTSA in an August 2, 1998 letter to the NTSB noted:

*"People who ride with the seat back reclined are not aware of the associated risk."*

These government recognitions of the public's unawareness for transportation safety are intuitively obvious given the aknowledged lack of either public or private efforts at public education regarding the hazards of reclining seats while vehicles are in motion. These official recognitions also emphasize that automobile manufacturers have never performed any public education campaigns or surveys regarding the state of knowledge of the ordinary passengers of their vehicle with regards to the hazards of reclining one's seat while the vehicle is in motion.

There are a number of alternatives that have a direct application to the risks, hazards and dangers associated with a reclined seat while the vehicle is in motion.

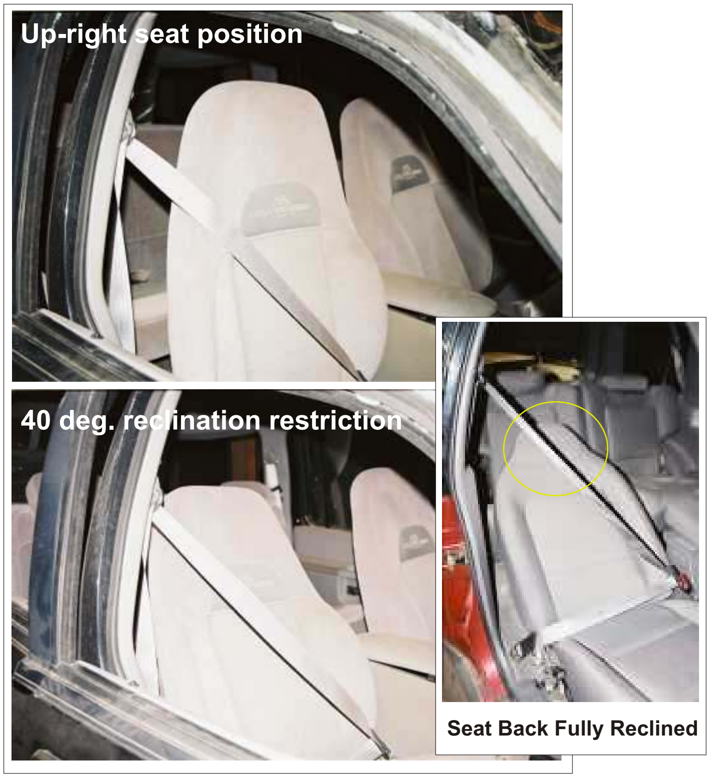
An ANSI standard warning label on the instrument panel directly in front of the right front occupant warning of the hazards of reclining one's seat while the vehicle is in motion would cost only pennies per vehicle and would satisfy the basic requirements of attention getting and instructing on the extreme hazards of reclining one's seat. BMW's are shipped from the factory with a warning label in the center of the right front instrument panel warning of the out-of-position dangers for air bags. FMVSS regulations clearly permit this simple and long-used method to address reclined seat hazards.

Another alternative design is an interlock to prevent the seat from reclining while the vehicle is in motion. This alternative design is totally supported by the industry position that the reclined seat feature is meant only for when the vehicle is stationary. There are patents for this design dating back to the 1960's.

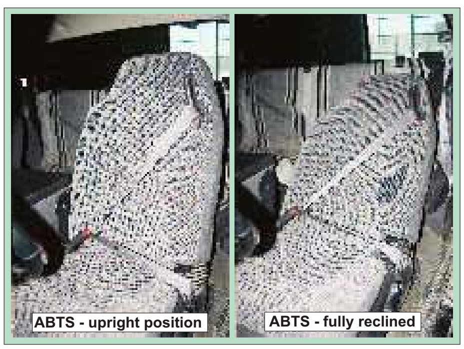
An activated electro-mechanical tie-in between the seat back and an illuminated and possibly back-lit warning in the center of the right front instrument panel or on the header cluster panel is totally feasible. The associated components were previously and concurrently used in numerous applications elsewhere in the vehicles. Cost would be commensurate with other feasible occupant warnings, and although being somewhat more than the minimal cost of the warning label described above, would be justified considering the catastrophic consequences of this forseeable failure and injury mode. Such an approach might also address objections by auto industry stylists that an orange and black warning label in the occupant compartment would be dissonant with interior styling.

A functional tie-in is achieved when an operator movement or action activates a warning light or audible warning, but does not interfere with the operation of the vehicle. Both tie-in and interlocks have been and are widely used in current automobiles for safety reasons. Examples are not being able to shift out of "Park" unless the brake pedal is depressed; "Door Ajar" light if a door is not completely closed. There are, of course, many others described in most vehicles owner's manuals. There are already numerous examples of starter, shift lever, brake pedal, clutch pedal, electric window, and other operating interlocks and tie-ins that manufacturers already include in their cars. Thus, by offering the alternative design of an interlock or tie-in for a reclining seat is hardly a new or different application. Finally, interlocks address the contention that reclining seats are intended by the industry only for when the vehicle is stopped by the side of the road so the occupants can rest. If that contention is true, then the vehicle manufacturers should have no objection to the interlocks proposed, since those would only serve as reminders for the safe operating limits that vehicle manufacturers already advocate.

One alternative design that is being used by Ford in its SUV's prevent the seats from reclining beyond 40 degrees. This angulation restriction insures that the reclination does not destroy the seat belt restraint function.




Another alternative design that is being used today is the ABTS where all the belt anchors are anchored to the seat frame. This design allows the auto manufacturer to permit some additional degrees of safe recline from the nominally upright position while the vehicle is in motion. Several patents for ABTS point out that mounting the seat belt to the frame of the seat, rather than the B-pillar, permits vehicle seats to be more safely reclined while a vehicle is in motion. The presence of a reclining feature with a body mounted seat belt invites even a sophisticated user to put himself at an unnecessary and extreme risk of serious to fatal injury. It defies logic that a user will not recline his seat while the vehicle is in motion. If manufacturers truly do not want occupants to use the seat recline feature while the vehicle is in motion, it is incumbent on the manufacturers to design-in safety. One such design is from Mercedes Benz who use a design feature that self-aligns the front seats to a proper angle if panic braking is applied.




Manufacturers routinely contend in litigation that if a person is injured or killed because they reclined their seat, that they are responsible for the devastating consequences. These arguments should fail because vehicle advertisements routinely show people reclining in their seats while the vehicle is in motion.


Chrysler Pacifica Ad 2003

Advertisement by KIA

## Ejection- Glass/Glazing

1950's Ad demonstrating laminated side glass.

Dupont in the 1960's notified the consuming public that the automobile industry were putting lives at risk by replacing laminated glass with cheap tempered glazing. Their warning went unheeded by the vehicle industry.

The Experimental Safety Vehicle (ESV) program had an occupant retention requirement for rollovers. Several ESV's, including the GM ESV and Minicars RSV, had fixed laminated side glass.

The initial FMVSS 208 contained a dolly rollover test requirement for occupant retention. GM tested a number of alternatives, including glass/plastic glazing in the early 1970's in response to that requirement. The automobile industry knew in the early 1970's that the techniques outlined by the NHTSA in 2000 for occupant retention glazing were necessary and available and concluded that *"a new approach to passive rollover protection was required."* This approach was outlined as requiring, *"three vehicle modifications: channeled side glass in all cars; laminated glass for all windows and improved door latches."*

In most vehicles still today, only the windshield is currently made of occupant retention glazing, vis-a-vis laminated glass. This glazing is extremely effective in preventing ejection of even unrestrained occupants, provided it is appropriately bonded into the opening. Side and rear windows are generally tempered glazing. Tempered glass like most "brittle" materials is a poor energy absorber. Once it is loaded to failure, it shatters into a multitude of small fragments and ceases to provide occupant retention or structural reinforcement.

Glazing technology to mitigate ejection has been available for decades. Occupant retention glazing was used in most vehicle side windows from the late 1930's until the early 1960's. Then, as a cost saving move, the automotive industry phased in tempered side glazing, after having used laminated glass for more than 20 years. Ford noted in its rollover test reports that the 1960 Falcon with tempered side glass allowed the test dummies to be ejected, yet vehicles equipped with laminated side glass provided occupant retention:

*"One obvious difference between this roll-over test on a Falcon and similar tests conducted on other company products was the failure of the glass in the doors. The door glass is commonly broken during a roll-over but in other company products, the laminated safety glass usually remains in position. However, the tempered glass used in the Falcon shattered completely and allowed the dummy's arm to hang out of the opening and be torn off."*

To utilize tempered glass effectively, the roof structure must have sufficient inherent integrity that the deformation does not exceed the elastic limit of the glass. If the structural design has sufficient integrity, the glass and the body of the vehicle can behave synergistically to reinforce each other. This design philosophy was condemned by GM when it conducted its rollover test series:

*"The rollcaged vehicles has less glass breakage than the standard roof vehicles."*

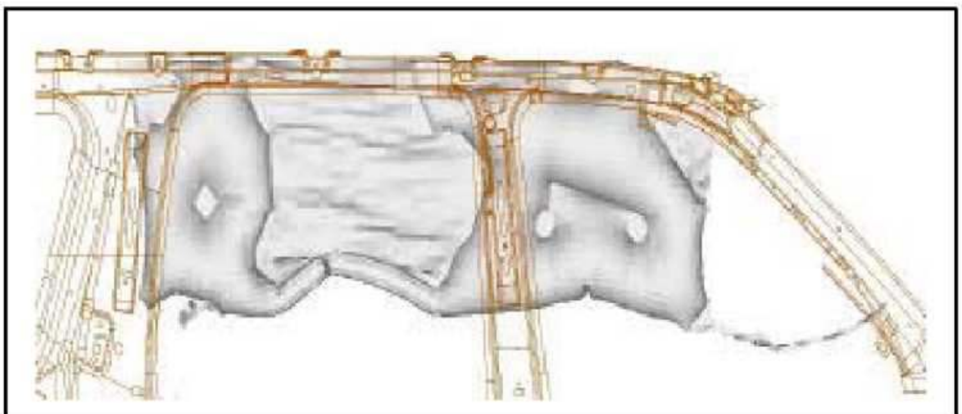
One of the primary reasons used by manufacturers on why non-tempered glass has not been used on side window applications has been a phenomena known as "horse collaring" which entails slicing the occupant's neck with shards of glass during extrication. However during the development of Securiflex,tm chamois testing revealed low lacerative injury potential. As such, vehicle manufacturers such as Volvo, Mercedes-Benz, Pugeot, Audi, Chrysler, Ford and BMW are phasing in laminated side glass in side and rear windows.

Another reason why non-tempered glass has not been used extensively in side glass stems from concerns dealing with neck injury. This concern is not supported by field data from the NHTSA.

Vehicle manufacturers have also indicated that using non-tempered glass in a side window application will render inflatable side impact air bags useless. Yet the BMW 750, Mercedes Benz 500, and Volvo XC90 each have occupant retention glass and side curtain air bags.

Each year more vehicle manufacturers install non-tempered glass in their side and rear windows. Vehicle manufacturers claim this type glass is used as an anti-theft measure. However occupant retention and ejection mitigation is an added safety benefit. Testing has revealed that occupant retention glazing is effective in restraining unrestrained occupants. Biomechanical data from this testing has also demonstrated that no increased risk of head and neck injury is seen when compared to tempered glass.

The use of glass as an occupant retention device is long overdue. Mandatory seat belt use laws apply only to front seated occupants in all but five states. The NHTSA has concluded that second row belt use is 37% and third row belt use is 5% in SUV's and minivans. The vehicle manufacturers have reached similar conclusions. As such, knowing that people are not using their seat belts in the rear seats, manufacturers must find ways to passively protect these people from ejection related injuries. Glazing is a perfect design solution.



**BMW Side Curtain with Laminated Side Glass**

**Non-Tempered Glass**

**Tempered Glass**

# Crashworthiness:

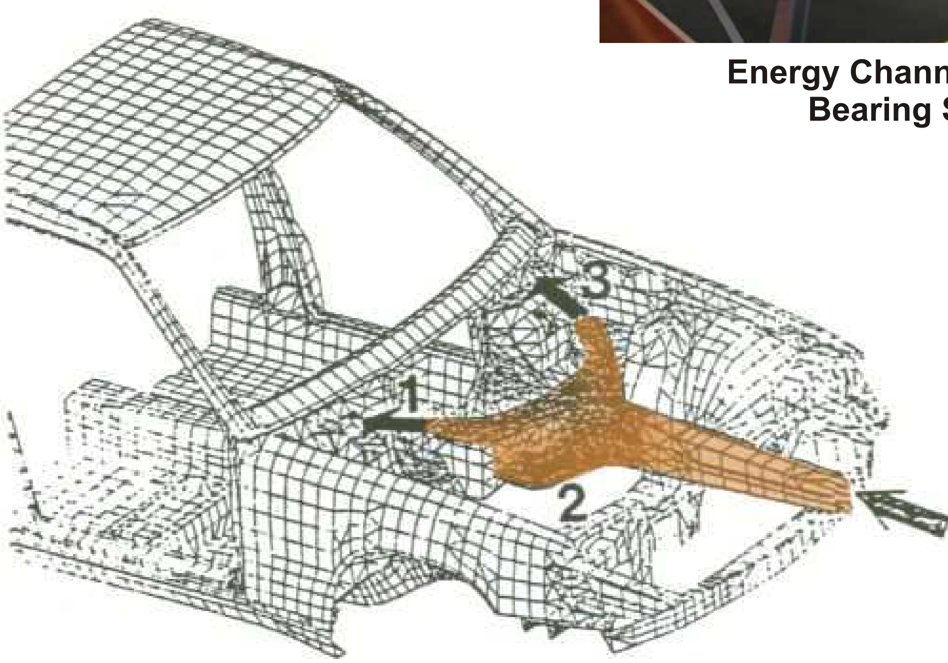
- **Control Energy / Transfer Energy**


## Vehicle Structure

The structural integrity of vehicles is now, more than ever, a critical design element considering the new, lightweight materials that are being used to build vehicles. Low carbon and high strength low alloy steel are now being replaced by SMC (sheet molding compound), plastic resin, polymer and kevlar blends. As less steel is used in vehicles, the ability of a vehicle's structure to absorb energy is reduced.

Without adequate vehicle structure, occupant protection measures are seriously compromised. Years ago, it was thought that a vehicle's front structure should be "stiff" and non-deforming. Automobile engineers quickly discovered that reinforcing the front structure to the point that it did not crush was improper since a stiff vehicle was not necessarily a safer vehicle because the energy in a stiff vehicle was transmitted into the occupant space. As such, energy levels would not be dissipated until late in the crash pulse, well after the energy had surrounded or penetrated the survival space. Energy that is not absorbed by controlled crushing was leading to deceleration type injuries such as transected aorta, contrecoup brain injuries and internal organ disruption (lacerated spleen, liver and pancreas).

**Energy Channeling and Load Bearing Structures**

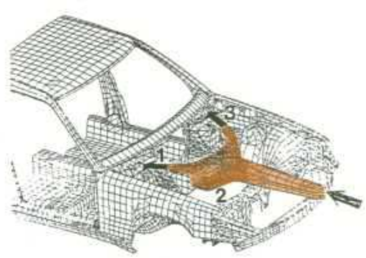



**Y-Fork Channel Feature Patented By Mercedes**

Controlled vehicle crush is the key to energy dissipation and energy transfer. A prime example of the manner in which energy is dissipated in a crash can be seen in race cars. As the outside structure breaks free, stored energy is reduced and removed from what is ultimately transferred into the monocoque safety cell that houses the racer. This same engineering technology is used in helmet manufacturing. Exterior crushing and deformation is essential. In fact, all helmet manufacturers advise users that their helmets are only effective for one accident.

Kenny Brack - 235 mph Crash - Texas Motor Speedway

Some passenger cars today channel energy through controlled longitudinal load bearing members that distribute energy stress levels evenly. The most prevalent is the forked front body member whereby impact forces are channeled into three structural branches: tunnel, floorpan, and side panel. The beauty of the three-forked concept is that energy is allowed to be channeled regardless if the front structural member is loaded directly. This feature is important because most accidents involve accident forces that are not purely frontal but are rather offset and oblique in nature.



In vehicles that do not contain an energy channeling design, impact forces can overload the front structure resulting in components stacking up until overload is achieved. Once overload occurs, the stored energy is imparted to the survival space. An example of improper control of survival space can be seen on a vehicle whose FMVSS 214 side door beam is not deformed, yet the door space is deformed considerably. During the accident, stored energy overloads the attachment points for the side beam, latch or striker. Consequently, when the door unlatches or the hinges separate the beam can never be loaded to help absorb energy, compromising the survival space.

The testing of vehicles is another important area that has been overlooked by most manufacturers when designing a

Occupant Survival Space Destroyed in Frontal Offset

vehicle's front structure. In the United States, there is no requirement that a manufacturer test a vehicle by performing a crash test into an offset barrier. Instead, vehicles are impacted into barriers where the full frontal aspect of the vehicle is engaged. This test scenario is quite unrealistic considering that the majority of real world crashes involve only partial overlap of the vehicle's front. The reason full engagement of the front is uncommon in real world crashes is common sense—people tend to try and avoid collisions and thus usually end up impacting only a portion of the vehicle. As such, it is incumbent on vehicle manufacturers to test vehicles in more real world like conditions.


Offset Impact

For years, European and Australian manufacturers have performed 40% and 50% offset barrier impacts that replicate car-to-car collisions with anticipated avoidance. These tests were initiated in response to criticism from European automotive magazines and consumer advocacy organizations. Recently, an organization in the United States called IIHS (Insurance Institute for Highway Safety) has been featured on NBC's Dateline where they have conducted frontal 40% offset impacts. The NHTSA as well as various manufacturers have begun performing offset frontal testing. The results are oftentimes shockingly bad because manufacturers insist on designing vehicles to pass a test whereby the vehicle runs into a several ton block of concrete. This mentality of course begs the question—When was the last time a real world impact involved the full, complete front structure of a vehicle? The answer would probably be never since vehicles in the real world have different bumper heights and vehicle weights, which lead to underride/override type impacts, and besides, drivers routinely swerve to avoid head-on impacts.

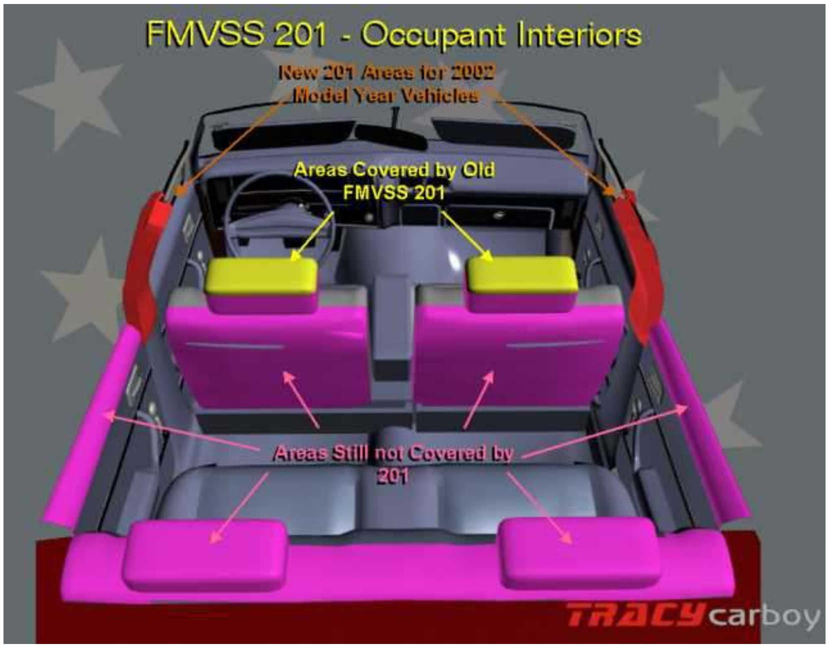
Front Override Test 8 mph

## Vehicle Interior Padding

There is a misconception by the majority of people who wear safety belts- "I will not contact the steering wheel, windshield, instrument panel or other parts of the vehicle interior if my seatbelt is worn during a mild to moderate impact." However the truth is that even with a seat belt on, restrained occupants receive significant injuries to their head, face and spine due to vehicle interior contact. Watch any 30 mph barrier crash film and you will quickly learn that simply buckling up is not enough. Yet, despite knowing that seat belts are not preventing occupant contact with the interior, manufacturers persist in delaying efforts to make vehicle interiors more "occupant friendly" in the event of collision contact.

## FMVSS 201 History

On February 3, 1967, FMVSS 201 was proposed and called for specific requirements for the design of instrument panels, seatbacks, sun visors and armrests to afford protection to vehicle occupants involved in accidents. In October 1967, FMVSS 201 was revised to include protruding areas, windshield headers, A and B pillars, rearview mirrors, roofs and consoles.




Unfortunately, due to lobbying by the vehicle manufacturers, a meaningful standard was not adopted until 1994, even though several variations were proposed by the government. Still today, the latest revision did not take effect until 1995, for 2002 model year vehicles.

Just weeks after the government announced that it would seek to improve vehicle interior padding, the powerful vehicle lobbying arm of the automobile makers noted that "[we] recognize that some of the language in Standard 201 to which we now [disagree with] was suggested by the manufacturers in earlier comments." The lobbying group called the Automobile Manufacturers Association (AMA) also suggested that 201 should be eliminated since "most serious impact injuries to passenger car occupants of all ages could be avoided or alleviated if the occupants were properly restrained."

## Selected Ford FMVSS 201Comments

In October 1967, Ford criticized 201 claiming that there was a "total lack of appropriate test equipment and head form devices which can be used to effectively measure levels of performance for interior components other than instrument panels, seatbacks and consoles."

After the government indicated a desire to extend 201 to multipurpose passenger vehicles, trucks and buses in 1970, Ford argued that 201 was a design standard rather than a performance standard so that the entire standard 201 was not in conformity with the National Traffic and Motor Vehicle Safety Act of 1966 and should be disregarded.

In July 1990, Ford requested that the impact speed for the head be reduced from 15 mph to 12 mph. Ford responded in May 1993, that it could not implement interior head impact protection until the 2003 model year. Ford also wrote, as did the successor lobbying interest for the AMA, renamed as the American Automobile Manufactures Association, that no data existed that indicated A-pillar contact was a significant risk area. In May 1994, Ford requested that A-pillars be exempted from the proposed standard 201 because the extra padding seriously compromised interior spaciousness.

## Selected GM FMVSS 201Comments

In 1968, GM wrote that the "occupant, whether driver or passenger, receive equal protection. The passenger proposed system is to allow no injury at 40 mph barrier impact if fully restrained."

In 1969, GM wrote that instrument panels shall "provide a safe target for passenger impact." and shall prohibit "significant discontinuities, unyielding knobs, protruding trim, or other features that would produce head, eye or facial trauma." GM also wrote that "half inch padding or metal air gap material shall be used on all objects that might produce injury if struck by the head."

Quiet until 1974, GM actually advocated the use of a padded interior as a means of passive protection for occupants. In fact, at the Society of Automotive Engineers Third International Conference on Occupant Protection (July 11, 1974), the president of GM, Edward N. Cole, coined the phrase "friendly interior" in a speech describing ways to protect front-seated, unrestrained occupants.

On May 19, 1975, GM commented during a public meeting on passive restraints that "padded interiors have a potential for increased protection and offer the advantages of low cost and high reliability." However, in the same meeting, Ford, Chrysler and the AMA indicated that padded interiors were actually more dangerous due to vision obstruction. One month later, GM changed its tune and wrote " a padded interior capable of meeting the arbitrary test requirement would probably result in the interior spacing being too confining to be considered acceptable by the consumer."

In October 1980, GM engineers wrote that "a full assessment of instrument panel characteristics and their possible relationship to head impact of restrained occupants would seem to be appropriate." When the government began pushing for increased occupant protection after a watered down standard had been in effect for only two years, GM, in 1983, dusted off its friendly interior concept which it had criticized just eight years earlier. In December 1983, GM announced the implementation of the VSIP. The VSIP called for the elimination of airbags and automatic belts as a solution to the government's desire to require passive restraint systems for front seated occupants. GM called its VSIP a "built-in" safety approach because "vehicle safety improvements can benefit both belted and unbelted occupants... and we believe that the 'built-in' safety approach can save more lives than automatic belts...Furthermore, this built-in safety approach is more cost effective." GM repeated its endorsement for "built-in" safety during its 1983 Annual Report where it claimed that "built-in" safety is at a cost far below that of airbags.

In 1984, GM publicly announced that it had performed 25 mph crash tests with unrestrained occupants and that meaningful progress had been made on "built-in" safety. During the ESV conference in July 1985, GM engineers wrote that the interior of the "vehicle would be used to control energy absorption. Any such system would be considered supplemental to the 3-point lap/shoulder belt system."

GM, again in 1986, requested the government to rescind the passive requirement that would mandate that a certain percentage of vehicles after September 1, 1990, incorporate airbags or automatic belts.

In November 1990, GM threw in the towel in its efforts to have the government rescind the requirement of airbags or automatic belts in vehicles if "built-in" safety measures were used. Instead, GM wrote, "It had no current plans to produce vehicles with occupant protection systems that do not incorporate safety belts or airbags."

## Conclusion

Manufacturers of vehicles are quick to point out that designing and assembling vehicles is an evolutionary process, and they are correct. However, during the development phase of an automobile, new, innovative and state-of-the-art designs and concepts should be considered. Failing to consider technological improvements is tantamount to breaching the evolutionary nature of vehicle design. This is why the failure to develop, enhance and scrutinize interior padding for occupant protection is extremely difficult for the manufacturers to address since they have boasted internally about the effectiveness of padded interiors. Moreover, manufacturers have praised the low cost associated with interior padding.

## Prevent Post Crash Fires

# Crashworthiness:

- Fire Prevention

Many fuel system design concepts that are used by vehicle manufacturers today were initially developed by the military. Helicopters that had been shot down and crash-landed were protecting the helicopter passengers. However, the crash would cause the rupture of tanks and/or lines and the fire would kill the survivors. Consequently, fuel tanks with bladders and fuel cells were created to prevent the tank from being breached. Also, fuel lines with quick-disconnect valves were designed to prevent fuel leakage. Metal braided lines replaced rubber lines to minimize incineration.

Even though many of the design fixes used by the aerospace industry were adopted by the vehicle manufacturers, vehicle manufacturers continued having fuel-fed fires because of tank placement. As a fundamental rule, a designer should never place a fuel tank in an area that can be impacted directly by an intruding vehicle or by deformed parts of the vehicle. Clearly, the safest place for a fuel tank is in between the frame rails in front of the rear axle. However, this was not always the case. Until 1978, a number of light trucks had fuel tanks that were positioned directly behind the driver and passenger. Until 1984, a number of vehicles had fuel filler necks that were not recessed and could easily be torn off in the event of an accident. Up until 1987, most fuel tanks served as the top of the trunk that left very little zone of encroachment. Even today, many vehicle designs have fuel tanks that are located behind the axle. These problems have now been replaced by other design issues, that will need to be corrected by the automotive industry.

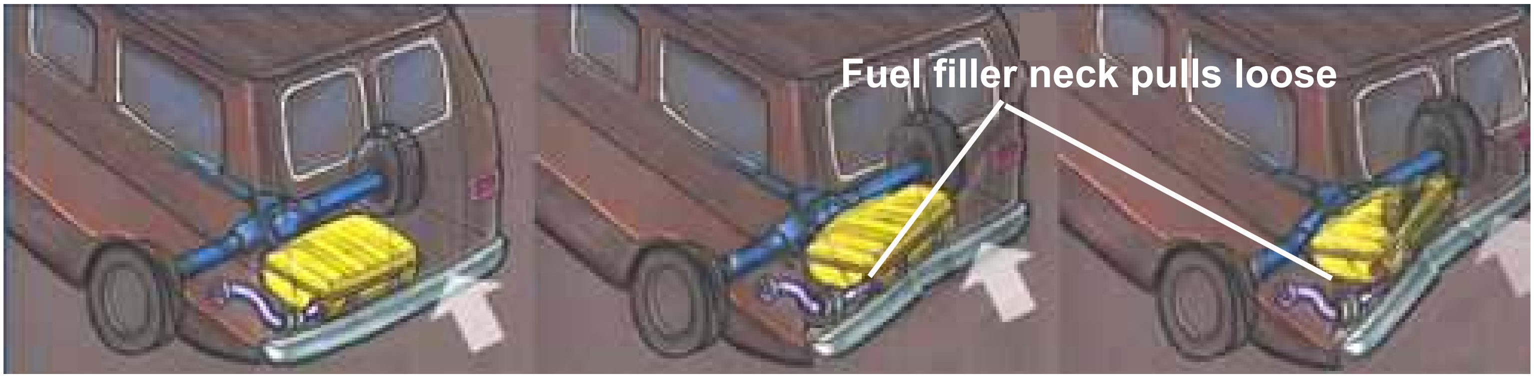
Fuel tank behind the axle


Side saddle tank - Tank outside rail
C/K Series Pickup Truck

Top of tank serves as trunk

One of the primary sources of fuel comes from the electronic fuel pump that keeps pumping fuel even after the engine is off. Most vehicles now have shut off switches, but this is a recent development. A frequent source for fuel to feed a fire is from the lines. Today, most vehicles still use rubber lines with only minimal metal braiding, although most of the lines under the vehicle are metal. Also, the manner in which lines are routed is subject to disruption. For example, if the engine has a rigid metal line that runs along the firewall, in a frontal impact the line can be crimped. Many manufacturers are replacing rigid non-flammable metal fuel lines with flammable rigid plastic fuel lines. Further, quick disconnect valves are still not used except for high performance vehicles.

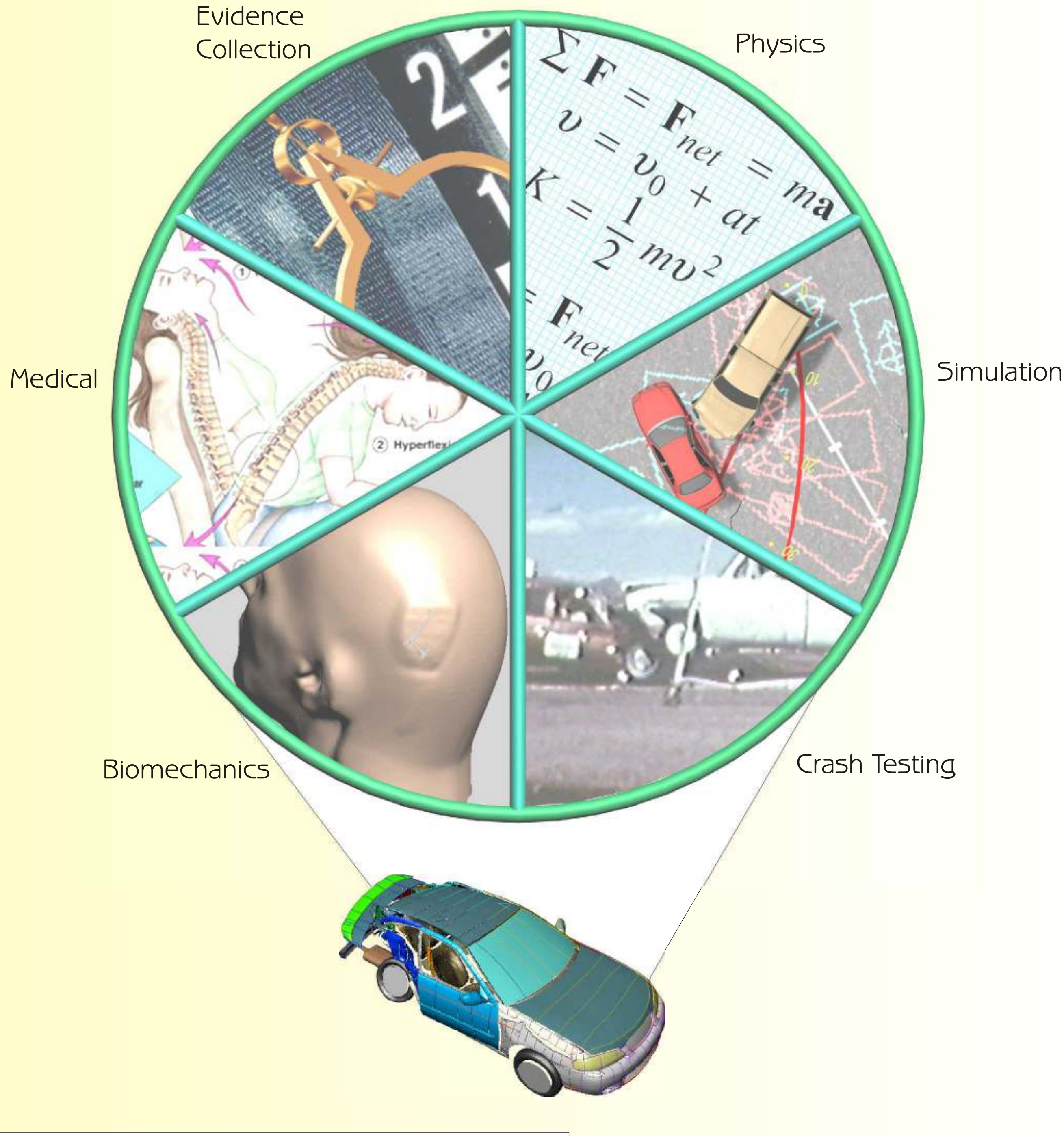
In the 1990's, fuel-fed fire defect trends were virtually silent. However, as vehicles became lighter and more reliant on SMC and plastic, more and more fires are being seen. Also, engine fires will always be problematic because of the manifold. Honda has devised a material process that keeps its manifold to below 1300 degrees which prevents ignition.




Not all fires however are fuel fed. Wiring harness problems continue to plague much of the industry. This is understandable considering the gadgets that are now on vehicles. Wire chafing from repeated contact with a metal surface can also lead to an electrical fire. Recently, there have been recalls from GM, Ford, Chrysler and Toyota related to the potential for electrical fires. These recalls covered millions of vehicles.

Good engineering practice demands that if a person survives the crash, they should not perish due to vehicle fire.

Fuel tank in front of axle - no leakage

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