ALASKA LEGISLATURE COMMITTEE FILES 1987-1988 8672
5560 SSTA HB 167 (file 1)

1132

HB

167

- file 1 -

SENATE COMMITTEE REPORT

FURTHER:
SA
L&C
FIN

DATE TURNED INTO OFFICE May 14, 1987

Mr. President:

TRANSPORTATION Committee considered CSHB 167 (JUD) am

mandatory use of safety devices in motor vehicles

and recommended:

[ ] replace with CS FOR ______) [] same title
[ ] or adopt ______ CS FOR ______) [] new title

[ ] attached amendment(s) and

[ ] do pass

[ ] do not pass

[ ] no recommendation

[ ] individual recommendations

[ ] further referral to ______

[ ] letter of intent adopted ______

Committee [ ] attached or [ ] adopted fiscal note(s)
[ ] new [ ] updated or [✓] previous
[✓] zero [ ] fiscal impact

MEMBERS SIGNING DO PASS

OTHER RECOMMENDATIONS

Fahrenkamp No Rec
Kelly - E No Rec

Lloyd Jones (Do Pass)
Chairman signature and recommendation

[ ] Committee Backup Attached

No. 1

STATE OF ALASKA 1987 LEGISLATIVE SESSION
FISCAL NOTE

Bill Version: CSHB 167(SA)
Publish Date: HOUSE 3/23/87

REQUEST:

Revision Date:
Title: An act relating to mandatory safety devices
Sponsor: Cotton, Ulmer, Koponen, et al
Requestor:

Agency Affected: Health
BRU: State Health Services
Components: Public Health Administration services - EMS

EXPENDITURES/REVENUES: (Thousands of Dollars)

OPERATING	FY 87	FY 88	FY 89	FY 90	FY 91	FY 92
PERSONAL SERVICES						
TRAVEL						
CONTRACTUAL						
SUPPLIES						
EQUIPMENT						
LAND & STRUCTURES						
GRANTS, CLAIMS						
MISCELLANEOUS						
TOTAL OPERATING	-0-	-0-	-0-	-0-	-0-	-0-
CAPITAL	-0-	-0-	-0-	-0-	-0-	-0-
REVENUE	-0-	-0-	-0-	-0-	-0-	-0-

FUNDING: (Thousands of Dollars)

	FY 87	FY 88	FY 89	FY 90	FY 91	FY 92
GENERAL FUND						
FEDERAL FUNDS						
OTHER						
TOTAL	-0-	-0-	-0-	-0-	-0-	-0-

POSITIONS:

	FY 87	FY 88	FY 89	FY 90	FY 91	FY 92
FULL-TIME						
PART-TIME						
TEMPORARY	-0-	-0-	-0-	-0-	-0-	-0-

ANALYSIS: (Attach a separate page if necessary)

Enactment of HB 167 would have no direct fiscal impact on the Department of Health and Social Services.

Prepared by: Mark S. Johnson
Division: Public Health
Phone: 465-3027
Date: March 12, 1987

Approved by Commissioner: [signature]
Date: 3/19/87
Agency: Dept. of Health & Social Services

Distribution (by preparer):
- Legislative Finance
- Legislative Sponsor
- Requestor
- Office of Management and Budget
- Impacted Agency(ies)
- Senate Secretary

No. 2

STATE OF ALASKA 1987 LEGISLATIVE SESSION
FISCAL NOTE

Bill Version: CSHB 167(SA)
Publish Date: HOUSE 3/23/87

REQUEST
Revision Date:
Title: "An Act relating to mandatory use of safety devices."
Sponsor: Cotten, Ulmer, Koponen, ...
Requestor: House Judiciary

Agency Affected: PUBLIC SAFETY
BRU: Highway Safety Planning Agency
Components:

EXPENDITURES/REVENUES: (Thousands of Dollars)

OPERATING	FY 87	FY 88	FY 89	FY 90	FY 91	FY 92
PERSONAL SERVICES						
TRAVEL						
CONTRACTUAL						
SUPPLIES						
EQUIPMENT						
LAND & STRUCTURES						
GRANTS, CLAIMS						
MISCELLANEOUS						
TOTAL OPERATING		0	0	0	0	0
CAPITAL						
REVENUE						

FUNDING:: (Thousands of Dollars)

	FY 87	FY 88	FY 89	FY 90	FY 91	FY 92
GENERAL FUNDS		0	0	0	0	0
FEDERAL FUNDS						
OTHER						
TOTAL		0	0	0	0	0

POSITIONS:

	FY 87	FY 88	FY 89	FY 90	FY 91	FY 92
FULL-TIME						
PART-TIME						
TEMPORARY						

ANALYSIS: (Attach a separate page if necessary)

No fiscal impact is anticipated. Amendment reduces the maximum fine for violation of the child restraint law from $300 to $15 and changes it from primary to secondary enforcement. This negative revenue impact will be offset by fines collected for violation of the adult use provision.

Prepared by: Ellen Moore, Program Coordinatory   Phone: 465-4375
Division: Highway Safety Planning Agency   Date: 3/23/87

Approved by Commissioner: [signature]   Date: 3/23/87
Agency: Public Safety

Distribution (by preparer):
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- Senate Secretary

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LETTERS

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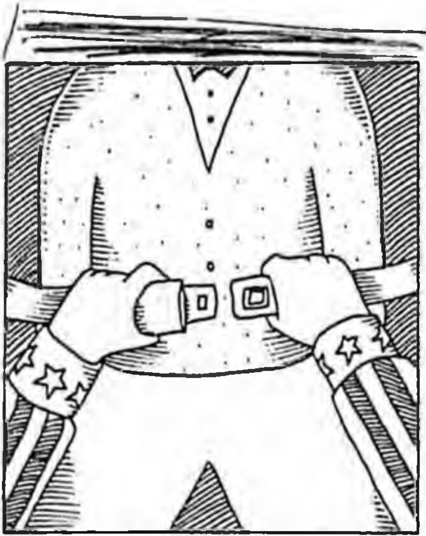

Seat Belts and Safety

Thomas B. Darr's use of New York statistics on the seat belt law (January, p. 54) is not indicative of the results of seat belt legislation.

Darr notes a decrease in fatalities from 1981, "the year before several traffic safety programs took effect." Improvements in roads, cars, tires and medical techniques leading to increased survival tend to produce a decline every year. As for the seat belt law, National Highway Traffic Safety Administration figures show 2,060 fatalities in New York state in 1984 and 2,003 in 1985, when the law was being enforced, a decrease of 2.8 percent. Three-fourths of this decrease occurred in March, a month that was devoid of bad weather conditions.

Seat belt laws have never reduced fatalities in warm-weather situations. New York's April-December fatalities *rose* in the first year of the law. Illinois' law, which took effect in July 1985, also saw an increase in fatalities. California saw an increase in fatalities both after passage of a child restraint law and after enactment of the adult seat belt law.

If traffic deaths in New York state increased from 2,060 in 1984 to 2,114 in 1986, the seat belt law could not possibly have saved 225 lives a year.

Joe Naiman
Political Consultant/Lobbyist
San Diego

Primary Agenda

I want to congratulate you on a very fine publication, but I want to make a correction to the article on the 1987 mayoral elections in the December issue (p. 27).

The article said that in last May's Gary, Indiana, mayoral primary campaign, I accused my opponent, incumbent Mayor Richard Hatcher, "of pursuing a national agenda while ignoring Gary's problems." I think it would be more correct to say that in my campaign I referred to my opponent's pursuing a personal agenda on a national level and not paying adequate attention to the concerns of Gary's constituency.

My concern was not that my opponent had a national agenda, which I perceive as entirely proper so long as the purpose of that agenda is the elevation of the primary agenda — the city of Gary.

Thomas V. Barnes
Mayor
Gary, Indiana

Sorry State

So this is the 21-year-old dream of Idaho Gov. Cecil Andrus — to kill a mountain goat! (December, People, p. 65.) What a pathetic individual! And what a sorry state to elect him as governor.

Thank you, GOVERNING, for your enlightening piece of journalistic nonsense. Let's try to put the People spotlight on those who deserve our attention, not our pity.

Janine Stanley-Dunham
Member
People for the Ethical Treatment of Animals
Nyack, New York

Who's Weak?

I look forward to reading your magazine every month. I was especially interested in Jane Mobley's article on city managers in the February issue (p. 42).

However, after having spent the past 33 years in the city management profession, I was surprised to learn that I have been operating in what Mobley refers to as the "weak-mayor" form of government. I always thought that "weak-mayor" referred to the authority of the mayor as compared to that of the council.

There is mayor-council government, which may be strong-mayor or weak-mayor, but neither, in my opinion, refers to council-manager government.

Warren B. Browning
City Manager
Centralia, Illinois

Dronelike Solution

What I see beneath Irvine, California, Mayor Larry Agran's manifesto ("Local Officials Should Speak Out on Foreign Policy," December Commentary, p. 74) is simply the mayor of another small city who has rationalized his way out of grabbing the bull by the horns and raising taxes. His dronelike solution is to reduce defense spending so his town can lap up more of the federal honey, and at the same time he slaps his benefactor in the face.

I wonder if he's been able to take time out from his attempts to establish foreign policy independent of our nationally elected bodies to investigate existing programs such as Community Development Block Grants and Urban Development Action Grants.

If Irvine has problems in these areas and can come up with practical solutions involving the use of some local funds, the federal government will give a lot of assistance. Our little town of Nacogdoches (population 28,000) has received more than $8 million in these funds in the past nine years.

Fred Bussa
Chief Building Official
Nacogdoches, Texas

Letters should be addressed to Letters to the Editor, GOVERNING, 1414 22nd St. N.W., Washington, D.C. 20037, and should include the writer's telephone number. Letters are subject to editing.

Randy Lyhus illustration

From Rep Adams

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Property tax rises more slowly than personal income

Property tax revenue rose more slowly than personal income in all but five states between fiscal years 1978 and 1986. The biggest decreases in property tax revenue per $100 of personal income were in the two states where the biggest Tax Revolt uprisings occurred--California (down 54.9 percent) and Massachusetts (down 48.7 percent). For the entire country, the proportion of personal income going for property tax payments fell 22.8 percent, according to U.S. Census Bureau reports. Other taxes also decreased as a proportion of personal income during these years, but at a much slower rate, decreasing just 5.7 percent.

Bizarre twist: 60 mph is illegal while 75 isn't?

Twelve states that have kept the 55 mph speed limit could lose millions of dollars in highway funds if too many of their drivers exceed that limit, but in the 38 states that have raised their limits (on certain highways) to 65 mph, no federal penalty applies for not observing the higher limit. The states that have not raised the limits are Alaska, Connecticut, Delaware, Georgia, Hawaii, Maryland, Massachusetts, New York, New Jersey, Pennsylvania, Rhode Island and Virginia. "So the way it works out," a New York transportation official told The New York Times, "we could be penalized because too many cars in the state have been clocked at 60 miles an hour. Vermont would incur no penalties even if traffic there was going at 70, 75, 100 or the speed of sound. It's crazy."

New study finds seat-belt laws get mixed results

A new study on the use of automobile seat belts found wide variations among the 24 states examined, in both the frequency of seat belt use and the success of laws requiring them. Deaths among front-seat occupants actually increased in three states (Missouri, Nebraska and North Carolina) where such laws were enacted. Of the 31 states that have imposed mandatory seat belt use, Massachusetts and Nebraska have since repealed their laws. The study said 52 percent of motorists still do not buckle up. While the belt use rate exceeds 60 percent in a half-dozen states, it is far below that in many others, with a low of 22 percent in Utah. Enforcement also varies widely, ranging from fewer than 50 tickets issued per 100,000 population in Idaho and Illinois to more than 840 tickets per 100,000 in Ohio and Hawaii.

California raises minimum wage to $4.25, nation's top

Effective July 1, California's minimum wage will rise to $4.25, highest in the nation. Connecticut's rate will also increase to $4.25 next October. Six other states and the District of Columbia have raised the rate above the federal level of $3.35. They are Alaska, Maine, Massachusetts, New Hampshire, Rhode Island and Vermont. In a national survey conducted by NCSL, at least 15 states indicated they would be reviewing their minimum wage rates this year.

870486

Fatality and Injury Reducing Effectiveness of Lap Belts for Back Seat Occupants

Charles J. Kahane
National Highway Traffic Safety Administration

ABSTRACT

The fatality and injury reducing effectiveness of lap belts for back seat occupants is estimated by applying the double pair comparison method to 1975-86 Fatal Accident Reporting System and 1982-85 Pennsylvania accident data. Lap belts significantly reduce the risk of fatalities by 17-26 percent, serious injuries by 37 percent, moderate to serious injuries by 33 percent and injuries of any severity by 11 percent, relative to the unrestrained back seat occupant. Lap belts are primarily effective in nonfrontal crashes because the unrestrained back seat occupant is already well protected in frontals. Lap belted occupants have lower head injury risk but higher torso injury risk than unrestrained back seat occupants.

This paper presents the views of the author and not necessarily those of the National Highway Traffic Safety Administration (NHTSA).

USAGE OF LAP BELTS IN THE BACK SEAT has increased in recent years (1)*. The safety community has focused on crash protection for back seat occupants. Specifically, a report by the National Transportation Safety Board (2), based on selected in-depth investigations of frontal crashes, suggested that lap belts may offer little or no improvement over being unrestrained in the back seat and may actually increase the risk of abdominal injuries. The NTSB report did not estimate the overall effectiveness of lap belts because, indeed, it is difficult to derive effectiveness estimates from a small selected sample of case histories. Statistical analysis of large, representative accident samples is the best approach, but in past years there was never a large enough sample of lap belted back seat occupants available for a meaningful analysis. Now, thanks to the recent usage increases and the gradual accumulation of data in NHTSA files, adequate samples have become available.

The Fatal Accident Reporting System (FARS) for 1975-86 contains records of nearly 500 rear seat occupants age 5 or older who wore lap belts and were fatally injured. It is by far the best source of data for an analysis of fatality reduction by lap belts in the back seat. "Double pair comparison" is an appropriate procedure for analyzing effectiveness in FARS (3). Fatality risk of back seat occupants is measured relative to drivers in the same crash. The technique has two important advantages over the "conventional" approach of calculating and comparing the casualty rates per 100 crash involved back seat occupants, with and without belts. First, the conventional approach cannot even be used with FARS, since calculation of unbiased casualty rates requires nonfatal as well as fatal crashes. Second, double pair comparison more or less eliminates the need to "control" the data for differences in the severity of crashes involving belted and unrestrained populations - the comparison with drivers in the same crashes automatically controls the data to a large extent.

Pennsylvania accident files for 1982-85 contain records of over 2000 back seat occupants age 5 or older who wore lap belts and were injured, nearly 400 of them with moderate or serious injuries. Pennsylvania data are well suited for the analysis, since they have a record for every occupant, injured or uninjured. The record contains information on belt usage, the car's impact location and,

* Numbers in parentheses designate References at end of paper.

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best of all, a detailed description of the person's most severe injury including the customary police rating scale ("A" for serious, "B" for moderate and "C" for minor), the body region and the type of lesion. Double pair comparison can be used with Pennsylvania data just like on FARS. Although the conventional approach could also have been used with State data, double pair comparison eliminates many of the potential biases due belted occupants being in less severe crashes, etc.

With FARS and Pennsylvania data, it is possible to estimate the overall fatality and injury reducing effectiveness of lap belts for back seat occupants and develop confidence bounds for the estimates. Effectiveness can also be calculated, in the case of nonfatal injuries, by injury location (head, torso, etc.).

FATALITY REDUCTION: ANALYSES OF FARS DATA

The double pair comparison procedure requires a data format in which each record contains information on two occupants: a person who sat in the back seat and the driver of that vehicle. The drivers essentially act as a control group. First, the records of all back seat occupants, age 5 or more, excluding motorcycle riders, were extracted from the 11 complete years of FARS data, 1975 through 1985, and from those 1986 FARS cases which were available for analysis at NHTSA as of November 1986. Next, the driver's restraint usage and injury severity was appended to the back seat occupant's record. Cases in which either the driver's or the passenger's restraint usage was "unknown" were discarded. So were cases in which neither the driver nor the back seat occupant was killed (and the case is in the FARS because a fatality happened at another seat position, or in another vehicle, or to a pedestrian, etc.). The remaining cases were recoded according to four dichotomous variables: passenger dead or alive, passenger restrained (almost all lap belts) or unrestrained, driver dead or alive, driver restrained (about 85 percent lap/shoulder belts and 15 percent lap belts, for cars on the road during 1975-86) or unrestrained. The data file used here differs principally from those analyzed by Evans (4) in that it includes 1986 FARS cases, plus center rear seat occupants, plus children between the ages of 5 and 15, plus persons riding in the second seat of a van or other light truck equipped with such a seat. The objective here has been to include all persons, other than toddlers, who wear belts in the back seat. Another minor difference from Evans' approach is that only drivers are used as a control group, not right front passengers, etc. It is a statistically more straightforward approach, since each back seat occupant case is used just once in the analysis.

Thus, for each back seat occupant on FARS, it is possible to compare that person's survival and restraint use with the driver's. The individual comparisons can be summarized in tabular form, as in the following example where both driver and passenger were unrestrained and at least one of them was killed:

N of FARS Cases	
Driver died, passenger survived	17,255
Passenger died, driver survived	10,616
Both died	5,261

Thus, there was a total of 10,616 + 5,261 = 15,877 back seat passengers who died in those crashes; 17,255 + 5,261 = 22,516 drivers died. The risk factor for unrestrained back seat passengers relative to unrestrained drivers is 15,877/22,516 = 0.7051 - i.e., the unrestrained back seat passenger has 29 percent lower fatality risk than the unrestrained driver in the same crash.

For lap belted back seat passengers accompanied by unrestrained drivers, the comparable FARS statistics are:

Driver died, passenger survived	176
Passenger died, driver survived	70
Both died	35

Here, 70 + 35 = 105 passengers and 176 + 35 = 211 drivers died; the risk factor for lap belted back seat passengers relative to unrestrained drivers is 105/211 = 0.498. With the plausible assumption that the two control groups of unrestrained drivers are subject to about equal risk, the probability of fatality is 1 - (0.498/0.705) = 29 percent lower for lap belted passengers than for unrestrained passengers in the back seat.

OVERALL EFFECTIVENESS - Table 1 recapitulates the preceding calculation and carries out another, this time using restrained drivers as the control group for both the unrestrained and restrained rear seat passengers. With this control group, lap belted rear seat passengers have 13 percent lower fatality risk than the unrestrained rear seat passengers. Since the calculation with this control group is based on a sample of 377 belted back seat fatalities, while the preceding one was based on only 105 fatalities, it should be given proportionately greater weight. The weighted average of the two fatality reduction estimates (based on the formula at the bottom of Table 1) is 17 percent - the 1975-86 FARS estimate of the effect of lap belts for all back seat passengers age 5 or above. (The difference in the estimates based on the two control groups - 29 vs. 13 percent - is well within the "noise" range and does not indicate that either estimate is biased. In one of the three Pennsylvania analyses - see Table 4 - the

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reductions are counterintuitive and suggest that the conventional approach, when applied to State data, is biased by differences in the accident severities of belted and unrestrained persons, etc.

OVERALL EFFECTIVENESS - BASED ON DOUBLE PAIR COMPARISON - Table 4 shows the results of three separate analyses, for serious (including fatal), moderate to serious, and overall injury risk, carried out in exactly the same way as was done with the FARS data. The resulting effectiveness estimates are each just over half as large as those produced by the "conventional" method.

The upper section of Table 4 applies to serious and fatal injuries. The available data are rather sparse, with a total of 51 lap belted back seat occupants who were seriously injured. When unrestrained drivers are the control group, lap belted back seat occupants have 20 percent lower injury risk than unrestrained back seat passengers. With belted drivers as the control group, the reduction is 43 percent. The weighted average effectiveness is 37 percent - the serious injury reduction for a lap belted vs. an unrestrained back seat occupant.

Likewise, Table 4 shows that lap belts reduce moderate-to-serious injuries by 33 percent and overall injury risk by 11 percent. These findings are consistent with intuition and the FARS results (17-26% fatality reduction). Belts typically are more effective in reducing serious injuries than fatalities or minor injuries (6).

When effectiveness is estimated separately from each individual calendar year of Pennsylvania data, there is no obvious trend of the type seen in FARS:

Pennsylvania Calendar Year	Back Seat Lap Belt Effectiveness (%)		
	Serious	Moderate	Overall
1982	9	17	1
1983	-5	31	12
1984	61	31	15
1985	46	39	10

CONFIDENCE BOUNDS FOR EFFECTIVENESS - The Pennsylvania analysis file was split into 10 systematic random subsamples in order to calculate variances, just as was done with FARS. In the analysis of serious injuries, the standard deviation of effectiveness for the full sample, based on the variation of the subsample estimates, is 7.2 percent. A 90 percent confidence interval for effectiveness is obtained by taking 1.833 standard deviations on either side of the point estimate of 37 percent derived in Table 4 (since 1.833 is the 95th percentile of the t distribution with 9 df). Thus the confidence bounds for effectiveness are 23 to 51 percent.

For moderate-to-serious injuries, the standard deviation of effectiveness is 3.5 percent. The point estimate in Table 4 is 33 percent and its confidence bounds are 26 to 40 percent. In the analysis of overall injury risk, the standard deviation of effectiveness is 2.0 percent. The point estimate in Table 4 is 11 percent and its confidence bounds are 7 to 15 percent. In other words, the Pennsylvania data support a conclusion that lap belts are effective in reducing the injury risk of back seat occupants at all severity levels.

EFFECTIVENESS BY INJURY LOCATION - An important conclusion of the NTSB report (2) was that lap belts might be ineffective or increase the risk of abdominal injuries of back seat occupants. The Pennsylvania data indicate the body region of an occupant's most severe injury. The double pair comparison analyses of Table 4 were carried out separately for each four major body regions (by counting back seat occupants and drivers as "injured" only if their injury was in that particular region). Since Pennsylvania does not have separate codes for thorax and abdomen, they had to be analyzed as a single region, the "torso."

Body Region	Back Seat Lap Belt Effectiveness (%)		
	Serious	Moderate	Overall
Head	63	31	4
Torso	-86	-16	-21
Neck/back	49	39	16
Arm/leg	55	58	28

The Pennsylvania data are consistent with NTSB's conclusion, showing an increase in torso injuries at all severity levels for lap belted vs. unrestrained back seat occupants. But in these data which include crashes of all impact modes, lap belts were effective in reducing head, neck, back and, especially, arm and leg injuries.

FRONTAL VS. OTHER CRASHES - In comparison to the unrestrained back seat occupant, lap belts are more effective in nonfrontal than in frontal crashes, except at the minor injury level:

Back Seat Lap Belt vs. Back Seat Unrestr. Injury Reduction (%)			
	Serious	Moderate	Overall
Frontals	17	25	10
Nonfrontals	55	42	11

The principal reason that lap belts are not as

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TABLE 4

PENNSYLVANIA 1982-85: BACK SEAT OCCUPANTS AGE 5 OR MORE
LAP BELT EFFECTIVENESS BASED ON DOUBLE PAIR COMPARISON

SERIOUS OR FATAL INJURIES

Back Seat Restr. Use	Back Seat Fatalities	Unrestrained Driver Fats.	Risk Factor	Lap Belt Fat Red.
Unrestrained	937	1,184	0.791	
Lap belts	19	30	0.633	20%
		Belted Driver Fats.		
Unrestrained	84	57	1.474	
Lap belts	42	50	0.840	43%

Average injury reduction for lap belted vs. unrestrained back seat occ.:

$$1 - \left[\frac{19 + 42}{19(0.791/0.633) + 42(1.474/0.840)}\right] = 37 \text{ percent}$$

MODERATE, SERIOUS OR FATAL INJURIES

Back Seat Restr. Use	Back Seat Fatalities	Unrestrained Driver Fats.	Risk Factor	Lap Belt Fat Red.
Unrestrained	4,706	5,780	0.814	
Lap belts	80	161	0.497	39%
		Belted Driver Fats.		
Unrestrained	397	307	1.293	
Lap belts	313	353	0.887	31%

Average injury reduction for lap belted vs. unrestrained back seat occ.:

$$1 - \left[\frac{80 + 313}{80(0.814/0.497) + 313(1.293/0.887)}\right] = 33 \text{ percent}$$

ALL INJURIES

Back Seat Restr. Use	Back Seat Fatalities	Unrestrained Driver Fats.	Risk Factor	Lap Belt Fat Red.
Unrestrained	17,212	17,916	0.961	
Lap belts	494	637	0.776	19%
		Belted Driver Fats.		
Unrestrained	1,703	1,486	1.146	
Lap belts	1,806	1,719	1.051	8%

Average injury reduction for lap belted vs. unrestrained back seat occ.:

$$1 - \left[\frac{494 + 1806}{494(0.961/0.776) + 1806(1.146/1.051)}\right] = 11 \text{ percent}$$

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effective in frontal crashes, however, is that even unrestrained back seat occupants have lower injury risk than unrestrained drivers, due to the relatively safe environment which the rear passenger compartment offers in those crashes. But the back seat has no safety advantage in the nonfrontal crashes:

Back Seat Unrestr. vs. Unrestrained Driver
Injury Reduction (%)

	Serious	Moderate	Overall
Frontals	34	30	11
Nonfrontals	none	1	-4

If the injury risk of lap belted back seat occupants is compared to unrestrained drivers rather than unrestrained back seat passengers, there would be little difference between frontal and nonfrontal crashes:

Back Seat Lap Belt vs. Unrestrained Driver
Injury Reduction (%)

	Serious	Moderate	Overall
Frontals	45	48	20
Nonfrontals	55	43	7

What it all adds up to is that a back seat occupant wearing a lap belt may be as safe or safer than a driver wearing lap/shoulder belts:

Back Seat Lap Belt vs. Driver Lap/Sh. Belt
Injury Reduction (%)

	Serious	Moderate	Overall
Frontals	none	20	none
Nonfrontals	35	3	-9

CONCLUSIONS

1. Lap belts significantly reduce the overall fatality risk of back seat occupants.
2. Lap belts significantly reduce the injury risk of back seat occupants at every level of injury severity.
3. Lap belted and unrestrained back seat occupants have about the same fatality risk in frontal crashes. That is because the back seat area protects even unrestrained occupants well in comparison to an unrestrained driver.
4. In frontal crashes, lap belted and unrestrained back seat occupants are about as safe as drivers wearing lap and shoulder belts.
5. In nonfrontal crashes, lap belted occupants are substantially safer than unrestrained back seat passengers.
6. For all crash modes combined, lap belts appear to increase the risk of torso injuries but substantially reduce injury risk for all other body regions.
7. Double pair comparison is a satisfactory method for measuring the injury reduction of belts in State data, provided that the State encodes records of every occupant of a crash involved vehicle.

REFERENCES

1. Goryl, M.E., "Restraint System Usage in the Traffic Population." National Highway Traffic Safety Administration, Report No. DOT HS 806 987, 1986.
2. "Safety Study - Performance of Lap Belts in 26 Frontal Crashes." National Transportation Safety Board, Report No. PB86-917006, 1986.
3. Evans, L., "Double Pair Comparison - A New Method to Determine How Occupant Characteristics Affect Fatality Risk in Traffic Crashes." Accident Analysis and Prevention, Volume 18, June 1986.
4. Evans, L., "Rear Compared to Front Seat Restraint System Effectiveness." SAE International Congress, Detroit, 1987.
5. Kahane, C.J., "An Evaluation of Child Passenger Safety: The Effectiveness and Benefits of Safety Seats." National Highway Traffic Safety Administration, Report No. DOT HS 806 890, 1986.
6. "Final Regulatory Impact Analysis - Amendment to Federal Motor Vehicle Safety Standard 208 - Passenger Car Front Seat Occupant Protection." National Highway Traffic Safety Administration, Report No. DOT HS 806 572, 1984.

FROM 04/29/88 14:42 P. 3 TOTAL P. 3

TABLE 1

FARS 1975-86: BACK SEAT OCCUPANTS AGE 5 OR MORE LAP BELT EFFECTIVENESS

Back Seat Restr. Use	Back Seat Fatalities	Unrestrained Driver Fats.	Risk Factor	Lap Belt Fat Red.
Unrestrained	15,877	22,516	0.705	
Lap belts	105	211	0.498	29%
		Belted Driver Fats.		
Unrestrained	858	707	1.214	
Lap belts	377	356	1.059	13%

Average fatality reduction for lap belted vs. unrestrained back seat occupant:

$$1 - \left[\frac{105 + 377}{105(0.705/0.498) + 377(1.214/1.059)}\right] = 17 \text{ percent}$$

Fatality reduction for unrestrained back seat occupant relative to unrestrained driver:

1 - 0.7051 = 29 percent

TABLE 2

FARS 1983-86: BACK SEAT OCCUPANTS AGE 5 OR MORE LAP BELT EFFECTIVENESS

Back Seat Restr. Use	Back Seat Fatalities	Unrestrained Driver Fats.	Risk Factor	Lap Belt Fat Red.
Unrestrained	4,246	6,115	0.694	
Lap belts	56	145	0.386	44%
		Belted Driver Fats.		
Unrestrained	486	336	1.446	
Lap belts	241	207	1.164	20%

Average fatality reduction for lap belted vs. unrestrained back seat occupant:

$$1 - \left[\frac{56 + 241}{56(.694/.386)41 + 241(1.446/1.164)}\right] = 26 \text{ percent}$$

FROM 04/29/88 17:28 P. 1

difference is in the opposite direction.)

The last line of data in Table 1 shows that there were 377 back seat passenger fatalities and 356 driver fatalities in the vehicles where both the driver and the back seat passenger were belted. In other words, a lap/shoulder belted driver is slightly safer than a lap belted back seat passenger.

One important caveat with the FARS analysis is that back seat lap belt usage may have been underreported in the earlier years of FARS. In those years, so few back seat occupants were belted that their belt usage may often have gone unnoticed or unreported, except when they were killed in the crash. The same phenomenon unquestionably occurred with child safety seats, as described in Chapter 4 of NHTSA's evaluation (5). The result of that type of underreporting would be to bias effectiveness estimates against the restraint system. The possibility of biases can be investigated by performing the analysis described in Table 1 separately for each individual year of FARS. The effectiveness estimates are:

FARS Calendar Year	Back Seat Lap Belt Effectiveness (%)
1975	-9
1976	+4
1977	+30
1978	+20
1979	-42
1980	+24
1981	-5
1982	-4
1983	+31
1984	+22
1985	+27
1986 (partial)	+23

Note that the estimate is negative in 4 of the first 8 years of FARS but is better than 20 percent in each of the last 4. Since the first 8 years of FARS do contain 4 positive estimates (unlike the situation with child restraints, where estimates were always negative in the earlier years), it is not clear whether the year to year pattern shown above is due to underreporting of survivors' lap belt usage in the earlier years or is merely a coincidence.

Table 2, which is based only on FARS calendar years 1983-86, indicates a 26 percent fatality reduction for lap belts in the back seat. The effectiveness estimate based on calendar years 1975-82 alone is 6 percent.

CONFIDENCE BOUNDS FOR EFFECTIVENESS - A straightforward, empirical approach for assessing the precision of the effectiveness estimates is to split the FARS data into 10 systematic random subsamples, calculate effectiveness separately for each of the subsamples and note the variation in the estimates. Since the full sample is 10 times as large as the subsamples, the confidence bounds for the full sample estimate equals the bounds for the subsample estimates divided by the square root of 10. (The splitting of FARS is accomplished by numbering the cases consecutively and assigning them to subsamples based on the last digit of the case number.)

For the 1975-86 FARS data analyzed in Table 1, the standard deviation of effectiveness for the full sample, based on the variation of the subsample estimates, is 7.6 percent. A 90 percent confidence interval for effectiveness is obtained by taking 1.833 standard deviations on either side of the point estimate of 17 percent derived in Table 1 (since 1.833 is the 95th percentile of the t distribution with 9 df). Thus the confidence bounds for effectiveness are 3 to 31 percent.

For the 1983-86 FARS data analyzed in Table 2, the standard deviation of effectiveness is 5.7 percent. The point estimate in Table 2 is 26 percent and its confidence bounds are 15 to 37 percent. In other words, the FARS data support a conclusion that lap belts are effective in reducing overall fatality risk of back seat occupants.

FRONTAL VS. OTHER CRASHES - The principal conclusion of the NTSB report (2) was that lap belts might not reduce fatality risk in frontal crashes. The FARS data show that a lap belted back seat occupant in a frontal crash, although not necessarily safer than an unrestrained back seat occupant, is much safer than an unrestrained driver. Meanwhile, in nonfrontal crashes, lap belts are quite effective. If separate double pair comparison analyses are performed for frontal crashes (based on the principal impact site reported in FARS) and for nonfrontal crashes, the following estimates are obtained:

Fatality Reduction (%)	1975-86	1983-86
Frontals	-8	+1
Nonfrontals	+34	+43

Effectiveness in frontal crashes is close to zero when, as is customarily done, the fatality risk for lap belted rear seat occupants is compared to <u>unrestrained rear seat occupants</u>. But a <u>different picture emerges when</u> either of these groups is compared to the drivers of the same vehicles.

Fatality Reduction, 1983-86 FARS Frontals (%)	
Back seat lap vs. back seat unr.	+1
vs. unrestrained driver	+46
vs. lap/sh. belted driver	+10
Back seat unr. vs. unr. driver.	+45
vs. lap sh. belted driver	+9

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A lap belted back seat occupant is much safer than a front seat occupant, even in frontal crashes. But in frontal crashes, sitting unrestrained in the back seat also is a great improvement over being in the front seat. In fact, it is such a great improvement that the lap belted back seat occupant is no better off than the unrestrained back seat occupant, even though both are far better off than the unrestrained front seat occupant and, actually, might be safer than the lap/shoulder belted front seat occupant.

Another way to describe this is to say that the back seat is a relatively benign environment in frontal crashes and the unrestrained back seat occupant is as safe or safer than a lap/shoulder belted driver or lap belted back seat occupant.

In nonfrontal crashes, on the other hand, the unrestrained back seat occupant is only 16 percent safer than the unrestrained driver and at much greater risk than the restrained driver. The lap belt, which is especially valuable in nonfrontal crashes because it can prevent occupant ejection, offers a 43 percent improvement over being unrestrained in the back seat.

INJURY REDUCTION: PENNSYLVANIA DATA

Data formatting with the Pennsylvania files is almost identical to FARS. Records of all back seat occupants age 5 or more, excluding motorcycle riders, were extracted from 4 complete years of Pennsylvania data, 1982-85. Lap belt usage in the back seat increased steadily during that time, from 7 percent in 1982 to 23 percent in 1985. Injury severity was recoded as serious (police reported category "A" or fatal), moderate ("B"), minor ("C") or none. Injury body region was recoded as head (including face), torso ("chest/stomach" and "internal"), neck/back or arm/leg. Next, the driver's restraint usage and injury data was appended to the back seat occupant's record. Cases in which either the driver's or the passenger's restraint usage was "unknown" were discarded. Pennsylvania does not distinguish between lap and lap/shoulder belts for back seat occupants; however, over 99 percent of the cars on the road in 1982-85 had only lap belts in the rear seat.

"CONVENTIONAL" ANALYSIS - Before any of the cases with uninjured persons was discarded, simple injury rates were calculated in the "conventional" manner on the full 1982-85 data file. Table 3 shows, for example, that 1.82 percent of unrestrained back seat occupants had serious injuries as compared to only 0.67 percent of lap belted occupants: a "reduction" of 63 percent. Similarly, Table 3 shows that lap belted occupants had a 51 percent lower moderate to serious injury rate and a 21 percent lower overall injury rate. Such large

TABLE 3

PENNSYLVANIA 1982-85: BACK SEAT OCCUPANTS AGE 5 OR MORE
LAP BELT "EFFECTIVENESS" BASED ON CONVENTIONAL INJURY RATES

	N of Back Seat Occupants	n of Injuries	Injury Rate (%)	Reduction Rel. to Unrestrained (%)
SERIOUS OR FATAL INJURIES				
Unrestrained	57,560	1,048	1.82	
Lap belts	9,056	61	0.67	63
MODERATE, SERIOUS OR FATAL INJURIES				
Unrestrained	57,560	5,331	9.26	
Lap belts	9,056	412	4.55	51
ALL INJURIES				
Unrestrained	57,560	19,673	34.18	
Lap belts	9,056	2,445	27.00	21

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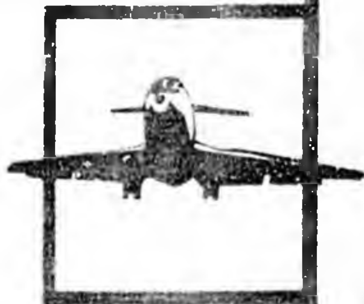

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NATIONAL TRANSPORTATION SAFETY BOARD

WASHINGTON, D.C. 20594

SAFETY STUDY

PERFORMANCE OF LAP BELTS IN 26 FRONTAL CRASHES

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16. Abstract

This study reports on the performance of lap belts in 26 frontal crashes of passenger vehicles investigated by the Safety Board. The report discusses the Board's findings, selected lap belt cases, statistical estimates of seat belt effectiveness, related research on lap belt performance, and Federal regulations and manufacturers' practices on motor vehicle seat belts. The report concludes with recommendations to U.S. and foreign manufacturers of passenger vehicles, to the National Highway Traffic Safety Administration, to the International Chiefs of Police, and to associations and groups concerned with emergency medicine.

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NATIONAL TRANSPORTATION SAFETY BOARD
WASHINGTON, D.C.

SAFETY STUDY

Adopted: July 28, 1986

PERFORMANCE OF LAP BELTS IN 26 FRONTAL CRASHES

INTRODUCTION

For many years, the National Transportation Safety Board has supported efforts to increase the use of seat belts to protect motorists from severe injury or death in crashes. More recently, however, the Safety Board has felt that it would be useful to undertake a special crash investigation program focused on accidents involving the use of seat belts to learn more about their performance. This view was based on a number of facts. First, the manual belt systems in motor vehicles today are not required to be dynamically tested for crash protection performance (those requirements are limited to passive systems, such as passive belts or airbags). Second, data on real-world performance of belt systems are limited. Furthermore, there have been basic changes in vehicle designs over the years that could affect the performance of belt systems designed for vehicles of the 1970's. For example, there was concern that, with the "downsizing" of automobiles, the ability of seat belts to provide crash protection might be diminished. In vehicles with less distance between front seat occupants and frontal interior surfaces, for instance, such problems as excessive spool-out of the upper torso restraint in lap/shoulder belts might permit injurious contact between the occupant and the interior surfaces, despite use of the belt.

Therefore, in the fall of 1984, the Safety Board embarked on a program to investigate approximately 200 crashes in which the crash performance of seat belts would be thoroughly examined. The criteria for investigating a crash were:

- -- Case vehicle must be post-1974 model car, light truck, or van;
- -- At least one occupant in the case vehicle must have been using a seat belt 1/;
- -- The crash must have been of sufficient severity to require that the case vehicle be towed from the scene 2/; and
- -- The crash must not have been so severe for the case vehicle as to be deemed unsurvivable for its belted occupant(s). 3/

1/ Before the program was completed, it was decided to investigate a few cases in which no occupants were restrained, for comparison purposes.

2/ As the program progressed, it was found that, for a wide variety of reasons, vehicles may be towed even though they are essentially undamaged. Since in these cases the "crash" was extremely minor and seat belts could not be expected to affect the outcome, these particular towaway cases were not followed up.

3/ That is, there must have been sufficient space after the crash at the seating locations of the belted occupants to permit survival.

The Safety Board's investigators were alerted to potential cases for the study in a number of ways. The Board's highway field investigators, trained in the techniques of investigating crashes involving restrained occupants, are located in eight cities: Atlanta, Chicago, Denver, Fort Worth, Kansas City (Missouri), Los Angeles, New York, and Seattle. At the beginning of the program, each of these field offices arranged an accident notification scheme, involving a network of law enforcement and medical authorities in the multistate region surrounding the Board field office. These authorities agreed to notify the Board investigators of any crash meeting the Board's criteria as soon as they became aware of it. Upon notification, Board investigators would go to the accident location, explore the facts sufficiently to determine that the crash in fact met the selection criteria, and if so, begin a detailed examination to establish all the relevant facts.

A careful examination of the case vehicle was carried out in each crash investigation, documenting its "vital statistics" and information about the restraint system available to each occupant. The size, weight, and seating location of each occupant was determined. For each occupant, the investigator determined whether the available seat belt was used, whether it was used correctly, the nature and severity of each injury sustained (expressed in terms of the Abbreviated Injury Scale (AIS)), and the probable source of each injury. Necessary measurements were made that permitted the Safety Board to estimate the collision severity in terms of the velocity change ("Delta V") experienced by the case vehicle. Based on these data, an analysis could be made of the performance of each belt system in use during the crash, and some overall conclusions drawn about the role of belt restraint systems in the crashes studied.

After about a quarter of the investigations had been initiated, several cases involving lap belted rear seat occupants began to draw the Safety Board's attention to these belt systems in particular. For example, in one case involving a rather moderate collision (Delta V 25.7 mph), the lap/shoulder belted front seat occupants sustained no injuries, while the lap belted left rear seat occupant sustained three critical intra-abdominal injuries, two severe intra-abdominal injuries, five serious intra-abdominal injuries, one serious hip injury, one moderate intra-abdominal injury, and three moderate hip injuries--all induced by the lap belt itself. This man died after 39 hours in the intensive care unit.

Despite the concern about the apparent poor performance of the lap-only belt in several early cases, the accident notification criteria were not changed. However, after several more cases turned up involving rear seat lap belts, it was decided to alert the field investigators to look especially carefully at potential cases involving occupants restrained in the rear seat (as distinct from the earlier, more general criterion of "at least one occupant in the vehicle using a seat belt").

In all, the Safety Board was notified of 26 accident cases involving lap belt restrained occupants that also met the other notification criteria established for the program. This report presents findings on the performance of the seat belts used in these 26 cases--50 lap-only belts, 32 lap/shoulder belts--and on the experience of the 57 unrestrained occupants in these cases and in 3 other cases involving only unrestrained occupants, studied for comparison purposes. In addition, one case involving front and rear seat occupants, all using lap/shoulder belts, was studied, again for purposes of comparison.

It is important to remember that this study is limited in two important respects. First, the crashes examined here (with one exception) are all frontal crashes. Results derived from analysis of frontal collisions cannot be applied to other crash configurations.

The benefits that may be derived from lap belt use (compared to no restraint) in minimizing the possibility of ejection during rollover or side impact cannot be discovered through analyzing frontal collisions. Second, the small size of the sample in this study means that no statistically valid conclusions can be drawn from it. The Safety Board's study is a case study which emphasizes the collection of accurate, complete data on a number of specific points relevant to the question of belt performance.

The report begins with an overview of the findings of the lap belt crash investigation program. This overview is followed by brief summaries of several illustrative cases and discussion of their significance. The next section discusses the reasons why large-scale databases have been inappropriate for assessing seat belt effectiveness. A chapter describing what has been known about lap belts and lap/shoulder belts since their use began in the 1960's is next, including knowledge of the special problems in diagnosing and treating lap belt injured persons. The relationship of the Federal Motor Vehicle Safety Standards to lap belt and lap/shoulder belt installation is covered in the next section. The final section presents several recommendations for improving occupant restraint systems and recommendations for improving the handling of persons injured in motor vehicle crashes while wearing a seat belt.

Several appendices follow the report, the first being a presentation, in brief format, of all the study cases, describing the facts of each case and discussing the Safety Board's interpretation of these facts. Other appendices present additional cases from other sources of lap belt injured persons; a glossary; discussions of "Delta V" and the use of the AIS; anatomical drawings to assist in understanding the nature of the injuries described in this report; a chronology of selected events related to seat belts since their early development; and a number of tables depicting various findings from the Board's lap belt case investigations.

OVERVIEW OF FINDINGS FROM SAFETY BOARD CRASH INVESTIGATIONS

The Safety Board investigated 26 crashes involving at least one lap belted person and concluded that, overall, the crash performance of the lap belts in these cases was very poor. Among the 50 persons using a lap-only belt, the Board determined that at least 32 of them would have fared substantially better if they had been wearing a lap/shoulder belt. In many cases, the lap belts induced severe to fatal injuries that probably would not have occurred if the lap belts had not been worn. The occurrence of lap belt induced severe to fatal injuries was not limited to severe crashes: 14 lap belted occupants sustained belt induced injuries of AIS 3 or greater severity (including 6 fatally injured) in crashes of Delta V 28 mph or lower. Even correctly 4/ worn lap belts induced severe injury: 24 occupants who received AIS 3 or greater injuries from the belt itself are believed to have been wearing it correctly. Twenty-six of the lap belted occupants sustained serious to fatal injuries in crashes in which other occupants--either unrestrained or lap/shoulder belted, and often seated in the more vulnerable front seating locations--were less seriously injured or not injured at all. The injuries characteristically induced by the lap belt were among the most dangerous types of injuries: those to the head, spine, 5/ and abdomen. The ages of lap belt injured persons ranged from 4 to

---

4/ There is no officially agreed-upon definition of "correct" lap belt use, but the Safety Board has used the term to mean snugly crossing the lower abdomen between the pubis and the umbilicus, with the belt low on the hips below the crest of the ilium. This appears to be the generally accepted meaning.

5/ In this study, lap belt induced head and spine injuries are those brought about by the violent jackknifing motion over the lap belt--injuries that would not have occurred but for the use of the lap belt.

82 years (more than half were younger than 15 years, however) and included both males and females. Finally, the postcrash medical handling of several of the lap belt injury victims demonstrated the need for improved understanding by medical personnel of the possibility and gravity of seat belt induced injuries in motor vehicle crashes.

Injuries to Case Vehicle Occupants

Thirty-one vehicles (passenger cars or vans), occupied by 139 persons ranging in age from 10 months to 82 years, were involved in this lap belt study. 6/ The crash forces involved in these primarily frontal crashes ranged from Delta V 9.8 mph to Delta V 43 mph. Fifty-seven of the occupants were unrestrained, 27 of them in a front seat location, 30 in some other seating location. Thirty-two were wearing a lap/shoulder belt, all but 1 in a front seat. Fifty were wearing a lap belt, all but 3 in a rear seating location.

Only 7 of the 139 occupants were uninjured. Five of them were in crashes of low Delta V (10-13 mph)--4 of them unrestrained, 1 lap belted, all in the rear seat. The other 2 were in the front seat wearing lap/shoulder belts in a moderately severe crash (Delta V 25 mph).

Another 48 occupants received AIS 1 (minor) injuries as their most severe injury (MAIS); 32 received AIS 2 (moderate) injuries as most severe; 21 received AIS 3 (serious) injuries as most severe; 31 received AIS 4 (severe), AIS 5 (critical), or AIS 6 (maximum) injuries. Eighteen persons died of their crash induced injuries: 1 with AIS 2 injuries, 1 with AIS 3, 1 with AIS 4, 11 with AIS 5, and 4 with AIS 6.

	Uninjured	MAIS 1	MAIS 2	MAIS 3	MAIS 4	MAIS 5	MAIS 6	(Fatal)
Unrestrained (57)	4	20	17	11	1	2	2	(4)
Lap belted (50)	1	16	5	7	6	13	2	(13)
Lap/shoulder belted (32)	2	12	10	3	4	1	-	(1)

Restraint Use, Injuries, Delta V

AIS 2 As Most Severe Injury (MAIS 2). Of the 139 occupants, 32 received MAIS 2 (moderate) injuries; 17 of them were not restrained, 5 were wearing lap belts, and 10 were wearing lap/shoulder belts.

Persons With MAIS 2 Injury,
by Case Vehicle Delta V and Restraint Use

	<15 mph	15-25 mph	26-35 mph	36-45 mph
Unrestrained (17)	-	4	2	11
Lap belted (5)	-	3	1	1
Lap/shoulder belted (10)	1	3	4	2

6/ A 5-month-old boy, using an improperly installed child restraint device, sustained AIS 3 head injuries in a crash of Delta V 33.6 mph; this occupant will not be included in the discussion and tables that follow.

Most of the unrestrained persons at the moderate injury level were in severe crashes (11 of the 17 in crashes of Delta V greater than 35 mph); the lowest case vehicle Delta V for these occupants was 23 mph. There were only 5 lap belted persons at the moderate injury level; 1 was in a crash at Delta V 38.5 mph, 1 at Delta V 35.7 mph, and 3 at Delta V 15-25 mph. The lap/shoulder belted persons with moderate injuries were in moderate to severe crashes (6 of 10 in crashes at Delta V 26-45 mph).

AIS 3 As Most Severe Injury (MAIS 3). Of the 139 occupants, 21 received MAIS 3 (serious) injuries; 11 of them were not restrained, 7 were wearing lap belts, and 3 were wearing lap/shoulder belts.

Persons With MAIS 3 Injury,
by Case Vehicle Delta V and Restraint Use

	<15 mph	15-25 mph	26-35 mph	36-45 mph
Unrestrained (11)	-	1	4	6
Lap belted (7)	-	1	6	-
Lap/shoulder belted (3)	-	1	2	-

Most of the unrestrained persons with MAIS 3 injuries were in severe to very severe crashes (6 of 11 at Delta V greater than 35 mph, 3 more at Delta V 33-35.5 mph). Most of the lap belted persons with MAIS 3 injuries were in moderately severe crashes (6 of 7 at Delta V less than 35 mph, 4 of these at Delta V less than 30 mph). All three lap/shoulder belted persons with MAIS 3 injuries were in moderately severe or severe crashes (Delta V 33.6 mph, 32 mph, and 22.5 mph).

MAIS 4, 5, or 6, or Fatal Injuries. Of the 139 occupants, 33 received MAIS 4, 5, or 6 injuries, or were killed. Only 5 of these occupants were not restrained; 5 of them were wearing lap/shoulder belts. The remainder, 23 of the 33, were wearing lap belts.

Of the 33 occupants in this category, 18 were killed; 4 of them were not restrained and were in higher Delta V collisions (43 mph and 35.5 mph); 1 was wearing a lap/shoulder belt (a driver in a Delta V 36 mph crash); 13 were wearing lap-only belts (6 at Delta V less than 30 mph, 7 at Delta V 30-40 mph).

Persons With MAIS 4, 5, or 6 Injuries or Killed, 7/
by Case Vehicle Delta V and Restraint Use

	<15 mph	15-25 mph	26-35 mph	36-45 mph
Unrestrained (5)	-	-	1	4
Lap belted (23)	-	5	12	6
Lap/shoulder belted (5)	-	-	3	2

Only 5 of the 57 unrestrained persons sustained these level injuries; 4 were in vehicles that underwent Delta V of greater than 35 mph; 1 was in a crash of Delta V 25-28 mph. Four of the 5 were in a front seat in these severe frontal collisions.

7/ Of the 31 persons who sustained MAIS 4, 5, or 6 injuries, 16 were killed. In addition, 2 other persons were killed, 1 with MAIS 2 injuries, and 1 with MAIS 3 injuries.

The 5 lap/shoulder belted persons who suffered these levels of injuries also were involved in severe crashes (3 at Delta V 32 mph, 1 at Delta V 36 mph, and 1 at Delta V 38.5 mph). Four of the 5 were drivers.

There were 23 lap belted persons in this category. Six were in crashes involving Delta V 36-40 mph, 12 were in crashes of Delta V 26-35 mph, and 5 were in crashes of Delta V 20-25 mph. One of the 23 persons was a driver, 1 was seated center front, and 2 were seated right front. The remaining 19 were all seated in rear locations.

Thirteen of the 23 lap belted persons in this category were killed, all by lap belt induced injuries. Five more sustained MAIS 4 injuries but were not killed, and another 5 sustained MAIS 5 injuries but were not killed.

Sixteen of the 23 lap belted persons who sustained MAIS 4, 5, or 6 injuries or were killed were judged to have been wearing the belt correctly and also did not slide downward under the belt or have the belt slide up over the iliac crests ("submarining"). Four were judged to have been wearing the belt correctly but possibly to have submarined. One was judged to have been wearing the belt incorrectly (loose or too high).

Twenty-one of the 23 lap belted persons in this category were in vehicles in which at least one other person, unrestrained or lap/shoulder belted, was either uninjured or had MAIS 1, 2, or 3 level injuries. In all but one of these cases, there was more than one non-lap belted person who survived the crash with less than AIS 3 injuries, often in a front seat position.

Seven of the 23 lap belted persons in this category were younger than 10 years; 8 were aged 10-20; 4 were aged 21-50; 4 were older than 51. Fifteen were male, 8 were female.

Additional Information on Persons Wearing Lap-Only Belts

The Safety Board's investigators concluded that 37 of the 50 lap belted occupants were wearing the belt correctly and also did not submarine. Four other lap belt wearers were judged to have been wearing the belt correctly but to have experienced, or possibly experienced, submarining. Five of the lap belt wearers were judged to have worn the belt incorrectly or probably incorrectly. For four of the lap belt wearers, there was insufficient evidence to determine whether it was being worn correctly and whether it rode up during the impact.

Correct/Incorrect Use, Submarining	
Wore lap belt correctly, no submarining	37
Wore lap belt correctly, but possible submarining	4
Wore lap belt incorrectly	5
Correctness of use and occurrence of submarining unknown	4

Of the 50 persons wearing a lap belt in these crashes, 49 were injured:

Outcomes for 50 Lap Belt Users

Survivors	MAIS 1:	16
	MAIS 2:	4
	MAIS 3:	6
	MAIS 4:	5
	MAIS 5:	5
Killed		13

There was little or no intrusion or compression of the occupant space in the areas surrounding the 13 fatally injured lap belt wearers. They all received their fatal injuries as a result of wearing the lap belt. Eleven of these 13 were wearing the lap belt correctly; there was possible submarining in 3 of the 13 lap belt induced fatalities, all involving proper use of the belt.

Of the 33 lap belted persons who received AIS 2 or greater injuries, 30 received one or more of these injuries as a direct result of the lap belt. One other person received an intra-abdominal injury as a result of lap belt use, but its severity was undocumented.

Of the 29 persons with AIS 3 or greater (or fatal) lap belt induced injuries, 21 sustained more than one injury at this level (induced by the lap belt itself):

Distribution of AIS 3 or Greater Lap Belt Induced Injuries

Persons with 2 such injuries:	4
Persons with 3 such injuries:	3
Persons with 4 such injuries:	4
Persons with 5 such injuries:	5
Persons with 6 such injuries:	1
Persons with 7 such injuries:	1
Persons with 10 such injuries:	3

SELECTED LAP BELT CASES

Detailed factual and analytical summaries of each case in this study are presented in appendix A. Several cases are presented here to illustrate many of the findings set out in the previous section.

In Case 1, a 15-year-old female driver lost control of the 1983 Pontiac Phoenix she was driving and crashed head-on into a tree. The Delta V was calculated to be 37 mph. The girl driving and the 12-year-old boy in the right front seat sustained only minor to moderate injuries, despite the fact that they were not using the available lap/shoulder belts and despite the fact that they were in the most vulnerable seating location for a frontal collision. The two 13-year-old boys wearing lap belts in the rear seat, however, both sustained violent injuries to the intra-abdominal organs and connecting tissue; one boy was pronounced dead less than 1 hour after the crash, and the other boy died 5 days later (he had shown no brain activity from the time of the crash). The Safety Board concluded that both boys probably were wearing the lap belt in the proper pelvic area, though it is possible that one boy's belt "rode up" over the iliac crests during the crash.

In Case 4, a 1983 Dodge 15-passenger van was struck by a 1970 Chevrolet Chevelle, with the van undergoing an estimated Delta V 38.5 mph. The van driver, a 36-year-old man, was using his 3-point lap/shoulder belt; however, since he was seated directly behind the area of major crash induced vehicle collapse, he sustained moderate to severe injuries, primarily to his head, face, and legs. The unrestrained right front passenger, a 17-year-old boy, sustained only minor injuries. Eight other unrestrained young people sustained only minor or moderate injuries; all were treated and released the same day.

The remaining four young men in the van were wearing lap belts. One sustained serious lap belt induced injuries to the head, spine, and iliac crest and severe lap belt induced intra-abdominal injuries (in addition to numerous other minor to moderate lap belt induced injuries); he was hospitalized for an extended period and continued under out-patient care after hospitalization. When last contacted by the Safety Board, 7 months after the crash, he was still unable to work.

A second lap belted passenger received moderate, serious, and severe lap belt induced head injuries and spent 4 months in a hospital before being transferred to another facility for long-term care. Seven months after the crash, he was still under extended care and on full disability.

A third lap belted passenger received fractures of his left leg due to an unsecured spare tire under his seat moving forward and compressing his leg against the forward seat framework. His head struck the seatback in front of him, as those of the first two lap belted passengers did, but with reduced severity, probably due to the lesser rigidity of the seat framework immediately in front of him. He also received an injury to his urinary tract, probably lap belt induced, of unknown severity. He was in a hospital for a week, and could not return to work for 4 months.

The fourth lap belted passenger sustained critical and severe lap belt induced intra-abdominal injuries and serious lap belt induced spine injuries. He spent 2 months in a hospital and had to return for out-patient care once a month after that. Seven months after the accident he had not returned to work and was on disability.

In Case 6, a 1983 Chevrolet Malibu was struck in the front by a 1980 Ford Mustang, with a resulting Delta V for the Chevrolet of 23 mph. The lap/shoulder belted Chevrolet driver, a 58-year-old man, received only minor injuries; the unrestrained right front passenger, a 55-year-old woman, received a moderate level injury to her head, in the form of a 2-inch temple laceration when she struck the rearview mirror; her other injuries were minor. However, the lap belted rear seat passenger, a 56-year-old woman, received fatal lap belt induced intra-abdominal injuries and died within minutes of reaching the hospital.

In Case 23, 12 small children (aged 6-7 years) were being transported in a day care van. The Ford van struck a 1984 Lincoln Town Car, resulting in a Delta V of 25-28 mph for the van. The unrestrained 24-year-old woman driver of the van received severe injuries. The five unrestrained small child occupants received only minor injuries and were either treated and released or did not receive medical treatment at all. The seven children wearing lap belts, however, all received serious to critical injuries including head, pelvic, intra-abdominal, and spinal injuries, all induced by the lap belt. One of these children was killed due to her massive head, spine, and intra-abdominal injuries; the others spent considerable time in a hospital, two being transferred later to extended-care facilities.

In Case 24, six young men (21-25 years old) were crowded into a 1979 VW Rabbit when it struck a 1977 Chevrolet Impala. The VW underwent a Delta V of 35.5 mph, while the Chevrolet underwent a Delta V of 23 mph. The four unrestrained men in the Chevrolet, all aged 22, sustained only minor to moderate injuries; all were treated and released immediately. The unrestrained driver of the VW Rabbit sustained critical injuries and died instantly. The lap/shoulder belted right front passenger sustained only moderate injuries, as did two of the unrestrained rear seat passengers. A third unrestrained rear seat passenger, sitting on the lap of the man in the center position, sustained serious injuries, due to being compressed between the center occupant and front seat. The remaining rear seat occupant, wearing a lap belt, sustained critical lap belt induced head and intra-abdominal injuries, serious lap belt induced spinal injuries, and moderate lap belt induced injuries to the abdomen.

In Case 26, a 1985 Ford Escort struck a 1974 International Harvester tractor-trailer, with a resulting Delta V of 33.5 mph for the Ford. The most serious injury sustained by the unrestrained 16-year-old girl driving the Ford was a fractured left femur (AIS 3); the same was true for the unrestrained 15-year-old girl in the right front seat. A 14-year-old boy in the rear, wearing a lap belt, sustained severe to critical lap belt induced intra-abdominal injuries and died 5 hours later. An 11-year-old boy wearing a lap belt in the rear seat sustained 4 severe intra-abdominal injuries, 4 critical intra-abdominal injuries, 1 critical spinal injury, 1 serious abdominal injury, and 1 moderate abdominal injury (in addition to other minor lap belt induced injuries). All his moderate to critical injuries were lap belt induced. He spent 2 months in a hospital before being transferred to an extended-care facility, due to paraplegia from his spinal column injury.

In Case 27, a 1980 Dodge Colt struck a tree head-on, with a resulting Delta V of 28 mph for the Dodge. The lap/shoulder belted front seat occupants sustained only minor injuries; however, the lap belted 15-year-old boy in the rear seat sustained severe intra-abdominal and spinal injuries due to the lap belt.

These cases illustrate why the Safety Board is concerned about the poor performance of lap belts in many crashes. Although virtually all of the lap belted persons were seated in rear seats (less vulnerable in a frontal crash), they often sustained serious to fatal injuries while front seat occupants received lesser or no injuries. Often the lesser injured occupants were unrestrained, while the more seriously or even fatally injured were lap belted. The unrestrained or lap/shoulder belted occupants tended to sustain only AIS 1-3 level injuries, even in severe to very severe crashes (only 5 of the 57 unrestrained occupants sustained higher level injuries, although 43 of these occupants were in severe to very severe crashes; only 5 of the 32 lap/shoulder belted occupants sustained higher level injuries, although 15 of these occupants were in severe to very severe crashes). At the same time, the lap belted occupants tended to receive AIS 4, 5, 6, and fatal injuries (21 of the 50 lap belted occupants, 11 of whom died, received AIS 4-6 level injuries; 2 of the 28 lap belted occupants whose highest documented injury was AIS 1-3 also died). The majority (23 of 29) of seriously to fatally injured lap belt wearers were believed to have been using the lap belt correctly--snug and low on the hips.

It is also important to understand that even in the cases in which lap belted persons did not sustain serious belt induced injuries, the lack of injury could not be attributed to effective crash protection performance by the lap belt. In Case 5, for instance, a 14-year-old lap belted boy sustained only AIS 1 injuries. However, the Delta V involved in this crash was only 9.8 mph; three unrestrained persons sustained no injuries, and the highest injury among all six occupants was AIS 2 (the lap/shoulder belted driver). Significantly, it was found that the buckle of the lap belt did not hold at impact; either the buckle failed (the evidence was against this) or the boy had not latched it properly in

the first place (most likely). Thus, little or no restraint was provided by the lap belt in this low Delta V crash. In three other crashes (Cases 14, 15, and 16), the Delta V was quite low and no occupants (even unrestrained) sustained other than minor injuries.

In four crashes (Cases 8, 11, 12, and 21), the Delta V was moderate (around 20 mph). In one, a lap belted 5-year-old girl in the rear of a 1977 Chevette sustained only AIS 1 injuries. However, another 5-year-old girl seated next to her, of identical size and weight, was also lap belted; she sustained maximum level injuries (AIS 6) to her head and cervical spine, plus other injuries. She died of her lap belt induced head/spine injuries. The Safety Board concluded that the radical difference in these children's experiences was probably due to slight differences in the attitude of their heads as their upper bodies flexed violently downward--a matter of chance.

In Case 11, all four lap belted children received only AIS 1 level injuries. Two toddler boys were belted together in the front seat using the lap portion of a 3-point lap/shoulder belt; the Safety Board concluded that little restraint was provided by the belt, however, since much of the crash energy acting on them was dissipated by the contact between their bodies and their head strikes into the well-padded instrument panel. The outboard seated child also avoided belt induced abdominal bruising, the Board concluded, because he loaded the inboard seated child into the belt; that child received belt bruising on both the left and right sides. The lap belted 5-year-old girl in the left rear seat probably avoided more serious lap belt injuries because she flexed over the belt in a leftward direction, thus bringing her upper body and head down onto her left upper leg; this prevented the serious head and neck injuries sustained by children wearing lap belts who flex downward between the legs. The same was true for the lap belted 4-year-old girl in the right rear seat.

In Case 12, a woman was lap belted in the left rear seat position. She sustained three moderate (AIS 2) injuries to her head and face, resulting from violent jackknifing induced by the lap belt, and an AIS 2 hip injury (plus several other injuries). She sustained the most serious injuries of the three occupants.

In the final example of a quite moderate crash, Case 21, the two lap belted rear seat occupants sustained only minor injuries. The Safety Board concluded that they had decelerated mainly into the front seatback, not into the lap belt. The two lap/shoulder belted front seat occupants also sustained only minor injuries.

There were three cases involving moderately severe to severe crashes in which lap belted occupants sustained only minor to moderate injuries. However, even in these cases the Safety Board concluded that this was not due to safe and effective restraint provided by the lap belt. In Case 3, the lap belted 6-year-old boy in the center rear seat of the 1984 Chevrolet Impala involved in a head-on crash at Delta V 28.6 mph sustained only minor injuries. However, the Board found that 1) the lap belt was not in fact "snugged up" around him at the time of the crash; 2) when his body slid forward and finally made contact with the belt webbing, the latchplate did not lock the webbing in place but allowed it to slip through for several inches before it finally jammed on a folded-over section; and 3) a large plastic box on the boy's lap was shattered between the boy and the front seatback, thus accounting for much of the boy's deceleration. Thus, this boy was not restrained to any significant degree by the lap belt.

In Case 7, a 1983 Chevrolet Celebrity was involved in a severe crash (Delta V 38 mph). The most severe injury sustained by the lap belted left rear seat occupant was AIS 2. However, the Safety Board investigation showed that he decelerated primarily into the left interior side wall and B pillar, not into the lap belt, so that his lack of lap belt induced internal or spinal injuries is not surprising. The belt was not effective in preventing head injuries; he sustained five AIS 2 injuries to his head and face, necessitating more than 8 weeks in a hospital and 2 months' loss of work.

Finally, in Case 13, three children were lap belted: one at center front seat, two in the rear seat. The child at center front sustained AIS 2, 3, and 4 (two) injuries to her head and face, resulting from the violent jackknifing over the lap belt. 8/ Fortunately, the two children in the rear seat benefited from the wide, firm seats provided in this 1978 Buick station wagon; because of the wideness and firmness of the seats, these children were not able to be injured through either jackknifing or submarining, as children on narrower, softer seats were (see Cases 8 and 10, for example).

In sum, the cases investigated during the Safety Board's project do not support the view that lap-only belts are effective countermeasures against crash injury in frontal collisions. In most of the Board cases, the lap belt itself induced serious to fatal injuries. However, in those cases in which the lap belt did not induce injuries, it does not appear that the lack of induced injuries could be attributed to effective lap belt performance. Furthermore, in these latter cases, either the lap belt failed to prevent other (nonbelt-related) crash injuries or the crash was so mild that few or no injuries were sustained by any occupant, regardless of their seating location or restraint system use. The evidence of these cases however, strongly supports the effective performance of lap/shoulder belts.

STATISTICAL ESTIMATES OF SEAT BELT EFFECTIVENESS

Databases

The Safety Board is aware that the cases investigated in its project are not representative of the range of real-world accidents and, therefore, the findings are not necessarily representative of overall lap belt performance. That is, it may be that if sufficient, accurate data were available on lap belt performance in crashes, it would be shown that lap belts reduce crash losses to a greater extent than they increase them. Unfortunately, the data needed to make such a showing are not available.

As part of this study, the Safety Board examined many studies that have been used in attempts to determine seat belt effectiveness. The types of work done in this area fall into three general categories: observational surveys of restraint use, laboratory tests, and analysis of large databases, most of which are derived from police accident records. Observational surveys, while useful in providing estimates of belt use rates by nonaccident-involved occupants, provide no information on accidents and injuries.

8/ It is useful to compare the types and severity of head and face injuries sustained by this child with those of a girl of similar size seated center front, unrestrained, in a car of similar size and loaded weight, involved in a frontal collision of almost identical Delta V, in Case 34. In that case, the child's most serious head injury was a moderate contusion on her forehead; her most serious injury of any sort was a fractured left leg.

Laboratory tests can provide certain kinds of information about belt performance, but the enormous variations in crash possibilities and human responses cannot be approached in the laboratory, thus severely limiting the significance of laboratory tests for estimating real-world belt performance.

Although the Safety Board's approach, of necessity, involves investigation of a relatively small number of lap belt cases, it has certain distinct advantages over other studies based on large numbers of crashes. Most effectiveness studies are based on analysis of data from police accident reports. Many studies use these police-reported data "as is," accepting their validity at face value. Studies based on one or more States' traffic accident databases are examples of these; the Fatal Accident Reporting System (FARS) of the National Highway Traffic Safety Administration (NHTSA) is another (the FARS database is limited to fatal accidents reported by the police).

Other studies are based on analysis of data from the NHTSA's National Accident Sampling System (NASS) or its predecessor, the National Crash Severity Study (NCSS). These two databases consist of a sample of accidents, drawn from among all police-reported accidents, that were reinvestigated for inclusion in the NASS or NCSS database.

For a variety of reasons, none of these databases (singly or in combination) provide wholly suitable information for estimating the real-world performance of seat belts. The police report databases, for example, contain a number of easily described deficiencies, as discussed in the following sections.

Uncertainties in information on restraint use. In the NCSS database, for instance, the NCSS investigators found that the original police accident reports had, on average, 33 percent "unknown" restraint use; one large State had an "unknown" rate of 85 percent, another 96 percent. 9/

--A review of the FARS database for 1980 showed that for mor [illegible] ercent of the fatalities recorded by California, Indiana, and Illinois police. [illegible] no record of restraint use. 10/

--Some State accident report forms do not even provide space for recording restraint use.

--Despite the high rate of "unknown" restraint use on many State accident forms, the NCSS investigators (and presumably their successors, the NASS investigators) converted the original police information into a database with few "unknowns." An extreme example of this process was one NCSS area in which only 4 percent of the police forms indicated whether a restraint had been used, but the NCSS versions of the same accidents displayed this information in 96 percent of the cases. 11/

9/ S. Partyka, "Corrections for the Effect of Data Source on Restraint Effectiveness Estimates," National Highway Traffic Safety Administration (October 1982), Table C, p. 6.
10/ Ibid., p. 20.
11/ Ibid., p. 8

--The NCSS (possibly also NASS) database also differs considerably from its police report origins on the question of what type of restraint was recorded as used. The police reported lap belt use more frequently than lap/shoulder belt use; the NCSS database, derived from the same accidents, shows just the opposite. (This resulted partly from the fact that the NCSS investigators, in making a decision on a police-recorded "unknown," tended to code more of them as "lap/shoulder belted" than as "lap belted.") As the NHTSA study reporting these facts notes, "This has important implications for the computation of restraint effectiveness rates from police-reported data." 12/

--Among the State report forms that do include an item for restraint use, there is wide variation in the terminology and the options available for marking the type of restraint used. A review of the report forms used in the seven NCSS areas, for example, shows the following options:

Lap belt, harness, lap belt and harness
Belt
No restraint use item
Lap belt, harness
Seat belt, shoulder harness, seat belt and shoulder harness
Strap, belt, strap and belt
No restraint use item

Even assuming the police accurately report which of these many "restraints" were used, it is difficult to translate the terms reliably into the different categories used on Federal databases.

--Lacking (or failing to use) physical evidence of restraint use or nonuse, those who record accident information seem to be guided to some degree, at least, by certain biases. Police, as a group, tend to overreport restraint use by crash survivors (particularly those with minor or no injuries) and underreport restraint use by those killed (or seriously injured). This, of course, "results in high estimates of restraint effectiveness." 13/ Compared to the police reports, NCSS investigators more frequently determined that a seriously or fatally injured occupant was restrained and that an uninjured or only slightly injured person was unrestrained.

What remains completely uncertain, of course, in all of this is what is factually correct. Are the police reports correct on the rate of restraint use by accident-involved persons, or are the "corrected" data of the NCSS/NASS investigators correct? Is the truth somewhere between the two versions? If so, which version is more nearly correct, and how much closer to the truth is it? Obviously, it is critical to know this, because "a small difference in the percentage of restrained occupants may imply a 50 percent difference in the computed fatality rate." 14/

The same substantial uncertainties also exist, of course, concerning what type of restraint was used--an uncertainty with enormous implications for not only the relative effectiveness of various restraints but also whether any given type (lap belt, for instance) is of net benefit at all.

12/ Ibid., p. 10.
13/ Ibid., p. 33.
14/ Ibid., p. 26.

Uncertainties in information on crash severity. Some evidence suggests that the rate of restraint use is lower among accident-involved occupants than among nonaccident-involved, and that this tendency may be more marked as accident severity increases. Without a reliable measure of crash severity, used consistently throughout the data on which the effectiveness estimate is based, the estimate may be biased by the different accident experience of restrained and unrestrained occupants. Estimates of "pre-impact speed" or "impact speed," for instance--commonly used in police reports--are not meant to be precise and do not permit estimation of the crash forces experienced by the vehicle occupants. Thus, the apparent "effectiveness" of restraint systems may be biased by differences in the severities of crashes experienced by restrained and unrestrained people.

Uncertainties in information on injury severity. Many States use broad injury classifications (for example, the KABCO scheme 15/) that are of little use in analyzing restraint systems' potential to reduce (or increase) injury. In KABCO, for example, a broken arm and a broken skull are both coded as "A" injuries, despite their vastly different level of threat to life. Internal injuries (the sort produced by lap belts, for instance) are not likely to be recorded at all. Furthermore, each officer's "definition" of injuries may be different (unlike the superior AIS system, which leaves little or no room for individual bias in coding injuries). Because specific injury data are needed for an accurate estimate of restraint system effectiveness, databases from police-reported information are unsuitable.

Lack of injury source information. The source of injuries is not included in police-reported data. Most police officers are not trained in the collection of such data, nor do they have the time to collect it. However, without these data it is not possible to determine whether, for example, an unrestrained person would have been less severely injured if restrained, or whether the injuries sustained by a lap belted person were caused by the belt itself or in spite of the lap belt.

Lack of injury information. Police reports often do not provide any information on uninjured occupants or those with minor injuries, especially in cases with fatally or seriously injured persons. This is another way in which restraint effectiveness becomes impossible to derive, with any level of confidence, from police-reported data.

Incomplete databases. Police report databases are incomplete. Studies comparing emergency room records and police accident reports have found that only 55 percent of the persons treated in the hospitals for motor vehicle crash injuries were included in police accident reports. 16/ How the addition of the missing 45 percent of injury cases would affect the estimates of seat belt effectiveness that are drawn from such incomplete databases is not known.

15/ In the KABCO scheme, injuries are defined as "K" for any injury that "results in death;" "A" for "severe lacerations, broken or distorted limbs, skull fracture, crushed chest, internal injuries, unconscious when taken from the scene, unable to leave scene without assistance;" "B" for "lump on head, abrasions, minor lacerations;" and "C" for "momentary unconsciousness, limping, nausea, hysteria, complaint of pain (no visible injury)."

16/ J.P. Bull and B. J. Roberts, "Road Accident Statistics--A Comparison of Police and Hospital Information," Accident Analysis and Prevention, 5:45-53, 1973; Jerome I. Baranick and Daniel Fife, "Northeastern Ohio Trauma Study IV: Discrepancies in Vehicular Crash Injury Reporting," Brookhaven National Laboratory (1984).

In addition to these problems in the original police reports, the three large databases which derive from police reports (NCSS, NASS, and FARS) have other drawbacks for estimating restraint performance and net effectiveness.

NCSS. An obvious problem with the NCSS data is that they are aging. They were collected during the 1970's, and since that time, vehicle crashworthiness, restraint system designs, and restraint use have changed considerably.

Second, NCSS data are weighted toward crashes of greater severity. Restraints are more likely to provide benefits (and disbenefits) in these crashes than in, say, non-towaway crashes; but patterns of restraint use may be different among occupants involved in crashes of higher severity from use patterns among occupants in less severe crashes.

Finally, NCSS data uncertainties are compounded by the fact that the second source of information (besides the original police report) for the NCSS investigations--interviews of people acquainted with the accident and/or with its victims--was also plagued by missing data (more than 30 percent, as with the police data). However, the 30 percent missing data were not the same data missing from the police reports. The NCSS investigators tended, furthermore, to "correct" for the missing interview data (or interview data they considered incorrect) differently than they "corrected" the police data.

NASS. The NASS database has the advantage of being more representative of the overall national motor vehicle accident picture than any other database. It includes both towaway and non-towaway accidents. However, the vast majority of accidents--even of towaway accidents--are of such low severity that restraints are not expected to have much, if any, effect (positive or negative). Thus, the majority of NASS cases are not particularly relevant to the question of restraint effectiveness, and must be removed from any sample used to estimate belt effectiveness. However, in most cases they are not removed, and therefore the potential effect of belt use is masked.

The sampling scheme that guides the selection of cases for the NASS database was devised to produce a database representative of U.S. accidents overall. It was not devised to measure the performance of restraint systems. Furthermore, the NASS sampling scheme was devised on the basis that ultimately there would be 75 teams collecting accident cases--a goal the NHTSA has never reached (there are now only 50 NASS teams nationwide). Given the (relatively) small number of crashes in which a restraint system might be expected to have some effect (either good or bad), the even smaller number of crashes in which restraints were used, and the even smaller number of crashes in which lap belts were used, it is not surprising that the NASS sample (the small set of cases which are then "weighted" to represent the national accident population) includes very few cases on which to base lap belt effectiveness estimates.

For example, in 1979 and 1980 combined, the NASS sampling scheme picked up only six persons recorded as fatally injured in a lap/shoulder belt, only one killed in a child safety seat, and none killed in a lap belt. The lap belt "sample" (zero cases) translates into zero cases nationally.

In the 1984 data, looking only at towaway crashes, only three "restrained" rear seat fatalities were captured in the sample (these could have been lap belted, in a child safety seat, possibly in lap/shoulder belts, or some combination of these possibilities). These numbers are simply too small to use for national extrapolations.

FARS. The FARS database is regarded as a census of all fatal accidents. Thus, in theory, it should be useful for estimating restraint effectiveness in reducing fatal injury. The major problem in using it for this purpose is that it is a completely "uncorrected" police-reported database. All the many uncertainties about police-reported data on restraint use pertain to the FARS data.

When the Safety Board reviewed 1984 FARS data for rear seat, belted fatalities, for instance, more than 25 percent of them were reported in FARS as having been killed in rear seat lap/shoulder belts. Probably fewer than 1 percent of passenger cars even have rear seat lap/shoulder belts; it is not possible for 25 percent of those killed in the rear seat while belted to have been using lap/shoulder belts.

Inappropriateness of Databases

Finally, it is important to understand that none of the databases were designed to permit exploration of belt induced injuries. These injuries are indistinguishable, in the databases as currently constituted, from injuries sustained despite use of the lap belt. In contrast, in each case in this Safety Board study it is possible to discern the extent to which the lap belt protected against injury, the extent to which the lap belt was unable to protect against injury, and the extent to which the lap belt itself actually induced injury.

The NHTSA has concluded that the effectiveness of lap belts can be estimated, and that lap belts have a net benefit. For the front seat, the most recent official estimate by the NHTSA 17/ is 30 to 40 percent effectiveness against fatalities, 25 to 35 percent effectiveness against moderate to critical injuries, and 10 percent effectiveness against minor injuries. 18/ For rear seats, the NHTSA estimates 50 to 60 percent effectiveness. 19/ Because of the data weaknesses discussed earlier, the Safety Board is convinced that the available data are inadequate for estimating even the range of possible effectiveness of lap belts.

17/ U.S. Department of Transportation, Final Regulatory Impact Analysis of the Amendment to FMVSS 208: Passenger Car Front Seat Occupant Protection, July 11, 1984.
18/ These are expressions of estimated effectiveness based on 100 percent use compared to zero use. That is, the NHTSA estimates that if there were 100 percent use of lap belts by front seat occupants, there would be 30 to 40 percent fewer front seat fatalities, 25 to 35 percent fewer front seat occupants with moderate to critical injuries (but not killed), and 10 percent fewer front seat occupants with minor injuries, compared to the outcome if no front seat occupants used any restraint. These types of effectiveness estimates cannot be translated into statements such as, "People who use lap belts have 30 to 40 percent less chance of being killed than nonusers."
19/ U.S. Department of Transportation Denial of Petition for Rulemaking (49 FR 15241, April 18, 1984).

RELATED RESEARCH
ON LAP BELT PERFORMANCE

The Safety Board reviewed a considerable body of literature related to seat belt performance. Several points emerged from this review.

> The fact that lap belts may induce serious, even fatal, injuries has been known by medical professionals and those working in areas related to motor vehicle safety since the mid-1950's.

A 1967 paper published by researchers at the University of Michigan, for example, noted:

> Although the [lap] belt restraint system has been demonstrated to provide effective reduction of injuries and fatalities in automobile accidents by preventing ejection, with increasing usage of belts by automotive occupants a pattern of injuries directly attributable to impingement on the belt itself is becoming evident. . . .Due to the overall increase in the wearing of belts, the patterns of injuries which may be identified as caused by the belt are becoming clearer. . . . Some idea of the sharp increase in injuries attributed to the seat belt can be found by noting that of the clinical reports referenced in this paper, only three studies occurred prior to 1956, and these were addressed to safety belt injuries in aircraft; yet over 20 clinical reports alone have been concerned with this problem since 1961. . . . [M]ost such cases are probably never reported in the literature. (135) 20/

The author pointed out that the lap belt "has the disadvantage of allowing the head and thorax to swing free in a 'jack-knife' motion during impact" and that it "cannot provide adequate protection to a seated occupant since the upper body components (e.g., head) are free to move during abrupt decelerations and strike surrounding structures."

A 1966 paper, published in the Journal of Trauma, noted that "it is evident from the cases . . . in the literature that the [lap] belt is capable of producing a wide variety of injuries." The authors showed that injuries can be sustained even when the belt is worn correctly, and they provided extensive discussion of the type of injuries sustained by lap belted persons, the mechanisms that produce these injuries, and the importance and difficulty of early diagnosis. (170) Many other papers dating from 1956 to 1985 have discussed the problem of lap belt induced injury. 21/ Indeed, early knowledge of the severe limitations of lap belts persuaded safety authorities in some countries not to approve these as acceptable seat belt systems. A 1961 paper by a Swedish safety researcher stated that "the single lap strap does not comply with" the minimum performance requirements the Swedish experts considered essential: "it does not maintain the occupant in an upright position, it does not protect the head and thorax, and it does not hold the vital parts of the body together within the car during an accident--so it has not been considered as a safety belt in Sweden." (4)

20/ The numbers in parentheses shown throughout this section refer to the references listed on pages 39 through 46.

21/ See References 3, 4, 9, 13, 25, 32, 33, 41, 44, 47, 59, 69, 76, 78, 80, 86, 92, 129, 132, 133, 145, 146, 162, and 169.

Lap belts produce characteristic injuries, alone or in combination, and these have been systematically documented since at least 1952.

The characteristic injuries include rupture, perforation, avulsion, transection, laceration/tearing, and fracture of the numerous intra-abdominal organs and their connecting tissue; fracture, dislocation, subluxation, and transection of the spinal column components; a variety of injuries to the cervical spine; numerous types of serious head and facial injuries; fracture of the bones in the pelvic girdle; and abrasion, contusion, and avulsion of the abdominal and hip areas. These have been discussed extensively in many papers. 22/

The injuries characteristically induced by lap belts are of types that are inherently serious, unlike many other types of injuries sustained by crash victims.

The injuries to the spinal column and head that can be induced by lap belt use are obviously very dangerous (see Cases 4, 7, 8, 10, 12, 13, 19, 23, 24, 28, 29, and 30). As for intra-abdominal injuries, a 1966 paper (170) presented an extensive discussion of the variety and gravity of these types in lap belt users, noting that "delays in treatment lead to a high morbidity and mortality." A 1970 paper, after discussing the variety and gravity of intra-abdominal injuries induced by lap belts, reviewed the "patterns of lumbar vertebral injuries associated with lap type seat belts," and noted that "paraplegia results in a significant number of patients." (120)

A 1982 Canadian paper notes that "abdominal injury is . . . one of the most dangerous of all injury types, accounting for 37.8% of injuries at the AIS 4 to AIS 6 level" in the cases studied. These researchers found that "those individuals who were restrained by a single lap belt in the rear seat had a very high incidence of abdominal injuries and in most cases, these were of a more serious nature. . . . The most common cause of abdominal injury is through the intrusion of the belt into the abdomen." (41)

Many of the various types of serious, characteristic injuries induced by lap belts were seen in the Board-investigated cases.

Lap belt induced injuries, particularly those to the intra-abdominal region, are often not immediately apparent; yet delays in treatment can result in long-term disability or even death, so attending medical personnel should suspect internal injury in victims who were belted, or possibly belted.

As early as 1956, medical journal articles began to report cases indicating that lap belt-induced injuries may not be immediately apparent. (76) The delays ranged from 5 hours to 16 months in the medical journal cases reviewed by the Safety Board. 23/ In some of these cases, the victim was able to talk coherently and move about (one man went on from the crash to a ball game before he collapsed). In others, the victim was in discomfort or even pain, but aside from abdominal bruising, evidence of internal injury was not readily apparent for a period of time.

22/ Especially in References 13, 35, 123, 135, 169, and 170.
23/ See References 3, 9, 10, 13, 25, 32, 35, 59, and 69.

In many of these cases, medical personnel attending the victim did not seem to be sufficiently aware of the strong possibility of serious internal injury from the belt itself and did not take the necessary steps to sufficiently explore this possibility. Lacking unmistakable evidence, treatment was delayed, sometimes resulting in long-term disability or death that might have been prevented by more timely intervention. For example, a 61-year-old woman was admitted to a hospital with abdominal bruising evident; the attending medical personnel knew she had been in a car crash while wearing a lap belt. She was complaining of abdominal pain, but her condition "apparently stabilized within a short time," and no further exploration was undertaken until the next morning when she went into shock. At surgery, "a tear in the mesentery of the small bowel with about 12 inches of gangrenous bowel was found. Generalized peritonitis was present as the result of perforation [of the gangrenous organ]. The patient's condition deteriorated rapidly, and she died while on the operating table." (9)

In 1970, researchers at Johns Hopkins University and the Maryland Chief Medical Examiner's Office reviewed the handling of 33 motor vehicle crash deaths in local hospitals between 1964 and 1969. (10) In all these cases the primary injury was intra-abdominal. They found that "half of these lives might have been salvaged by prompt and proper diagnosis and treatment." Nearly half "involved either failure to operate or excessive delay in surgery, despite symptoms of abdominal injury." One-third of the exploratory surgery was not undertaken for more than 12 hours after the victim arrived at the hospital. In at least 21 of the cases there had been "errors or inordinate delay in diagnosis or treatment." The authors concluded: "It is obvious that the key to successful treatment of patients with blunt abdominal trauma is a high index of suspicion and close observation. Early laparotomy should be strongly considered for traffic victims with otherwise unexplained shock and any signs compatible with abdominal injury."

These themes are repeated in the medical literature on lap belt injury victims:

> (1965) -- In all 4 cases presented in this report, evidence of seat belt trauma was externally evident by the contusions across the lower abdominal wall and flanks . . . . At this time, it would appear worthwhile to be suspicious of lower torso injuries when seat belt markings exist. Furthermore, the insidious nature of ileal perforation would warrant careful observation for abdominal symptoms which cannot be attributed to the abdominal wall contusions. Early exploration in suspicious cases appears to be warranted. (35)

> (1966) -- [E]arly diagnosis and treatment are essential in the management of intra-abdominal safety belt injuries. Furthermore, diagnosis may be difficult because of associated injury or circumstances . . . . [I]t is important to approach the accident victim who has been wearing a safety belt with a high index of suspicion that he might have an intra-abdominal injury. Historical data regarding the circumstances of the accident should be obtained from the patient or ambulance personnel. . . . External evidence of trauma conforming to the configuration of the safety belt is helpful in suspecting intra-abdominal injury, but its presence or absence does not confirm or rule out intra-peritoneal trauma. Case 1 in this series had no external evidence of trauma and yet the patient had a perforation of his ileum . . . . [A] negative [peritoneal tap] should not be interpreted as meaning intra-abdominal injury has not occurred. (170)

(1967) -- Diagnosis is often obscured by the absence of abdominal symptoms and the paucity of physical findings on the initial post-accident examination. Seat belt contusions of the lower abdominal wall, especially about the iliac crests, should alert the examiner to possible intra-abdominal injuries, especially within the lower abdomen and pelvis. (13)

(1967) -- It is of interest that often intra-abdominal injury associated with wearing a safety belt is unsuspected or unrecognized when the patient is first seen after an automobile accident. The physician must be alert to this possibility and observe such an individual carefully. (80)

(1968) -- Abdominal taps and [X-rays] are not dependable when giving negative results. . . . [These cases were written up] to emphasize the significance of the sign of marked contusion in the abdominal area, and to underline the need for maintaining a very high index of suspicion for intra-abdominal injuries. As more patients are saved from ejection . . . by the use of seat belts, physicians will need to become increasingly aware of the possibility of intra-abdominal injuries in victims of automobile crashes. (32)

(1970) -- The extent of intra-abdominal injury may not be as easily perceived . . . . a delay of 24 hours or more occurred in more than 50 percent of the patients. It is also apparent that delay contributed significantly to mortality. Unfortunately, the early clinical findings may be minimal, consisting only of ecchymosis of an abdominal wall. . . . Both delay in laparotomy and the inadvertent production of paraplegia can be avoided by recognizing that the 2 classical components of lap belt injury [intra-abdominal and lumbar spine injuries] may be present concomitantly. Abdominal ecchymosis, signs of peritoneal irritation, even though minimal, and back pain, should alert the attending physican to the combination. (120)

(1971) -- When surgical intervention was undertaken within 12 hours of injury, morbidity was minimal and mortality was low. However, delay of more than 12 hours was accompanied by considerable morbidity and mortality. Deaths were the result of peritonitis with overwhelming sepsis, and were related to delay in diagnosis, the abdominal findings being masked by associated injury. . . . External evidence of belt trauma was present in less than one-third of the patients. Abdominal tenderness on initial examination was present in over 50 percent of the intra-abdominal injuries, and was either overlooked or masked by associated injuries in the remaining cases. The presence or absence of bowel sounds was little diagnostic help. . . . Early peritoneal paracentesis done in 13 cases was positive in only 6 and was falsely negative in 7. . . . [T]he physician must be alert to the injury potential of [the lap belt] when caring for an accident victim who has been wearing such a restraint. Just because an individual has been wearing a lap belt does not mean he is uninjured. (169)

(1984) -- This case history highlights some important principles in the care of victims of multiple trauma: 1) Rapid evacuation to a centre able to give definitive management is lifesaving. Attempts to stabilize in the field are not likely to be successful and will disadvantage the patient if they cause delay. . . . 3) Surgery often is required to stop severe bleeding. If resuscitation does not reverse shock rapidly and effectively, an undiagnosed injury (with the need for laparotomy) must be considered; prolonged attempts at resuscitation are not successful. 4) Rupture of the diaphragm is always a possibility with chest and abdominal trauma and those patients on whom impressions of a seatbelt are noted are likely to have serious internal injuries. . . . 6) Peritoneal lavage serves only to delay definitive treatment in patients who have clinical signs of abdominal trauma. (162)

In several of the Safety Board-investigated cases there was evidence that the outcome might have been more positive for the lap belt injury victims if the medical personnel handling them had been more suspicious of intra-abdominal injury and had acted promptly and appropriately to determine if this was so and treat the injuries (see especially Cases 6, 8, 17, 27, 28, and 29).

The experience of the 15-year-old boy wearing a lap belt in the right rear seat in Case 27 is an example of the type of medical handling problem referred to throughout the literature of the 1960's and 1970's and especially discussed by Baker in her 1970 paper. This attending physician noted that the boy "experienced immediate deep back abdominal pain" after the crash "but was not unconscious. He was able to walk." Upon arrival at the emergency room, he had "a rigid abdomen" that was "silent"; he was "mildly hypertensive and tachycardic." He vomited in the emergency room and blood clots were noted. He had "normal sensation in all extremities" and his "breathing was normal." During the night he vomited again and bile was noted; he was able to urinate, his urine was clear, and there was no occult blood finding.

By the next day, he was "in acute distress," complaining of "severe abdominal pain." The doctor found "no abdominal scars," but the "abdomen was flat, rigid," and no bowel sounds were heard. The doctor noted "diffuse abdominal tenderness" and "marked tenderness over the midback extending from about T-10 down to L5 but maximal in the central portion with moderate paralumbar spasm. Any back flexion is extremely painful." The doctor's record of this examination states (under a section titled "Impression"): "Rule out compression fracture of the lumbar spine. Rule out possible small bowel or viscus injury. Doubt there is ruptured liver or spleen." No X-rays had yet been taken.

Later that day, the boy was examined by a second doctor. By this time, X-rays had revealed a "Chance fracture" of the lumbar spine at the second and third vertebrae. This doctor's record of his examination states that the boy had received "injuries to the abdomen" that had created an obstruction within his intestine, and that he was "under observation for this."

Eleven days later his abdomen was again distended, he began vomiting again, and exploratory laparotomy was undertaken. It was found that, in addition to the fracture of the lumbar spine, the jejunum had been traumatically perforated in two places, each about 1 inch across, and multiple intraperitoneal abscesses had formed.

Three days after surgical repairs had been made, he became feverish again, and was "acutely ill-appearing" with signs of sepsis and abdominal discomfort. A second consulting doctor noted that he suspected "recurrent sepsis from intra-abdominal pus," that the boy "most likely has an undrained focus of pus." The consulting doctor noted that he expected the boy would need a second laparotomy later that day.

A second operation was performed that day; this time, the boy's ruptured spleen, previously undiagnosed, was removed.

Case 29 also illustrates the need for a deepened awareness among emergency medical personnel of the possibility for belt induced trauma and the urgency of treatment. The man in this case arrived at a hospital with many severe internal injuries. Laparotomy was not undertaken for 4 hours, however; furthermore, no additional surgery was undertaken even though his blood pressure could not be maintained postoperatively. He died within about a day and a half of the laparotomy. At autopsy, fecal matter from a poorly repaired bowel and 4,000 grams of blood clots were found within his abdominal cavity. A blood clot of about 300 grams was found near the liver. A consulting physician told Safety Board investigators that a surgeon trained in treatment of trauma would have undertaken the surgery sooner, would have used more appropriate repair procedures, and would have undertaken additional surgery to correct the continuing problems.

Discussion of other instances of these types of medical handling problems is included in the Safety Board's case summaries in appendix A.

> Some researchers, while admitting that lap belts can induce serious injuries, have claimed that this happens mainly in older, obese women, or only in "high speed" or "severe" crashes, or only if the belt is worn "loosely," or "too high," or only if the wearer "submarines" under the belt.

These are common themes in much of the published work from the 1960's and 1970's, and some of these beliefs are still being expressed in current published work. 24/ Certainly, many of the reported cases said--correctly or incorrectly--that one or more of these elements was involved. Many researchers and other authors seem to have extrapolated from these cases that one or more of these elements was necessary for lap belt induced injury.

However, there has been ample evidence all along that none of these factors is necessary for lap belt injury to occur. Medical articles began appearing as early as 1963 documenting severe belt induced injuries in persons who had almost certainly been wearing the belt snug and low (based on the type and location of their injuries). Papers throughout the period also demonstrated clearly that lap belts were inducing serious injuries in all kinds of people--young and old, of many body sizes, male and female--and in a range of crash severities, with correctly worn and properly functioning lap belts. 25/ Certainly the Safety Board's cases, and several of the Canadian cases presented in appendix B, also clearly demonstrate that this continues to be so.

24/ See References 6, 29, 32, 38, 41, 44, 45, 59, 62, 86, 100, 115, 123, 146, 148, and 172.
25/ See References 3, 9, 13, 32, 35, 36, 37, 38, 44, 59, 69, 76, 78, 80, 82, 123, 135, 145, and 170.

The primary purpose of lap belts was widely understood in the 1950's and 1960's to be the prevention of ejection, at that time the main cause of motor vehicle crash mortality.

For example, a 1965 paper at the 7th Stapp Car Crash Conference concluded that if all occupants wore lap belts all the time, about 5,000 fewer fatalities would occur solely due to ejection prevention, and that severe injuries could be reduced by about one-third, again in connection with ejection control. (21) A 1966 paper found that "ejection of a crash victim at the time of, or subsequent to, impact is the leading cause of serious injury and mortality resulting from an automobile accident." (170) A 1967 University of Michigan paper stated that "there appears to be relatively universal agreement among researchers as well as clinicians that the major usefulness of any seat belt restraint system is in the prevention of ejection from the vehicle during an impact." (135; emphasis in original). Other papers from that time until the early to mid-1970's drew similar conclusions: that ejection was the single most important cause of crash injury and that the major effectiveness of lap belts was in reducing ejection-caused injury. 26/

The 1965 paper cited, however, went even further, to conclude that lap belts offer no crash protection benefits beyond ejection control:

> [T]here was a hope that [lap] belts would beneficial beyond the control of ejection. It was hoped that belted occupants would suffer fewer and/or less severe injuries inside the car than their unbelted counterparts, even though neither was ejected. This hope was based on estimates that belted occupants would less often or less violently strike interior objects than would unbelted occupants in a similar accident. (Emphasis in original)

However, after studying 232 matched pairs of crashes (same impact speed, same angle of impact, same make/model car, same physical characteristics of subject occupants, etc.), the authors found that this hope was not fulfilled in the crashes they studied. They concluded:

> In summary, there is a very similar injury situation for [lap] belted and unbelted occupants when consideration is given to performance beyond ejection control. It is found, however, that a different pattern of injury cause emerges as a consequence of being belted. This gives useful clues for seeking countermeasures.... [E]fforts for improving restraint systems should be extended to include upper body restraints.

Other studies strongly supported the conclusion that lap belts were not effective at reducing deaths and injuries sustained by nonejected occupants. 27/

Although some research papers found that "seat belts" were effective in reducing even nonejection-related injuries, 28/ most did not distinguish among the "seat belts" in their databases (whether they were lap-only belts, separable lap and shoulder belts, integrated "3-point" lap/shoulder belts, or some mixture of these). The conclusions of these studies, therefore, are not necessarily valid for lap-only belts. Even studies

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26/ See References 9, 13, 21, 32, 39, 65, 135, 164, 169, and 170.
27/ See References 39, 116, 129, 130, and 164.
28/ See References 19, 37, 45, 46, 61, 74, 75, 82, 102, 119, 149, and 163.

that did distinguish among belt types usually failed to take into account basic factors such as collision severity; thus, their conclusion that lap belt use reduced injury severity was not adequately supported (since the lap belted occupants may have tended to be involved in less severe crashes than unrestrained occupants). 29/ Other fundamental flaws marred many of these studies.

Furthermore, some of these studies, while concluding that "seat belts" (or even lap-only belts) are effective in reducing nonejection-related injuries, also found that lap belts induce serious injuries. For example, a 1975 report prepared for the NHTSA looked at computerized crash data on 1,442 lap belted persons and concluded that the lap belted group did better, overall, than the unrestrained group. (37) At the same time, however, the study found:

-- About half of the lap belted occupants, in the front seat and in the rear, who sustained AIS 4-6 injuries, got them from the lap belt itself;

-- 15 percent of the rear seat, lap belted occupants received minor to severe injury from the belt itself;

-- Approximately 47 percent of all the rear seat passenger injuries were due to the lap belt itself. The most frequently injured body part was the abdomen/pelvis, and a snug lap belt was considered responsible;

-- Although the average severity of various injuries was lower when the lap belt was worn snugly, in the case of pelvic girdle, abdominal wall, and abdominal contents, the average severity was higher when the belt was worn snugly;

-- Unbelted persons in the rear were less likely to be injured than lap belted front seat occupants.

Early papers (and some recent ones) often stress that lap belt-induced injuries are "rare." 30/

For instance, a 1979 paper presented at the International Symposium on Seat Belts states: "To conclude, I acknowledge that we have all heard of isolated instances in which belts are supposed to have made the situation worse. We have heard speculations as to various unusual circumstances where the belt is said to be ineffective. Such cases are difficult to trace and vanish like smoke when one tries to locate them." (19) 31/

29/ For example, in two major bodies of motor vehicle crash data, the NCSS and the NASS, the NHTSA found that this was so. In the NCSS data file, in fact, it was found that "restrained occupants were involved in less severe accidents to such an extent that the severity of the accident itself could explain most of the fatality effectiveness." (158) In using these databases to prepare belt effectiveness estimates, the NHTSA attempted to correct for this serious drawback. Many of the other researchers publishing papers on belt effectiveness have not indicated whether such corrections were attempted on their data.

30/ See References 19, 38, 45, 148, and 168.

31/ This paper discusses both lap/shoulder belts and lap-only belts and does not clearly distinguish whether both types, or only one or the other, is being referred to at many points. Such is the case with these statements.

The claim of rarity deserves attention. It is true that there are not hundreds or thousands of documented cases of lap belt induced injury in the literature. However, there may be a number of reasons why this is so.

First, it is worth noting the comment by an experienced occupant restraint researcher in his 1967 paper (135) that most lap belt induced injuries are probably never reported. Given the serious and varied inadequacies in the databases used in many analyses of seat belt performance over the years, it is simply not possible to assert with assurance that these injuries are "rare." Without examination of the vehicles involved, the belt systems, and each occupant's medical records, many injuries may have been unrecorded and others may have been incorrectly attributed to other sources. As noted earlier, lap belt injuries are not necessarily apparent for a time. As is clear from the literature of the 1960's and 1970's, many doctors were not sufficiently aware that lap belts could induce injuries and may not have recorded them as belt induced.

Although the limitations inherent in this study do not permit the Safety Board to accurately estimate the total number of lap belt induced fatalities or serious injuries, the data at least suggest that these problems may not be as rare as many researchers have thought. For example, given the scope of the Board's accident notification system in eight field offices, it is reasonable to assume that the 13 instances of lap belt induced fatalities and 17 more of moderate to critical belt induced injuries may represent approximately 10 percent of all such cases nationally. If this estimate is correct (and it is important to note that it is only an estimate), then there would have been approximately 130 lap belt induced fatalities and 170 belt induced moderate to critical injuries during the same 15-month period. Even if the Board's investigations constitute 25 percent of the cases nationally (which is highly unlikely), then there were 52 such fatalities and 68 such injuries.

The Safety Board is concerned about the problem of lap belt induced injuries because this problem will increase as the passage of mandatory seat belt use laws and other education efforts cause more people to use rear seat lap belts. The loss estimates outlined above reflect the rear seat belt use rates observed in 1984 and 1985--6 percent and 9 percent, respectively, or an average of 7.5 percent. If rear seat belt use rates rise significantly, such as to 15 percent, belt induced fatalities would likewise increase to 260 and moderate to critical injuries to 340.

It is important to understand what these elements represent. There will always be some number of people injured or killed while wearing a seat belt, no matter what belt system is used, because no belt system can protect against all harm and some crashes are simply unsurvivable. This is true of lap/shoulder belts as well as lap-only belts. In those cases, belt use is immaterial--the occupant will either be injured/killed wearing a belt or injured/killed unrestrained. Therefore, as belt use rates increase, the number of people injured or killed while wearing a belt obviously will also increase, because more of the people involved in unsurvivable crash situations will be belted. In these instances, it is not that the belt system brings about injury or death that would not otherwise occur; it is that the belt system in these cases is unable to prevent injury sufficiently. Thus, these cases are not additional injuries and deaths due to increased use rates, they are simply injuries and deaths that move from the unrestrained to the restrained category.

It is not that sort of increase in lap belted injuries/fatalities that concerns the Safety Board. The estimated numbers of lap belt induced injuries and fatalities discussed above represent injuries and fatalities that would not otherwise occur. In other words, they are in addition to the unavoidable injuries and deaths among lap belted occupants (those that the belt is unable to prevent).

Belt systems that include both a lap and an upper torso belt have been widely recognized for many years as providing better overall crash protection, and less inherent hazard, than lap belts.

This is a major theme running through a great deal of the literature from the earliest days of seat belt research and regulation. Although most researchers recognize that even lap/shoulder belts can induce some injuries, they are also recognized as having two major advantages over lap belts alone: they are much more effective at preventing, or reducing in severity, dangerous (non-belt induced) injuries, and the injuries they may produce are typically less severe than those from lap belts. For one thing, the shoulder belt portion prevents the violent jackknifing of the upper body over the lap belt, a motion that can result in severe injuries to the spine, head, and face. For another, the shoulder belt helps to distribute the crash forces over a larger area of the body, rather than concentrating them on the narrow band of vulnerable abdomen covered by even a properly positioned lap belt.

A fleet experiment in the early 1960's in Australia concluded that "the lap belt should not be fitted unless it was impracticable to fit a more effective type." The Australian safety authorities recognized "from the outset, . . . the desirability of requiring seat belts with nondetachable upper torso restraints. This contrasted with the then U.S. approach, where fitting of belts with detachable [shoulder] straps was common." (99)

A 1965 paper presented at the 9th Stapp Car Crash Conference discussed several advantages of the lap/shoulder belt over the lap-only belt and cites communications from experts in England:

> The evidence in this country is, of course, all in favor of the . . . lap/shoulder combination. . . . [W] e have no evidence at all that neck or head injuries have been caused from shoulder straps . . . . Head injuries, on the other hand, have been caused by jackknifing in occupants wearing lap belts alone; these, of course, on occasion, have also been responsible for associated neck injuries due to hyperextension. Shoulder harness would prevent such jackknifing. . . . In the UK, and probably in Europe as well, 3-point lap and diagonal safety belts . . . are the types most frequently fitted to cars . . . . almost no lap belts by themselves are now used . . . . We in the Road Research Laboratory have encouraged the use of safety belts with shoulder restraint as it has been shown that by far the majority of fatal and serious injuries to car occupants are to their heads or chests. We do not think that lap belts can greatly reduce head injuries in frontal impacts because the velocity with which the head can strike the facia is likely to be high when the body is folding about the lapbelt. . . . Our opinion is that the belts with shoulder restraint should always be used. It appears to us significant that the saving in injuries due to the wearing of lap belts in the U.S.A. agrees very well with the saving that would be expected if ejections were prevented; whereas in this country, where almost all seat belts are 3-point belts, the saving in injuries is about three times higher. (129)

A U.S. paper presented at the next Stapp conference (in 1966) compared the impact dynamics of unrestrained, lap belted, and lap/shoulder belted anthropomorphic dummies in sled tests and found that the lap/shoulder belt, "in addition to minimizing or eliminating impact forces [from striking] the vehicle interior, . . . appreciably reduces the forces in the lap belt [acting on the abdomen]." (112)

A 1973 U.S. paper analyzing data on several hundred frontal and side impacts found that front outboard occupants using lap/shoulder belts "were much less likely to have been severely or fatally injured than those with lap belt only. . . . [Those] with lap belts were only somewhat less likely to have been killed than the unrestrained people, but more likely to have been severely injured (AIS 4-5)." The author went on to say that "for both seating positions [driver and right front], the use of a torso device is correlated with a greater reduction in injury than when the person is wearing only a lap belt." (130)

A 1975 paper at the 19th Stapp conference compared injury patterns by type of restraint used. Those using lap/shoulder belts had a greater probability of receiving fewer injuries than lap belted occupants, the researchers found. The rate of facial injuries with lap/shoulder belts was half the rate for lap-only belt users. (94)

The NHTSA sponsored a study in 1976 of 15,000 cars in towaway crashes in several States. Lap belt use by drivers and right front seat passengers reduced their chances of AIS 2 or greater injuries by 31 percent (how much of this reduction was due to ejection prevention alone is not discussed). However, lap/shoulder belts reduced these chances by 57 percent. (119)

Many other such findings of superior lap/shoulder belt effectiveness could be cited, including the NHTSA's own estimates of front seat belt effectiveness, 32/ published in July 1984 as part of the occupant restraint rulemaking proceedings (158):

NHTSA Estimates of Seat Belt Effectiveness (July 1984)

	Manual Lap-only	Manual Lap/Shoulder
Fatalities	30-40%	40-50%
AIS 2-5 Injuries	25-35	45-55
AIS 1 Injuries	10	10

Certainly the injury outcomes observed in the crashes investigated by the Safety Board are consistent with these types of findings. The lap/shoulder belted persons in the Board-investigated frontal crashes, with one exception, were all in the much more vulnerable front seating positions, while the lap belted persons (with only three exceptions) were all seated in the less vulnerable rear seating positions. Even so, a much smaller proportion of the lap/shoulder belted persons received AIS 4, 5, 6, or fatal injuries, compared to the lap belted persons (16 percent compared to 46 percent). All of the fatal injuries, most of the serious injuries, and many of the less serious ones sustained by the lap belted persons were induced by the lap belt itself, whereas the severe or fatal

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32/ Three months earlier, in denying a petition from University of Michigan researchers to require lap/shoulder belts in rear outboard seats, the NHTSA had estimated that lap-only belts are 50 to 60 percent effective against fatalities in rear seats. (149) Furthermore, the denial stated that lap/shoulder belts in the rear "would not likely be substantially more effective than this." It is not clear to the Safety Board why lap belts would be so much more effective in rear seats than in front seats (50 to 60 percent, versus 40 percent), nor why lap/shoulder belts would be substantially more effective than lap belts in front seats but not in rear seats.

injuries sustained by the lap/shoulder belted persons were the result of severe intrusion or compartment compression at their seating position, in high Delta V crashes, in which these persons were in a direct line with most of the crash forces. Twenty-five percent of the severely to fatally injured lap belted persons were in crashes of less than Delta V 25 mph; the five lap/shoulder belted persons who received these level injuries were all in severe crashes (Delta V 32-39 mph); the five unrestrained persons who received severe to fatal injuries were also in higher Delta V crashes (1 at 28 mph, 1 at 36 mph, 3 at 43 mph).

Case 13 is useful to consider in this context. In this head-on (slightly left of center) crash of a 1978 Buick stationwagon, the Delta V was 28.9 mph. The driver and the right front seat passenger, both lap/shoulder belted, received AIS 2 and AIS 1 injuries, respectively, as their most severe injuries, while the center front seat passenger wearing a lap belt received an AIS 4 facial fracture, an AIS 3 facial fracture, an AIS 4 skull fracture, and an AIS 2 facial contusion (plus AIS 1 nose fracture and forehead laceration). This 5-year-old boy was similar in size to the 6-year-old boy wearing a lap/shoulder belt next to him.

The experience of the 15-year-old boy lap belted in the rear seat in Case 27 is also instructive. In this Delta V 28 mph crash, this boy (wearing the lap belt correctly) sustained very grave internal injuries and fractures of the second and third lumbar vertebrae, all caused by the lap belt itself; while the two boys in the front seat, using lap/shoulder belts, sustained only minor injuries.

Certainly the 8-year-old girl wearing a lap/shoulder belt in the left rear seat in Case 2 received crash protection superior to that of the many other rear seat occupants in this study who wore only lap belts. She was involved in a severe frontal collision, yet she received only AIS 1 neck and lower abdomen contusions; she was treated and released from a hospital the same day.

Case 29 also illustrates this point vividly. The two persons in the front seat in this frontal collision (Delta V 25.7 mph) sustained no injuries; yet the lap belted man in the rear (less vulnerable) location sustained many moderate to critical internal injuries, resulting in his death.

<u>Lap/shoulder belts do not present a hazard to children; rather they can provide far superior protection than lap-only belts; they can be used with child safety seats and booster seats.</u>

Several studies have been directed at the question of whether lap/shoulder belts present hazards to children (or other short people). In particular, dangerous injuries to the neck or chest have been suggested as possible outcomes for children wearing 3-point belts.

A Swedish paper examined this question in detail in 1977. (106) Researchers looked at 683 serious crashes in which at least one child younger than 15 years was involved. Of the 822 children involved, 101 were restrained by 3-point lap/shoulder belts (2 were in center front seats, with lap-only belts). For the lap/shoulder belted occupants the findings were:

-- Children were not injured more frequently or more seriously than adults, but less frequently and less seriously;

-- Children did not sustain head, chest, or neck injuries to a greater extent than adults, but to a lesser extent;

- Short occupants, including children, should not be expected to sustain neck injuries caused by the shoulder belt;

-- 3-point lap/shoulder belts have a positive protective/restraining effect on children.

The total injury rate for the lap/shoulder belted children was 16 percent and for the lap/shoulder belted adults was 31 percent. Of the 101 lap/shoulder belted children, 16 were injured: 15 at AIS 1 level, 1 at AIS 2 level. Among the 309 lap shoulder belted adults, 106 were injured, 102 at AIS 1 level, 3 at AIS 2 level, 1 at AIS 4 level. Adults sustained injuries in all major body parts; children, however, sustained no back, abdominal, or hip injuries; children younger than 10 sustained no head injuries. (It should be noted here that in the Board cases, not only did the lap belt fail to prevent head injuries; often it increased the severity of head injuries through the violent jackknifing effect.)

A 1976 Australian study (54) included 20 cases of children younger than 8 years who were restrained by lap/shoulder belts. Although some of them were injured when they were ejected from loosely adjusted belts, the authors concluded: "The use of adult [lap/shoulder] seat belts by children of any age is not a dangerous practice. . . . [C] hildren appear to be afforded good protection by the [lap/shoulder] adult belt even down to 2 years of age as long as the restraint is properly adjusted."

A 1978 Australian study (57) examined alternative crash protection mechanisms for children after their third birthday. The authors concluded: "For the average 3-year-old, the best restraint is [an approved child safety seat], the next is a properly adjusted child's harness, followed by a properly adjusted adult's lap-sash [lap/shoulder] belt." (Note that lap-only belts are not mentioned at all.)

A 1984 British paper (87) reported on dynamic tests to compare the outcome in a 30 mph frontal impact involving a 50th percentile 3-year-old child dummy variously restrained in an adult 3-point lap/shoulder belt, a booster seat with an adult 3-point belt, an approved child safety seat, and a child harness. The researchers concluded: "[The] data suggest that a 3-year-old child is at no greater risk from excess forward movement or inertial forces when restrained in an adult [lap/shoulder] belt than when using a child restraint of proven accident performance." Furthermore, when the same child dummy was restrained by a lap belt only, it experienced "excessive forward movement with a substantial risk of head contact." Use of a lap/shoulder belt-restrained booster seat eliminated "even the small risk" of submarining that was observed for 3-year-olds in lap/shoulder belts.

A 1984 French paper (31) presented test data for child surrogates using 3-point lap/shoulder belts. These were very violent frontal collisions with "very low injury severities" for lap/shoulder belted children; there was no abdominal injury. Even the "quite high position of the shoulder belt did not produce any dangerous loading of the neck, even with some submarining for a small female."

On the question of whether lap/shoulder belts are effective with child safety seats or booster seats, the answer of most researchers familiar with these devices is yes. In 1984, two of these researchers at the University of Michigan petitioned the NHTSA to require 3-point lap/shoulder belts in rear outboard positions of passenger cars. One of their main arguments was that lap/shoulder belts work effectively with child safety seats and booster seats and would eliminate the need for top tethers on these devices (failure to install and attach top tethers is the commonest form of misuse in devices that require

them). Provision of lap/shoulder belts would also benefit the majority of children who are not in any kind of child restraint device (because their parents have not provided one or because they are too large to use one) and adults who use the rear seat.

The NHTSA denied this petition, however. (149) The NHTSA said it does not agree with the petitioners' argument that child booster seats used with lap/shoulder belts are as effective as booster seats equipped with their own shoulder harnesses. The agency said that both children and adults can withstand greater forces on their shoulders than on their chests, and that "very young children" in particular have chest cavities that are "very flexible and vulnerable to chest belt loads," the sort of loads that lap/shoulder belts "would create." Harnesses provided with booster seats would "concentrate loads on the more sturdy shoulders of children."

The concern expressed by the agency about chest loads induced by lap/shoulder belts is, however, at variance with the evidence presented by the research papers noted above and by the experience of the children using lap/shoulder belts in the Safety Board's accident cases. Whether or not children's shoulders can bear greater loads than their chests, there was no evidence in the studies or the Board's cases that children were injured by the chest loads that may have been induced. Indeed, the children in the Swedish lap/shoulder belt study sustained fewer, and less severe, chest injuries than the adults; none sustained greater than AIS 2 injuries of any sort (only one child received AIS 2 level injuries). The same was true of the children using lap/shoulder belts in the Board's cases, all of whom were in severe frontal collisions.

Furthermore, the NHTSA's argument assumes that shoulder harnesses provided with some types of booster seats are in fact being used and used properly. Before using these harnesses, a tether anchorage system must be installed and the harnesses must then be attached to the tether anchor. An earlier Safety Board study 33/ noted that most child safety seats that require a tether do not, in fact, have the tether attached. Thus, most children using these booster seats do not have a properly attached shoulder harness in place; they are riding on the booster seat either totally unrestrained or, worse yet, restrained with a lap belt. (Use of a lap belt alone with a booster seat that requires a tethered harness is a very hazardous way to transport children.)

Finally, it should be noted that the types of booster seats discussed by the NHTSA have now been replaced in the market by booster seats with only a small shield in front of the child. When these boosters are used with only a lap belt around them (as they must in the rear seats of American cars and some foreign models), there is risk of abdominal injury, according to research recently conducted at the University of Michigan. If these boosters were used with lap/shoulder belts, the research showed, the risk of abdominal injury would be minimal, due to upper torso restraint provided by the shoulder belt.

The NHTSA also said that using a lap/shoulder belt with child safety seats would be "much less convenient" than using a lap-only belt. The reasoning behind this argument is not apparent to the Safety Board. Child safety seats are frequently used in the front outboard positions of American cars, where lap/shoulder belts are required by the NHTSA. According to a national child occupant protection organization, the Physicians for Automotive Safety, NHTSA-sponsored research has in fact shown that using the shoulder belt portion enhances the stability of the child safety seat, decreasing head excursion.

33/ Safety Study--"Child Passenger Protection Against Death, Disability, and Disfigurement in Motor Vehicle Accidents" (NTSB/SS-83/01).

FEDERAL REGULATIONS AND MANUFACTURERS' PRACTICES ON MOTOR VEHICLE SEAT BELTS

Beginning with the first Federal Motor Vehicle Safety Standard (FMVSS) regulating occupant restraint systems in the United States, lap/shoulder belts have been required for the front outboard positions, while only lap belts have been required for the center front seat and all rear seat positions. No U.S. manufacturer has voluntarily provided any other configuration, 34/ although many foreign cars have provided lap/shoulder belts at rear seating positions for several years. Indeed, in the earliest days of Federal regulation of seat belts, several U.S. manufacturers opposed any requirement for shoulder belts, even in front seating positions. General Motors (GM), for example, said:

> [W] e believe shoulder belts should continue to be offered [only] as optional equipment . . . we believe it would be premature and undesirable to require the installation of shoulder belts in all passenger cars . . . . Little is known about the safety utility of shoulder belts . . . . General Motors knows of no reliable statistical data on shoulder belts. (GM comments on Docket No. 3, Notice 1, December 30, 1966)

Ford Motor Company (Ford) also opposed requirements for front seat shoulder belts:

> Shoulder belts should be optional rather than mandatory equipment . . . . A carefully and individually adjusted shoulder belt does make some contribution to safety, but a poorly adjusted belt may introduce new hazards and proper adjustment cannot be made in every case. (Ford comments on Docket No. 3, Notice 1, March 2, 1967)

American Motors Corporation (AMC) was in agreement with GM and Ford on this point: "The available evidence on the safety benefits of [lap/shoulder] belts is not conclusive enough to support a mandatory requirement." (AMC comments on Docket No. 3, Notice 1, December 24, 1966) The Automobile Manufacturers Association (AMA) (now the Motor Vehicle Manufacturers Association) seemed to disagree with GM about the known safety benefits of lap/shoulder belts over lap-only belts, but opposed a requirement for them nevertheless:

> AMA does agree that significant safety benefits would be derived from the development and installation of improved upper torso restraint systems. Such systems could go a long way toward alleviating many of the problems of occupant interior impact. However, shoulder belts are still generally uncomfortable, unpopular and unused by the public. (AMA comments on Docket No. 3, Notice 1, January 3, 1967)

However, the NHTSA was not apparently swayed by these arguments; the first Federal standard required that the front outboard positions have (detachable) shoulder belts in addition to lap belts.

34/ In June 1986, General Motors announced that it will begin providing lap/shoulder belts at rear outboard positions in selected 1987 and 1988 passenger vehicles and in all remaining passenger vehicles during model year 1989. In July 1986, Ford Motor Company announced that it plans to introduce lap/shoulder belts at rear outboard positions during the next few years.

So far as the Safety Board can determine, the possibility of requiring lap/shoulder belts at rear outboard positions has been considered on only two occasions in the rulemaking history of FMVSS 208: Occupant Crash Protection. The first occurred very early in the regulation's history, in the course of the first significant revision of the initial standard. In 1970, the NHTSA published a proposal to begin moving away from active, or manual, seat belt systems toward passive, or automatic, occupant crash protection systems (such as air bags). In the interim stage before the proposed beginning date for passive system requirements, however, the agency proposed to require, "at all seating positions," seat belts "including upper torso restraints." (Docket 68-7, Notice 4, 35 FR 7187, May 7, 1970) This requirement for lap/shoulder belts at every seating position, front and rear, would apply only to vehicles manufactured between January 1, 1972, and January 1, 1973 (at which time, the agency proposed, the requirements for passive protection would come into effect).

Statements from the NHTSA and from those who commented on this proposal suggest that the interim lap/shoulder belt requirements were given little attention. The agency's views were reflected in its statements at a public meeting held by the NHTSA during the rulemaking comment period:

> We feel that the time of passive occupant crash protection is upon us and we do not intend to further pursue, beyond 1972, what has been a generally unpopular and futile effort to employ active restraint systems as a means of protecting occupants in crashes. [Statement of Ralph Hitchcock, then Product Engineer at NHTSA, at meeting held June 24 and 25, 1970]

This attitude appears to have been shared by auto manufacturers and others who commented on the proposal. For example, even though the auto makers opposed the passive restraint proposal, they did not comment extensively on the proposal to require lap/shoulder belts at all seating positions. Most of the comments on belt requirements addressed the question of whether lap/shoulder belts should be integrated, 3-point systems (rather than the then-current systems with detachable shoulder belts), and there was no differentiation in their comments between requirements for front and rear seats, or front outboard versus center front.

Two commenters did address the issue of requiring lap/shoulder belts in all seating positions. A seat belt manufacturing company opposed requiring them in the rear seats because, they said, rear seat occupants "are afforded ample protection by their location and other factors" and that rear seat occupants were able to survive severe crashes because of the padded front seatbacks in front of them. The other comment was submitted by the Motor Vehicle Safety Advisory Council of the U.S. Department of Transportation, which argued that this proposal would be too costly and lap/shoulder belts should be required only for drivers.

In all the later stages of this proposal, including the publication of the "final rule" on March 10, 1971 (36 FR 4600), the requirement for shoulder belts was limited to the front outboard seating positions. There was no discussion or explanation of why the proposal to require them at all seating positions had been dropped, and seat belt requirements have remained in this basic configuration to this day.

The only other point at which there appears to have been official consideration of the concept of requiring lap/shoulder belts at rear seating positions came as a result of the petition from researchers at the University of Michigan in 1984, discussed in an earlier section of this report.

Since 1972, the NHTSA has required that manufacturers provide an anchor location for after-market installation of separate, detachable shoulder belts at rear outboard positions. These are simply holes drilled into solid metal somewhere within the acceptable area defined by FMVSS 210, and they are not easily detectable. The Safety Board examined current owner's manuals for American and some foreign cars and found that none mentioned the existence of this anchorage. The manuals for GM models did note that shoulder belts are available. The GM manuals note that, "when properly worn with a lap belt, a shoulder belt can give riders added protection. It can prevent or reduce impact with the inside of the car by restraining the upper body in a collision. This is especially true in a frontal collision." Apparently only GM makes these belts available as a dealer-installed option; it is not certain whether GM shoulder belts could be used in other companies' models. Even to install these in GM cars requires removal of the original lap belts and installation of new lap belts with a "keyhole" suited for the insertion of the nonretractable shoulder belt.

Many foreign models (Audi, BMW, Honda, Jaguar sedan, Mercedes-Benz, Peugeot, Rolls Royce, Saab, some VWs, and Volvo) provide 3-point lap/shoulder belts in rear outboard positions, even though U.S. regulations do not require them. Of course, these systems have been required in several countries for many years (Sweden, Australia, and Germany most notably; see appendix I). A recently introduced "captive import," the Merkur XR4 Ti, also provides rear seat lap/shoulder belts, as will the second Merkur model, the luxury sedan Scorpio. In addition, as noted earlier, GM and Ford recently announced plans to begin providing rear seat lap/shoulder belts.

CONCLUSIONS

Based on the information collected by the Safety Board in its special crash investigation program and corollary research, summarized in this study report, the Board concludes the following:

- In frontal collisions, persons using lap-only belts may not be adequately protected against injury and may sustain additional injuries, induced by the lap belt itself.

- Lap belts may induce injury, ranging in severity from minor to fatal, to the head; spine; abdomen; intra-abdominal viscera, connecting tissue, and blood vessels; and intra-thoracic viscera, connecting tissue, and blood vessels. Such injuries may occur singly or in combination.

- The types of injuries induced by lap belts can be difficult to diagnose, particularly if attending medical personnel are unfamiliar with the symptoms or are unaware that serious injury can be belt induced; in some cases, symptoms of belt induced injury may not become apparent for some time. Inadequate medical treatment may also occur if attending medical personnel have been misinformed about the patient's use or nonuse of a belt system, about the type of belt system used, about whether the patient was ejected during the crash, or about other important facts of the crash.

- The gravity of typical lap belt induced injuries is such that if appropriate treatment is not provided quickly, serious irreversible consequences, including death, may result; some physicians advise that medical personnel attending a motor vehicle crash victim should suspect serious injury has occurred, particularly if lap belt use is known or suspected, and to act quickly to explore this possibiity and begin appropriate treatment.

- Because of a variety of weaknesses in available accident databases, it is not possible to determine the overall effectiveness of lap belts in preventing fatalities and reducing injury; the Safety Board is unable to state with confidence whether passenger vehicle occupants should be advised to use rear seat lap belts or not.

- The relative inadequacy of lap belts to provide crash protection, and their ability to induce serious injury, have been known for many years to researchers, some parts of the medical profession, and to others concerned with occupant crash protection.

- Lap/shoulder belts provide superior crash protection to that of lap belts alone, and present a significantly lesser risk of induced injury; such systems appear to work effectively even for children, and they can be used with child safety seats and booster seats.

- The U.S. Federal Motor Vehicle Safety Standards have required since the early 1970's that front outboard seating positions in passenger vehicles be fitted with 3-point lap/shoulder belts; however, all other seating locations may be fitted with a lap-only belt.

- Most manufacturers have not provided 3-point lap/shoulder belts at any seating location except the front outboard, where they are required.

- Since the early 1970's, the U.S. Federal Motor Vehicle Safety Standards have required that anchor locations for the after-market installation of detachable shoulder belts be provided at the rear outboard seating locations of passenger cars. However, few manufacturers note this fact in the owner's manuals for their cars and it is unlikely that many car owners are aware of it. So far as the Board could determine, only General Motors sells a detachable shoulder belt that could be fitted at the anchor locations.

- Several countries require that 3-point lap/shoulder belts be provided at rear outboard seating locations; several foreign manufacturers provide such systems even in vehicles manufactured for sale in the United States.

Given the known deficiencies of lap-only belt systems and the superior crash protection offered by belt systems that incorporate an upper torso restraint, the Safety Board believes that government and industry should take a number of steps to reduce reliance on lap belts and increase the availability of lap/shoulder belt systems. The implementation of State mandatory belt use laws will inevitably increase pressure for

more widespread use of belt systems in other than front seat locations. Indeed, at this writing, two States have passed laws that require all passenger vehicle occupants to wear the belts available to them; three more States require children to use belts in the rear seats (and some State laws on use of child restraint devices permit the alternative use of lap belts).

Therefore, the Safety Board believes that early action should be taken by the motor vehicle industry to provide aftermarket retrofit assemblies to convert lap-only belts to lap/shoulder belts. As mentioned above, attachment points for the upper anchor location have been required for more than 10 years at rear outboard locations; at least one domestic manufacturer also makes a separate, detachable shoulder belt available for aftermarket installation at these anchor locations. At a minimum, such retrofit assemblies should be available for all passenger vehicles required to be equipped with the necessary upper anchor locations, and manufacturers should aggressively market these systems and encourage owners to have them installed.

However, rather than merely supplementing the lap belts at these outboard locations with an add-on shoulder belt, manufacturers should provide integrated, continuous loop, self-storing lap/shoulder belt systems to replace the outboard lap belts entirely. These systems are preferable because they will be far more comfortable and convenient to use and are thus more likely to be used than the more awkward, cumbersome system created by merely adding a separate shoulder belt to existing lap belts.

For newly manufactured passenger vehicles (automobiles and multipurpose vehicles), all rear outboard seating positions should be equipped with integrated, continuous loop, self-storing lap/shoulder belts. The reasons for this are similar to those for urging an aggressive program of retrofit: increasing use of seat belts due to State laws, the inferior performance of lap-only systems, and the greater overall crash protection offered by lap/shoulder belts. Many foreign car models have provided these systems for some time, and some countries have in fact required their installation. Two U.S. manufacturers have announced plans to begin providing them. The Safety Board believes that there is no reasonable justification for continuing to forego these improvements in all passenger vehicles sold here.

Furthermore, the Safety Board believes that it may be technically feasible to provide 3-point lap/shoulder belts at every seating location; if so, such systems should be required as soon as possible. As long ago as the early 1970's, the NHTSA proposed such a requirement, at least for passenger cars.

There are a number of ways in which shoulder belts at nonoutboard seating locations could be attached. Some of the passenger cars that already provide 3-point lap/shoulder belts in rear outboard positions attach the upper anchor to the "rear deck" or "parcel shelf" behind the rear seat; a third shoulder anchor also could be located in this area. In such vehicles as vans, the upper anchor for shoulder belts might be located in the back of the seat itself, or they could be floor anchored if care were taken not to interfere with the foot area of the persons in the next seat behind. The Safety Board believes passenger vehicle manufacturers and the NHTSA should research this concept in depth, and should provide these restraints for every seating position if it is possible to do so.

It may be argued that the center front and center rear seating locations in passenger cars have the lowest rates of occupancy, and that therefore it is not warranted to provide the superior protection of lap/shoulder belts at these locations. The Safety Board believes that, to the extent these seating locations are used, their occupants deserve crash protection equal to those provided for other occupants. Furthermore, most of the seating locations in vehicles such as passenger vans are just such nonoutboard positions; as the two van cases in the Board's study vividly illustrate, persons using lap belts in such vehicles may be receiving substantially less crash protection even than persons altogether unrestrained.

Since designs for installing lap/shoulder belts at every seating location may require more vehicle modifications than either of the other two steps outlined above, the Safety Board realizes that more time may be required for implementation of this step. Nevertheless, the Board believes it is important to move as rapidly as possible to bring about the necessary design modifications to make such systems available to every occupant of passenger vehicles in this country.

Finally, the Safety Board believes that many emergency medical personnel, including those operating ambulance service, police or fire rescue personnel, emergency room nurses and physicians, and others called on to treat motor vehicle crash victims remain unaware of the possibility and gravity of seat belt induced injuries. Although the Board found many articles in leading medical journals concerning this problem, it appears that there is still a widespread lack of understanding in this area. In 6 cases reviewed by the Board, out of the 26 in which a lap belted person was involved (nearly 25 percent), there was serious question about the adequacy of the medical handling of the lap belted victim. In some there was little doubt that poor diagnosis and inadequate treatment contributed to the death of a person who might well have survived with prompt, appropriate treatment. As more people begin to use their belt systems, it will be very important for the medical community to educate itself about the type of injuries they may be called on to diagnose and treat, and take action to ensure that this knowledge is rapidly and effectively disseminated to those who will need it.

RECOMMENDATIONS

As a result of this safety study, the National Transportation Safety Board made the following recommendations:

--to U.S. manufacturers of passenger vehicles:

> Provide aftermarket retrofit assemblies for passenger vehicles to convert lap-only belt systems at outboard positions to integrated, continuous loop, self-storing lap/shoulder belt systems; make the availability of these retrofit systems widely known to vehicle owners and installation of them as simple and inexpensive as possible. (Class I, Urgent Action) (H-86-38)
>
> Provide, on a voluntary basis, in newly manufactured passenger vehicles, integrated, continuous loop, self-storing lap/shoulder belts in all non-front outboard seating positions. (Class II, Priority Action) (H-86-39)

Cooperate with the National Highway Traffic Safety Administration in determining the technical feasibility of providing lap/shoulder belts at non-outboard seating positions of passenger vehicles, and work toward providing such systems in newly manufactured vehicles at the earliest practicable time. (Class II, Priority Action) (H-86-40)

--to foreign manufacturers of passenger vehicles:

For any passenger vehicles with lap-only belts at outboard positions, provide aftermarket retrofit assemblies to convert these belts to integrated, continuous loop, self-storing lap/shoulder belt systems; make the availability of these retrofit systems widely known to U.S. vehicle owners and installation of them as simple and inexpensive as possible. (Class I, Urgent Action) (H-86-41)

Provide, on a voluntary basis, in newly manufactured passenger vehicles that do not already have them, integrated, continuous loop, self-storing lap/shoulder belts in all non-front outboard seating positions. (Class II, Priority Action) (H-86-42)

Cooperate with the National Highway Traffic Safety Administration in determining the technical feasibility of providing lap/shoulder belts at non-outboard seating positions of passenger vehicles, and work toward providing such systems at the earliest practicable time in newly manufactured vehicles sold in the United States. (Class II, Priority Action) (H-86-43)

--to the National Highway Traffic Safety Administration:

Encourage manufacturers of passenger vehicles to provide aftermarket retrofit assemblies to convert lap-only belt systems at outboard positions to integrated, continuous loop, self-storing lap/shoulder belt systems; urge manufacturers to make the availability of these retrofit systems widely known to vehicle owners and installation of them as simple and inexpensive as possible. (Class I, Urgent Action) (H-86-44)

Require that lap/shoulder belts be installed at all outboard seating positions in newly manufactured passenger vehicles manufactured for sale in the United States; initiate rulemaking action to this end immediately. (Class I, Urgent Action) (H-86-45)

Until such time as they are required to do so, encourage manufacturers of passenger vehicles to provide, on a voluntary basis in newly manufactured vehicles, integrated, continuous loop, self-storing lap/shoulder belts in all non-front outboard seating positions. (Class II, Priority Action) (H-86-46)

Determine the feasibility of requiring that 3-point lap/shoulder belts be provided at every seating position in newly manufactured passenger vehicles manufactured for sale in the United States; if found technically feasible, undertake rulemaking to require such lap/shoulder belts. (Class II, Priority Action) (H-86-47)

--to the International Association of Chiefs of Police:

Disseminate information to your members on the possibility for serious head, spine, and internal injuries to motor vehicle crash victims who were using a lap belt; ensure that your members are aware that these injuries, particularly internal injuries induced by lap belt use, may not be apparent for some time, and that it may be prudent even for seemingly uninjured lap belt users to be provided early medical attention by physicians familiar with treatment of trauma. (Class II, Priority Action) (H-86-48)

--to associations and groups concerned with emergency medicine:

Through communication with your organization's members and with other medical personnel, disseminate informed guidance to those called on to treat motor vehicle crash victims concerning the nature, severity, and appropriate handling of injuries that can be sustained by those using belt restraint systems. Ensure that emergency medical personnel receive training on the internal, head, and spine injuries that should be suspected in the case of crash victims who were using a lap belt, and the urgency of proper diagnosis and treatment. Encourage those emergency personnel who transport injured crash victims to relate accurate information to hospital emergency room personnel concerning the circumstances of the victim's involvement in the crash (seating location, use or nonuse of seat belt, type of belt used, etc.) (Class II, Priority Action) (H-86-49)

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

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Member

/s/ JOHN K. LAUBER
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July 28, 1986

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APPENDIX A

SUMMARIES OF SAFETY BOARD CRASH INVESTIGATIONS IN LAP BELT PERFORMANCE STUDY

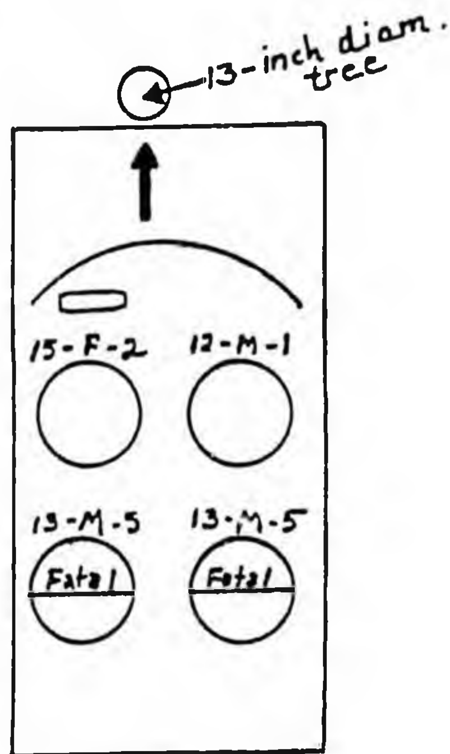
The following case summaries present detailed information on each case. On the first page of each summary there is a sketch of the crash configuration, showing the case vehicle and whatever object it struck (or was struck by). Each occupant is shown by a circle drawn at the occupant's seating location. The type of restraint used by that occupant is indicated also: two lines drawn across the circle indicate a 3-point lap shoulder belt, one line indicates a lap-only belt. If the occupant was killed. the word "fatal" is across, or near, the circle. Each occupant's age, sex, and highest AIS injury level is indicated on or near each circle. For example, 3-M-5 would indicate a 3-year-old boy who received an AIS 5 level injury as his most severe injury; 37-F-1 would indicate a 37-year-old woman whose most severe injury was AIS 1.

A photograph of the case vehicle is also provided. It should be noted that a substantial amount of crush in the front area of a passenger car does not necessarily denote severe crash forces. There is a considerable difference in the "stiffness" of various motor vehicle designs; if a "stiff" vehicle sustains substantial deformation, that would suggest larger crash forces than the same degree of deformation in a less "stiff" vehicle. It is also important to focus attention on the condition of the passenger compartment, for evidence of intrusion.

There is a glossary in appendix D and anatomical drawings in appendix G for assistance in understanding unfamiliar types of injuries or parts of the body.

CASE 1 (CHI-84-H-OR23)

Case vehicle:	1983 Pontiac Phoenix
Case vehicle weight:	2,893 pounds
Case vehicle Delta V:	37.1 mph



Circumstances

A 1983 Pontiac Phoenix struck a 13-inch-diameter tree head-on. The impact destroyed the front structure of the vehicle, with rearward structural collapse of up to 39 inches at the approximate center front. The car was driven by a 15-year-old girl and occupied by a 12-year-old boy in the right front seat, a 13-year-old boy in the left rear seat, and a 13-year-old boy in the right rear seat. The boys in the rear seat were wearing lap belts; the driver and right front passenger were unrestrained.

The accident resulted in moderate injuries to the unrestrained driver and minor injuries to the unrestrained right front passenger. The lap belted left rear passenger sustained massive abdominal injuries and was found to be without vital signs upon arrival at a hospital. All attempts to revive this boy failed, and he was pronounced dead approximately 48 minutes after the crash. Paramedics responding to the accident found that the lap belted right rear passenger had no blood pressure. This boy arrived at a hospital 1 hour after the crash. He was in cardiac arrest and without vital signs. Initial attempts to restore vital signs were successful but repeated tests made from the time of admission to the hospital over a period of several days failed to show any brain activity. He was pronounced dead 5 days after the crash.

Restraint and Injury

Seating location: Driver
Sex: F
Age: 15
Height: 4 feet 10 inches
Weight: 92
Seated height: 28 inches
Restraint used: None
Proper use? NA

Although a 3-point, continuous loop, lap/shoulder belt was provided at the driver's seat position, it was not in use at the time of this crash. The entire steering assembly in front of this occupant was displaced forward, with the wheel rim severely deformed.

Injuries	AIS	Probable Source
Partial avulsion of upper teeth	1	Steering wheel rim
Fractured anterior maxilla	2	Steering wheel rim
Laceration (5-6 cm), anterior maxilla gingiva	1	Steering wheel rim
Laceration (4 cm), upper lip	1	Steering wheel rim
Grade 1 strain, lateral collateral ligaments, left knee	2	Lower instrument panel
Contusion, left knee	1	Lower instrument panel
Strain, left ankle	1	Below instrument panel
Strain, right ankle	1	Below instrument panel
Laceration, right front scalp	1	Windshield
Contusion, left upper arm	1	Steering wheel rim
Abrasion, right knee	1	Lower instrument panel
Abrasion, left knee	1	Lower instrument panel
Abrasion, outer right thigh	1	Unknown

This occupant was admitted to the hospital for an unspecified period.

Seating location: Right front
Sex: M
Age: 12
Height: 5 feet 2 inches
Weight: 105
Seated height: 28 inches
Restraint used: None
Proper use? NA

This boy said he was wearing the 3-point lap/shoulder belt furnished at his seat position, with both the lap belt and shoulder strap adjusted "very loosely." However, Safety Board investigators could find no corroborating evidence of belt use, however loosely adjusted. A comparison of injury locations to known and most probable contact points shows that this boy could not have been permitted sufficient forward travel within the restraint system for these to have occurred. In such a collision, it would be expected that well-defined loading marks from both the cinching type of latchplate and the D-ring would occur. An abrasion caused by the shoulder strap would also be expected with an adjustment such as this boy described. In sum, the Board does not believe that this occupant was restrained at the time of the crash.

The instrument panel forward of this boy was displaced rearward several inches and appeared to be depressed inward at its lower center. The windshield was also broken outward, with "spiderweb" effect, in front of this boy's seat position.

Injuries	AIS	Probable Source
Scratches across forehead	1	Windshield
Contusions, right inner thigh	1	Unknown
Laceration, anterior lower left leg	1	Lower instrument panel
Lacerations, lower left junction of ribs with abdomen	1	Instrument panel
Contusion, left hip	1	Lower instrument panel

These injuries were described by the victim; he did not seek medical attention.

Seating location: Left rear
Sex: M
Age: 13
Height: 4 feet 11 inches
Weight: 106
Restraint used: Lap belt (ALR)
Proper use? Probably, with possible submarining

This boy was restrained by a lap belt with an automatic locking retractor (ALR), a sewn-in type of latchplate, and a pushbutton release type of buckle. The right front passenger said this boy's belt was positioned across the stomach and that the boy was "slouched" forward in his seat. The hospital records indicate that abrasions and contusions were across his lower abdomen, but do not define "lower abdomen" well enough for a proper evaluation. The Safety Board believes it is entirely possible the belt was in proper position before the crash, lying over the iliac crest, but that the foam lower seat cushion was compressed sufficiently downward and forward during the crash to allow a

submarining action. This was probably great enough to allow body travel under the belt, resulting in the belt rising above the iliac crest and causing the apparent massive internal injuries. Had the belt initially been adjusted too high, over the top of the iliac crest, it is very likely that the boy's internal injuries would have been to major organs located higher in the abdominal cavity and that the medical record would reflect a much higher location of the abdominal abrasions and contusions. This would especially be true if major submarining did indeed occur. (This analysis is based on an assumption that the left rear occupant received the same type of internal injuries as those of the right rear occupant. This assumption appears reasonably valid, since both occupants displayed the same area of abrasions and contusions, along with similarly distended abdomens noted by the hospital, and because both were subjected to the same collision forces.)

There were no contact points noted in the investigation other than feet contact with the lower rear framework of the driver's seat.

Injuries	AIS	Probable Source
Large abrasion across lower abdomen with ecchymosis	2	Lap belt
Massive internal injuries	7	Lap belt
Contusions, left upper chest	1	Contact with legs (or CPR)
Level of consciousness	5	Internal bleeding due to lap belt

This occupant was never revived after the crash. He was pronounced dead 48 minutes after the accident. Hospital officials noted that abdominal abrasions due to the lap belt were present. A note on the hospital records also indicated a distended abdomen. No autopsy was performed, but the coroner attributed death to "massive internal injuries from a seat belt which was thought to be fastened too high across the abdomen, or too loose, in which, upon impact, the belt raised up across the victim's abdomen, transmitting all the impact force to a confined area across the victim's abdomen approximately midway between his navel and the pubic area." (But see discussion above concerning probable fit.) No evidence of head injury was found.

Seating location: Right rear
Sex: M
Age: 13
Height: 5 feet
Weight: 90
Restraint used: Lap belt (ALR)
Proper use? Probably

This occupant was restrained by a lap belt similar to the one used by the left rear passenger. The right front passenger said the right rear passenger had his belt loosely "about his waist or legs" and that he was leaning forward onto the rear surface of the front seat cushion. Postcrash witnesses found him bent forward with his head between his knees. The medical records report contusions and abrasions about the lower abdomen and hip. The only occupant contact points noted in the Safety Board investigation were feet contact with the lower framework of the front seat.

This occupant was revived from complete cardiac arrest and kept on life support systems for 5 days. At admission to the hospital, he was noted to have a distended abdomen. His abdominal injuries were identified as lap belt related. Surgical records indicated an unspecified amount of blood found in the abdominal cavity. The coroner's report noted that the victim apparently bled severely into the abdominal cavity, resulting in brain death due to lack of blood in the brain. While the cause of death did not specifically mention the lap belt, the fatal injuries were described by medical records as being caused by the lap belt.

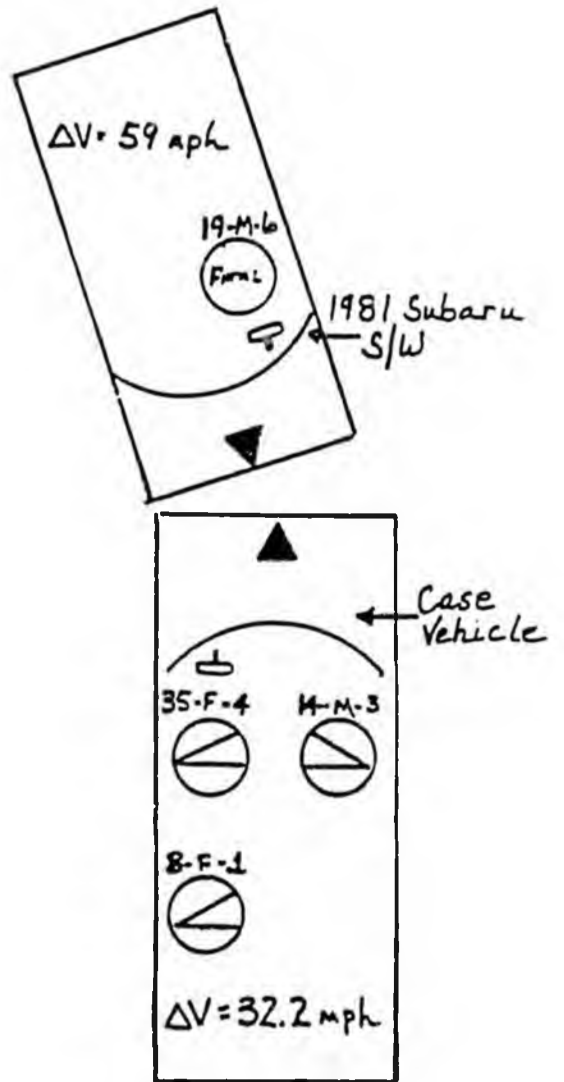
Taking all the facts into account, the Safety Board believes this boy was probably wearing the lap belt within the zone considered proper fit. Even if he had been leaning forward before the crash, this posture would not contribute to improper belt adjustment.

Injuries	AIS	Probable Source
Contusion with hematoma, lower abdomen	2	Lap belt
Small bowel totally detached from its mesentery	4	Lap belt
Deserosalization, small bowel (several areas of 1 to 1 1/2 inches)	7	Lap belt
Deserosalization, sigmoid colon	7	Lap belt
Torn mesentery of small bowel (1 to 2 feet of devascularization)	4	Lap belt
Abrasions, lower abdomen	2	Lap belt
Abrasions, hip	1	Lap belt
Level of consciousness	5	Internal bleeding due to lap belt

Compare the external injury notations for both rear, lap belted occupants (both boys of about the same height and weight): both had abdominal contusions and abrasions in the same location, both had the same distended abdomen, and both suffered brain death due to lack of sufficient blood for supplying oxygen to the brain. In short, they underwent the same impact forces, had the same external evidence of injury, and both died of the same cause. The available information seems to indicate that both fatally injured rear seat passengers were wearing the lap belt restraints properly prior to the crash.

CASE 2 (FTW-84-H-OR16)

Case vehicle:	1982 Jaguar XJ-6, 4-door
Case vehicle weight:	4,350 pounds
Case vehicle Delta V:	32.2 mph



Circumstances

A 1982 Jaguar was struck in the left front by a 1981 Subaru stationwagon, approximately 18 degrees from direct head-on. The impact forces completely destroyed the frontal structures of both cars. The Jaguar was driven by a 35-year-old woman and occupied by her 14-year-old son, seated right front, along with her 8-year-old daughter, seated left rear. All of the Jaguar occupants were wearing 3-point, continuous loop, lap/shoulder belts.

This accident resulted in fatal injuries to the 19-year-old unrestrained driver of the Subaru. The driver of the Jaguar sustained serious injuries due to the rearward collapse of the frontal compartment at her seating position. Moderate injuries resulted to the Jaguar right front passenger, while the left rear passenger sustained only minor abrasions, attributed to the restraint webbing.

Restraint and Injury

Seating location: Driver
Sex: F
Age: 35
Height: 5 feet 2 inches
Weight: 100
Restraint used: Lap/shoulder belt (ELR)
Proper use? Yes

This driver was wearing a 3-point, continuous loop, lap/shoulder belt with an emergency locking retractor (ELR), a free-sliding latchplate, and a pushbutton release type of buckle mounted to a flexible stalk. The seat was adjusted to its forwardmost position on an 8-inch track, secure at its attachments and without permanent deformation. The belt webbing was cut during rescue and extrication efforts. A force loading scar was found on the system webbing, beginning at 59 inches above the lower outboard anchor and extending for 2 7/8 inches. The plastic housing of the stalk-mounted buckle was shattered, with the latchplate torque still inserted and secure.

The frontal area of the driver's compartment was displaced rearward several inches due to the impact forces, resulting in a compression of the space between the seatback cushion and steering assembly, from 21 inches down to 13 inches. The instrument panel was displaced rearward a total of 13 1/2 inches at its left outboard side, and the left side A pillar was 12 inches rearward of its original position. The vehicle's floorpan, along with foot controls, was deformed rearward with the collapsing structure.

The Jaguar driver was subjected to severe impact forces, acting in a direct line through her seating position. With the crash induced frontal interior collapse at this position, there was no available space for a safe ride-down. The interior actually collapsed rearward into the driver, rather than the driver traveling forward a great distance. The underdash components and foot controls were pushed rearward and inboard, producing severe injuries to the occupant's lower extremities.

Injuries	AIS	Probable Source
Laceration, inside lower lip	1	Steering wheel rim
Contusion, lower front face	2	Steering wheel rim
Contusions, lower right neck	2	Steering wheel rim
Concussion	4	Forces from impact with steering assembly
Fractured femur, right side	3	Lower instrument panel
Laceration into right knee joint	2	Lower instrument panel
Contusion, left knee	1	Lower instrument panel
Fractured right ankle	2	Floorpan and foot controls
Fractured toes, left foot	2	Floorpan and foot controls
Contusions, lower abdominal area	2	Lap belt
Multiple contusions, upper torso	2	Shoulder strap and steering assembly

This driver required hospitalization for 19 days. The recovery period was longer than 6 months.

Seating location: Right front
Sex: M
Age: 14
Height: 5 feet 4 inches
Weight: 125
Restraint used: Lap/shoulder belt (ELR)
Proper use? Yes

This passenger was wearing a 3-point, continuous loop, lap/shoulder belt with an ELR, a free-sliding latchplate, and a pushbutton release type of buckle mounted to a flexible stalk. There was a circular area of damage in the front and upper surface of the instrument panel, located several inches inboard of the longitudinal centerline of this seating position. Further inspection revealed a force loading scar on the belt webbing, beginning at 61 inches from the lower outboard anchor and extending for 2 1/2 to 2 3/4 inches. The bucket seat was adjusted to its forwardmost limit on an 8-inch track. The front portion of the lower seat cushion was compressed from an original 21-inch width down to 16 inches, due to rearward and right outboard distortion of the center console structure. The precrash seatback position was not determined, due to post crash and extrication alteration of adjustment. The seat assembly's attachment to the lower right rear track was displaced approximately 2 inches upward and forward. The right front passenger, absorbing an angular force line, was propelled forward into head contact with the dashboard. Had no restraint been used, a severe head impact into the windshield would have occurred. There also would have been a possibility of ejection through the windshield.

Injuries	AIS	Probable Source
Major contusion, nose and left face	2	Instrument panel
Nose fracture	1	Instrument panel
Fractured cheekbone	2	Instrument panel
Major contusion, lower abdomen	2	Lap belt
Contusion, bladder	3	Lap belt
Contusion, lower right neck	1	Shoulder strap
Contusion, shoulder	1	Shoulder strap

This boy required 4 days of hospital treatment and missed 4 more days of school.

Seating location: Left rear
Sex: F
Age: 8
Height: 4 feet 2 inches
Weight: 45
Restraint used: Lap/shoulder belt (ELR)
Proper use? Yes

This passenger was restrained by a 3-point, continuous loop, lap/shoulder belt with an ELR mounted on the rear parcel deck, a free-sliding latchplate, and a pushbutton release type of buckle attached to a short length of webbing. An examination of the webbing revealed a 2-inch scar, beginning 51 inches above the lower outboard anchor. There was no significant deformation of the interior compartment at this seating position other than a 2-inch forward displacement of the extreme upper left outboard seatback cushion.

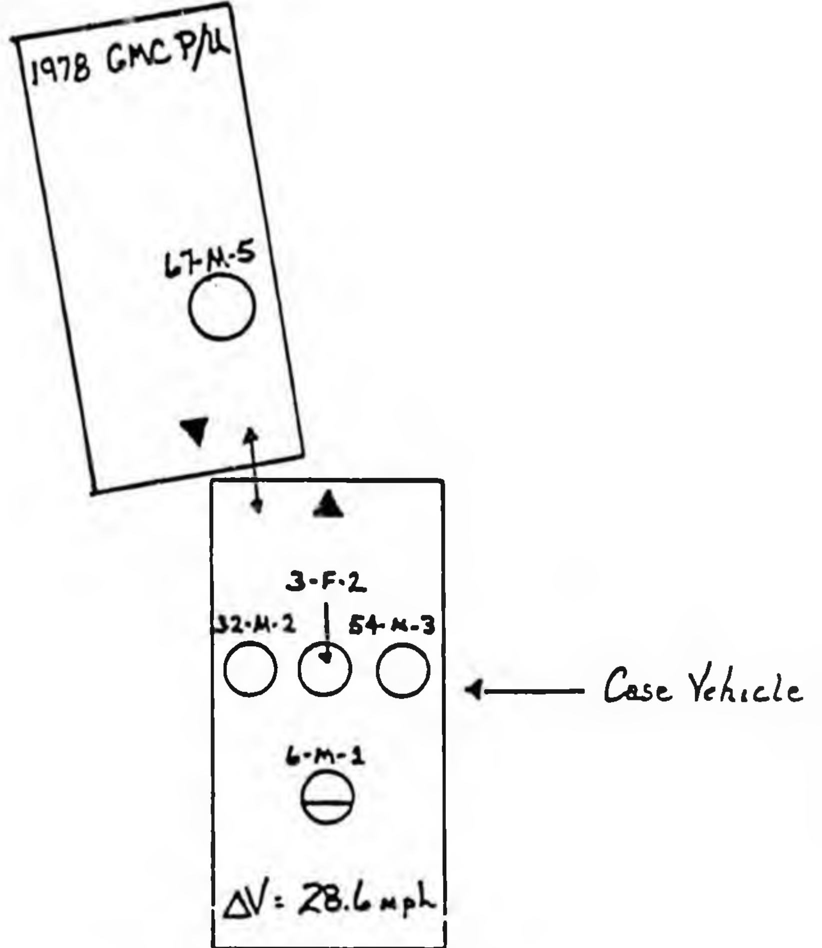
Injuries	AIS	Probable Source
Contusion, left side of neck	1	Shoulder strap
Lower abdominal contusions	1	Lap belt

This passenger was treated and released. There was no loss of school attendance reported.

A comparison can be made between the success of this left rear occupant's full restraint and cases involving similar dynamics with only a lap belt used. These comparisons suggest that this occupant would have suffered some level of pelvic or abdominal injuries if she had been restrained by a lap belt only. The severity of those injuries would be open to speculation. Consider Case 13, in which two small children rode down a crash of Delta V 29 mph with only minor injuries, while restrained by lap belts only. One factor which could have influenced the severity of the Jaguar left rear passenger's injuries, had she been wearing a lap belt only, is her additional height over that of the smaller occupants of Case 13. This extra height would have placed her head and neck forward of her upper legs and knees, should she have jackknifed over a lap belt. This condition would certainly have increased the probability of severe cervical injury due to hyperflexion.

CASE 3 (FTW-84-H-OR17)

Case vehicle:	1984 Chevrolet Impala 4-door
Case vehicle weight:	4,000 pounds
Case vehicle Delta V:	28.6 mph



Circumstances

A 1984 Chevrolet Impala was struck virtually head-on, left front to left front, by a 1978 GMC pickup. The Impala was occupied by a 32-year-old unrestrained male driver, an unrestrained 3-year-old girl seated center front, a 54-year-old man riding unrestrained at the right front, and a 6-year-old boy riding center rear restrained by a static lap belt. The force of the collision halted the Impala's forward travel and pushed it backward several feet. The front structures of both vehicles were destroyed by the severe collision forces.

This accident resulted in serious injuries to the unrestrained front seat occupants of the Impala. The lap belted 6-year-old rear seat passenger received minor abdominal contusions and minor facial lacerations and abrasions. The unrestrained 67-year-old driver of the pickup reportedly sustained critical (AIS 5) injuries.

Restraint and Injury

Seating location: Driver
- Sex: M
- Age: 32
- Height: 6 feet
- Weight: 170
- Restraint used: None
- Proper use? NA

This driver was not wearing the available 3-point lap/shoulder belt. The instrument panel in front of him was displaced rearward up to 2 inches. The steering assembly was deformed downward, with the wheel rim bent forward approximately 10 inches along its top circumference. Windshield damage with a "spider web" pattern was found forward of and slightly inboard of the seating position.

Injuries	AIS	Probable Source
Large abrasion, left forehead	2	Windshield
Large abrasion/contusion, right upper quadrant of abdomen	2	Steering assembly
Large abrasion/contusion, abdominal wall at the umbilical area	2	Steering assembly
Contusion, right thigh	1	Steering assembly
Abrasion, right knee	1	Instrument panel
Abrasion, left knee	1	Instrument panel
Major abrasion, right forearm	2	Instrument panel
Lacerations, right hand	1	Instrument panel
Lacerations, left hand	1	Instrument panel

The man spent 3 days at a hospital and missed several days of work due to his injuries and treatment.

With the available clear space forward of the driver, observed postcrash, it can reasonably be suggested that his injuries would have been substantially less if he had used the lap/shoulder belt, properly adjusted.

Seating location: Center front

Sex: F
Age: 3
Height: 38 inches
Weight: 33
Restraint used: None
Proper use? NA

This child was not wearing the available static lap belt. The center of the instrument panel was displaced rearward approximately 1 inch; the panel surface was severely distorted, due to buckling and crushing of the components. A two-way radio control head was mounted below the instrument panel, directly over the transmission tunnel.

Injuries	AIS	Probable Source
Major contusion, forehead	2	Instrument panel
Avulsion, three primary incisors	1	Instrument panel
Laceration of tongue	2	Instrument panel
Abrasion, chin	1	Instrument panel
Fracture, left tibia	2	Instrument panel
Fracture, left fibula (displaced)	3	Instrument panel
Major contusion, left forearm	2	Instrument panel
Abrasion, right knee	1	Instrument panel
Laceration, lower right leg	1	Instrument panel
Contusions, posterior right thigh	1	Instrument panel

The girl was hospitalized for 3 days. Although hospital records state she was ejected from the vehicle, this was not so.

It is instructive to compare this unrestrained child's injuries with those sustained by a child of similar size seated in the same position, in a car of similar size and loaded weight, involved in a frontal collision of almost identical Delta V, this latter child wearing a static lap belt (see Case 13). Such a comparison suggests that if the child in this case had been lap belted, she might have sustained severe head injuries, although many of her actual minor to moderate injuries probably would have been prevented.

Seating location: Right front

Sex: M
Age: 54
Height: 6 feet 2 inches
Weight: 220
Restraint used: None
Proper use? NA

This man was not wearing the available 3-point lap/shoulder belt. The instrument panel was displaced rearward by approximately 1 inch, with the panel surface badly broken and distorted. An area of windshield damage was also noted forward of and slightly outboard of this seat position.

Injuries	AIS	Probable Source
Small laceration, left medial eyebrow	1	Windshield
Small laceration, bridge of nose	1	Windshield
Contusion, left eye	2	Windshield
Contusion, chin	1	Windshield
Comminuted fracture and dislocation of left hip	3	Instrument panel
Abrasion/contusion, left knee	1	Instrument panel
Laceration, lower right leg	1	Instrument panel
Laceration, lower left leg	1	Instrument panel
Laceration, right hand	1	Instrument panel
Laceration, left hand	1	Instrument panel
Laceration, superior right shoulder	1	Instrument panel
Small (1/2 cm) laceration, tongue	1	Windshield

He was transferred to a second hospital 5 days after the crash and spent several weeks in treatment and rehabilitation.

This position had the greatest postcrash clear space available forward of the occupant. A properly worn, properly adjusted lap/shoulder belt would have prevented the major injury-causing contacts.

Seating location: Center rear
Sex: M
Age: 6
Height: 4 feet 3 inches
Weight: 50
Restraint used: Lap belt (static)
Proper use? No

This boy was wearing the static lap belt provided at his center rear seat position. He apparently was riding with a plastic tackle box resting on his lap. The rear surface of the front seatback in front of him was deformed forward 9 inches at its uppermost surface and 5 inches at its lower surface. The seatback deformation was approximately centered along the cushion width, directly behind a fold-down center armrest for the front seat. Sharp indented scars, 12 inches in width, were found in the seatback fabric, 8 to 13 inches below the uppermost surface. These indentations matched the exterior dimensions of the plastic tackle box. Shards of the plastic box were found on the rear compartment floor and the rear seat cushion.

The static lap belt at this position had a sewn-in, pushbutton release type of buckle attached to a length of webbing which extended 6 1/2 inches from the seat cushion junction. An adjustable position, cinching type of latchplate was attached to a 36-inch portion of webbing, which also came out from between the seat cushions. A 14-inch lateral separation was measured between the webbing entry points. A webbing scar from force loading was found at 14 to 16 1/2 inches from the latchplate webbing's entry point between the cushions. The latchplate was found, jammed by a folded-over portion of webbing, at 14 inches from the entry point.

As the collision forces acted, the plastic box was between the child and the rear surface of the front seat. The box, weighing an estimated 10 to 14 pounds, struck the seatback with enough force to shatter the box and severely deform the seat structure. The facial cuts and abrasions received by the boy were probably the result of contact with the box. An inspection of the vehicle interior surrounding this seating position revealed no other surfaces that might have produced such injuries.

The lap belt probably was not adjusted to a snug fit. The load mark location found on the webbing does not seem consistent with proper adjustment to the body size of the occupant. The 2 1/2 inches of webbing travel through the latchplate was not excessive when the Delta V is considered. However, the latchplate did not lock properly. The point of lockup was on a folded-over portion of the webbing. There was a retarding effect on the webbing, shown by the load mark, leading up to the folded-over area within the latchplate locking bar, but it is not known how much latchplate travel would have been allowed over normal (unfolded) webbing. It appears possible that without the webbing fold, the webbing might have continued to slip through the latchplate.

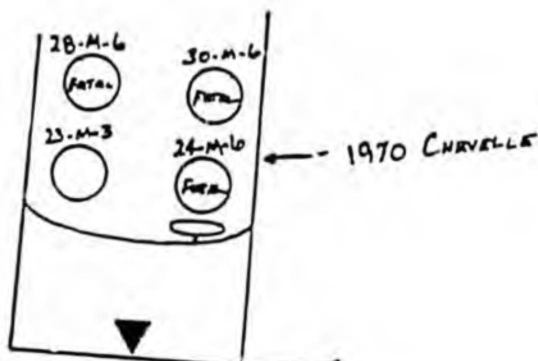
The Safety Board believes the performance of the center rear lap belt in this case was probably affected by three factors: 1) the loose belt adjustment, 2) the distance of webbing travel allowed through the cinching type of latchplate, and 3) the energy-absorbing effect of the plastic tackle box between the occupant and his possible contact points. These factors allowed the child to ride down the severe impact forces without serious head, spine, or abdominal injuries. As the child began to reach the limits of travel within the loosely adjusted restraint webbing, the plastic box began to absorb and help dissipate the forces. Had the webbing system been "snugged up" and had the latchplate not allowed several inches of webbing travel through its cinching bar, this child would have been decelerated from high speed, in a very brief time period, by a 2-inch-wide piece of webbing in the abdominal area. It can reasonably be expected that serious internal injuries might have occurred had the system been adjusted properly and functioned properly, given the forces involved in this collision.

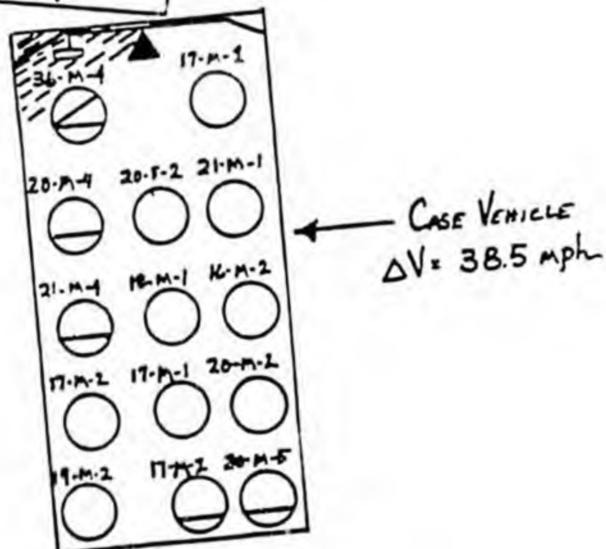
Injuries	AIS	Probable Source
Laceration (1 cm), under left eye	1	Tackle box
Small laceration, below right side of nose	1	Tackle box
Contusion, gums	1	Tackle box
Abrasion, chin	1	Tackle box
Abrasions, scattered over chest	1	Tackle box
Contusions. abdomen	1	Lap belt

The boy was treated and released at a hospital and attended school on the day following the accident.

CASE 4 (SEA-84-H-OR06)

Case vehicle:	1983 Dodge Maxi-Wagon (15-passenger van)
Case vehicle weight:	7,410 lbs.
Case vehicle Delta V:	38.5 mph





Circumstances

A 1983 Dodge 15-passenger van was struck head-on by a 1970 Chevrolet Chevelle. The van was being driven by a 36-year-old man restrained by a lap/shoulder belt. There were 13 other occupants in the van, 4 of whom were restrained by static lap belts at various seating positions, 9 of whom were unrestrained.

The collision destroyed the front structure of both vehicles. Three of the four unrestrained Chevrolet occupants received fatal head injuries. The remaining Chevrolet occupant, seated right front, sustained serious to critical head injuries and multiple fractures.

The collision caused serious to critical injuries to all belted occupants of the van, most of them lap belt induced. The unbelted occupants sustained only minor to moderate injuries.

This case should be compared to Case 23, also involving a van but occupied by lap belted and unrestrained small children, with similar results.

Restraint and Injury

Seating location: Driver
Sex: M
Age: 36
Height: 5 feet 10 1/2 inches
Weight: 160
Restraint used: Lap/shoulder belt (ELR)
Proper use? Yes

This man was restrained by a 3-point, continuous loop, lap/shoulder belt with an ELR, a cinching type of latchplate, and a pushbutton release type of buckle rigidly mounted to the base of the bucket seat. A "windowshade" type of tension relief device was also incorporated into the system. The Safety Board investigation did not document loading scars on the belt webbing, due to the compartmental damage and the inaccessibility of system components. For the same reasons, no determination of seat track adjustment could be made.

There was massive rearward deformation of the frontal area at this position. The collapsing front structure of the van resulted in this occupant being trapped in his seating area for 2 hours. The steering assembly showed severe rearward and upward displacement; some of the upward displacement was due to extrication efforts.

This driver related that, prior to the crash, his lap belt was positioned low on his hips with "snug" tension. He said that the shoulder strap crossed over his mid-sternum, but he could not describe webbing tension. The restraint webbing at this position was cut by rescue workers.

Injuries	AIS	Probable Source
Fracture, anterior cranial fossa floor	4	Steering assembly
Fracture, frontal maxillary	2	Steering assembly
Complex fracture, right zygomatic	2	Steering assembly
Fracture, intraorbital rim	2	Steering assembly
Fracture, 2nd left molar	1	Steering assembly
Scalp laceration (victim stated 3 inches)	2	Steering assembly
Comminuted fracture, right patella	3	Lower instrument panel and below
Comminuted fracture, left tibia	3	Lower instrument panel and below
Comminuted fracture, left fibula	3	Lower instrument panel
Dislocation and fracture, right foot metatarsals	2	Lower instrument panel and below
Open lacerations, right leg tibia	2	Lower instrument panel and below
Abrasion, right side, top of iliac crest	1	Lap belt
Contusion, upper left chest	1	Shoulder strap and/or steering rim

He spent 13 days in two hospitals, and an extended period of outpatient care was required following his initial hospital release. As of 7 months after the crash, he was still unable to return to work.

The restraint system performed much better than could be expected in a crash of this severity. The nature of a van's frontal structure is such that, in an offset frontal collision, there is little survivable space left in line with the rearward collapse. An unrestrained occupant seated behind this collapsing structure is normally decelerated by a combination of jagged metal, broken plastic, and windshield glass. With the steering control gearbox located under the extreme left front, an impact such as the one in this case forces the steering assembly rearward and upward very quickly. In fact, the steering wheel rim in this case probably had already reached the level of the driver's face just as he reached the limits of restraint provided by his shoulder strap. If this speculation is accurate, an unrestrained driver, given the same crash circumstances, would have had his head travel stopped instantaneously, while his torso continued moving forward several inches. This probably would have resulted in fatal cervical injuries, at a minimum.

Thus, the lap/shoulder belt worn by this driver was instrumental in preventing fatal injuries. Given the crash force line and severity, an unrestrained driver would have been fatally injured.

Seating location: Right front
Sex: M
Age: 17
Height: 5 feet 10 inches
Weight: 135
Restraint used: None
Proper use? NA

This man was not wearing the available 3-point lap/shoulder belt. There was moderate rearward distortion of the lower inboard frontal compartment at this position. Additionally, the vehicle's windshield was displaced out of its framework. This occupant and other witnesses said that he was partially ejected through the windshield space.

Injuries	AIS	Probable Source
Laceration (3 stitches), right side of face	1	Front exterior of van
Laceration (1 stitch), right elbow	1	B pillar area
Laceration (3 stitches), right lower arm	1	B pillar area
Lacerations, lower right leg	1	Below instrument panel
Lacerations, lower left leg	1	Below instrument panel
Contusion, right lower hip and upper thigh	1	Instrument panel and sidewall
Contusion, right knee	1	Instrument panel and below

He was treated and released at a hospital. He related that out-patient care was required following release and that he lost 1 month of work as a result of the accident injuries.

The missing windshield allowed deceleration with the occupant's upper body bowing over the padded dashboard forward of his seat. If the windshield had not been displaced, this occupant's head would have struck the glass, probably followed by a severe rearward flexion of his neck. Furthermore, it should be noted that the friendly deceleration undergone by this occupant is an exception rather than a rule. The smooth, rounded surface into which he decelerated could be compared to that provided by a child restraint device such as the Ford "Tot Guard," which incorporates a large, rounded shield in front of the child.

Seating location: Bench 1, extreme left
Sex: M
Age: 20
Height: 6 feet 2 inches
Weight: 155
Restraint used: Lap belt (static)
Proper use? Yes

This man was restrained by a static lap belt that incorporated a cinching type of latchplate, adjustable in position on a 49-inch webbing, and a pushbutton release type of buckle attached to a 9-inch length of webbing. Both buckle and latchplate webbing were attached to the seat framework approximately 4 inches behind the junction of the upper

and lower seat cushions. The tubular lower seat support posts were bent forward 4 inches directly below this position. The seatback cushion was deformed forward several inches, with an overall bow of 4 1/2 inches in the 1-inch tubular frame concealed by upholstery just under the top of the cushion.

The seatback of the van driver, directly forward of this occupant, was removed by rescue personnel and was not available for the Safety Board investigation. Consequently, no documentation of this occupant's forward area could be made.

This man related that his lap belt was routed low on his hips and that the tension was "snug." He said he was wearing a heavy coat under the belt.

Injuries	AIS	Probable Source
Basilar skull fracture	3	Driver's seatback
Ruptured right tympanic membrane	2	Driver's seatback
Fractured right mandible-unspecified	1	Driver's seatback
Dislocation, teeth	1	Driver's seatback
Transverse process fracture, L2	2	Lap belt
Transverse body fracture, L4	3	Lap belt
Comminuted fracture, right iliac crest	3	Lap belt
Two lacerations, small bowel	4	Lap belt
Torn mesentery and omentum	4	Lap belt
Abrasion right iliac crest	1	Lap belt
Abrasion (4x4 cm), left iliac crest	1	Lap belt
Fractured left foot	2	Lower driver seat frame

This occupant spent a total of 37 days in two hospitals, plus an extended period of outpatient care. At 7 months after the crash, he was still unable to return to work.

The severe (AIS 4) injuries sustained by this man can be attributed directly to the lap belt. The presence of abrasions on both the right and left iliac crests indicate that the belt was, at some point during the deceleration, placed in the area considered proper. The fracture of the right iliac crest indicates that the belt was positioned over that crest as severe loading of the webbing occurred. The small bowel is located in the mid-abdominal area, just above the iliac crest, and approximately centered between the second and fourth lumbar vertebrae. The injury-producing travel of the lap belt can be traced by the injuries.

The nature of the driver's seatback configuration, located directly forward of this man, did not allow containment of his upper torso and head travel. With his travel path being forward to the right, his head probably struck the sloping right side of the driver's seatback. This action allowed his upper torso and head to continue forward and downward, with the abdominal cavity being penetrated by the lap belt. Had the driver's seatback afforded containment of this passenger's upper body and head travel, the critical abdominal injuries probably would not have occurred, as the major deceleration would have been into the seatback instead of into the 2-inch-wide lap belt webbing.

Had this occupant not been wearing the lap belt, the dissipation of impact forces would have occurred over a much larger area. Given the driver's seatback configuration, he probably would have forcefully contacted that seatback, then twisted inboard into the center area between the front bucket seats. His loading of the driver's seatback possibly would have contributed enough additional forces through the driver's body, into the restraint system, for serious torso injuries to the driver, however.

Thus, the nature and extent of this passenger's injuries would have been much different if he had not been wearing the lap belt. The Delta V 38+ mph would certainly have resulted in injury of some type, but a comparison of this man's injuries to those of the persons seated unrestrained alongside him suggests they would have been much lower. Certainly this man would not have sustained the many serious to severe head, spine, and intra-abdominal injuries induced by the lap belt if his upper torso had been restrained in a lap/shoulder belt.

The forward folding of his seatback did not contribute to his injury. At the time that the seatback was bending forward under loading by the second bench passengers, this man had already traveled forward several inches, probably more than a foot, into the lap belt. Maximum loading of his seatback occurred simultaneously with maximum loading of his lap belt. In short, his lower body was out of position when the seatback folded.

Seating location: Bench 1, center
Sex: F
Age: 20
Height: 5 feet 6 inches
Weight: 240
Restraint used: None
Proper use? NA

This woman was not wearing the available static lap belt. Forward of her seating position, the engine cover had been displaced during the crash, with rearward distortion of the instrument panel area. The engine cover itself was not available for inspection.

Injuries	AIS	Probable Source
Fractured fibula, left	2	Engine and engine cover
Fractured tibia, left	2	Engine and engine cover
Deep laceration, left leg below knee	2	Engine and engine cover
2nd degree burns, lower left leg	1	Engine
Laceration, right knee	1	Engine cover
Hairline fracture, unspecified hip	2	Engine cover

She spent 5 days in an area hospital; several followup visits were required for treatment of complications. Three to 6 months of work were lost as a result of the accident.

If she had been wearing a lap belt, it could be reasonably expected that she would have experienced abdominal injuries similar to those of the man seated next to her on the left. There was no seatback forward of her position to provide any type of containment; thus, all deceleration would have been into the 2-inch-wide belt. Considering her obesity, there is little possibility that even a properly positioned and tensioned lap belt could have remained in proper position during the deceleration forces of this impact. The belt probably would have ridden up, over the iliac crest, into the abdominal cavity. With a properly positioned lap/shoulder belt, she would not have sustained the fractures, burn, and lacerations to her legs.

Seating location: Bench 1, extreme right
Sex: M
Age: 21
Height: 6 feet
Weight: 205
Restraint used: None
Proper use? NA

This man was not wearing the available static lap belt. The right front bucket seatback cushion directly forward of him was displaced. The extreme right side of the first bench seat ends several inches inboard of the vehicle interior sidewall, so that he was centered behind the inboard or left side of the right front bucket seat.

Injuries	AIS	Probable Source
Abrasion, forehead	1	Right front seatback
Abrasion, upper left leg	1	Engine cover
Superficial laceration, left elbow	1	Engine cover
Abrasion, right flank	1	Right front seatback
Contusion, right knee	1	Right front seatback

He was treated and released at a hospital; he said he was unable to work for 1 week.

This man's forward travel was mostly contained by the seatback cushion of the right front seat. Following the major deceleration provided by the seatback, he probably twisted inboard into the area between the front seats. The nature of his injuries enable the tracing of this travel path. The abrasions and contusion to his body's right side are from the cushion seatback, while the left side injuries are probably from the engine and damaged engine cover.

Seating location: Bench 2, extreme left
Sex: M
Age: 21
Height: 5 feet 1 inch
Weight: 130
Seated height: 30 inches
Restraint used: Lap belt (static)
Proper use? Probably

This man was wearing a static lap belt with a cinching type of latchplate attached to and adjustable on a 46-inch length of webbing, and a pushbutton release type of buckle attached to a 9-inch length of webbing. The tubular supports of this second bench were bent forward at the top, 3 inches on the left side and 3 3/4 inches on the right side. The extreme top of the second bench seatback cushion was displaced forward several inches, but accurate documentation was not possible, due to alteration during extrication efforts. Further examination of the position compartment revealed severe distortion of the first bench seatback directly forward of this occupant. The tubular framework located at the top of the first bench back cushion was bowed forward and down approximately 4 1/2 inches at its center point. A circular indentation was found in the top surface of the cushion material at 12 to 14 inches inboard of the extreme left side. Additionally, the tubular supports for the first bench were bent forward, 4 inches at the left side and 3 inches at the right side. There were no webbing scars found at this position.

Injuries	AIS	Probable Source
Unspecified laceration, forehead	1	Bench 1 back cushion
Contusion, area of both eyes	1	Bench 1 back cushion
Depressed frontal skull fracture	3	Bench 1 back cushion
LeFort III maxillary fracture	4	Bench 1 back cushion
Closed head injury	2	Bench 1 back cushion
Unspecified laceration, right foot	1	Bench 1 seat framework

This man spent 4 months in a hospital for treatment before being transferred to an extended care facility. Seven months after the crash he was still under extended care and on full disability.

The absence of abdominal contusions or abrasions indicates that his knees probably contacted the rear of the first bench at or before the major force loads of the impact. This type of contact would prevent the lap belt from traveling over the iliac crests into penetration of the abdomen.

The lap belt used by this occupant provided sufficient restraint of the lower body for a pivoting action, about the lap belt, to occur. This pivoting action of the upper body mass resulted in the occupant's face striking down into the uppermost tubular steel framework of the first bench seatback. Had this occupant not been wearing the lap belt, his deceleration probably would have been with a major portion of his upper body into the seatback in front of him, rather than his head into the seat framework and his lower body into the lap belt. Under these circumstances, his injuries probably would not have been so severe. A lap/shoulder belt also would have prevented this dangerous pivoting action and its resultant head injuries.

Seating location: Bench 2, center
Sex: M
Age: 18
Height: 5 feet 8 1/2 inches
Weight: 150
Seated height: 34 inches
Restraint used: None
Proper use? NA

This man was not wearing the static lap belt available at his seating position. In front of him was severe distortion to the first bench seatback and lower framework. The tubular steel seat top frame was bowed forward and down approximately 4 1/2 inches, and the lower seat framework supports were bent forward, 4 inches on the left and 3 1/2 inches on the right. The second bench seat was found with its left side support posts bent forward 3 inches and the right side posts bent 3 3/4 inches. This occupant said that he was displaced from his seat but he was unaware of his postcrash location.

Injuries	AIS	Probable Source
Left leg sprain	1	Bench 1 seatback
Left elbow sprain	1	Bench 1 seatback
Laceration (3 inch), just below left knee	1	Bench 1 lower framework
Lacerations, lower right leg	1	Bench 1 lower framework
Lacerations, lower left leg	1	Bench 1 lower framework
Pain in left shoulder	0	Bench 1 seatback

He was treated and released at a hospital. He said he lost 10 days of work due to his injuries.

This man's forward travel was contained by the seatback of the first bench. Without the lap belt restraint to restrict forward travel of his lower body, he was allowed to decelerate with dissipation of force spread over a major portion of his body. The energy management provided by containment is demonstrated by the minor injuries sustained by this passenger.

Seating location: Bench 2, extreme right
Sex: M
Age: 16
Height: 6 feet
Weight: 125
Seated height: 36 inches
Restraint used: None
Proper use? NA

This man was not wearing the static lap belt available at his seat position. The first bench back was bent forward approximately 3 inches at the right side tubular frame supports. The tubular supports of the second bench were bent forward 3 3/4 inches directly under this man's seating position. The upper framework of the first bench seatback was displaced forward in front of this man an undetermined distance. He said his postcrash position was in the floor area between the first bench and the second bench.

Injuries	AIS	Probable Source
Laceration to forehead(19 stitches), with caudal avulsion (wearing sunglasses)	2	Bench 1 seatback
Abrasion, left upper ankle	1	Bench 1 lower framework
Abrasion, right knee	1	Bench 1 seatback
Abrasion, left knee	1	Bench 1 seatback
Contusion, right elbow	1	Cargo floor area
Contusion, left elbow	1	Cargo floor area
Minor lacerations, right shoulder	1	Exit through side window
Minor lacerations, right hand	1	Exit through side window
Minor lacerations, left hand	1	Exit through side window

This man was treated and released at a hospital. He said he lost 7 to 9 days of work.

Clearly, containment also worked at this position. The moderate injury level (rather than minor, as with the unrestrained seat mate to his left) was the result of the extreme outside edge of the forward seatback being more rigid than at the center. This additional rigidity is due to the outboard vertical framework.