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SIDE IMPACTS: AN ANALYSIS OF LIGHT TRUCKS, INTRUSION, AND INJURY IN FARS AND NCSS DATA

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This report complements an earlier report which was devoted to the subject of side impacts of passenger cars. In this report, side impacts of light trucks are studied with respect to where, how, and why they occur using the data of the Fatal Accident Reporting System (FARS), and the National Crash Severity Study (NCSS). Data from the second phase of the NCSS program is also used to study side-impact injury and their relation to intrusion in both passenger cars and light trucks.

One-eighth of the fatalities in light trucks result from side impacts. The serious injury rate for side impacts is approximately the same as for other types of impacts to light trucks. Impacts by passenger cars resulted in only 23 percent of the side-impact fatalities in light trucks, and 25 percent of the serious injury. Collisions with heavy trucks and buses, and single-vehicle impacts resulted in 62 percent of the fatalities. Light-truck side impacts resulting in fatality or serious injury are of a variety of configurations, with a variety of impacting objects and vehicles.

Intrusion of the passenger compartment is associated with a greatly increased proportion of serious injury in side-impacted passenger car and light trucks. However, it is not clear if the increase results from intrusion per se, or from greater impact severity associated with the intrusion.

The body region most frequently injured seriously in side impacts is the head, which accounts for 38 percent of such injury. The chest receives only 21 percent of the serious injuries.

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1.0 INTRODUCTION

This report covers the second phase of a two-phase effort. The first phase addressed side impacts of passenger cars, and was based on data from the Fatal Accident Reporting System (FARS) operated by the National Highway Traffic Safety Administration (NHTSA) and from the National Crash Severity Study (NCSS).[1] The second phase is an extension of the prior effort. While this report is complete and self-contained, its greatest value is as an extension or companion of the earlier work, and it should be introduced and explained in that context.

The first phase covered only passenger cars and was intended to describe the phenomena of side impacts with regard to when, where, and how they occur, and to some extent to examine the consequences to the occupants. FARS data for 1979 and data from the first phase of the NCSS project--collected from January 1, 1977 to March 31, 1978--were used. Case material for that phase of the NCSS program was limited to passenger cars. The injury data contained a rather large proportion of missing data, and for this reason statistical description of the causes of injury in side impacts were not presented.

The FARS data are nearly a census of all U.S. fatal traffic accidents, and as a census, they present no inferential problems. The FARS data, although extremely valuable, do have two limitations. Because of practical constraints in such a large mass-data collection, the level of detail is restricted. Since the data are confined to fatal accidents, rates which relate to a broader spectrum of accidents, e.g., fatality rates among ejectees, cannot be computed. The NCSS data, on the other hand, result from in-depth investigations that provide considerable detail on each case. Furthermore, the cases represent a sample of the broad spectrum of towaway accidents. Although the

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[1]Robert E. Scott, James O'Day, Wendell Young, Side Impacts of Passenger Cars: An Analysis of FARS and NCSS data, Highway Safety Research Institute, The University of Michigan, Report No. UM-HSRI-81-20, April 1981.

judgement sample is intended to provide a representation of the mix of urban/rural accidents of the U.S., it can only be considered as a surrogate for the national population of towaway accidents with some reservation. The problems of drawing inferences from the NCSS data are discussed in depth in a report to the NHTSA.[2]

With the beginning of the second phase of the NCSS program, which ran from April 1, 1978 through March 1979, two changes to the data collection protocol were introduced which provide much of the basis for the effort reported here. The case vehicle criteria were broadened to include light trucks, thus providing quasi-national data from in-depth investigations on light trucks for the first time.[3] In addition, a protocol was introduced to collect detailed data on intrusion into the passenger compartment with a coding structure that provides links between the intrusion-inducing impacts and the intrusion, and in turn between the intrusions and any consequential injury. Phase two of the NCSS program and the data emanating from it will be denoted in this report as NCSS2.

The study reported here has three objectives, all closely related to the changes introduced in NCSS. These are:

(1) Estimating the frequency and describing the severity of side impacts into light trucks using data from FARS and NCSS2

(2) Evaluate the contribution to injury of intrusions into the passenger compartment

(3) Examine injury causation in side-impact crashes.

The study of light-truck side impacts parallels that of passenger cars in the first phase of the program. The impacts are described with

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[2]Gimotty, P. A., K. L. Campbell, T. Chirachavala, O. Carsten, and J. O'Day, Statistical Analysis of the National Crash Severity Study Data, Final Report, HSRI, The University of Michigan. Report No. UM-HSRI-80-38. Sponsored by the National Highway Traffic Safety Administration, Contract No. DOT-HS-8-01944.

[3]Data from multi-disciplinary teams from across the country have been available for many years, but their case-selection criteria were not intended to provide a sample representative of any identifiable population.

respect to where and how they occurred, and the consequences to the occupants. Side impacts are compared to other light-truck involvements across a variety of variables, then single-vehicle and multi-vehicle side impacts are compared. Finally, consequential injuries to the occupants are examined.

Accident researchers have long assumed that intrusion into the passenger compartment, or reduction in the size of the compartment, greatly increases the likelihood of significant or dangerous injury. While both intrusion and injury increase with impact severity and are thus correlated, it has been widely held that intrusion is dangerous per se. Accident investigation forms for documenting intrusion in detail and providing means for linking individual intrusions and injury were introduced in NCSS2 specifically to allow examination of these hypotheses. The second objective, then, is to use the NCSS2 data to study injury from intrusion in side impacts in both light trucks and passenger cars.

It was noted in the report on side impacts of passenger cars that identification of injury-producing contacts by occupants was not possible because of the relatively large proportion of missing data on individual injuries. It was hoped that the missing data rate on injury and associated contacts would be substantially lower in the NCSS2 data. The third objective was included in this study for that reason. While the missing data rate did improve, it was still substantial in NCSS2; particularly among the serious injuries, those of primary interest. Consequently, the description of injury causation presented here is based on both NCSS1 and NCSS2 data sets. Pooling the data increases the amount of data available and this is of value. It must be noted however, that inferences drawn from the data are subject to error from any bias that may exist in the missing data. Pooling the two data sets does not ameliorate the effects of such bias. The substantial missing injury data also limit the utility of the link between intrusions and associated injury. Consequently, the value of the detailed intrusion data is also limited to some extent.

A number of terms and conventions used in the study should be explained as well as characteristics of some of the variables in the two data sets.

The light trucks as used in this study include pickup trucks, small vans, and large station wagons based on light truck chassis. Identification of these types of vehicles is possible in both the FARS and NCSS2 data. Pickup cars are excluded from the material using NCSS2 data. These vehicles can not be identified in the FARS data, so they may well be included with pickups.

Side-impacted vehicles in the FARS data are identified as those with "principal" damage in the side--coded as 2-4 or 8-10 o'clock in the FARS reports. This use of clock direction should not be confused with the direction-of-impact force used in the Collision Deformation Classification (CDC). As used in FARS, the codes refer not to direction, but to the location of damage on the vehicle as viewed from above, with 12 o'clock indicating the front and 6 o'clock the rear. Codes 1, 5, 7, and 11 denote the corners. Major tabulations are made only of side-impacted vehicles in which at least one fatality occurred. Vehicles which also rolled over were excluded. Since the FARS data are a very biased sample of non-fatally injured occupants, all occupant counts from the FARS data include only fatalities unless otherwise indicated. Although the same coding scheme is not used in the NCSS data, a selection process was devised which is believed to be nearly equivalent. Up to two Collision Deformation Classification (CDC) codes may be assigned to a vehicle in the NCSS, in order of severity of damage to the car. The subset chosen for analysis here includes all cases coded "right" or "left" on the first letter of either CDC, as long as that CDC represents the first chronological crash event. Cases identified as rollover by the CDC have been excluded.

Occupant exposure to impacted surfaces, as either near-side or far-side impacts, has been derived from the "side struck" and "seated location" codes. Center-seated occupants are classified as near-side if there were no intervening occupants between them and the side impacted, otherwise they are treated as far-side. This convention is used for both FARS and NCSS data sets.

Injuries are coded in NCSS using the Occupant Injury Classification (OIC)[4] scheme in conjunction with the Abbreviated Injury Scale (AIS),[5] and by a separate severity classification (Fatal, Hospitalized, Treated and Released, etc.). NHTSA has derived a series of dichotomous injury codes split at different levels (e.g., AIS 0-2, 3-6, and AIS 0-3, 4-6). These variables were based on the overall AIS (OAIS) when available, or other items when the OAIS was unknown. This permits recovery of a substantial number of cases in which injury was not completely reported in the NCSS data, and thus relieves some of the limitations on the use of the original AIS variable, but without providing occupant contact information. The dichotomous variable giving injury of AIS 4-6 (with fatalities included) is used as the primary injury variable in the study of light-truck involvements for two reasons. The missing-data rate is much lower in this variable than in the other dichotomous variables (4.3% compared with 17.6% for the others). In addition, the threshold between AIS 3 and AIS 4 injuries to the chest was proposed as an appropriate performance criteria for passenger cars, light trucks, and multipurpose passenger vehicles in the advance notice of proposed rulemaking.[6]

One of the parameters determined for vehicles in the NCSS study is the change of velocity during impact, delta-v. This quantity was computed from descriptions of the damage to the vehicle or vehicles using the CRASH2 algorithm. Although an objective measure of crash severity would be desirable for the analyses presented here, particularly for the study of intrusion and injury, delta-v was not used. It is not used in the general study of light-truck side impacts because the force-deflection coefficients used to represent pickups in the algorithm were those originally derived for full-sized passenger cars. Their validity for side impacts into pickups is questionable.

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[4]Marsh, J. C. "Vehicle Occupant Injury Classification," HIT-Lab Reports, Vol. 4, No. 1, September 1973, pp. 1-11.

[5]The Abbreviated Injury Scale (AIS) - 1976 Revision. American Association for Automotive Medicine, 1976. 53p.

[6]Docket No. 79-04, Notice 1, Federal Register, Vol. 44, No. 236, December 6, 1976, p. 70207.

With later availability of actual crash data, NHTSA has modified the coefficients, at least for frontal and rear impacts. These changes were not made until after the NCSS data collection. Severity as measured by delta-v was not used as a control variable in the intrusion study because delta-v is determined primarily by the depth of crush of the external surfaces of the vehicle. The depth of crush is so closely associated with the amount of intrusion that it becomes essentially a surrogate for intrusion, not an independent measure of severity.

The organization of the remainder of this report is as follows. Section 2.0 contains a summary with the principal findings, and the conclusions. Section 3.0 contains the description of light-truck side impacts with injury information. A case summary of each case involving serious injury in the NCSS2 data is given in Appendix A. An examination of side-impact intrusions and associated injury for both passenger cars and light trucks is presented in Section 4.0. Descriptive information on serious injuries in both types of vehicles is given in Section 5.0.

Most of the variables used in each section are subject to some missing data. When single-variable percentages are derived, the cases with missing data are generally excluded. This is equivalent to distributing the missing data the same as the non-missing cases. The quantity of missing data (M.D.) is included in most of the tables.

2.0 SUMMARY AND CONCLUSIONS

2.1 SUMMARY AND FINDINGS

This report presents descriptive statistics relative to occupants in side impacts. Two data sets provide the basis for the statistics. These are (1) FARS for 1979, and (2) the NCSS program. A companion report addressing occupants of passenger cars in side impacts based on 1979 FARS and the first phase of the NCSS program was published earlier. This report complements the earlier report by extending the analysis to light trucks using data from 1979 FARS and the second phase of NCSS (NCSS2). In addition, the relation between injury and intrusion of the passenger compartment is examined using NCSS2 data, and the cause of serious side-impact injuries are examined in both NCSS1 and NCSS2.

These three subjects will be summarized separately. The summary of light trucks will be further subdivided into the information from FARS and NCSS2. Where results for light trucks are compared to those for passenger cars, the latter are from the earlier report on Phase I.[7]

2.1.1 Fatal Light-Truck Side Impacts in FARS

The number of light trucks in accidents in the U.S. in 1979 with at least one occupant of the truck killed was 5825. Of these, 710 or 12.2 percent were side impacts into the side of the truck. The total number of fatalities in light tucks in 1979 was 6458. This is 27 percent as many as were killed in passenger cars. The number of side-impact fatalities was 809 or 12.5 percent of the light-truck fatalities. This is one half of the corresponding proportion found for passenger cars.

Side impacts are more likely to be in urban areas than are other types of fatal light-truck involvements, as shown in Table 1. The same

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[7]Robert E. Scott, James O'Day, Wendell Young, Side Impacts of Passenger Cars: An Analysis of FARS and NCSS Data, Highway Safety Research Institute, The University of Michigan, Report No. UM-HSRI-81-20, April 1981.

trend was found for passenger cars, but with a greater overall proportion in urban areas, i.e., 47 percent of side impacts were in urban areas, but only 37 percent of other accidents. Side impacts are apparently more prevalent in areas where the exposure to intersecting or angle traffic is greater, namely urban areas.

TABLE 1
Fatal Light Truck
Accidents by Locality

Locality	Side Impacts		Other Impacts	
	N	%	N	%
Urban	221	31.4	1243	24.6
Rural	483	68.6	3813	74.4
Total	704	100.0	5056	100.0

Figure 1 depicts the location of the principal impact point of the fatal light-trucks side impacts. The three major areas of the side, excluding the corners, were used as the definition of side impacts. It follows that the front, rear, and corners all have zero impacts. Impacts are nearly equally divided between the two sides with 51.3 percent on the left and 48.7 percent on the right. There is less symmetry in the fore-aft directions. Nearly two-thirds of the impacts are into the center sides. Just under one-quarter are into the front side, while only four percent are into the rear-side.

Figure 2 gives an estimate of the distribution of fatalities by the type of vehicle struck. An estimate is used because the type of vehicle impacting the light truck in a side impact cannot be determined for those accidents involving three or more vehicles. For these cases, it was necessary to impute the type of striking vehicle from the distribution in two-vehicle accident cases. Since the number of involvements with three or more vehicles was a small fraction of the side impact involvements, any bias resulting from the estimation would

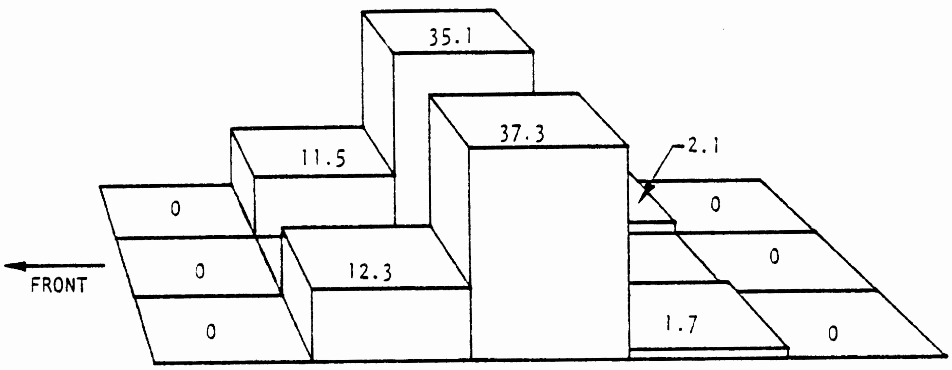

FIGURE 1
Principal Impact Point of FARS Fatal Light-Truck Side Impacts

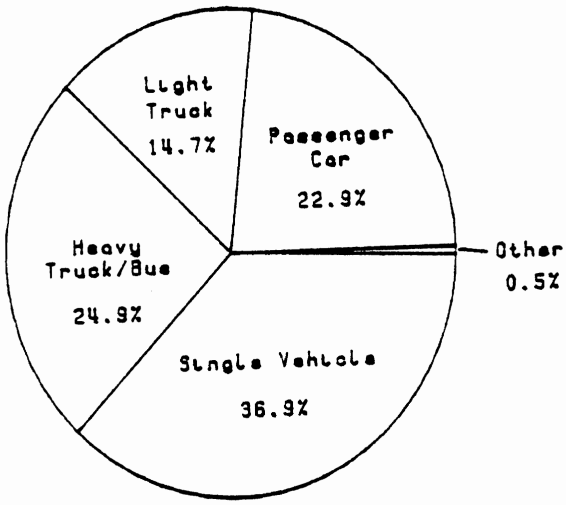

FIGURE 2

FARS 79, Light Truck Side Impact Fatalities
by Object Struck

be small. The largest single group of fatalities resulted from single-vehicle crashes. Impacts from heavy trucks or buses was the next largest group. Together these two groups of impacts accounted for 61.8 percent of the light-truck side-impact fatalities. Impacts by passenger cars resulted in only 22.9 percent. Even if a compliance test could reliably represent all the impact configurations of passenger cars and light trucks into the side of light trucks, only 37.6 percent of the side-impact fatalities would be represented. Nearly two-thirds of the fatalities were caused by impacts with much stiffer, more unyielding objects.

Fatalities by type of light truck are shown in Table 2 along with the proportion that were ejected for each type of vehicle. Pickups accounted for nearly 85 percent of the side-impact fatalities, with small vans accounting for only 13.5 percent. Even the absolute numbers are small for vans and large station wagons--109 for vans and only 14 for large station wagons in one year of national data.

TABLE 2
FARS 79
Light Truck Fatalities and Ejection by Type of Truck

Truck Type	Fatalities		Proportion of Fatalities That Were Ejections in Percent
	N	%	
Pickups	686	84.8	24.1
Small Vans	109	13.5	34.0
Large Station Wagons	14	1.7	7.1
Total	809	100.0	25.1

A substantial proportion of the fatalities involved ejections of the occupant from the vehicle, approximately one-quarter in pickups. Small vans had a higher proportion of ejections although, again, the absolute number is small. Only one fatal ejection occurred from a side-impacted large station wagon. Occupants with missing data on ejection were excluded from the computations of ejection rates shown in the table.

The 200 documented ejections were 8.7 percent of the total 2290 ejections of light truck occupants in the 1979 FARS data. Since 12.5 percent of the light truck fatalities were in side impacts, ejections are underrepresented among side-impact fatalities compared to other types of impacts. Nevertheless, ejection remains a problem in light-truck side impacts.

While fatalities are nearly equally divided between left and right-side impacts (51.7 percent left and 48.3 percent right), impact exposure of the fatalities is not. Over half (55.3 percent) of those killed had near-side exposure, i.e., the impact was on the same side as the occupant seat location. Less than a third (32.6 percent) were exposed to far-side impacts. The remaining 12.1 percent were of unknown exposure because of unknown seat location.

2.1.2 Light-Truck Side Impacts in NCSS

Table 3 gives the number of light trucks in the NCSS2 data set, and the number of trucks and occupants in side impacts. Both the unweighted numbers (actual observations) and the results of weighting by the inverse of the sampling fractions are included. The analysis and results presented in this report are based on weighted data, but the unweighted figures are provided here to indicate the quantity of data available. It should be noted that the actual number of occupants of light trucks in side impacts is 209. This number is not large, and restricts or limits the detail or depth to which analysis can be meaningfully extended.

TABLE 3
Light Trucks in NCSS2

	Pickups	Small Vans	Large Wagons	Total
Total in File:				
Unweighted	666	186	9	861
Weighted	2490	764	9	3263
Number in Side Impacts:				
Unweighted	102	32	2	136
Weighted	408	163	2	573
Occupants in Side Impacts:				
Unweighted	152	54	3	209
Weighted	560	240	3	803

The proportion of light trucks in the file which were in side impacts is 573/3263 or 17.6 percent. This is considerably higher than the 12.2 percent found in FARS. The difference may result from the difference in severity; the NCSS2 data represent towaways. Additionally, the definition of side impacts used in NCSS, which was based on two CDC's, may be more inclusive than that used in FARS. For example, corners (1,5,7, and 11 o'clock) were not included in FARS, yet the definition of these codes is not precise. Corner impacts were included in NCSS, so long as the impact was principally into the side rather than an end of the vehicle.

The distribution of occupants among the three types of vehicle also differs from that in FARS. Over two-thirds were in pickups, but 29.9 percent were in small vans, over twice the proportion in FARS. Whether this difference between the data sets reflects a lower fatality rate in vans than in pickups (in side impacts) or is a consequence of the geographic areas sampled in the NCSS project is not known.

The incidence of severe or serious injury among the side-impacted towaways is given in Table 4. The injured occupants, i.e., AIS=3+ and AIS=4+, include the fatalities regardless of their AIS. The 22 serious (AIS=4+) side impact cases include 14 fatalities. The differences in the injury rate between the side and other impact occupants are not significant at the 0.10 level using Fischer's exact probability.

TABLE 4
NCSS2
Light-Truck Occupants, Severe or Serious Injury
(weighted)

	Side Impacts	Other Impacts
Total Occupants	803	5034
Number With AIS=3+ (severe)	26 (3.2%)	140 (2.8%)
Number With AIS=4+ (serious)	22 (2.7%)	123 (2.4%)

The side-impact injury rate for AIS=4+ is slightly higher than for passenger cars but not significantly so.

Ejection and injury is shown in Table 5. Among all occupants for which valid ejection data were given, ejection was only 1.9 percent. However, it was 62.5 percent among the seriously injured, and 71.4 percent of the ejectees were seriously injured. The portals through which the 14 ejections occurred are shown in Table 6.

TABLE 5
NCSS2 - Light Truck Ejection in Side Impacts (weighted)

Injury Severity		Occupant Ejected			
		Yes	No	Total	M.D.
AIS = 0-3	N	4	707	711	52
	%	0.6	99.4	100.0	
AIS = 4-6	N	10	6	16	6
	%	62.5	37.5	100.0	
Total	N	14	713	727	58
	%	1.9	98.1	100.0	
	MD	0	16	16	2

TABLE 6
NCSS2 - Light Truck Ejection Portals

Portal	Number of Ejections
Side Window	5
Side Door Area	6
Windshield	2
Total	13
M.D.	1

Although the numbers of ejections are small, they account for a substantial portion of the serious injury, and ejection through both side windows and door continues to be a problem.

The direction of impact force in the side impacts is given in the CDC describing the impact. The distribution of the direction of force for light truck occupants is shown in Figure Fourteen percent of the impacts were within 15 degrees of the forward axis of the vehicle. Most of the impacts, 50.4 percent, were from 45 to 75 degrees to the side of the forward axis, with only 12.4 percent within 15 degrees of the lateral directions. It should also be noted that 50.3 percent were to the left side, and only 35.5 percent on the right--thus there is a left-right asymmetry.

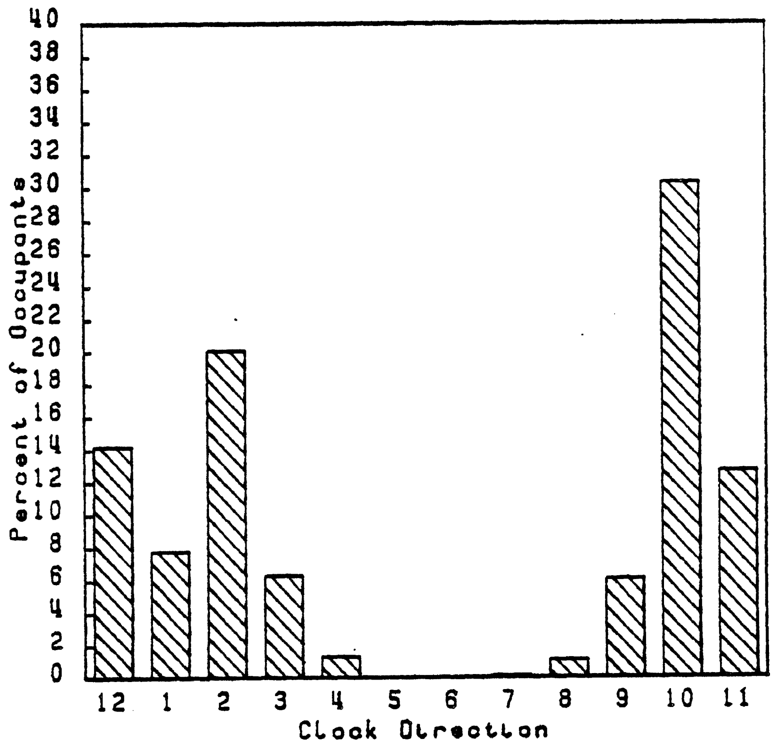

FIGURE 3

Direction of Impact Force
Light Truck Occupants in Side Impacts

The side impact vehicles which have been selected from NCSS are those cases coded "R" (right) or "L" (left) on the the first letter of the CDC. impacts are included. The second letter of the CDC provides more detail as to the actual horizontal location of damage along the defined side according to the following scheme:

D= Distributed (whole side)
Y= Front + passenger compartment
Z= Back + passenger compartment
P= Passenger compartment only
F= Front only (not passenger compartment)
B= Back only (not passenger compartment)

The exposure of occupants to each of these damage locations, the numbers with serious injury, and the serious-injury rates for each are shown in Figures 4-6. Figure 4 indicates that the most frequent damage pattern was distributed--from the front to rear areas. The next most frequent was damage to the passenger compartment and rear areas. Altogether, 64.3 percent involved multiple areas--only 35.7 percent involved a single region of the side. The passenger compartment was involved in 70.5 percent of the impacts. Figure 5 gives the number of serious (AIS=4+ and fatal) injuries for each location. Again multiple areas were important, accounting for 63.6 percent of the injuries. A substantial number, 22.7 percent, were in vehicles damaged in the front only. The proportion of occupants sustaining serious injury for each location is shown in Figure 6. The rates vary over a wide range and do not follow the pattern observed for passenger cars where the rate of "D" was high, with Y, Z, and P approximately equal but with about half the rate of D. In light trucks, the rate for Y is highest, and over twice the rate for D. However, the number of actual cases of AIS=4+ in each location category is very small. As a result the rates given in Figure 6 have wide confidence intervals, and the rates and their ratios would not be stable.

The total number of light-truck occupants who received injuries of AIS=4 or greater is only 22. Since each of these cases had a sampling fraction of one, the 22 are actual observations as well as the weighted number. Each is described in detail in Appendix A, but a brief summary will be given here. The 22 seriously injured were occupants of 18 vehicles of which 11 were pickups and 7 were small vans. Only 8 were

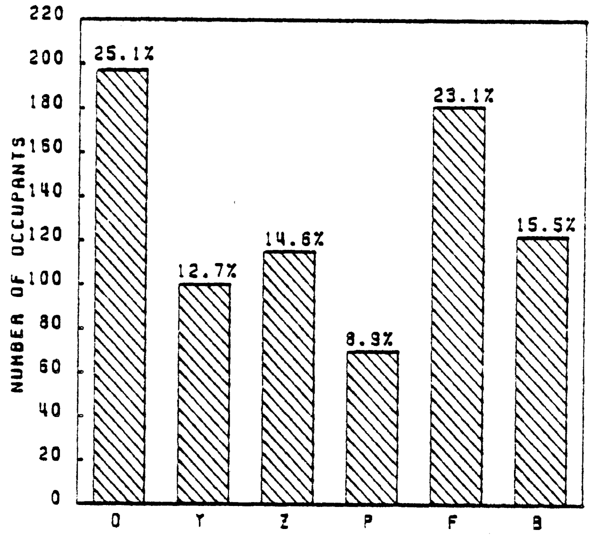

FIGURE 4

NUMBER OF LIGHT TRUCK OCCUPANTS IN SIDE IMPACTS BY SECOND LETTER OF CDC

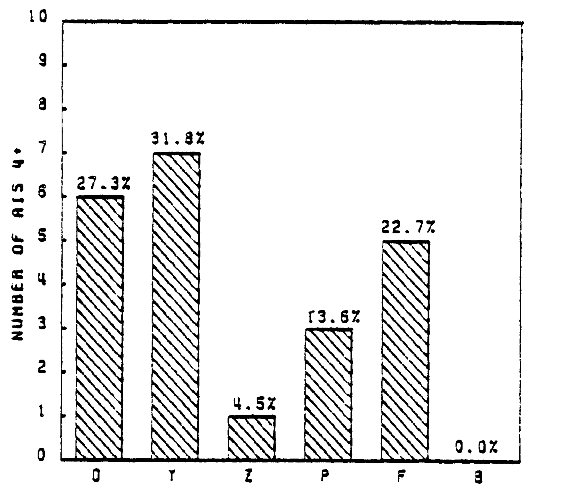

FIGURE 5

NUMBER OF LIGHT TRUCK OCCUPANTS IN SIDE IMPACTS WITH SERIOUS INJURY BY SECOND LETTER OF CDC

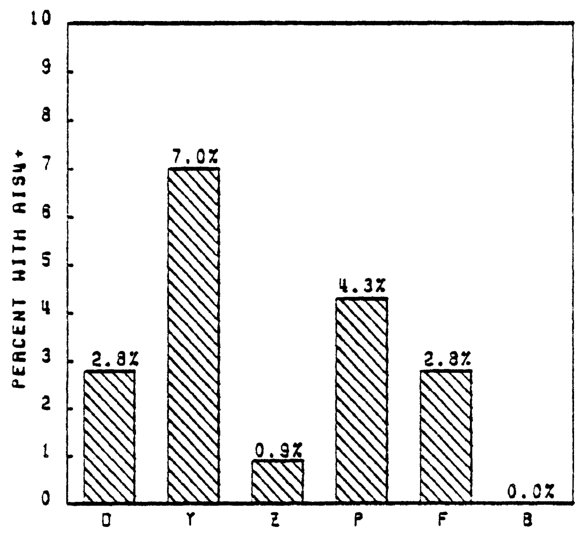

FIGURE 6

PROPORTION OF LIGHT TRUCK OCCUPANTS IN SIDE IMPACTS WITH SERIOUS INJURY BY SECOND LETTER OF CDC non-fatals. The other 14 were fatalities which included six occupants of vehicles with catastrophic intrusion, i.e., intrusion with damage so great that it could not be properly measured and documented by the investigators. Six of the fatalities were ejections. Of the eight non-fatalities, four were ejections.

Of the 22 occupants with serious injury, six were in vehicles impacted by passenger cars, two by light trucks, five by large trucks, and eight were in single-vehicle accidents. Thus, impacts with passenger cars accounted for one-third, and large trucks or objects for nearly two-thirds.

Only two of the fatalities and one non-fatality had their most serious injuries recorded as caused by contact with an intruding component.

2.1.3 Intrusion and Injury

This section summarizes the examination of data collected on intrusion and injury using the intrusion and occupant contact forms introduced in NCSS2.

The total number of passenger-car occupants in side impacts in NCSS2 are 10,005 (weighted). Intrusion into the passenger compartment occurred in vehicles containing 3700 of these, or 37 percent. Many of the intruding surfaces or components were not contacted by an occupant, and thus could not have been responsible for either causing or aggrevating injury. The number of passenger car occupants contacting an intrusion is 1092, or 29.5 percent of the 3700 in cars with intrusion. These 1092 occupants constitute 10.9 percent of those in side-impacted passenger cars. In addition to the 3700 in intruded cars, as documented by the intrusion and occupant contact forms, another 112 were in vehicles with catastrophic intrusion. It might be assumed that the latter 112 also contacted intrusions, bringing the total number of contacting occupants to 1204 or 12.0 percent of the occupants in side impacts.

Lack of injury and accompanying contact data on a substantial proportion of occupants in vehicles with intrusion limits the evaluation of intrusion as a cause of injury. Of the 1092 occupants who contacted an intrusion, the injury severity of any injury associated with the contact was given for only 238 (21.8 percent). Of these 212, or 89.1 percent, had an intrusion associated injury equal in severity to the most severe injury received. Thus we may conclude that for those occupants with documented intrusion associated injuries, the injuries were significant. However, the documentation appears to be incomplete, allowing the possibility of bias if only the more severe intrusion-contact injuries are reported.

Occupant exposure to intrusion and contact in side impact accidents are shown in Figure 7 for passenger cars, and Figure 8 for light trucks. About half the occupants were in vehicles with no intrusion. The other half (45.8 percent in cars and 54.4 percent in trucks) were exposed to intrusion, i.e., they were occupants of vehicles which had intrusion of the passenger compartment. Actual contacts between occupants and an intrusion were much fewer, however. Only 14.3 percent of the occupants of passenger cars and 13.3 percent of those in light trucks contacted an intrusion.

The dichotomous injury variables derived by NHTSA have much less missing data than the AIS variables and in this context are more reliable. Missing data on the AIS=4+ variable among occupants in vehicles with intrusion is only seven percent. The proportion of occupants of each exposure who received injuries of AIS=4+ (from all injury sources) are shown in Figures 9 and 10. Figure 9 leads to several observations. The incidence of serious injury to occupants of passenger cars who did not contact an intrusion is low--less than 1.3 percent. If an intrusion was contacted, the rate is over seven times as high (9.3 percent). Eighty-nine percent of the occupants of passenger cars who received an injury of AIS=4 or higher were in cars with an intruded passenger compartment. While only 29 percent of the occupants of non-catastrophic passenger car crashes contacted on intrusion, those that did represent 62 percent of the serious injury.

The most frequently contacted intruding components are door panels or side surfaces, which account for 50.8 percent of such contacts. The A-pillar and instrument panel are next, but only produce 10.9 percent

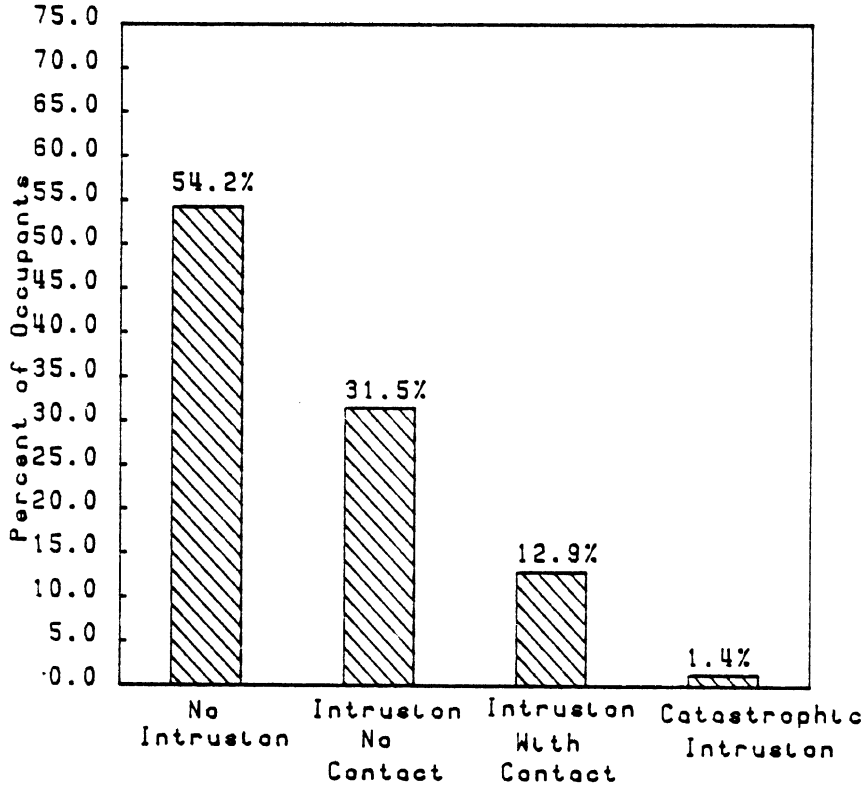

FIGURE 7

Occupant Exposure to Intrusion, Passenger Cars

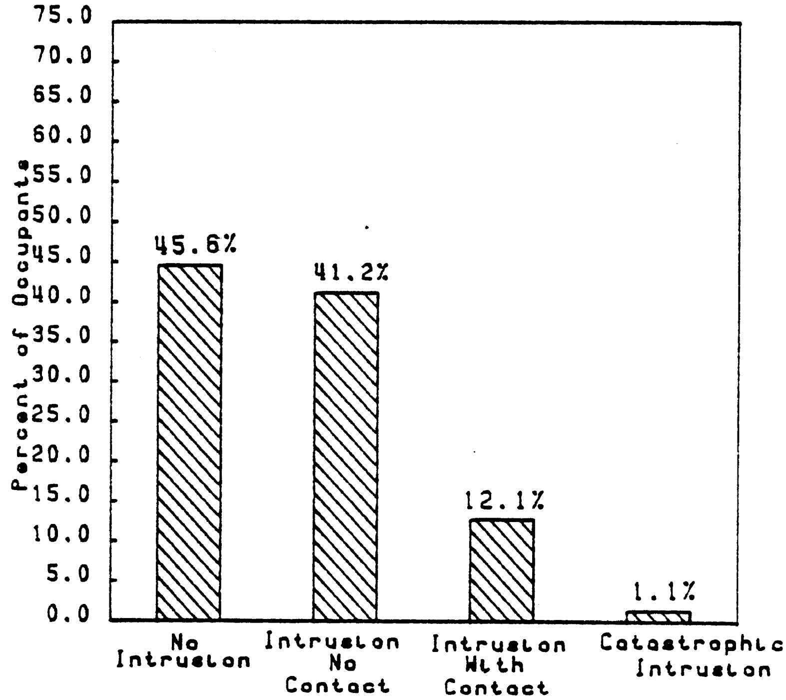

FIGURE 8

Occupant Exposure to Intrusion, Light Trucks

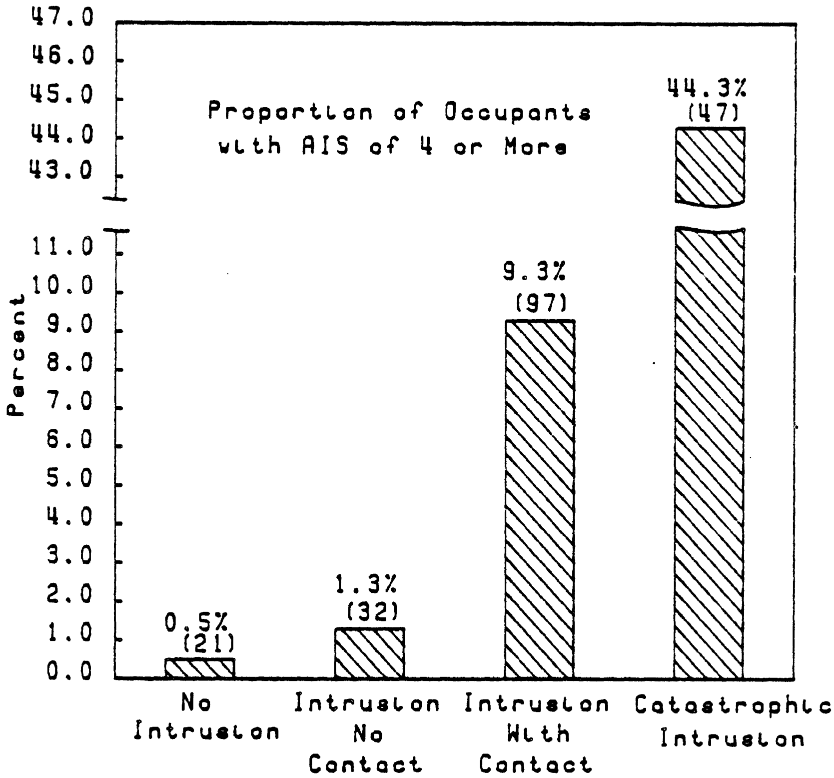

FIGURE 9

Occupant Injury by Contact With Intrusion,
Passenger Cars

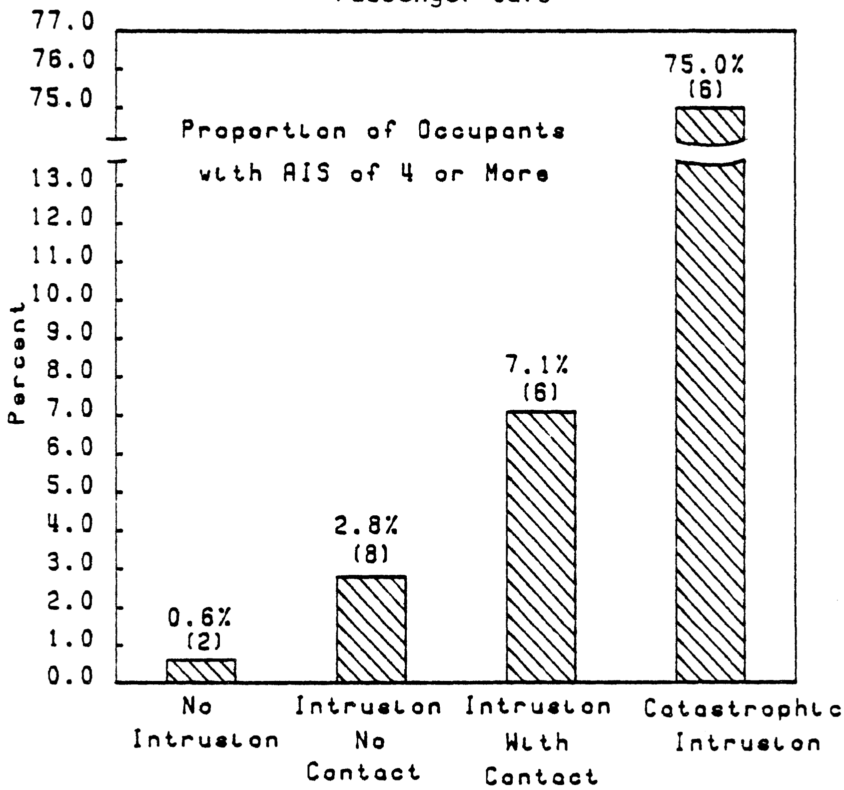

FIGURE 10

Occupant Injury by Contact With Intrusion,
Light Trucks

and 10.2 percent of the contacts, respectively. The other intruding components each account for six percent or less.

Side impacts which were classes as catastrophic account for only 1.1 percent of the occupants in side impacts, yet they resulted in 23.9 percent of the serious injuries in passenger cars and 27.3 percent of those in light trucks. The catastrophic damage to passenger cars was major separation, such as transection at the firewall in 49.1 percent of the cases, and extreme compression in 42.9 percent. Interestingly, while ejection was high (14.9 percent) among the serious injury cases in the passenger cars, it was even higher (26.5 percent) among the occupants with less severe injuries (AIS 0-3).

It is not correct to interpret catastrophic intrusion, as used in the NCSS intrusion data collection, as unsurvivable. Over 50 percent of the occupants of these vehicles received injuries of AIS=3 or less, 53.5 percent in passenger cars and 65 percent in light trucks.

2.1.4 Serious Injury in Side Impacts

Information on the details of serious (AIS=4+) injury to occupants of side-impacted passenger cars and light trucks will be summarized in this section. Specifically, the summary will present the body regions injured, and the proximate cause of injury, i.e., the occupant contact most likely to have caused the most severe injury received by occupants with serious injury.

Figures 11 and 12 depict the distribution of the body region of the most severe injury of occupants who were seriously injured. The seriously injured are those with an AIS of 4+ on the dichotomous injury variable, and fatalities. The dichotomous injury variable was used because it has little missing data--approximately five percent. Information on the body region injured is only available from the individual OIC's, which are accompanied by the AIS and contacted object, all of which have considerably missing data. The distribution of Figures 11 and 12 are taken from the first listed OIC, describing the most severe injury to the occupant. Passenger car occupants (Figure 11) with serious injuries have a missing data rate on body region of 28.5

percent. This is largely among the fatalities, which constitute 65.1 percent of the serious injury cases.

The body region seriously injured most frequently is the head (including the skull and face), in both passenger cars and light trucks. The head and neck grouped together account for 50.9 percent in cars and 55.5 percent in light trucks. Injury to the chest are second most frequent in passenger cars, but account for only 20.8 percent. In light trucks, chest injuries account for only 5.6 percent, while the abdomen accounts for 27.8 percent. The figures for light trucks are subject to large sampling errors however, since they are based on a total of only 22 serious injury cases.

The most frequent proximate cause of injury is side-interior surfaces including doors and armrests; listed or 27.6 percent of the passenger car occupants. The steering wheel was given for 14.3 percent; and the instrument panel, windshield, glove compartment, or mirror for 11.4 percent. Each of the other components was responsible for less than 10 percent, except objects exterior to the passenger compartment which was listed for 14.3 percent.

2.2 CONCLUSIONS

Side-impacted light trucks are defined in this report as all pickups, small vans, or large (truck based) station wagons for which the first impact involved direct damage to the right or left side. Rollovers constitute a small proportion of these, but they have been eliminated from the analyses presented here.

Light trucks, as defined above, have 6458 occupant fatalities per year in the U.S. This is 27 percent of the number of passenger car occupants killed in a year.

Side impacts of light trucks result in 12.5 percent of the light truck fatalities. Side impacts account for twice this proportion (24.8 percent) of passenger car occupant fatalities.

Side impacts produce 15.2 percent of the cases of serious injury (AIS=4+) among light truck occupants, while 13.8 percent of the

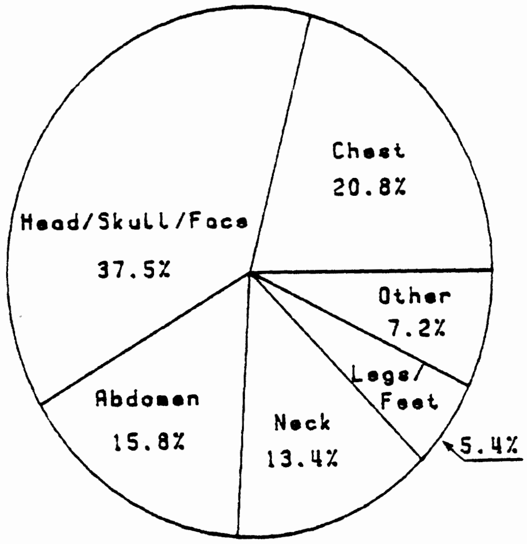

FIGURE 11

Body Region of Serious (AIS=4+) Injury,
Passenger Car Occupants

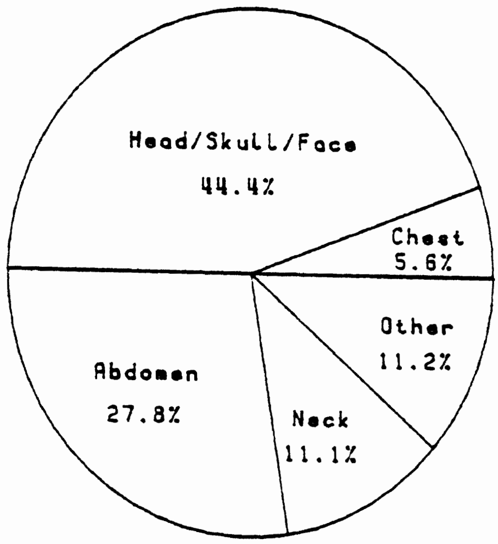

FIGURE 12

Body Region Receiving Serious (AIS=4+) Injury,
Light Truck Occupants

occupants are inside impacted vehicles. These proportions are also approximately half as great as was found for passenger cars.

Ejection of occupants from light trucks in side impacts remains a significant problem. One-quarter of the fatalities and 63 percent of the serious injury were among ejected occupants, although the latter figure is based on a small number (10) of cases. Portals through which the ejections occurred were approximately equally divided between side windows and door areas.

Impacts with passenger cars account for only 20.7 percent of the light-truck side impact fatalities, and 27 percent of the serious AIS=4+ injury. Heavy trucks and single-vehicle collisions produce 62 percent of the fatalities.

Light-truck side impacts resulting in serious injury or death are of a variety of configurations, with a variety of striking objects. The location of point of impact and distribution of damage also varies widely.

A single side-impact test protocol for light trucks would represent only a small portion of the serious impacts.

A surface or component intruding into the passenger compartment was contacted by only 12 percent of the occupants of passenger cars and light trucks in side impacts. However, 62 percent of the serious injury in non-catastrophic cases were occupants who contacted intrusions, even though only 29 percent of the occupants in <u>intruded</u> vehicles actually contacted an intrusion.

Injuries to the head (and skull and face) account for 38 percent of the serious (AIS=4+) side-impact injuries; only 21 percent are of the chest. Thus, an occupant-protection performance criteria based on thoracic injury would represent only one-fifth of the serious and fatal injuries. The fraction becomes much smaller if only a subset of the possible impact configurations and damage patterns are represented.

It is still not possible to quantitatively assess the injury contribution of occupant compartment intrusion above and beyond the effects of impact severity.

SECTION 3.0 LIGHT TRUCKS

Side impacts into light trucks are examined in this section, using data from the 1979 FARS and NCSS2 files. The general format used in presenting the data is as follows. Side impacts are compared with other impacts across a number of accident and vehicle descriptors in Section 3.1. Similar comparisons across a number of occupant-related variables are presented in Section 3.2. Single- and multi-vehicle side impacts are compared across both vehicle and occupant descriptors in Section 3.3. Finally, more detailed information on side-impact fatalities, injury, and ejection is given in Section 3.4.

Results from both FARS and NCSS2 are presented in each section, generally together arranged by subject. However, there are a number of data elements or variables given in NCSS which do not have counterparts in FARS, and vice versa.

Before presenting the results, it may be useful to describe the quantity of material available in each source of data.

The 1979 FARS data which have been used to represent fatal light-truck side impacts contain information on 5825 light trucks, of which 710 or 12.2 percent are side impacted without rollover. The total number of fatalities among all light truck occupants in the file is 6458, of which 809 or 12.5 percent are in side-impacted vehicles.

The distribution of fatalities among the three classes of light trucks used in this study are given in Table 7. These figures are taken as a national census of light-truck side-impact fatalities.

The number of light trucks in the NCSS2 data set, along with the numbers of vehicles and occupants in side-impacted trucks is shown in Table 8. The NCSS project employed stratified random sampling, so each case has a weighting factor associated with it that is the inverse of the sampling fraction. Weighting factors for the data are 1, 4, 10, or 20, with only one team (Southwest Research Institute) producing weights of 20. While the analyses are all based on weighted, data unless

TABLE 7
Side-Impact Fatalities in 1979 FARS by Type of Light Truck

Truck Type	N	%
Pickup	686	84.8
Vans	109	13.5
Large Station Wagons	14	1.7
Total	809	100.0

otherwise indicated, both the weighted and unweighted quantities are shown in Table 8.

TABLE 8
Light Truck Cases in NCSS2

	Pickups	Small Vans	Large Wagons	Total
Total in File:				
Unweighted	666	186	9	861
Weighted	2490	764	9	3263
Number in Side Impacts				
Unweighted	102	32	2	136
Weighted	708	163	2	573
Occupants in Side Impacts				
Unweighted	152	54	3	209
Weighted	560	240	3	803

Table 9 gives the distribution of cases by the teams participating in the NCSS data collection.

TABLE 9
NCSS2
Light Trucks by Team
(unweighted)

Team	Total Light Trucks		Light Trucks in Side Impacts	
Calspan	92	10.7	15	11.0
HSRI	91	10.6	13	9.6
Indiana	150	17.4	23	16.9
Kentucky	135	15.7	17	12.5
Miami	62	7.2	12	8.8
Southwest Research Institute	301	35.0	52	38.2
Urban	184	21.4	37	27.2
Rural	117	13.6	15	11.0
Dynamic Sciences	30	3.5	4	2.9
Total	861	100.0	136	100.0

3.1 VEHICLES IN SIDE IMPACTS COMPARED TO OTHER IMPACTS

Three types of light trucks have been grouped together in this study: pickup trucks, small vans, and large station wagons. All three are based on truck-type chassis and thus have similar operating and crush characteristics, although their use patterns may differ. Comparisons of the distributions of the three vehicle types in side versus other other impacts are shown in Tables 10 and 11. Not surprisingly, pickups are the dominant type of vehicle in side impacts in both data sets. However, vans appear substantially more frequently in the NCSS data.

Table 12 indicates that fatal side impacts occur predominantly in rural areas. However, they are more likely to be in urban areas than are other fatal light-truck accidents. Table 13 gives the corresponding

TABLE 10
FARS 79
Body Type

Body Type	Vehicles			
	Side Impact		Other Impact	
	N	%	N	%
Pickup	609	85.8	4241	82.9
Van	91	12.8	802	15.7
Large Station Wagon	10	1.4	72	1.4
Total	710	100.0	5115	100.0
M.D.	0		0	

TABLE 11
NCSS2
Light Trucks
Vehicle Type (Weighted)

Type	Vehicles					
	Side Impacts		Other Impacts		Total	
	N	%	N	%	N	%
Pickup Truck	408	71.2	2082	77.4	2490	76.3
Van	163	28.4	601	22.3	764	23.4
Large Station Wagon	2	0.3	7	0.3	9	0.3
Total	573	100.0	2690	100.0	3263	100.0
M.D.	0		0		0	

information for a random sample of towaway crashes. Here the side impacts are predominantly an urban phenomena, more so than other impacts. The two tables are not as inconsistent as they might first appear. Side impacts are evidently more likely to occur in urban areas where the exposure to intersecting traffic situations is high. However, accidents of high severity, i.e., fatal, are more likely to occur in rural areas. Urban areas present greater exposure to angled traffic situations (e.g., intersections) per unit of travel. The urban/rural split of the NCSS data also reflect the demographic characteristics of the sites used in the program. There are very few environmental or situational variables that are associated with side-impact/other, but the few that are, such as urbanization and highway class, are probably explained on the basis of exposure to angled traffic situations.

TABLE 12
FARS 79
Land Use

Land Use	Vehicles			
	Side Impacts		Other Impacts	
	N	%	N	%
Rural	483	68.6	3813	75.4
Urban	221	31.4	1243	24.6
Total	704	100.0	5056	100.0
M.D.	6		59	

Highway class is shown in Tables 14 and 15. Consistent with the above observation, side impacts are more likely on local streets and county roads. The only exception is that they are also relatively more prevalent on arterial highways in the NCSS data.

Tables 16 and 17 show accident type by road surface condition. The fatal accidents (FARS) have a greater proportion of side impacts on wet

TABLE 13
NCSS2
Light Trucks
Rural/Urban (Weighted)

Rural/Urban	Vehicles					
	Side Impacts		Other Impacts		Total	
	N	%	N	%	N	%
Rural	154	269	1115	41.4	1269	38.9
Urban	419	73.1	1575	58.6	1994	61.1
Total	573	100.0	2690	100.0	3263	100.0
M.D.	0		0		0	

TABLE 14
FARS 79
Highway Class

Highway Class	Vehicles			
	Side Impacts		Other Impacts	
	N	%	N	%
Limited Access	33	4.6	546	10.8
U.S./State Route	367	52.1	2799	55.2
Major Artery	11	1.6	81	1.6
County Road	161	22.9	996	19.6
Local Street	120	17.0	527	10.4
Other	12	1.7	121	2.4
Total	704	100.0	5070	100.0
M.D.	6		45	

TABLE 15
NCSS2
Light Trucks, Highway Class (Weighted)

Highway Class	Vehicles					
	Side Impacts		Other Impacts		Total	
	N	%	N	%	N	%
Freeway/Expressway	11	1.9	276	10.4	287	8.8
Arterial Highway	145	25.3	542	20.3	687	21.2
Minor Arterial Major Street/Hwy	132	23.0	502	18.8	634	19.5
Collector-Through Street/Hwy	113	19.7	584	21.8	697	21.5
Local Street/Road	172	30.0	721	27.0	893	27.5
Other	0	0.0	48	1.8	48	1.5
Total	573	100.0	2673	100.0	3246	100.0
M.D.	0		17		17	

roads and fewer on dry roads. The reverse is true for the NCSS data. An explanation for this contrast in the two data sets is not evident.

Table 18 gives the distribution of collision configuration for light trucks in the FARS data. As would be expected, the majority of multi-vehicle side impacts are angle collisions, and fewer of the side impacts are single-vehicle accidents than of other impacts.

Because of the definitions used in FARS coding, there are a small proportion of head-on, rear-end, and other configurations among the side impacts.

The principal impact point of the FARS cases is given in Table 19. The clock direction used here should not be confused with direction of impact force as used in the Collision Deformation Classification. It is used here not to specify a direction of the principal damage, but the

TABLE 16
FARS 79
Surface Condition

Surface Condition	Vehicles			
	Side Impact		Other Impact	
	N	%	N	%
Dry	532	75.1	4178	82.2
Wet	135	19.1	688	13.5
Snow/Ice	37	5.2	193	3.8
Sand,Dirt,Oil	0	0.0	10	0.2
Other	4	0.6	16	0.3
Total	708	100.0	5085	100.0
M.D.	2		30	

location on the vehicle. Codes 12 and 6 denote the front and rear areas; 1, 5, 7, and 11 the four corners. Each side is divided into three regions--2-4 on the right and 8-10 on the left. All side impacts fall into the 2-4 and 8-10 ranges because these were used as the defining criteria. The 6.9 percent of the "other" impacts which were to the side of the vehicle also involved rollover, and hence were not included with the side impacts. The location of the side impacts is nearly symmetrical right and left (48.7 percent and 51.3 percent, respectively).

The extent of deformation for the FARS data are shown in Table 20. As might be expected, nearly all of the crashes with fatalities had disabling damage. The proportion among side impacts and other impacts is nearly identical.

The FARS data do not have a variable directly identifying the object struck. However, the "Most Harmful Event" is very similar. The major difference between this and the typical object struck variable is

TABLE 17
NCSS2
Light Trucks, Road Condition (Weighted)

Condition	Vehicles					
	Side Impacts		Other Impacts		Total	
	N	%	N	%	N	%
Dry	435	75.9	1769	65.8	2204	67.5
Wet	125	21.8	708	26.3	833	25.5
Ice	1	0.2	140	5.2	141	4.3
Snow	12	2.1	53	2.0	65	2.0
Other	0	0.0	20	0.7	20	0.6
Total	573	100.0	2690	100.0	3263	100.0
M.D.	0		0		0	

that the FARS variable has little detail on the type of motor vehicles struck, but does include information on non-collisions.

The distributions of most harmful event for side and other impacts is given in Table 21. Over two-thirds of the side impacts are with non-fixed objects, namely vehicles in transport (55.5 percent) and railroad trains (10.1 percent), while 28.4 percent were fixed-object collisions. It is interesting to note that both types of collisions, i.e., non-fixed-object and fixed-object, have higher proportions among side impacts than among other impacts, while Table 18 showed a higher proportion of single-vehicle accidents among other than side impacts. The reason is that all rollovers were assigned to the other impact category and non-collisions rollovers account for 35 percent of the other impacts. It should be noted that although these rollovers are non-collision events, they may have been associated with a collision, e.g., following an impact with another vehicle.

TABLE 18
FARS 79
Collision Configuration

Collision Configuration	Vehicles			
	Side Impact		Other Impact	
	N	%	N	%
Single-Vehicle	293	41.3	3225	63.1
Rear-end	9	1.3	297	5.8
Head-on	45	6.3	928	18.2
Rear-to-Rear	0	0.0	1	0.0
Angle	319	45.0	492	9.6
Sideswipe same direction	20	2.8	56	1.1
Sideswipe opposite direction	23	3.2	110	2.2
Total	709	100.0	5109	100.0
M.D.	1		6	

The distributions of object struck for side- and other-impacted vehicles in NCSS are given in Table 22. Collisions with motor vehicles and railroad trains account for 68.7 percent of the side impacts. This is nearly identical to the results for fatal side impacts in FARS (68.3 percent). The results given in Tables 21 and 22 for other vehicles must be compared with caution, since the large number of non-collision rollovers in Table 21 would have occurred in either multi-vehicle or fixed-object collisions.

The objects struck in Table 22 have been regrouped and consolidated in Table 23 to give a better representation of striking vehicles by type and size. Collisions with passenger cars account for 55.3 percent of the side impacts, or 82 percent of side impacts with motor vehicles.

TABLE 19
FARS 79
Principal Impact Point

	Vehicles			
	Side Impact		Other Impact	
	N	%	N	%
Non-Collision	0	0.0	774	15.6
1 O'Clock	0	0.0	251	5.1
2 O'Clock	82	11.5	24	0.5
3 O'Clock	249	35.1	141	2.8
4 O'Clock	15	2.1	8	0.2
5 O'Clock	0	0.0	17	0.3
6 O'Clock	0	0.0	64	1.3
7 O'Clock	0	0.0	26	0.5
8 O'Clock	12	1.7	5	0.1
9 O'Clock	256	37.3	148	3.0
10 O'Clock	87	12.3	17	0.3
11 O'Clock	0	0.0	398	8.0
12 O'Clock	0	0.0	2054	41.4
Top	0	0.0	976	19.7
Undercarriage	0	0.0	44	0.9
Underride	0	0.0	14	0.3
Total	710	100.0	4961	100.0
M.D.	0		154	

Other light trucks and heavy trucks and buses account for only 12.1 percent. The distribution for other impacts is significantly different

TABLE 20
FARS 79
Extent of Deformation

Extent of Deformation	Vehicles			
	Side Impact		Other Impact	
	N	%	N	%
None	3	0.4	200	3.9
Minor	6	0.9	39	0.8
Functional (moderate)	62	8.8	320	6.3
Disabling (severe)	632	89.9	4533	89.0
Total	703	100.0	5092	100.0
M.D.	3		23	

than for side impacts, at the 0.00 level, but the differences are not large. Impacts with passenger cars are less frequent and this difference is accounted for by an increased incidence of object impacts and to a lesser extent by light trucks.

The numbers of light trucks with doors opening during the collision are shown for the NCSS data in Table 24 (the FARS data do not provide similar information). One or more doors opened in 15 percent of the light trucks in side impacts, but in only 9.5 percent of the other impacts. The major difference is the 5.5 percent of "other combinations" in side impacts. Apparently these are vans and utility vehicles, and may involve the rear door. In side impacts, the right and left front doors opened with equal frequency, while the left opened twice as frequently as the right in other impacts.

The number of fatalities per vehicle is shown in Table 25. Although there are small differences between side and other impacts,

TABLE 21
FARS 79
Most Harmful Event

	Vehicles			
	Side Impacts		Other Impacts	
	N	%	N	%
Non-collisions	23	3.2	2241	44.0
Overturn	0	0.0	1804	35.3
Fire/explosion	15	2.1	120	2.3
Immersion	2	0.3	73	1.4
Gas Inhalation	0	0.0	1	0.0
Fell from vehicle	6	0.8	224	4.4
Injured in vehicle	0	0.0	6	0.1
Other non-collision	0	0.0	13	0.3
Collision				
Not-Fixed-Object	484	68.4	1772	34.8
R.R.Train	72	10.1	52	1.0
Animal	0	0.0	3	0.1
Vehicle in Transport	393	55.5	1578	30.9
Vehicle in Other Roadway	10	1.4	29	0.6
Parked Vehicle	8	1.1	97	1.9
Other Object (not fixed)	1	0.1	13	0.3
Fixed Object	201	28.4	1085	21.3
Building	5	0.7	16	0.3
Culvert/Ditch	9	1.3	96	1.9
Curb/Wall	5	0.7	35	0.7
Divider	0	0.0	8	0.2
Embankment	7	1.0	151	3.0
Fence	1	0.1	14	0.3
Guard Rail	8	1.1	70	1.4
Light Support	5	0.7	12	0.2
Sign Post	1	0.1	14	0.3
Tree/Shrubbery	99	14.0	375	??
Utility Pole	46	6.5	128	2.5
Other Pole or Support	6	0.8	15	0.3
Impact Attenuator	0	0.0	1	0.0
Other fixed object	5	0.7	43	0.8
Bridge/Overpass	4	0.5	107	2.1
Total	708	100.0	5098	100.0
M.D.	2		17	

TABLE 22
NCSS2
Light Trucks, Object Struck (Weighted)

Object	Vehicles					
	Side Impacts		Other Impacts		Total	
	N	%	N	%	N	%
Passenger Car:	317	55.3	1121	42.0	1438	44.4
Sub Compact	30	5.2	205	7.7	235	7.3
Compact	39	6.8	247	9.3	286	8.8
Intermediate	144	25.1	349	13.1	493	15.2
Standard	45	7.9	260	9.7	305	9.4
Luxury/Limousine	59	10.3	60	2.2	119	3.7
Truck	69	12.0	396	14.8	465	14.3
Truck (to 10,000 lb.)	49	8.6	331	12.4	380	11.7
Truck (over 10,000)	3	0.5	14	0.5	17	0.5
Tractor w/wo Trailer	17	3.0	51	1.9	68	2.1
Bus	0	0.0	29	1.1	29	0.9
School	0	0.0	11	0.4	11	0.3
Other	0	0.0	18	0.7	18	0.6
Other Vehicle	1	0.2	4	0.1	5	0.2
R.R.Train	1	0.2	0	0.0	1	0.0
Other Vehicle	0	0.0	4	0.1	4	0.1
Unknown Vehicle	7	1.2	54	2.0	61	1.9
Fixed Object	126	22.0	1033	38.7	1159	35.8
Tree (to 6" diameter)	11	1.9	29	1.1	40	1.2
Tree (over 6")	28	4.9	163	6.1	191	5.9
Utility Pole	58	10.1	239	9.0	297	9.2
Breakaway Pole	1	0.2	4	0.1	5	0.2
Culvert/Ground/ R.R.Tracks/Curb	1	0.2	107	4.0	108	3.3
Abutment/Retaining Wall/Bridge Support	0	0.0	22	0.8	22	0.7
Embankment	1	0.2	29	1.1	30	0.9
Building	0	0.0	5	0.2	5	0.2
Bridge Rail	10	1.7	64	2.4	74	2.3
Guard Rail	15	2.6	85	3.2	100	3.1
Other Not-movable Object	1	0.2	286	10.7	287	8.9
Movable Object:	53	9.2	31	1.1	84	2.6
Total	573	100.0	2668	100.0	3241	100.0
M.D.	0		22		22	

TABLE 23
NCSS2
Light Trucks, Vehicle Struck (Weighted)

Vehicle Struck	Vehicles					
	Side Impact		Other Impact		Total	
	N	%	N	%	N	%
Passenger Car	317	55.3	1121	42.0	1438	44.4
Light Truck	49	8.6	331	12.4	380	11.7
Heavy Truck/Bus	20	3.5	94	3.5	114	3.5
Object	179	31.2	1064	39.9	1243	38.4
Other	8	1.4	58	2.2	66	2.0
Total	573	100.0	2668	100.0	3241	100.0
M.D.	0		22		22	

they are not significant at the 0.05 level. Only about two percent of the vehicles had more than two occupants fatally injured.

3.2 OCCUPANTS IN SIDE IMPACTS COMPARED TO OTHER IMPACTS

The tables that have been presented (10 through 25) give vehicle counts, and are intended to represent where and under what conditions side impacts occur, and compare them with other impacts. They also include a few tables for which the information is vehicle oriented, and thus for which vehicle counts are appropriate; e.g., vehicle type, object struck, and door opening during the collision. Occupants in side impacts are compared with those in other impacts in Tables 26 through 38 for a number of occupant variables, as well as a few vehicle-related variables.

Table 26 gives the distributions of occupants in fatal involvements by the type of light truck. The figures are the total numbers of occupants in vehicles in which there was a fatality, not just a count

TABLE 24
NCSS2
Light Trucks
Door Opening During Collision (Weighted)

Door Opening	Vehicles					
	Side Impacts		Other Impacts		Total	
	N	%	N	%	N	%
None Opened	477	85.0	1907	90.5	2384	89.3
Left Front	26	4.6	116	5.5	142	5.3
Right Front	26	4.6	55	2.6	81	3.0
Right Rear	1	0.2	1	0.0	2	0.1
Left & Right Front	0	0.0	24	1.1	24	0.9
Right Front & Rear	0	0.0	2	0.1	2	0.1
Other Combination	31	5.5	3	0.1	34	1.3
Total	561	100.0	2108	100.0	2669	100.0
M.D.	12		582		594	

the fatalities. Over 80 percent of the occupants in fatal light trucks were in pickups. Fewer than one-fifth were in vans, while truck-based station wagons accounted for less than two percent. The distribution for vehicles in side and other impacts are nearly the same. The actual number of fatalities are shown in Table 27. Again, the distributions for the two types of impacts are similar and also similar to those for all occupants in fatal vehicles given in Table 26. A total of 6457 occupants of light trucks were fatally injured in 1979, of whom 809 or 12.5 percent were in side-impacted vehicles.

The distributions of object struck among occupants in the NCSS data are given in Table 28, with results nearly the same as in Table 22 for vehicles. This suggests that the occupancy of light trucks is nearly the same for both types of impacts and for all objects struck. Table 29

TABLE 25
FARS 79
Total Fatalities in Vehicle

Fatalities	Vehicles			
	Side Impact		Other Impact	
	N	%	N	%
One	634	89.3	4699	91.9
Two	60	8.5	339	6.6
Three	10	1.4	58	1.1
Four	5	0.7	10	0.2
Five	1	0.1	5	0.1
Six-Ten	0	0.0	4	0.1
Total	710	100.0	5115	100.0
M.D.	0		0	
Total Number of Fatalities	809		5649	

gives the results with a regrouping of object struck to give a better representation of types of striking vehicles, and corresponds to Table 23 which gave vehicle counts. The results in Table 29 are nearly the same as those of the earlier table, and the same observations apply.

Table 30 indicates that somewhat more males are involved in side impacts than other impacts, although the difference is small and of little practical significance. Age distributions are given in Table 31. The notable differences are in the 15-19 year-olds who are overrepresented in side impacts, and the 20-24 year-olds who are correspondingly underrepresented. Other age groups are either similarly represented in both types of impacts or have small numbers in the side impacts (0-14 and 65 and over).

Restraint usage among fatally-injured occupants is shown in Table 32. The results are nearly the same for both types of impacts, with

TABLE 26
FARS 79
Body Type

Body Type	Occupants*			
	Side Impact		Other Impacts	
	N	%	N	%
Pickup	1088	81.1	7780	80.2
Van	233	17.4	1745	18.0
Large Station Wagon	20	1.5	172	1.8
Total	1341	100.0	9697	100.0
M.D.	0		0	

*All occupants of the vehicle, not just fatals.

TABLE 27
FARS 79
Fatalities by Vehicle Type

Vehicle	Fatalities			
	Side Impact		Other Impact	
	N	%	N	%
Pickups	686	84.8	4660	82.5
Vans	109	13.5	907	16.1
Large Station Wagon	14	1.7	81	1.4
Total	809	100.0	5648	100.0

only 1.2 percent of the occupants in side impacts using restraints. Table 33 gives the corresponding results for all light truck occupants

TABLE 28
NCSS2
Light Trucks
Object Struck (Weighted)

Object	Occupants					
	Side Impacts		Other Impacts		Total	
	N	%	N	%	N	%
Passenger Car	439	54.7	1806	43.0	2145	42.9
Sub Compact	32	4.0	328	7.8	360	7.2
Compact	46	5.7	390	9.3	436	8.7
Intermediate	203	25.3	525	12.5	728	14.6
Standard	72	9.0	478	11.4	550	11.0
Luxury/Limousine	86	10.7	85	2.0	171	3.4
Truck:	102	12.7	637	15.2	739	14.8
Truck (to 10,000 lb.)	78	9.7	557	13.3	635	12.7
Truck (over 10,000)	4	0.5	18	0.4	22	0.4
Tractor w/wo Trailer	20	2.5	62	1.5	82	1.6
Bus:	0	0.0	40	0.9	40	0.8
School	0	0.0	22	0.5	22	0.4
Other	0	0.0	18	0.4	18	0.4
Other Vehicle:	1	0.1	6	0.1	7	0.1
R.R.Train	1	0.1	0	0.0	1	0.0
Other Vehicle	0	0.0	6	0.1	6	0.1
Unknown Vehicle	8	1.0	64	1.5	72	1.4
Fixed Object:	190	23.7	1605	38.3	1795	35.9
Tree (to 6" diameter)	31	3.9	30	0.7	61	1.2
Tree (over 6")	55	6.8	286	6.8	341	6.8
Utility Pole	70	8.7	309	7.4	379	7.6
Breakaway Pole	1	0.1	4	0.1	5	0.1
Culvert/Ground/ RR Tracks/Curb	1	0.1	147	3.5	148	3.0
Abutment/Retaining Wall/Bridge Support	0	0.0	22	0.5	22	0.4
Embankment	2	0.2	40	1.0	42	0.8
Building	0	0.0	10	0.2	10	0.2
Bridge Rail	10	1.2	169	4.0	179	3.6
Guard Rail	19	2.4	95	2.3	114	2.3
Other Not-Moveable Object	1	0.1	493	11.7	494	9.9
Movable Object:	63	7.8	38	0.9	101	2.1
Total	803	100.0	4196	100.0	4999	100.0
M.D.	0		35		35	

TABLE 29
NCSS2
Light Trucks, Occupants (Weighted)
Vehicle Struck

Vehicle Struck	Occupants					
	Side Impacts		Other Impacts		Total	
	N	%	N	%	N	%
Passenger Car	439	54.7	1806	43.2	2245	45.1
Light Truck	78	9.7	557	13.3	635	12.7
Heavy Truck/Bus	24	3.0	120	2.9	144	2.9
Object	253	31.5	1625	38.9	1878	37.7
Other	9	1.1	70	1.7	79	1.6
Total	803	100.0	4178	100.0	4981	100.0
M.D.	0		53		53	

TABLE 30
NCSS2
Light Trucks, Occupants (Weighted)
Occupant Sex

Sex	Occupants					
	Side Impacts		Other Impacts		Total	
	N	%	N	%	N	%
Male	662	82.6	3397	80.9	4059	81.1
Female	139	17.4	804	19.1	943	18.9
Total	801	100.0	4201	100.1	5002	100.0
M.D.	2		30		32	

TABLE 31
NCSS2
Light Trucks, Occupants (Weighted), Occupant Age

Age (years)	Occupants					
	Side Impacts		Other Impacts		Total	
	N	%	N	%	N	%
0-14	45	5.7	364	8.7	409	8.2
15-19	222	28.1	766	18.3	988	19.8
20-24	108	13.7	1006	24.0	1114	22.3
25-34	192	24.3	968	23.1	1160	23.3
35-44	98	12.4	465	11.1	563	11.3
45-64	113	14.2	446	10.6	559	11.2
65 and over	13	1.7	179	4.3	192	3.8
Total	791	100.0	4194	100.0	4985	100.0
M.D.	12		37		49	

in the NCSS data. Although restraint usage among all injury categories is higher than among the fatals of Table 32, the usage is still very low; only 2.4 percent in both side and other impacts.

The extremely low restraint usage rates raise the question of ejection rates for light truck occupants. Among fatals, ejection are 25.1 percent for those in side impacts, and 27.3 percent for other impacts as shown in Table 34. Thus while ejection is often associated with fatality in light-truck side impacts, ejection is nearly one-and-one-half times as frequent in other impact fatalities. Ejection among all occupants is much lower. While most of the ejections in FARS are from pickups, the ejection rate is higher for small vans as shown in Table 35. The numbers in Table 35 are the number ejected, while the percentages are the proportion of the fatalities in each type of vehicle who were ejected.

TABLE 32
FARS 79
Restraints

Restraint	Occupants			
	Side Impact		Other Impacts	
	N	%	N	%
None	633	98.6	4541	98.8
Lap belt	4	0.6	29	0.6
Shoulder belt	1	0.2	4	0.1
Lap & Shoulder	0	0.0	14	0.3
Restraint used-type unknown	4	0.6	8	0.2
Total	642		4596	
M.D.	167		1053	

The results for the NCSS data are given in Table 36 where ejection is only 1.9 percent for side impacts. Here also, ejection in other impacts is about one-and-one-half times as frequent in side impacts. Thus, although ejection is not frequent in light-truck side impacts, it is frequent among the fatally-injured occupants.

Ejection portals are not given in the FARS data, but are shown in Table 37 for the ejected occupants of NCSS. Approximately half the side-impact ejections are through window openings (53.8 percent) and about half through door areas (46.2 percent). Although the numbers of cases are small, nearly identical results were obtained for other impacts (52.3 percent and 47.7 percent, respectively).

Injury severity among occupants in side and other impacts in the NCSS data are compared in Tables 31 and 32. Table 31 gives the proportions with AIS=3 or greater, and Table 39 gives the proportions with AIS=4 or greater. The difference in proportions for side and other

TABLE 33
NCSS2
Light Trucks, Occupants (Weighted), Restraint Used

Restraint	Occupants					
	Side Impacts		Other Impacts		Total	
	N	%	N	%	N	%
None Used	740	92.3	3378	85.3	4118	86.4
Lap Only	12	1.5	63	1.6	75	1.6
Lap and Torso	7	0.9	20	0.5	27	0.6
Child Seat	0	0.0	11	0.3	11	0.2
None Available	43	5.4	490	12.4	533	11.2
Total	802	100.0	3962	100.0	4764	100.0
M.D.	1		269		270	

TABLE 34
FARS 79
Ejection

Ejection	Fatally-Injured Occupants			
	Side Impact		Other Impacts	
	N	%	N	%
Not Ejected	597	74.9	3516	62.7
Ejected	200	25.1	2090	37.3
Partially	24	3.0	250	4.5
Completely	176	22.1	1840	32.8
Total	797	100.0	5606	100.0
M.D.	12		43	

TABLE 35
FARS 79
Ejection by Vehicle Type

Vehicle Type	Fatally-Injured Occupants			
	Side Impacts		Other Impacts	
	N	%*	N	%*
Pickups	163	24.1	1699	36.6
Vans	36	34.0	351	39.4
Large Station Wagons	1	7.1	40	49.4
Total	200	25.1	2090	37.3

*Row percent.

TABLE 36
NCSS2
Light Trucks, Occupants (Weighted), Ejection

Ejection	Occupants					
	Side Impacts		Other Impacts		Total	
	N	%	N	%	N	%
Ejected	14	1.9	114	2.9	128	2.7
Not Ejected	729	98.1	3844	97.1	4573	97.3
Total	743	100.0	3958	100.0	4701	100.0
M.D.	60		273		333	

impacts are not significant at the 0.1 level for either table. The number of fatalities is nearly twice as great as the number with AIS=4 and 5 in both impact types. The 22 occupants of side impacts with

TABLE 37
NCSS2
Light Trucks, Occupants (Weighted)
Ejection Portal, Ejected Occupants

Portal	Occupants					
	Side Impacts		Other Impacts		Total	
	N	%	N	%	N	%
Left Front Window	1	7.7	6	6.8	7	6.9
Right Front Window	4	30.8	5	5.7	9	8.9
Windshield	2	15.4	30	34.1	32	31.7
Rear Window	0	0.0	3	3.4	3	3.0
Left Front Door	5	38.5	36	40.9	41	40.6
Right Front Door	1	7.7	5	5.7	6	5.9
Right Rear Door	0	0.0	1	1.1	1	1.0
Other	0	0.0	2	2.3	2	2.0
Total	13	100.0	88	100.0	101	100.0
M.D.	1		26		27	

injuries of AIS=4 or greater (including fatals) are summarized individually in Appendix A.

3.3 COMPARISONS OF SINGLE- AND MULTI-VEHICLE LIGHT TRUCK SIDE IMPACTS

The previous section presented comparisons of light truck side impacts with all other impacts. In this section, light trucks in side impacts will be examined by comparing those in single-vehicle involvements with those in multi-vehicle involvements.

The total number of fatalities in each vehicle containing at least one fatality is given in Table 40 from the FARS data. The distributions are nearly identical for both types of involvements. A total of 509 occupants were killed in single-vehicle involvements, or 38.0 percent of

TABLE 38
NCSS2
Light Trucks, Occupants (Weighted)
Injury - AIS3+

AIS	Occupants					
	Side Impacts		Other Impacts		Total	
	N	%	N	%	N	%
0-2	683	94.5	3354	93.9	4037	94.0
3-5 (non-fatal)	26	3.6	140	3.9	166	3.9
Fatal	14	1.9	79	2.2	93	2.2
(3-Fatal)	40	5.5	219	6.1	259	6.1
Total	723	100.0	3573	100.0	4296	100.0
M.D.	80		658		738	

those killed in side impacts. The proportion of vehicle fatals in single-vehicle involvements was 39.9 percent of the side impacts, not appreciably different from that for occupants.

The location of the principal impact point for the FARS involvements is given in Table 41, where the numbers represent vehicle counts. The right side was impacted in 56.8 percent of the single-vehicle collisions, with the left side receiving only 43.2 percent of the impacts. Just the reverse occurred in multi-vehicle accidents, with 43.3 percent of the impacts in the right and 56.7 on the left. The center side area was most frequently struck in the fatal impacts, regardless of which side was involved or the type of involvement. Few impacts to the rear third occurred in either single- or multi-vehicle impacts.

Tables 42 through 46 describe the damage for the side impacts in the NCSS project, all based on the CDC representing the side impact.

TABLE 39
NCSS2
Light Trucks, Occupants (Weighted), Injury - AIS4+

AIS	Occupants					
	Side Impacts		Other Impacts		Total	
	N	%	N	%	N	%
0-3	763	97.2	4034	97.0	4797	97.1
4-5 (non-fatal)	8	1.0	44	1.1	52	1.1
Fatal	14	1.8	79	1.9	93	1.9
(4-Fatal)	22	2.8	123	3.0	145	3.0
Total	785	100.0	4157	100.0	4942	100.0
M.D.	18		74		92	

Only occupant counts are given as the results are nearly the same for vehicle counts.

Table 42 indicates the left side was struck more frequently than the right in both single and multiple involvements. The small difference between single- and multi-vehicle involvements is not significant at the 0.1 level. The result for multi-vehicle crashes in NCSS is nearly the same as in the FARS data of Table 41, but NCSS does not show the reversal for single-vehicle crashes.

Table 43 gives the clock direction of impact force. Clock directions of 11, 12, and 01, i.e., force directions within 45° of forward, account for 34.7 percent of the impacts. However, 50.5 percent of the single-vehicle impacts are 11, 12, and 01 o'clock compared with only 29.2 percent among the multi-vehicle impacts. The patterns for single- and multi-vehicle are quite different. Whereas 31.9 percent of the single-vehicle cases are at 3 and 9 o'clock, only 5.3 percent of the multi-vehicle cases are. However, 62.4 percent of the multi-vehicle impacts have force directions of 2 and 10 o'clock. At appears that many

TABLE 40
FARS 79
Side Impacts, Fatalities in Vehicle

Fatalities in Vehicle	Vehicle			
	Single-Vehicle		Multi-Vehicle	
	N	%	N	%
One	253	89.4	381	89.2
Two	22	7.8	38	8.9
Three	5	1.8	5	1.2
Four	3	1.1	2	0.5
Five	0	0.0	1	0.2
Total	283	100.0	427	100.0
M.D.	0		0	

of the single-vehicle impacts occur with the vehicle moving nearly forward--almost sideswipes. Nearly a third result in directly lateral impacts, presumably after a rotational skid. Multi-vehicle impacts are more likely to occur in intersection traffic situations where both vehicles have comparable velocity, resulting in 84.7 percent of the impacts between 15 and 75 degrees of the forward longitudinal axis.

The horizontal location of damage is given in Table 44. Again the patterns are quite different for the two types of impact. Nearly half of the single-vehicle impacts have distributed damage, damage to the front, passenger compartment, and rear areas of the car. This is consistent with the forward force directions noted in Table 43 which result in a swiping along the side. Involvement of the passenger compartment dominates the single-vehicle cases, with damage limited to the front or rear areas of the sides in 18.6 of the cases. These results contrast with multi-vehicle impacts where only 17.7 percent are distributed, but 46.5 percent are confined to the front or rear portions. Interestingly, the proportions which involve the passenger

TABLE 41
FARS 79
Side Impacts, Principal Impact Point

Principal Impact Point	Vehicle			
	Single-Vehicle		Multi-Vehicle	
	N	%	N	%
Two O'Clock	38	13.4	44	10.3
Three O'Clock	117	41.3	132	30.9
Four O'Clock	6	2.1	9	2.1
Eight O'Clock	3	1.1	9	2.1
Nine O'Clock	88	31.1	177	41.5
Ten O'Clock	31	11.0	56	13.1
Total	283	100.0	427	.0
M.D.	0		0	

TABLE 42
NCSS2
Light Trucks, Side Impacts, Occupants (Weighted)
Side Struck

Side	Single-Vehicle		Multi-Vehicle		Total	
	N	%	N	%	N	%
Right	86	39.1	253	43.4	339	42.2
Left	134	60.9	330	56.6	464	57.8
Total	220	100.0	583	100.0	803	100.0
M.D.	0		0		0	

TABLE 43
NCSS2
Light Trucks, Side Impacts, Occupants (Weighted)
Direction of Impact Force

Direction	Occupants					
	Single-Vehicle		Multi-Vehicle		Total	
	N	%	N	%	N	%
Twelve O'Clock	73	34.8	40	6.9	113	14.2
One O'Clock	9	4.3	53	9.1	62	7.8
Two O'Clock	12	5.7	147	25.2	159	20.1
Three O'Clock	42	20.0	8	1.4	50	6.3
Four O'Clock	0	0.0	10	1.7	10	1.3
Five O'Clock	0	0.0	0	0.0	0	0.0
Six O'Clock	0	0.0	0	0.0	0	0.0
Seven O'Clock	0	0.0	1	0.2	1	0.1
Eight O'Clock	2	1.0	7	1.2	9	1.1
Nine O'Clock	25	11.9	23	3.9	48	6.1
Ten O'Clock	23	11.0	217	37.2	240	30.3
Eleven O'Clock	24	11.4	77	13.2	101	12.7
Total	210	100.0	583	100.0	793	100.0
M.D.	10		0		10	

compartment are nearly the same in both cases; 37.8 percent for single-vehicle, and 35.8 percent for multi-vehicle impacts.

Table 45 gives the vertical location of damage. The major contrasts here are that 97.6 percent of the multi-vehicle impacts involved all structures below the beltline, whereas 63.2 percent of the single-vehicle cases involved "all," i.e., the roof-side rails and roof as well. This difference evidently does not result from the horizontal

TABLE 44
NCSS2
Light Trucks, Side Impacts, Occupants (Weighted)
Horizontal Location of Damage

Location (along side of vehicle)	Occupants					
	Single-Vehicle		Multi-Vehicle		Total	
	N	%	N	%	N	%
Front	21	9.5	163	28.0	184	22.9
Rear	20	9.1	108	18.5	128	15.9
Distributed	96	43.6	103	17.7	199	24.8
Passenger Compartment	47	21.4	23	3.9	70	8.7
Front and Passenger Compartment	18	8.2	83	14.2	101	12.6
Rear and Passenger Compartment	18	8.2	103	17.7	121	15.1
Total	220	100.00	583	100.0	803	100.0
M.D.	0		0		0	

location, as both types of impacts involved the passenger compartment with nearly equal frequency. It is more likely a consequence of the nature of the striking object. May single-vehicle impacts are into trees or poles or other objects which are high enough to involve the roofline. Multi-vehicle impacts usually involve the front of a passenger car with a hood striking at the beltline level or below.

The type of damage distributions are given in Table 46. Consistent with earlier observations, the single-vehicle impacts have substantial numbers of sideswipe damage patterns and narrow impact areas--about one-third for each of the major three categories. The multi-vehicle impacts nearly all involve wide impact areas, areas wider than 16 inches.

TABLE 45
NCSS2
Light Trucks, Side Impacts, Occupants (Weighted)
Vertical Location of Damage

	Occupants					
	Single-Vehicle		Multi-Vehicle		Total	
	N	%	N	%	N	%
All	139	63.2	11	1.9	150	18.7
Everything Above Frame	8	3.6	0	0.0	8	1.0
Everything Below Glass	71	32.3	569	97.6	640	79.7
Top of Frame and Below	1	0.5	0	0.0	1	0.1
Top of Frame to Glass or Hood	1	0.5	3	0.5	4	0.5
Total	220	100.0	583	100.0	803	100.0
M.D.	0		0		0	

Of the last five tables presented, Table 46 is the only one for which the results for occupant counts, as presented, differ significantly from vehicle counts. The difference for multi-vehicle occupant and vehicle counts is significant at the 0.01 level. The significance results largely from a greater incidence of sideswipes in the occupant count than in the vehicle counts. The reason for an association between vehicle occupancy and sideswipes is not clear and may be spurious.

The seat locations for occupants of NCSS side impacts are given in Table 47. A small number of occupants were seated in the second seat or rearward. These occupants were all in truck-based station wagons or pickups. None were in pickups, nor were there any in the external cargo area of vans. The distributions are similar, but with a greater

TABLE 46
NCSS2
Light Trucks, Side Impacts, Occupants (Weighted)
Damage Distribution Type

Type	Occupants					
	Single-Vehicle		Multi-Vehicle		Total	
	N	%	N	%	N	%
Wide Impact Area	76	34.5	512	87.8	588	73.2
Narrow Impact Area	70	31.8	10	1.7	80	10.0
Sideswipe	74	33.6	60	10.3	134	16.7
Corner	0	0.0	1	0.2	1	0.1
Total	220	100.0	583	100.0	803	100.0
M.D.	0		0		0	

incidence of passengers in multi-vehicle impacts, although the difference is small.

Occupant exposure to the side impacted is given in Table 48. Occupants have near-side exposure if the impact is on the same side of the vehicle as the seat location. In the case of center seat occupants, the exposure is near-side if there are no intervening occupants between the center occupant and the side struck. Otherwise the exposure is far-sided. The distributions for single- and multi-vehicle impacts are significant at the 0.024 level. The greater incidence of near-side impacts in multi-vehicle collisions is consistent with the greater incidence of left side impacts shown in Table 35, since many vehicles have only a driver. The reason for the reversal in single-vehicle impacts is not evident, since most of these collisions were also impacts to the left side.

Occupant ejection is shown in Table 49, and is not substantially different for the two types of impacts--low in both cases when all occupants are included. The ejection portals are shown in Table 50, and

TABLE 47
NCSS2
Light Trucks, Side Impacts, Occupants (Weighted)
Seated Location

	Occupants					
	Single-Vehicle		Multi-Vehicle		Total	
	N	%	N	%	N	%
Left Front	168	76.4	405	69.7	573	71.5
Center Front	2	0.9	24	4.1	26	3.2
Right Front	42	19.1	136	23.4	178	22.2
Left Second*	4	1.8	4	0.7	8	1.0
Center Second*	0	0.0	6	1.0	6	0.7
Right Second*	4	1.8	4	0.7	8	1.0
Entire Second*	0	0.0	1	0.2	1	0.1
Other, Center Floor*	0	0.0	1	0.2	1	0.1
Total	220	100.0	581	100.0	801	100.0
M.D.	0		2		2	

*All are occupants of vans or large station wagons.

are about equally divided between windows and door areas in both types of collisions, although the numbers are small. The association between ejection and injury will be discussed in a later section.

Tables 51 and 52 give the incidence of substantial injury. The incidence of AIS=3 or greater (Table 51) is significantly different for the two types of collision, with $p = 0.005$--single-vehicle collisions having over twice the incidence of substantial injury of multi-vehicle impacts. This difference may result from higher speeds in rural areas where single-vehicle involvements are more likely to occur. The more severe injuries of Table 52 are not significantly different however, with $p > 0.1$, although the pattern is the same, with more severe injury

TABLE 48
NCSS2
Light Trucks, Side Impacts, Occupants (Weighted)
Occupant Exposure to Impact

	Occupants					
	Single-Vehicle		Multi-Vehicle		Total	
	N	%	N	%	N	%
Near Side	106	48.2	333	57.1	439	54.7
Far Side	114	51.8	250	42.9	364	45.3
Total	220	100.0	583	100.0	803	100.0
M.D.	0		0		0	

TABLE 49
NCSS2
Light Trucks, Side Impacts, Occupants (Weighted)
Occupant Ejection

Ejection	Occupants					
	Single-Vehicle		Multi-Vehicle		Total	
	N	%	N	%	N	%
Not Ejected	169	97.7	572	98.3	729	98.1
Completely Ejected	2	1.2	10	1.7	12	1.6
Partially Ejected	2	1.2	0	0.0	2	0.3
Total	173	100.0	582	100.0	743	100.0
M.D.	47		13		60	

in single-vehicle crashes. The lack of statistical significance may result from the small number of injuries of AIS=4 or greater.

TABLE 50
NCSS2
Light Trucks, Side Impacts, Occupants (Weighted)
Ejection Portal, Ejected Occupants

	Occupants					
	Single-Vehicle		Multi-Vehicle		Total	
	N	%	N	%	N	%
Left Front Window	1	25.0	0	0.0	1	7.7
Right Front Window	1	25.0	3	33.3	4	30.7
Left Front Door	2	50.0	3	33.3	5	38.5
Right Front Door	0	0.0	1	11.1	1	7.7
Windshield	0	0.0	2	22.2	2	15.4
Total	4	100.0	9	100.0	13	100.0
M.D.	0		1		1	

3.4 FATALITIES, INJURIES, AND EJECTION IN LIGHT TRUCK SIDE IMPACTS

The previous sections have compared side impacts with other impacts, and single-vehicle side impacts with multi-vehicle side impacts, all across a number of variables which together provide descriptive statistics on side impacts.

In this section, fatalities, injury rates, and ejections will be examined in further detail, but only for side impacts, and in general without regard to the number of vehicles involved.

The type of striking vehicle cannot be determined directly from the FARS data; the "most harmful event" variable describes objects struck in detail, but groups all striking motor vehicles together. However, the body type of the case vehicle is given in some detail, and all vehicles in each fatal accident are included in the vehicle file as case vehicles. Thus it is possible to pair the vehicles in all two-vehicle

TABLE 51
NCSS2
Light Trucks, Side Impacts, Occupants (Weighted)
Injury - AIS=3+

AIS	Occupants					
	Single-Vehicle		Multi-Vehicle		Total	
	N	%	N	%	N	%
0-2	177	90.3	506	96.0	683	94.5
3-5 (non-fatal)	11	5.6	15	2.8	26	3.6
Fatal	8	4.1	6	1.1	14	1.9
(3-fatal)	19	9.7	21	3.9	40	5.5
Total	196	100.0	527	100.0	723	100.0
M.D.	24		56		80	

accidents and consequently determine the type of striking vehicle. In addition to 284 occupants of light trucks fatally injured in single-vehicle side impacts, 377 fatalities occurred in two-vehicle side impacts for which the other vehicle is in the file and can be identified. An additional 108 victims of side impacts were killed in side impacts involving three or more vehicles. In these cases it is not possible to determine which vehicle was the impacting vehicle from data available in the FARS file. However, we may impute the type of striking vehicle in the 108 multi-vehicle fatalities on the basis of the 377 two-vehicle fatalities.

The resulting estimate of side-impact fatalities by type of striking vehicle is given in Table 53.

The fractional numbers of vehicles result from the imputation of the distribution of fatalities in crashes involving three or more vehicles.

TABLE 52
NCSS2
Light Trucks, Side Impacts, Occupants (Weighted)
Injury - AIS=4+

AIS	Occupants					
	Single-Vehicle		Multi-Vehicle		Total	
	N	%	N	%	N	%
0-3	210	95.9	553	97.7	763	97.2
4-5 (non-fatal)	1	0.5	7	1.2	8	1.0
Fatal	8	3.7	66	1.1	14	1.8
(4-fatal)	9	4.2	13	2.3	22	2.8
Total	219	100.0	566	100.0	785	100.0
M.D.	1		17		18	

TABLE 53
FARS 79
Estimated Side Impact Fatalities by Type of Striking Vehicle

Striking Vehicle	Fatalities	
	Number	Percent
Single Vehicle	284	36.9
Passenger Car	176.2	22.9
Buses	2.6	00.3
Special Vehicles	3.9	0.5
Light Trucks	113.2	14.7
Heavy Trucks	189.1	24.6

Special vehicles include ambulances, fire trucks, dune buggies, snowmobiles, etc. Heavy trucks are those with a GVW of 10,000 lb. or greater. Heavy vehicles (large trucks and buses) account for 24.9 percent of the fatalities. These together with single-vehicle impacts are responsible for 61.8 percent of the fatalities, while impacts with passenger cars account for only 22.9 percent.

Occurrences of serious injury for a similar classification of striking vehicle in the NCSS data are similarly distributed as shown in Table 54. Two columns of percentages are shown, the first giving the distribution of serious injury across the striking vehicles, the second giving the proportion of occupants who sustain serious to fatal injury for each type of striking vehicle. Heavy trucks and buses account for 22.7 percent of the serious injury, while heavy trucks and buses together with single-vehicle (object) impacts account for 63.6 percent. Impacts with passenger cars produced 27.3 percent of the serious injury. Although the number of serious injury casualties is small, only 22 including 14 fatalities, the results are remarkably similar to those of the fatalities of NCSS.

Even though single-vehicle impacts produced the highest frequency of serious injury, they did not have the highest probability of injury. The probability of injury at the AIS=4 or greater level for single-vehicle accidents was 3.57 percent, over twice that for passenger cars, but far less than the 20.8 percent for vehicles impacted by heavy trucks and buses. Although the probability of serious injury is greater in involvements with heavy trucks/buses, single-vehicle involvements produced a greater number of serious injuries simply because their frequency was much greater. These results must be viewed with caution however, since the number of serious injury cases is small, even in the aggregate.

Light-truck side-impact fatalities by the side of vehicle struck and occupant exposure (i.e., exposure to impacts on the same or opposite side of the vehicle from their seated position) are shown in Table 55. Both row and column percentages are presented. The impacts are about equally divided between the right and left sides. The majority of the fatalities resulted from near side impacts. However, the imbalance was

TABLE 54
NCSS2
Side-Impact Injury by Type of Striking Vehicle (Weighted Occupants)

Striking Vehicle	AIS				
	0-3 N	4-5, Fatal			M.D.
		N	Proportion by Obj.,%	Proportion of Inj., (Col.%)	
Passenger Car	423	6	27.3	1.40	10
Light Truck	70	2	9.1	2.78	6
Heavy Truck/Bus	19	5	22.7	20.83	0
Object	243	9	40.9	3.57	1
Other	8	0	0.0	0.0	1
Total	763	22	100.0	2.78	18

not dramatic; far side impacts accounted for nearly one-third of the fatalities.

Fatality rates by exposure cannot be derived from the FARS data since they don't include the large number of non-fatal involvements which would constitute the denominators of rate computations. The weighted NCSS data may be used to compute rates, within the limitations imposed by the size of the data set.

Table 56 presents occupant injury in the NCSS data across two dimensions. These are occupant exposure and the horizontal location of the damage to the side of the vehicle. The 785 occupants included in the tabulations are those without missing data on the dichotomous injury variable.

Occupants exposed to near and far side impacts experienced the same rate of serious injury--2.8 percent for both exposures.

Those impacts which involved the passenger compartment (N=482) resulted in 17 serious injuries for a rate of 3.5 percent. The 303

TABLE 55
FARS 79
Light Trucks, Occupants (Weighted)
Fatalities by Occupant Exposure

Occupant Exposure		Side of Impact					
		Right		Left		Total	
		N	%	N	%	N	%
Near Side	N %	129 28.9	33.0	318 71.1	76.1	447 100.0	55.3
Far Side	N %	216 81.8	52.2	48 18.2	11.5	264 100.0	32.6
Other/Unknown	N %	46 46.9	11.8	52 53.1	12.4	98 100.0	12.1
Total	N %	391 48.3	100.0	418 51.7	100.0	809 100.0	100.0

impacts which did not involve the passenger compartment resulted in five injuries or a rate of 1.7 percent. The difference in these two rates is significant at the 0.01 level. Because of the small number of cases of serious injury, none of the other comparisons of injury rates shown in Table 56 are statistically significant.

With only 22 cases of serious injury, including 14 fatalities, it is not practical to give many descriptive statistics. Instead, a summary of each case is given in Appendix A. The 22 seriously injured occupants were in 18 vehicles. A summary is given for each of the 18 vehicles and all the occupants.

Ejection by serious injury in the NCSS data is given in Table 57. Only 14 occupants were ejected (either partially or completely), but another 60 were coded as ejection unknown. Omitting the cases with missing data on ejection (or the equivalent of assuming the ejection-rate among the missing data cases is the same as among those with valid

TABLE 56
NCSS2
Injury by Occupant Exposure and Horizontal Area Struck

	AIS=0-6		AIS=4+, fatal	
	N	%	N	%
All Occupants	785	100.0	22	2.8
All Near-Side Occupants	429	54.6	12	2.8
All Far-Side Occupants	356	45.4	10	2.8
<u>All Occupants</u>				
Front	181	23.1	5	2.8
Rear	122	15.5	0	0.0
Distributed	197	25.1	6	3.0
Pass.Compartment	70	8.9	3	4.3
Front,Pass.Comp.	100	12.7	7	7.0
Rear,Pass.Comp.	115	14.6	1	0.9
<u>Near Side Occupants</u>				
Front	87	20.3	3	3.4
Rear	75	17.5	0	0.0
Distributed	99	23.1	3	3.0
Pass.Compartment	55	12.8	1	1.8
Front,Pass.Comp.	51	11.9	4	7.8
Rear,Pass.Comp.	62	14.5	1	1.6
<u>Far Side Occupants</u>				
Front	94	26.4	2	2.1
Rear	47	13.2	0	0.0
Distributed	98	27.5	3	3.1
Pass.Compartment	15	4.2	2	13.3
Front,Pass.Comp.	49	13.8	3	6.1
Rear,Pass.Comp.	53	14.9	0	0.0

data) gives an ejection rate for all occupants of 1.9 percent.[8] The corresponding rate among those with AIS=4 or more serious injuries is 37.5 percent. Looking at the data from a different perspective, we find

[8]Bertram and O'Day noted that while the use of the unknown codes varied among teams, most of the "unknown" cases were actually not ejections. <u>Passenger Car Occupant Ejection</u>, Bruce Bertram and James O'Day, Highway Safety Research Institute, The University of Michigan, Report No. UM-HSRI-81-42, August 1981.

that the probability of sustaining injury of AIS=4 or greater is 0.84 percent among the non-ejected, but 71.4 percent among the ejectees--85 times as great. However, these results are based on very few cases, both of ejection and of serious injury, and the missing data on ejection is substantial; they must be interpreted with caution.

TABLE 57
NCSS2
Light Trucks, Serious Injury by Ejection

Injury	Ejection			
	Yes	No	Missing Data	Total
AIS 0-3	4	707	52	763
AIS=4+ (including fatals)	10	6	6	22
M.D.	0	16	2	18
Total	14	729	60	803

Ejection by seat position from the FARS data are shown for each type of light truck in Tables 58-60. The tables provide information on the distribution of occupant seat location by type of vehicle, as well as on ejection. There are several caveats that must be observed in interpreting these tables also. As all tabulations represent fatalities, ejection rates cannot be computed. The occupancy of seats other than the front is so low that the ejection proportions are meaningless. The total number of side-impact fatalities in large (truck based) station wagons is so low that about the only inference that can be drawn from Table 60 is that side-impact fatality in these vehicles is not a great societal problem.

The overall proportion of ejections among the pickup fatalities is 34.0 percent, but only 24.1 percent in vans. These results are significantly different at the 0.04 level; thus we may conclude that

TABLE 58
FARS 79
Side Impacts, Fatal Pickup Truck Occupants,
Ejection by Seat Location

Seat Location		Ejection			
		Not Ejected	Ejected	Total	M.D.
Left Front	N	361	92	453	7
	%	79.7	20.3	100.0	
Center Front	N	23	9	32	0
	%	71.9	30.1	100.0	
Right Front	N	104	44	148	2
	%	70.3	29.7	100.0	
Other Front	N	0	1	1	0
	%	0.0	100.0	100.0	
Left Second	N	1	2	3	0
	%	33.3	66.7	100.0	
Right Second	N	1	0	1	0
	%	100.0	0.0	100.0	
Other Second	N	0	1	1	0
	%	0.0	100.0	100.0	
Other Passenger	N	7	11	18	0
	%	38.9	61.1	100.0	
On Exterior	N	5	0	5	0
	%	100.0	0.0	100.0	
Unknown	N	12	3	15	0
	%	80.0	20.0	100.0	
Total	N	514	163	677	9
	%	75.9	24.1	100.0	

ejection is not associated as strongly with fatality in vans as in pickup side impacts.

TABLE 59
FARS 79
Side Impacts, Fatal Van Occupants
Ejection by Seat Location

Seat Location		Ejection			
		Not Ejected	Ejected	Total	M.D.
Left Front	N	29	22	51	1
	%	56.9	43.1	100.0	
Center Front	N	2	0	2	0
	%	100.0	0.0	100.0	
Right Front	N	15	8	23	0
	%	65.2	34.8	100.0	
Left Second	N	8	0	8	0
	%	100.0	0.0	100.0	
Center Second	N	2	0	2	0
	%	100.0	0.0	100.0	
Right Second	N	1	0	1	0
	%	100.0	0.0	100.0	
Left Third	N	1	0	1	0
	%	100.0	0.0	100.0	
Other Passenger	N	2	2	4	0
	%	50.0	50.0	100.0	
Unknown	N	10	4	14	2
	%	71.4	28.6	100.0	
Total	N	70	36	106	3
	%	66.0	34.0	100.0	

Ejection is more likely among pickup left-front seat occupants than among right-front occupants, and this result is significant at the 0.03 level. The opposite pattern is observed in van front-seat occupants, but the number of cases is so low that the difference is not

TABLE 60
FARS 79
Side Impacts, Fatal Large Station Wagon Occupants
Ejection by Seat Location

Seat Location		Ejection			
		Not Ejected	Ejected	Total	M.D.
Left Front	N %	8 88.9	1 1.1	9 100.0	0
Right Front	N %	1 100.0	0 0.0	1 100.0	0
Left Second	N %	1 100.0	0 00.0	1 100.0	0
Middle Second	N %	1 100.0	0 0.0	1 100.0	0
Right Second	N %	1 100.0	0 0.0	1 100.0	0
Other Passenger	N %	1 100.0	0 0.0	1 100.0	0
Total	N %	13 92.9	1 7.1	14 100.0	0

significant. Thus we may not conclude that the pattern in reality differs from that of pickups.

4.0 INTRUSION

This section presents the results of an analysis of data on passenger compartment intrusion provided by the second phase of the NCSS program. Intrusion into both passenger cars and light trucks are addressed.

During the first phase of the NCSS program, some information was collected on intrusion of objects into the passenger compartment. However, the data contained little detail, and none that could be used to relate the intrusion to possible consequences. Specifically, it was not possible to relate intrusions to occupant injury.

With the beginning of the second phase of the NCSS data collection starting in April 1978, the protocol was changed to include much more information related to and describing intrusion. The data can most easily be understood by reference to the data collection forms. The forms from which data were used in this study are given in Appendix B. Three forms are included: a form for documenting intrusion of internal surfaces of the passenger compartment (IS), one for occupant contact with intruded surfaces (OC), and a form for catastrophic intrusion (CC).[9]

The internal-surfaces form provides a physical description of each intrusion, including identification of the intruding component/object, the location of the intrusion, and the impact that caused the intrusion. Up to twelve intrusions may be recorded, with each combination of an intruding component and the occupant space intruded upon constituting an individually recorded intrusion. The intrusion form is coded, without columns G and H, in the vehicle level file. Individual intrusions and any attendant contact by an occupant, along with injury numbers, if any are associated with the contact, are recorded on the occupant-contact

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[9]Detailed instructions on the use of the forms are given in Methodology for the Measurement of Intrusion in Motor Vehicle Accidents, Peter Cooley et al. Highway Safety Research Institute, The University of Michigan, Report No. UM-HSRI-78-17-1, April 1978.

form (OC). This form documents any occupant contact with an intrusion, and provides a link between the intrusion and any associated injury. The occupant-contact form is coded in the occupant-level file. However, the link between injury and intrusion is limited to a maximum of six intrusions, since this is the maximum number of documented injuries.

When the intrusion was so great that the passenger compartment integrity failed completely, or so massive that measurements were not practical, a catastrophic-intrusion (CC) form was employed. This form provided only a brief, gross description of the extent of damage, and did not link the damage to specific injuries. Since the data provided for cases of catastrophic intrusion is not compatible with that from the intrusion form, the two sources were analysed separately and the results are presented separately here.

The incidence of intrusion of side-interior surfaces in side impacts, and of occupants contacting intruded surfaces is shown in Table 61. There are 10,005 occupants (weighted) in passenger cars and 803 in light trucks which were side impacted in the NCSS2 data set. The weighted number of occupants who were in vehicles with intruding side surfaces was 3700 in passenger cars and 385 in light trucks.[10] Thus the proportion of the occupants who were in intruded vehicles was 37.0 percent in cars and 47.9 percent in light trucks. Intrusion of side surfaces is apparently a common phenomenon in side impacts, especially in light trucks.

The occurrence of intrusion does not necessarily imply that an occupant contacted the intruding surfaces or components. The number of occupants contacting intrusions is shown in the bottom row (Table 61). Only 29.5 percent of the occupants of passenger cars with intrusion actually contacted an intruding component. The corresponding figure for light truck occupants is 23.7 percent. The resulting proportion of occupants of side-impacted vehicles who contacted an intruding component is then 10.9 percent in passenger cars, and 11.6 percent in light trucks. Table 61 is based on the side-surface intrusion and occupant-

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[10]The actual unweighted number of occupants in both types of vehicles with intruding surfaces was 1468.

TABLE 61
NCSS2
Incidence of Side Surface Intrusion and Occupant Contact (Weighted)

	Passenger Cars	Light Trucks
Number of Occupants in Side Impacts	10,005	803
Occupants in Vehicles with Side-Surface Intrusion	3700 (37.0%)	385 (47.9%)
Number of Occupants Contacting Intruded Side Surface	1092 (29.5%)	93 (23.7%)

contact forms, and does not include 112 occupants of passenger cars and four of light trucks with catastrophic intrusion.

The analysis that can be performed on the intrusion data is disappointingly limited by missing data on injury severity--the ability to link intrusions with injury via the occupant contact form is only of value if valid injury information is available in the injury (Occupant Injury Classification) portion of the file.

Of the 3700 occupants of passenger cars with side-surface intrusion, 985 or 26.6 percent had an Overall AIS (OAIS) of 0, indicating no injury. Another 1465 or 39.6 percent had an OAIS of 1-6, while 1253 or 33.9 percent had an OAIS of 8 or 9 indicating an "injury of unknown severity" or "unknown if injured." If the uninjured occupants are omitted, and only those with an AIS coded 1 through 9 are considered, the missing data rate becomes 46 percent for passenger car occupants.

Only 238 (or 21.8 percent) of the 1092 passenger car occupants who contacted an intruding component had a non-zero, non-missing data AIS listed for the contact. Only 26 (10.9 percent of the 238) had another injury coded more severe than that associated with the intrusion. The remaining 212 (89.1 percent of the 238) had an injury associated with intrusion equal in severity to the most severe injury reported for that occupant. The numbers for light trucks are much smaller. Of the 93 occupants contacting an intruding component, 22 (23.7 percent) had a valid non-zero AIS associated with the contact. Of these 22, 19 had an intrusion associated injury equal in severity to their most severe injury, and three had an injury more severe than the intrusion injury. Thus in very few cases of valid recorded injury severity, was the intrusion-associated injury less severe than other injuries sustained from other sources.

The figures in the paragraph above would seem to indicate that contact with an intruding surface is a significant source of injury, even though Table 61 indicates that only one-quarter to one-third of the occupants in vehicles with intrusion actually contact the intruding surface. The problem with this observation is that the missing data rate on injury severity, both individual AIS's and the overall occupant AIS (OAIS), is high. Consequently, we must recognize that many cases of either minor or no injury from the contact may be coded as missing data. Indeed, many cases of contact without consequent injury may have been undetected by the investigators.

The dichotomous injury variable denoting injury of AIS=0-3 and 4+ (and fatals) has a much lower missing data rate; only 6.7 percent among occupants of side-impacted vehicles with intrusion. While it has the disadvantage of not permitting the linking of intrusion and injury data, it provides more reliable inferences within the confines of its limitations.

Table 62 gives the incidence of serious injury by combinations of intrusion and occupant contact with intrusions. Injury severity for the cases of catastrophic intrusion is also included. A number of observations can be drawn from the table.

Occupant exposure to intrusion is given by the second column. Approximately half of the occupants experiencing side impacts are in vehicles with no intrusion (54.2 percent for cars and 45.6 percent for light trucks). Substantial proportions are in vehicles with intrusion, but do not contact an intruding surface. Only 14.2 percent of the car occupants and 13.2 percent of those in light trucks actually contacted an intruding surface.

TABLE 62
NCSS2
Side Impacts, Occupant Injury Severity by Intrusion and Contact with Intrusion (weighted)

	AIS=0-6, Fatal		AIS=4-6, Fatal		Missing Data
	N	%	N	Row %	N
Passenger Cars:					
No Intrusion	4374	54.2	21	0.5	31
Intrusion, No Contact	2543	31.5	32	1.3	65
Intrusion with Contact	1041	12.9	97	9.3	51
Catastrophic Intrusion	106	1.3	47	44.3	6
Total	8064	100.0	197	2.4	153
Light Trucks					
No Intrusion	321	45.6	2	0.6	2
Intrusion, No Contact	290	41.2	8	2.8	9
Intrusion with Contact	85	12.1	6	7.1	8
Catastrophic Intrusion	8	1.1	6	75.0	2
Total	704	100.0	22	3.1	21

The proportion of serious injury is given for each combination of intrusion/contact, and as one might anticipate, injury rate increases in cases with intrusion. If there was contact with intrusion, the rate again increases, by a factor of seven for passenger cars. Catastrophic collisions, as expected, have a very high rate of injury. Nearly half (44.3 percent) of the occupants of these vehicles received injuries of severity AIS=4 or greater.

Similar trends were observed in light trucks, although the precision of the proportions is low because of the very limited number of serious injuries. The only comparison of injury rates between successive levels in Table 62 that is not statistically significant at the 0.05 level is the comparison between contact and no-contact of light-truck intrusions.[11]

[11]Comparisons based on Fisher's exact probability for 2x2 tables.

The results included in Table 62 can be viewed in a different way. Of the 10,005 occupants of passenger cars in side impacts, only 197 or 2.0 percent received serious injury (AIS=4 or greater, or fatality). The corresponding figure for light trucks is 2.7 percent of the 803 occupants in side impacts. However, intrusion was very common in the cases of serious injury. Eighty-nine percent of the serious injuries in passenger cars were in vehicles with intrusion, as were 91 percent of the seriously injured light truck occupants. While not all the serious injuries in intruded vehicles are associated with the intrusion, the proportion of seriously injured occupants who contacted an intrusion is large. In passenger cars the proportion is 144/197 = 73 percent, and 12/22 = 54.5 percent in trucks. Those figures include occupants of catastrophically-intruded vehicles.

The discussion above clearly indicates that serious injury is more likely in side impacts if there is intrusion into the passenger compartment. It does not indicate that the intrusion was responsible for the injury. They--intrusion and injury--are both associated strongly with impact severity; their correlation may result from these associations and not from a causal relationship.

Stronger evidence of serious consequences from intrusion is provided by the much higher incidence of serious injury among occupants who contacted an intruding surface or component. Even here the evidence is not entirely clear. The greater contact may have been the consequence of more severe crashes which may cause greater injury independently of the intrusion. The more severe impacts might result in more violent occupant kinematics with greater excursion from the normal seated position and hence an increased likelihood of contacting an intruding surface.

One group of occupants of particular interest are those that were seriously injured in side impacts in which there was <u>no</u> intrusion into the passenger compartment. Table 62 indicates 21 in passenger cars and two in light trucks. The 23 weighted occupants represent 20 actual occupants. A descriptive discussion of the 20 cases and a summary of each is given in Appendix C. A brief outline of the cases is shown in Figure 13.

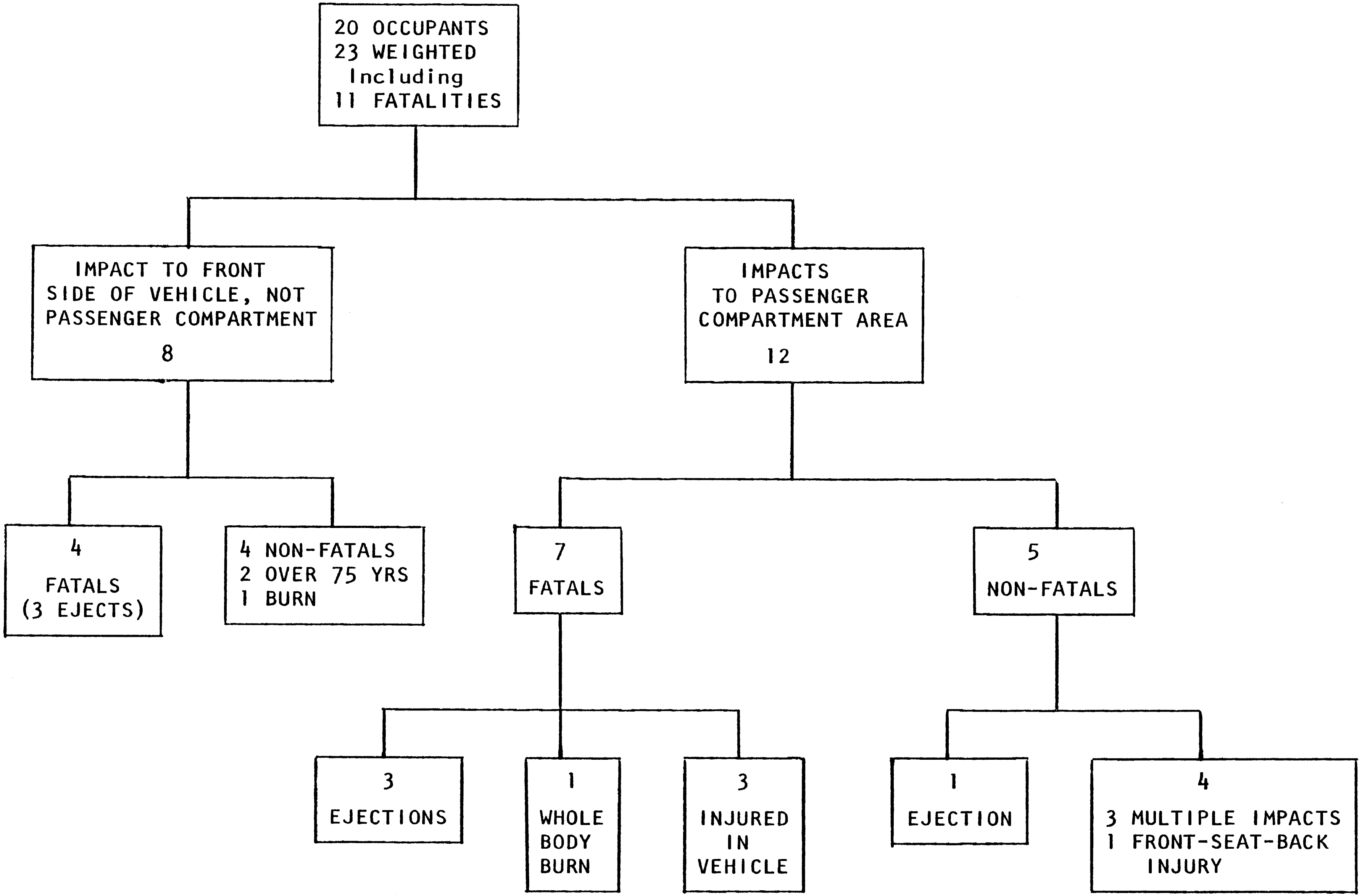

FIGURE 13. Occupants With Serious Injury in Vehicles Without Intrusion

Eight of the twenty occupants were in vehicles that were struck in the side forward of the passenger compartment. There was no intrusion for this reason quite independent of the severity of the impact. Four of the eight were fatalities which included three ejections. The four non-fatals in this group included one burn victim and two occupants over 75 years of age. Other investigators hve found positive association between advanced age and injury.[11]

Among the 12 occupants in vehicles impacted in the passenger compartment area but without intrusion, seven were fatals, of which three were ejections, one sustained a whole body burn, one was injured on the steering column, and two died of unspecified injuries.

Of the 20 occupants seriously injured without intrusion, seven were ejections and five of the remaining 13 were over 65 years of age.

The limitations on the assessment of intrusion upon injury production imposed by the high rate of missing data on injury was discussed earlier. However, information on the occupant contact form can be linked to the intrusion form to determine which intruding components were actually contacted by an occupant. Linking in this direction can be accomplished even if the associated injury details are missing. Thus it is possible to provide some information on the intruding components that were contacted and to give the frequency distribution of the contacts.

A total of 1468 actual occupants were in vehicles with intrusion from side impacts. The weighted number is 4108 and includes both passenger cars and light trucks. Of these occupants, 1189 (weighted) made one or more contacts with intruding surfaces or components. Each occupant may have contacted more than one of the intrusions listed on the intrusion form. Since the occupant contact form provides for listing up to six contacts per occupant, the maximum number of occupant contacts is 1189 x 6 = 7134.

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[11]<u>Statistical Analysis of the National Crash Severity Study Data</u>, P. A. Gimotty et al. Highway Safety Research Institute, The University of Michigan, Report No. UM-HSRI-79-11, March 1979.

The distributions of contacts by surface or components are given in Table 63. Those components which had a frequency of less than one percent were grouped into the "other" category. It should be noted that the component coding on the intrusion form (see Appendix B) contains several codes denoting a group of items. For each of these group codes, a contact with each of the components in the group was counted in deriving the frequencies. This could result in some overcounting of the contacts with grouped items. However, only seven percent of the listed codes were for grouped items.

Two-thirds of the contacts in passenger cars were with a door panel or side surface, which would include door hardware and armrests. The next most frequently contacted items are the A-pillars, but with less than 10 percent of the contacts. Forward components--A-pillars, instrument panels, and steering columns--account for an aggregate total of 17.6 percent. These contacts result from classical intersection-type collisions into the side of a forward-moving vehicle. The direction of impact force is then in a forward quadrant as discussed in an earlier section of this report.

The results for light trucks are similar, but with only 50 percent of the contacts attributed to door panels or side surfaces, and a corresponding increase for A-pillars and other components.

The information that has been presented above on intrusion has been limited to data from the internal surfaces intrusion forms (IS), except for Table 62. As noted there, 112 occupants of passenger cars and 10 of light trucks were in vehicles for which a catastrophic crash (CC) form was completed. Very little intrusion data were collected on these cases, and no attempt was made to associate injury with intrusion.

However, a brief summary of these cases will be given. The description of the principal catastrophic damage for the passenger cars is given in Table 64. Major separation occurred in half the cases, with separation at the B-pillar in 43 percent. Major separation at the B-pillar is equivalent to transection of the vehicle at that point. Nearly half of the cases were of extreme compression, primarily from the lateral directions.

TABLE 63
NCSS2
Occupant Contact with Intruding Components (weighted)

Component	Contacts*			
	Passenger Cars		Light Trucks	
	N	%	N	%
Door Panel/Side Surface	1043	65.1	65	50.8
A-Pillar	145	9.1	14	10.9
Instrument Panel	108	6.7	13	10.2
B-Pillar	49	3.1	5	3.9
Roof	46	2.9	7	5.5
Roof Side Rails	45	2.8	6	4.7
Front-Seat Back	32	2.0	0	0.0
Toe Pan	26	1.6	7	5.5
Steering Column/ Assembly	29	1.8	1	0.8
Other	79	4.9	10	7.8
Total	1602	100.0	128	100.0

*The tabulated frequencies are the number of occupants crossed with the individual components they contacted, e.g., each occupant could have contacted several items. The percentage distribution thus gives the distribution of components among all component contacts.

Ejection is a potentially important consideration, particularly in cases of major separation. Table 65 shows the number of ejected occupants for the primary damage categories. Ejection among all 112 occupants was 17.8 percent, a much higher rate than for all other side impacts. The rate was particularly high in cases of major separation.

Injury rates for various categories of ejection are given in Table 66. In side-impact accidents in general, non-fatal AIS=4 and -5

TABLE 64
Catastrophic Intrusion Damage
Passenger Car Occupants (weighted)

Description of Principal Damage	N	%
Major Separation:	55	49.1
At Firewall	4	3.6
At B-Pillar	48	42.9
At Roof	3	27
Extreme Compression	48	42.9
Vertical Roof	9	8.0
Longitudinal-From Rear	3	2.7
Longitudinal From Front	0	0
Lateral-From Right	14	12.5
Lateral-From Left	22	19.6
Other	9	8.0
Total	112	100.0

injuries and fatalities occur with approximately equal frequency. In the cases of catastrophic intrusion, fatalities were much more frequent. Interestingly, the fatality rate was not higher among the ejectees, indicating the extreme severity of damage. Maybe the most surprising observation is that over half the occupants in vehicles with catastrophic intrusion had injuries of AIS=3 or lower.

Only 10 occupants of light trucks were in cases of catastrophic intrusion. Rather than tabulate these few cases, they are individually summarized in Appendix D.

TABLE 65
Catastrophic Damage and Ejection
Passenger Car Occupants (Weighted)

Damage	Ejection		
	Ejected	Not Ejected	Total
Major Separation			
N	15	40	55
%	27.3	72.7	100.0
Extreme Compression			
N	5	43	48
%	10.4	89.6	100.0
Other			
N	0	9	9
%	0.0	100.0	100.0
Total			
N	20	92	112
%	17.8	82.1	100.0

TABLE 66
Ejection and Injury in Catastrophic Intrusion

Injury Severity	Ejection					
	No		Yes		Total	
	N	%	N	%	N	%
AIS 0-3	46	53.5	13	65.0	59	55.7
AIS 4-5 (non-fatal)	7	8.1	1	5.0	8	7.5
Fatal	33	38.4	6	30.0	39	36.8
Total	86	100.0	20	100.0	106	100.0
M.D.	6		0		6	

5.0 DESCRIPTION OF SERIOUS INJURY IN SIDE IMPACTS

The description of injury in the NCSS data set is provided by the Occupant Injury Classification (OIC) code which includes the severity index (AIS). It is accompanied by the most probable source of injury, the ocupant contact code which gives the object or vehicle component impacted by the occupant. The injury data have a substantial amount of missing information. Because of this, NHTSA has derived a set of dichotomous (split) injury variables. These are based largely on the overall AIS (OAIS), but there this is missing, they have derived the variables based on other points of information when available. By this procedure, the missing data rate on injury severity is reduced substantially, although with a lower level of detail. It is because of the much lower missing data rate, and because the Advanced Notice of Proposed Rulemaking[13] suggested an AIS=4 (serious) threshold, that one of the dichotomous variables has been used for tabulating injury severity in this study.

In looking at more detailed information on injury, elements of the OIC must be used. These variables have substantial missing data, even for those occupants coded as AIS=4+ (including all fatals) on the dichotomous variable. The rate is even higher on the occupant contact variables. While the missing data rate for OIC is somewhat less for Phase II, it is still substantial.

Because the rate is high in both phases, and to have as much data available as possible, both phases will be used for examining the injury detail on seriously injured (AIS=4+, fatal) occupants of passenger cars. Light truck data must, of necessity, be limited to Phase II. Since there were only 22 seriously injured occupants of light trucks, and they are described individually in Appendix A, this section will be restricted largely to passenger car occupants.

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[13]"Federal Motor Vehicle Safety Standard: Side Impact Protection," Federal Register, Vol. 44, No. 236, p. 70204, December 6, 1979.

It must be noted that while using both phases does increase the amount of data, it does nothing to reduce any biases that might be associated with the missing data.

The detail to be examined below is that given for the first listed injury. Presumably this is the most serious in the case of multiple injuries, and the one responsible for the OAIS>

The body distribution region injured for passenger car occupants with a derived AIS of 4 or greater, including fatalities, is shown in Table 67. The most frequent injuries were to the head, accounting for over a third of the serious injuries. The second most prevalent were injuries to the chest (20.8 percent). Among non-fatal cases with AIS=4,5, injuries to the abdomen were second most prevalent. However, these are less likely to be fatal than those to the head, neck, or chest.

It sould be noted that the missing data on body region among the AIS=4+ occupants is 28.5 percent, and that it is almost exclusively among the fatals. The missing data rate reflects the rate among the OIC data of which body region is an element. The fatals for which the body region is missing were identified through a separate variable, not by the AIS code which is part of the OIC. These are generally fatalities without a medical record or autopsy report.

Similar information for occupants of light trucks is given in Table 68. The results are similar to those for passenger cars, but with a higher proportion for the abdomen. However, this observation is are based on a very small number of cases.

Table 69 gives the horizontal location of damage to the car for each of the frequently injured body regions. For all four listed regions, damage to more than one-third of the car (D, Y or P) dominate. Impacts into a single location is less likely to cause serious injury. Damage to the front and passenger compartment caused more of the serious injuries to each body region than any other horizontal pattern of damage.

It is not difficult to conjecture the reason for these results. Generally, side impacts involving more than one horizontal area are more

TABLE 67
Seriously Injured Occupants of Side Impacts (Weighted)
Body Region Injured
(Injury Number 1)

Passenger Cars
(Phases I and II)

	New AIS					
	4,5		Fatal		4-Fatal	
	N	%	N	%	N	%
Head/Skull/Face	55	33.7	71	41.0	126	37.5
Neck	7	4.3	38	22.0	45	13.4
Chest	21	12.9	49	28.3	70	20.8
Back	1	0.6	1	0.6	2	0.6
Abdomen	41	25.2	12	6.9	53	15.8
Pelvic/Hip	5	3.1	0	0.0	5	1.5
Shoulder	0	0.0	0	0.0	0	0
Upper Extremities	15	9.2	0	0.0	15	4.5
Lower Extremities	17	10.4	1	0.6	18	5.4
Whole Body	1	0.6	1	0.6	2	0.6
Total	163	100.0	173	100.0	336	100.0
M.D.	1		133		134	
% of All		0.6		43.5		28.5

severe than those confined to one area, and result in more severe injury. Whether in a classical intersection accident or a single vehicle impact with a fixed object, the car impacted in the side usually has a substantial forward component of velocity. Since penetration of the impacting object increases with time, the greatest penetration is usually toward the rear of the damaged area. Thus, in Z area impacts

TABLE 68
Seriously Injured Occupants of Side Impacts (Weighted)
Body Region Injured
(Injury Number 1)

Light Trucks

	New AIS					
	4,5		Fatal		4-Fatal	
	N	%	N	%	N	%
Head/Skull/Face	3	37.5	5	50.0	8	44.4
Neck	0	0.0	2	20.0	2	11.1
Chest	0	0.0	1	10.0	1	5.6
Back	0	0.0	0	0.0	0	0.0
Abdomen	3	37.5	2	20.0	5	27.8
Pelvic/Hip	1	12.5	0	0.0	1	5.6
Shoulder	0	0.0	0	0.0	0	0.0
Upper Extremities	0	0.0	0	0.0	0	0.0
Lower Extremities	1	12.5	0	0.0	1	5.6
Whole Body	0	0.0	0	0.0	0	0.0
Total	8	100.0	10	100.0	18	100.0
M.D.	0		4		4	
% of All		0.0		28.6		18.2

the greatest penetration is frequently in the quarter-panel region, with less in the passenger compartment. Furthermore, these impacts are likely to involve more damage in the low-occupancy rear-seat area of the passenger compartment. Conversely, impacts involving the front and passenger compartment usually result in maximum penetration in the passenger compartment, often in the front-door area.

TABLE 69
Horizontal Location of Damage by Body Region Injured
Seriously Injured Passenger Car Occupants in Side Impacts
(AIS=4+, Phases I and II, weighted)

Horizontal Loation of Damage	Body Region (Injury 1)							
	Head/Skull/ Face		Neck		Chest		Abdomen	
	N	%	N	%	N	%	N	%
Front (F)	10	7.9	5	11.1	3	4.3	4	7.5
Rear (R)	11	8.7	0	0.0	0	0.0	1	1.9
Distributed (D)	21	16.7	10	22.2	17	24.3	6	11.3
Passenger Compartment (P)	18	14.3	5	11.1	8	11.4	6	11.3
Front & Pass. Compartment (Y)	39	31.0	17	37.7	33	47.1	24	45.3
Rear & Pass. Compartment (Z)	27	21.4	8	17.8	9	12.9	12	22.6
Total	126	100.0	45	100.0	70	100.0	53	100.0
M.D.	0		0		0		0	

Direction of impact force by body region is shown in Table 70. The more common directions among the severely injured are 2 and 10 o'clock--for all four body regions.

The types of injury (lesion) and causes of injury (object contacted) are given in Tables 71 and 72. Most of the head injuries, 62.2 percent, are brain (or brain stem) concussions or contusions. The most common single cause is contact with objects exterior to the passenger compartment--cases of either partial or complete ejection. Impact with the A-pillar accounts for one-fifth. Contact with side surfaces which are most likely to intrude--side interior surfaces and armrests--only account for 4.5 percent. The roof, roof side rail, and window frame account for 19.9 percent. Intrusion of these latter

TABLE 70
Direction of Impact Force by Body Region Injured
Seriously Injured Passenger Car Occupants in Side Impacts
(AIS=4+, Phases I and II weighted)

Force Direction (O'Clock)	Body Region (Injury 1)							
	Head/Skull/ Face		Neck		Chest		Abdomen	
	N	%	N	%	N	%	N	%
One	11	8.8	3	7.3	5	7.2	3	6.0
Two	38	30.4	13	31.7	22	31.9	16	32.0
Three	7	5.6	8	19.5	2	2.9	3	6.0
Four	6	4.8	1	2.4	2	2.9	3	6.0
Five	0	0.0	1	2.4	1	1.4	0	0.0
Six	0	0.0	0	0.0	0	0.0	0	0.0
Seven	1	0.8	1	2.4	1	1.4	2	4.0
Eight	5	4.0	1	4.9	1	1.4	2	4.0
Nine	7	5.6	0	0.0	5	7.2	3	6.0
Ten	34	27.2	8	19.5	21	30.4	12	24.0
Eleven	11	8.8	3	7.3	6	8.7	5	10.0
Twelve	5	4.0	1	2.4	3	4.3	1	2.0
Total	125	100.0	41	100.0	69	100.0	50	100.0
M.D.	1		4		1		3	

objects usually results from impacts with fixed objects such as trees and poles.

Non-contact was the most likely cause of serious neck injury. This usually results from hyperextension which can occur in two ways. High rotational acceleration of the head can result in hyperextension, as in whiplash. Probably more frequent, however, is hyperextension resulting

TABLE 71
Lesion by Body Region
Seriously Injured Passenger Car Occupants in Side Impacts
(AIS=4+, Phases I and II, weighted)

Lesion	Body Region (Injury 1)							
	Head/Skull/ Face		Neck		Chest		Abdomen	
	N	%	N	%	N	%	N	%
Laceration	21	17.6	1	2.2	27	38.6	23	46.0
Contusion	27	22.7	0	0.0	7	10.0	0	0.0
Fracture	6	5.0	36	80.0	16	22.9	0	0.0
Concussion	47	39.5	0	0.0	0	0.0	0	0.0
Hemorrhage	4	3.4	0	0.0	3	4.3	0	0.0
Avulsion	2	1.7	0	0.0	0	0.0	2	4.0
Rupture	0	0.0	0	0.0	3	4.3	24	48.0
Dislocation	0	0.0	7	15.6	0	0.0	0	0.0
Crushing	8	6.7	0	0.0	10	14.3	0	0.0
Amputation	0	0.0	0	0.0	0	0.0	1	2.0
Other	0	0.0	1	2.2	4	5.7	0	0.0
Total	119	100.0	45	100.00	70	100.0	50	100.0
M.D.	7		0		0		3	

from contact of the head with an object. Ejection was also a frequent cause of these injuries. Nearly all neck (AIS 4+) injuries were fractures or dislocations of the cervical vertebrae.

Severe chest injuries were most likely lacerations (38.6 percent), with fractures accounting for another 22.9 percent. Only fractures of the spine or rib fractures resulting in flail chest are coded as AIS=4+. Contact with side-interior surfaces including the armrest caused 62

TABLE 72
Object Contacted by Body Region
Seriously Injured Passenger Car Occupants in Side Impacts
(AIS=4+, Phases I and II, weighted)

	Body Region (Injury 1)											
	Head/Skull/ Face		Chest		Abdomen		Neck		Other		All Body Regions	
	N	%	N	%	N	%	N	%	N	%	N	%
Instrument Panel, Windshield Glove Compartment, Mirror	8	11.9	6	12.0	2	5.9	1	3.6	7	22.6	24	11.4
Steering Wheel	2	3.0	9	18.0	12	35.3	0	0.0	7	22.6	30	14.3
Side-Interior Surface (includes door surfaces)	3	4.5	28	56.0	8	23.5	0	0.0	7	22.6	46	21.9
Armrest	0	0.0	3	6.0	7	20.6	0	0.0	2	6.5	12	5.7
A-Pillar	14	20.9	1	2.0	0	0.0	0	0.0	0	0.0	15	7.1
B-Pillar	3	4.5	0	0.0	0	0.0	0	0.0	0	0.0	3	1.4
C-Pillar	2	3.0	0	0.0	0	0.0	0	0.0	0	0.0	2	1.0
Window Glass	3	4.5	0	0.0	0	0.0	0	0.0	0	0.0	3	1.4
Window Frame	6	9.0	0	0.0	1	2.9	1	3.6	0	0.0	8	3.8
Roof, Roof Side Rail	8	11.9	0	0.0	0	0.0	5	17.9	0	0.0	13	6.2
Exterior to Passenger Comp.	16	23.9	2	4.0	1	2.9	6	21.4	5	16.1	30	14.3
Non-Contact	0	0.0	0	0.0	0	0.0	14	50.0	0	0.0	14	6.7
Other	2	3.0	1	2.0	3	8.8	1	3.6	3	9.7	10	4.8
Total	67	100.0	50	100.0	34	100.0	28	100.0	31	100.0	210	100.0
M.D.	59		20		19		17		11		126	

percent of the serious chest injury, but contact with forward components, i.e., the steering assembly, or instrument panel area, caused another 30 percent.

Abdominal injuries, which account for only 15.8 percent of the serious injuries, are lacerations (including avulsions) of internal organs. They are caused by contact with the side-interior surfaces, armrests, or the steering wheel (79.4 percent). The armrest causes nearly as many as side-interior surfaces, but this results more from its location than from higher relevant aggression.

The aggregate of serious injury number one (the first recorded OIC) to all body regions is given in the last column of Table 72. Side-interior surfacs and armrests caused 27.6 percent. Roofs, roof-side rails, and window frames accounted for another 10 percent. Frontal components such as the steering assemly, instrument panel, windshield and mirror produced 25.7 percent of the serious injuries. This figure rises to 32.8 percent if the A-pillars are included, the frontal group then becoming the dominant injury source.

The material that has been presented on injuries all has substantial missing data. Occupant contact information (Table 72) was missing on 37.5 percent of the seriously injured occupants with valid body region data, while body region information was missing on 30 percent of the seriously injured occupants. The inferences that have been drawn are based on the assumption that the missing data are unbiased. Yet we have no substantiation that such is the case. On the contrary, it seems likely that the missing data on the body region variables are biased since the majority of all such cases were fatalities. Injury details are available in NCSS on the fatally injured occupants only when a medical diagnosis or autopsy report was available, and such were available for only about one-half of the fatally-injured occupants. Thus documentation of body region injured is missing on 43.5 percent of the fatals. Those without the required documentation tend to be DOA's. Those kinds of injuries which lead to early death would thus be overrepresented in the missing data. These are likely to be head injury, with the consequence that the frequency of chest injury among all fatals may be even lower than is shown in Tables 67 and 68.

Since chest injury criteria equivalent to AIS=4+ has been suggested as a performance test threshold, it is particularly germane to consider chest injury in the data presented above.

Of the 336 seriously or fatally injured occupants with valid data on body region, 70 (20.8 percent) received the most severe injury (OICI) to the chest. Of these, 43 received the chest injuries in impacts with force directions of 45-75 degrees off the forward longitudinal axis (clock directions of 2 or 10), equally divided between right and left side impacts. Only seven occupants (two percent of the 336 seriously injured with valid body region data) received primary chest injury in 3 or 9 o'clock impacts.

The chest injuries were typically sustained in impacts that involved a substantial area of the car. Only 15 percent resulted from damage to a single area as defined by the horizontal location element of the CDC.

The primary lesions coded for serious chest injuries were lacerations and fractures (61.5 percent), with crushing accounting for another 14.3 percent.

Contact with a side-interior surface or armrest produced 62 percent of the AIS=4+ chest injuries, while 32 percent resulted from foward components such as the instrument panel, steering wheel, windshield, A-pillar, etc.

It is important to note that only 14.8 percent of the seriously injured or fatal occupants had, as their primary injury, chest lesions from contact with side-interior surfaces or armrests.[14]

Injuries to the head, skull, and face account for over one-third of the occupants with AIS=4+--more than any other body region. These injuries are primarily lacerations, contusions, and concussions. They result from occupant contact with a variety of objects. Forward

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[14]Based on 31 occupants out of 210 with valid data on both body region and contact. Of the total of 470 occupants with AIS=4+, 134 had missing data on body region, and of the remainder 126 had missing data on contact as shown in Table 72, leaving the remainder of 210. The 14.8 percent was calculated on the assumption that the missing data cases were unbiased on all the above variables.

components, i.e., the instrument panel, windshield, steering wheel, etc., along with A-pillars, roof side rails, roofs, and objects exterior to the passenger compartment together account for 71.9 percent of the head injuries. Side-interior surfaces, including armrests and door hardware account for only six percent of such injuries.

Primary injury to the abdomen accounts for 15.8 percent of the AIS=4+ occupants. These injuries are lacerations and ruptures of internal organs. Most of them result from contact with the steering wheel, side-interior surfaces, and armrest; the latter two accounting for 44.1 percent of such cases.

Neck injuries constitute 13.4 percent of the AIS=4+ cases, but none result from door structures or supporting pillars (except a small number from the upper window frame). Half of the neck injuries did not result from direct contact.

From the injury patterns and causes observed in the NCSS program, it appears that a chest injury criteria based on a test configuration representing a single impact force direction would at best represent only 13 percent of the seriously injured occupants of side impacts.[15] The proportion would be even lower if the test represented only car-to-car impacts or fixed-object impacts.

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[15]Based on 43 at 2 and 10 o'clock out of 336 with valid data on body region.

APPENDIX A

CASE SUMMARIES OF LIGHT-TRUCK SIDE IMPACTS WITH SERIOUS INJURIES

CASE SUMMARIES OF LIGHT-TRUCK SIDE IMPACTS WITH SERIOUS INJURIES

This appendix includes individual case summaries of light-truck side impacts in the NCSS project with serious injury--injuries with a dichotomous AIS of 4 or more.

Of the 803 weighted occupants of side-impacted light-trucks in the NCSS2 dataset, only twenty-two received injuries of AIS 4+. Because of the severity of their injuries, they all had a weighting factor of one; hence they are represented by twenty-two actual occupants. The group is composed of fourteen fatalities and eight non-fatalities, and represent eighteen vehicles. Thus eighteen case vehicles are summarized. All occupants of each vehicle are included, not just those with the serious injuries.

Each summary incorporates data from the vehicle and occupant files, and includes all information available from the interior surfaces intrusion form, the catastrophic intrusion and occupant contact forms, and all injury information. A table of intrusions is given for each case for which intrusion was documented. The direction of intrusion is given by the measurement axis used by the investigator. These are the X-axis (fore and aft), Y-axis (lateral), and Z-axis (vertical).

A synopses of the twenty-two serious injury cases is provided by Figures 14 and 15. The type of collision is given in Figure 14. Single-vehicle collisions included nine of the serious injuries of which eight were fatals. Two-vehicle collisions accounted for thirteen of the serious injuries of which six were fatals. Five of the six fatals resulted from collisions with large trucks; only one from a light vehicle.

The injury causations are outlined in Figure 15. Catastrophic intrusion was involved in six of the 8 fatalities while the same number--but not all the same occupants--were ejections.

Only two of the fourteen fatalities resulted from occupant contact with intruding surfaces. These were an intruding A-pillar in case number 480722061, and a roof in case number 680819040.

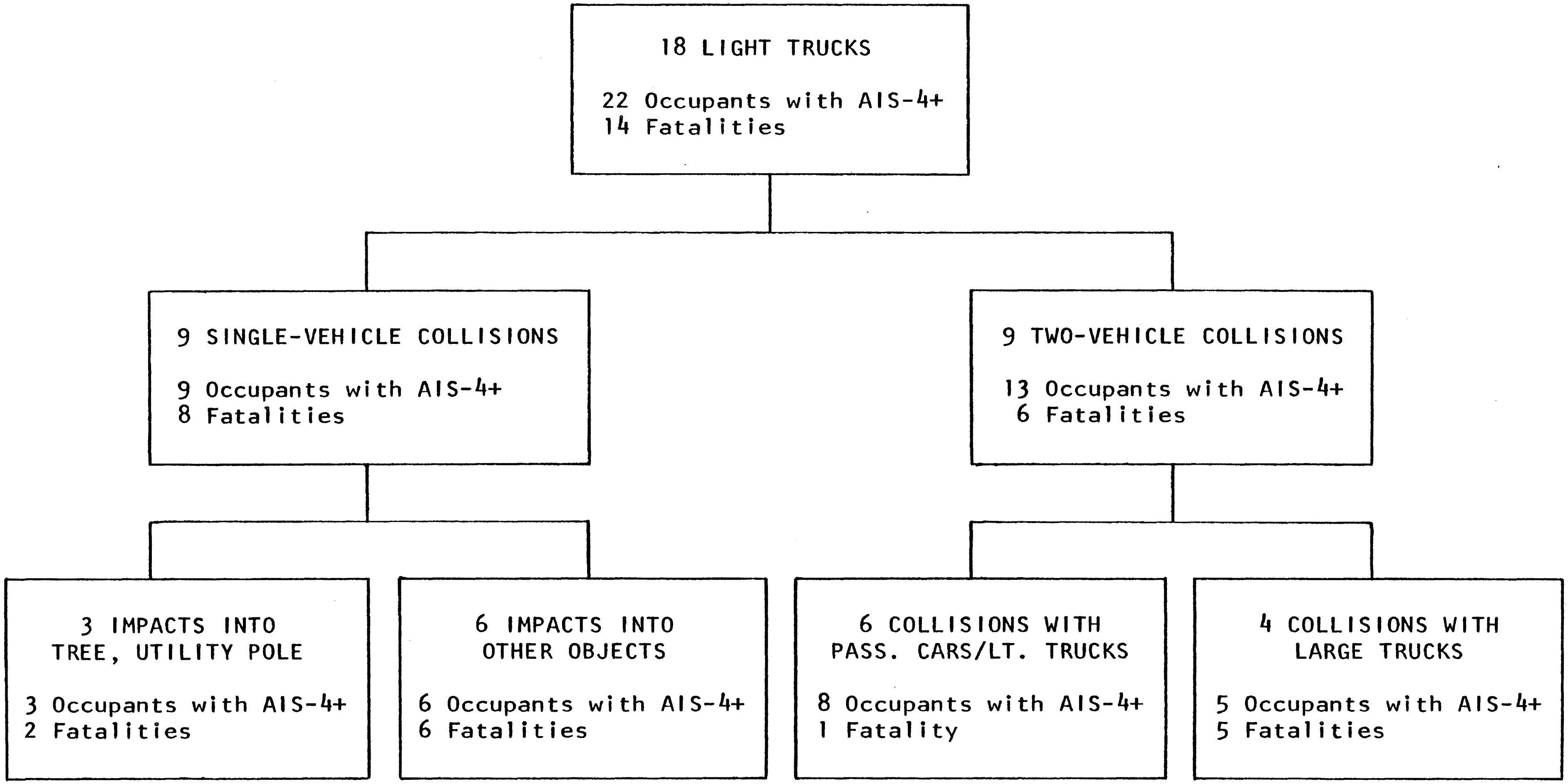
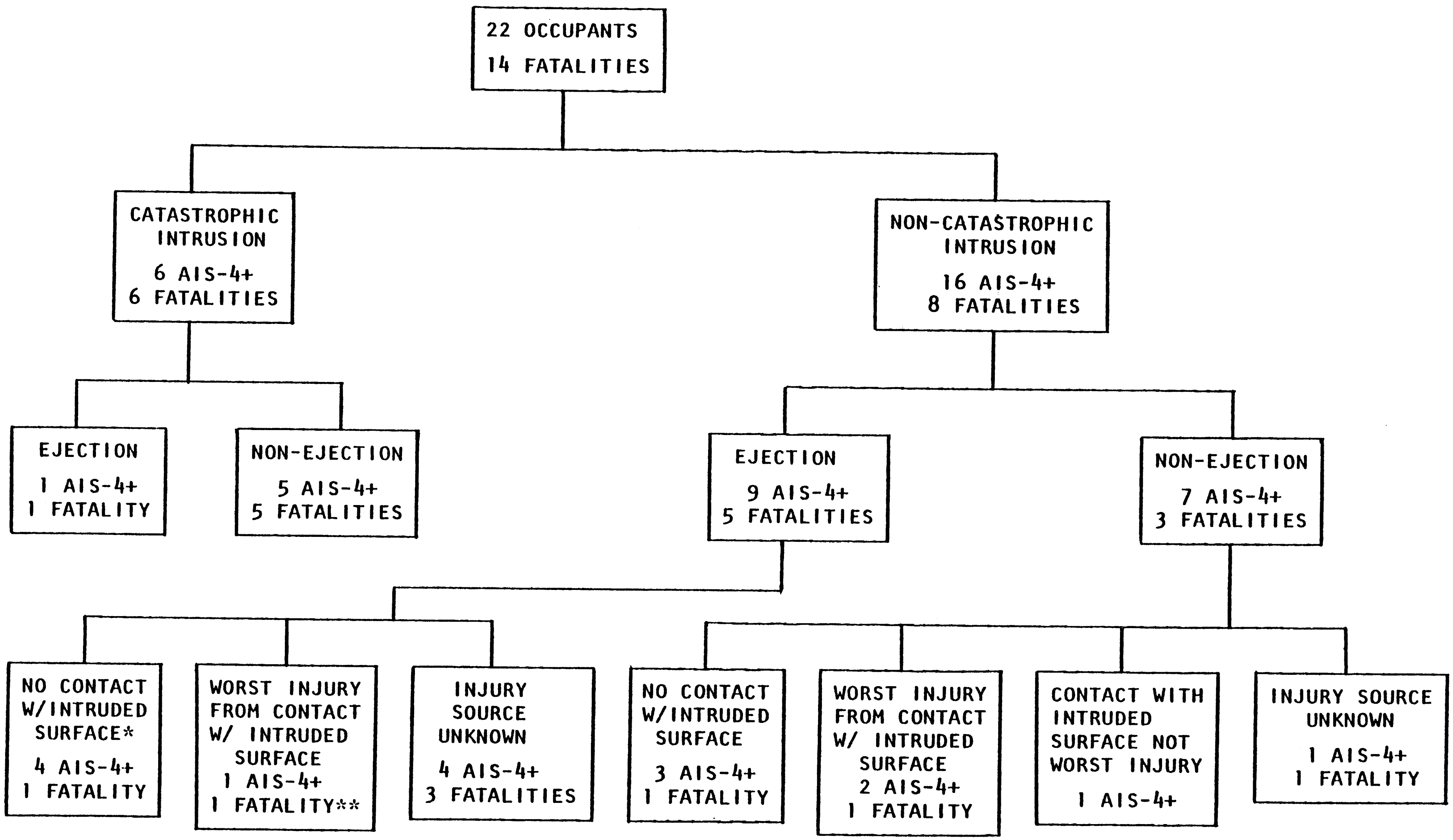


FIGURE 14. Light Truck Occupants with Serious Injury--Type of Collision



*One fatality and two non-fatalities were from vehicles that eventually rolled over.

**The fatality involved a vehicle that eventually rolled over with roof crush.

FIGURE 15. Light Truck Occupants With Serious Injury - Injury Causation

The individual case summaries follow.

CASE NO. 180807003

VEHICLE: 1977 Chevrolet C-20 Pickup
VEHICLE NO.: 2

NO. OF VEHICLES: 2
NO. OF OCCUPANTS: 2

First Impact: Truck >10,000 lb. GVW

CDC 1, 10LDAW4
Delta V: Unknown
Lateral Delta V: Unknown
Left-front door opened.

Second Impact: Utility Pole

CDC 2, 03RBEN1

Catastrophic Intrusion

Opened or separated at B-pillar.
Catastrophic compression from left.
 60-80% reduction in left-front occupant space.
 20-40% reduction in center-front occupant space.
 Less than 20% reduction in right-front occupant space.

Driver: 57 years, Male, Unrestrained, Fatal

Lacerated aorta, AIS 5, steering wheel.
Lacerated heart, AIS 5, steering wheel.
Lacerated spleen, AIS 4, door handle.
Lacerated digestive organ, AIS 5, armrest.
Fractured, bilateral, lower legs, AIS 4, instrument panel.

Right-Front Occupant: 31 years, Male, Unrestrained, Fatal

Lacerated heart, AIS 5, instrument panel.
Lacerated aorta, abdomen, AIS 5, front hardware.
Lacerated aorta, abdomen, AIS 4, front hardware.
Lacerated liver, AIS 5, front hardware.
Lacerated right lung, AIS 4, front hardware.
Lacerated spleen, AIS 4, front hardware

CASE NO. 181110020

VEHICLE: 1974 Dodge W100 Pickup
VEHICLE NO.: 1

NO. OF VEHICLES: 1
NO. OF OCCUPANTS: 1

First Impact: Culvert/Ground/RR Tracks

CDC 2, 10LDLW1
Delta V: Unknown
Lateral Delta V: Unknown
Left-front door opened.

Second Impact: Tree >6" dia.

CDC 1, 00LYAW6

Catastrophic Intrusion

Passenger compartment opened or separated at fire wall.
Extreme vertical compression at roof and laterally from left side.
60-80% reduction of left-front occupant space.
100% reduction of center-front occupant space.
60-80% reduction of right-front occupant space.

Driver: 19 Years, Male, Unrestrained, Trapped in Vehicle, Fatal

Lacerated liver, AIS 5, side interior.
Lacerated spleen, AIS 4, side interior.
Contused brain (left), AIS 4, roof siderail.
Bilateral contused lungs, AIS 3, steering wheel.
Bilateral fractured ribs, AIS 3, steering wheel.
Fractured left femur, AIS 3, side interior.

CASE NO. 190120044

VEHICLE: 1973 Volkswagen Van
VEHICLE NO.: 2

NO. OF VEHICLES: 2
NO. OF OCCUPANTS: 1

First Impact: Subcompact 1973 Datsun

CDC 1, 10LYEW2
Delta V: 8 MPH
Lateral Delta V: 8 MPH
Left-front door opened.

Second Impact: Same subcompact

CDC 2, 09LZEW1

No intrusion or other supplementary forms.

Driver: 37 years, Female, Unrestrained, Completely ejected through left-door area, AIS 4 or greater

Contused brain (left), AIS 5, "other."
Lacerated head (posterior), AIS 1, "other."
Abrasion of forehead, AIS 1, "other."
Pain in posterior neck, AIS 1, no contact.
Pain in right side of head, AIS 1, "other."

CASE NO. 280729028

VEHICLE: 1966 GMC Pickup
VEHICLE NO.: 1

NO. OF VEHICLES: 1
NO. OF OCCUPANTS: 1

First Impact: Non-Movable Object

CDC 2, 10LFEN1
Delta V: Unknown
Lateral Delta V: Unknown
Left-front door opened.

Second Impact: Non-Movable Object

CDC 1, 09LBEW3

Driver: 60 Years, Male, Unrestrained, Fatal, Complete ejection through left-door area.

All injury information is unknown.

CASE NO. 280802053

VEHICLE: 1973 Dodge B-200 Van
VEHICLE NO.: 1

NO. OF VEHICLES: 1
NO. OF OCCUPANTS: 2

First Impact: Tree >6 in. dia.

CDC 1, 00LYAW4
Delta V: Unknown
Lateral Delta V: Unknown
Left-front door opened.

Second Impact: Tree <6 in. dia.

CDC 2, 03RBAW2

Catastrophic Intrusion

Passenger compartment opened or separated at roof and B-pillar.
Less than 20% reduction of driver's occupant space.
No reduction of right-front occupant space.
Less than 20% reduction of left-rear occupant space.

Driver: 34 Years, Female, Unrestrained, Fatal

All injury data unknown.

Right-Front Occupant: 19 Years, Male, Unrestrained, OAIS=3, Unknown ejection

Fractured left wrist/hand, AIS 3, steering wheel.
Fractured left shoulder joint, AIS 2, non-contact.
Unknown injury to back muscle, AIS 1, non-contact.
Laceration of left wrist, AIS 1, steering wheel.
Abrasion of face, AIS 1, Unknown.
Contusion of face, AIS 1, Unknown.

CASE NO. 280816030

VEHICLE: 1973 Chevrolet C-10 Pickup
VEHICLE NO.: 2

NO. OF VEHICLES: 2
NO. OF OCCUPANTS: 4

First Impact: Interm. 1969 Chevrolet

CDC 1, 01RYEW3
Delta V: Unknown
Lateral Delta V: Unknown

Third Impact: Rollover

CDC 2, 00TDH03

Intrusions: 6

No.	Object	Occupant Space	Impact No.	Axis	Max. Intrusion In.	out of In.
1	Toe Pan	Left Front	1	X	12	24
2	Toe Pan	Center Front	1	X	13	20
3	Instrument Panel	Right Front	1	X	15	24
4	Instrument Panel	Right Front	1	Y	7	20
5	Not applicable	---	--	--	--	--
6	---	---	--	--	--	--

Driver: 33 Years, Female, Unrestrained, AIS 4 or greater, Completely ejected through windshield area

Ruptured spleen, AIS 5, steering wheel.
Fractured right ankle, AIS 3, foot controls.
Fractured thoracic vertebra, AIS 2, non-contact.
Concussion, AIS 1, windshield.
Contused right foot, AIS 1, foot controls.
Abrasion of back, AIS 1, "other."

Right-Front Occupant: Under 1-Year-Old, Male, Unrestrained, AIS 4 or greater, Completely ejected through closed r-f window

Concussion, AIS 5, glove compartment.
Fractured right femur, AIS 3, glove compartment.
Abrasion of forehead, AIS 1, glove compartment.

Center-Front Occupant: 3 Years, Male, Unrestrained, "C" Injury on Police Scale, Not Ejected, Transported and Released

Injury data unknown.

Right-Front Occupant: 11 Years, Male, Unrestrained, OAIS=2, Completely ejected through closed right-front window

Lacerated right arm, AIS 2, window glass.
Contused right ankle/foot, AIS 2, floor.
Abrasion of left face, AIS 1, "other" exterior to passenger compartment.
Abrasion of left neck, AIS 1, "other" exterior to passenger compartment.
Other muscle injury posterior neck, AIS 1, non-contact.
Contusion of forehead, AIS 1, "other" exterior to passenger compartment.

CASE NO. 290302001

VEHICLE: 1978 Chevrolet C-10 Pickup
VEHICLE NO.: 1

NO. OF VEHICLES: 1
NO. OF OCCUPANTS: 1

<u>First Impact</u>: Utility Pole

CDC 1, 03RPAW5
Delta V: Unknown
Lateral Delta V: Unknown

<u>Intrusions</u>: 8

No.	Object	Occupant Space	Impact No.	Axis	Max. Intrusion In.	out of In.
1	A-Pillar	Center Front	1	Y	6	20
2	A-Pillar	Right Front	1	Y	20	20
3	Door/Side Panel	Right Front	1	Y	20	20
4	Window Frame	Right Front	1	Y	20	20
5	Door/Side Panel	Center Front	1	Y	4	20
6	Window Frame	Center Front	1	Y	4	20
7	Roof Side Rail	Right Front	1	Y	Unk.	20
8	Windshield Header	Right Front	1	Z	Unk.	Unk.

<u>Driver</u>: 29 Years, Male, Unrestrained, OAIS 4, Unknown ejection

Fractured pelvis, multiple, AIS 4, side interior.
Right pneumothorax, AIS 3, side interior.
Fractured right rib, AIS 3, side interior.
Concussion, AIS 2, A-pillar.
Burns, right side of body, AIS 2.
Contusion, right chest, AIS 1, side interior.

CASE NO. 380504001

VEHICLE: 1978 Ford Pickup
VEHICLE NO.: 2

NO. OF VEHICLES: 2
NO. OF OCCUPANTS: 2

First Impact: Tractor-Trailer

CDC 1, 02RFEW7
Delta V: Unknown
Lateral Delta V: Unknown
Right door opened.

Intrusions: 8

No.	Object	Occupant Space	Impact No.	Axis	Max. Intrusion In.	out of In.
1	Floor Pan	Front Front	1	Z	10	22
2	Instrument Panel	Left Front	1	X	5	36
3	Steering Column	Left Front	1	X	Unk.	Unk.
4	Door Panel	Right Front	1	Y	7	22
5	Instrument Panel	Right Front	1	X	6	36
6	Instrument Panel	Center Front	1	X	9	36
7	Floor Pan	Center Front	1	Z	8	22
8	A-Pillar	Right Front	1	Y	Unk.	Unk.

Driver: 79 Years, Male, Unrestrained, Fatal,
Completely ejected through unknown portal

Fractured neck, AIS 6, non-contact.
Lacerated head, AIS 1, windshield.

Right-Front Occupant: 70 Years, Male, Unrestrained, Fatal,
Completely ejected through right-door area

Fractured neck, AIS 6, non-contact.
Fractured left lower leg, AIS 2, unknown contact.
Lacerated right hand or wrist, AIS 1, unknown contact.

CASE NO. 480722061

VEHICLE: 1975 Chevrolet Van-10
VEHICLE NO.: 1

NO. OF VEHICLES: 1
NO. OF OCCUPANTS: 1

First Impact: Tree >6 in. diameter

CDC 1, 11LYAW3
Delta V: Unknown
Lateral Delta V: Unknown

Intrusions: 13

No.	Object	Occupant Space	Impact No.	Axis	Max. Intrusion In.	out of In.
1*	A-Pillar	Left Front	1	Y	4	31
2	B-Pillar	Left Front	1	Y	5	31
3	Roof Side Rail	Left Front	1	Y	6	31
4*	Door Panel	Left Front	1	Y	2	31
5	Windshield Header	Left Front	1	X	Unk.	Unk.
6	Front Seatback	Right Front	1	Y	Unk.	Unk.
7*	Window Frame	Left Front	1	Y	Unk.	31
8	Side Panel	3rd Seat--All	1	Y	Unk.	Unk.
9	Roof Side Rail	3rd Seat--All	1	Y	Unk.	Unk.
10	Roof	Left Front	1	Z	Unk.	Unk.
11	Roof	3rd Seat--All	1	Z	Unk.	Unk.
12*	Exterior Object	Left Front	1	Y	Unk.	31

*Indicates an injury associated with this intrusion.

Driver: 29 Years, Male, Unrestrained, Fatal, Unknown ejection

Fractured skull (left), AIS 4, A-pillar.
Fractured trachea or larynx, AIS 4, unknown contact.
Hemothorax (left), AIS 3, side interior.
Fractured left face, AIS 3, window frame.
Contused left lung, AIS 3, side interior.
Fractured shoulder, AIS 2, exterior object.

CASE NO. 481212021

VEHICLE: 1978 Chevrolet K-10 Pickup (4-Wheel Drive)
VEHICLE NO.: 2

NO. OF VEHICLES: 2
NO. OF OCCUPANTS: 2

First Impact: 1974 Lincoln

CDC 1, 02RFEW3
Delta V: 19 MPH
Lateral Delta V: Unknown

Second Impact: Same Lincoln

CDC 2, 03RBEW1

Intrusions: 6

No.	Object	Occupant Space	Impact No.	Axis	Max. Intrusion In.	out of In.
1	Front Seatback	Left Front	1	X	4	31
2	Front Seatback	Center Front	1	X	4	31
3	Front Seatback	Right Front	1	X	4	31
4	Seat Cushion	Left Front	1	X	4	31
5	Seat Cushion	Center Front	1	X	4	31
6	Seat Cushion	Right Front	1	X	4	31

Driver: 19 Years, Female, Unrestrained, Fatal

Concussion, AIS 5, Unknown source.
Fractured neck, AIS 5, non-contact.

Right-Front Occupant: 81 Years, Male, Unrestrained, OAIS 4

Lacerated digestive organ, AIS 4, side interior.
Hemothorax (right), AIS 3, side interior.
Fractured right rib, AIS 3, side interior.
Concussion, AIS 2, side interior.

NOTE: Intrusion by seat components, but not by body shell components.

CASE NO. 680418047

VEHICLE: 1966 Ford Econoline Van
VEHICLE NO.: 2

NO. OF VEHICLES: 2
NO. OF OCCUPANTS: 1

First Impact: 1976 Chevrolet C-10 Pickup

CDC 1, 10LZEW3
Delta V: 29 MPH
Lateral Delta V: 22 MPH
Left door opened.

Intrusions: 1

No.	Object	Occupant Space	Impact No.	Axis	Max. Intrusion In.	out of In.
1	Side Panel	3rd Seat--All	1	Y	15	33

Driver: 42 Years, Male, No Restraints Available, OAIS 4, Complete ejection through left door

Fractured right lower leg, AIS 4, "other."

CASE NO. 680512041

VEHICLE: 1977 Volkswagen Van
VEHICLE NO.: 2

NO. of VEHICLES: 2
NO. OF OCCUPANTS: 1

First Impact: 1976 Chevrolet Suburban-20

CDC 1, 02RYAW4
Delta V: 22 MPH
Lateral Delta V: Unknown

Intrusions: 13

No.	Object	Occupant Space	Impact No.	Axis	Max. Intrusion In.	out of In.
1*	Toe Pan	Left Front	1	X	2	21
2*	Toe Pan	Right Front	1	X	18	21
3	Toe Pan	Right Front	1	Y	15	30
4	Dash (Cowl)	Right Front	1	X	14	22
5	A-Pillar	Right Front	1	X	13	30
6	Window Frame	Right Front	1	Y	9	30
7*	Instrument Panel	Right Front	1	X	19	31
8	Door Panel	Right Front	1	Y	16	30
9	Roof	Right Front	1	Z	4	46
10	B-Pillar	Right Second	1	Y	16	16
11	Front Seatback	Right Second	1	X	10	24
12	Door/Side Panel	Right Second	1	Y	Unk.	Unk.

*Indicates an injury associated with this intrusion.

Driver: 35 Years, Female, Unrestrained, OAIS 4

Ruptured spleen, AIS 4, steering wheel.
Lacerated liver, AIS 4, steering wheel.
Concussion, AIS 4, instrument panel.
Laceration of top of head, AIS 2, window glass.

CASE NO. 680610038

VEHICLE: 1978 Chevrolet C-10 Pickup
VEHICLE NO.: 1

NO. OF VEHICLES: 1
NO. OF OCCUPANTS: 4

First Impact: Movable Object

CDC 2, 09LPEN1
Delta V: Unknown
Lateral Delta V: Unknown

Second Impact: Rollover

CDC 1, 00TDH03

Intrusions: 9 (All from Rollover)

No.	Object	Occupant Space	Impact No.	Axis	Max. Intrusion In.	out of In.
1	Roof	Left Front	2	Z	11	37
2	A-Pillar	Left Front	2	Z	Unk.	Unk.
3	Windshield Header	Left Front	2	Z	Unk.	Unk.
4	Roof	Right Front	2	Z	13	37
5	A-Pillar	Right Front	2	Z	Unk.	Unk.
6	Windshield Header	Right Front	2	Z	13	Unk.
7	Roof Side Rail	Right Front	2	Z	Unk.	Unk.
8	Roof	Center Front	2	Z	12	37
9	Windshield Header	Center Front	2	Z	Unk.	Unk.

Driver: 19 Years, Male, Unrestrained, Fatal, Partial ejected through open left window

Crushed skull, AIS 6, outside surface of vehicle.
Fractured right upper arm, AIS 2, outside surface of vehicle.
Abrasion of left chest, AIS 1, outside surface of vehicle.
Abrasion of right lower arm, AIS 1, outside surface of vehicle.
Abrasion of left wrist, AIS 1, outside surface of vehicle.
Abrasion of right shoulder, AIS 1, outside surface of vehicle.

Center-Front Occupant: 20 Years, Male, No Restraint Available, "B" Injury on Police Scale, Not Ejected, Injured, Severity Unknown

Right-Front Occupant: 19 Years, Male, Unrestrained

No Injury information.

Right-Front Occupant: 19 Years, Female, Unrestrained, "C" Injury on Police Scale

No other injury information.

CASE NO. 680819040

VEHICLE: 1976 Datsun Pickup
VEHICLE NO.: 1

NO. OF VEHICLES: 1
NO. OF OCCUPANTS: 1

First Impact: Movable Object

CDC 2, 03RPEN1
Delta V: Unknown
Lateral Delta V: Unknown

Second Impact: Rollover

CDC 1, 00TDH04

Intrusions: 13 (All from Rollover)

No.	Object	Occupant Space	Impact No.	Axis	Max. Intrusion In.	out of In.
1*	Roof	Left Front	2	Z	18	39
2	Roof	Right Front	2	Z	19	39
3	Roof	Center Front	2	Z	17	39
4	Windshield header	Left Front	2	Z	Unk.	Unk.
5	Windshield Header	Center Front	2	Z	Unk.	Unk.
6	Windshield Header	Right Front	2	Z	Unk.	Unk.
7	Roof Side Rail	Left Front	2	Z	Unk.	Unk.
8	Roof Side Rail	Right Front	2	Z	Unk.	Unk.
9	Window Frame	Left Front	2	Z	Unk.	Unk.
10	Window Frame	Right Front	2	Y	Unk.	Unk.
11	Backlight Header	Left Front	2	Z	Unk.	Unk.
12	Backlight Header	Center Front	2	Z	Unk.	Unk.

*Indicates an injury associated with this intrusion.

Driver: 29 Years, Male, Unrestrained, Fatal, Completely Ejected through left-door area

Contusion, posterior brain, AIS 5, roof.
Lacerated right lung, AIS 5, steering wheel.
Contusion, brain, AIS 4, roof.
Fractured bilateral rib, AIS 3, steering wheel.
Fractured skull, AIS 2, roof.
Fractured left shoulder, AIS 2, side armrest.

CASE No. 681018071

VEHICLE: 1976 Chevrolet Van-10
VEHICLE NO.: 1

NO. OF VEHICLES: 1
NO. OF OCCUPANTS: 2

First Impact: Embankment

CDC 1, 08LDAW4
Delta V: 26 MPH
Lateral Delta V: 23 MPH

Catastrophic Intrusion

Extreme lateral compression from left side.
Left-front occupant space reduction less than 20%.
"Other" occupant space reduction was 20-40%--not front or second seat area.

Driver: 18 Years, Male, Unrestrained, Fatal, Unknown Ejection

Concussion, AIS 5, unknown contact.
Fractured left arm, AIS 4, unknown contact.

Right-Front Occupant: 20 Years, Female, Unrestrained, OAIS=1, Ejection Unknown

Abrasion, left forearm, AIS 1, instrument panel.

CASE NO. 690121066

VEHICLE: 1976 Ford F-100 Pickup　　　NO. OF VEHICLES: 2
VEHICLE NO.: 2　　　NO. OF OCCUPANTS: 1

First Impact: 1977 Full-Sized Ford

CDC 1, 02RDEW3
Delta V: Unknown
Lateral Delta V: Unknown

Intrusions: 5

No.	Object	Occupant Space	Impact No.	Axis	Max. Intrusion In.	out of In.
1	Instrument Panel	Left Front	1	Z	3	14
2	Instrument Panel	Right Front	1	Z	2	14
3*	Door Panel	Right Front	1	Y	5	20
4	A-Pillar	Right Front	1	Z	3	19
5	Instrument Panel	Center Front	1	Z	3	14

*Indicates occupant contact, no injury.

Driver: 41 Years, Male, Lap-Belted (no upper torso belt)

Contused brain, AIS 5, roof.
Fractured skull, AIS 4, roof.
Contused forehead, AIS 1, window glass.
Abrasion of forehead, AIS 1, window glass.

NOTE: There was no indication of rollover, no rollover form.

CASE NO. 690319083

VEHICLE: 1967 Dodge D-100 Pickup	NO. OF VEHICLES: 2
VEHICLE NO.: 2	NO. OF OCCUPANTS: 1

First Impact: Truck >10,000 lb. GVW

CDC 1, 02RDAW4
Delta V: Unknown
Lateral Delta V: Unknown
Left-front door opened, latch released.

Catastrophic Intrusion

Extreme lateral compression from right side.
Less than 20% reduction in left-front occupant space.
20-40% reduction of center- and right-front occupant spaces.

Driver: 73 Years, Male, Unrestrained, Fatal, Complete ejection through left door area.

Injuries unknown.

CASE NO. 781029029

VEHICLE: 1974 Dodge B-300 Maxi-Van
VEHICLE NO.: 1

NO. OF VEHICLES: 1
NO. OF OCCUPANTS: 1

First Impact: Non-Movable Object

CDC 2, 01RYMW3
Delta V: Unknown
Lateral Delta V: Unknown
Left-front door opened.

Third Impact: Utility Pole

CDC 1, 12LFEN4

Intrusions: 5

No.	Object	Occupant Space	Impact No.	Axis	Max. Intrusion In.	out of In.
1	Door Panel	Right Front	1	Y	8	22
2	Front Seatback	Left Front	3	X	9	28
3	Front Seatback	Right Front	3	X	6	28
4	Instrument Panel	Left Front	3	X	Unk.	Unk.
5	Instrument Panel	Right Front	3	X	4	31

Driver: 35 Years, Male, No Restraint Available, Fatal

Ruptured spleen, AIS 4, steering wheel.
Fractured right ribs, AIS 3, steering wheel.
Fractured sternum, AIS 2, steering wheel.
Abrasions to unknown area, AIS 1, unknown contact.

APPENDIX B

NCSS PHASE II INTRUSION FORMS

NCSS PHASE II INTRUSION FORMS

The following three forms were used in the second phase of the NCSS program (April 1, 1978 through March 31, 1979) to document intrusions of internal surfaces, and link the intrusions with associated occupant injury. Cases of massive destruction of the passenger compartment were documented on the catastrophic crash form without a link to injury.

UPDATE	TEAM	YEAR	MONTH	DAY	SEQUENCE
_ 1	_	_	_ _	_ _	_ _ _ 10

CC

NATIONAL CRASH SEVERITY STUDY

INTRUSION: CATASTROPHIC CRASH

Complete this form *ONLY* if the intrusion satisfies the definition of a CATASTROPHIC CRASH (see User's Manual, Section 2.2).

[11-13] Vehicle No. ___ 0 0

1. Complete the General Intrusion Diagram so as to depict the approximate intrusions (supplemental sketches may be required).

2. Type(s) of catastrophic vehicle damage (code not more than three):

[14] ___

[15] ___

[16] ___

CODES FOR CATASTROPHIC VEHICLE DAMAGE

Passenger compartment opened or separated:*
1 At firewall
2 At B pillar
3 At roof
9 Other--Describe at Code 9 BELOW

Vertical Compression--Extreme:
4 Roof

Longitudinal Compression--Extreme:
5 From front
6 From rear

Lateral Compression--Extreme:
7 From right hand side
8 From left hand side

9 Describe briefly: ______________________
____
____
____

*Separation or opening need not be complete, but should be of major proportions.

3. Occupant Space Volume Reduction

	Occupant Space Number*	Approximate Volume Reduction
[17]	11 (front, left [driver])	___
[18]	12 (front, center)	___
[19]	13 (front, right)	___
[20]	21 (rear, left)	___
[21]	22 (rear, center)	___
[22]	23 (rear, right)	___
[23]	34 (third, fourth, or fifth seat/cargo area)	___

CODES FOR VOLUME REDUCTION

1 No Reduction
2 < 20%
3 20% - 40%
4 40% - 60%
5 60% - 80%
6 > 80%
7 Total (100%)
8 Not Applicable
9 Unknown

*See User's Manual, Table 6.2-1: Vehicle Configuration at Time of Crash as an aid to determining appropriate OCCUPANT SPACE NUMBERS to code.

GENERAL RULE:

A. *For a vehicle with more than two seats and with a cargo area behind the seat, code spaces 11, 12, 13, 21, 22, 23, and 34 (to denote area behind the second seat).*

B. *For a vehicle with one seat and a cargo area behind the seat, code spaces 11, 12, 13, and 34 (to denote the area behind the seat), and use Code 8 for 21 through 23.*

[80] I.D. 3

* END OF CATASTROPHIC INTRUSION DATA FORM *

UPDATE	TEAM	YEAR	MONTH	DAY	SEQUENCE
1					10

IS

NATIONAL CRASH SEVERITY STUDY

INTRUSION: INTERNAL SURFACES OF THE PASSENGER COMPARTMENT

Complete this form *ONLY* when there is intrusion of the internal surfaces of the passenger compartment. Supplemental sketches may be required.

[11-13] Vehicle No. __ 0 0

1. Complete the General Intrusion Diagram so as to depict the intrusion(s) of the passenger compartment internal surface(s).

   A. For a 2 occupant space vehicle, sketch intrusion on the passenger car diagram and cut-away sections A, C, D.
   B. For a 4 occupant space vehicle, sketch intrusion on the passenger car diagram and cut-away sections A, C, D, E.
   C. For a 5 or 6 occupant space vehicle, complete the passenger car diagram and all cut-away sections.
   D. For a station wagon, complete the station wagon diagram and all cut-away sections. If it is a 3 seat vehicle, ink in the 3rd seat.
   E. For a passenger van, complete the van diagram and all cut-away sections. If it is a 4 or 5 seat van, ink in the 4th and 5th seat.
   F. For a pickup vehicle, complete the pickup diagram and appropriate cut-away sections depending upon the seating arrangements.

[14] 2. Total Number of Occupant Spaces in the Vehicles: ____
8 = 8 or More; 9 = Unknown

[15-16] 3. Total Number of Intrusions __ __
If more than 7 intrusions occurred, code 7 intrusions below and code the balance of intrusions on back of this page.

4. Areas of intrusion, associated impacts and resulting maximum intrusion.
Code intrusions in this order: Occupant Space 11, then 13, 23, 21, 12, 22, seats 3, 4, 5. See User's Manual, Section 6.3 for further information.

	Intrusion Number	Intruded Area or Exterior Object	Occupant Space No.	Associated Impact No.*	Intrusion: Intrusion Maximum Extent	Intrusion: Occupant Space Dimension	Occupant Contact**: Intrusion Extent at Contact†	Occupant Contact**: Occupant Space Dimension†
	A	B	C	D	E	F	G	H
[17-25]	01							
[26-34]	02							
[35-43]	03							
[44-52]	04							
[53-61]	05							
[62-70]	06							
[71-79]	07							

*From Impact Number on page 1 of VEHICLE DATA FORM (V), column 54, etc.
CODES: 1, 2, 3, or 4, 7 = Other Impact; 8 = Not Applicable, 9 = Unknown.

**Noted here for convenience of measurement. Also record as needed in columns G and H of OCCUPANT CONTACT FORM (OC) as appropriate. If no occupant contact occurred for a particular intrusion, leave blank.

†At Point of occupant contact.

NOTE: ALL MEASUREMENTS ARE IN INCHES.

[80] I.D. 4

3/78 IS-1
HSRI

Column B: Codes for Intruded Area or Exterior Object

Individual Component

Internal	**CODE**
Instrument Panel	01
Dash Panel--Cowl	02
Toe Pan	03
Steering Column	04
Windshield Header	05
A Pillar	06
Door Panel or Side Panel	07
Window Frame	08
B Pillar	09
C Pillar	10
D Pillar	11
Roof Side Rails	12
Roof or Convertible Top	13
Floor Pan	14
Backlight Header	15
Front Seat Back Surface/ Seat Back Back Surface	16
Second Seat Back Surface/ Seat Back Back Surface	17
Third Seat Back Surface/ Seat Back Back Surface	18
Fourth Seat Back Surface Seat Back Back Surface	19
Fifth Seat Back Surface Seat Back Back Surface	20
Windshield	21
Back Panel/Back Door Surface	22
Seat Cushion Surface/Edge	23
Other: ____________	28
Unknown Internal Surfaces	29
Exterior	
Hood	43
Objects Exterior to Car	44
Outside Surface of Car	45
Other: ____________	46
Unknown Exterior Object	49
Not Applicable	98
Unknown	99

Grouped for Massive Intrusion into an Occupant Space

	CODE
Instrument Panel-01 A Pillar-06 Door Panel-07	31
Instrument Panel-01 A Pillar-06 W/S Header-05	32
Door Panel-07 B Pillar-09 Roof Rail-12	33
Instrument Panel-01 Floor Pan-14 A Pillar-06 Door Frame-07	34
Roof Rail-12 A Pillar-06 B Pillar-09 Window Frame-08	35
Roof Rail-12 A Pillar-06 B Pillar-09 C Pillar-10 Door Panel-07	36
Roof-13 Roof Rail-12 Window Frame-08 Door Panel-07	37
Backlight Header-15 Roof-13 C Pillar-10 3rd Seat Back-17	38
Roof-13 Roof Rail-12 A Pillar-06 B Pillar-09 C Pillar-10 Window Frame-08 Door Panel-07 Floor Pan-14	39
Instrument Panel-01 Toe Pan-03 W/S Header-05 A Pillar-06 Roof Rail-12 Window Frame-08 Door Panel-07 Roof-13	40
Roof-13 Roof Rail-12 C Pillar-10 Window Frame-08 Floor Panel-14 2nd Seat-17 Door Panel-07	41
Roof Rail-12 Roof-13 B Pillar-09 Window Frame-08 Floor Pan-14 Door Panel-07 2nd Seat-17 Front Seat-16	42

*Use only if all these components components intruded into a single occupant space.

Column C: Codes for Occupant Space Number

Occupant Space Number is a 2-digit code. The use of the code is determined by the vehicle seat configuration at the time of the crash.

The first digit (left digit) denotes the seat row, with code values from 1-5. The second digit (right digit) denotes the position on the seat and (in some instances) the width of the seat.

Second Digit Codes:

Seat Type		Code Value
Individual seat (bucket)		1=left, 3=right
Bench:	Full width 3 passenger	1=left, 2=center, 3=right
	Full width 4 passenger	1=left, 2=left center, 6=right center, 3=right
	Partial width - left	1=left, 2=center, 5=right+ aisle space
	Partial width - centered	0=left + space, 2=center, 5=right + space
Cargo area		4=entire vehicle width

EXAMPLES

Passenger Car
5 passengers

11, 13	x x
21, 22, 23	x x x

Van
12 passenger capacity

11, 13	x x
21, 22, 25	x x x
31, 32, 35	x x x
41, 42, 46, 43	x x x x

If door intrusion occurred, complete DOOR INTRUSION Form (DR).

If seat intrusion occurred, complete SEAT INTRUSION Form (ST).

If occupant contact resulted, complete the appropriate OCCUPANT CONTACT with INTRUDED SURFACES Form (OC).

END OF INTERNAL SURFACES INTRUSION DATA FORM

UPDATE	TEAM	YEAR	MONTH	DAY	SEQUENCE
___ 1	___	___	___ ___	___ ___	___ ___ 10

OC

National Crash Severity Study

INTRUSION: OCCUPANT CONTACT WITH INTRUDED SURFACES

[11-13] Occupant No. ___ ___ ___

Complete this section *ONLY* if there is evidence that an occupant(s) contacted an intruded internal surface (including seats) of the passenger compartment. An injury need not have resulted from the contact.

		Intrusion Number*	Associated Injury Numbers** 1	Associated Injury Numbers** 2	Intrusion Extent at Point of Contact (Inches)† (G)	Occupant Space Dimension†† (Inches) (H)
[14-21]	A	___ ___	___	___	___ ___	___ ___
[22-29]	B	___ ___	___	___	___ ___	___ ___
[30-37]	C	___ ___	___	___	___ ___	___ ___
[38-45]	D	___ ___	___	___	___ ___	___ ___
[46-53]	E	___ ___	___	___	___ ___	___ ___
[54-61]	F	___ ___	___	___	___ ___	___ ___

*From INTERNAL SURFACES INTRUSION FORM, item 4, column A.

**From page 5 or 5a of OCCUPANT DATA PAGE, CASE SUMMARY REPORT. Code 0 if no injury was received from the contact.

†From INTERNAL SURFACES INTRUSION FORM, item 4, column G.

††From INTERNAL SURFACES INTRUSION FORM, item 4, column H.

[80] I.D. 2

* END OF OCCUPANT CONTACT FORM *

APPENDIX C

DISCUSSION AND SUMMARIES OF CASES OF SERIOUS INJURY WITHOUT INTRUSION

DISCUSSION AND SUMMARIES OF CASES OF SERIOUS INJURY WITHOUT INTRUSION

The twenty-three weighted cases of AIS 4+ without intrusion are of interest because they represent an unexpected result--serious injury without severe damage to the passenger compartment. These weighted cases represent twenty actual occupants, eleven of whom were killed even though there was no intrusion of the passenger compartment.

Eight of the twenty occupants were in vehicles damaged only in the front, and thus without intrusion into the passenger compartment. Four of the eight were fatalities, with unknown injury details, including an adult and infant ejected through the same right-front window, and a 60-year-old ejected through the left-front door. The remaining four (non-fatals) include an AIS 5 from burns over the entire body, an AIS 4 fractured left arm from contacting the steering assembly, an AIS 4 fractured right leg from contacting the instrument panel, and the amputation of the left thigh (AIS 5) of an 82-year-old driver by the left-side interior surface.

Twelve of the twenty occupants were in cars that did have side impacts involving the passenger compartment area, even though there was no intrusion. Seven of these were fatalities, of which two were complete ejections (through the door) and one was a partial ejection with a fractured neck. The partial ejection was from a car that struck an embankment in a side impact, and subsequently rolled over. The roll probably produced the ejection. One fatality was from burns, one from contact with the steering wheel, and two from unknown injury sources. The five non-fatalities among the twelve with passenger compartment impacts were injured by a variety of contacts. A 62-year-old right-rear occupant suffered a contused heart (AIS 4) from the front seatback. This occurred in a sideswipe impact with a force direction of nearly 12 o'clock. One of the non-fatal cases was an ejection of the 37-year-old driver of a van through the left-front door, who received a brain contusion (AIS 5) exterior to the van.

The remaining three cases are occupants of vehicles that received multiple impacts, with injuries that are likely the result of a subsequent impact. One was a passenger car that tstruck a utility pole with a CDC of 02-RPAN-2, then a building with a CDC of 01-FDEW-2 from the building. The 69-year-old right-front occupant received a brain concussion (AIS 4) from striking the windshield.

Both impacts had a longitudinal component and either may have resulted in the injury. A similar case was a passenger car that struck a utility pole (11-LDES-1) then another passenger car (12-FDEW-2). The 52-year-old right-front occupant struck the rearview mirror and received a brain contusion, AIS 4. Finally, a passenger was struck in the side by another passenger car (07LZES-1) then struck a guardrail (11-FDEW-3). Contact with the steering assembly resulted in a lacerated liver (AIS 4) to the 29-year-old driver, likely as a result of the impact with the guardrail.

Individual case summaries of the twenty cases of serious occupant injury without intrusion of the passenger compartment are given below, but a few synoptic observations are appropriate. A substantial number of cases (14) involved subsequent impacts of the case vehicle with other objects--other than the object or vehicle causing the side impact. Seven of the cases--nearly a third--were ejection. One of the most interesting facets of these cases is the age of the injured occupants. The average age, as well as the median, is 45. Seven of the twenty, or 35% are 60 years or older. It is also interesting that six of the seven ejections were of people under 60 years. Only seven of the thirteen under 60 years were seriously injured without ejection. It almost appears that occupants seriously injured in minor side impacts, specifically those without intrusion into the passenger compartment, are either old or ejected.

The weighting factor for each case summarized below is 1 unless otherwise indicated. The Delta V (in mph) resulting from the side impact is given if it was available. No ejection occurred unless it is described. Crush measurements are given if the documented crush resulted from the side impact and was located in the passenger compartment area. Crush is documented by three parameters. These are the width of the area of deformation (L); either 2, 4, or 6 equally-spaced measurements of the depth of crush; and the offset from the center of crush to the lateral center-line of the vehicle (D). All crush measurements are in inches.

<u>Case Summaries</u>

1. Passenger Car Struck by a Light Truck

   CDC: 10-LFEW-3
   Second Impact: 09LVEW-1 (Light Truck)
   Total Delta V=12 Lateral Delta V=11
   78 Yr. Driver: Fractured right leg, AIS 4, instrument panel.
   Note: This case has a weight of 4.

2. Passenger Car Struck a small tree

   CDC: 12-LDES-1
   Second Impact: 12-FYEW-1 (large tree)
   62 Yr. Right-Rear: Contused heart, AIS 4, front seatback.

3. Passenger Car Struck Utility Pole

   CDC: 02-RPAN-2
   Second Impact: 01-FDEW-2 (building)
   Total Delta V=6 Lateral Delta V=5
   69 Yr. Right-Front: Brain concussion, AIS 4, windshield.

4. Van Struck by Passenger Car

   CDC: 10-LYEW-2
   Second Impact: 09-LZEW-1 (passenger car)
   Total Delta V=8 Lateral Delta V=7
   L=61 C's=2,1 D=56
   37 Yr. Driver: Ejected through left-front door.
   Brain contusion AIS 5, exterior to car.

5. Passenger Car Struck Utility Pole

   CDC: 11-LDES-1
   Second Impact: 12-FDEW-2 (passenger car)
   52-Yr. Right Front: Brain contusion, mirror, AIS 4.

6. Passenger Car Struck by Passenger Car

   CDC: 01-RZEW-2
   Third Impact: 12-FCEN-2 (passenger car)
   56-Yr. Driver: Lacerated liver, AIS 5, steering assembly, fatal.

7. Pickup Struck Movable Object

   CDC: 10-LFEN-1
   Second Impact: 09-LBEW-3 (other object)
   60 Yr. Driver: Ejected left-front door, fatal, injury unknown.

8. Passenger Car Struck by Passenger Car

   CDC: 10-LFEW-4
   Second Impact: 09-LZEW-3 (passenger car)
   Total Delta V=18 Lateral Delta V=16
   82 Yr. Right-Front: AIS 4, Amputation of left thigh, side interior surface.

9. Passenger Struck Culvert, Tracks, Curb, or Ground

CDC: 02-RFEW3
Third Impact: 00-BLAE-6 (tree)
1 Yr. Center-Front: Ejected through open right-front window, fatal, injury information not available.

10. Same Vehicle as Case No. 9

20 Yr. Right-Front: Ejected through open right-front window, fatal, injury information not available.

11. Passenger Struck Utility Pole

CDC: 10-LFEW-4
Third Impact: 12-FYEW-1 (tree)
40 Yr. Driver: Fatal, unknown injury.

12. Passenger Car Struck by Passenger Car

CDC: 01-RYEW-4
L=110 C's=4,4,4,6,12,15 D=80
40 Yr. Driver: Fatal, unknown injury.

13. Passenger Car Struck Movable Object

CDC: 04-RDEW-1
45 Yr. Right-Front: Ejected through right-front door, fatal, injury information not available.

14. Passenger Car Struck Utility Pole

CDC: 01RYEW-2
Second Impact: 12-FREW-3
39 Yr. Driver: Fatal, burns over entire body.

15. Passenger Car Struck by Passenger Car

CDC: 02RZEW2
Second Impact: 09-LZEW-3 (different passenger car)
Total Delta V=10 Lateral Delta V=10
L=58 C's=6,4,3,3,5,3 D=-75
65 Yr. Driver: Brain contusion, fatal, injury information not available.

16. Passenger Car Struck by Passenger Car

CDC: 07=LZES-1
Second Impact: 11FDEW-3 (Guardrail)
29 Yr. Driver: Lacerated liver AIS 4, steering assembly.

17. Passenger Car Struck by Passenger Car

CDC: 10LZEW-3
Third Impact: 11-FZEN-1 (utility pole)
17 Yr. Driver: Ejected through left-front door, fatal, injury information not available.

18. Passenger Car Struck Embankment

CDC: 02-RDEW-1
Second Impact: 00-LDA0-2 (rollover)
29 Yr. Driver: Partially ejected through left-front window, fractured neck, roof side rail, fatal.

19. Passenger Car Struck Utility Pole

CDC: 11-LFEW-2
Total Delta V=12 Lateral Delta V=6
L=25 C's=1,7,8,7,6,4 D=53
37 Yr. Right-Front: Fracture of left arm, AIS 4, steering assembly.

20. Passenger Car Struck Guardrail

CDC: 11-LFEW-1
Second Impact: 00-TDH0-2 (rollover)
19 Yr. Driver: Burns over entire body, AIS 5.

APPENDIX D

CASE SUMMARIES OF CATASTROPHIC INTRUSION OF LIGHT TRUCKS

CASE SUMMARIES OF CATASTROPHIC INTRUSION OF LIGHT TRUCKS

Only ten occupants of six light trucks were in side impacts with catastrophic intrusion, all with a weighting of one. The ten occupants include six fatalities and four non-fatals. Because the number of cases is small, a summary of each case can be given. The intrusions in percent of occupant space given below are the volumetric reductions in the space originally available to each particular occupant.

1. Pickup Truck Struck by Another Light Truck

   CDC: 10LDAW4
   Second Impact: 03-RBEN-1 (utility pole)
   Catastrophic intrusion was separation at the B-pillar and extreme compression from the left.
   Driver: Intrusion into 60-80% of driver's occupant space. Fatal lacerated artery in chest from steering assembly.
   Right-Front Occupant: Intrusion into occupant space was less than 20%. Fatal lacerated heart from instrument panel.

2. Pickup Struck Culvert/Ground/Trucks/Curb/then Tree

   CDC: 10LDLW1 (culvert, etc.)
   Second Impact: 00LYAW6 (tree)
   Catastrophic intrusion was separation at B-pillar, extreme compression of roof, and extreme lateral compression from left.
   Driver: Intrusion into 60-80% of driver's occupant space. Driver trapped, with fatally-lacerated liver from side surfaces.

3. Van Struck Large Tree

   CDC: 00-LYAW-4
   Second Impact: 03-RBAW-2 (small tree)
   Catastrophic intrusion was separation at roof and B-pillar.
   Driver: Intrusion into driver's space was less than 20%, fatal unknown injury.
   Right-Front Occupant: No intrusion into occupant space. Fractured left wrist (AIS 3) from steering assembly.

4. Van Struck by Light Truck (<10,000 lb. GVW)

   CDC: 10-LZAW-4
   Second Impact: CDC: 09LFEW1 (light truck)
   Catastrophic intrusion was separation at the B-pillar.
   Driver: Intrusion into driver's occupant space was less than 20%. Non-fatal injury unknown.
   Center-Rear Occupant: No intrusion into occupant space. Non-fatal injury unknown.

5. Van Struck Embankment

CDC: 08-LDAW-4
Catastrophic intrusion was extreme lateral compression from left.
Driver: Intrusion into the driver's occupant space was less than 20%. Driver received fatal brain concussion from unknown source.
Right-Front Occupant: No intrusion into occupant space. Abrasion of left forearm (AIS 1) from instrument panel.

6. Pickup Struck by Light Truck (Under 10,000 lb. GVW)

CDC: 02-RDAW-4
Catastrophic intrusion was extreme lateral compression from right.
Driver: Intrusion into driver's occupant space was less than 20%. Driver completely ejected, fatal from unknown injury.