

ANALYSIS OF NCSS SIDE IMPACT CASES

by

John W. Melvin  
D. Hurley Robbins  
Donald F. Huelke  
James O'Day

UM-HSRI-79-50

Highway Safety Research Institute  
The University of Michigan  
Ann Arbor, Michigan 48109

August 1979

## Technical Report Documentation Page

|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                      |                                                        |                                 |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------|--------------------------------------------------------|---------------------------------|
| 1. Report No.<br>UM-HSRI-79-50                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | 2. Government Accession No.                          | 3. Recipient's Catalog No.                             |                                 |
| 4. Title and Subtitle<br>Analysis of NCSS Side Impact Cases                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                      | 5. Report Date<br>August 1979                          | 6. Performing Organization Code |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                      | 8. Performing Organization Report No.<br>UM-HSRI-79-50 |                                 |
| 7. Author(s) J. W. Melvin, D. H. Robbins,<br>D. F. Huelke, J. O'Day                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                      | 10. Work Unit No. (TRAIS)                              |                                 |
| 9. Performing Organization Name and Address<br>Highway Safety Research Institute<br>The University of Michigan<br>Ann Arbor, Michigan 48109                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                      | 11. Contract or Grant No.<br>DOT-HS-8-01944            |                                 |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                      | 13. Type of Report and Period Covered<br>Final         |                                 |
| 12. Sponsoring Agency Name and Address<br>Department of Transportation<br>National Highway Traffic Safety Administration<br>Washington, D.C. 20590                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                                      | 14. Sponsoring Agency Code                             |                                 |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                      | 15. Supplementary Notes                                |                                 |
| 16. Abstract<br><p>Selected side-impact cases from the National Crash Severity Study (NCSS) were studied to determine similarities and differences between actual crashes and laboratory (sled) crash tests. Sled tests simulating side impact have been conducted almost exclusively at 90° impact angle, so the NCSS cases analyzed were those with a near-side occupant and a reported 3 o'clock or 9 o'clock impact vector.</p> <p>Of approximately 90 cases studied, 51 were judged comparable to the laboratory situation. The remainder generally involved cars struck at a point remote from the passenger compartment, and often involved considerable rotation of the vehicle. Injuries for the 51 cases were tabulated by crash severity (Delta V) and were judged to be quite similar to those observed in laboratory (sled) tests at a somewhat higher Delta V.</p> <p>Brief notes are appended to the report concerning each of the reviewed cases.</p> |                                                      |                                                        |                                 |
| 17. Key Words<br>Side-impact, Injury, Accident,<br>Crash tests                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                      | 18. Distribution Statement<br>Unlimited                |                                 |
| 19. Security Classif. (of this report)<br>Unclassified                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | 20. Security Classif. (of this page)<br>Unclassified | 21. No. of Pages<br>16                                 | 22. Price                       |

## ANALYSIS OF NCSS SIDE IMPACT CASES

March, 1979

The NCSS files have been searched to list those cases with either a 9 o'clock or 3 o'clock principal direction of force (from the Primary CDC) and a near side occupant. The purpose was to identify cases which might be comparable to sled testing situations that have been studied in lateral impact research with cadavers. Ninety one cases were identified by the computer sorting, and the hard copies were retrieved for reading by a team consisting of D. H. Huelke, D. H. Robbins, and J. W. Melvin. This memorandum contains excerpts from those cases found to be similar to sled testing situations (in tabular form), and also presents a brief analysis of the data file relative to side impacts.

Cases with non-trivial injuries have been excerpted and tabulated in three groups following. Injury information was sometimes available in coded form, but has been derived from review of the hard copy when not in computer form.

### Case Review

The intention of the case review was to evaluate the information available in the NCSS files with respect to the realism of laboratory sled testing impact injury results. In the laboratory, virtually all biomechanics research testing has involved a simple  $90^0$  lateral impact configuration with the interaction velocity between the side structure and the test subject as the major dynamic variable. Both flat rigid wall tests and simple two-dimensional contoured side structure tests have been conducted. By the nature of the test method it is not possible to simulate a dynamic intrusion of the exterior of the vehicle into the interior. In the field, the conditions are somewhat different than in the laboratory. There are a variety of impact directions and in many cases there is intrusion of the vehicle side structure into the passenger compartment. Unlike the laboratory, the actual interaction velocity of the occupant with the vehicle structure is ill-defined and the occupant kinematics are also poorly defined.

The shortcomings of both data sources can be minimized to some

degree through careful definition of the test conditions and the field conditions that might be analogous. The lack of dynamic intrusion in sled tests can be accounted for by considering sled test data of a given interaction velocity to be similar to field data with a somewhat lower vehicle velocity change ( $\Delta V$ ). This may be able to account for the effect of intrusion on the actual interaction velocity of the vehicle occupant. Additionally, by considering only field cases which are essentially  $90^\circ$  impacts and which produce a generally blunt impact to the occupant (that is, excluding sharp interior surface interactions) a set of data may be obtained from the NCSS files which has general comparability with laboratory test data. There are some additional difficulties which must be addressed, however. The lack of accurate occupant kinematics information and documentation of interior surface conditions makes many field cases of limited value to the present purpose.

The fact that a vehicle has been struck on the side in a predominantly lateral direction does not guarantee a predominantly lateral occupant response. Lateral impacts away from the occupant compartment can generate large rotational components of motion which can produce occupant kinematics and loadings that are quite different than purely lateral translational motion would produce. The  $\Delta V$  calculated by the CRASH2 program may be quite misleading in terms of crash severity as well as in the resulting occupant motions. The production of injury to the body is a function of the loads applied to the body and these are, in turn, dependent not only on the  $\Delta V$  but the time increment,  $\Delta T$ , during which the  $\Delta V$  takes place. Lateral impacts that are remote from the occupant compartment may have large  $\Delta V$  but they do not appear to produce injuries which are as severe as more direct compartment impacts. This may be due to several factors involved in the actual methods of calculation of  $\Delta V$  by the CRASH 2 program (see Appendix I for a detailed discussion of this aspect) as well as the above factors.

With all the above considerations in mind, a total of 51 cases were identified as being somewhat comparable to laboratory tests. The information from these cases is listed in Appendix II as Table 1. The

forty cases that were rejected are listed in Appendix II as Table 2, along with the reason for exclusion. (Note: These cases were selected for review from an early NCSS tape, subsequent revisions to the tape have changed the impact direction by +1 in about 20% of the cases reviewed and have deleted and modified some of the delta V values so that a new search of the tape using the 3 o'clock and 9 o'clock filter may not turn up some of these cases.)

The pattern which emerges from this limited sample shows the most severe injuries occurring for the highest lateral Delta V's, the largest amount of intrusion (which is not necessarily correlated with Delta V), and the most central impacts with respect to the vehicle center of gravity (definitely not correlated with Delta V). In cases where the impact is not in line with any occupant, it does not necessarily produce a similarly large occupant interaction velocity with the vehicle side structure. This observation is based on the lack of significant interior surface deformations for some high Delta V cases, and on the lack of serious injuries in those cases. It appears that the lateral sled test situation is most closely matched by lateral impacts to the side of the vehicle close to where an occupant is seated.

Examination of Table 2 (Appendix II) shows that AIS 3 level injuries begin to occur at a delta V of 9 mph (a 35 year old driver with three broken ribs, a concussion and lacerations from a pole impact which intruded behind the drivers seat.) and continue to occur up to a delta V of 35 mph (a 16 year old right front passenger with a fractured neck, concussion and additional left side injuries from occupant contact due to a pole impact which intruded in the back seat area.) AIS 3 level sled injuries begin to occur at about 15 mph.

There has been a great deal of discussion with respect to skeletal injuries and age effects in cadaver tests. Table 1 lists all of the cases in which skeletal injuries have occurred. Rib fractures appear to occur with older individuals (33 years or older with the exception of a 23 year old who met with direct intrusion) while younger people tend to get extremity fractures. Pelvic fractures seem to occur across the age range (15 - 80 years old).

TABLE 1  
SUMMARY OF SKELETAL INJURY CASES

| CASE NO.      | AGE | Delta<br>V | SKELETAL INJURY             |
|---------------|-----|------------|-----------------------------|
| 6-7-09-04-010 | 22  | 24         | Forearm fracture            |
| 6-7-12-03-012 | 19  | 20         | Bilateral Hip Dislocation   |
| 2-7-05-20-021 | 59  | 10         | Chest, 5 R Rib fracture     |
| 6-7-02-26-099 | 47  | 14         | Chest, 4 Rib fracture       |
| 7-7-05-08-009 | 24  | 25         | Pelvis fracture             |
| 6-7-06-23-099 | 80  | 10         | Pelvis fracture             |
| 5-7-06-04-007 | 26  | 14         | Tibia, fibula fracture      |
| 6-8-01-30-084 | 35  | 9          | Chest, 3 Ribs fracture      |
| 1-7-01-01-008 | 23  | 12         | Chest, Ribs L(6-9) fracture |
| 1-8-02-27-042 | 25  | 13         | Clavical fracture           |
| 6-7-07-14-062 | 70  | 13         | Chest, 2 R Rib fracture     |
| 1-7-08-08-025 | 23  | 19         | R arm fracture              |
| 1-7-11-23-048 | 37  | 15         | Pelvis fracture             |
| 1-7-05-21-030 | 62  | 11         | Chest Rib fracture          |
| 3-7-04-22-016 | 16  | 22         | Pelvis Bilateral fracture   |
| 3-7-08-21-033 | 61  | 11         | Chest, Rib fracture         |
| 3-7-11-19-034 | 16  | 23         | Neck, fracture              |
| 4-7-03-07-020 | 18  | 12         | Tibia fracture              |
| 4-7-04-03-005 | 16  | 7          | Upper leg fracture          |
|               | 15  | 7          | Pelvis fracture             |
| 6-7-06-02-009 | 16  | 11         | Face, fracture              |
|               | 15  | 11         | Face, fracture              |
| 6-8-02-22-061 | 16  | 35         | Neck, fracture              |

### Data File Analysis

The cases selected for clinical review in this study were restricted to nearside occupants with three or nine o'clock impacts. A principle finding of the review was that direct occupant compartment impacts yielded injuries consistent with laboratory results; but impacts with the same Delta V which were principally into the front or rear (of the vehicle side) produced observably lower injuries.

A somewhat broader set of side collisions has been selected from the NCSS data set to further illuminate this matter. Table 2 is based on all nearside occupants in collisions with a clock direction of 02-04 or 08-10 and with the general area of damage being either the right or left side (i.e. a combination of the PDOF and the first letter of the CDC). A total of 208 occupants (unweighted) fit these criteria in cars with a Delta V of 11 to 20 miles per hour and had a reported injury severity (OAIS) between 0 and 6. These are shown in the following table:

TABLE 2  
INJURY DISTRIBUTION FOR NEARSIDE OCCUPANTS OF CARS STRUCK  
IN THE SIDE WITH 11-20 MPH DELTA V's.

| Damage Location   | AIS 0 | AIS 1 | AIS:2 | AIS:3 | AIS 4-6 | Total |
|-------------------|-------|-------|-------|-------|---------|-------|
| Front . . . . .   | 16    | 18    | 2     | 2     | 0       | 38    |
| Back . . . . .    | 4     | 0     | 3     | 0     | 0       | 7     |
| Distributed . . . | 0     | 3     | 2     | 4     | 1       | 10    |
| Side Center . . . | 3     | 5     | 5     | 10    | 4       | 27    |
| Front/Side Center | 12    | 28    | 12    | 18    | 9       | 79    |
| Back/Side Center  | 14    | 11    | 5     | 12    | 5       | 47    |
| Total . . . . .   | 49    | 65    | 29    | 46    | 19      | 208   |

Note that all of the AIS 4-6 injuries involve impact to the passenger compartment, and that only 2 of 45 persons in cars struck in the front or rear of the side sustained injuries as great as level 3. By contrast 63 of 163 occupants of vehicles with passenger compartment damage sustained injuries as the AIS-3 or greater level. All of these occupants were in cars with reported Delta V's of 11 to 20 miles per hour.

While the number of cases in the 21-30 mph Delta V range is smaller, the results are quite similar. For back and front (side) damage there was one person (out of ten) injured to the AIS-3 level, but with passenger compartment damage 17 of 38 were injured to AIS-3 or more. For crashes with more than 30 miles per hour Delta V there were 12 (of 16) persons injured when the passenger compartment was involved, and none (of 1) injured when the impact was into the front side.

#### Problems Encountered

1. Reviewing of the hard copy of the reports was often difficult because of poor interior and exterior photography.
2. Occupant contact points were poorly documented in most reports.
3. Cases for the study were originally drawn from a early computer file which subsequently underwent many modifications. Thus, while the cases originally were limited to 09 and 03 o'clock impacts, many have now been recoded to 02, 04, 08 and 10 o'clock.
4. Information on rotational motion of the vehicle (at impact) would have been helpful, but is not coded in the computer file.

#### Conclusions

1. Lateral impacts remote from the occupant compartment produce substantially lower injuries (at a given calculated Delta V) than would be expected from sled tests. This may be the result of vehicle rotation at impact which leads to occupant contacts not directly on the side of the struck vehicle.
2. When the occupant compartment is struck directly, injuries reported in NCSS compare favorably with those observed in sled tests of a somewhat higher Delta V.
3. Under similar severity of lateral impact, young people sustain fewer skeletal injuries than older people. This is particularly so for rib fractures.

## APPENDIX I

CRASH2 Delta V Computation Considerations for Side Impacts  
K.Campbell

As part of the clinical review effort, side impact cases have been studied to compare results of NCSS crash investigations with laboratory experiments. Questions have arisen with regard to the computation of velocity change, Delta V, using the CRASH2 computer program and the relationship of this result to the laboratory measurements. The following is a short discussion of some aspects of the use of CRASH2 for side impacts which may aid the comparison with laboratory results.

Four aspects of the CRASH2 program will be discussed:

- 1) the general application of the damage and momentum computations
- 2) non-central collisions
- 3) existing data on vehicle force-deflection characteristics
- 4) rotational effects

These are discussed in the order listed in the following paragraphs.

The CRASH2 program has the capability to generate two estimates of the velocity change during the impact, or contact, phase: a damage-based computation of the vector impulse, and a linear momentum computation based on post-impact trajectories of the vehicles. In general, pre-impact lateral and rotational velocities are assumed to be negligible, angular momentum and rotational kinetic energy are also neglected. Within these assumptions, the momentum computation using trajectories is best suited to intersection type collisions. Accurate determination of the point-of-impact and final rest position of each vehicle seems to provide a reasonable estimate of impact speeds and Delta V as long as rotational effects and secondary impacts are not present. As the collision becomes collinear ( $<10^0$ ), the momentum computation becomes very sensitive to the measurement of the angle between the two velocity vectors. Delta V estimates from CRASH2 are always based on damage information for these collinear collisions. In fact, trajectory measurements are seldom available in the NCSS program, and the Delta V values taken for the side impact study were all based on the damage-only computation.

The damage-only computation is best suited to central impacts (impulse vector acting through the center of mass). The vehicles are assumed to arrive at a common velocity at the end of the crushing phase. For non-central impacts, this common velocity is assumed to occur at the centroid of the damaged area. For side impacts, this assumption would not be met if there was sliding of one vehicle along the other during contact. This sliding might be expected to occur if the angle between the two vehicles was small (as the angle approached a sideswipe configuration).

A uniform force-deflection, or crush resistance, is used for the entire side structure. It might be expected that the side structure would be better modelled in three zones; the front and rear zones which include the wheels and axles would be stiffer, while the center section would be softer. Assuming a uniform stiffness could produce a systematic bias error if impacts to the front or rear side zones were compared with side impacts to the area between the wheels.

An additional consideration arises when the collision forces are not at right angles to the contacted vehicle surface. First, the crush measurements are always taken perpendicular to the undeformed vehicle perimeter. Consequently, the distance the force acted through is not directly measured. Second, the existing data on vehicle structural stiffness is entirely limited to deformations in the normal direction. These considerations make the damage computations less sound as the impact angle becomes more removed from the normal.

Rotational effects are also present when the side impact is not to the passenger compartment. When rotation of the vehicle occurs, the velocity change of an occupant not seated at the center of mass will be different from the computed velocity change of the center of mass. This effect does not seem to be large since occupants are not located more than a foot or two from the center of mass, and the angular velocities for a 10-20 mph Delta V with impact in the front wheel area are on the order of 3 or 4 radians per second. However, it is likely that rotation of the vehicle will alter the occupant contact point for an unrestrained passenger. This may appreciably influence the injury mechanism.

APPENDIX II  
TABLES OF REVIEWED CASES

TABLE 1  
 CASES CLASSIFIED AS COMPARABLE TO LABORATORY TESTS

| CALSPAN<br>Case No. | Delta V<br>MPI(Lateral) | CDC<br>Extent | Occupant<br>Position | Occupant<br>Age | Injuries                                                                                 |                                  |
|---------------------|-------------------------|---------------|----------------------|-----------------|------------------------------------------------------------------------------------------|----------------------------------|
|                     |                         |               |                      |                 | Region                                                                                   | AIS                              |
| 6-7-08-17-042       | 4                       | 2             | Driver               | 44              | Head<br>Neck                                                                             | 1<br>1                           |
| 6-7-09-04-010       | 24                      | 4             | Driver               | 22              | Head<br>Forearm                                                                          | 2<br>3                           |
| 6-7-11-27-078       | 10                      | 3             | Driver               | 58              | Abdomen<br>Head<br>Chest                                                                 | 1<br>Est.1<br>Est.1              |
| 7-7-05-27-048       | 10                      | 3             | RF Pass              | 46              | General. Body<br>tenderness                                                              | Est.1                            |
| 06-7-12-03-012      | 20                      | 4             | RF Pass              | 19              | Bilateral<br>Hip Dislocation                                                             | Est.3                            |
| 2-7-09-26-040       | 6                       | 3             | RR Pass              | 25              | Contusion, ribs<br>Laceration, right ankle<br>Laceration, right knee<br>Laceration, head | Est.1<br>Est.1<br>Est.1<br>Est.1 |
| 7-7-02-01-005       | 15                      | 3             | Driver               | 43              | Severe pain and<br>Contusion l. hip                                                      | Est.2                            |
| 7-7-02-01-005       | 15                      | 3             | Driver               | 48              | Pain to head,<br>Chest & l. side                                                         | Est.2                            |
| 2-7-05-20-021       | 10                      | 4             | Driver               | 59              | Chest(5broken ribs)<br>Knee<br>Head                                                      | 3<br>1<br>1                      |

TABLE 1 (Continued)

| CALSPAN<br>Case No. | Delta V<br>MPH(Lateral) | CDC<br>Extent | Occupant<br>Position | Occupant<br>Age | Injuries                                                         |                |
|---------------------|-------------------------|---------------|----------------------|-----------------|------------------------------------------------------------------|----------------|
|                     |                         |               |                      |                 | Region                                                           | AIS            |
| 6-7-11-07-017       | 12                      | 3             | Driver<br>LR Pass    | Unknown         | Leg bruise(belt)<br>Bruise(forehead)                             | Est.1<br>Est.1 |
| 6-7-02-26-099       | 14                      | 3             | Driver               | 47              | Chest<br>Head                                                    | 3<br>1         |
| 7-7-05-08-009       | 25                      | 3             | Driver               | 24              | Head<br>Pelvis<br>Face                                           | 3<br>2<br>1    |
| 6-8-02-06-006       | 5                       | 3             | Driver               | 16              | Contused<br>Left Hip                                             | 1              |
| 3-7-04-20-015       | 18                      | 4             | RF Pass.             | 17              | Concussion,Cerebral<br>Contusion/Coma 4 days<br>Laceration(face) | 5<br>1         |
| 5-7-09-03-022       | unknown                 | 3             | RF Pass              | 52              | Cervical Sprain<br>Contused right arm                            | 1<br>1         |
| 6-7-03-03-010       | 19                      | 5             | RF Pass              | 7               | Laceration(forehead)<br>Contusion(right ribs)                    | 1<br>1         |
| 6-7-06-23-099       | 10                      | 3             | RF Pass              | 80              | Fractured Pelvis(right.side)                                     | 2 or 3         |
| 5-7-06-04-007       | 14                      | 5             | Driver               | 26              | Concussion<br>Avulsion(scalp)<br>Closed Fracture(tibia&fibula)   | 2<br>1         |
| 6-8-01-11-028       | 5                       | 2             | Driver               | 52              | Bruise(on head)<br>Black Eye<br>Bruised left hip                 | 1<br>1<br>1    |
| 6-8-01-30-084       | 9                       | 4             | Driver               | 35              | 3 Broken Ribs(left)<br>Concussion<br>Laceration                  | 3<br>2<br>1    |

TABLE 1 (Continued)

| CAL SPAN<br>Case No. | Delta V<br>MPH(Lateral) | CDC<br>Extent | Occupant<br>Position | Occupant<br>Age | Injuries                                                                               |       |
|----------------------|-------------------------|---------------|----------------------|-----------------|----------------------------------------------------------------------------------------|-------|
|                      |                         |               |                      |                 | Region                                                                                 | AIS   |
| 1-7-03-18-023        | 12                      | 3             | Driver               | 53              | Disfiguring laceration on<br>left side of head<br>Cut on left ankle                    | 1     |
| 1-7-01-05-012        | 12                      | 4             | Driver               | 23              | Bump concussion left<br>side of head (window)<br>Bruised left hip                      | 1     |
| 1-7-01-03-009        | 4                       | 2             | Driver               | 31              | Acute lumbosacral and<br>cervical strain                                               | 1     |
| 1-7-01-01-008        | 12                      | 3             | Driver               | 23              | Fracture 1 ribs (6-9)<br>Hemopneumothorax<br>Ruptured spleen<br>Liver laceration       | 3     |
| 1-8-03-03-004        | 8                       | 3             | Driver               | 17              | Driver torso contact<br>at upper arm-no injury                                         | 0     |
| 1-8-02-27-042        | 13                      | 3             | Driver               | 25              | L kidney contusion<br>L clavical fracture<br>Bruised L ribs<br>Bruised L shoulder-knee | 2     |
| 3-7-01-09-037        | 57                      | 8             | Driver               | 30              | Massive, All<br>Organ groups                                                           | 6     |
| 2-7-05-07-025        | 14                      | 3             | Driver               | 22              | Surface contusion L thigh<br>Pain, back of neck                                        | Est.1 |
| 1-7-11-23-047        | 24                      | 5             | Driver               | 47              | Crushed between door<br>column & instrument panel                                      | 6     |
| 1-7-04-27-066        | 11                      | 3             | Driver               | 25              | Headache, Pain<br>in shoulder                                                          | Est.1 |
| 6-7-07-14-062        | 9                       | 3             | RF Pas               | 70              | 2 R rib fractures<br>Contusions, R back                                                | 3     |
| 3-7-03-05-026        | 10                      | 3             | Driver               |                 | L forehead cuts<br>Punctured liver, R kidney<br>dam, bruises L side                    |       |
| 1-7-08-08-025        | 19                      | 4             | RF Pas               | 23              | Severe R arm fracture<br>Head contusion & laceration                                   |       |
| 1-7-11-23-048        | 15                      | 3             | Driver               | 37              | Forehead bump, Broken<br>pelvis, Internal injuries, Body cuts                          | 2     |

TABLE 1 (Continued)

| CAL SPAN<br>Case No. | Delta V<br>MPH(Lateral) | CDC<br>Extent | Occupant<br>Position | Occupant<br>Age | Injuries                                                                                  |             |
|----------------------|-------------------------|---------------|----------------------|-----------------|-------------------------------------------------------------------------------------------|-------------|
|                      |                         |               |                      |                 | Region                                                                                    | AIS         |
| 1-7-05-21-030        | 11                      | 3             | F R Pass             | 62              | R. Chest, fractured ribs,<br>face hit ext. object,<br>laceration of R. knee               | 3<br>1<br>1 |
| 1-7-07-04-003        | 24                      | 5             | F R Pass             | 15              | concussion, bruised<br>R thigh, bruised L<br>kidney, chest, R hand                        | 2           |
| 3-7-04-22-016        | 22                      | 4             | Driver               | 16              | Fractured pelvis bilateral.                                                               | 3           |
| 3-7-08-21-033        | 11                      | 2             | Driver               | 61              | Bruised L chest<br>rib pulled from spine                                                  | 2           |
| 3-7-11-19-034        | 23                      | 3             | Driver               | 16              | Fractured neck                                                                            | 6           |
| 4-7-03-07-020        | 12                      | 3             | Driver               | 18              | Unconscious, lac.-left ear,<br>L temple bruise, fractured<br>L tibia, neck pain           | 3<br>2      |
| 4-7-04-03-005        | 07                      | 2             | Driver<br>L Rear     | 16<br>15        | Upper leg fracture<br>Pelvic Fractures                                                    | 2<br>2      |
| 4-7-11-19-037        | 05                      | 2             | Driver               | 64              | Knee bruise                                                                               |             |
| 4-7-11-23-062        | 05                      | 2             | Driver               | 41              | Eye                                                                                       | 1           |
| 5-7-01-15-050        | 12                      | 1             | Driver               | 50              | L eye bruise, hit on<br>L temple, L shoulder<br>bruised L rib-cage pain,<br>R upper thigh | Est.1       |
| 5-7-02-04-007        | 17                      | 3             | Driver               | 17              | Injured neck                                                                              | Est.1       |

TABLE 1 (Continued)

| CALSPAN<br>Case No. | Delta V<br>M <sub>PHI</sub> (Lateral) | CDC<br>Extent | Occupant<br>Position | Occupant<br>Age | Injuries                                                                                                                                |     |
|---------------------|---------------------------------------|---------------|----------------------|-----------------|-----------------------------------------------------------------------------------------------------------------------------------------|-----|
|                     |                                       |               |                      |                 | Region                                                                                                                                  | AIS |
| 5-7-02-12-025       | 15                                    | 3             | Driver               | 27              | Face lacerations<br>abdominal trauma<br>laceration L proximal tibia                                                                     | 1   |
| 5-7-03-07-007       | 09                                    | 3             | Driver               | 33              | Back and shoulder<br>pain, head contusion                                                                                               | 1   |
| 5-7-09-20-051       | 16                                    | 3             | Driver<br>L R Pass   | 17<br>16        | L leg, head concussion,<br>neck, shoulder                                                                                               | 2   |
| 5-7-10-11-046       | 08                                    | 3             | R F Pass             | 22              | No injuries                                                                                                                             | 0   |
| 5-7-12-17-056       | 06                                    | 2             | R F Pass             | 18              | Not injured                                                                                                                             | 0   |
| 6-7-06-02-009       | 11                                    | 3             | Driver               | 16              | Mult. deep lacerations-face,<br>chin, laceration L shoulder<br>tender neck, separation<br>L shoulder joint, L trimal<br>fracture (face) | 3   |
|                     |                                       |               | L R Pass             | 15              | Amnesia disoriented<br>loose tooth, lac. gingiva<br>fractured L mandible,<br>hairline laceration (R)                                    | 2   |
| 6-8-02-22-061       | 35                                    | 4             | R F Pass             | 16              | Neck Fracture                                                                                                                           |     |

TABLE 2  
 CASES NOT CONSIDERED COMPARABLE TO LABORATORY TESTS

| CALSPAN<br>Case No. | Delta V<br>MPH(Lateral) | DBC<br>Extent | Reason For Exclusion           |
|---------------------|-------------------------|---------------|--------------------------------|
| 5-7-03-05-014       | 02                      | 2             | Corner impact                  |
| 5-7-04-21-035       | 05                      | 3             | Corner impact                  |
| 5-7-05-21-050       | 20                      | 4             | Far side occupant              |
| 6-7-02-09-026       | 09                      | 1             | No injuries                    |
| 6-7-03-16-058       | 07                      | 2             | Corner impact                  |
| 6-7-04-16-051       | 11                      | 3             | Corner impact                  |
| 6-7-05-14-044       | 13                      | 3             | Unknown injuries               |
| 6-7-07-01-008       | 11                      | 4             | Corner impact                  |
| 6-7-07-01-009       | 06                      | 2             | Rear corner hit                |
| 6-7-08-11-021       | 10                      | 2             | Corner impact                  |
| 6-7-08-14-026       | 07                      | 3             | Corner impact                  |
| 6-7-12-07-009       | 09                      | 3             | Corner impact                  |
| 6-7-12-23-119       | 02                      | 1             | Corner impact                  |
| 6-8-01-27-075       | 05                      | 1             | Corner impact                  |
| 1-8-03-05-006       | 03                      | 2             | Corner impact                  |
| 2-7-10-12-004       | 00                      | 2             | Unknown injuries               |
| 2-7-12-05-024       | 05                      | 2             | Unknown injuries               |
| 3-7-07-26-074       | 03                      | 2             | Corner impact                  |
| 3-7-08-28-036       | 22                      | 3             | Corner impacts with rotation   |
| 3-7-12-17-007       | 13                      | 4             | Corner impact                  |
| 4-7-05-11-015       | 07                      | 2             | Corner impact                  |
| 4-7-09-10-012       | 05                      | 1             | No injuries                    |
| 4-7-10-25-053       | 10                      | 3             | Ejection-left front wheel well |
| 5-7-01-05-022       | 05                      | 3             | Corner impact                  |

TABLE 2 (Continued)

| CAL SPAN<br>Case No. | Delta V<br>MPH(Lateral) | CDC<br>Extent | Reason For Exclusion            |
|----------------------|-------------------------|---------------|---------------------------------|
| 6-7-06-12-037        | 08                      | 3             | Corner impact                   |
| 6-7-06-05-012        | 19                      | 3             | Corner impact                   |
| 5-7-03-10-027        | 07                      | 2             | Non Horizontal Secondary Impact |
| 7-8-02-08-012        | 14                      | 3             | Non Horizontal Secondary Impact |
| 7-7-12-22-036        | 19                      | 2             | No Injury Formation             |
| 7-7-04-19-019        | 15                      | 3             | Non Horizontal Secondary Impact |
| 6-7-10-23-125        | 12                      | 2             | Non Horizontal Secondary Impact |
| 1-7-12-19-042        | 07                      | 2             | Corner impact                   |
| 1-8-01-12-022        | 07                      | 3             | Corner impact                   |
| 2-7-04-06-028        | 06                      | 2             | Corner impact                   |
| 2-7-05-04-005        |                         | 3             | No injury, front left corner    |
| 2-7-07-19-019        | 08                      | 3             | Corner impact and ejection      |
| 4-7-09-20-031        | 04                      | 1             | Not a case Vehicle              |
| 4-7-12-17-021        | 05                      | 3             | Rear Impact                     |
| 4-7-12-19-025        | 06                      | 2             | Corner impact                   |
| 4-8-02-17-024        | 02                      | 1             | Corner impact                   |

