D. F. Mela. (1974). NHTSA's Evaluation of Air Cushion Restraint System Effectiveness (ACRS). Washington, DC: National Highway Traffic Safety Administration.

# NHTSA'S EVALUATION OF AIR CUSHION RESTRAINT SYSTEM EFFECTIVENESS (ACRS)

Reported by

Donald F. Mela

# Table of Contents

## INTRODUCTION

The General Motors Air Cushion Restraint System (ACRS), popularly known as the "air bag," is being installed in several thousand 1974 U.S. General Motors passenger car production models.

There is intense interest in the performance of this passive restraint system because the occupant passive restraint safety standard* is presently scheduled to take effect in two years (September 1976). Therefore, the evaluation of the ACRS effectiveness is a high-priority program for NHTSA. Let me describe how NHTSA is carrying out the evaluation.

The material in the paper developed by a task group of members of NHTSA's Office of Statistics and Analysis (formerly Office of Accident Investigation and Data Analysis). William E. Scott, C. J. Kahane, John Keryeski and Scott Lee were the principal contributors, and should be given credit for the work that is described here.

General Motors Corporation in 1973 announced its aim to produce and sell 50,000 full-size ACRS-equipped cars in the 1974 model-year, and 100,000 1975 model cars. The introduction of these cars began about January 1, 1974. Subsequently, there

*Standard 208

has been a drastic reduction in the expected rate of introduction of ACRS vehicles. It now appears (May 1974) that the number of ACRS cars on the road in the United States by the end of 1974 will not exceed 8,000 cars. So the original NHTSA estimates of crash data availability have also had to be reduced.

OBJECTIVES

The basic objectives of the evaluation program are:

1. Assess the injury-reducing effect of ACRS;
2. Determine operational characteristics of the ACRS, and
3. Evaluate public/owner acceptance.

This discussion will be concerned mainly with the first objective, but objectives two and three will also be discussed briefly. As noted above, the drastic reduction that has occurred in the rate of introduction of ACRS vehicles has made it necessary to replan. However, much of the general approach and many of the specifics will either be preserved or will be utilized at a later date, when more ACRS vehicles are on the road. Therefore, it is felt that the information should be of interest to participants in this Conference, particularly since it affords the opportunity to comment and to influence the later conduct of the evaluation.

GENERAL CONSIDERATIONS

Based upon the expected sales rate, it had been estimated that there would be about 12,000 ACRS vehicles in crashes by the end of August 1975. This includes all accident types from minor to total demolishment. It also includes crashes in which the ACRS is not deployed (ACRS is designed only to deploy in impacts with a significant frontal component). Of these 12,000 crashes, about 4,000 would damage the vehicle severely enough to require towaway and 1,300 crashes would result in some injury. Table 1 provides a further classification, according to severity level of the injury.

The estimates in Table 3 were developed from previous accident experience for vehicles similar to the ones expected on the road. The injury frequencies presented would be expected if all occupants in the control group were unrestrained. The observed frequencies of injuries in ACRS crashes should be much lower.

To compare the ACRS with active restraint systems such as safety belt systems, we ask two general questions:

1. Is the overall safety performance of the ACRS better than that of cars equipped with devices such as the ignition interlock or buzzer supplements to safety belt systems?
2. How do vehicle occupant injury rates compare for persons involved in crashes who are protected by

a. ACRS,

b. Three-point belt,

c. Lap belt,

or

d. with no restraints.

This identifies several groups for comparisons with the ACRS fleet.

1. Interlock Fleet - 1974 and 1975 model years,
2. Buzzer Fleet - 1972 and 1973 model year cars,
3. Car occupants wearing lap and shoulder belts, 1968 and later model years,
4. Car occupants wearing lap belts,

   and

5. Unrestrained occupants.

Since the ACRS will be in full-size 1974-75 Cadillacs, Buicks and Oldsmobiles, these control groups should be restricted to cars of the same size and body construction, viz. full-size 1973-75 Cadillacs, Buicks, Oldsmobiles, Pontiacs and Chevrolets.

<u>Rationale for Objective #1</u>

Ideally, it would be best to compare injury performance of the ACRS and control group for the "same" exposure or accidents. There are two well-established approaches to the ideal of "sameness" that is unattainable in real-life:

1. Assume that, overall, ACRS and control-group cars have similar exposure or accident experience and

that any difference in gross injury rates is attributable to the restraint system alone,

and

2. Use some criteria to stratify the exposure units or accidents into sub-groups. The stratification is of a sort that corresponding sub-groups may be compared using approach (1). A statistical method is employed to aggregate the comparison of the sub-groups into a net comparison of ACRS and control group.

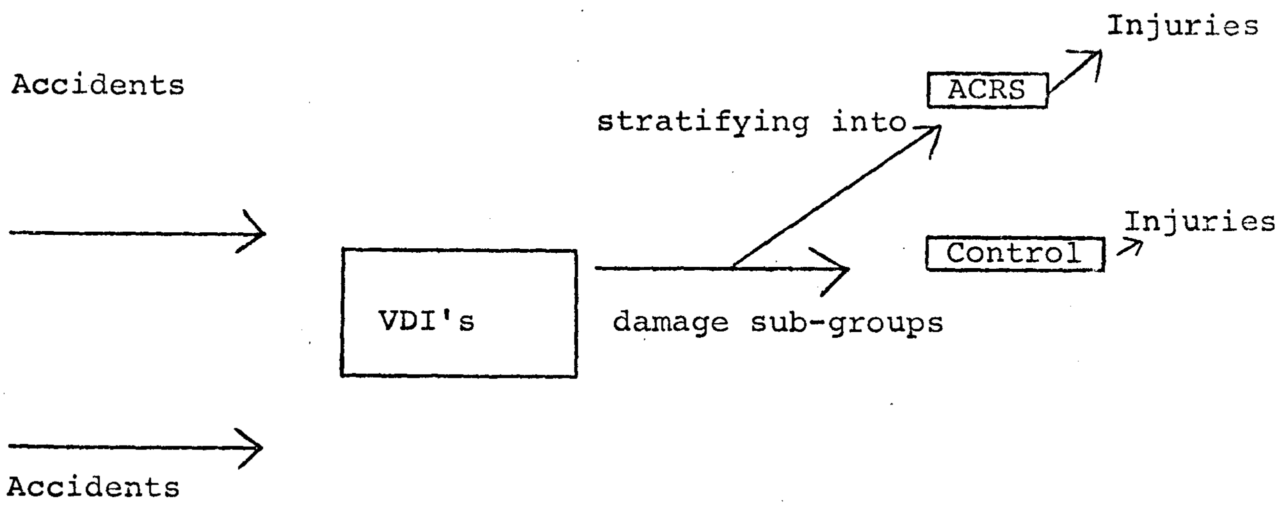
Approach (1) is rejected because there is no evidence to support its underlying assumption. ACRS-car owners may well be highly unrepresentative of the automobile population with regard to both exposure and accident experience. In fact, some have conjectured that ACRS buyers would be extremely safety-conscious, while others felt they would be reckless drivers eager to evade the interlock system.

Therefore, Approach (2) was selected. However, the use of "exposure units" had to be rejected. At this time, there is no widely recognized method for stratifying the exposure units - e.g., sub-dividing the miles driven into "dangerous" and "non-dangerous" categories - making it impossible to use fleet exposure as a basis for stratifying until such theory is developed.

On the other hand, there are four well-established means for stratifying accidents into severity classes: accident descriptors used by the police, such as "pre-impact speed"; economic descriptors such as "dollar damage"; damage descriptors that can be measured by looking at post-crash photographs, such as "inches of crush"; and highly sophisticated engineering descriptors such as "velocity-vector change during impact." Accident and economic descriptors are highly inadequate because past experience showed them to be poorly correlated with real accident severity, subject to large errors of measurement, and subject to different methods of measurement in different States (an important consideration since the sparse ACRS data will require collection in more than one State). Furthermore, dollar damage has year-to-year inconsistencies due to secular economic trends. The engineering descriptors were considered the best measures of accident severity, but these were rejected for three reasons: (1) some of the descriptors, such as "vehicle aggressiveness" have not yet been adequately defined, (2) the methods for measuring them (either crash recorders or the Calspan computerized accident reconstruction program) would not be available in time, and (3) these methods are exceedingly expensive. However, there is a damage descriptor presently being used on an international basis. This is the Vehicle Deformation Index (VDI) and is described in the SAE recommended practice J224a (Reference 4). <u>With vehicles that are of essentially the same body style and</u>

with similar crashworthiness characteristics, the VDI is considered to give a good comparative measure of the magnitude of impact forces sustained by a vehicle. The VDI's may be readily and inexpensively calculated by looking at photographs of the damaged vehicle. Hence it was decided to collect photographs and construct VDI's. Nevertheless, the option was left open to extending the data collection later to obtain engineering descriptors, just in case the VDI's failed to come up to expectations, or in case there were unforseen advances in the theory and measurement of engineering descriptors.

An examination of the inputs, therefore, determined the following analytic approach:




Finally, the expected data on injury production were examined. Usually "injury severity" is coded for each <u>occupant</u> of the vehicle, but it can also be construed as a vehicle characteristic by using some composite measure, such as "worst injury in vehicle." The latter approach was rejected because, for example, if the control group consists of occupants wearing "lap belts," then "worst injury in vehicle" cannot be fairly defined for a vehicle in which some occupants used belts and others did not. Thus, injuries per occupant were considered, but here again there were several possibilities: occupant injuries could be stratified according to seated position, or seated position could be ignored. For this study, a middle course was taken. Since the ACRS will have no influence whatever on back-seat occupants, only front-seat occupants would be studied. Moreover, further stratification would dilute the statistical significance of the sparse ACRS data. Hence, a restriction of output "injury production" to "injuries to front-seat occupants" was effected.

The ACRS system is not expected to totally eliminate all injuries, but rather to lower their severity. It is, therefore, imperative that the measure of injury production be not a "yes-no" tally, but a severity scale.

The doctor-reported Abbreviated Injury Scale (AIS) defines severity levels in precise medical terms that are fairly consistently interpreted nationwide and properly distinguish intermediate levels of injury. Therefore, it was decided to obtain a medical report on each injured front-seat occupant, and to compare ACRS and control-group injury production at each severity level from minor through fatal, but with special interest in the intermediate levels.

Following the decision to obtain injury rates at each level of severity, analytic methods for comparing the respective rates of ACRS and Control Groups were considered. The primary question addressed was whether the statistical comparison should be a qualitative or quantitative statement. (A qualitative statement takes the form, "Front-seat occupants of ACRS cars had a significantly lower severe-injury rate than unrestrained occupants;" a quantitative example would be "front-seat occupants of ACRS cars had a 25 $\pm$ 5 percent lower severe-injury rate than unrestrained occupants.") The qualitative statements are second-best for a cogent reason: when comparisons are made between the ACRS and belts, it is expected that the ACRS may perform better with regard to severe injuries and worse on less severe injuries.* This is expected because the bag, if it deploys, should be superior to the belt, but there will be many less severe injuries in crashes where the bag was not designed to deploy. Therefore, unless it is determined how much better and how much worse (after attaching some dollar-cost to each type of injury), it will be impossible to decide which restraint system is superior. (See Tables 2 and 3 for examples of quantitative results).

*Unbelted occupants of ACRS cars may suffer minor injuries in crashes below the deployment speed.

Three acceptable statistical methods for comparing injury rates for a population stratified by damage severity were considered:

1. Stratify the ACRS and control-group front-seat occupants into four or five classes according to the VDI extent and impact direction of the crash involved vehicle. Compare injury rates for corresponding strata. Take an appropriate weighted average over the strata to estimate net injury reduction.
2. For each front-seat occupant of an ACRS car, search the file of control-group cases and find the one which best matches the ACRS car with regard to numerous vehicle damage descriptors and other characteristics. Obtain two groups of vehicles of equal size who are so "similar" that any significant difference in gross injury rate of occupants is entirely attributable to the different restraint systems.
3. For each front-seat occupant of an ACRS car, search the file of control-group cases and find about 20 that closely match the ACRS car. Compare the ACRS occupant's injuries to the median injury or to other percentiles of the corresponding 20 or, perhaps, do a Ridit analysis (Reference 3). Some of the ACRS occupants will fare better than the median, some the same, and

some worse. An appropriate non-parametric test can be applied to the list of comparisons to determine which system, if any, is significantly better.

Only Methods (1) and (2) give adequate quantitative comparisons. Method (1) is preferred because it requires fewer and less detailed data than for (2) to attain a given level of precision.

In the contingency that the ACRS fleet is much smaller than expected (which now appears to be the case) Method (1) will not yield statistically significant quantitative comparisons. This is precisely where Method (3) is best. That is, when the test group is small and the control group large.

Hence, if things were still to go as originally planned Method (1) would be used to obtain quantitative results, but due to the apparent reduced ACRS fleet contingency, Method (3) will probably be used for qualitative results.

Most of the conceptual model was constructed simply by carefully examining the objectives. Figure 2 displays the model constructed. The details of the operational plans were not described in the rationale presented in the preceding pages. These include:

1. Details of notification, sampling, data collection, and analysis chosen to respond to objectives #2 and #3 (e.g., the collecting of more detailed data on injuries in deployment accidents).

2. Sampling techniques used to optimize statistical efficiency - i.e., maximize statistical precision per data-gathering dollar (e.g., use of stratified rather than simple random sampling).
3. Real-world constraints that force the collection of extraneous data or prevent the collecting of data.

Rationale for Objective #2

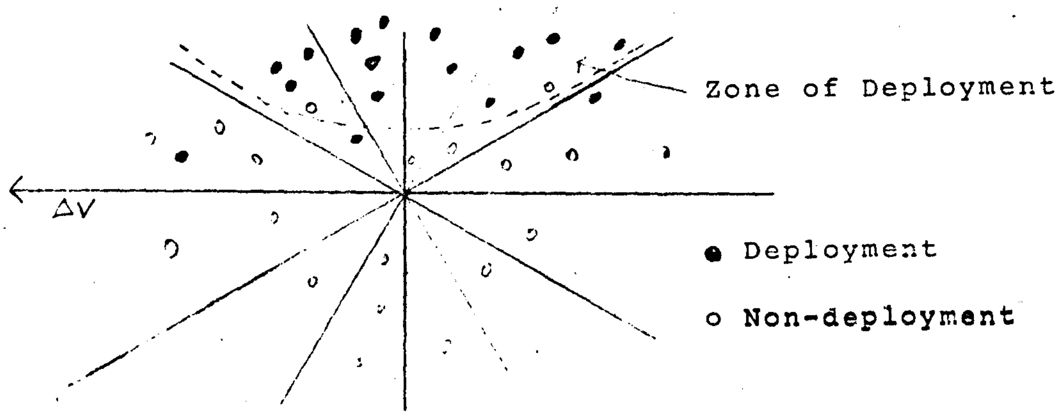
(Evaluate the performance of the ACRS in those accident events for which protection was designed.)

The first point which must be clarified is the definition of "Operational Characteristics." This is taken to include the following:

1. The types of crashes which deploy the ACRS.
2. The types of injuries that result from ACRS deployment, and
3. The tendency of the ACRS to deploy inadvertently.

The types of crashes which deploy the ACRS:

What one would ideally want would be a polar plot as shown where

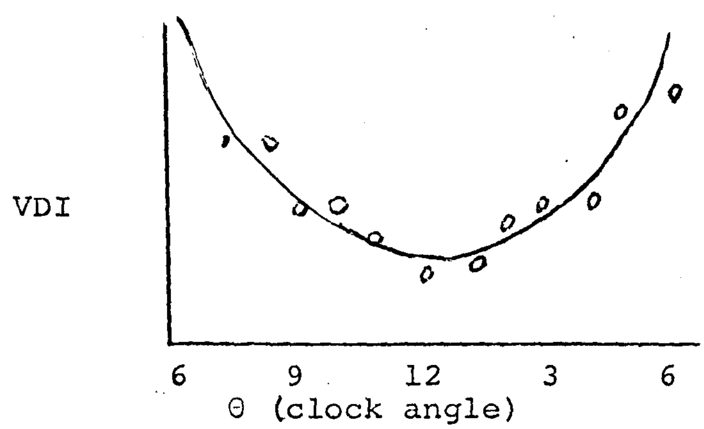


the principal direction of force ($\Theta$) and the change in velocity of the vehicle during impact ($\Delta V$) would be plotted for accidents in which the bag both did and did not deploy. The "zone of deployment" would thus characterize those accidents which result in ACRS deployment.

To construct such a plot one would need detailed information concerning a significant number of accidents: "detailed" means either crash recorders on the vehicles or a computerized accident reconstruction program used together with an investigating team to estimate $\Delta V$'s and directions of force from physical evidence at the scene. This degree of data-taking cannot be done on every accident and hence no true engineering description of the "zone of deployment" can be obtained.

An inferior but perhaps useful description of the type of accidents that result in ACRS deployment, is a graph of mean or median VDI's and principal direction of force, such as shown in Figure 3.

FIGURE 3

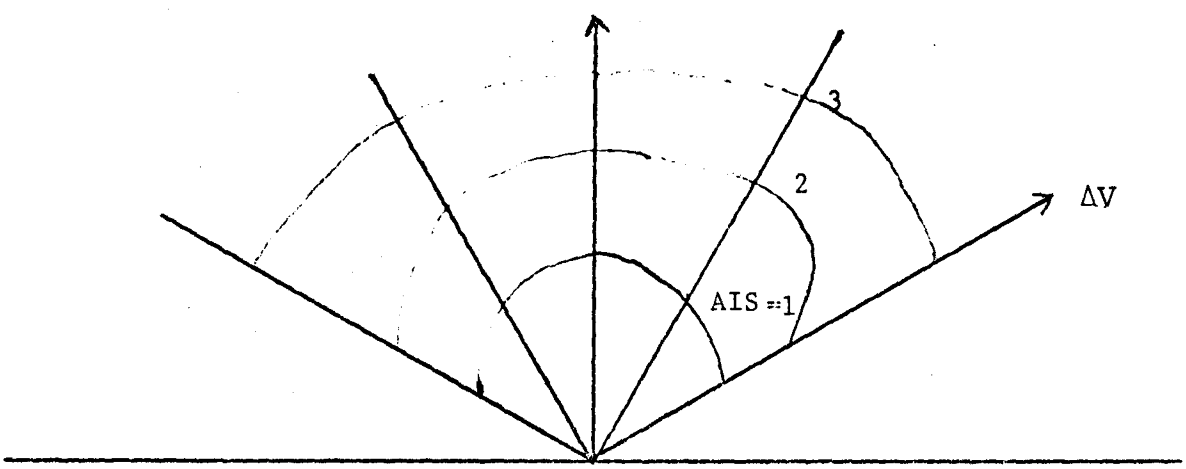


One would not expect the correlation of deployment with the VDI to be as strong as with ΔV. Both of these data reductions require data on crashes where the bag did not deploy. So it is necessary for NHTSA to investigate a representative sample of ACRS non-deployments.

A third option is merely to summarize those VDI's and Θ's where ACRS deployment occurred. This could be misleading since we could not say whether accidents outside this range would have caused deployment. However, the data might be useful to point out some unexpected deployment modes (e.g., side impacts). This could be done, of course, using the data from the hundreds of deployments that will be investigated.

The types of injuries that result from crashes where the ACRS deploys:

Again the ideal is a polar plot showing injury levels (AIS) as a function of ΔV and Θ using only deployment data, for example, as shown below:



However $\Delta V$'s will not be obtained, so we must depend upon the next best indicator of crash severity, VDI, and consider plots like the ones in Figures 4 and 5.

Again, one would not expect the correlation of injury level with VDI to be as strong as with $\Delta V$.

It is expected that among 460 random deployments there would be at most 240 injuries (.52 x 460), of which only about 80 (.175 x 460) will be moderate or worse, 32 severe or worse, 17 life-threatening or fatal, and 8 fatals. Obviously then, construction the low-injury level contours should be possible (with up to 100 data points). The moderate injury contours (with up to 20-25 data points) might be possible. Clearly, insufficient data will preclude constructing the higher injury severity contours. This justifies additional investigations of accidents with severe and worse injuries.

So far only the severities of the injuries where deployment occurs has been discussed. Certainly we also would like to know about the nature and mechanism of the injuries.

Lower limb injuries at all levels of accident severity and perhaps some neck injuries in otherwise fatal level crashes can be expected. Fatal injuries will probably be due to ejection, or severe underride/override frontals. Table 2 exemplifies a tabulation summarizing these injuries.

The tendency of the ACRS to deploy inadvertently:

What is desired is the inadvertent firings per vehicle mile. It is probable that NHTSA will know of inadvertent firings. It will require more effort to determine the total vehicle mileage accumulated at any point in time. Estimates will probably have to be made based on owner surveys and odometer readings.

Rationale for Objective #3

To evaluate owner/public acceptance we must determine how the general population of new car buyers will react when they purchase a new car equipped with an ACRS.

The method to achieve this would require owner surveys to determine the reaction to the General Motors ACRS. There are problems with this approach in that those people who will purchase the GM luxury class vehicles with the relatively expensive ACRS option are likely not representative of the new car buyer population. For the purpose of this survey, this and other similar potential biases must be regarded as setting upper bounds for favorable reaction. It is simply anticipated that the biases are not significant and that this group of purchasers will be similar to that of the general population of new car buyers. There would be less concern if the ACRS option was available to all potential new car buyers.

The owner survey function is planned to be carried out under contract. The following indicates the type of information that can be obtained.

DATA TO BE OBTAINED FROM OWNER

A. DEMOGRAPHIC INFORMATION

AGE
SEX
OCCUPATION
EDUCATION

B. VEHICLE DATA

MODEL
AIR BAG
AIR BAG WITH LAP BELT
DATE OF PURCHASE

C. USE OF VEHICLE

WORK
PLEASURE
OTHER
ANNUAL MILEAGE (DRIVEN BY RESPONDANT)
MILEAGE AT TIME QUESTIONNAIRE IS ANSWERED

D. RESTRAINT SYSTEM (PREVIOUSLY OWNED/DRIVEN CAR)

YEAR & MODEL OF PREVIOUS CAR
USE OF LAP & SHOULDER BELTS IN THIS CAR
IF 72-73 CAR, WAS WARNING SYSTEM DEFEATED OR CIRCUMVENTED

E. RESTRAINT SYSTEM (AIR BAG CAR)

HOW LEARNED OF AIR BAG OPTION
WHY CHOSE AIR BAG CAR
UNDERSTANDING OF SYSTEM OPERATION
WHY OR WHY NOT CHOSE ADDITIONAL LAP BELT
USE OF LAP BELT
REASON FOR SUE OR NON-USE OF LAP BELT
MODIFICATION OR TAMPERING WITH SYSTEM(S)
SATISFACTION/SECURITY DERIVED FROM SYSTEM & BASIS FOR SUCH
REACTION TO SYSTEM BY FRIENDS, RELATIVES ETC. WHEN THEY ARE DRIVEN IN CAR

F. RESTRAINT SYSTEM DEFECTS (AIR BAG CAR)

NATURE OF DEFECT
HOW IT WAS DISCOVERED
WAS IT REPAIRED, BY WHOM, COST

G. ACCIDENT INVOLVEMENT

HAS ACRS VEHICLE BEEN INVOLVED IN AN ACCIDENT
DID AIR BAGS DEPLOY
WAS ANYONE IN ACRS VEHICLE INJURED
NO TREATMENT REQUIRED, TREATED AND RELEASED, HOSPITALIZED
MAJOR DAMAGE WAS SUSTAINED TO THE FRONT, REAR, OR SIDES
WAS VEHICLE TOWED FROM THE SCENE
REPAIR COST

## ANALYSIS OF THE DATA

### Objective #1. Injury Reduction

From general considerations, it was concluded that the best course of action was to collect ACRS crash data; to obtain or collect control-group crash data; to stratify each data set into four classes according to vehicle damage; to estimate, for various AIS injury levels, the injury rates for front-seat occupants in test and control groups, for each stratum; to estimate the "true" sizes of each stratum for the "total" vehicle population; to obtain the net injury rates by taking the averages weighted by the "true" sizes of the strata; and to give some confidence range on the percentage injury reduction (or increase) due to ACRS with respect to the other restraint system.

For each crash, the Vehicle Damage Index (VDI), including "damage extent" (measured on a 0-9 scale) and "direction of impact" (measured by "clock direction") will need to be obtained. Also required for each injured front-seat occupant will be a medical report, including the overall injury severity as measured using the Abbreviated Injury Scale (AIS).

Data of these kinds must be collected by technicians, who, in turn, must be notified by the police that an accident has occurred. A realistic notification threshold is that either the car had to be towed from the scene or that an occupant had a disabling injury. Non-injury, non-towaway accidents are more elusive.

Table 5 gives the nationwide totals for the 20-month time-frame from January 1, 1974, to August 31, 1975, for towaway-involved, front-seat occupants of ACRS cars, and for front-seat occupants of the 1973-1975 full-sized GM cars equipped with other restraint systems. It also gives the number of injuries more severe than or equal to a given AIS level, that would be expected if none of the restraint systems were effective.

The reader who has some experience in statistical hypothesis-testing will quickly note that nearly the entire national ACRS occupant population would be needed to detect significant injury reduction at the life-threatening or fatal levels. Each of the control groups, on the other hand, is much larger and need only be sampled.

The four damage strata into which the towaway crashes are likely to be subdivided are defined as follows:

1. Major Frontal Impacts: VDI$\geq$ 3 and 11:00 - 1:00; or VDI$\geq$ 4 and 9:00 - 3:00; or VDI$\geq$ 4 and rollover.
2. Non-Major Frontal Impacts: VDI$\leq$ 2 and 11:00 - 1:00.
3. Non-major Side Impacts and Rollovers: VDI$\leq$ 3 and 9:00 - 3:00; or VDI$\leq$ 3 and rollover.

4. Rear-end Impacts: All towaways with 4:00 o'clock - 8:00 o'clock angles of impact.

It is anticipated that within each stratum, the ACRS and control groups will be closely matched with regard to accident severity.

The strata were defined this way because it is expected that nearly all of the (non-inadvertent) deployments will be concentrated in one stratum. Essentially, the ACRS occupants are "unrestrained" outside Stratum 1 (or, at worst, Strata 1 and 2). Hence, outside these strata, we may replace or supplement the sparse ACRS-group data with more easily obtained "unrestrained" data. Further, the other strata would, as a result, contribute no variance when comparing with unrestrained. As a result, the precision of our estimates would greatly increase.

Furthermore, this method is, in a sense, self-checking. VDI's were justified in the foregoing rationale because they were believed to be a good surrogate for engineering descriptors of crash severity for vehicles of similar makes and models. Since the sensor threshold is defined in terms of an engineering descriptor (velocity vector change during impact), most deployments will be in Stratum 1 if and only if this rationale is correct.

The following discussions gives the formulas to be used to give net injury rates. A definitive measure of the precision of these rates for various sample sizes is under development.

Let t be the total number of front seat occupants of ACRS towaways in the data collection. Let $t_1, \ldots, t_4$ be the number of occupants in each stratum.

Let $t', t'_1, \ldots, t'_4$ be the corresponding numbers of unrestrained occupants in the various control groups.

Let $t'', t''_1, \ldots, t''_4$ be the lap-shoulder belted and $t'''$, $t_1'''$, ..., $t_4'''$ be the lap-belted.

Let $T = t + t' + t'' + t'''$ be the total number of front-seat occupants in all of the data.

Let $T_i = t_i + t'_i + t''_i + t'''_i$ be the totals for the ith stratum. $T_i/T$ will be used to give an estimate of the "true" size of the ith stratum.

Let $x_i$ be the number of occupants of ACRS cars who are in the ith stratum and who sustained injuries of at least some specified AIS (e.g., the number with severe or worse injuries). Let $x'_i$, $x''_i$, $x'''_i$ be corresponding numbers for control groups.

Then $x_i/t$ is the sample estimate of the injury rate for the ith stratum of ACRS occupants and $x'_i/t'_i$ is the estimated rate for unrestrained occupants.

The net rate for injuries at some AIS level to ACRS occupants in towaways is estimated by $R = \frac{x_1}{t_1} \cdot \frac{T_1}{T} + \ldots \frac{x_4}{t_4} \cdot \frac{T_4}{T}$

The estimated net rate for injuries to unrestrained front seat occupants is given by $R' = \frac{x'_1}{t'_1} \frac{T_i}{T} + \ldots + \frac{x'_4}{t'_4} \frac{T_4}{T}$

If the assumption is correct that most of the deployments fall in Stratum 1, R may be replaced by R. Then:

$$\tilde{R} = \frac{x_1}{t_1} \frac{T_i}{T} + \frac{x'_2}{t'_2} \frac{T_2}{T} + \frac{x'_3}{t'_3} \frac{T_3}{T} + \frac{x'_4}{t'_4} \frac{T_4}{T}$$

Now, $\tilde{R}$ and R' have a large covariance, and this will improve the precision of $\frac{R' - \tilde{R}}{R'}$, i.e., the estimate for the net injury reduction due to ACRS.

Improved Sampling Plan

There appears to be a method for greatly improving statistical efficiency - i.e., getting the same degree of precision with a much smaller number of investigations. In the first approach collection of many thousands of non-injury towaways is only for the purpose of seeing which stratum they were in - i.e., finding $t_1, \ldots, t_4$; $t'_1, \ldots, t'_4$; etc. This is wasteful of data. In fact, after looking at a random sample of only 25-50% of the non-injury towaways in ACRS and each control group one may estimate with great precision the distribution of the remaining non-injury towaways among the 4 injury causing strata. Hence, one need only keep a tally of all non-injury towaways and extrapolate their distribution among the strata from the small sample. The disabling injuries, of which there are few, already have to be investigated to find the AIS. It is necessary also to collect VDI's for all of them; there are not enough of them so that they can be precisely distributed among the strata on the basis of a less than 100% sample.

The more efficient sampling plan, then, consists of:

1. Keeping a tally of all towaway crash involved front-seat occupants in ACRS and control groups, and collecting police accident reports.
2. Get the AIS and the vehicle VDI for all occupants for whom the police report stated that they were taken to a hospital - this will include most AIS>2 injured.
3. Get the VDI's for a random sample of crashed vehicles for which no occupants required treatment. The appropriate sample sizes are now being determined by NHTSA.

As in the first approach, the net injury rates R and R' are calculated and $\frac{R' - \tilde{R}}{R'}$ is estimated. The only difference is that $t_i$, $t_i'$, and $T_i$ are algebraically calculated from a smaller sample, and are subject to more variance than before. Sample sizes will be chosen to optimize the balance of the variance of the t's against the variance of the x's.

The control groups can be obtained by using existing data that classifies VDI and AIS, or by collecting new data. Each control group should be somewhat larger than the ACRS group. In order to obtain the precision desired, we need an ignition interlock crash involvement that will produce 7,500 towaways in the 20-month study period and a 1973 vehicle crash involvement which will have a like number. Fleets of that size will also give us slightly more lap/shoulder belted front seat occupants than ACRS occupants, and twice as many unrestrained occupants as in ACRS vehicles. As indicated in the rationale for Objective #1, these cars should be of the same makes and models as the ACRS cars, i.e., they should be full-sized GM cars, preferably Buicks, Oldsmobiles, and Cadillacs.

Neither Calspan intermediate level data nor the Multidisciplinary Accident Investigation files which are available have anywhere near the sufficient number of crashes.

Motors Insurance Corporation file, which is at this time proprietary to GM, is unusable because of missing data. The VDI's are not coded for non-injury accidents, so it is impossible to determine which of the damage strata they belong to.

Therefore, it will be necessary for NHTSA to collect the needed control group data.

The control group must obviously be collected in some pre-defined areas of the country where either NHTSA or MVMA* accident investigation teams are presently located and where all moderate to fatal injury producing crashes in those regions could be investigated. A systematic sample of the "minor" and "no injury" towaways would also be collected. As for the ACRS group, every moderate to fatal ACRS injury in the country needs to be collected because of the smallness of the population. With regard to the "minor" to "no injury" ACRS towaway crashes, there are two approaches to collecting the sample towaways not involving occupant brought to a medical facility:

1. Collect every ACRS towaway in areas where control group data is collected,** and
2. Collect the towaways across the nation by a systematic sampling procedure.

*Motor Vehicle Manufacturers Association

**Currently, and until more ACRS cars are on the roads, all possible ACRS towaways are being investigated.

Approach #1 appears to involve less travel and thus to be less costly, but it is fraught with difficulties:

a. It presumes that teams must cover areas large enough to contain the required sample of ACRS towaways.

b. The distribution of accidents among the damage strata in the areas may be unrepresentative of the nation. The only clue as to whether they are representative is to compare the percentage of the area towaways resulting in deployment to the national percentage. This clue is worthless if the assumption were incorrect that the deployment population closely resembles Stratum 1 (major frontals). Therefore, Approach (2) is highly recommended.

## DATA COLLECTION

Two distinct data collection systems are employed to cover both ACRS equipped vehicles involved in crashes and control group crashes. ACRS data are collected nationally by Multidisciplinary Accident Investigation Teams (MDAI) operating in five regions around the country. Control group crashes are also investigated by the five MDAI teams but in selected counties in each of the team regions.

Notification of the occurrence of a crash involving an ACRS equipped vehicle and the initiation of an investigation is based on a 24-hour-per-day, 7-days-a-week operation of a National Response Center (NRC) located at DOT Headquarters in Washington, D.C. The control group sampling system depends heavily upon the liaison that has already been established between the MDAI teams and the police agencies in their counties for notification of crashes involving acceptable control group vehicles.

Through the help of the NHTSA regional administrators and the respective governors' highway safety representatives in their regions, it is expected the ACRS evaluation program will receive wide publicity and cooperation. In addition, an explanatory letter containing the NRC toll free telephone number 800/424-8802 was mailed out to all police jurisdictions having a population of 15,000 or greater requesting that the

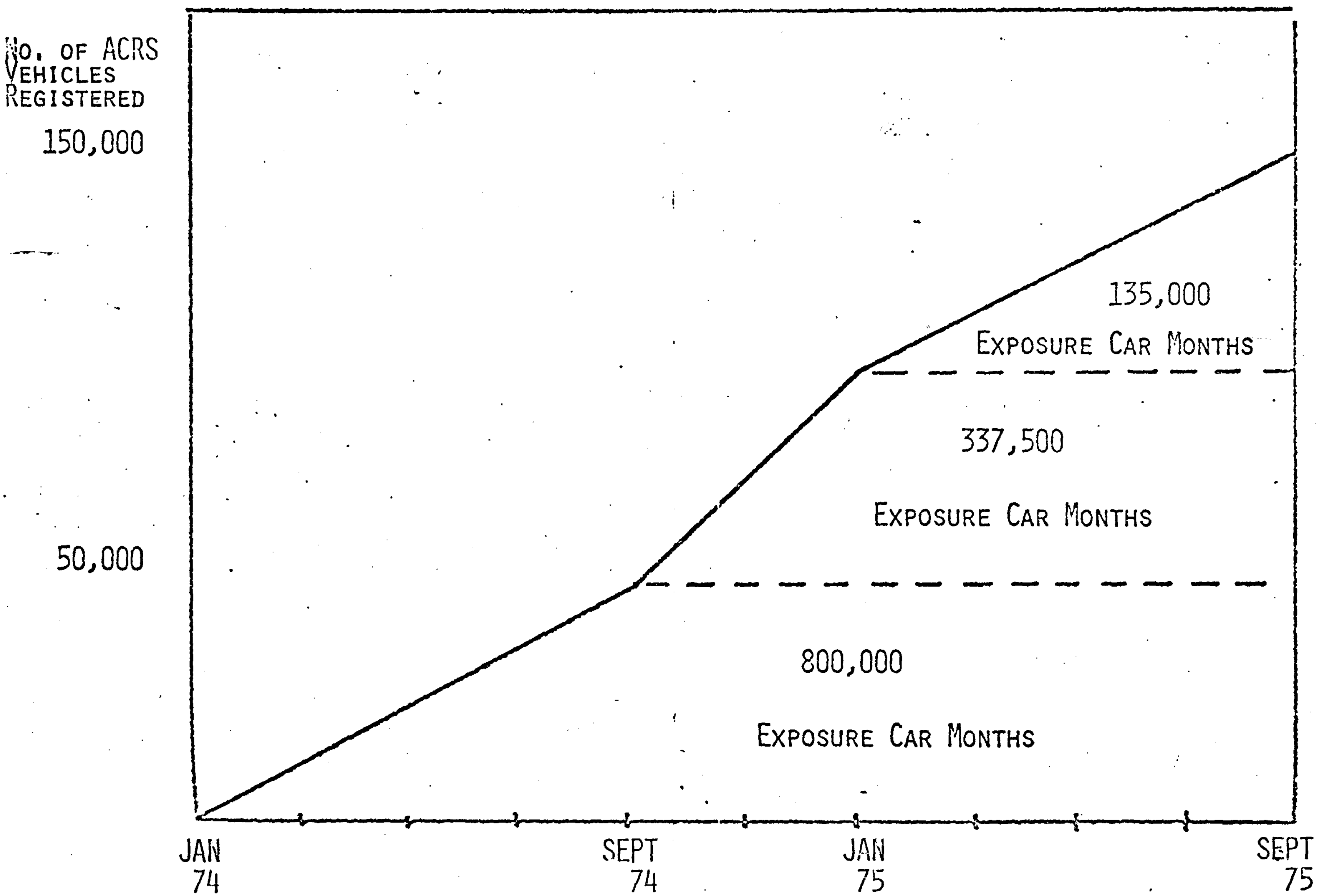
NRC be notified of all traffic crashes in their area involving an ACRS equipped vehicle. General Motors has also requested owners and dealers to provide information. Once the NRC has been contacted, a member of the NHTSA's Accident Investigation staff makes the decision as to what depth the accident will be investigated. The level of investigation is determined by accident severity, whether it involved towing the vehicle from scene or not as well as injury severity based on the Abbreviated Injury Scale (AIS) developed under the auspices of the American Medical Association.

In the case of crashes involving a 1973-1975 GM full size car (control group) the procedure is basically the same except the NRC is not notified. Notification and response are accomplished at the regional level. Local and State police operating in the selected counties will notify the team whenever a crash involving a vehicle meeting control group criteria occurs. If preliminary information provided to the MDAI team indicates that an occupant was taken to a treatment facility, a technician is dispatched to carry out an intermediate level type of investigation. Intermediate level investigations provide police and medical reports plus photographs of the vehicle to provide for developing a VDI.

When the crash did not require an occupant to be transported to a treatment facility, the MDAI staff will apply the systematic sampling procedure specified by NHTSA. If the procedure selects the crash, an intermediate level investigation will be made.

The sampling fractions will be determined by the optimization procedure mentioned in "Analysis of the Data." There will probably be different fractions for buzzer and for ignition interlock cars.

Figure 1 ORIGINAL SCHEDULE FOR PLANNING ACCIDENT INVESTIGATIONS (BASIS FOR TABLE 1.)



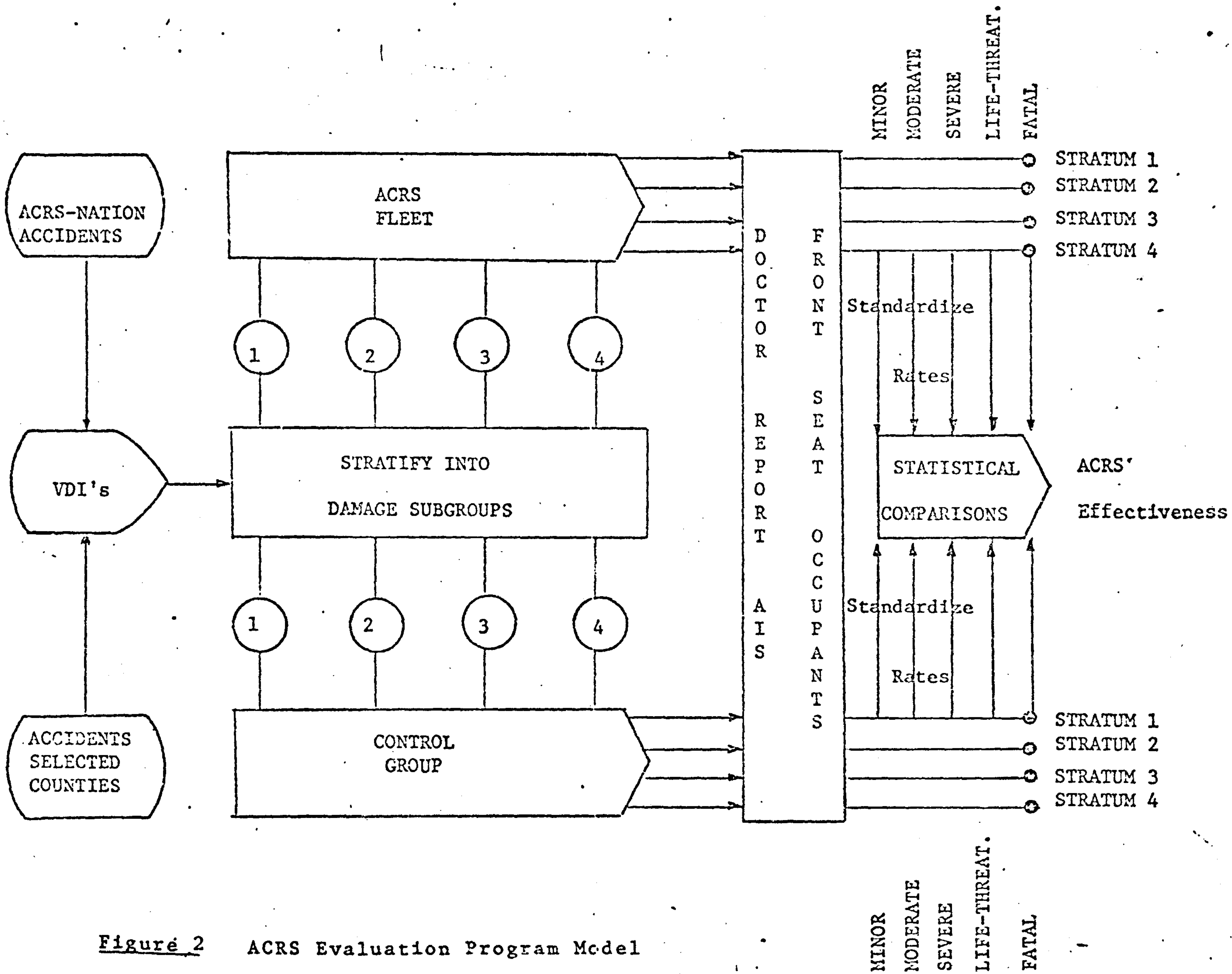



Figure 2 ACRS Evaluation Program Model

FIGURE 4

# INJURY RATES & ACCIDENT SEVERITY

## FOR A FIXED DIRECTION OF IMPACT

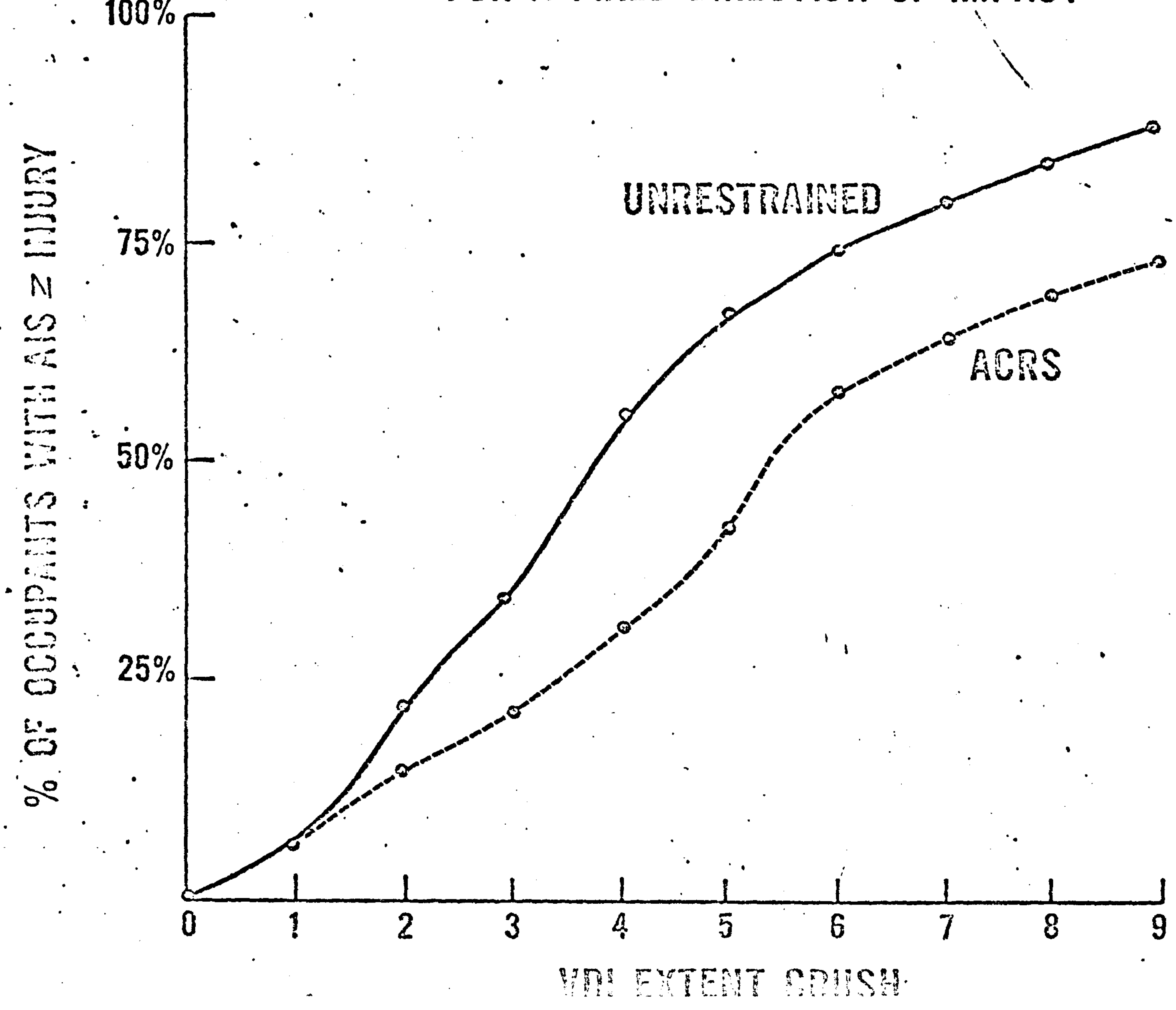
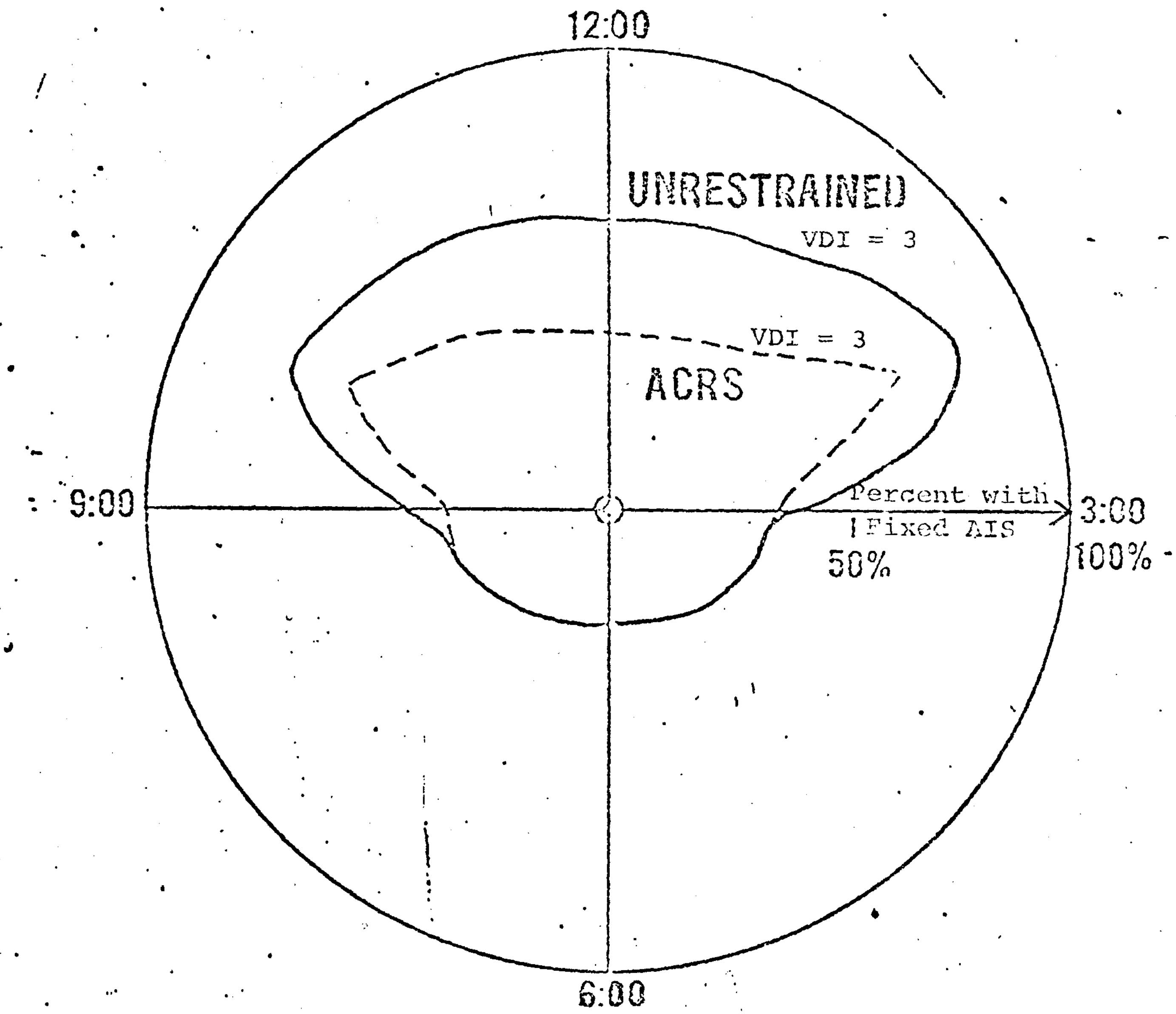


FIGURE 5

INJURY RATES & ACCIDENT SEVERITY

FOR A FIXED EXTENT OF CRUSH




O'CLOCK DIRECTION OF IMPACT

TABLE 1.

## PREDICTED ACRS CRASH EXPERIENCE (PREDICTED IN DECEMBER 1973)

| VEHICLES/EVENTS | LEVEL OF INVOLVEMENT |
|---|---|
| 12,000 | ALL POLICE REPORTED ACCIDENTS |
| 4,000 | TOWAWAYS |
| 1,300 | TOWAWAYS WITH MINOR OR GREATER INJURY |
| 360 | TOWAWAYS WITH MODERATE OR GREATER INJURY |
| 120 | TOWAWAYS WITH SEVERE TO FATAL INJURY |
| 20 | TOWAWAYS WITH FATAL INJURY |

TABLE 2

INJURY SUMMARY

| Accident Severity | Part(s) of the Body Affected | | | | | |
|---|---|---|---|---|---|---|
| | Head | Neck | Thorax | Arms | Upper Leg | Lower Legs |
| VDI=1 | | | | | | |
| VDI=2 | | | | | | |
| VDI=3 | | | | | | |
| VDI=4 | | | | | | |
| VDI=5 | | | | | | |

TABLE 3

EXPECTED NUMBER OF INJURIES AMONG TOWAWAY-INVOLVED FRONT SEAT OCCUPANTS

(20-MONTH PERIOD - FULL SIZED GM CARS - NATIONWIDE)

| | ACRS GROUP | CONTROL GROUPS | | |
|---|---|---|---|---|
| CUMMULATIVE INJURY SEVERITY | ACRS 1974-75 | UNRESTRAINED 1973-75 | LAP/ SHOULDER 1973-75 | LAP 1973 |
| ALL TOWAWAY-INVOLVED FRONT-SEAT OCCUPANTS | 5,300 | 220,000 | 130,000 | 50,000 |
| ALL AIS ≥1 | 1,660 | 68,700 | 40,150 | 15,600 |
| ALL AIS ≥2 | 430 | 17,600 | 10,700 | 4,000 |
| ALL AIS ≥3 | 140 | 5,760 | 3,500 | 1,300 |
| ALL AIS ≥4 | 46 | 1,860 | 1,100 | 420 |
| ALL FATALITIES | 22 | 900 | 500 | 200 |

# REFERENCES

(1) States, J.D., Fenner, H.A. Jr., Flamboe, E.E., et. al. Field Application and Research Development of the Abbreviated Injury Scale, SAE Print 710783, New York Society of Automotive Engineers, 1971

(2) Committee on Medical Aspects of Automotive Safety: Rating the Severity of Tissue Damage I. The Abbreviated Injury Scale, Journal of American Medical Association 215:277-280, 1971

(3) "How to Use Ridit Analysis" - Irwin D.J. Bross, Biometrics, March 1958

(4) Collision Deformation Classification - SAE J224a - SAE Recommended Practice, Society of Automotive Engineers, New York 1972