APPENDIX F

STATISTICAL RATIONALE FOR THE NUMBER OF AUTOMOBILE CRASH RECORDERS PROPOSED FOR PROCUREMENT AND INSTALLATION BY NHTSA

National Highway Traffic Safety Administration

February 5, 1975
(date of receipt)

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The statistical justification for the number of crash recorders requested by NHTSA depends primarily on the answers to two general questions.

A. If N crash recorders are installed in passenger cars, what number of crashes will be recorded annually in each category, or "cell" of interest? For example, how many frontal impacts with impact speed (Δv) 30 mph or more will be recorded by the crash recorders?

B. Given the answers to question A, will these numbers provide adequate information on the crash environment. This involves statements about the precision and accuracy of various estimates of rates, proportions or distributions, such as confidence limits or error standard deviations.

Figure 1 summarizes much of the basic factual information needed to answer question A. The figure shows numbers of crashes of various types that would be expected in 1 year from a crash recorder fleet of 100,000 vehicles. The numbers are derived from NHTSA's experience with the current restraint systems study and other accident studies. The estimated recovery rate for crash recorders in accidents is 64 percent; this is a judgment factor on which there are few relevant data.

Figure 1 shows an initial fleet of 100,000 recorders, and it is easy to modify the figure to obtain two other useful sets of figures. If one adds three zeros to each number in the figure, the resulting numbers are estimates of the numbers of crashes occurring with the entire U.S.-automobile population in 1 year. If the numbers are each divided by 1,000, the result is the percent in each category. For example, we can see that about 1.6 percent of the vehicles each year will be involved in towaway crashes from which the recorder is recovered.

Figure 2 illustrates the problem of estimating the cumulative distribution of crash speeds. ("Speed" may refer to any measured value such as Δv, barrier equivalent velocity (BEV), traveling speed, etc.). The figure shows a "true" distribution function, represented by the solid curve, and an empirical distribution, obtained through the recorder, and represented by the stepped graph. The maximum vertical distance D between the two curves is a random variable. As the number of observations increases, the probability that D will exceed any specified value decreases; i.e., the empirical distribution function approaches the true population distribution function. The following table shows the numbers of observations needed to obtain 80. and 90-percent confidence that the maximum deviation between true and empirical distribution functions does not exceed a specified value.

Figure 1 - Yield from 100,000 Crash Recorders in 1 Year

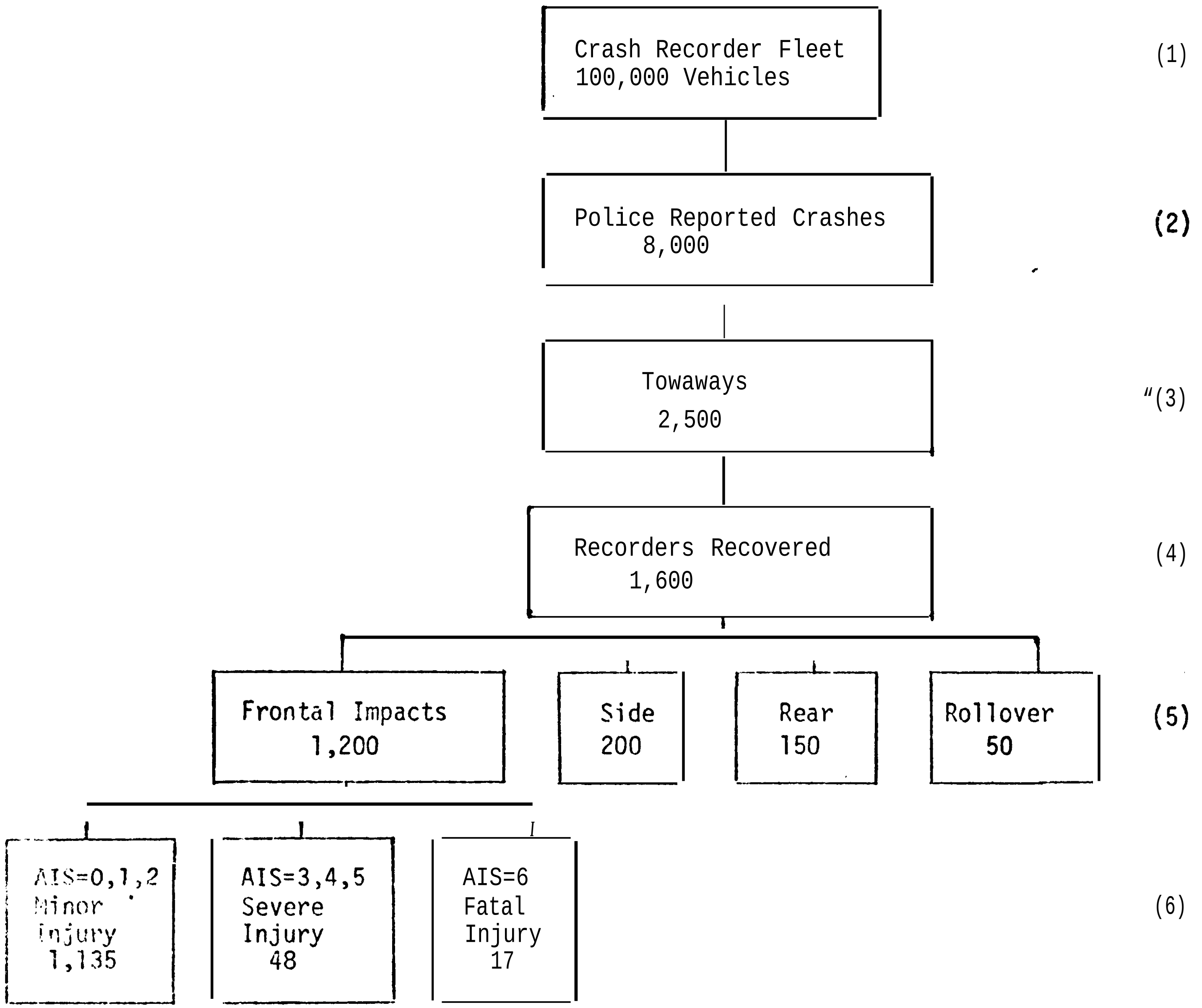

Figure 2 Cumulative Distribution of Crash **Speeds**

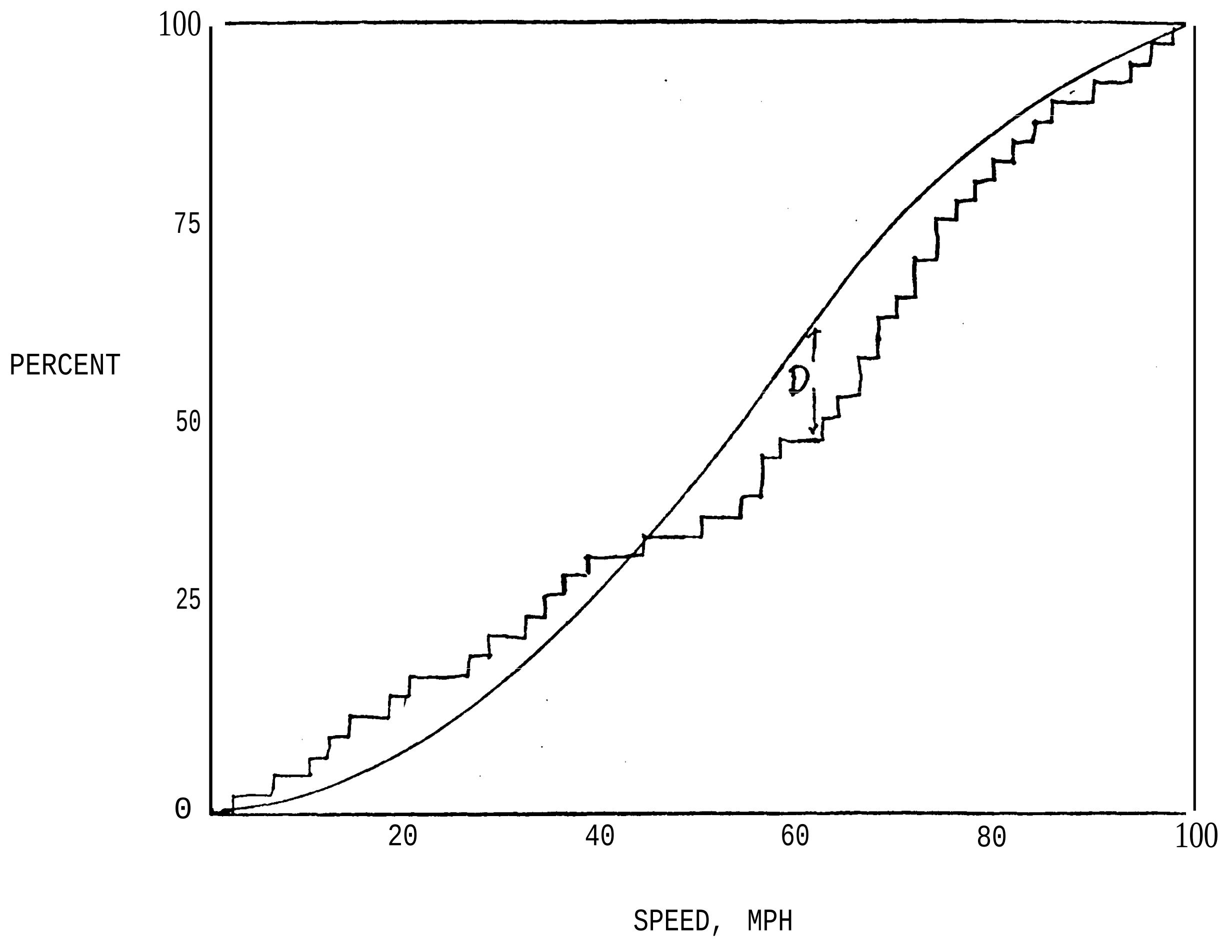

Table 1. Number of Observations Required for Specified Confidence That Maximum Deviation Between Empirical and Hypothetical Distribution Does Not Exceed . Value Shown

Maximum Deviation	Confidence Level	
	80 Percent	90 Percent
.01	11,449	14,884
.02	2,862	3,721
.03	1,272	1,653
.04	716	931
.05	458	595
.08	179	233
.10	115	150

In estimating the fraction of the crashes that fall into a category of interest (e.g., impact speed over 30 mph), we are concerned with the variability of an observed proportion f in a sample from a population in which the "true" proportion is p. In large samples (> 25) the observed fraction is distributed normally with mean p and standard deviation:

$$\sigma = \left[\frac{p(1-p)}{n}\right]^{1/2} = \left[\frac{pq}{n}\right]^{1/2}$$

where n is the sample size. The greatest variability occurs when p = .5, in which case the formula reduces to

$$\sigma = \frac{1}{2\sqrt{n}}$$

So if we specify a probability (confidence level) that the observed results shall not deviate by more than D from the population proportion p, the required sample size can be estimated. Table 2 shows maximum sample sizes required at two confidence levels.

Table 2. Sample Size Required to Estimate a Proportion with Error Less Than D

Maximum Deviation D From Population Proportion	Confidence Level	
	80 Percent	90, Percent
,01.	.4,107	6,767
.02	1,027	1,692
.03	456	752
.04	207	423
.05	164	231
.08	84	106
.10	41	58

The preceding material will now be applied to let us reach some conclusions on how many crash recorders NHTSA should purchase and install.

1. To estimate the proportion of fatal crashes at barrier equivalent velocity below a stated speed, close to a million recorders would be needed. From line (6) of Figure 1, we see that these would yield 170 frontal impact fatalities in a year and 510 in 3 years. This would permit us to state, for example with 80-per cent confidence, "the percent of fatalities in frontal impacts in which BEV exceeds a stated speed is x ±3 percent" after 3 years of data collection with 1,000,000 recorders. For deaths in crashes other than frontal, the requirements range from at least six times as great for side crashes to at most 24 times as great (i.e., 24,000,000) for rollover crashes. The costs to determine any of these fatality distributions directly with the crash recorder appear to be prohibitive.

if we use the injury criterion of either fatal or severe injury . (AIS > 3), (see line 6, Figure 1) the required numbers reduce by a factor of approximately 4, but are still very high.

2. A *more* limited goal is to determine the distribution of barrier equivalent speeds in crashes by impact type. This information is an essential input for crashworthiness design. In this case, the distribution of BEV's for <u>frontal</u> crashes can be determined quite well in a year to about ±.03 with 100,000 recorders> The error in estimating a single proportion (for example, the fraction of BEV under 30 mph) will be less

than .02 with 80 percent confidence and less than .03 with 90-percent confidence. For side and rear impacts, the BEV distribution can be estimated within ±.80 with 85-percent confidence.

3. Table 1 shows that to reach 80-percent confidence that the distribution of impact speeds observed with a crash recorder is within ±.03 **of the "true" distribution function** of observed population of crashes, it is necessary to record 1,272 crashes.

The number of recorders needed to be sure of 1,272 recordings depends upon the frequency of the crash type that is of interest. The following table shows the number needed for several crash types of interest. These numbers assure us at the 80-percent confidence level that the maximum error does not exceed ±.03.

Impact Direction	Severity Level	1 Year	3 Years
Frontal	Fatal	7,490,000	2,500,000
Frontal	AIS > 3	1,960,000	653,000
Frontal	Towaway	106,000	35,000
Side	Towaway	636,000	212,000
Rear	Towaway	849,000	283,000
Rollover	Towaway	2,546,000	852,000

4. Another goal of the crash recorder program is to "calibrate" other measures of crash severity. Some cheaper, less accurate, even biased measurements may become very useful if their biases are consistent and if we can estimate their error distributions. For example, we might use vehicle deformation more readily if we know how

to associate a speed with each point on the vehicle damage scale and could determine the expected errors. The situation is analogous to using a ruler that is 1 inch too long. If we knew the “true” values corresponding to the erroneous ones given by the ruler, we would be able to use the ruler and make corrections.

To accomplish this calibration it would be necessary to consider separately vehicles whose deformation characteristics differ substantially. A minimum of four groups would be required, corresponding to various classes of vehicles. Additionally, it is necessary to consider the type of object struck: soft or hard, concentrated or distributed. . Finally, the calibration needs to be done for at least five points on a speed curve, preferably more. There could be a requirement for up to 80 groups of observations or cells (4x4x5).

With a fleet of 100,000 crash recorders, NHTSA could obtain 1,200 frontal crash impact recordings in a year, which is an average of 1,200 ÷ 80 = 15 per group, and many groups would have much less than 15 observations. Over a period of 3 years the average group size would reach 45. If one assumes a 5 mph standard deviation for the inaccurate measurements, then with 15 measurements the mean for each measured point on a speed curve will be determined with 90-percent confidence to within 1.3 mph. For a 10 mph standard deviation in the measurements to be calibrated, the 90-percent limits will lie 12.5 mph from the mean.

Conclusions:

1. Installing 100,000 recorders would permit a reasonably accurate determination of impact speeds for frontal towaway crashes in a year's time. Less accurate determinations of side and rear crash speed distributions for towaways would be available by the end of 3 years. These statements rest on the assumptions that:

(a) The energy crisis and 55 mph speed limit will not reduce the rate of crashes drastically.

(b) NHTSA can find a way to get a representative sample of crashes.

2. With 100,000 recorders, it will be possible to "calibrate" the various proxy measures used by accident investigators with an acceptable degree of accuracy.

3. The recorder program does help provide a basis for rulemaking. The NHTSA rulemaking organization was quite clear in the requirement for data which only recorders can provide. Attached are 4 charts which state the application of recorder data. The standard writers have consistently provided positive support to the recorder program because of the additional dimensions they provide the technical data base upon which standards are based.

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AUTOMOTIVE RECORDER RESEARCH PROGRAM

BASIS FOR RULEMAKING

<u>RECORDER</u>: MEASUREMENT OF VEHICLE CRASH SEVERITY

<u>PLUS</u>: ACTUAL DATA ON INJURIES AND FATALITIES

<u>EQUALS</u>: FIRM UNBIASED RELATIONSHIP OF CRASH SEVERITY WITH OCCUPANT INJURIES AND FATALITIES

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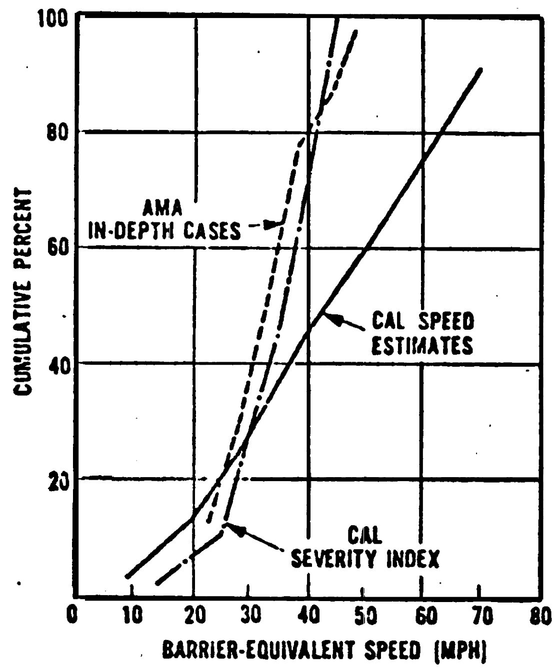
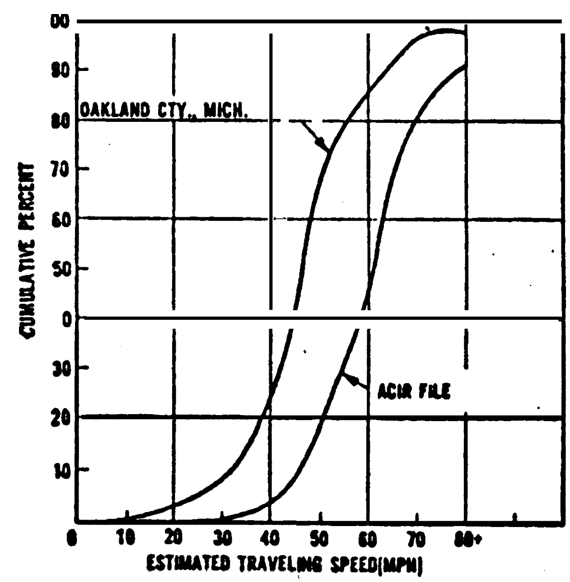
AUTOMOTIVE RECORDER RESEARCH PROGRAM

CURRENT RELATIONSHIPS

PERCENTAGE DISTRIBUTION OF BARRIER—EQUIVALENT SPEEDS FOR SINGLE COLLISION FRONTAL FATALITY VEHICLES BY SOURCE OF DATA



CUMULATIVE FREQUENCY DISTRIBUTION OF SPEED OF FASTER VEHICLE IN FATAL MULTIVEHICLE CRASHES



STUDIES TO DATE INDICATE DISAGREEMENT PRIMARILY AT THE HIGHER SPEEDS WHICH CONSTITUTE THE CRITICAL RANGE FOR CRASH SURVIVABILITY RULEMAKING

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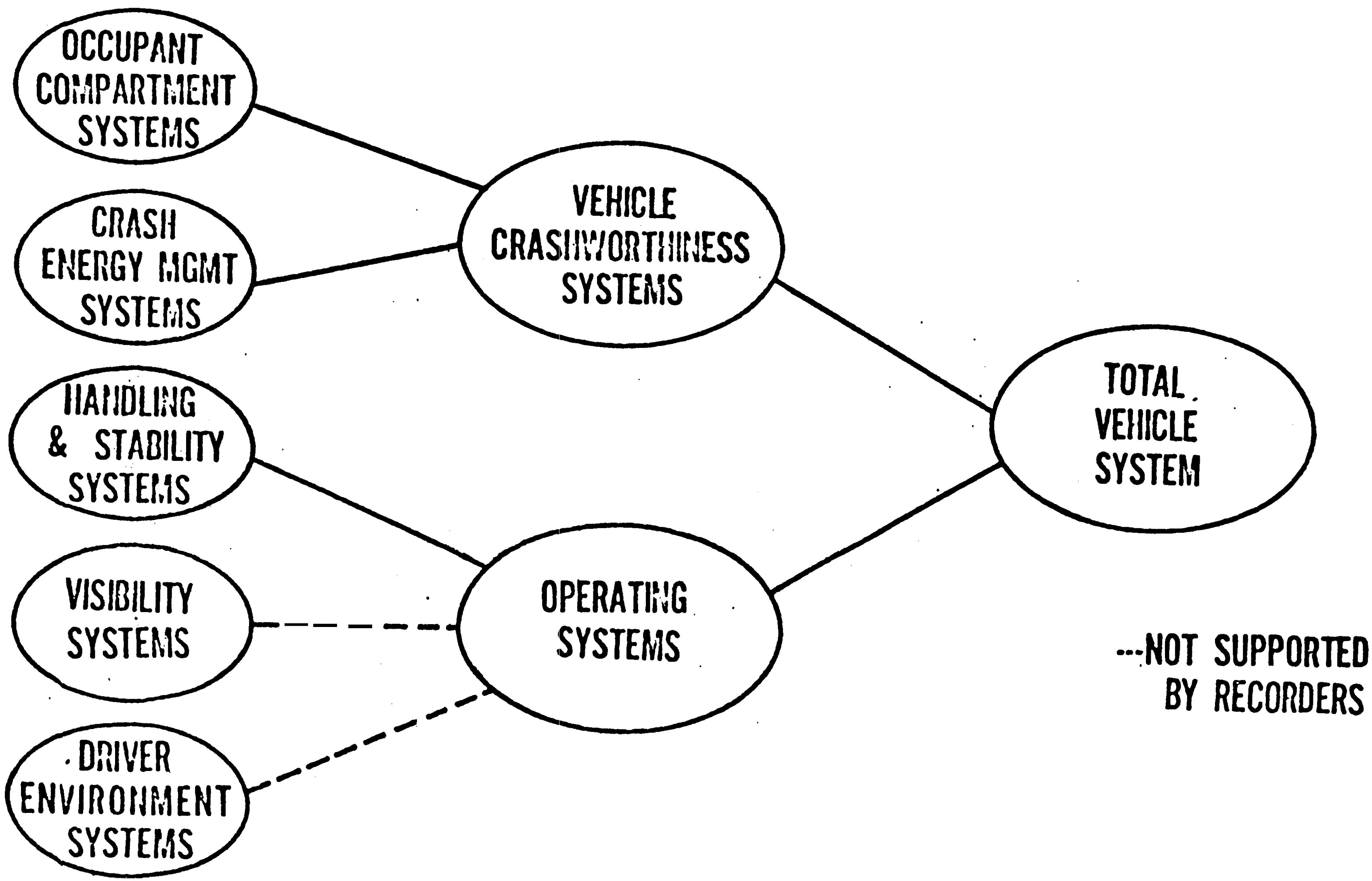
AUTOMOTIVE RECORDER RESEARCH PROGRAM

RECORDERS SUPPORT PLANS FOR SAFETY STANDARDS



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AUTOMOTIVE RECORDER RESEARCH PROGRAM

RECORDERS AND TITLE II

AUTOMOBILE CONSUMER INFORMATION STUDY

PART B. CONDUCT A COMPREHENSIVE STUDY AND INVESTIGATION OF THE DEGREE OF CRASHWORTHINESS OF PASSENGER VEHICLES

RECORDER RESEARCH COULD SUPPORT THIS EFFORT DIRECTLY BY:

- PROVIDING CURRENT DATA ON SEVERAL VEHICLE MODELS
- CONFIRMING STUDY RESULTS OVER SEVERAL YEARS