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RESIDENTS' REACTIONS TO LONG-TERM SONIC BOOM EXPOSURE:  
PRELIMINARY RESULTS

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INTRODUCTION

The presentation this morning is about residents' reactions to sonic booms in a long-term sonic boom exposure environment. Although two phases of the data collection have been completed, the analysis of the data has only begun. The results are thus preliminary. The list of four authors reflects the complex multi-disciplinary character of any field study such as this one. Carey Moulton is responsible for Wyle Laboratories' acoustical data collection effort. Robert Baumgartner and Jeff Thomas of HBRS, a social science research firm, are responsible for the social survey field work and data processing. The study is supported by the NASA Langley Research Center.

The study has several objectives. The preliminary data we will consider today address two of the primary objectives. The first objective is to describe the reactions to sonic booms of people who are living where sonic booms are a routine, recurring feature of the acoustical environment. The second objective is to compare these residents' reactions to the reactions of residents who hear conventional aircraft noise around airports.

Here is an overview of the presentation. This study will first be placed in the context of previous community survey research on sonic booms. Next the noise measurement program will be briefly described and you will hear part of a social survey interview. Finally data will be presented on the residents' reactions and these reactions will be compared with reactions to conventional aircraft.

Twelve community studies of residents' reactions to sonic booms were conducted in the United States and Europe in the 1960's and early 1970's. None of the 12 studies combined three essential ingredients that are found in the present study. Residents' long-term responses are related to a measured noise environment. Sonic booms are a permanent feature of the residential environment. The respondents do not live on a military base. The present study is important because it provides the first dose/response relationship for sonic booms that could be expected to apply to residents in civilian residential areas.

## DATA COLLECTION

The present study was conducted in a Western state in five small communities near military operations areas. The communities are separated by from 18 to 104 miles and are from 50 to 150 miles from the Air Force base from which the training operations are conducted. Less than three percent of the residents have employment related to the Air Force base. Although this is a sparsely settled area, all of the respondents live in these five settlements and fewer than five percent live on a ranch or farm.

Two phases of the study have been completed. The first-phase interviews were conducted in April and May of 1993 and the second phase in December of 1993. In both phases residents were asked about sonic booms during the "last six months". Thus, before interviews could be conducted, the preceding months' booms had to be measured. Unattended noise measurements were made with Boom Event Analyzer Recorders (BEARs) (Lee, et al., 1989). The BEAR is a 16-bit microprocessor-based instrument equipped with a special pressure transducer. The BEAR continuously samples the background noise then captures and stores the wave form of loud impulsive sounds along with other identifying information. For these measurements the BEARs were set to store noise events which exceeded 107 dB, lasted at least 15 msec., had a positive pulse time of 10 msec., and a rise time of at least 6 dB/35msec. measured just before the peak. The stored events were later downloaded and examined to eliminate thunder and occasional other events that did not have acoustical profiles that are characteristic of sonic booms. The BEARs were located in weatherproof boxes on government property or in a cooperative resident's backyard at one or two locations in each community.

Depending on the site, approximately 20 to 80 percent of the days in the six months preceding the interviews were monitored with functioning BEARs. Late BEAR placement at two sites for Phase I and sporadic equipment malfunctions during both phases at all sites resulted in 20 to 80 percent monitoring rates rather than 100 percent monitoring rates. These data were used to calculate average daily exposures for each of the five sites during each of the two 6-month periods. These exposures vary from an average of one boom per day to one boom per 10 days and from a Day-night Average Noise Level (DNL) of 41 dB(A) [58 dB(C)] to 20 dB(A) [36 dB(C)].

<b>CARD A: AMOUNT</b>
<b>VERY MUCH</b>
<b>MODERATELY</b>
<b>A LITTLE</b>
<b>NOT AT ALL</b>

**Figure 1:** Response card for noise questions

Q6. We want to learn how you feel about the neighborhood right around here and about any advantages that make you feel it is a good place to live. In the six months since we last talked to you what are the one or two things you have liked most about this area?

Q7. How about any things that are disadvantages. What are the one or two disadvantages that you have disliked the most about this area in the last six months?

**Figure 2:** Beginning page of sonic boom questionnaire

The residents' reactions were obtained through fixed-format, interviewer-administered, face-to-face questionnaires. The questionnaire was developed during three rounds of pretests at three other locations in the United States at which booms are heard. The pretests provided the basis for improvements such as reducing unneeded material (all respondents were familiar with the term "sonic booms from jets") and maintaining rapport despite detailed questions about sonic boom effects. Interviewing procedures and the questionnaire were designed so that respondents were not initially alerted to the subject matter of the survey.

The professional interviewers on this project received an additional day of study-specific training for this study. Question-specific instructions were prepared. Control was maintained over interviewing procedures through on-site supervision, interview tape recordings and verification of 20 percent of the interviews by staff visits or follow-up telephone calls. An overall response rate of 78 percent was achieved.

Homes were randomly selected in three communities with strict procedures for identifying pre-selected respondents within homes. In the two smallest communities all eligible adults were interviewed. Due to the small study populations, about 400 of the Phase I respondents were reinterviewed during Phase II with a slightly shortened questionnaire.

- Q8. Now some questions about noises you might have heard when you have been at home in the last six months.
- a. What are some of the different types of noises you have heard around here? (PROBE: Anything else?) [MARK "VOL" FOR VOLUNTEERED NOISES]
- b. [ASK FOR ALL NOISES NOT VOLUNTEERED] In the last six months, have you ever heard the noise from ...(cars or trucks or other road traffic going by)... when you were here at home?
- [STOP!!!: COMPLETE ENTIRE LIST WITH b BEFORE STARTING c]
- c. Here is an "AMOUNT" card for choosing your answer for the next question. [HAND CARD A TO RESPONDENT] [ASK FOR EACH SOUND HEARD]  
During the last six months has the noise from ...(cars or trucks or other road traffic going by)...bothered or annoyed you very much, moderately, a little, or not at all?

	a, b HEARD	c. BOTHERED OR ANNOYED				
		VERY MUCH (1)	MODER- ATELY (2)	A LITTLE (3)	NOT AT ALL (4)	DK (8)
i. Cars or trucks or other road traffic going by	1 VOL. ↓ 2 YES ↓ 3 NO ↓ 4 DK ↓	VERY 1	MODER 2	LITTLE 3	NOT 4	DK 8
ii. Motorcycles	1 VOL. ↓ 2 YES ↓ 3 NO ↓ 4 DK ↓	VERY 1	MODER 2	LITTLE 3	NOT 4	DK 8
iii. Neighbors' tools or outdoor equipment	1 VOL. ↓ 2 YES ↓ 3 NO ↓ 4 DK ↓	VERY 1	MODER 2	LITTLE 3	NOT 4	DK 8
iv. [REPEAT FULL QUESTION] ..Sonic booms from jets	1 VOL. ↓ 2 YES ↓ 3 NO ↓ 4 DK ↓ FINISH THROUGH Q10	VERY 1	MODER 2	LITTLE 3	NOT 4 [MARK Xs ⇒]	DK 8
v. Any other explosions or bangs or booms (besides the sonic booms) (DESCRIBE) _____	1 VOL. ↓ 2 YES ↓ 3 NO ↓ 4 DK ↓	VERY 1	MODER 2	LITTLE 3	NOT 4	DK 8
vi. Low-flying jet aircraft	1 VOL. ↓ 2 YES ↓ 3 NO ↓ 4 DK ↓	VERY 1	MODER 2	LITTLE 3	NOT 4	DK 8
vii. Any other airplanes (besides the low-flying jets) (DESCRIBE) _____	1 VOL. ↓ 2 YES ↓ 3 NO ↓ 4 DK ↓	VERY 1	MODER 2	LITTLE 3	NOT 4	DK 8
viii. [DESCRIBE ANY OTHER VOLUNTEERED NOISES HERE] _____	1 VOL. ↓ 3 NO ↓ 4 DK ↓	VERY 1	MODER 2	LITTLE 3	NOT 4	DK 8

MARK X AT Q12 & Q20

Figure 3: Second page of sonic boom questionnaire

I have a tape recording of one of the interviews for you to listen to now. The interviewer

switched on the recorder after entering the home, making the routine selection of the respondent, and obtaining permission to turn on the tape recorder. The interview begins with Question Q6. (Items Q1 to Q5 were for sample identification.) For the respondent this is almost entirely an aural event. The respondent sees only the interviewer and the occasional answer card (Figure 1). Only the interviewer sees the questionnaire, the relevant parts of which are reproduced in Figure 2 and Figure 3.

The sonic boom question (Question 8.iv in Figure 3) exactly parallels the aircraft noise question that has been previously used with over 10,000 residents near airports. The remainder of the questionnaire obtained reactions on other sonic boom annoyance scales and obtained detailed information about vibration, startle reactions, suspected damage, types of activity interference, demographic characteristics, and more general attitudes.

## RESULTS

After the 1042 interviews were entered into a computer file and merged with the noise data, the reactions in each community were plotted by noise level. Figure 4 shows that at, for example, about DNL 25 to 35 dB(A), about 30 percent of the respondents said that they were "very much" annoyed by sonic booms (Question 8.iv. in Figure 3). To obtain a broader perspective on the meaning of that degree of annoyance, the respondents chose numbers to compare their feelings about sonic booms (arbitrarily set at a score of 100) with their feelings about other life-familiar events for which they could choose any number. Logarithmic averages of the ratios of their numerical ratings of sonic booms and other events indicate that the 79 percent of the respondents in the 25 to 35 dB range who expressed any annoyance with sonic booms felt that sonic booms were about as annoying as "hearing big noisy trucks if you lived near an intersection" or "having a dog next door that regularly barks in the middle of the night". As for all noise sources there is considerable variation in the respondents' reactions. In the 25 to 35 dB range, for example, about 21 percent are "not at all annoyed" by sonic booms. The remaining 79 percent who are at least a little annoyed consist of 27 percent who are "a little annoyed", 22 percent who are "moderately" annoyed, and 30 percent who choose the highest category of "very much" annoyed.

From a regulatory perspective the most important comparison is not with reactions to "barking dogs" but with reactions to other aircraft. In later analyses it is planned to relate the sonic boom results directly to 8 surveys that used the annoyance scales that are included in the sonic boom survey. The present preliminary results can be directly compared with one of those surveys; a 1985 survey of residents around five airports in the United Kingdom. Figure 4 presents this comparison for DNL (A). The figure indicates that the level of annoyance that is expressed in the sonic boom study at about 40 dB is not reached in this conventional aircraft noise study until about 60 to 70 dB.

The next figure (Figure 5) adds another line. The new line is the dose/response relationship predicted by a logistic regression analysis of 400 data points from 26 community noise survey data sets (Finegold, Harris, and von Gierke, 1994; Federal., 1992). These 400 data points were drawn from a larger set of 453 data points that appeared in a dose/response synthesis study (Fidell, Barber, and Schultz: 1991). The new line is thus broadly consistent with the previous conclusion that sonic booms are much more annoying than other community noises.

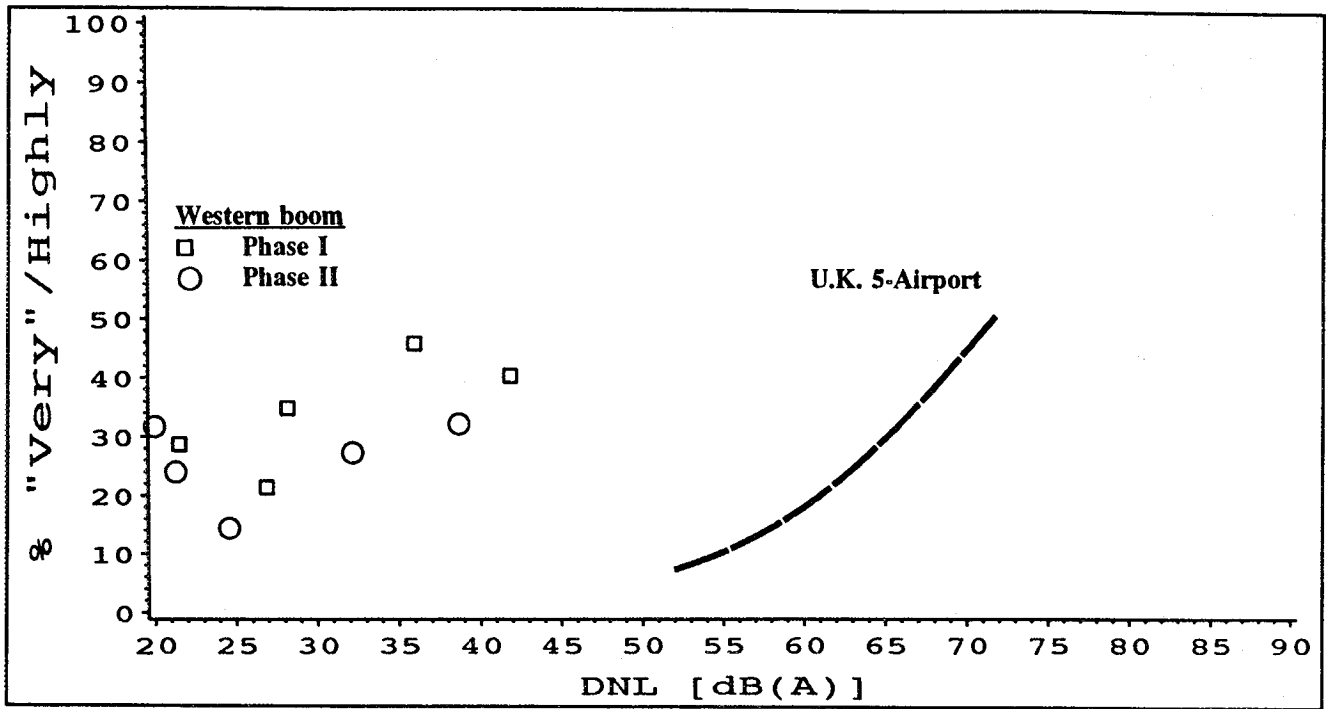


Figure 4: Comparison of Western Boom Study and UK 5-Airport Study

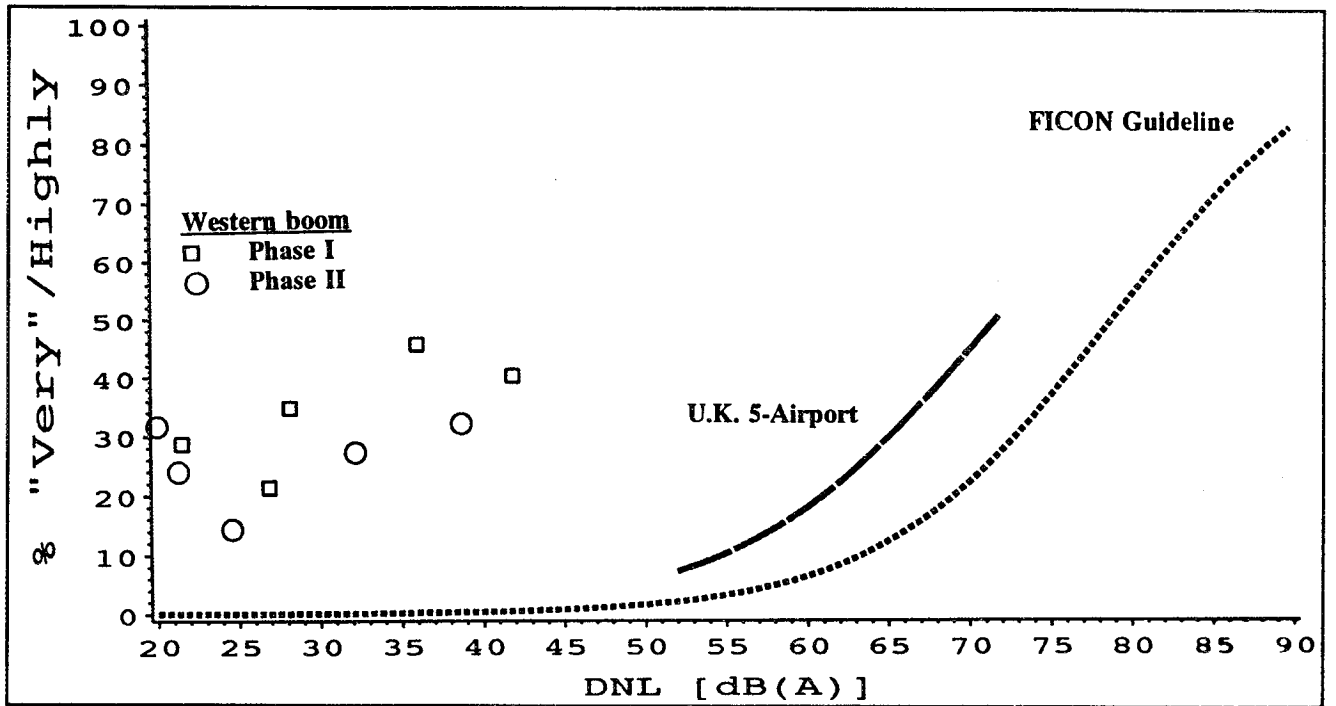


Figure 5: Comparison of Boom, UK 5-Airport and FICON guideline

In the following figure (Figure 6) the sonic boom sites are compared to all 453 data points from the complete synthesis study (Fidell, Barber, and Schultz: 1991). The general conclusion remains unchanged; sonic booms appear to be more annoying than would be predicted by other community noise data. While all of the displays of data come to this same general conclusion, several difficulties interfere with drawing more precise conclusions about the size of the difference

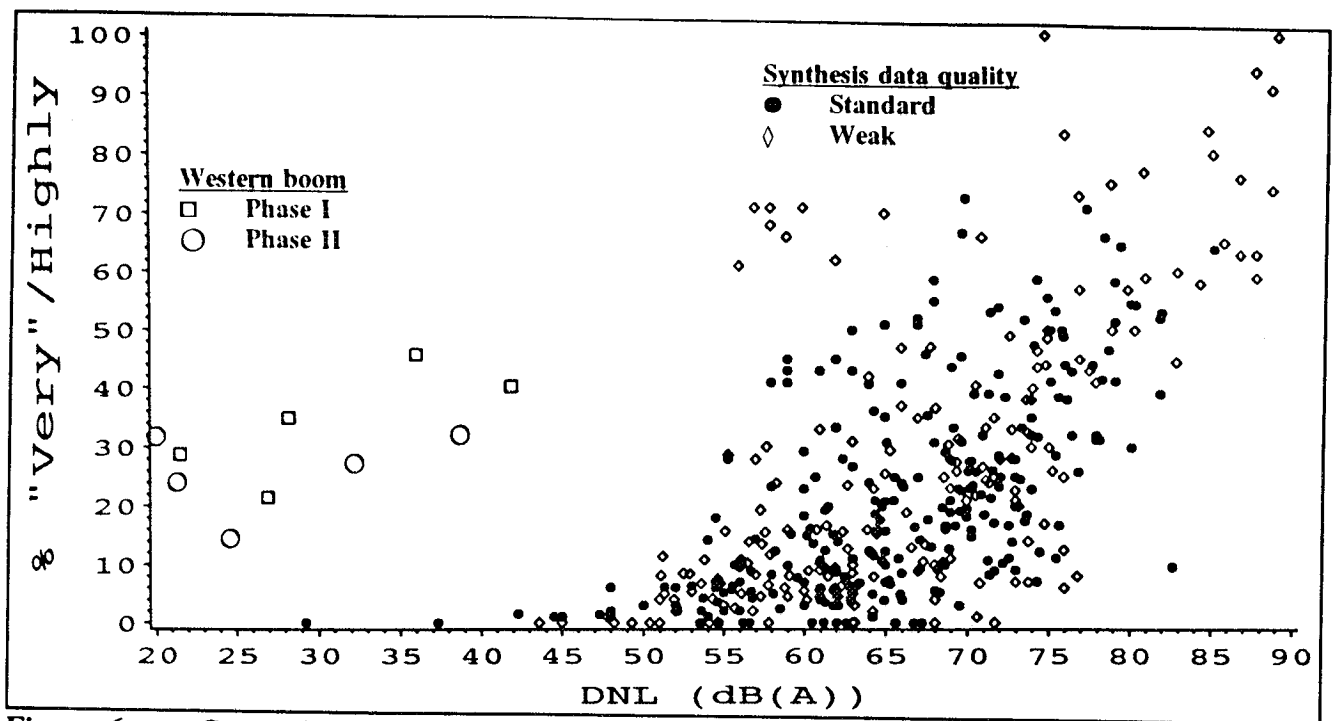


Figure 6: Comparison of Western Boom and 453 non-impulse noise community study data points

between reactions to sonic booms and to other aircraft. First, the 453 data points are based on a diverse set of annoyance questions, only one of which was the same as was used in the sonic boom survey. Second, the 453 data points represent studies of reactions to a diverse set of noise sources including aircraft, road traffic and undifferentiated community noise. Third, the 453 data points from the 29 studies differ from one another in more fundamental ways that hinder any comparison. The points marked with open symbols in Figure 6, for example, are based on data from studies with the following types of weaknesses: 1) the respondent was not asked about the measured noise environment, 2) the annoyance measure is relative to local features that vary between sites, (3) a transportation noise source is not specified in the question, or 4) the annoyance measure is a complex combination of questions that is not clearly definable as high annoyance (Fields, 1994).

Figure 6 raises one other issue; there is very little overlap between the noise levels observed for the sonic boom study and the noise levels observed for the other surveys. Although the three lowest overlapping data points in the synthesis study (between DNL 29 and 43 dB) used the same annoyance scale as was used in the boom survey, all three come from a railway noise survey in which the respondents have been shown to be less annoyed than respondents to conventional aircraft noise surveys (Fields and Walker, 1982). These very low sonic boom exposures are a result of the very low frequency of the sonic boom events. The use of energy averaging for such infrequent events has not been examined in previous studies. If it were speculated that respondents at such low levels do not react to the long-term average, but rather to the worst sonic boom days, then the sonic boom reactions should be plotted at higher noise levels. To examine the implications of such speculations, the sonic boom reactions in Figure 7 are plotted at noise levels which are DNL 14 dB(A) higher than previously. The 14 dB difference is approximately the average difference between the average noise level for all days and for the three highest days. Even after this speculative adjustment that does not make a corresponding adjustment for the three highest days around

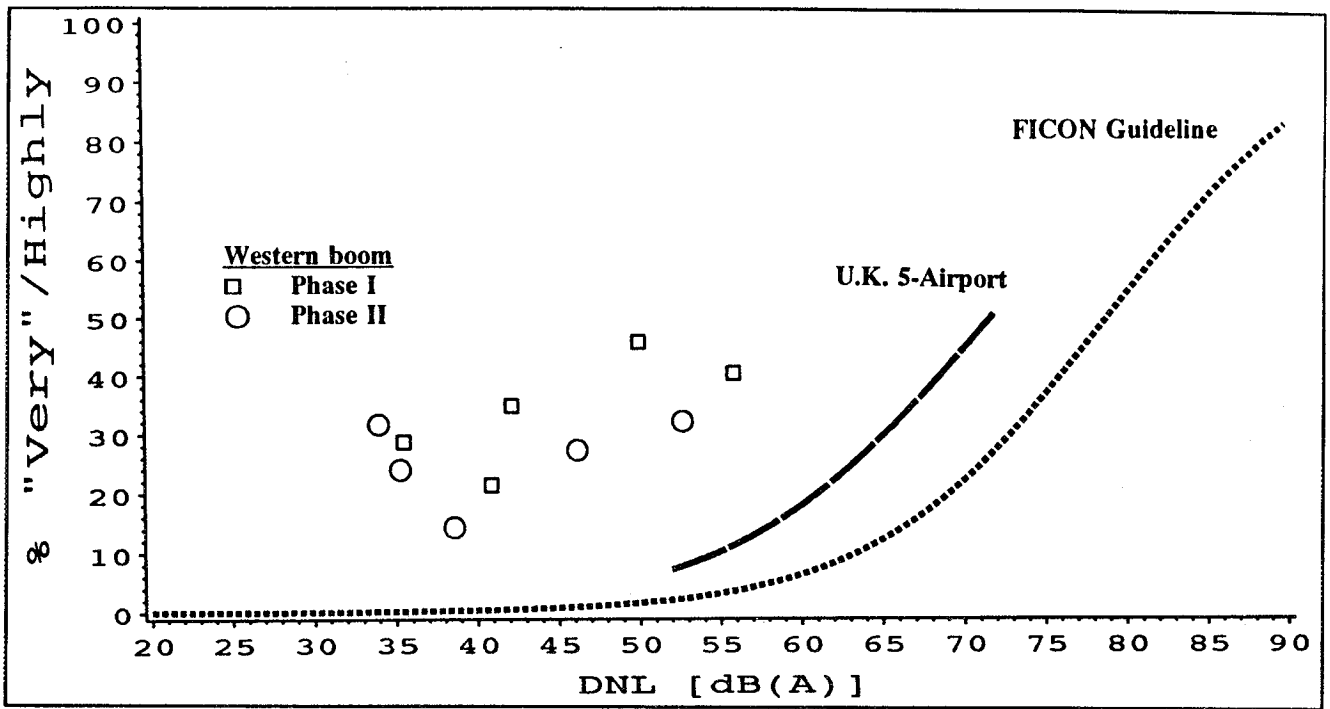


Figure 7: Speculative comparison if respondents misunderstood and reported reactions to the worst three days for only the sonic boom study

conventional airports, the sonic boom reactions are stronger than those to other noise sources.

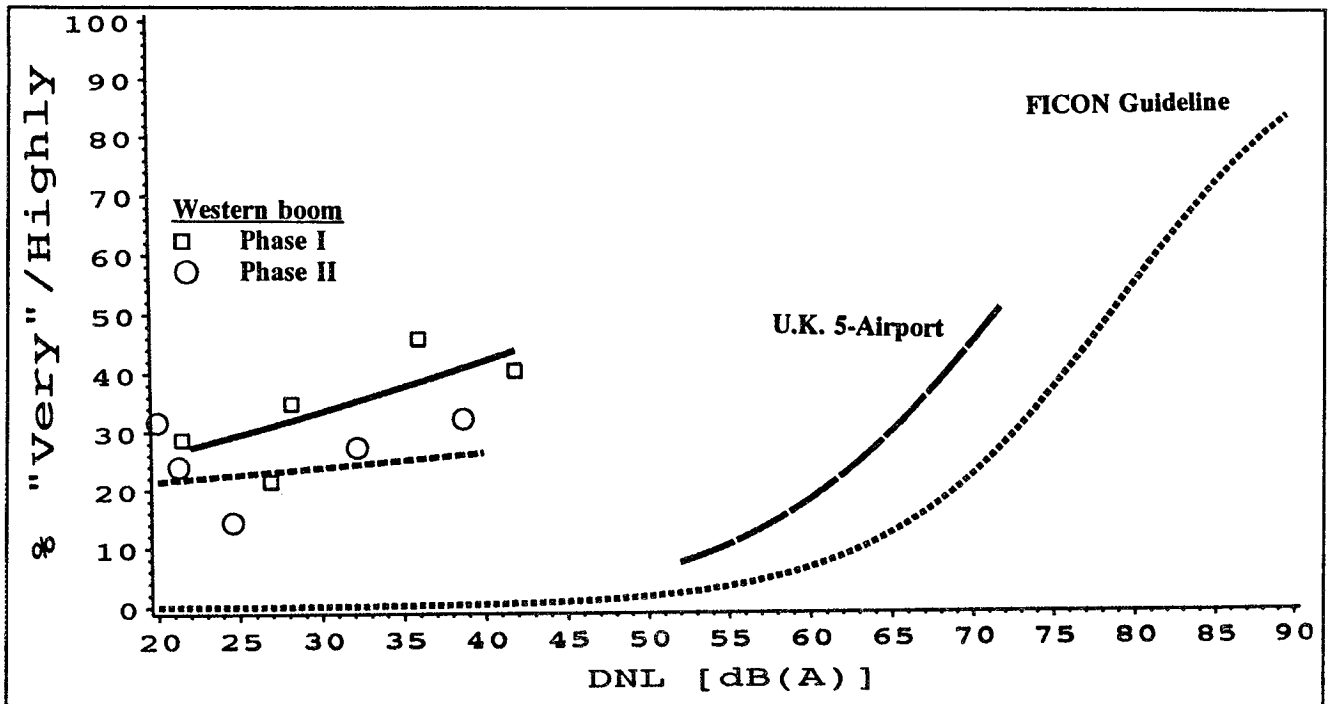


Figure 8: Comparison of logistic relations for four data sets

The final figure (Figure 8) shows four logistic regression lines; one for each of the two boom study phases, one for the five-airport UK study and one for the 400 point synthesis. This figure



raises at least one additional point: the difference between the two phases of the boom study. While we can presently theorize about the reasons for such a difference, the data have still to be examined. The precision of the noise estimates and the dose/response relationships must both be examined before these and other issues can be addressed.

It is important to conclude by emphasizing that these are preliminary results from an on-going project. An additional data collection phase is planned, some aspects of the noise data have still to be examined, and detailed analyses of the social survey data have not begun. The present data indicate that sonic booms are more annoying than would be predicted from the findings from one carefully matched aircraft noise survey and from widely-accepted summaries of dose/response relationships. More analysis is planned before the size of this difference is quantified and before explanations for the differences in reactions can be examined with these data.

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