HUMAN RESPONSE TO SONIC BOOMS-RECENT NASA RESEARCH

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INTRODUCTION

The proposed development of a second-generation supersonic commercial transport has resulted in renewed sonic boom research. Aircraft configurations are being designed to reduce the impact of sonic booms by generating sonic boom signatures which have specific shapes other than N-waves and which may be more acceptable to the public.

In an effort to provide guidance to aircraft designers and to aid in the establishment of sonic boom impact criteria, a program to study human response to sonic booms was formulated. It consists of three components: (a) laboratory studies using a sonic boom simulator to assess response to individual sonic booms having a range of pressure-time signatures, (b) an in-home simulation system to investigate response to daily combinations of individual boom amplitudes and their frequency of occurrence, and (c) response to sonic booms in communities that are routinely exposed to supersonic aircraft operations.

LABORATORY SIMULATOR STUDIES

The simulator consists of a loudspeaker-driven concrete booth which can accommodate one test subject. Sonic boom signatures are computer-generated and may be of any arbitrary shape and amplitude up to about 140 dB. A series of experiments have been conducted to examine the loudness and annoyance of a wide range of sonic booms, both N-waves and shaped booms. Results have generally confirmed predictions made using a loudness model based upon Stevens' Mark Vll Perceived Level method (refs. 1,2). A typical result is shown in Figure 1, in which average loudness ratings of a group of test subjects are compared to the peak overpressure and calculated Perceived Level of a wide range of sonic boom signatures. Other experiments have examined simulated "indoor" booms, asymmetrical booms and ground-reflected booms. The signatures utilized in these tests were idealized shapes, lacking the distortion caused by propagation through a real atmosphere. Response to such distorted signatures was examined (ref. 3) using booms recorded during flight tests of a supersonic aircraft operating under a range of atmospheric conditions. These recorded signatures were generated in the simulator and the results for a group of test subjects are presented in Figure 2. It is clear that the loudness prediction method is able to account for the spectral changes induced by propagation through a real atmosphere.

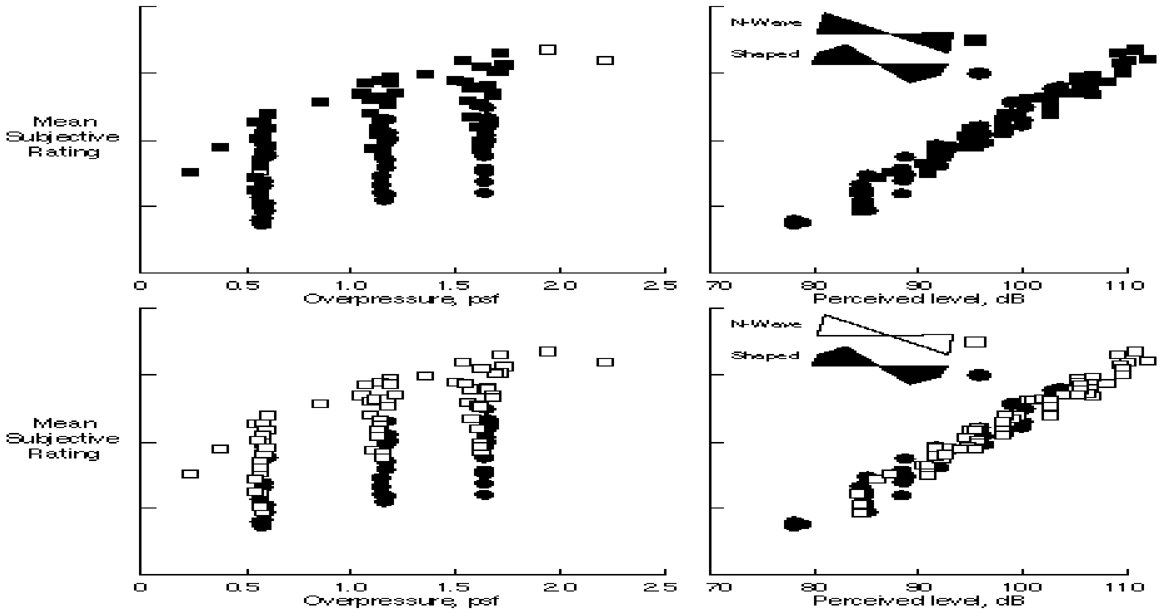

Fig. 1. Loudness responses for N-waves and shaped sonic boom signatures

IN-HOME SIMULATION STUDY

The in-home simulation system (ref. 4) provides a degree of situational realism not present in the laboratory and a degree of control over the noise exposure not found in community settings. The system consists of a computer and compact disc player that generates simulated sonic booms using three or four loudspeakers located in different rooms of a house. Sound level meters are used to monitor sonic boom amplitudes and ambient noise levels. At the end of each day's exposure to simulated sonic booms, the resident answers a series of questions about his or her activities during the day and his or her overall subjective response to the total sonic boom exposure for the day. The system is periodically monitored to ensure normal operation using a central computer and modem.

Thirty-three test subjects (one per home) were selected from a pool of local residents. The simulation system was programmed to produce a range of daily sonic boom exposures, consisting of combinations of three sonic boom pressure signatures, three amplitudes of presentation, and seven rates of sonic boom occurrence. Individual sonic boom signatures and amplitudes were constant throughout any given day. Single event levels ranged from 66–74 dB (A-weighted sound exposure level), and occurrence rates varied from 4 to 63 booms per daily 14 hour test period. No booms were generated during the subjects' normal sleeping hours. At the end of each day each test subject responded to several questions via the computer. They were asked to identify time periods during which they were absent from the home in order that their actual sonic boom exposure could be calculated. They were also asked to rate the day's exposure on a 0–10 scale from "not at all annoying" to "extremely annoying". The system was deployed for eight weeks in each subject's home.

The resultant data set consists of 1673 days of sonic boom exposure for which annoyance judgments were obtained. The principal analyses were aimed at an examination of noise exposure metrics and their relationships with the test subjects' responses. Figure 3 shows the relationship between the average annoyance ratings and the sound exposure level of individual sonic booms, for various numbers of daily sonic boom occurrences (i.e., the number heard—not the number generated). The regression lines in the figure indicate that annoyance increases with increasing single event level and increasing frequency of occurrence. A more detailed examination of these effects is presented in Figure 4, in which the combined effects of level and

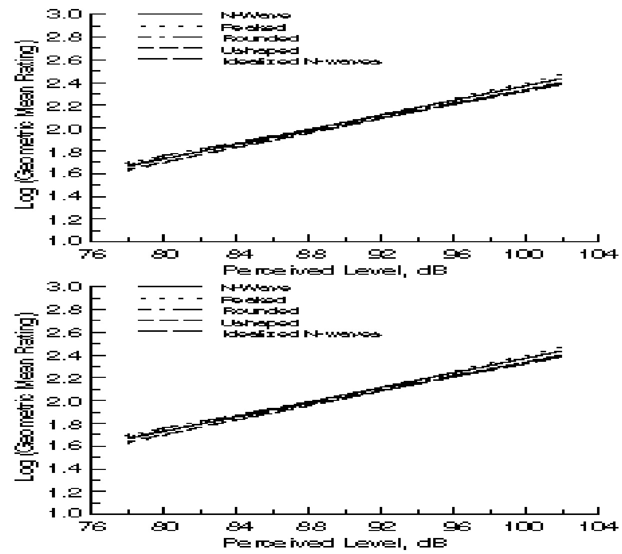

Fig. 2. Regression lines describing loudness responses for several categories of sonic booms

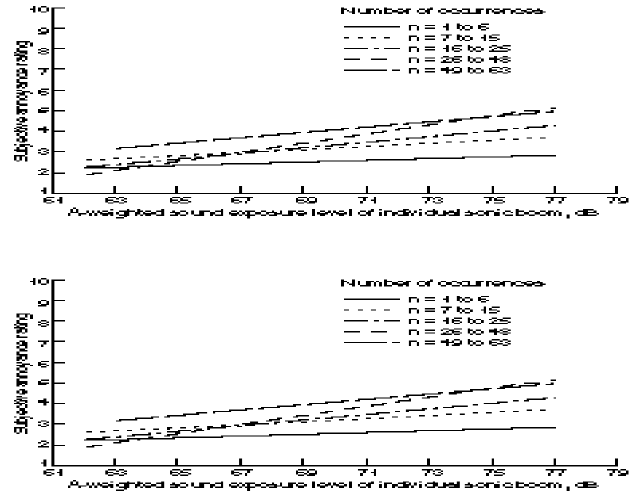

Fig. 3. Regression lines describing loudness responses to sonic booms for several categories of number of occurrences

number are modeled using multiple linear regression. Various metrics are shown and include Stevens' Mk Vll (PL), Zwicker loudness level (LLZd and LLZf), perceived noise level (PNL) and A-weighted, C-weighted and linear (no weighting) sound exposure level (SEL(A), SEL(C) and SEL(U)). The figure indicates that, for the majority of these metrics, the coefficient of the logarithm of the number of occurrences is not significantly different from 10, thus supporting the conventional energy-addition model customarily applied to a wide range of types of noise. It should be noted that the rank order of the metrics, based on correlation coefficients, matches the abscissa of Figure 5 such that PL is ranked first and SEL(C) is ranked last.

COMMUNITY STUDIES

The laboratory and in-home simulation experiments described above are able to provide useful information regarding the subjective response to booms of different types and the manner in which people integrate multiple sonic booms. However, they are not able to provide credible predictions of community residents' reactions in a real, long-term sonic boom environment. In an effort to obtain such information, an ongoing study (ref. 5) is being conducted in areas which are routinely exposed to sonic booms from military training operations. Two phases of the study are complete, although the data analysis is not.

The two phases, eight months apart, were conducted in five small communities near military operations areas in the western United States. 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 using instruments specifically designed for sonic boom monitoring. These instruments capture the entire sonic boom waveform, thus enabling the identification of spurious signals and the calculation of any desired noise metric. Residents' reactions were obtained using fixed-format, interviewer-administered, face-to-face questionnaires. Interviewing procedures and the questionnaire were designed so that respondents were not initially alerted to the subject matter of the survey. The primary sonic boom annoyance question exactly parallels an aircraft noise question that has previously been used with over 10,000 residents near airports (a four point scale: "very much", "moderately", "a little", "not at all" "bothered or annoyed"). Data from the

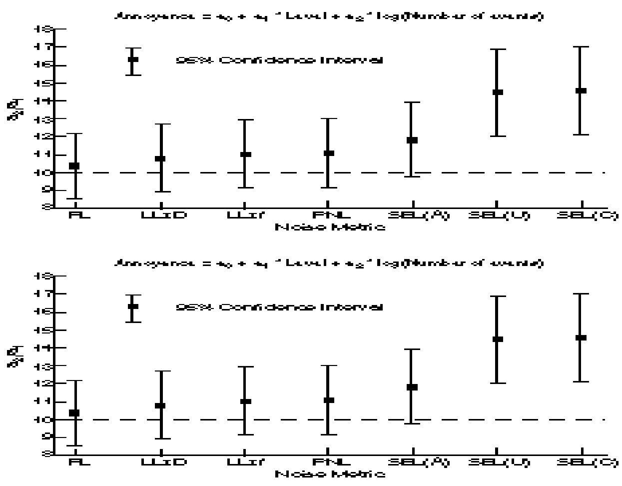

Fig. 4. Coefficient of "log (n)" for several noise metrics

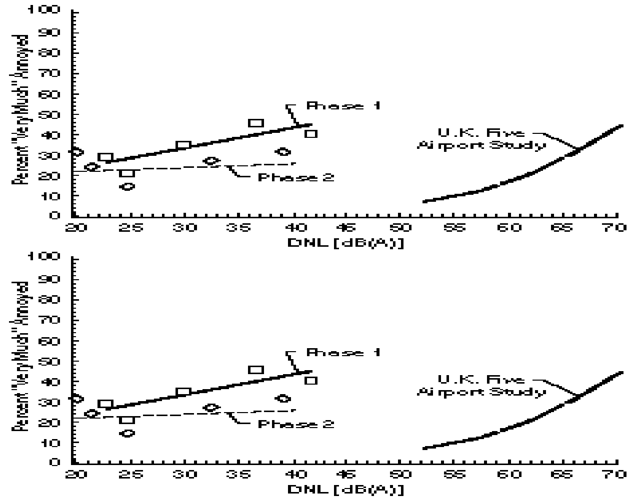

Fig. 5. Percent of population "very much" annoyed as a function of sonic boom exposure

1042 interviews were merged with the noise data in order to plot the reactions in each community against noise level. Figure 5 shows that at, for example, about DNL 25 to 35 dB(A), about 30 percent of the respondents said they were "very much" annoyed by sonic booms. These results can be directly compared with a 1985 survey of residents around five airports in the United Kingdom. Figure 5 indicates that the level of annoyance expressed in this sonic boom study at about 40 dB is not reached in the aircraft noise study until about 60–70 dB.

It should be noted that these are preliminary results from an ongoing project. An additional data collection phase is planned, some aspects of the noise data have still to be examined, and detailed analysis of the social survey data have not yet begun.

SUMMARY

Laboratory studies using a sonic boom simulator have examined human response to a wide range of sonic boom signatures. Results illustrate the importance of the shape of the signature and the ability of a loudness model to adequately predict the subjective responses. An in-home sonic boom simulation system has been used to determine human response to daily sonic boom exposures. The results clearly support the use of energy addition as is customarily used for the assessment of other types of noise. Studies of community residents' reactions to long-term sonic boom exposure are on going. Preliminary results indicate that reactions to sonic booms are far more severe than reactions to other types of noise at similar levels of noise exposure.

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