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# EFFECTS OF SONIC BOOM ON PEOPLE: ST. LOUIS, MISSOURI, 1961-1962

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# Effects of Sonic Boom on People: St. Louis, Missouri, 1961–1962*

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The vicinity of St. Louis, Missouri, was exposed to approximately 150 sonic booms during a 10-month period from July 1961 to April 1962. Ground overpressures, ranging up to about 3 lb/sq ft, were carefully measured for a series of 17 of the supersonic flights. Data obtained from over 2300 direct interviews, analyses of complaints, and engineering evaluations of alleged damage were related to information on aircraft operations and sonic-boom overpressure measurements. Most residents interviewed indicated some interference with routine living activities, yet less than 1% filed formal complaints. Alleged building damage was superficial in nature and consisted mostly of cracks in brittle surfaces. There were no reports of direct adverse physiological effects.

## INTRODUCTION

MYSTERIOUS "explosivelike" sounds experienced in 1950 at Wright-Patterson Air Force Base, Ohio, and in neighboring communities were attributed to aircraft diving at speeds that exceeded the speed of sound. As aircraft capable of maintaining supersonic speeds in level flight were developed, the problem of sonic booms became a matter of more general public concern. Numerous theoretical and operational research programs investigating the nature of the sonic boom have been accomplished by various agencies since its accidental discovery approximately 15 years ago.

The physical nature of sonic boom and its generation and propagation were explained by the midfifties. This was followed by examination of its gross effects on structures and on other aircraft. Maneuvers at supersonic speeds were studied and the "superboom" was described. Later, responses of specific test structures and biological responses of humans to very intense booms were observed. During this period, military aircraft were operating in increasing numbers on supersonic missions over populated as well as unpopulated regions. The impact of sonic boom was demonstrated by growing numbers of complaints and by alleged damage claims that were being received by the U. S. Air Force. Eventually, individual and community reactions to measured sonic booms were evaluated in a research program in the metropolitan area of St. Louis, Missouri.[1] This paper attempts to flash back to the years 1961 and early 1962 and to discuss the St. Louis community-response program in terms of the background from which the study emerged, its objectives, and its main findings. Since the St. Louis study was the first of the population-response studies, the material contained herein may serve as an introduction for the other community-response experiences presented in the articles that follow.

The public-opinion polling method employed in the St. Louis study was based upon, and was to a degree an extension of, earlier research on community reaction to aircraft noise.[2]

* This paper is identified as AMRL Tech. Rept. No. AMRL-TR-65-196. Further reproduction is authorized to satisfy needs of the U. S. Government.

[1] C. W. Nixon and H. H. Hubbard, "Results of the USAF-NASA-FAA Flight Program to Study Community Responses to Sonic Booms in the Greater St. Louis Area," NASA Tech. Note No. D-2705 (May 1965).

[2] P. N. Borsky, "Community Reactions to Air Force Noise," WADD Tech. Rept. No. 60-689 (I,II) (Mar. 1961).



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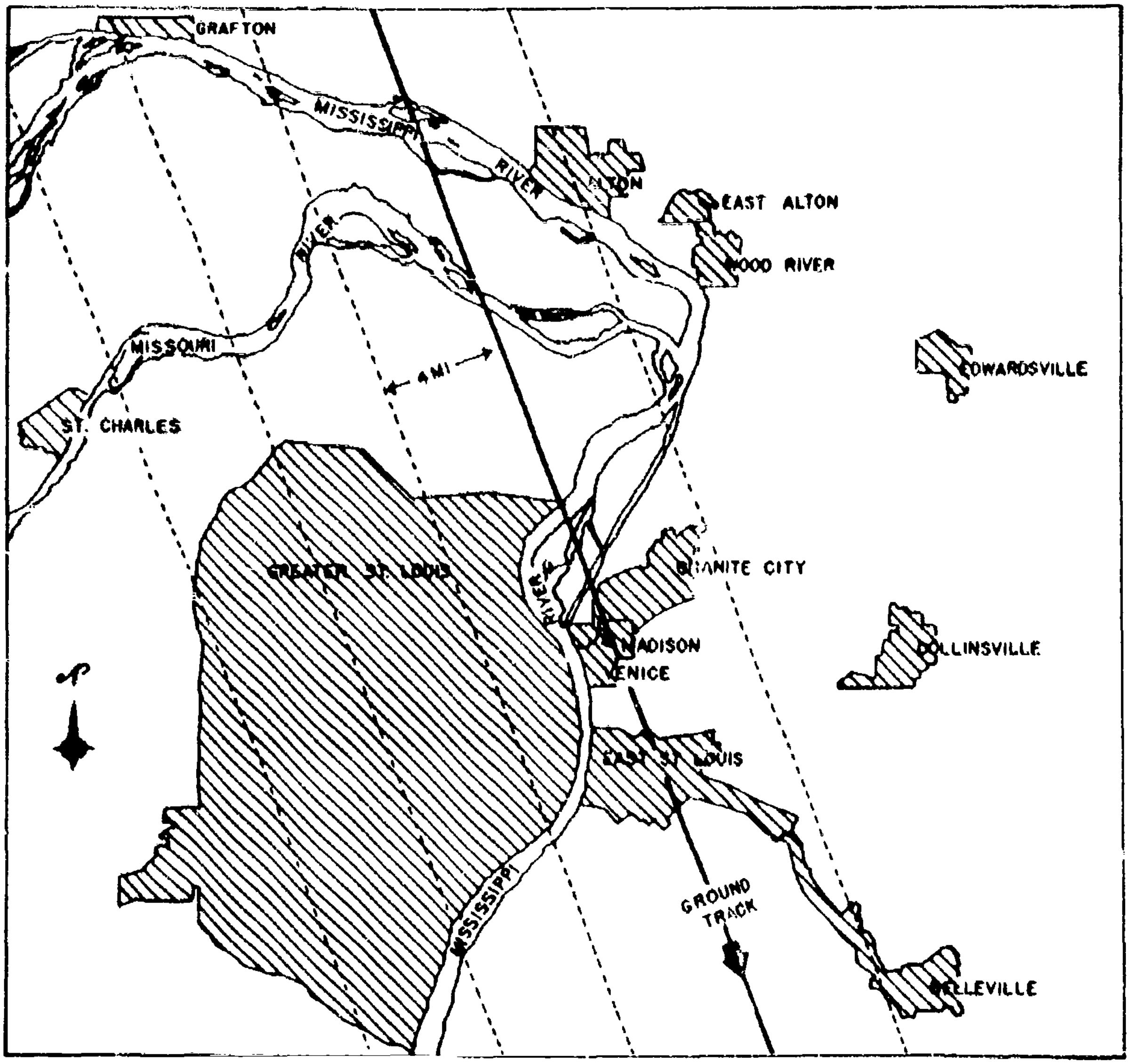


FIG. 1. Map of greater St. Louis area, with ground track of Bongo aircraft superposed. Shading denotes urban areas.

## I. BACKGROUND

In June 1961, the "Commercial Supersonic Transport Aircraft Report,"[3] the SST "Bluebook," was released jointly by the U. S. Department of Defense, the National Aeronautics and Space Administration, and the Federal Aviation Agency. This document reported that the development of a commercial supersonic-transport (SST) aircraft was considered technically feasible and that a national program of research and development would eventually be required to solve many of the problems presented by such a venture. Of the major technical obstacles noted at that time, the most important operating problem of the supersonic transport was considered to be associated with the effects of the sonic boom on the general population. It was essential to know what kinds of boom exposures might be accepted by the public or to what extent widespread annoyance and complaints might be generated.

A logical approach to the community-response question was a review of all prior experiences involving complaints attributed to sonic booms. Total data accumulated at that time consisted almost exclusively of U. S. Air Force records of individual complaints and claims of alleged damage to property. An intensive investiga-

[3] Anon., "Commercial Supersonic Transport Aircraft Report," U. S. Department of Defense, National Aeronautics and Space Administration, and the Federal Aviation Agency (June 1961).

tion of these records was accomplished at numerous installations across the United States of America. However, lack of specific information relating sonic booms to the incidents described in the reports imposed critical limitations on their usefulness for purposes of prediction or generalization. In most instances, an aircraft responsible for the sonic boom could not be identified, so that for many situations reported the actual occurrence of sonic booms was not verified. Also, there was no means of determining the exact location of identified supersonic aircraft at the time of the boom; consequently, the magnitude of the boom could not be estimated. Actually, correlation of the individual responses documented in the accumulated records with the respective stimulus exposures was not possible, except for a very few unusual incidents such as those that occurred at air shows and air races. Even for these incidents only rough estimates of the magnitudes of the booms were possible. In addition, response behavior consisted almost entirely of descriptions of alleged damage to property or statements of objection to the boom experience. These data could not be used to estimate or predict community reactions to other sonic booms in other residential areas.

The important question of public acceptance was wide open. On the basis of all prior experience, it was evident that few liked the sonic boom. There would be varying degrees of acceptance, depending primarily upon the magnitude of the stimulus and the time of day but also upon other factors such as economic involvements, knowledge of the cause, effects, purpose, and the like. It became clear that a special operational program would be required in which various levels of community reaction to measured sonic booms could be evaluated.

## II. OBJECTIVES

The fundamental objective of the St. Louis community-response study was to obtain for the first time well-documented data on public reaction to sonic booms. Specifically, results obtained from direct personal interviews and engineering evaluations of alleged damage to property were to be correlated with information on aircraft operations and sonic-boom pressure measurements. The influence upon reaction to the boom of other factors in this psychological stimulus–response situation—such as socioeconomic factors, tendency to complain about things in general, nighttime booms, and knowledge of the nature of sonic boom—would also be evaluated. In the final analysis, the well-documented data regarding effects of sonic booms were to be utilized to formulate guidelines and criteria for scientists, engineers, and management personnel involved in an SST development program.

## III. APPROACH

The metropolitan area of St. Louis, with a population of about 2 600 000, demonstrated many features considered important for the study. In particular, a B-58 training program of the Strategic Air Command (SAC) had in the past, and would in the future, generate sonic booms in the area on a somewhat regular basis. In addition, the area had a history of previous sonic-boom experience, contained structures and buildings of various types of construction and ages, provided commercial jet and propeller-driven aircraft operations, gave access to the required aircraft staging point, had no sharp or irregular topographic features, and contained a population that represented a wide range of socioeconomic factors.

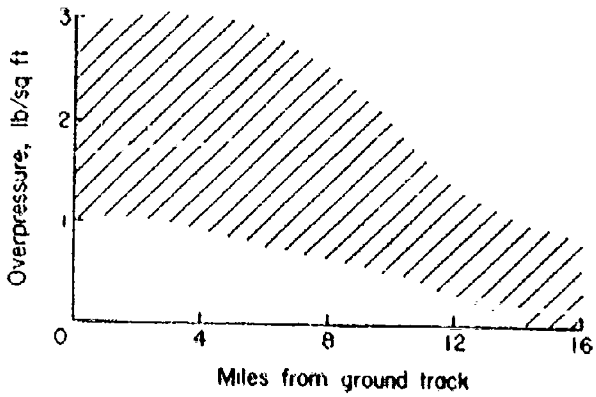


Fig. 2. Estimated ranges of sonic-boom overpressure as a function of distance from ground track for Bongo flights.

Supersonic flights associated with the SAC training program occurred in the St. Louis area from July 1961 to April 1962. Prior to the first sonic boom, a public-information program was initiated with a dinner presentation to civic leaders, members of the news media, and the like, of populated areas to be affected by the training programs. Information was presented about the SAC, the B-58, the training activities, and the sonic boom. An informational program, which provided periodic news releases, films, and frequent lectures to community organizations, was maintained by personnel of Scott Air Force Base during the entire 10-month training program.

About 40 sonic booms were generated by B-58 aircraft over the initial 4-month period. Following these experiments, 13 additional flights were made over the same area at various times of day and night during a 6-day period, beginning 6 November. Four other flights, with booms at higher overpressures than those experienced earlier, occurred on 3 and 6 January 1962. About 000 residents were interviewed twice during the study to learn about their reactions to the booms, once immediately following the first special flights and a second time following the special flights in January. All sorties were flown over the same predetermined supersonic corridor, which passed along the edge of the main urban area of greater St. Louis (Fig. 1). Data-collection areas were designated at various lateral distances from ground

TABLE I. Estimated sonic-boom ground overpressures as a function of distance from the ground track for the Bongo flights.

| Distance | Overpressures (lb/sq ft) for | | | | |
|---|---|---|---|---|---|
| | B-58 at an altitude of (ft) | | | | F-106 at an altitude of (ft) |
| (miles) | 46 000 | 41 000 | 36 000 | 31 000 | 41 000 |
| 0-2 | 1.6 | 1.8 | 2.3 | 2.7 | 1.3 |
| 2-4 | 1.5 | 1.7 | 2.1 | 2.4 | 1.2 |
| 4-6 | 1.3 | 1.6 | 1.8 | 2.1 | 1.1 |
| 6-8 | 1.2 | 1.4 | 1.5 | 1.6 | 1.0 |
| 8-10 | 1.1 | 1.2 | 1.2 | 1.2 | 0.8 |
| 10-12 | 1.0 | 0.9 | 0.8 | 0.8 | 0.6 |
| 12-14 | 0.9 | 0.7 | 0.6 | 0.4 | 0.4 |
| 14-16 | 0.8 | 0.6 | 0.4 | 0.2 | 0.3 |

TABLE II. Percentage of 1145 interviewed in the St. Louis area who reported various interferences due to sonic booms and resulting annoyance.

| Nature of Interferences Reported | Percentage of Total Interviewed who Reported: Interference | Annoyance |
|---|---|---|
| House shaking | 93 | 38 |
| Startled | 74 | 31 |
| Sleep interrupted | 42 | 22 |
| Rest and relaxation interrupted | 24 | 16 |
| Conversation interrupted | 22 | 10 |
| Radio and television interrupted | 14 | 6 |

track to represent exposures to different sonic-boom intensities. All flights relating to this study were assigned the code name "Bongo."

In order to assure that the sonic booms to be experienced by local residents were well controlled and defined, provisions were made to monitor both the supersonic flights by the aircraft and the magnitude of the sonic booms on the ground. The aircraft were directed from an area north of the city so that steady, level supersonic flight was in a southerly direction across the target area. A radar-control procedure was formulated whereby Bongo aircraft were continuously guided along the flight corridor and a permanent record was made of the plan position and ground speed of the aircraft for each supersonic pass. Observation of these records revealed no maneuvers or quick deviations from the flightpath during the supersonic flights. Maximum lateral deviation of the aircraft from the flight track was only 1¼ miles, a deviation considered negligible for purposes of the community-reaction program.

Sonic-boom pressure measurements were made at recording stations located on the ground track and at lateral distances from it of about 4.5 and 9 miles. The estimated ranges of sonic-boom overpressures as a function of distance from the ground track for Bongo flights are shown in Fig. 2. From these overpressure data, the sonic-boom exposure of any population subsample could be estimated for correlation with the respective interview responses.

Reactions of local residents to the sonic booms as influenced by their attitudes, opinions, socioeconomic factors, the news media, reported damage to personal property, and the like, were evaluated by a carefully designed and executed personal-interview survey.[4] Approximately 1000 households in the various sampling areas participated in a 1- to 1½-h personal interview immediately following the first series of Bongo flights. The purpose of the study was not revealed in the interview, which was described as a broad community survey of how people felt about the communities in which they lived. Respondents were told that the survey would continue for several weeks and the interviewer might call back to obtain additional information.

A second series of special supersonic flights was made over the same ground track about 2 weeks following completion of the initial interviews. These flights were scheduled to provide fewer but more-intense booms than the first series. After the second flight series, callback interviews were begun with respondents who successfully completed the initial interview. A total of 1043 respondents completed both the interview and the reinterview.

The vast majority of formal complaints to the Government about sonic boom prior to 1961 referred to alleged damage to personal property. It appeared that communities might tolerate sonic booms so long as their property was not damaged. Conversely, the overpressure threshold of damage would seem to be an exposure level clearly unacceptable to the population. Consequently, architectural and engineering investigations were made of all reports of alleged damages to property attributed to the study flights. Inspections were accomplished by contractor personnel immediately following the booms with the cooperation and support of experienced U. S. Air Force investigation teams.

Weather information was accumulated to assist in estimating possible influences of various atmospheric conditions on the sonic boom. Weather measurements on the ground and at various altitudes were made as close as possible to the times of the Bongo flights.

## IV. RESULTS

The program was initiated in early November 1961 and was completed by late January 1962. All phases of the flight program, measurement of sonic-boom overpressures, personal interviews, and investigations of alleged damage were accomplished without incident and in accordance with the study design. The objectives of the program were adequately satisfied, although no

[4] P. N. Borsky, "Community Reactions to Sonic Booms," Natl. Opinion Res. Ctr., Chicago, Rept. No. 87 (Aug. 1962).

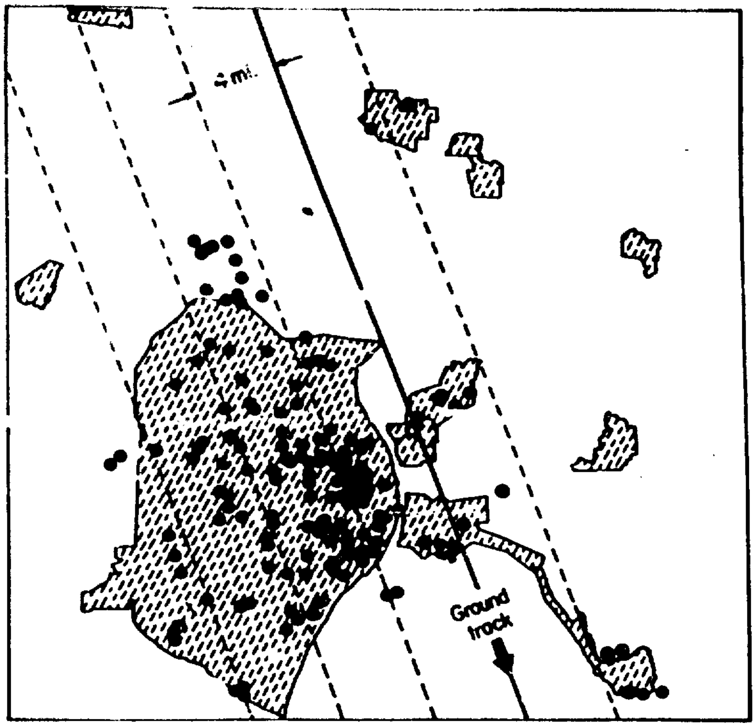


FIG. 3. Sketch of Greater St. Louis area, showing aircraft ground track with locations of reported damage superposed. Data points apply to Bongo flights and indicate locations at which engineering evaluations of reported damage were performed.

issues were completely resolved. The major findings of the program are stated below. More-complete discussions may be found in the basic documents, which are listed as references.

Sonic-boom overpressures recorded in the area were consistent with theory and with the results of earlier studies involving the same type aircraft. The estimated values obtained appear as a function of distance from ground track in Table I. Measured values at a lateral position 5 miles from the flight track were sometimes higher than those directly under the aircraft. However, analysis of weather information obtained during Bongo flights revealed in the atmosphere above the city a localized warm-air region to which the lateral shift in maximum overpressure was attributed.

Sonic-boom exposures measured outdoors in an open area were very different from exposures inside buildings. For a particular sonic boom, inside exposures were lower in intensity, existed for a longer period of time, and were generally more complex in nature than the outside exposures. Subjectively, sonic booms experienced inside were less acceptable than those experienced outside, presumably because of such factors as the longer duration, the rattling and shaking of items within the structure, and the actual vibration of the structure itself.

Community acceptance or tolerance of sonic booms cannot be defined in terms of a single level of overpressure. For practical purposes, there is no overpressure below which all sonic booms will be acceptable nor one below which no responses at all can be assured. When sonic-boom exposure occurs in populated areas, some reaction may be expected. The concept of a single overpressure value as the sole criterion for community acceptance of sonic booms should perhaps be abandoned. Furthermore, overpressure alone does not define sonic-boom exposure; it must be considered in terms of frequency of occurrence, intermittency, time of day or night, duration of the program, and the particular signature of the sonic boom.

Although millions of people were repeatedly exposed to sonic booms over a period of several months, no direct adverse physiological effects occurred and none was expected on the basis of existing knowledge.

Human response or the psychological reaction to sonic boom was shown to be very complex and highly variable, perhaps more so than initially predicted. This response was not a function of overpressure alone but instead involved other elements of the stimulus exposure as well as a wide range of sociopsychological variables.

Almost all local residents experienced interferences with ordinary living activities, yet feelings of annoyance were relatively low. Table II summarizes these findings. Interferences included such observations as shaking of the house, individuals being startled, disturbances to sleep, rest, conversation, and radio or television listening that people reported as interruptions to ordinary living activities. Annoyances, on the other hand, were classified as subjective responses dependent not only upon the

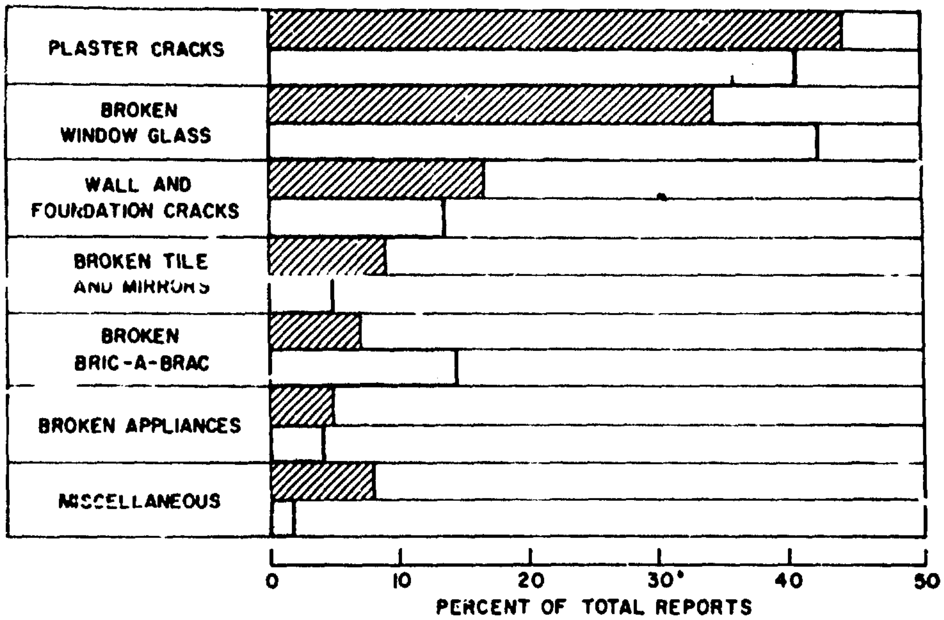


FIG. 4. Types of damage reported and investigated in the St. Louis area. *Hatched area:* Percentage values based on a total of 3114 complaints for which data were available. *Stippled area:* Percentage values based on a total 165 complaints investigated as a result of the Bongo flights.

intensity of the disturbance but also upon a wide range of attitudinal variables. Some of the variables found to be significant in this study were familiarity and understanding of the stimulus phenomenon, necessity and importance of the mission, considerateness and attitude of the aircraft operator, intensity of disturbance and possibility for reducing it, attitude toward neighborhood, general readiness to complain, and damage believed to have occurred to property. Each of these factors may have a positive or negative influence upon the attitude of the respondent. The manner in which the community is predisposed regarding these factors may largely influence the amount of annoyance with the sonic boom that is reported.

Approximately 1000 families had participated in the personal interviews. About 90% of this sample experienced some interference with ordinary living activities as a result of sonic booms, about 35% were annoyed by them, less than 10% contemplated complaint action, and only a fraction of 1% had actually filed a formal complaint.

Complaint activity reflected by the exposed population of about 500 000 families was manifested by telephone calls, letters, and an occasional personal visit to the complaint center at Scott Air Force Base. The cumulative total of complaints recorded at any time was approximately proportional to the total number of supersonic missions completed at that time. About 90% of the complaints about a particular sonic boom were received within 2 weeks of the incident. A large number of the complaints alleged damage to property. Approximately 20% of the recorded complaints resulted in the submission of formal claims to the Government for compensation.

In 1961–1962, few people in the St. Louis area felt that a commercial supersonic transport was very important. Only one-fourth of all persons said it was very important, while almost half said it was not important. Local residents expressed more willingness to accept sonic booms generated by military aircraft than those generated by commercial aircraft. Acceptance of sonic booms during the night was somewhat lower than acceptance of booms during the day. Further definition of the nighttime sonic boom was not possible with the data available.

Reports of alleged damage identified with the Bongo flights were carefully inspected and evaluated.[8] In most cases, these investigations were accomplished within a few hours of the time of the flight. The objectives of such prompt investigation were to evaluate the reported incident, to determine its nature, and to establish its validity as near to the time of actual occurrence as possible. Validity, as used here and elsewhere in this paper, implies that damage to property was caused by sonic booms. Damage to property due to factors other than sonic boom, or for which a clear contribution by sonic boom was not established, was considered not valid in this sense.

Approximately 165 on-site investigations were made at the locations shown in Fig. 3. The range of overpressure (Fig. 2) was essentially the same within the regions 0–8 miles from the flight track and became lower be-

[8] Anon., "Studies of Sonic Boom Induced Damage," Clark, Buhr and Nexsen, Norfolk, Va., NASA CR-227 (May 1965).

TABLE III. Estimated effects of sonic boom on structures and people.

| Sound Overpressure (lb/ft²) | (dyn/cm²) | Predicted Effects |
|---|---|---|
| 0–1 | 0–478 | No damage to ground structures; no significant public reaction, day or night. |
| 1.0–1.5 | 478–717 | No damage to ground structures; probable public reaction. |
| 1.5–1.75 | 717–837 | No damage to ground structures; significant public reaction particularly at night. |
| 1.75–2.0 | 837–957 | No damage to ground structures; significant public reation. |
| 2.0–3.0 | 957–1435 | Incipient damage. |

yond 8 miles. The relative concentration of alleged damage occurrences was much greater within than beyond the 0- to 8-mile distance; however, there was little differentiation between the 0- to 4- and the 4- to 8-mile zones. The types of alleged damage attributed to the flights for which overpressure was measured and which were investigated by contractor effort are summarized in Fig. 4. Types of damage reported in the complaint file at Scott Air Force Base during the entire B-58 program are included for comparison. In general, agreement was good between the alleged damage data accumulated during the 10-month SAC training and during the 2-month study effort.

Investigations and determinations in alleged damage incidents were somewhat difficult. Architectural and engineering criteria upon which to base investigations of sonic-boom damage had not been established. Consequently, evaluations were based upon the technical knowledge, past experience, and best judgment of the investigators. About 35% of the alleged damage incidents reported were obviously false; the sonic boom could not have been the cause. About 45% were judged questionable because of the presence of other contributing factors such as aging of materials, settling of the building, poor workmanship, and the like. In only about 20% of the cases investigated was the reported damage considered possibly valid; no visible contributing factors to the alleged damage existed.

The engineering findings and the complaint-file analysis indicated that damage to structures can occur as a result of sonic-boom exposures within the range experienced and that such damage is an important factor in community acceptance. Damage was superficial in nature, with plaster and glass cracks being most numerous, and was usually associated with stress concentrations in the structure. Contributing factors other than sonic booms were shown in most cases and a large portion of the reported damage incidents were considered probably not valid.

On the basis of only the possibly valid damage incidents, those referred to as superficial in nature, the estimated occurrence of damage incidents per flight per million population was tabulated. For the range of overpressure 0.4–2.3 lb/sq ft, which approximates the range of overpressure called for by a supersonic transport flight régime, a maximum of 0.83 damage incidents per flight per million was calculated.

A portion of the population interviewed was geographically located near the commercial airport and was periodically exposed to jet-aircraft noise. It was found that essentially all respondents who reported that their activities were greatly disturbed by civil jet-aircraft noise reported relatively greater interference and annoyance with sonic booms. Likewise, those who were not disturbed by jet noise were also not disturbed by sonic boom.

Estimated effects on structures and people of exposure to specific ranges of sonic-boom overpressure, as shown in Table III, were used as interim guidelines in planning this study. Although only a limited number of situations were observed in which structures and people responses were correlated with sonic boom, the general predictions of the Table were not contradicted. Findings were consistent with the information contained therein, which was considered the best basis for interim guidelines or estimations available at that time.

## V. SUMMARY

Effects of repeated exposures to sonic booms in the range of overpressures up to 3.1 lb/sq ft on the population and structures of a large city were evaluated. Data were obtained from personal interviews, analysis of complaints, and investigations of alleged damage, and were related to aircraft operations and sonic-boom pressure measurements.

Results indicated that, when sonic booms occur repeatedly over populated areas, some reaction may be expected. The nature of this reaction is complex and highly variable and as such does not lend itself to firm predictive schemes nor inflexible exposure criteria. Alleged building damage was superficial in nature and consisted mostly of cracks in brittle surfaces. There were no reports of direct adverse physiological effects.

## VI. RECOMMENDATIONS

On the basis of the preceding information, it was recommended that—

1. Additional community reaction studies of a similar nature be conducted utilizing larger samples of respondents representing various areas across the country.

2. Reaction to stimulus exposure be further defined in terms of (a) nighttime sonic booms, (b) frequency of occurrence of sonic booms, (c) day-to-day regularity, (d) large supersonic aircraft such as B-70.

3. Responses of structures be further examined (a) as part of future community response studies, and (b) in special studies isolated from populated areas where very intense booms could be utilized.

4. The influence of a public-information program oriented to a commercial supersonic aircraft on reaction to the boom be evaluated in the next study.

## VII. POSTSCRIPT

The reader is reminded that the information and discussion contained in this article reflect the state of the art regarding sonic booms as of the year 1962. It is intended to represent the understanding of sonic boom at that period of time and some of the needs for additional research that were identified. The articles that follow describe the development of the sonic-boom picture since that time.

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13. ABSTRACT

The vicinity of St. Louis, Missouri, was exposed to approximately 150 sonic booms during a 10-month period from July 1961 to April 1962. Ground overpressures, ranging up to about 3 lb/sq ft, were carefully measured for a series of 17 of the supersonic flights. Data obtained from over 2300 direct interviews, analyses of complaints, and engineering evaluations of alleged damage were related to information on aircraft operations and sonic-boom overpressure measurements. Most residents interviewed indicated some interference with routine living activities, yet less than 1% filed formal complaints. Alleged building damage was superficial in nature and consisted mostly of cracks in brittle surfaces. There were no reports of direct adverse physiological effects.

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