NSBEO-1-67

AD 655310

SONIC BOOM EXPERIMENTS AT EDWARDS AIR FORCE BASE

INTERIM REPORT

28 JULY 1967

NATIONAL SONIC BOOM EVALUATION OFFICE
1400 WILSON BOULEVARD
ARLINGTON, VIRGINIA

D D C
AUG 1 1967
E

Prepared under Contract AF 49(638)-1758 by Stanford Research Institute, 333 Ravenswood Avenue, Menlo Park, California.

20040820065

NOTICE

Unless otherwise provided by contract, the Government is not responsible for, nor has any obligation whatsoever respecting the use of, or reliance upon, drawings, specifications or other data contained herein. The fact that the Government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data is not to be regarded by implication or otherwise as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use, or sell any patented invention that may in any way be related thereto.

The information contained herein is a part of the Office of Science and Technology's national sonic boom research program funded by the Federal Aviation Agency under the supersonic transport development program. This research effort was conducted under the Executive Management of the United States Air Force through the National Sonic Boom Evaluation Office with technical support provided by the Department of Defense, the National Aeronautics and Space Administration, the U. S. Department of Agriculture, the Environmental Science Services Administration, and the Federal Aviation Agency. Advice and support were also provided by the National Academy of Sciences.

Qualified requesters may obtain copies of this report from the Defense Documentation Center (DDC), Cameron Station, Building 5, 5010 Duke Street, Alexandria, Virginia, 22314.

This report has been released to the Clearinghouse for Federal Scientific and Technical Information, U. S. Department of Commerce, Springfield, Virginia, 22151, in stock quantities for sale to the general public.

That portion of this report which reflects the views of the contractors does not necessarily reflect the official views or policy of the Government. This report does not constitute a standard, specification or regulation.

Distribution of this document is unlimited.

PAGES_____

ARE

MISSING

IN

ORIGINAL

DOCUMENT

SONIC BOOM EXPERIMENTS AT EDWARDS AIR FORCE BASE

INTERIM REPORT

28 July 1967

NATIONAL SONIC BOOM EVALUATION OFFICE
1400 WILSON BOULEVARD
ARLINGTON, VIRGINIA

Prepared under Contract AF 49(638)-1758 by Stanford Research Institute, 333 Ravenswood Avenue, Menlo Park, California.

FOREWORD

The U.S. Government is actively engaged in an extensive program of research on sonic booms and their effects on people, animals, and structures. A major goal of this research is to provide results that can be extrapolated to the effects to be expected from supersonic transports (SSTs) that are larger, heavier, and generally faster than presently existing supersonic aircraft.

This report presents results to date from experiments conducted at Edwards Air Force Base, California, with F-104, F-106, B-58, SR-71, and XB-70 supersonic aircraft. Because of widespread interest in sonic boom phenomena, this report is published at this time to make available detailed descriptions of the experiments, procedures, and experimental results obtained.

BLANK PAGES
IN THIS
DOCUMENT
WERE NOT
FILMED

CONTENTS

CONTENTS (continued)

CONTENTS (continued)

ILLUSTRATIONS

TABLES

SONIC BOOM EXPERIMENTS AT EDWARDS AIR FORCE BASE
INTERIM REPORT

I INTRODUCTION

A major question in the development of the SST has been the anticipated public reaction to the sonic boom*. To help obtain resolution of this question, the Office of Science and Technology (OST) was requested in the fall of 1965 to develop a program of research on the effects of sonic booms on people, animals, and structures that would supplement and complement previous and ongoing studies related to this problem. For this purpose the OST established a Coordinating Committee on Sonic Boom Studies.

By agreement between the President's Science Advisor and the Chairman of the President's Advisory Committee on Supersonic Transport (PAC/SST), the Secretary of Defense designated the USAF as the OST Committee's implementation agency and program manager. The National Sonic Boom Evaluation Office (NSBEO) was established in the Directorate of Science and Technology, Headquarters, USAF, to implement and manage those research studies approved and recommended by the OST. Stanford Research Institute (SRI) was selected to provide technical assistance for the definition of research problems and the analysis of research findings.

In January 1966 the OST Committee approved a series of experiments to be conducted at Edwards Air Force Base. The general objectives of these experiments were as follows:

1. To measure the judgments of the relative acceptability of sonic booms and noise of various intensities from various types of aircraft. The judgments were to be made by human observers situated both outdoors and in houses.

---

*See Annex I for a general discussion of the nature, generation, and propagation of the sonic boom and of the terms used.

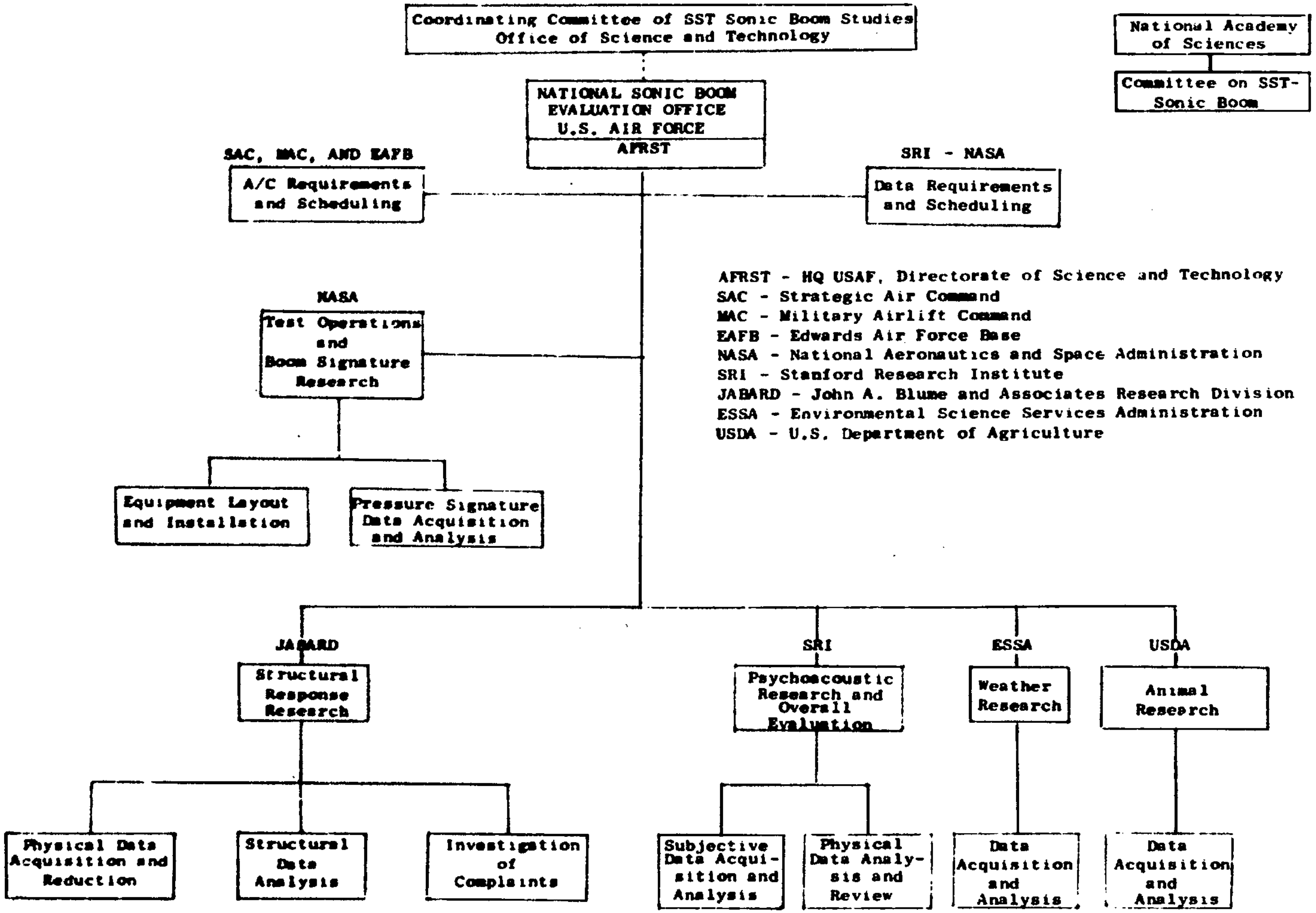
2. To determine the response of "typical" house structures to sonic booms having different signature characteristics.

3. To obtain detailed measures of sonic boom signatures in time and space as functions of the type of aircraft and mode of operation, and the atmosphere and ground through which the wave was propagated.

4. To observe the response of animals to the sonic booms.

Figure 1 is a chart of the organizations involved in the development and conduct of the Edwards experiments; the people involved in the establishment of policy, technical direction, and management of the experiments are listed in Fig. 2. The studies were carried out during the periods from 3 June 1966 to 23 June 1966 (called Phase I) and 31 October 1966 to 17 January 1967 (called Phase II). The interruption in the program from 23 June to 31 October was due to the nonavailability of an XB-70 aircraft during that period.

A detailed summary of the test procedures and requirements for equipment, subjects, facilities, and aircraft and operational support to carry out the experiments is presented in Annex A. Photographs of the test structures, some of the test subjects in one of the test houses, and the aircraft used for the majority of the tests are shown in Figs. 3, 4, and 5, respectively. Figure 6 is a schematic diagram of the test facilities and operations. Tables I and II summarize the number of sonic booms and noises from subsonic aircraft generated for the tests, and Table III shows the status of data reduction completed to date.



AFRST - HQ USAF, Directorate of Science and Technology
SAC - Strategic Air Command
MAC - Military Airlift Command
EAFB - Edwards Air Force Base
NASA - National Aeronautics and Space Administration
SRI - Stanford Research Institute
JABARD - John A. Blume and Associates Research Division
ESSA - Environmental Science Services Administration
USDA - U.S. Department of Agriculture

FIG. 1 ORGANIZATION CHART, EDWARDS AIR FORCE BASE EXPERIMENTS

OST COORDINATING COMMITTEE ON SONIC BOOM STUDIES

MEMBERS

Dr. Donald F. Hornig, CHAIRMAN
Dr. Nicholas E. Golovin, DEPUTY CHAIRMAN
Major General J. C. Maxwell, FAA
Brigadier General E. B. Giller, USAF
Dr. Charles E. Hutchinson, USAF
Mr. A. J. Evans, NASA
Dr. Arnold Moore, Ofc. Sec. of Defense
Mr. Bascom N. Lockett, Jr., FAA

PARTICIPANTS AND CONSULTANTS

(National Academy of Sciences Committee on Sonic Boom)

Dr. John R. Dunning
Dr. Everett F. Cox
Mr. Richard H. Tatlow, III
Dr. William Littlewood
Professor Raymond A. Bauer
Professor William D. Neff

OBSERVERS

Government

Mr. John Steadman
Ofc. Secretary of Defense
Mr. Walter Boehner
Bureau of Budget
Dr. Dan J. Edwards
U.S. Treasury

National Academy of Sciences

Colonel John P. Taylor, USAF, Ret.
Mr. Richard Park
Dr. Lauriston S. Taylor
Dr. Milton A. Whitcomb
Dr. Donald M. Weinroth

NATIONAL SONIC BOOM EVALUATION OFFICE

Brigadier General E. B. Giller
Executive Manager

Colonel Charles R. Foster
Deputy Executive Manager

Lt. Colonel David C. Lillard, Jr.
Assistant Deputy Executive Manager

Dr. Charles E. Hutchinson
Technical Director

Lt. Colonel Robert L. Atwood
Legal Director

Lt. Colonel William P. Dent
Information Officer

Lt. Colonel Robert R. Bartholomew
Operations Director

Mr. Kenton W. Morris
Financial Director

FIG. 2 EXECUTIVE MANAGEMENT AND TECHNICAL COORDINATION PERSONNEL FOR THE NATIONAL SONIC BOOM EVALUATION PROGRAM

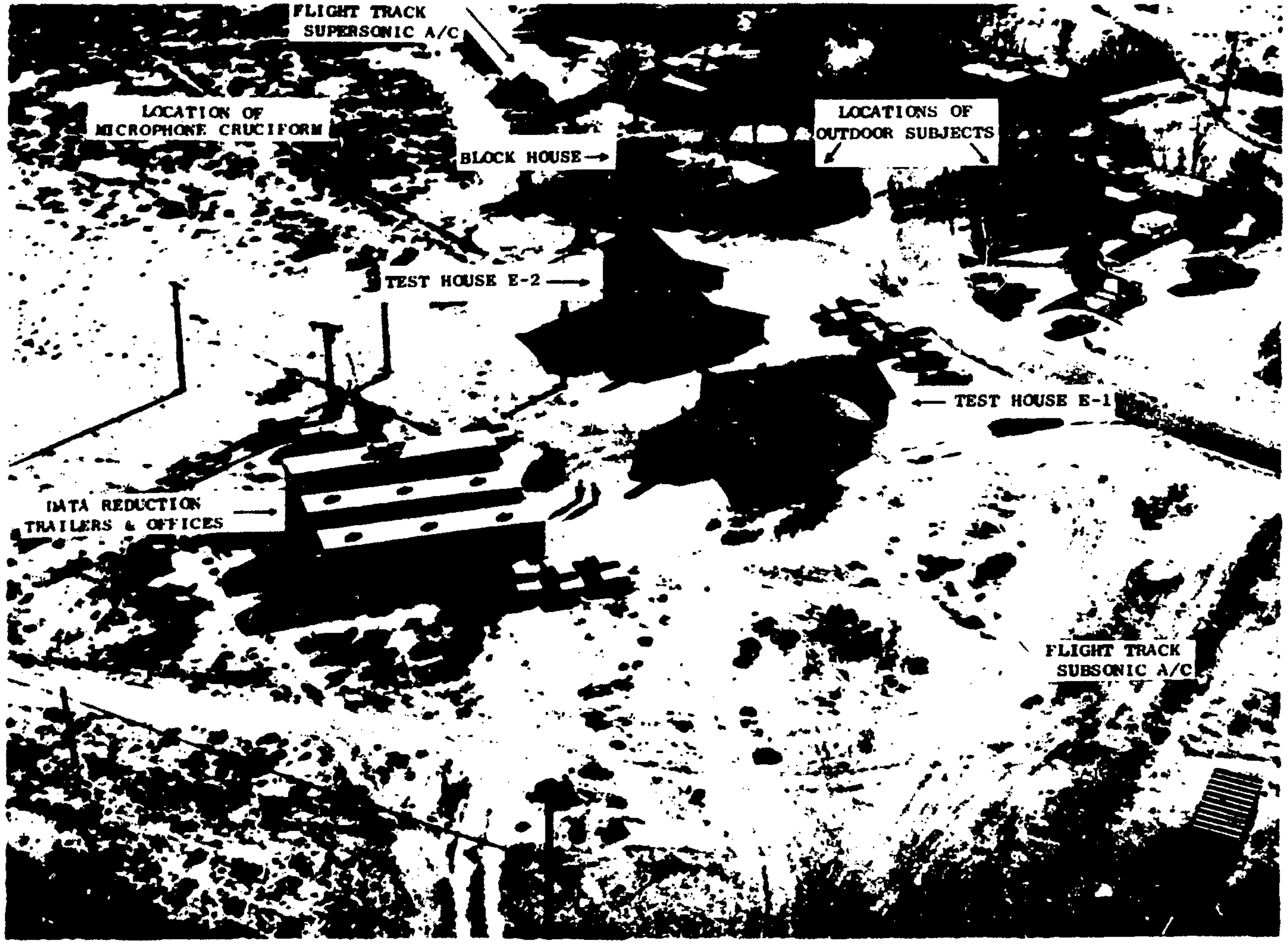
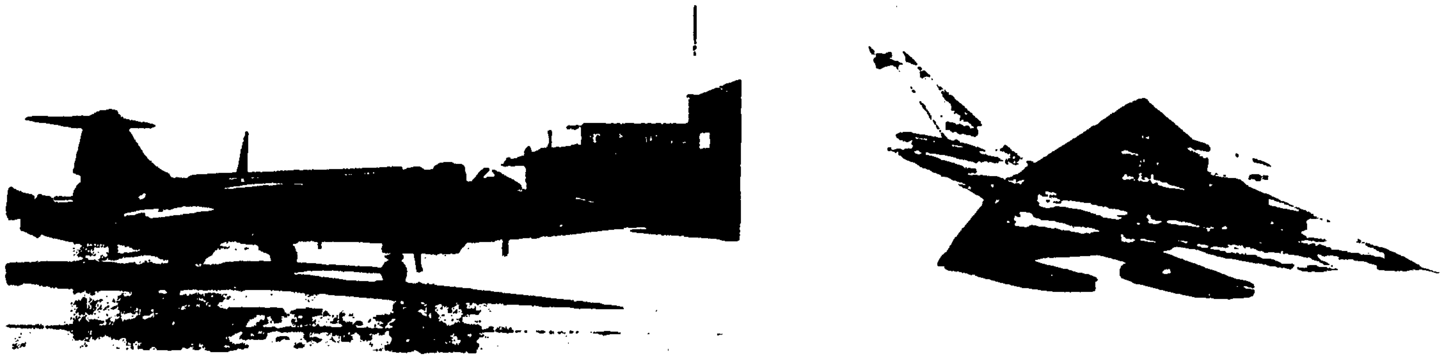


FIG. 3 PHOTOGRAPH OF TEST AREA SHOWING TYPE OF TERRAIN AND TEST STRUCTURES

FAMILY ROOM-KITCHEN E-2

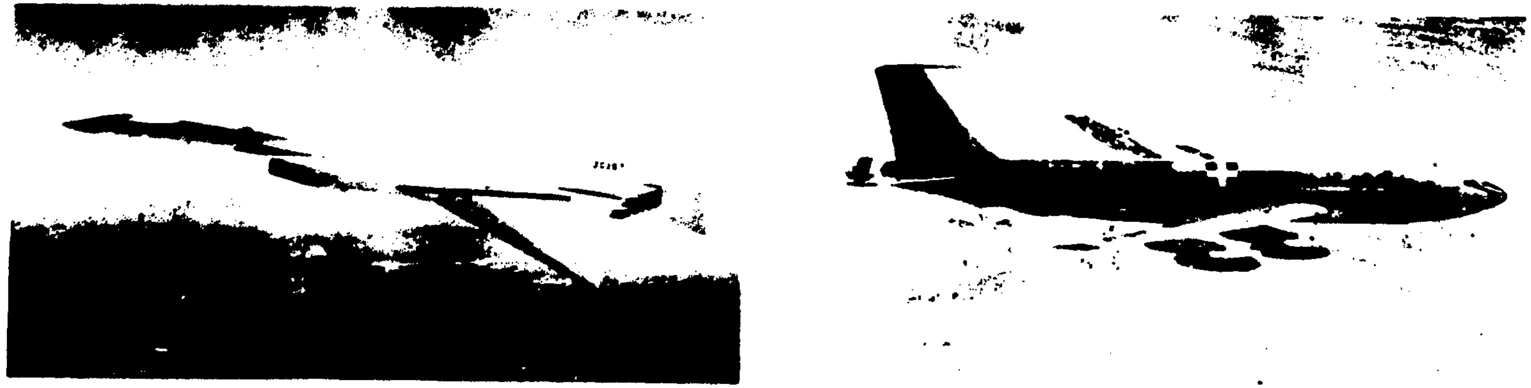
DINING ROOM E-2

FIG. 4 TEST SUBJECTS



(a) F-104

(b) B-58



(c) XB-70

(d) KC-135

FIG. 5 PHOTOGRAPHS OF AIRCRAFT USED IN MAJORITY OF THE TESTS

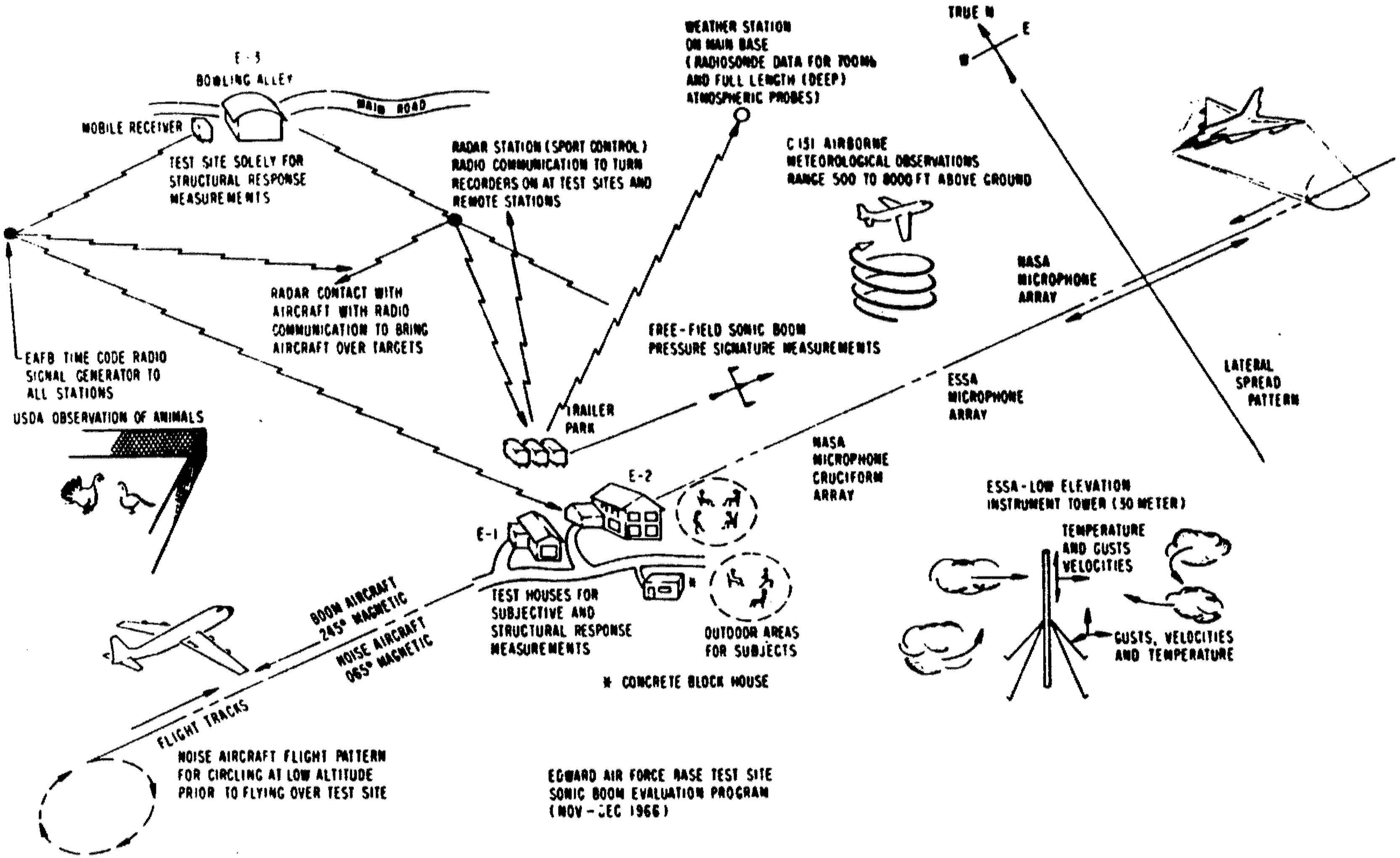


FIG. 6 SKETCH OF ACTIVITIES DURING SONIC BOOM TESTING (Arrows indicate flight tracks used for tests, except for 4 XB-70 flights flown offset 13 statute miles and certain B-58 flights flown offset 5 statute miles.)

Table I

EDWARDS EXPERIMENT PHASE I - JUNE 1966

NUMBER OF OVERFLIGHTS BY AIRCRAFT TYPE

SUPERSONIC		SUBSONIC	
YF-12	2	KC-135	99
SR-71	3	WC-135B	24
XB-70	3	BLIMP	6
B-58	100		
F-104	39		
F-106	18		
TOTAL	165	TOTAL	129

Table II

EDWARDS EXPERIMENT PHASE II - OCTOBER 1966 to JANUARY 1967

NUMBER OF OVERFLIGHTS BY AIRCRAFT TYPE

SUPERSONIC		SUBSONIC	
XB-70	17	C-131B	19
F-104	85	WC-135B	95
B-58	69	Cessna 150	18
SR-71	31		
TOTAL	202	TOTAL	132

Table III

STATUS OF DATA REDUCTION

		Percentage of Data Reduced to Date and in This Report
I	Psychological Data	
	A. Except for 20 judgment tests conducted outdoors on a special desert test site, all the psychological data have been analyzed and are related in Annex B to the nominal and measured peak overpressures of the sonic booms and the intensity (PNdB) of subsonic aircraft noise.	95%
	B. The results of the psychological tests will be related later to measures of structural response as appropriate and to physical measures other than peak overpressure and peak PNdB.	0%
II	Sonic Boom and Subsonic Aircraft Noise Generation and Propagation Data	50%
	Reported in Annexes B, C, E, and F.	
III	Structural Response Data	30%
	Reported in Annex G.	
IV	Meterological Data	20%
	Reported in Annex D.	
V	Animal Response Data	100%
	Reported in Annex H.	

II SUMMARY OF RATIONALE, PROCEDURES, AND RESULTS TO DATE

A. Psychological Experiments

The psychological studies were designed with the following conditions and assumptions in mind:

1. Subjects should be located both outdoors and in houses that would be "typical" for midwest USA, 1975, this being the area of the country that would most likely be exposed to sonic booms from proposed transcontinental SSTs.
2. Subjects would be adult males and females (the majority being housewives), and several hundred such subjects would be used.
3. The primary judgments to be made would be "relative" judgments of the acceptability of one sonic boom versus another sonic boom or of a sonic boom versus the noise from a subsonic aircraft. The rationale was that relative judgments allow the measurement of the effects upon listeners of variations in the physical characteristics of the sound and permit relating the subjective effects of one type of sound, such as a sonic boom, to those effects of a second sound, such as the noise from a subsonic aircraft. The results would presumably provide: (1) a "calibration" of human response in terms of different sonic boom physical parameters and signature types, and (2) a possible insight into how people will respond to sonic booms in real life. Information is already available as to how people respond in real life to subsonic aircraft noise.
4. The sonic booms and the noise from subsonic aircraft were to be presented to subjects who had been habitually exposed to sonic booms, such as those in the residential area at Edwards Air Force Base, and to subjects not usually exposed to sonic booms and aircraft noise, such as those from the towns of Fontana and Redlands, California.

5. The subjective judgments were to be made of sonic booms whose "nominal"* peak overpressure level varied from 0.75 pounds per square foot (psf) to 3.0 psf, whose duration varied from 0.075 to 0.3 sec, and whose speed across the ground varied from about 900 to 1700 mph. To obtain the desired ranges of speed, duration, overpressure, and near-field and far-field boom signatures, three types of supersonic aircraft (F-104, B-58, and XB-70) were used. Unfortunately, it was not always possible to vary independently these various parameters because of inherent limitations in the operating characteristics of the aircraft. Flyover noise from subsonic aircraft was obtained from 4-engined turbojets without noise suppressors and from 4-engined turbofan aircraft when operating with landing power and with takeoff power; the intensity levels of the noise were varied from about 90 to 125 PNdB.**

Detailed results of the psychological studies and their relation to the physical characteristics of the various sonic booms and noise from subsonic aircraft, insofar as present physical analysis of data will permit, will be found in Annex B. The intensities of the sonic booms are given in the following summary in terms of the nominal peak over-

---

* Nominal peak overpressure (or some other nominal physical parameter) of a boom is that to be expected on the basis of theory concerning the generation and propagation of sonic booms. Accordingly, the word nominal serves as a short and succinct way of labeling the aircraft operations, i.e., stating that a boom from a given aircraft will have a given nominal peak overpressure specifies, for practical purposes, the altitude, Mach, and weight at which the given aircraft will be operated. For further definition of nominal peak overpressure see Annex B, page 25.

** PNdB is a unit that indicates the intensities of a noise on a scale that approximates the response of the human auditory system. The PNdB values herein reported are the peak levels reached by the noise when flying over the subjects. The PNdB values are determined from sound level meter measurements of the noise after the noise has been filtered into 1/3 or full octave bands.

pressures; the results of the psychological tests will be compared, in a later report, to various other physical measurements of the booms, including total energy and energy in various portions of the spectrum.

Summary of Results of Psychological Experiments

To date the major findings from analysis of the results obtained for the subjects and listening conditions involved in these experiments are as follows:

1. Sonic Boom from B-58 Judged against Noise from Subsonic Aircraft
    - (a) When indoors, subjects from Edwards Air Force Base judged booms from the B-58 at 1.69 psf nominal peak overpressure outdoors to be as acceptable as the noise from a subsonic jet at an intensity of 109 PNdB* measured outdoors.
    - (b) When indoors, subjects from the towns of Fontana and Redlands judged the boom from the B-58 at 1.69 psf nominal peak overpressure outdoors to be as acceptable as the noise from a subsonic jet at an intensity of 118 to 119 PNdB** measured outdoors.
    - (c) The booms heard outdoors from the B-58 at 1.69 psf nominal peak overpressure were judged to be as acceptable as the noise heard outdoors from a subsonic jet at 105 PNdB, 111 PNdB, and 108 PNdB by subjects from Edwards Air Force Base, Fontana, and Redlands, respectively.

---

* Noises having these PNdB values would be generated on the ground directly under the flight path of a turbofan aircraft at an altitude of 800 or 1400 ft, depending on whether landing or takeoff engine power settings were used.

** Noises having these PNdB values would be generated on the ground directly under the flight path of a turbofan aircraft at an altitude of 300 or 600 ft, depending on whether landing or takeoff engine power settings were used.

(d) When indoors, 27 percent of the subjects from Edwards and 40 percent of the subjects from Fontana and Redlands, combined, rated the B-58 booms of nominal peak overpressure of 1.69 psf as being between less than "just acceptable" to "unacceptable."

(e) When outdoors, 33 percent of the subjects from Edwards and 39 percent of the subjects from Fontana and Redlands, combined, rated the B-58 booms of nominal peak overpressure of 1.69 psf as being between less than "just acceptable" to "unacceptable."

(f) Residents of Edwards Air Force Base who served as subjects had been in residence there for an average of two years and had been exposed during that period to about 4 to 8 booms per day of median nominal peak overpressure of 1.2 psf and to subsonic aircraft noise having peak PNdB levels of about 110 PNdB The towns of Fontana and Redlands, on the other hand, were not under or near the flight track of supersonic aircraft and were occasionally exposed to noise of subsonic aircraft at a peak level of about 95 to 100 PNdB.

2. <u>Acceptability of Sonic Booms from Different Military Aircraft</u>

(a) When of approximately equal nominal or measured peak overpressure and when heard indoors and judged against the aircraft noise, the boom from the XB-70 was slightly less acceptable than the booms from the F-104 or B-58 aircraft. When heard outdoors and judged against aircraft noise, the boom from the B-58 was slightly less acceptable than the booms from the XB-70 and F-104 aircraft.

(b) When one type of boom was judged against another type of boom at equal nominal peak overpressure, no significant difference in their acceptability was measured in these tests.

3. Acceptability of Booms and Aircraft Noise as a Function of Their Intensity

The unacceptability of sonic booms, as a function of intensity increases at about half again as fast a rate as does the unacceptability of the noise from subsonic aircraft; i.e., in terms of judged unacceptability, an increase of 10 PNdB in intensity of a noise from a subsonic aircraft was equivalent to about a 6-dB increase (from 1 psf to 2 psf) in the intensity of a sonic boom.

4. Acceptability of Booms or Noises for Indoor Listening Compared to Outdoor Listening

The results averaged over all tests indicates that both the booms and particularly the noise were rated slightly more unacceptable by the listeners outdoors than by the listeners indoors.* Also, the precision of the judgments and rate of growth of unacceptability as a function of the intensity of the booms or noise was about 50 percent greater for listeners outdoors than indoors.

5. Subsonic Aircraft Noise

The results obtained when sonic booms were judged against the noise from either turbojet or turbofan subsonic aircraft were comparable, provided the aircraft noise had about the same peak PNdB value. Also, noise from turbojet aircraft was generally judged to be equal in acceptability to noise from turbofan aircraft when the noises had the same PNdB value except when landing power was used and listeners were outdoors.

6. Discrimination of Intensity Differences in Booms and Subsonic Aircraft Noise

(a) On the average, two booms were judged to be significantly different in acceptability when their nominal or measured

---

*The intensity of the noise from the subsonic aircraft is reduced more than the intensity of the booms as the result of passing through the roof and walls of a house because the typical house attenuates the higher sound frequencies (where most of the energy of the aircraft noise is located) more than the lower sound frequencies (where most of the energy of the sonic boom is located). Probably, at least partly for this reason, the boom is rated less favorably relative to the noise of an aircraft when heard indoors than outdoors.

peak overpressures differed by about 1 dB, and by about 2 dB when the two booms were compared against a reference aircraft noise.

(b) On the average, two aircraft noises were judged to be significantly different in acceptability when they differed by about 2 PNdB, and by about 4 PNdB when the two aircraft noises were compared against a reference boom.

7. Differences in Judgments of Subjects Located in Different Rooms and When on Vibration Isolation Pads

Systematic differences were found among some of the subgroups of subjects located in different rooms in the test houses. When some of the subjects were exchanged among rooms, it was found that some of the differences in judgment were due to the test rooms and not to the subjects.

Placing the indoor and outdoor subjects on vibration isolation pads did not significantly change their judgments of the sonic booms relative to the noise from the subsonic aircraft.

8. Attitude Survey

An attitude survey of residents (15 percent of whom served as subjects in these experiments) at Edwards Air Force Base revealed that 26 percent rated the boom environment as being between less than "just acceptable" to "unacceptable" for the month of June, when there was an average of about 10 booms per day at a median nominal peak overpressure of about 1.69 psf. Fourteen percent of the residents also rated the boom environment prior to June as being between less than "just acceptable" to "unacceptable." During this previous period, there were about 4 to 8 booms per day at the median nominal boom level of 1.2 psf. Six percent rated the ambient daily aircraft noise and seven percent rated the street noise as being between less than "just acceptable" to "unacceptable."

9. Age and Sex of Subjects

Within the adult population studied, age and sex are not statistically significant factors in the ratings or paired-comparison of the unacceptability of sonic booms or the aircraft noises.

B. Propagation of Sonic Boom through the Air and Ground

On the basis of theory about the generation and propagation of sonic booms, certain "nominal" or expected sonic boom signatures were predicted for the various supersonic aircraft flying under different conditions and procedures. The overflights made for the psychological tests were designed in conjunction with the requirements for research on propagation and generation of sonic booms and provided the conditions necessary to validate and further develop generation and propagation theory. In addition, a number of supersonic flights were carried out for the sole purpose of making certain physical measurements of sonic boom propagation phenomena. The physical data from this aspect of the program that have been analyzed to date are presented in Annex C.

Much of the commonly observed variation in sonic boom signatures has been assumed to be the result of atmospheric action upon the shock wave passing through the air. The effects of the atmosphere on sonic boom propagation were studied in a program developed by ESSA. The program included: (1) detailed low-level turbulence statistics in the immediate area of surface overpressure measurements, (2) data on existence of waves on lower troposphere inversion surfaces as a possible mechanism for selective focusing of sonic booms, and (3) the area distribution and variability of overpressure by means of microphone grid arrays of two different intervals of spacing (50 and 200 ft). The meteorological and overpressure data obtained have not yet been correlated. Research data on atmospheric inhomogeneities were collected at Edwards and are reported in Annex D.

Seismic waves excited by sonic booms may also cause structural and subjective response. Seismic waves produced by sonic booms were measured and the results of these measurements will be found in Annex E.

Summary of Results on Propagation

Free-field sonic boom overpressure data were obtained by NASA for a series of 25 flights[*] of the XB-70 airplane. For cases where a large number of overpressure data points are available, the average measured values correlate well with current prediction theory. Variations in the signature shapes and the associated variations in overpressures, impulses, and time durations are similar in nature to those observed previously for smaller airplanes. Overpressure measurements obtained at a distance of 13 miles from the flight track show larger variability than those measurements made on the flight track. This increasing variability with distance from the flight track is also consistent with results of previous flight tests. Variability in the measured boom quantities are markedly greater in the June measuring period than in the November through January period, and this is believed to be related to atmospheric effects since reduced convective heating in the lower layers of the atmosphere is present during the winter. Sonic boom measurements made at 2000 feet in a Goodyear blimp showed that the lowest 2000 feet of the atmosphere is the most influential cause of variations produced by the atmosphere. In some cases, higher portions of the atmosphere may also be important. Ground measurements were made of sonic booms from a specially instrumented F-106 aircraft flown in smooth flight and in porpoising flight over an array of microphones. Aircraft motions of the F-106 were shown not to contribute significantly to observed sonic boom signature variations. A larger airplane has a sonic boom that depends relatively more on its lift, so motions of an SST in flight may still lead to significant variations in the sonic boom. Some differences in overpressure due to vortices in the air caused by subsonic aircraft flying through the boom path were noted.

---

[*] Some flights in addition to those involved in the Edwards Sonic Boom Tests are included.

Measurements were made by Geotech, under contract to NASA, of the seismic waves induced in the ground by sonic booms. The maximum ground particle velocity observed from a boom of 2.0 psf measured peak overpressure was less than 1 percent of the damage threshold criterion now recommended by the U.S. Bureau of Mines. Further analysis of the data and a seismic refraction survey of the local geology are required to obtain a more complete understanding of the mechanism by which seismic motion is produced in the ground by air shock waves.

C. Energy Spectra of Sonic Booms

Sonic booms have been typically measured in terms of peak overpressure, duration, impulse energy, "effective" overpressure, and rise time. Waves have been classified as rounded, peaked, etc. Since most of the information reflected in the various measures mentioned above is in the energy spectra of the boom signatures, it is likely that this property of the signatures may be more meaningful and helpful than any one of the various measures heretofore used. Therefore, part of the physical data analysis will be concerned with the question of what portions of the energy spectra are most highly correlated with the response of people or structures to sonic booms. The correlations between the various portions of the energy spectra and psychological response data are to be determined. Of possible theoretical and practical significance are the differences in the deviations from median values of ΔP and energies in various frequency bands as measured by five microphones recording the same event. Energy spectra obtained from each of five microphones for 16 B-58 flights occurring on 8 November 1966 and 8 December 1966, and for four flights involving XB-70, B-58, and F-104 aircraft are reported in Annex F.

Summary of Results on Energy Spectra

Theoretical properties of the energy spectral density function of the sonic boom have been compared to properties obtained from spectra calculated from actual booms, and good agreement and consistency have been found. In general, the experimental data indicate that all parts of the energy spectrum are correlated with observed variations of the peak overpressure (ΔP); the best correlations of ΔP occur with the energy in the frequency band 20 to 200 Hz* (E_{20-200}) and the band 20 to 1000 Hz ($E_{20-1000}$); energy in the band 0 to 50 Hz (E_{0-50}) is most independent of variations in ΔP for a series of 16 nominally similar events. Correlations of energy band content with rise time are poorer, though still significant; E_{20-200} and $E_{20-1000}$ correlate best with rise time and E_{0-50} correlates least with rise time.

For three comparable flights of XB-70, B-58, and F-104 aircraft, the energy band content for all bands, save the 10-30 Hz band, ranks downward in the order listed. In the band 10-30 Hz, the F-104 aircraft has the highest energy content by what appears to be something in excess of 2 dB relative to the XB-70. This particular result is consistent with the energy-spectral-lobe patterns of the sonic boom spectra of these aircraft, which in turn is associated with the differing sonic boom duration paramaters.

The least variability among the five microphones is observed in the energy measures E_{0-50}, E_{0-200}, E_{0-1000}, and E_{total}; the greatest variability is observed in ΔP and the energy measures E_{20-200} and $E_{20-1000}$.

D. Response of Structures

The structural response portion of the Edwards Experiment was designed to meet certain objectives:

1. Determine the response or reaction of structures to sonic booms generated by XB-70, B-58, and F-104 aircraft
2. Investigate any damage resulting from these sonic booms
3. Develop a means of predicting structural response and possible damage from sonic boom generated by the SST based on data from present aircraft.

---

*Hz = cycles per second

With these objectives in mind, two test house structures and the Bowling Alley at Edwards Air Force Base, and a two-story house structure in Lancaster, California, were instrumented.

Instruments were installed to measure the following: acceleration and displacements of the structures and various structural elements; acoustic levels and variations in levels at different locations in the test house structures; strain (compressive or tensile) of certain elements of structures such as windows; and overpressure levels on the exterior and interior of the structures.

In addition to the above physical measurements, a survey of all glass windows at Edwards Air Force Base was conducted prior to start of test overflights. All complaints of damage to residences and structures at Edwards Air Force Base and the surrounding area were investigated as soon as possible after being received.

Preliminary data and results are discussed in Annex G.* A summary of damage complaints and results of investigations is also presented.

<u>Summary of Results on Response of Structures</u>

The analysis of structural response data and the investigation of methods for predicting structural damage are in progress. The preliminary findings are as follows:

1. Sonic booms from large aircraft such as the XB-70 and the future Supersonic Transport will affect a greater range of structural elements (those elements responsive to frequencies below approximately 5 Hz) than will sonic booms from smaller aircraft such as the B-58 and F-104; these results are predictable from

---

*In addition to the data reported in Annex G the Department of Agriculture also made measurements of pressure differentials across house walls and plywood panels erected across the path of the sonic boom. In addition, "fatigue" of nail joints in the plywood panels due to sonic booms was also evaluated. At the present time these data have not been fully analyzed and evaluated. It is anticipated that in the near future the U.S. Department of Agriculture will publish a report on the results obtained from their measurements.

a knowledge of the characteristics of the boom signature and the response characteristics of the structural elements.

2. No damage that could be attributed to sonic booms was observed in the test structures during these experiments. However, some damage was alleged to have been caused by sonic booms in the vicinity of Edwards Air Force Base during the period of these tests. Fifty-seven complaints were received, which resulted in the filing of 19 claims against the Government for alleged sonic boom damage.

3. Three reports were received of glass damage to structures at Edwards Air Force Base that could be attributed to sonic booms from flights conducted for these experiments.

E. Response of Farm Animals to Sonic Booms

The U.S. Department of Agriculture observed the response of various animals on farms located near Edwards Air Force Base during the sonic boom tests conducted during June 1966. The results of their observations are reported in Annex H.

Summary of Results of Response of Farm Animals to Sonic Booms

1. The observed behavior reactions of animals to the sonic booms were minimal except for the avian species. Also, the reactions were more pronounced to noise from low-flying subsonic aircraft than to booms. Furthermore, the reactions were of similar magnitude and nature to those resulting from flying paper, the presence of strange persons, or other moving objects. For these reasons, a strong relationship between observed behavior reactions and possible herd or flock production depression is very unlikely.

2. Although no significant changes were noted in production, these tests were not adequate to produce any conclusive evidence on this aspect of sonic boom effects. The number of farms available was insufficient for evaluating production effects and the

location of those available was not suitable for proper evaluation.

3. It is also to be noted that the area around Edwards Air Force Base has been exposed to about 4-8 sonic booms per day for the past several years. Therefore, some of the farm animals may have become considerably "adapted" to sonic booms prior to these tests.

Annex A

CONTENTS

ILLUSTRATIONS

TABLES

Annex A

OPERATIONAL TEST PLAN FOR SONIC BOOM EXPERIMENTS AT EDWARDS AIR FORCE BASE

INTRODUCTION

A. Background

This operational Test Plan defines the initial requirements, responsibilities, and functional procedures for accomplishment of the Edwards Air Force Base Experiment. Phase I was carried out from June 4, 1966 to June 23, 1966, with a total of 165 sonic booms, and 129 subsonic flights. Phase II operations commenced on October 31, 1966, and were completed January 17, 1967, with a total of 202 sonic booms and 132 subsonic overflights.

B. Specific Tasks

The specific tasks in support of the general objectives were:

1. To determine the subjective reaction caused by sonic booms generated by XB-70, B-58, and F-104 aircraft.
2. To establish the acceptability of subsonic noise (KC-135 and WC-135B) versus sonic boom (B-58) to test subjects chosen from residents of Edwards Air Force Base and from civilian communities.
3. To perform a subsonic jet noise versus sonic boom subjective reaction study with F-104, XB-70, and WC-135B aircraft.
4. To determine the relations between various measures of the physical characteristics of the acoustic and vibrational signals reaching the subjects located in the test houses and outdoors as the result of sonic booms and aircraft noise.
5. To obtain subjective response data to sonic booms from separate groups of subjects located within 10 ft or so of each of 6 microphones located at various intervals along a straight 8000-ft line under the flight path of an F-104.

6. To determine the relationship between structural response and sonic booms of various signature characteristics.

7. To obtain statistical data regarding variations of signature shape (overpressure, rise time, etc.) at various measuring stations along lines parallel with and perpendicular to the flight track.

8. Verification and improvement on the general solution for predicting sonic boom overpressures and signature shapes for aircraft of the SST class through the use of SB-70 and SR-71 aircraft as research vehicles.

9. To study the atmospheric effects on sonic boom signature propagation.

10. To perform seismic investigation at Edwards, as well as over specially instrumented arrays in Utah and Arizona, to determine the contribution of seismic effects to total structural response.

11. To conduct some special experiments relating to the test structures; specifically, Helmholtz resonator studies, use of a sonic boom shock tube simulator, and shaker tests of the test structure at various attachment points.

12. To observe the behavior of farm animals subjected to sonic booms.

C. Work Assignments

The following general assignments of tasks were made for the experiments.

- NASA to specify, following consultation with the Air Force for operational practicability, the experiments that are concerned with the generation and propagation of sonic booms through the atmosphere.
- ESSA to specify, following consultation with NASA and the Air Force for operational practicability, the experiments that are concerned with the effects of weather and the atmosphere upon the propagation of sonic booms.
- Stanford Research Institute (SRI) to specify, following consultation with NASA and the Air Force for operational practicability, the experiments that are concerned with subjective reactions to sonic booms and subsonic aircraft noise.

- John A. Blume and Associates Research Division (JABARD) to specify, following consultation with NASA and the Air Force for operational practicability, the studies that are concerned with structural response.
- NASA to install instrumentation and make structural response measurements during Phase I. During Phase II, responsibility for all structural response instrumentation operations to be assumed by JABARD, including previously installed NASA-owned instrumentation in all test structures.
- NASA to be responsible for supervision and coordination of all sonic boom signature measurements not involving test structures.
- Instrumentation to be provided by the Boeing Company to augment the NASA-installed instrumentation of test structures. Lockheed-California Company (LAC) instrumentation to be utilized, under the supervision and coordination of NASA, in conjunction with the experiments to be conducted to satisfy the ESSA requirements. Boeing and Lockheed to operate under subcontract with JABARD.
- Structural response instrumentation and its operation to be provided during Phase I for test house in Lancaster, and some instrumentation in one test house at Edwards by Datacraft Company operating under subcontract with JABARD.
- Seismic measurements to be obtained by the Geotech personnel at Edwards Air Force Base during this test period. Additional measurements in Utah and Arizona to be made at the conclusion of the flight operations at Edwards. This study to be accomplished under contract to and supervision of NASA.
- Measurements of building response to shaker tests to be recorded by JABARD and the information made available to NASA. NASA to supply shakers and personnel for the operation; these operations to be conducted toward the end of the sonic boom program.
- Measurements of building response to shock tube "firings" to be recorded by JABARD and the information made available to NASA. Subjective response measurements to shock tube firings

to be made by SRI and the information made available to NASA. Ling-Temco-Vought (LTV), through NASA-LRC, to supply shock tube simulator and personnel for the operation; these operations were to be conducted toward the end of the sonic boom program.

- ESSA to provide all technical and supervisory personnel required to man their instrumentation. Additional instrumentation to be provided through JABARD and a USAF specially-instrumented C-131 aircraft. A Cessna 150 light aircraft was also instrumented by ESSA to more accurately probe the structure of the low-level temperature inversion.
- Aircraft support to consist of the XB-70 and B-58's, F-104's, WC-135B's, and C-131's from their respective home stations. Some aircraft to recover at Edwards Air Force Base for subsequent launch, while others to return with air refueling. In addition to the AFSC B-58 based at Edwards Air Force Base, SAC was to provide support to assure B-58 capability for each XB-70 flight. Control timing to be as outlined in SAC Operations Plan. F-104's to be provided by AFSC in accordance with a prearranged schedule. WC-135B aircraft to be provided by MAC 9th Weather Squadron at McClellan Air Force Base, California.
- USDA to provide all technical and supervisory personnel for the observation, recording, and analysis of the response to sonic booms of animals located on selected farms near Edwards AFB.

D. Data Reduction and Dissemination Responsibility

NASA was responsible for the analysis, interpretation, and documentation of all pressure data concerned with the generation and propagation through the atmosphere of the sonic booms. Publication of pressure data as required by ESSA, SRI, and JABARD was coordinated with NASA to insure best and most uniform presentation of these data.

JABARD provided preliminary reduction of structural response data, digitization of free-field pressure signature data, computer print-outs of mission logs and free-field pressure data, digitization of certain structural response data, and duplicate tapes of certain raw data records.

JABARD was responsible for disseminating raw instrument data from the test structures, computer print-outs, and digitized free-field and structural response data.

SRI digitized and analyzed all acoustic and structural response recordings data, which were to be correlated with the subjective response data, and correlated and interpreted the subjective response data, with respect to outdoor and indoor physical measures of sonic booms and aircraft noise. In addition, SRI is responsible for providing an overall assessment and evaluation of the Edwards Air Force Base sonic boom experiments.

II EXPERIMENTAL LAYOUT

A. General Layout of Test Areas

The general layout of the test area showing deployment of the sonic boom measuring stations and flight track is shown in Fig. A-1.

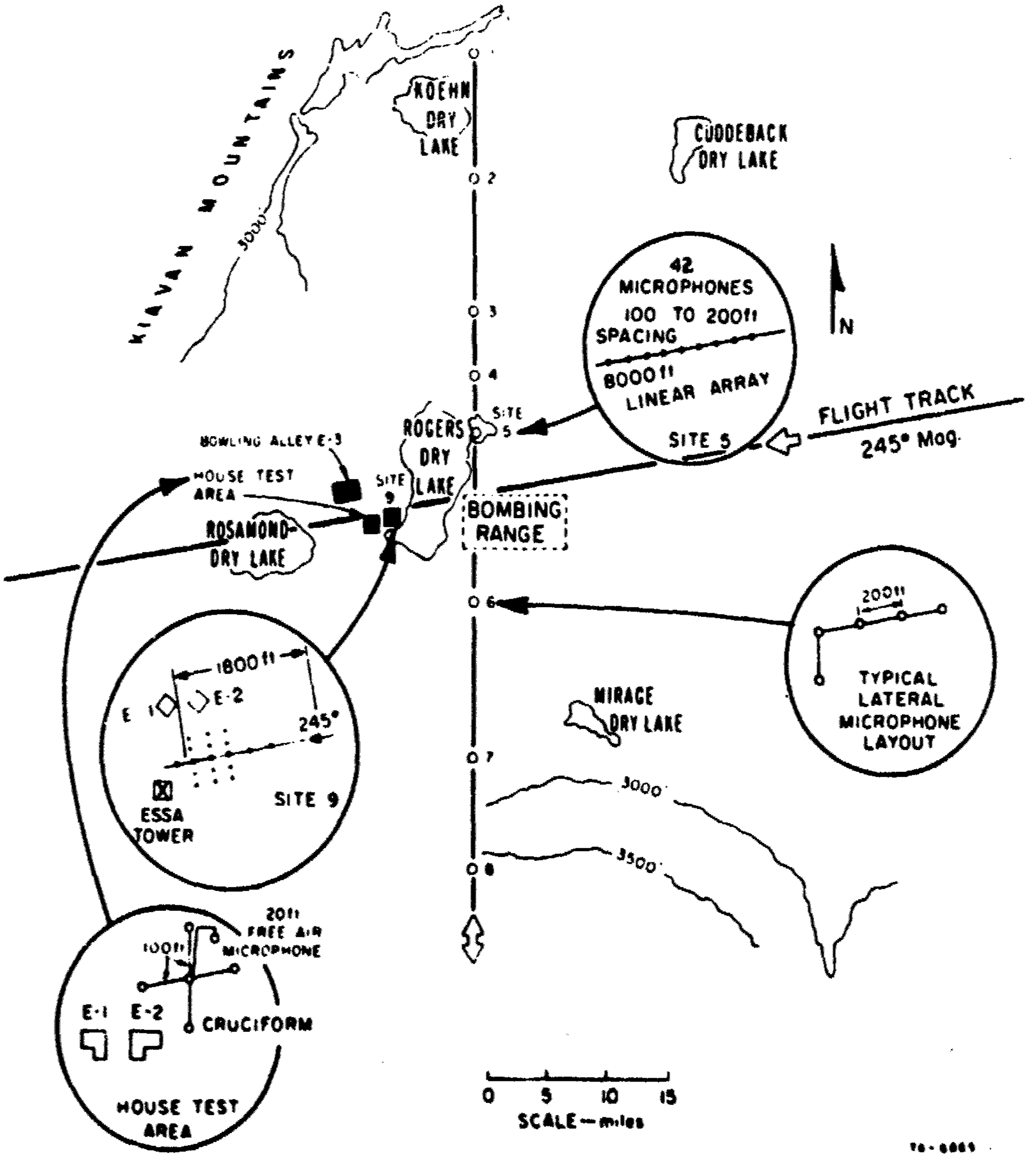
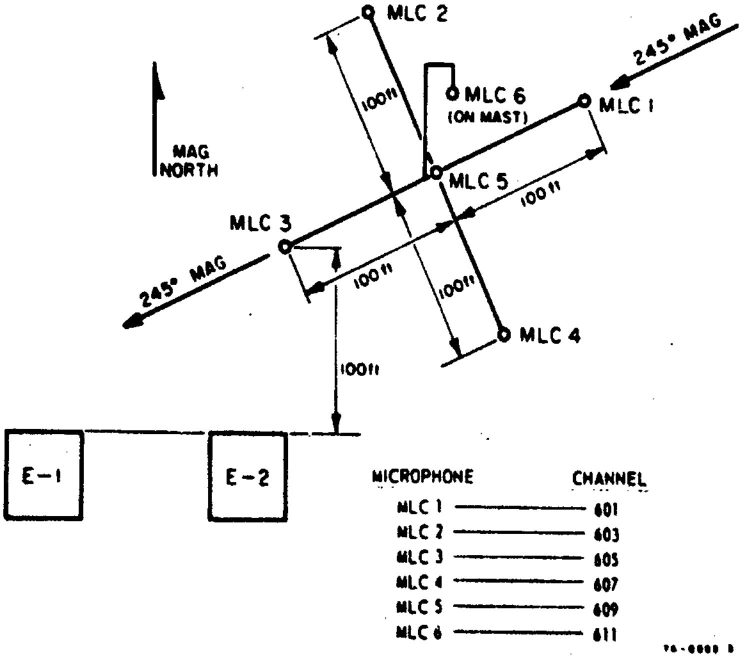


FIG. A-1 SCHEMATIC SHOWING TEST AREA SONIC BOOM MEASUREMENT STATION DEPLOYMENT, AND AIRCRAFT FLIGHT TRACK AND HEADING

B. Instrumentation Layout - Free-Field

The free-field microphone layout included 65 channels (31 NASA-LRC, 16 NASA-FRC, and 18 LCC) arranged in three basic deployments. (Figs. A-2, A-3).

The basic deployment for the XB-70 flights permitted a maximum number of microphones along the flight track including the cruciform array (see Fig. A-2) and also permitted stations to be set up for the lateral spread measurements to each side of the flight track (approximately



MICROPHONE	CHANNEL
MLC 1	601
MLC 2	603
MLC 3	605
MLC 4	607
MLC 5	609
MLC 6	611

FIG. A-2 FREE-FIELD MICROPHONE CRUCIFORM ARRAY

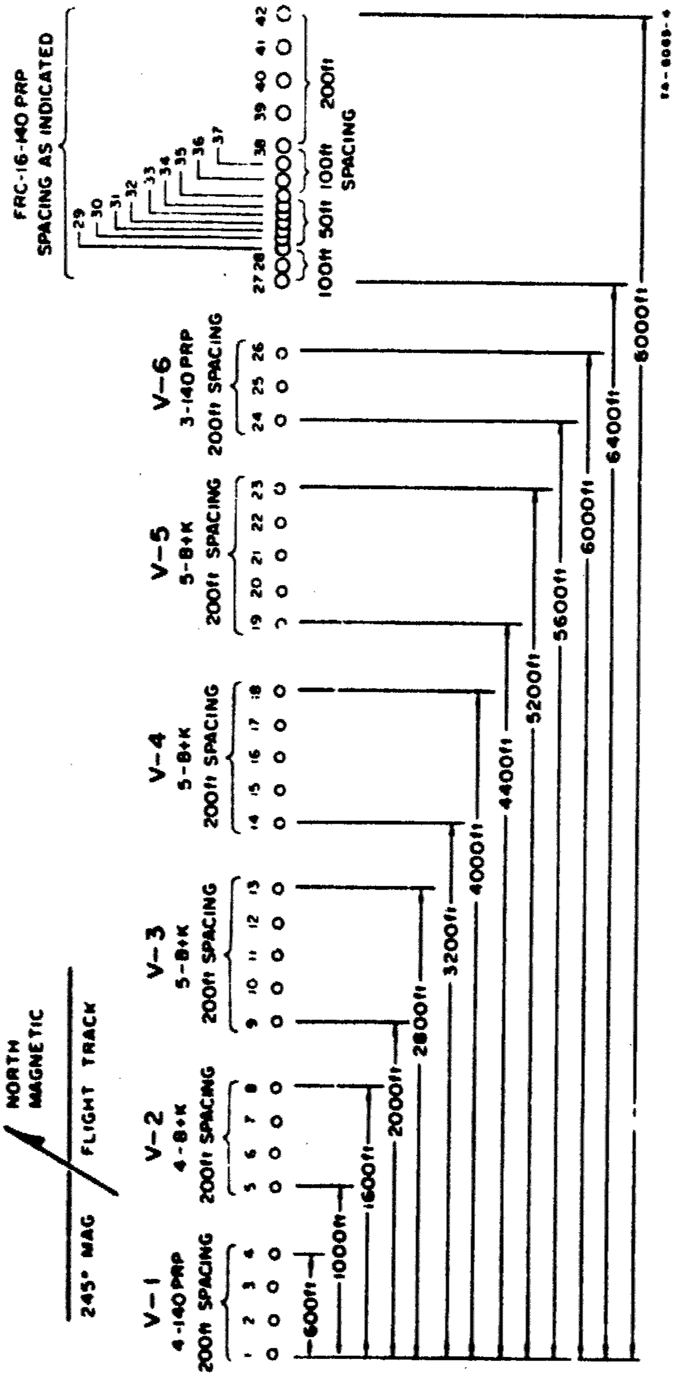
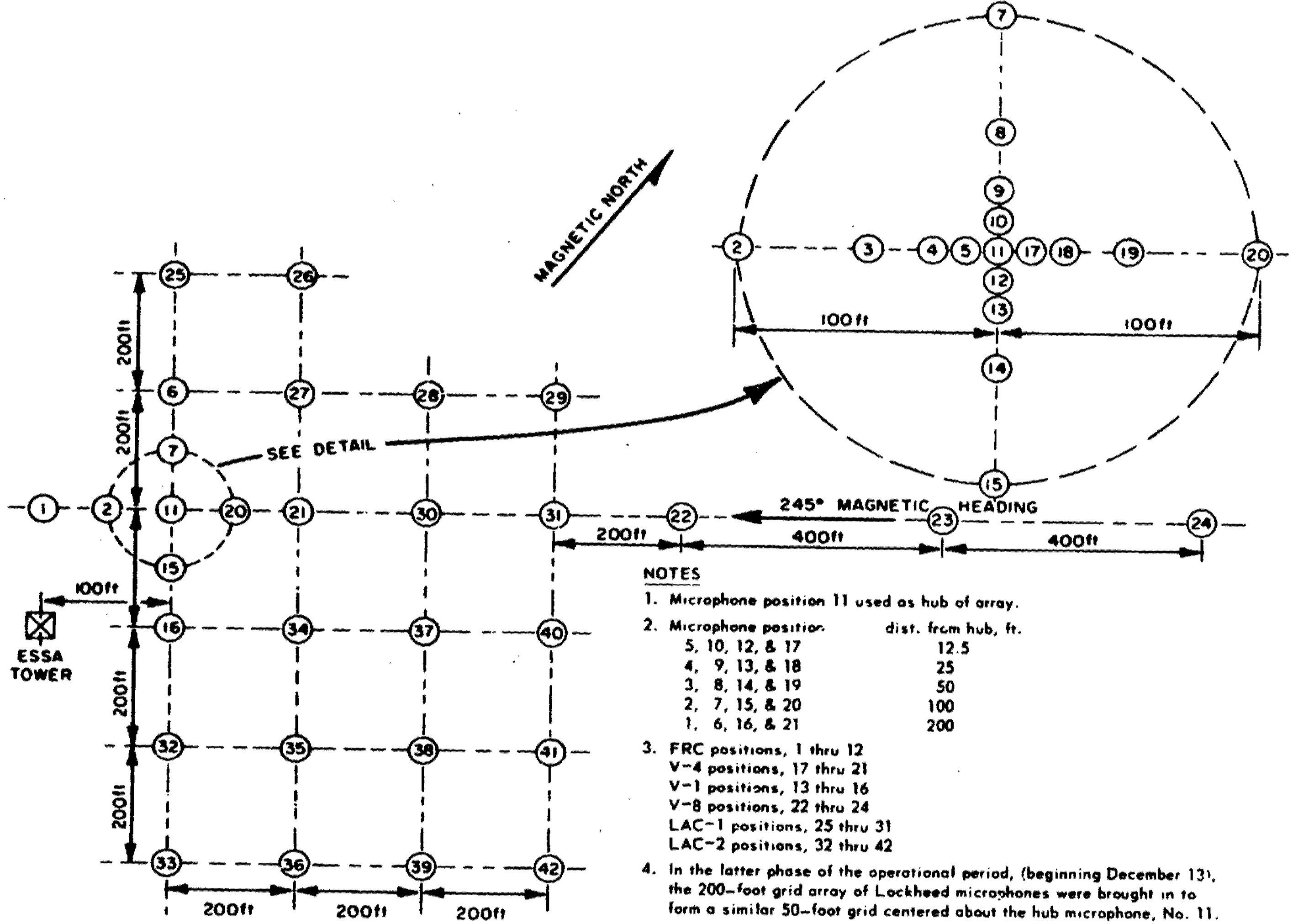


FIG. A-3 8000-FOOT MICROPHONE ARRAY ON EAST LAKE BED — SITE 5

30 miles to each side) out of the "cutoff point" determined by atmospheric refraction (Stations 1, 2, 3, 6, 7, 8, 9, and cruciform at E-2). In any case, each lateral measuring station had from 3 to 5 microphones (see insert, Fig. A-1) spaced approximately 200 ft apart along the flight track for determination of atmospheric distortion. A maximum of about 40 channels were located along the flight track. No pressure measurement stations were located within the bombing range.

The second basic deployment was for the B-58/F-104 flights and was used primarily to obtain a dense microphone array at Site 9 (see Fig. A-4) for the ESSA atmospheric studies and also to obtain lateral spread information relating to the aircraft offset studies originally proposed but not incorporated into the flight program. This microphone arrangement eliminated the scheduling of additional aircraft offset flights. This second basic deployment involved about 42 channels at Site 9 and also involved lateral Stations 3, 4, 6, and 7 (see Fig. A-1) plus the cruciform which was always fixed at the test house location (E-2).

The 65 channels measuring sonic boom overpressure data were installed to provide maximum positive and negative overpressure, period, and waveform class including near-field or far-field classification. The six cruciform microphones located near E-2 test structures provided positive overpressures, rise times, periods, waveform, etc., as shown by the sample waveforms in Fig. A-5. These data were supplied at the conclusion of each day's missions for inclusion into the data printout scheme set up and implemented by SRI and JABARD. Knowledge of the waveform permits an indication of the distortion resulting from the atmosphere and expedited transmittal of information to SRI, JABARD, ESSA, and Geotech without having to scan all of the many microphone channels. In conjunction with pressure measurements, measurements of air temperature at heights up to 10,000 ft MSL were made by means of modified, slow-rise radiosondes, and instrumented aircraft. The latter were used to obtain horizontal temperature profiles in the vicinity of any existing temperature inversions.



NOTES

1. Microphone position 11 used as hub of array.

2.

Microphone position	dist. from hub, ft.
5, 10, 12, & 17	12.5
4, 9, 13, & 18	25
3, 8, 14, & 19	50
2, 7, 15, & 20	100
1, 6, 16, & 21	200

3. FRC positions, 1 thru 12
   V-4 positions, 17 thru 21
   V-1 positions, 13 thru 16
   V-8 positions, 22 thru 24
   LAC-1 positions, 25 thru 31
   LAC-2 positions, 32 thru 42

4. In the latter phase of the operational period, (beginning December 13), the 200-foot grid array of Lockheed microphones were brought in to form a similar 50-foot grid centered about the hub microphone, No. 11.

TB-6065-15

FIG. A-4 MICROPHONE ARRAY FOR ESSA STUDIES — SITE 9

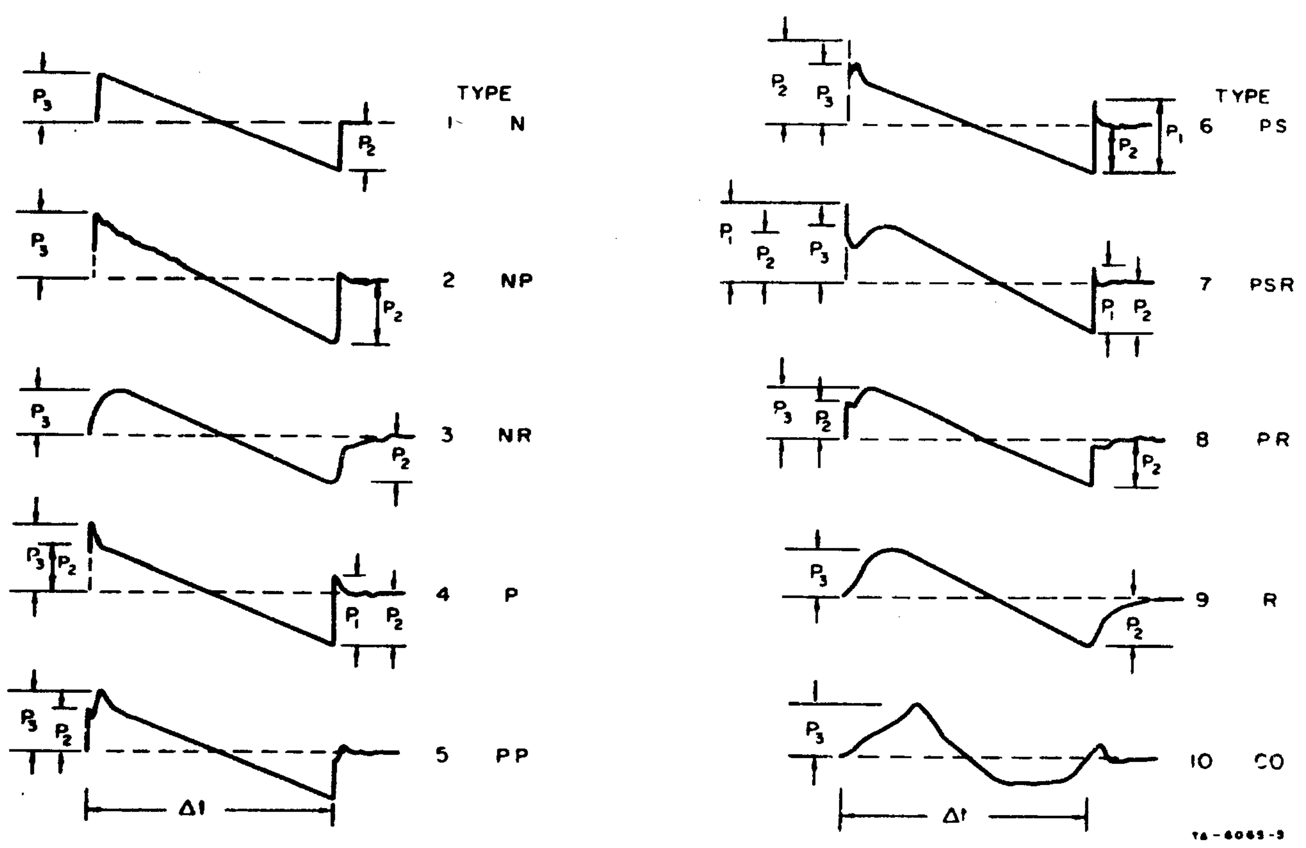


FIG. A-5 SONIC BOOM WAVEFORM CATEGORIES

C. Instrumentation Layout - Structures

The test facilities were comprised of two test structures and an adjacent concrete block house located about one mile south and west of the main runway at Edwards Air Force Base. The two main test structures were a one-story house, E-1, and a two-story house, E-2 (Fig A-1). Another test structure was the Bowling Alley, E-3, located about two miles north and west of the main runway (Fig. A-1). All structural and subjective responses were measured and recorded in and around E-1, E-2, a and E-2. Tables A-1 to A-3 and Figs. A-6 to A-11 present a listing of the locations of all instruments with their specifications, together with plan and elevation sketches of the test structures showing the dimensioned locations of the instrumentation for Phase II. Some changes in the instrument location were made during the tests. The most important changes were the addition of loading microphones on the outside of houses E-1 and E-2, additional audio microphones inside E-1 and E-2, and the displacement gages in E-2 between Phase I and Phase II.

D. Flight Mission Layouts

Figures A-12 through A-15 present the mission layouts for all scheduled flights. On each figure are indicated the mission numbers, basic setup, indication of parties involved, aircraft type including flight track and headings, steady point, recorders on, and end of run. Figure A-12 was designed for missions 1-84, Fig. A-13 is a supplement for probe flight missions 1-4, Fig. A-14 is for the 8000-ft linear array used in the ESSA study, and Fig. A-15 for the high altitude, high Mach number SR-71/Y12 flights in which some building response studies were scheduled (no subjective studies involved). One-hundred-one missions were flown in Phase I using one or two supersonic aircraft. Eighty-four missions were planned in Phase II using up to four aircraft per mission. Overflights were scheduled to occur between 0830 and 1230 on mission days. See Appendix A-1 for details of aircraft operational support.

TABLE A-1

INSTRUMENTATION LOCATION - STRUCTURE E-1

(See Fig. A-6)

Transducer	Channel	
MA-1	101	In center of LR suspended 6 feet from floor.
MA-2	102	In center of FR-KIT area suspended 6 feet from floor.
MA-3	103	Center BR #1 suspended 6 feet from floor.
MA-4	104	BR #1 movable.
MA-5	105	FR-KIT area, movable by SRI.
MA-7	113	Outside subject group.
A-1	304	On concrete block in LR.
A-2	305	On concrete block FR-KIT area.
A-3	106	On concrete block BR #1 (vertical).
A-5	201	At top plate on E wall at NE corner.
A-6	203	At top plate on N wall at NE corner.
A-11	202	BR #1 E wall (horizontal).
ML-1	803	Outside N wall above plate.
ML-2	804	Outside E wall.
ML-3	204	BR #1 next to A-11.
ML-4	205	Center ceiling attic side above FR-KIT area.
ML-5	805	Outside W wall of garage at plate line.
ML-6	806	Center outside S wall above plate line.
SG-3	207	Center big window (garage).
--	209	Trigger mike in field.

TABLE A-2

INSTRUMENTATION LOCATION - STRUCTURE E-2

(See Figs. A-7 through A-9)

	Channel	
MA-1	107	Between LR and DR 6 feet above floor.
MA-2	108	Over center in KIT 6 feet above floor.
MA-3	109	Center of BR #1 6 feet above floor.
MA-4	110	Center of FR 6 feet up.
MA-5	111	Movable FR-KIT-DR.
MA-6	112	Movable FR-KIT-DR.
A-1	301	On concrete block DR.
A-2	302	On concrete block FR.
ML-2	408	Suspended between LR and DR adjacent to MA-1.
ML-3	409	Located in attic above BR #1.
ML-4	410	Suspended below ceiling center BR #1.
A-3	303	On concrete block BR #1, vertical.
A1'	306	On concrete block FR.
A2'	307	Movable FR-KIT-DR area. (Dinette window 10/31)
A5'	308	Movable FR-KIT-DR area. (Pantry louver door 10/31)
A6'	309	Movable FR-KIT-DR area. (Cabinet door 10/31)
A9'	310	On concrete block BR #1. (N-S Direction) - Movable
A10'	311	Movable FR-KIT-DR area. (Side of stove 10/31)
A11'	312	Movable FR-KIT-DR area. (Dining room window 10/31)
A12'	313	On concrete block BR #1. (E-W direction) - Movable
A-5	401	On exterior at roof plate line on N side of NE corner.
A-6	403	On exterior at roof plate line on E side of NE corner.
A-7	405	On exterior at second floor plate line on N side of NE corner.
A-8	407	On exterior at second floor plate line on E side of NE corner.
A-9	402	On bottom chord of roof truss approximately over center of BR #1.
A-11	404	On center stud at mid-height on E wall of DR.
A-12	406	On center stud at mid-height on N wall of BR #1.
SG4-1	206	Located on large plate glass window garage entrance.
SG4-2	208	Located on large plate glass window garage entrance.
SG4-3	210	Located on large plate glass window garage entrance.
SG4-4	212	Located on large plate glass window garage entrance.
D-1	411	Adjacent to A-5 with same axis.
D-2	412	Adjacent to A-6 with same axis.
ML-11	811	Outside E wall middle of second story.
ML-12	812	Outside E wall middle of first story, outside of DR.
ML-13	810	Outside on wall above garage roof.
ML-14	809	Outside W garage wall above plate line.
ML-15	801	Center of roof N side.
ML-16	802	Center of high roof S side.
ML-17	807	Outside N wall middle of second story.
ML-18	808	Outside S wall mid-second story, midway between porch roof and eave line.

TABLE A-3

INSTRUMENTATION LOCATION - STRUCTURE E-3

(See Fig. A-10)

A1H	501	Top of steel column (interior of building) East-West racking acceleration.
A2H	502	Top of steel column (south side) East-West racking acceleration.
A3H	503	Top of steel column (south side) North-South racking acceleration.
A4H	504	Top of steel column (west side) North-South racking acceleration.
A5V	505	Center of roof girder, vertical acceleration of girder.
M-2	512	Interior - 3' below roof.
M-4	513	Exterior - above roof.
S1L	507	Strain gage on bottom flange of roof girder at centerline.
S2L	508	Strain gage on bottom flange of roof girder at 1/4 point.
S3L	509	Strain gage on bottom flange of purlin at centerline.

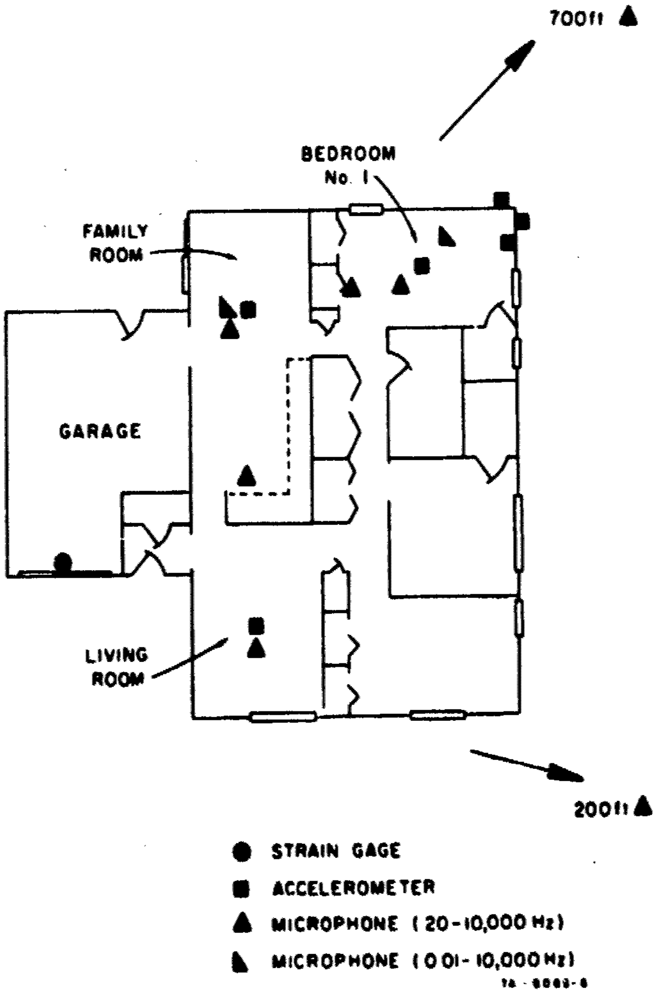
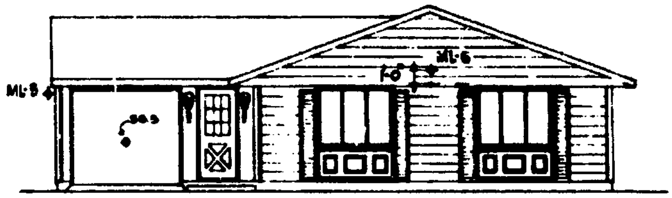
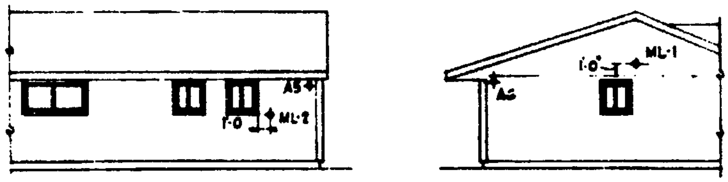


FIG. A-6 INSTRUMENTATION LOCATION, STRUCTURE E-1 FLOOR PLAN



SOUTH



PART EAST

PART NORTH

ELEVATIONS

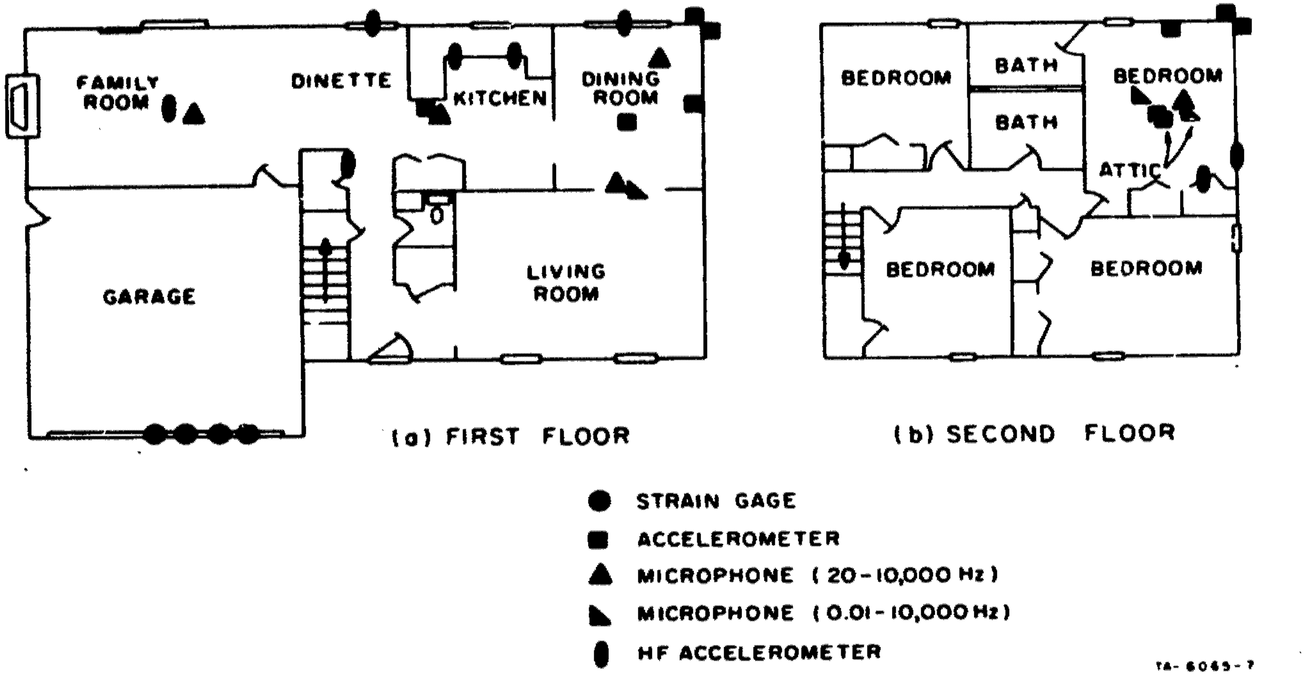
LOADING MICROPHONES

ML 1 NORTH WALL, CENTERED ABOVE PLATE LINE
ML 2 EAST WALL, CENTERED ABOVE PLATE LINE
ML 5 WEST WALL OF GARAGE AT PLATE LINE
ML 6 SOUTH WALL ABOVE PLATE LINE

ACCELEROMETERS

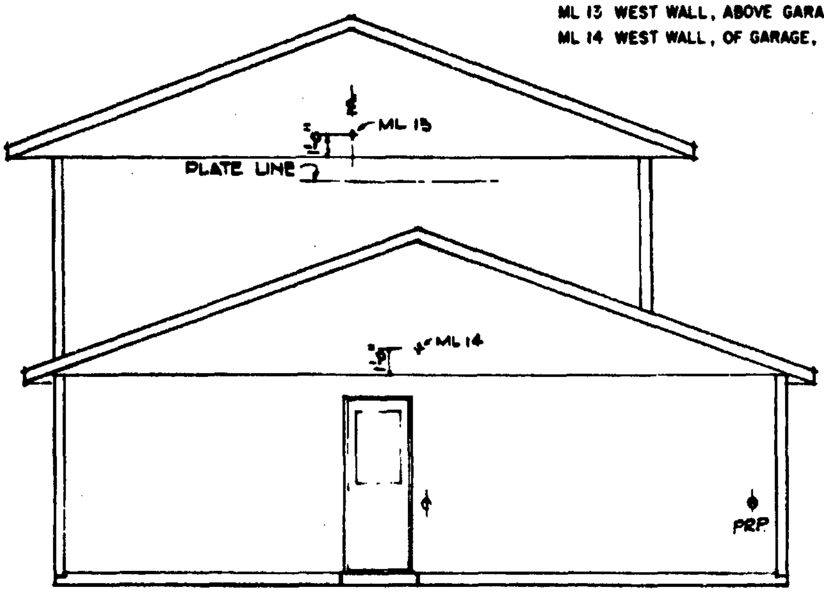
A5 EAST WALL EXTERIOR, NE CORNER, PLATE LINE
A6 NORTH WALL EXTERIOR, NE CORNER, PLATE LINE

FIG. A-7 INSTRUMENTATION LOCATION, STRUCTURE E-1 ELEVATION


(a) FIRST FLOOR

(b) SECOND FLOOR

FIG. A-8 INSTRUMENTATION LOCATION, STRUCTURE E-2 FLOOR PLAN

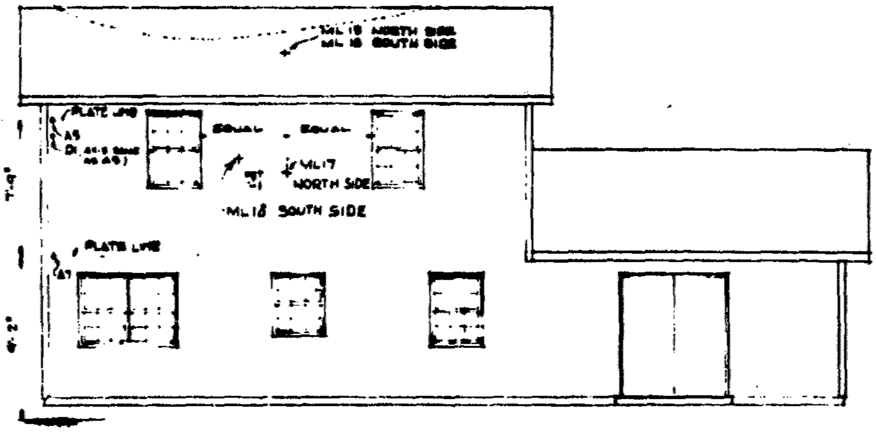


LOADING MICROPHONES

ML 13 WEST WALL, ABOVE GARAGE ROOF
ML 14 WEST WALL, OF GARAGE, ABOVE PLATE LINE

ELEVATION C

FIG. A-9 INSTRUMENTATION LOCATION, STRUCTURE E-2 ELEVATION



ELEVATION A

ACCELEROMETERS

A5 NORTH WALL, NE CORNER, 2nd STORY, PLATE LINE
A6 EAST WALL, NE CORNER, 2nd STORY, PLATE LINE
A7 NORTH WALL, NE CORNER, 1st STORY, PLATE LINE
A8 EAST WALL, NE CORNER, 1st STORY, PLATE LINE

LOADING MICROPHONES

ML 11 EAST WALL, MIDDLE OF 2nd STORY
ML 12 EAST WALL, MIDDLE OF 1st STORY, OUTSIDE DINING ROOM
ML 15 CENTER OF NORTH ROOF AREA
ML 16 CENTER OF SOUTH ROOF AREA
ML 17 NORTH WALL, MIDDLE OF 2nd STORY
ML 18 SOUTH WALL, MIDDLE OF 2nd STORY

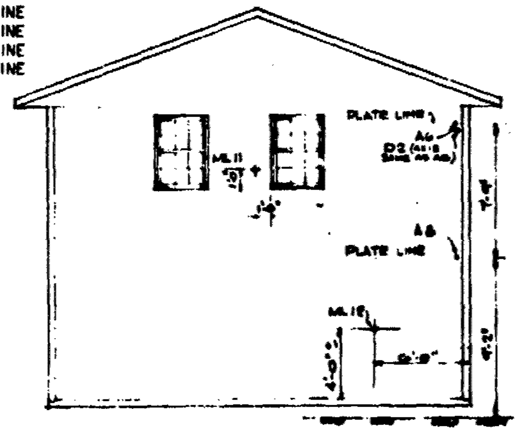
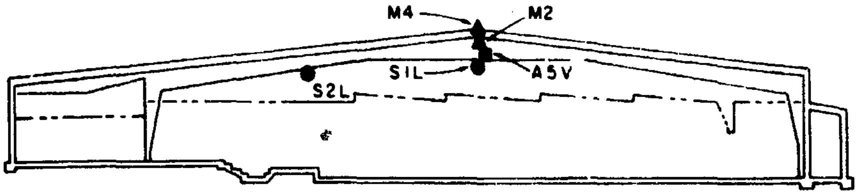
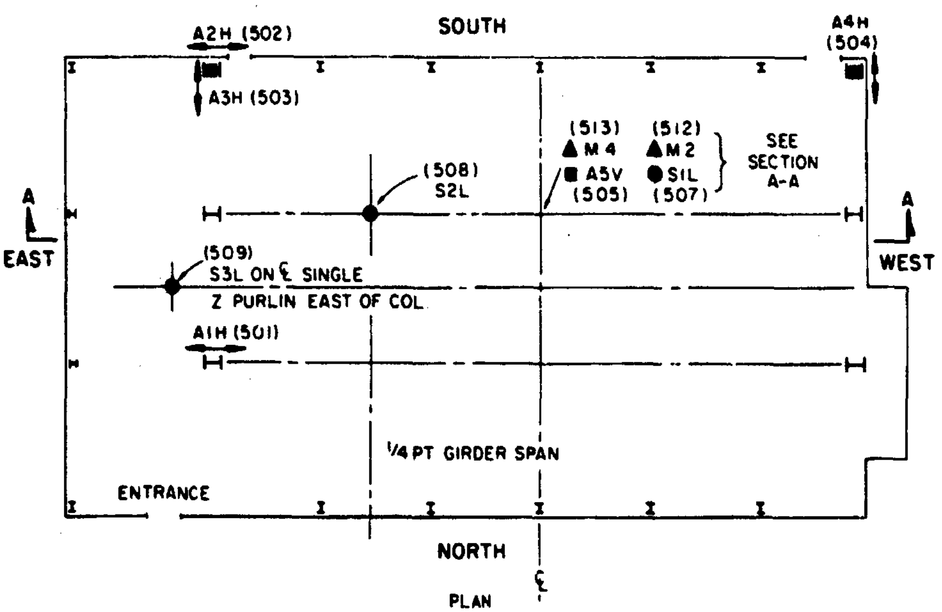


FIG. A-10 INSTRUMENTATION LOCATION, STRUCTURE E-2 ELEVATION



SECTION A-A



PLAN

ACCELEROMETERS

A1H TOP OF COL.
A2H TOP OF COL.
A3H TOP OF COL.
A4H TOP OF COL.
A5V CENTER OF GIRDER

MICROPHONES

M2 INSIDE 3' BELOW ROOF Z
M4 OUTSIDE ON ROOF
(504) CHANNEL

STRAIN GAGES

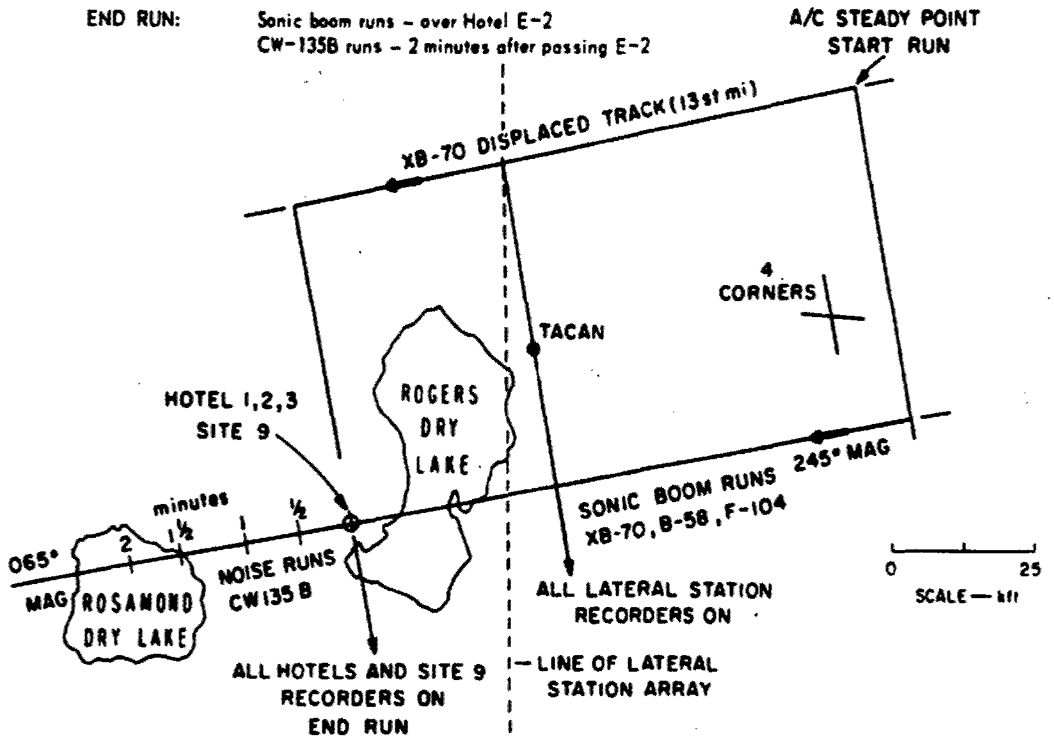
S1L BOTT. FLG. OF GIRDER AT ℄
S2L BOTT. FLG OF GIRDER AT ¼ PT
S3L BOTT. FLG. OF PURLIN AT ℄

TB-6065-8

FIG. A-11 INSTRUMENTATION LOCATION, STRUCTURE E-3 ELEVATION AND FLOOR PLAN

MISSION NO. 1 through 84
(For Probe Flights see map for mission 1-5, Fig. A-13)

SETUP:	All hotels (E-1, E-2, E-3) Site 9, lateral stations
FOR:	SRI, JAB, NASA, ESSA, and Geotech
A/C:	B-70, B-58, F-104, CW-135B (all a/c on 245° mag. hdg. over Hotel E-2 except some B-70 flights displaced 13 st. mi. north on 245° mag. hdg. and CW-135B on heading 065° mag. over Hotel E-2).
STEADY POINT:	B-58, F-104 at 22 n.mi. east of Hotel E-2, B-70 at minimum of 33 n.mi. east of Hotel E-2. B-58, B-70, F-104 hold conditions from steady point to Hotel E-2. CW-135B steady 2 minutes prior to overhead Hotel E-2 and hold 2 minutes after passing Hotel E-2.
RECORDERS ON:	For sonic boom runs at Tacan for all lateral stations and at overhead Hotel E-2 for all hotels and Site 9. For noise runs (CW-135B) count down only from 2, 1 1/2, 1, and 1/2 minute to overhead Hotel E-2 (not necessary to indicate recorders on).
END RUN:	Sonic boom runs - over Hotel E-2 CW-135B runs - 2 minutes after passing E-2



1. Note: For all above sonic boom runs all overpressure measurement stations, subjective response, and building response (Hotel E-1, E-2, E-3) are involved. For a/c noise runs (CW-135B) only subjective and Hotels E-1 and E-2 are involved.

2. Note: On B-70, NASA, F-104 probe flights, probe test must be completed by Four Corners and F-104 a/c turn off so as not to boom Hotel E-2. If probe mission not completed by Four Corners, then NASA probe F-104 must abort (see map for missions 1-5 Fig. A-10.)

TB-6065-9

FIG. A-12 FLIGHT TRACKS, MISSIONS 1-84

PROBE MISSIONS 1 - 5
(attachment to missions 1 - 84)

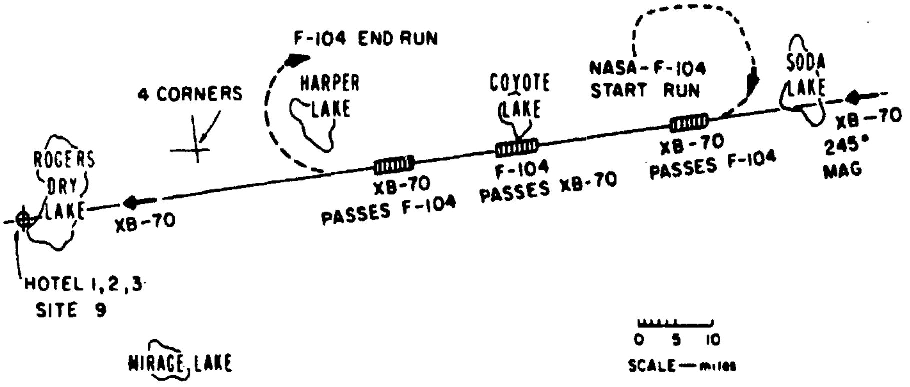
SETUP: (See missions 1-84, Fig. A-12)

FOR: NASA-LRC

A C: B-70 as generating aircraft and NASA FRC F-104. B-70 at M - 1.5 at 37,000' msl and F-104 at 1.3 to 1.7 at 42,000' msl. Hdgs 245° mag. on track over Hotel E-2.

START PROBE
PENETRATION: Soda Lake (approx. 90 n.mi. east of Hotel E-2)

END PROBE
PENETRATION: Four Corners (so as nct to boom Hotel E-2 area with NASA F-104 probe a c.)



1. Note: Probe mission is accomplished as follows: B-70 passes F-104 who is at M . 1.3, then F-104 accelerates to M - 1.7 and passes B-70, then F-104 decelerates to M . 1.3 back through B-70 flow field. Above is optimistic condition. Minimum consists of only single measurement.

2. Note: If probe F-104 does not complete his mission by Four Corners, then probe mission must abort.

TA-6088-10

FIG. A-13 FLIGHT TRACKS, MISSIONS 1-5

MISSION NO. 8K -1, 2, 3, - - -,

SETUP:	East Lakebed Site 8000' Linear Array
FOR:	ESSA
A/C:	F-104 at 30,500' msl at M 1.3 on 245° mag. hdg.
STEADY POINT:	Four Corners
RECORDERS ON:	At TACAN
END RUN:	East Edge of Rogers Lake (see sketch below)

Note: For these studies no building response measurements or subjective studies involved.

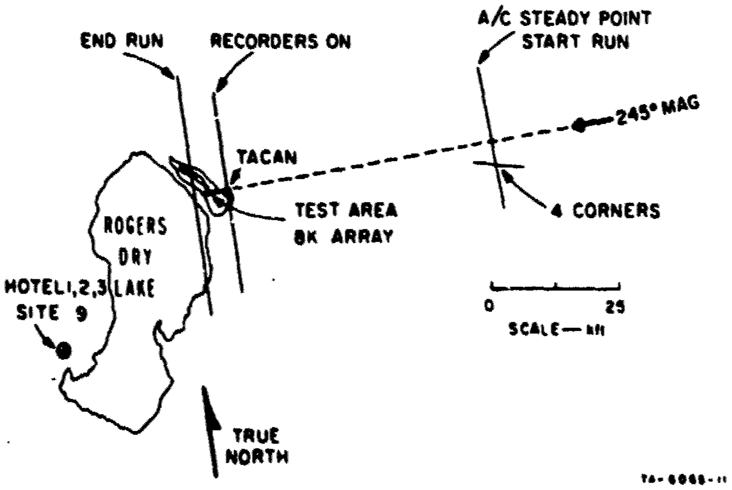
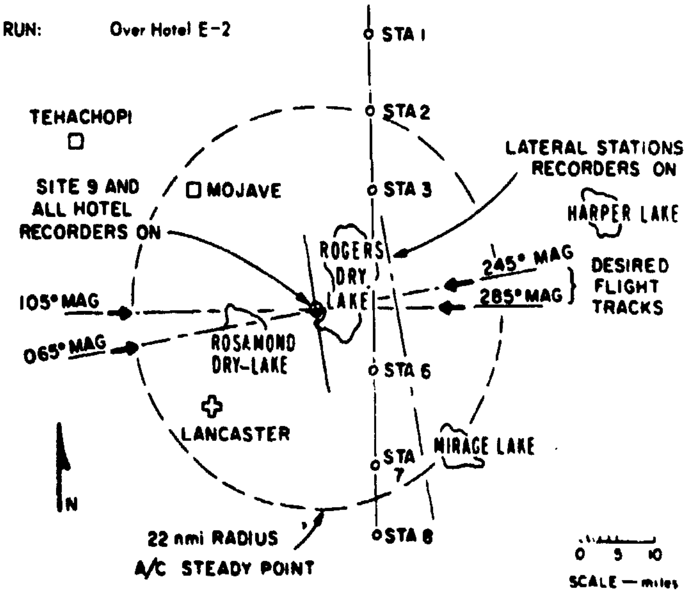


FIG. A-14 FLIGHT TRACKS, 8000-FOOT MICROPHONE ARRAY MISSIONS, F-104

MISSION NO. SR - 1, 2, 3, - - -.	
SETUP:	That existing for scheduled program mission
FOR:	NASA (radar plots to be held in file by SPORT – plots required from steady point to overhead.)
A/C:	SR-71 or Y-12 (always identified as SR but SPORT will mark plot as SR or Y-12 with call sign) all flights over Hotel E-2 at flight categories a, b, c, d, e, f, g, h (SPORT to notify Tango 1 of expected flight categories (i.e., a, b, etc.)
STEADY POINT:	Approx 25 n.mi., in any direction, from Hotel 2 (E-2)
RECORDERS ON:	At Tacan and again Hotel E-2 (see Note 1)
END RUN:	Over Hotel E-2



1. **Note:** For all east to west or west to east or over supersonic corridor runs all hotels and overpressure recording stations involved and recorders on at both Hotel E-2 and Tacan. For all flight heading other than [illegible] Tango 1 and Site 9 involved and [illegible] recorders on only at Hotel E-2.

2. **Note:** For these studies only NASA pressure measurements and at times building response measurements are involved (not subjective studies) depending on how SR or Y-12 missions are scheduled.

3. **Note:** Flight category specifies alt. and M. These will not be announced, only category (i.e., a, b, c, etc.). Δp settings obtained from separate listing.

76-6085-12

FIG. A-15 FLIGHT TRACKS, SR-71

III INSTRUMENTATION AND DATA REDUCTION

A. Instrumentation Installation and Operation

1. Free-Field

NASA installed and operated the six microphone systems in the cruciform array located near E-2. (Fig. A-2). The tape recorder, signal conditioning equipment, and direct write system were housed in a trailer located approximately due north of E-1. In addition, NASA together with Lockheed, installed and operated the microphone systems shown in Fig. A-3. Recording and signal conditioning equipment was installed in mobile vans or in fixed shelters. Power for equipment was supplied from portable generators.

Table A-4 gives the operating characteristics of the free-field microphones.

ESSA measured wind velocities and air temperatures at two levels above the ground (10 and 85 ft) with instruments located on a tower 90 ft high. (Appendix C) Measurements were recorded on a 14-channel FM tape recorder located in a temporary structure. Power was supplied by a portable generator supplied by NASA. The Air Weather Service Detachment also made soundings of temperature, humidity, and wind to at least 10,000 ft above the operating altitudes of aircraft producing the sonic booms.

2. Structures

Aerojet General Corporation, Aetron Division under subcontract to JABARD operated instrumentation during Phase II previously installed and operated by NASA during Phase I in E-1, and E-2, and E-3. The instruments in the house in Lancaster were installed and operated by Datacraft, Inc., under subcontract to JABARD during Phase I. Equipment was checked out and necessary adjustments were made for Phase II operation during the last two weeks in October. JABARD also rearranged some of the transducers in E-1 and E-2 to meet SRI Phase II requirements. JABARD furnished and installed four additional microphone systems and two displacement transducers in E-2 and two additional microphone systems in E-1 for Phase II.

TABLE A-4

OPERATING CHARACTERISTICS OF FREE FIELD MICROPHONES

Microphone type	Photocon PRP-464-15D (Modified by partly plugging vent hole to extend low frequency response)
Frequency response	0.02 - 10,000 Hz ±2 dB
Resonant frequency	About 7000 Hz
Signal Conditioner	Photocon DG-605D Dynagage
Amplifier	Burr-Brown Model 9077A

Boeing under subcontract to JABARD furnished, installed, and operated twelve microphone systems located on the exteriors of E-1 and E-2 to measure boom loadings on these two structures during Phase II. Recording, signal-conditioning, and direct-write equipment were installed in the garage of E-2. Boeing also provided IRIG time digital readout systems for use in E-2. Power for equipment was available in E-1 and E-2 from power panels separate from those used for supplying power for lights and receptacles in the two structures.

Aetron installed recording and signal conditioning equipment in a designated room at the Bowling Alley, connected it to instrumentation previously installed by NASA, and then checked out and operated the ten transducer systems.

Tables A-5 to A-7 present the operating characteristics of the instruments installed in the test structures.

A number of precautions were taken to minimize thermal drift in equipment subject to temperature changes. In test structures, E-1, E-2, and E-3, power to all equipment was left on so that temperature gradients in the equipment could stabilize. Racks were generally enclosed so that the temperature of the air immediately surrounding the equipment did not change too rapidly in case of a sudden change in ambient temperature. Power was also left on to minimize thermal shocks which tend to shorten component life.

Instruments were calibrated according to the procedures outlined in Appendix A-2.

3. Recording Systems

CEC Model No. VR 3300 magnetic tape recorders were used for all instrumentation. Fourteen track machines were used in and near the structures and seven track machines on the large microphone arrays. Tape speed was 30 ips with FM recording. Center frequency was 54.0 kHz with an information frequency of 0-10 kHz ±0.5 dB. The full-scale signal-to-noise ratio (RMS signal/RMS noise) was 43 dB. Harmonic distortion was 1.5%.

TABLE A-5

INSTRUMENT CHARACTERISTICS - STRUCTURE E-1

Trans-ducer	Type of Measurement	Tape Recorder	Channel	Frequency Response	Accuracy	Calibration Level	Oscillo-graph	Mag. Tape	Justification
MA-1	Audio Mike	TR-1	101	20-10,000 cps*	± 2.1 dB	120 dB	Yes	Yes	Psycho-Acoustic
MA-2	Audio Mike	TR-1	102	20-10,000 cps	± 2.1 dB	120 dB	Yes	Yes	Psycho-Acoustic
MA-3	Audio Mike	TR-1	103	20-10,000 cps	± 2.1 dB	120 dB	Yes	Yes	Psycho-Acoustic
MA-4	Audio Mike	TR-1	104	20-10,000 cps	± 2.1 dB	120 dB	Yes	Yes	Psycho-Acoustic
MA-5	Audio Mike	TR-1	105	20-10,000 cps	± 2.1 dB	120 dB	Yes	Yes	(Movable) Psycho-Acoustic
MA-7	Audio Mike	TR-1	113	20-10,000 cps	± 2.1 dB	120 dB	Yes	Yes	Psycho-Acoustic
A-1	Acceleration	TR-3	304	dc-500 cps	± 5%	0.5 g	Yes	Yes	Subjective (Tactile)
A-2	Acceleration	TR-3	305	dc-500 cps	± 5%	0.5 g	Yes	Yes	Subjective (Tactile)
A-3	Acceleration	TR-1	106	dc-500 cps	± 5%	0.5 g	Yes	Yes	Subjective (Tactile)
A-5	Acceleration	TR-2	201	dc-500 cps	± 5%	0.5 g	Yes	Yes	Structure Racking
A-6	Acceleration	TR-2	203	dc-500 cps	± 5%	0.5 g	Yes	Yes	Structure Racking
A-11	Acceleration	TR-2	202	dc-500 cps	± 5%	0.5 g	Yes	Yes	Plate Response
ML-1	Overpressure	TR-8	803	0.1-10,000 cps	± 2.1 dB	130 dB	Yes	Yes	Structure Loading Exterior
ML-2	Overpressure	TR-8	804	0.1-10,000 cps	± 2.1 dB	130 dB	Yes	Yes	Structure Loading Exterior
ML-3	Overpressure	TR-2	204	0.1-10,000 cps	± 2.1 dB	130 dB	Yes	Yes	Structure Loading Interior
ML-4	Overpressure	TR-2	205	0.1-10,000 cps	± 2.1 dB	130 dB	Yes	Yes	Structure Loading Interior
ML-5	Overpressure	TR-8	805	0.1-10,000 cps	± 2.1 dB	130 dB	Yes	Yes	Structure Loading Exterior
ML-6	Overpressure	TR-8	806	0.1-10,000 cps	± 2.1 dB	130 dB	Yes	Yes	Structure Loading Exterior
SG-3	Strain	TR-2	207	2000 cps	± 2%	20μ inch	Yes	Yes	Strain in Large Window

*cps (cycles per second) = Hz.

TABLE A-6

INSTRUMENT CHARACTERISTICS - STRUCTURE E-2

Trans- ducer	Type of Measurement	Tape Recorder	Channel	Frequency Response	Accuracy	Calibration Level	Oscillo- graph	Mag. Tape	Justification
MA-1	Audio Mike	TR-1	107	20-10,000 cps	± 2.1 dB	120 dB	Yes	Yes	Psycho-Acoustic
MA-2	Audio Mike	TR-1	108	20-10,000 cps	± 2.1 dB	120 dB	Yes	Yes	Psycho-Acoustic
MA-3	Audio Mike	TR-1	109	20-10,000 cps	± 2.1 dB	120 dB	Yes	Yes	Psycho-Acoustic
MA-4	Audio Mike	TR-1	110	20-10,000 cps	± 2.1 dB	120 dB	Yes	Yes	Psycho-Acoustic
MA-5	Audio Mike	TR-1	111	20-10,000 cps	± 2.1 dB	120 dB	Yes	Yes	Psycho-Acoustic (Movable)
MA-6	Audio Mike	TR-1	112	20-10,000 cps	± 2.1 dB	120 dB	Yes	Yes	Psycho-Acoustic (Movable)
A-1	Acceleration	TR-3	301	dc-500 cps	± 5%	0.5 g	Yes	Yes	Subjective (Tactile)
A-2	Acceleration	TR-3	302	dc-500 cps	± 5%	0.5 g	Yes	Yes	Subjective (Tactile)
A-3	Acceleration	TR-3	303	dc-500 cps	± 5%	0.5 g	Yes	Yes	Subjective (Tactile)
A1'	Acceleration	TR-3	306	100-2,000 cps	± 12%	0.05 g	Yes	Yes	Subjective (Tactile)
A2'	Acceleration	TR-3	307	100-2,000 cps	± 12%	0.05 g	Yes	Yes	Psycho-Acoustic (Movable)
A5'	Acceleration	TR-3	308	100-2,000 cps	± 12%	0.05 g	Yes	Yes	Psycho-Acoustic (Movable)
A6'	Acceleration	TR-3	309	100-2,000 cps	± 12%	0.05 g	Yes	Yes	Psycho-Acoustic (Movable)
A9'	Acceleration	TR-3	310	100-2,000 cps	± 12%	0.05 g	Yes	Yes	Subjective-Tactile (Movable)
A10'	Acceleration	TR-3	311	100-2,000 cps	± 12%	0.05 g	Yes	Yes	Psycho-Acoustic (Movable)
A11'	Acceleration	TR-3	312	100-2,000 cps	± 12%	0.05 g	Yes	Yes	Psycho-Acoustic (Movable)
A12'	Acceleration	TR-3	313	100-2,000 cps	± 12%	0.05 g	Yes	Yes	Subjective-Tactile (Movable)
A-5	Acceleration	TR-4	401	dc-500 cps	± 5%	0.5 g	Yes	Yes	Structure Racking
A-6	Acceleration	TR-4	403	dc-500 cps	± 5%	0.5 g	Yes	Yes	Structure Racking
A-7	Acceleration	TR-4	405	dc-500 cps	± 5%	0.5 g	Yes	Yes	Structure Racking
A-8	Acceleration	TR-4	407	dc-500 cps	± 5%	0.5 g	Yes	Yes	Structure Racking
A-9	Acceleration	TR-4	402	dc-500 cps	± 5%	0.5 g	Yes	Yes	Plate Response
A-11	Acceleration	TR-4	404	dc-500 cps	± 5%	0.5 g	Yes	Yes	Plate Response
A-12	Acceleration	TR-4	406	dc-500 cps	± 5%	0.5 g	Yes	Yes	Plate Response

TABLE A-6
(cont'd)
INSTRUMENT CHARACTERISTICS - STRUCTURE E-2

Trans-ducer	Type of Measurement	Tape Recorder	Channel	Frequency Response	Accuracy	Calibration Level	Oscillo-graph	Mag. Tape	Justification
ML2	Overpressure	TR-4	408	0.1-10,000 cps	± 2.1 dB	130 dB	Yes	Yes	Structure Loading Interior
ML3	Overpressure	TR-4	409	0.1-10,000 cps	± 2.1 dB	130 dB	Yes	Yes	Structure Loading Interior
ML4	Overpressure	TR-4	410	0.1-10,000 cps	± 2.1 dB	130 dB	Yes	Yes	Structure Loading Interior
D-1	Displacement	TR-4	411	5-100 cps	± 2%	40 mv	Yes	Yes	Structure Racking
D-2	Displacement	TR-4	412	5-100 cps	± 2%	40 mv	Yes	Yes	Structure Racking
SG4-1	Strain	TR-2	206	2000 cps	± 1%	20μ inch	Yes	Yes	Strain in Large Window
SG4-2	Strain	TR-2	208	2000 cps	± 1%	20μ inch	Yes	Yes	Strain in Large Window
SG4-3	Strain	TR-2	210	2000 cps	± 1%	20μ inch	Yes	Yes	Strain in Large Window
SG4-4	Strain	TR-2	212	2000 cps	± 1%	20μ inch	Yes	Yes	Strain in Large Window
ML11	Overpressure	TR-8	811	0.1-10,000 cps	± 2.1 dB	130 dB	Yes	Yes	Structure Loading Exterior
ML12	Overpressure	TR-8	812	0.1-10,000 cps	± 2.1 dB	130 dB	Yes	Yes	Structure Loading Exterior
ML13	Overpressure	TR-8	810	0.1-10,000 cps	± 2.1 dB	130 dB	Yes	Yes	Structure Loading Exterior
ML14	Overpressure	TR-8	809	0.1-10,000 cps	± 2.1 dB	130 dB	Yes	Yes	Structure Loading Exterior
ML15	Overpressure	TR-8	801	0.1-10,000 cps	± 2.1 dB	130 dB	Yes	Yes	Structure Loading Exterior
ML16	Overpressure	TR-8	802	0.1-10,000 cps	± 2.1 dB	130 dB	Yes	Yes	Structure Loading Exterior
ML17	Overpressure	TR-8	807	0.1-10,000 cps	± 2.1 dB	130 dB	Yes	Yes	Structure Loading Exterior
ML18	Overpressure	TR-8	808	0.1-10,000 cps	± 2.1 dB	130 dB	Yes	Yes	Structure Loading Exterior

TABLE A-7

INSTRUMENT CHARACTERISTICS - STRUCTURE E-3

Transducer	Type of Measurement	Tape Recorder	Channel	Frequency Response	Accuracy	Calibration Level	Oscillograph	Mag. Tape	Justification
A1H	Acceleration	TR-5	501	dc-500 cps	± 5%	0.2 g	Yes	Yes	Structure Racking
A2H	Acceleration	TR-5	502	dc-500 cps	± 5%	0.2 g	Yes	Yes	Structure Racking
A3H	Acceleration	TR-5	503	dc-500 cps	± 5%	0.2 g	Yes	Yes	Structure Racking
A4H	Acceleration	TR-5	504	dc-500 cps	± 5%	0.2 g	Yes	Yes	Structure Racking
A5V	Acceleration	TR-5	505	dc-500 cps	± 5%	0.2 g	Yes	Yes	Plate Response
M-2	Overpressure	TR-5	512	0.1-10,000 cps	± 2.1 dB	130 dB	Yes	Yes	Loading - Exterior
M-4	Overpressure	TR-5	513	0.1-10,000 cps	± 2.1 dB	130 dB	Yes	Yes	Loading - Interior
S1L	Strain	TR-5	507	2000 cps	± 1%	40μ inch	Yes	Yes	Girder Strain
S2L	Strain	TR-5	508	2000 cps	± 1%	40μ inch	Yes	Yes	Girder Strain
S3L	Strain	TR-5	509	2000 cps	± 1%	40μ inch	Yes	Yes	Roof Purlin Strain

4. Timing Information

A standard IRIG B time code format was recorded on one channel of each analog magnetic tape for time correlation to 1 millisecond or better. Some trouble was experienced with the time code in Phase I. During Phase II, this code was uninterrupted during duration of each test flight and met the specifications of REFERENCE IRIG DOCUMENT 104-60.

START and STOP times for accurately digitizing analog data were based on manual reading of direct-write oscillograph records. Nominal boom times were recorded from a time code translator located in test structure E-2 as a check on the values read from the oscillographs. Manual readout to the nearest second was required for booms. Noise recordings of a typical aircraft flyby included three minutes of uninterrupted aircraft noise with 75 seconds recorded before and after the aircraft passed overhead or as directed by SRI. Notation of START and STOP times for noise records was provided by SRI. Notation of START and STOP times for boom records was provided by Data Reduction. "Recorders On" signals were the responsibility of NASA and Edwards Air Force Base control.

B. Data Reduction

Analysis of the data recorded by the various participants is being made in two steps. The first step made use of preliminary results obtained by reading direct-write records, raw data summary sheets, subject records, and preliminary analyses by computer of selected records. Other more detailed analyses were made during the test flights and are now being made as required to fulfill each participant's responsibilities.

The primary responsibilities were as follows:

1. Signature Propagation - primarily NASA with some analyses by ESSA.
2. Weather and Meteorological Recording - The Base Weather Squadron furnished Rawinsonde readings for use by all participants as required. These and other weather data are being analyzed by ESSA.
3. Acoustic and Vibrational Response - SRI

4. Structural Response - the primary responsibility in this area was assigned to JABARD. Analysis of structural response data as required to correlate with subjective response was assigned to SRI.

In Phase II, the Data Reduction and Dissemination Group (DR and D) performed preliminary data reduction on the low-frequency accelerometers, pressure microphones, velocity and displacement meters, and strain gages located in E-1, E-2, and E-3. NASA reduced the radar plots, cruciform data, and supplied DR and D with copies of the summary sheets. NASA also supplied DR and D with a copy of the radar plots for all missions. SRI was responsible for the reduction of records from the high-frequency accelerometers and acoustic microphones. The DR and D group issued summaries of the above data as specified to the appropriate participants.

The data furnished to DR and D was logged daily and all information was punched on a series of six data cards so that they could be processed by computer and printed output furnished to participants. The information contained on each card and the arrangement of the data are as follows:

1. Mission Log

   a. Date
   b. Mission
   c. Aircraft
   d. Altitude, 1000 ft, MSL*
   e. Mach number (or speed kph for subsonic aircraft)*
   f. EPR (take-off or landing)*
   g. Heading*
   h. Offset from track, left or right*
   i. Observed boom time, or time overhead for subsonic aircraft, ZULU*
   j. Remarks
   k. Card type identification no. (1)
   *Over test structure E-2

2. Digitization Log - Data

   a. Date
   b. Mission
   c. Aircraft
   d. Digitizing start time
   e. Digitizing stop time
   f. Location (test structures E-1, E-2 or E-3)
   g. Card type identification no. (2)

3. Instrument Location Log

a. Date
b. Channel
c. House number and instrument designation
d. Instrument type
e. Location
f. Location number (0 = inoperative, 1 = 1st position,
2 = 2nd position, etc.
g. Card type identification no. (3)

4. Channel Calibration Log

a. Mission
b. Channel
c. House number and instrument designation
d. Pre-calibrations
e. Post-calibrations
f. Run attenuation and gain setting
g. Remarks
h. Digitization sample rate, sps
i. Digitization filter cutoff
j. Card type identification no. (4)

5. Digitization Log - Calibrations

a. Date
b. Channel
c. House number and instrument designation
d. Calibration type (pre or post)
e. Digitizing start and stop times
f. Digitization sample rate, sps
g. Digitization filter cutoff, cps
h. Card type identification no. (5)

6. Summary of Cruciform Data

a. Mission
b. Channel
c. House number and instrument designation
d. Wave form type code number for pressure mikes, See Figure A-5
e. Peak amplitudes in psf
f. Rise time, seconds
g. Period or duration of N-wave in seconds
h. Wave angle, degrees
Wave angle is the angle between the pressure wave front and the ground as determined from the cruciform array.
i. Wave ground speed, ft/sec
j. Card identification number (6)

The Mission Log in chronological order for Phase I is given as Table A-8. The Phase II Mission Log in order of mission numbers is given in Table A-9, omitting remarks and card type. The Instrument Location Log for 15 November 1966 is given in Table A-10 as an example of the logs that were compiled. A copy of the Summary of Cruciform Data is presented in Annex C. The data are arranged in chronological order for Phase I and in order by mission number for Phase II to facilitate use with the Mission Logs. A description of the N-wave and its characteristics is given in Fig. A-5. Cards 2, 4, and 5 are primarily for use during digitizing of the analog data.

In addition to the data punched on the series of six data cards, an Analog Tape Log and a Digital Tape Log were prepared containing the following information:

1. Analog Tape Log

   The purpose of this log is to record the information contained on each analog tape. There, one master copy of each log plus one copy of the appropriate log are filed with each analog tape. The log for each tape is as follows: (Numbers in parenthesis refer to data card numbers).

   a. Analog tape number, date, tape recorder number, and total number of missions
   b. Channel locations (Card 3)
   c. Pre-calibration digitization start-stop times (Card 5)
   d. Mission identification (Card 1)
   e. Mission digitization start-stop times (Card 2)
   f. Channel calibrations (Card 4)
   g. Post-calibration digitization start-stop times (Card 5)

2. Digital Tape Log

   The analog tape records all channel data, whereas the digital tape contains only selected channels. The digital tape log is similar to the analog tape log, but contains the necessary identification for only those channels that have been digitized. For example, the analog may contain channels 601 through 614, but the digital tape may contain only 602, 603, 605, and 607.

TABLE A-8

MISSION LOG - EDWARDS PHASE I

DATE DY MO YR	MSN	A/C	ALT KFT MSL	MACH OR SPD	EPR	HDG	OFF-SET N/S	BOOM TIME HR MN SC ZULU*
4 JUN 66	14	F-104	35.6	1.7				
4 JUN 66	14	XB-70	52.9	1.81		243	2.5N	17 28 00
6 JUN 66	39	B-58	31.4	1.25		244	4.64N	16 00 00
6 JUN 66	39B	KC-135	10.3		1.6			
6 JUN 66	70	B-58	43.9	1.60		245	0.55N	16 08 51
6 JUN 66	70B	KC-135	5.4		1.5			
6 JUN 66	40	B-58	31.4	1.48		246	0.20N	16 18 40
6 JUN 66	40B	KC-135	5.4		1.5			
6 JUN 66	71	B-58	44.2	1.59		245	5.00N	16 30 00
6 JUN 66	71B	KC-135	3.3		1.5			
6 JUN 66	41	B-58	31.3	1.45		247	0.17N	16 34 44
6 JUN 66	41B	KC-135	3.3		1.5			
6 JUN 66	72	B-58	43.9	1.55		244	4.85N	16 43 55
6 JUN 66	72B	KC-135	2.8		1.5			
6 JUN 66	74	B-58	32.4	1.30		242	.72S	17 01 52
6 JUN 66	74B	KC-135	8.3		2.35			
6 JUN 66	44	B-58	43.4	1.57		245	5.00N	17 11 00
6 JUN 66	44B	KC-135	8.3		2.35			
6 JUN 66	75	B-58	31.8	1.46		248		17 17 00
6 JUN 66	75B	KC-135	3.3		2.35			
6 JUN 66	42	B-58	43.3	1.53		245		17 24 40
6 JUN 66	42B	KC-135	2.8		2.35			
6 JUN 66	22	XB-70	72.0	2.83		262	4.10N	17 26 00
6 JUN 66	73	B-58	31.9	1.43		247	0.25N	17 31 30
5 JUN 66	73B	KC-135	2.5		2.35			
7 JUN 66	76A	B-58	31.6	1.48		241	1.09S	16 10 40
7 JUN 66	76B	KC-135	4.3		2.35			
7 JUN 66	45A	KC-135	3.0		2.35			
7 JUN 66	45B	B-58	43.7	1.70		244	4.95N	16 23 [illegible]0
7 JUN 66	77A	KC-135	3.0		2.35			
7 JUN 66	77B	B-58	31.7	1.51		244	0.10S	16 33 12
7 JUN 66	46A	KC-135	2.6		2.35			
7 JUN 66	46B	B-58	43.7	1.65		246	5.42N	16 40 05
7 JUN 66	48A	B-58	38.7	1.31		245	5.23N	17 11 20
7 JUN 66	48B	KC-135	3.0		2.35			
7 JUN 66	79A	B-58	31.6	1.52		244	0.12N	17 22 20
7 JUN 66	79B	KC-135	2.6		2.35			
7 JUN 66	49A	B-58	43.3	1.43		252	4.68N	17 28 15
7 JUN 66	49B	KC-135	4.3		2.35			
7 JUN 66	80A	B-58	31.6	1.53		244	0.25N	17 38 45
7 JUN 66	80B	KC-135	3.0		2.35			
7 JUN 66	50A	B-58	43.3	1.43		245	5.00N	17 47 37
7 JUN 66	50B	KC-135	8.3		2.35			
7 JUN 66	81A	B-58	31.4	1.49		245	0.06S	17 56 25
7 JUN 66	81B	KC-135	4.3		2.35			

*Local time is ZULU minus 8 hours.

TABLE A-8

MISSION LOG - EDWARDS PHASE I (Continued)

DATE DY MO YR	MSN	A/C	ALT KFT MSL	MACH OR SPD	EPR	HDG	OFF-SET N/S	BOOM TIME HR MN SC ZULU
8 JUN 66	1	XB-70	31.8	1.38		246	5.02S	15 19 00
8 JUN 66	43A	B-58	42.4	1.62		245	5.24N	16 00 22
8 JUN 66	43B	KC-135	14.3		2.35			
8 JUN 66	75A	B-58	31.2	1.44		244	0.23N	16 06 45
8 JUN 66	75B	KC-135	8.3		2.35			
8 JUN 66	42A	B-58	43.3	1.67		247	4.85N	16 14 50
8 JUN 66	42B	KC-135	2.8		1.5			
8 JUN 66	73A	B-58	31.2	1.50		245	0.10N	16 24 20
8 JUN 66	73B	KC-135	2.5		1.5			
8 JUN 66	41A	B-58	43.2	1.60		246	5.32N	16 30 10
8 JUN 66	41B	KC-135	5.3		1.5			
8 JUN 66	72A	B-58	31.2	1.49		245	0.16N	16 38 45
8 JUN 66	72B	KC-135	2.8		1.5			
8 JUN 66	57	KC-135	3.3		1.5			
8 JUN 66	57B	B-58	37.6	1.66		248	5.90N	17 05 10
8 JUN 66	80RA	KC-135	2.8		1.5			
8 JUN 66	80RB	B-58	31.3	1.46		247	0.14N	17 12 30
8 JUN 66	56RA	KC-135	5.3		1.5			
8 JUN 66	56RB	B-58	43.0	1.64		244	5.14N	17 21 22
8 JUN 66	87	KC-135	3.3		1.5			
8 JUN 66	87	B-58	31.4	1.49		245	0.40N	17 28 30
8 JUN 66	55RA	KC-135	10.3		1.5			
8 JUN 66	55RB	B-58	43.2	1.64		244	5.16N	17 36 10
8 JUN 66	86RA	KC-135	5.3		1.5			
8 JUN 66	86RB	B-58	31.4	1.49		229		17 45 00
9 JUN 66	86SA	KC-135	5.3		1.5			
9 JUN 66	86SRB	B-58	31.0	1.50		246	0.25N	16 08 30
9 JUN 66	55SA	KC-135	10.3		1.5			
9 JUN 66	55SRB	B-58	35.7	1.69		244	5.17N	16 19 20
9 JUN 66	87SA	KC-135	3.3		1.5			
9 JUN 66	87SRB	B-58	31.0	1.53		244	0.08S	16 25 58
9 JUN 66	56SA	KC-135	5.3		1.5			
9 JUN 66	56SRB	B-58	43.3	1.72		243	4.70N	16 34 50
9 JUN 66	80SA	KC-135	2.8		1.5			
9 JUN 66	80SRB	B-58	31.0	1.53		245	0.06N	16 41 40
9 JUN 66	57SA	KC-135	3.3		1.5			
9 JUN 66	57SRB	B-58	43.1	1.70		244	5.23N	16 49 10
9 JUN 66	41SA	B-58	42.9	1.52		240	4.87N	17 07 54
9 JUN 66	41SB	KC-135	5.3		1.5			
9 JUN 66	73SA	B-58	31.7	1.50		243	0.49S	17 16 15
9 JUN 66	73SB	KC-135	2.5		1.5			
9 JUN 66	42SA	B-58	43.1	1.52		241	4.69N	17 23 54
9 JUN 66	42SB	KC-135	2.8		1.5			
9 JUN 66	75SA	B-50	31.7	1.55		246		17 31 23
9 JUN 66	75SB	KC-135	8.3		2.35			

TABLE A-8

MISSION LOG - EDWARDS PHASE I (Continued)

DATE DY MO YR	MSN	A/C	ALT KFT MSL	MACH OR SPD	EPR	HDG	OFF-SET N/S	BOOM TIME HR MN SC ZULU
9 JUN 66	43SA	B-58	43.0	1.68		243	4.62N	17 39 00
9 JUN 66	43SB	KC-135	14.3		2.35			
9 JUN 66	42SA	B-58	43.3	1.70		244	4.92N	17 57 00
9 JUN 66	42SB	KC-135	2.8		1.5			
9 JUN 66	46SA	B-58	42.9	1.68		246	4.74N	18 11 10
9 JUN 66	46SB	KC-135	3.3		2.35			
9 JUN 66	72SA	B-58	31.3	1.53		248	0.63N	18 22 10
9 JUN 66	72SB	KC-135	2.8		1.5			
13 JUN 66	18A	B-58	37.7	1.64		231	0.09S	16 46 43
13 JUN 66	18B	B-58	49.6	1.66		234	0.36S	16 49 22
13 JUN 66	21A	B-58	37.8	1.69		230	0.21S	17 00 16
13 JUN 66	21B	B-58	49.2	1.72		231	0.35S	17 02 48
13 JUN 66	26A	F-104	21.2	1.40		231	0.08N	17 12 35
13 JUN 66	26B	F-104	29.7	1.60			0.64S	17 13 45
13 JUN 66	29A	B-58	49.3	1.67		233	0.03N	18 06 25
13 JUN 66	29B	B-58	38.1	1.67		232	0.11S	18 07 35
13 JUN 66	32A	B-58	49.8	1.64		235	0.53N	18 20 25
13 JUN 66	32B	B-58	38.0	1.67		233		18 21 10
14 JUN 66	26A	F-104						16 08 00
14 JUN 66	26B	F-104	29.9	1.54		238	0.10S	16 10 50
14 JUN 66	38A	F-104						17 45 00
14 JUN 66	38B	F-104	29.7	1.52		233		17 45 45
14 JUN 66	37A	F-104	29.7	1.49		231		17 57 30
14 JUN 66	37B	F-104	21.1	1.39		231	0.02S	17 58 40
15 JUN 66	1XA	F-104	14.1	1.21		236	0.47N	16 14 50
15 JUN 66	1XB	F-104	28.1	1.50		233	0.13N	16 16 40
15 JUN 66	2XA	F-104	29.7	1.32		237	0.66N	16 21 40
15 JUN 66	2XB	F-104	14.1	1.20		233	0.22N	16 22 10
15 JUN 66	3XA	F-104	29.1	1.58		234	0.17N	16 38 25
15 JUN 66	3XB	F-104	14.2	1.15		235	0.18N	16 39 55
15 JUN 66	4XA	F-104	14.1	1.28		235	0.18N	16 47 15
15 JUN 66	4XB	F-104	29.9	1.62		233	0.44S	16 48 20
16 JUN 66	27A	F-104	29.3	1.65		230	0.10S	15 56 25
16 JUN 66	27B	F-104	20.5	1.40		228	0.26S	15 57 50
16 JUN 66	5X	F-104	29.7	1.65		344	0.25E	16 04 25
20 JUN 66	48A	B-58	41.3	1.55		232	2.20N	15 54 50
20 JUN 66	48B	KC-135	5.3		1.5			
20 JUN 66	79A	B-58	32.1	1.45		232	1.90S	16 08 00
20 JUN 66	79B	KC-135	3.3		1.5			
20 JUN 66	53A	B-58	42.7	1.59		232	5.00N	16 18 54
20 JUN 66	53B	KC-135	4.3		2.35			
20 JUN 66	84A	B-58	31.2	1.43		236		16 27 10
20 JUN 66	84B	KC-135	3.0		2.30			
20 JUN 66	54A	B-58	43.0	1.59		230	4.87N	16 35 40
20 JUN 66	54B	KC-135	3.0		2.30			
20 JUN 66	59A	KC-135	12.0		2.35			

TABLE A-8

MISSION LOG - EDWARDS PHASE I (Continued)

DATE DY MO YR	MSN	A/C	ALT KFT MSL	MACH	EPR	HDG	OFF-SET N/S	BOOM TIME HR MN SC ZULU
20 JUN 66	59B	B-58	43.4	1.41		233	5.00N	17 10 00
20 JUN 66	98A	KC-135	6.0		2.35			
20 JUN 66	98B	B-58	31.3	1.50		233		17 15 45
20 JUN 66	60A	KC-135	6.0		2.35			
20 JUN 66	90A	KC-135	6.0		2.35			
20 JUN 66	90B	B-58	31.8	1.55		230	0.17S	17 32 00
20 JUN 66	85A	B-58	32.3	1.45		231	4.35N	17 40 00
20 JUN 66	85B	KC-135	2.6		2.30			
20 JUN 66	93A	KC-135	2.6		2.30			
20 JUN 66	93B	B-58	32.1	1.55		231	0.17S	17 47 50
21 JUN 66	89A	KC-135	2.5		1.5			
21 JUN 66	89B	B-58	31.8	1.46		232	0.12N	16 01 55
21 JUN 66	58A	KC-135	2.8		1.5			
21 JUN 66	58B	B-58	43.6	1.67		233	5.12N	16 11 02
21 JUN 66	99A	KC-135	4.3		2.35			
21 JUN 66	99B	B-58	31.7	1.47		233	0.17N	16 17 05
21 JUN 66	66A	KC-135	2.8		1.5			
21 JUN 66	66B	B-58	39.9	1.59		233	5.00N	16 25 17
21 JUN 66	100A	KC-135	3.0		2.35			
21 JUN 66	100B	B-58	31.8	1.46		232	0.14S	16 30 23
21 JUN 66	68A	KC-135	8.3		2.35			
21 JUN 66	68B	B-58	44.1	1.62		232	4.83N	16 39 19
21 JUN 66	69A	B-58	39.4	1.39		233	5.00N	17 29 35
21 JUN 66	69B	KC-135	4.3		2.35			
21 JUN 66	48A	B-58	43.1	1.60		232	5.00N	17 44 12
21 JUN 66	48B	KC-135	5.3		1.5			
21 JUN 66	40A	B-58	43.8	1.65		235	5.40N	17 56 55
21 JUN 66	40B	KC-135	5.3		1.5			
21 JUN 66	60A	KC-135	8.3		2.35			
21 JUN 66	60B	B-58	43.9	1.64		233	5.16N	18 08 59
21 JUN 66	61A	KC-135	4.3		2.35			
21 JUN 66	61B	B-58	43.3	1.62		232	4.76N	19 37 19
21 JUN 66	101A	KC-135	2.6		2.35			
21 JUN 66	101B	B-58	31.7	1.50		233		19 51 15
21 JUN 66	85A	B-58	31.7	1.50		234	0.22N	20 05 50
21 JUN 66	85B	KC-135	2.6		2.35			
22 JUN 66	28A	B-58	37.0	1.63		234	0.18N	16 13 27
22 JUN 66	28B	F-104	20.8	1.35		233	0.10S	16 13 43
22 JUN 66	19A	B-58	37.2	1.64		233	0.24N	16 28 15
22 JUN 66	19B	F-104	29.5	1.42		233	0.20S	16 30 05
22 JUN 66	6X	B-58	43.6	1.60		259	1.34S	16 48 24
22 JUN 66	30A	B-58	37.4	1.65		230	0.20S	17 43 34
22 JUN 66	30B	F-104	29.7	1.37		232	0.16S	17 44 38
22 JUN 66	34A	F-104	29.6	1.39		233		17 56 06
22 JUN 66	34B	B-58	43.4	1.61		230	4.00N	17 57 06
22 JUN 66	24A	B-58	43.3	1.60		233	5.06N	18 10 37
22 JUN 66	24B	F-104	20.9	1.36		231	0.23S	18 11 26

TABLE A-8

MISSION LOG - EDWARDS PHASE I (Continued)

DATE DY MO YR	MSN	A/C	ALT KFT MSL	MACH	EPR	HDG	OFF-SET N/S	BOOM TIME HR MN SC ZULU
22 JUN 66	35A	B-58	43.4	1.60		225	0.92S	18 21 21
22 JUN 66	35B	F-104	21.1	1.28		235	0.25N	18 22 47
22 JUN 66	25A	F-104	21.9	1.39		233	0.21N	18 36 39
22 JUN 66	25B	B-58	43.2	1.59		233	4.89N	18 37 59
22 JUN 66	23A	F-104	29.7	1.51		237	0.34N	18 50 21
22 JUN 66	23B	B-58	37.4	1.63		232	0.50N	18 52 05
23 JUN 66	17A	B-58	37.6	1.64		231	0.39N	15 46 08
23 JUN 66	17B	F-104	21.6	1.40		227	0.46S	15 48 00
23 JUN 66	22A	F-104	29.3	1.40		232		15 59 59
23 JUN 66	22B	B-58	43.4	1.67		229	4.25N	16 00 40
23 JUN 66	31A	B-58	37.5	1.64		231	0.12N	16 12 14
23 JUN 66	31B	F-104	21.3	1.39		232		16 12 21
23 JUN 66	33A	B-58	43.2	1.64		232	5.02N	16 21 38
23 JUN 66	33B	F-104	29.8	1.49		230	0.10S	16 22 04
23 JUN 66	20A	F-104	21.5	1.37		233	0.19N	19 51 20
23 JUN 66	20B	B-58	37.4	1.65		233	0.10N	19 54 17
23 JUN 66	36A	F-104	20.9	1.39		230	0.37S	20 05 15
23 JUN 66	36B	B-58	37.4	1.66		231	0.25S	20 06 26
23 JUN 66	7X	F-104	29.6	1.55		258	0.29S	20 18 18
23 JUN 66	6X2	B-58	43.5	1.67		258	9.86N	20 21 21

TABLE A-9

MISSION LOG - EDWARDS PHASE II

DATE DY	MO	YR	MSN	A/C	ALT KFT MSL	MACH OR SPD	EPR TKFF (LDG)	HDG	OFF-SET L/R,K	CRS	BOOM TME HR	MN	SC ZULU
23	NOV	66	1-1	XB-70	37.2	1.46		242	L10.3	327	18	21	42
23	NOV	66	1-2	F-104									
23	NOV	66	1-3	B-58	32.4	1.4		240	L 7.2	327	18	32	37
23	NOV	66	1-4	F-104	18.6	1.3		241	R 2.2	327	18	38	14
10	NOV	66	2-1	XB-70	37.3	1.48		236	L37.6	314	19	00	15
10	NOV	66	2-2	F-104									
10	NOV	66	2-3	B-58	33.0	1.50		257	L 7.5	314	19	11	42
10	NOV	66	2-4	F-104						314	19	15	32
12	DEC	66	3-1	B-58	32.4	1.5		247	R 7.8	346	18	27	31
12	DEC	66	3-2	XB-70	37.6	1.5		246	L 0.9	345	18	31	42
12	DEC	66	3-4	F-104	17.8	1.3		245	L 2.3	346	18	39	51
16	DEC	66	4-1	B-58	32.0	1.5		247	R 1.9	350	15	53	45
16	DEC	66	4-2	XB-70	38.6	1.5		246		350	15	57	40
12	DEC	66	5-1	B-58	36.3	1.65		245	R63.3	346	17	59	12
12	DEC	66	5-2	XB-70	59.1	2.49		246	R68.1	346	18	05	31
12	DEC	66	5-3	WC135B	1.8		1.76	058	L 0.8	346	18	07	23
20	DEC	66	6-1	B-58	35.5	1.65		244	R40.4	354	19	56	02
20	DEC	66	6-2	XB-70	60.0	2.5		248	R67.9	354	20	00	07
20	DEC	66	6-3	WC135B	3.7		1.76	76		354	20	01	49
13	JAN	67	7-1	B-58	35.8	1.62		241	R38.7	013	18	04	55
13	JAN	67	7-2	DC-8	3.7		1.76	068		013	18	15	02
13	JAN	67	7-3	XB-70	60.3	2.5		249	R71.3	013	18	17	20
17	JAN	67	8-1	B-58	35.5	1.65		265	L 3.3	017	17	47	50
17	JAN	67	8-2	DC-8	3.6		1.67	074	L 0.7	017	17	51	55
17	JAN	67	8-3	XB-70	60.0	2.5		246	R68.2	017	17	53	59
10	NOV	66	9-1	XB-70	59.4	2.51		246	R31.8	314	18	35	11
10	NOV	66	9-2	B-58	40.4	1.65		247	R 1.8	314	18	38	03
10	NOV	66	9-3	F-104	21.1	1.14		249	R 2.0	314	18	44	25
23	NOV	66	10-1	XB-70	59.7	2.46		246	L13.3	327	19	00	01
23	NOV	66	10-2	B-58	32.4	1.32		242	L 6.0	327	19	06	12
16	DEC	66	11-1	F-104	20.9	1.4		244	L 1.5	350	15	11	18
16	DEC	66	11-2	B-58	40.2	1.65		246	R 7.8	350	15	24	42
16	DEC	66	11-3	XB-70	59.4	2.5		245		350	15	20	35
4	JAN	67	12-1	B-58	39.2	1.65		245	L 2.1	004	20	38	05
4	JAN	67	12-2	XB-70	60.3	2.5		246	L .2	004	20	40	52
4	JAN	67	12-3	F-104	22.0	1.42		246	R 6.7	004	20	46	22
3	NOV	66	13-1	B-58	35.9	1.65		244	L 2.5	307	18	51	03
3	NOV	66	13-2	XB-70	60.0	1.80		241	R 6.4	307	18	54	33
3	NOV	66	13-3	F-104	20.0	1.40		240	R 3.4	307	18	57	13
20	DEC	66	14-1	XB-70	59.7	1.8		247	R 0.2	354	20	22	37
20	DEC	66	14-2	B-58	38.9	1.53		245	R 4.7	354	20	25	26
20	DEC	66	14-3	F-104	21.4	1.3		243	R 1.4	354	20	28	35

TABLE A-9

MISSION LOG - EDWARDS PHASE II (Continued)

DATE DY	DATE MO	DATE YR	MSN	A/C	ALT KFT MSL	MACH OR SPD	EPR TKFF (LDG)	HDG	OFF-SET L/R,K	OBS BOOM TIME DY	HR	MN	SC ZULU
13	JAN	67	15-1	XB-70	60.6	1.8		248	R 9.5	013	18	42	32
13	JAN	67	15-2	B-58	39.6	1.65		252		013	18	44	42
13	JAN	67	15-3	F-104	20.2	1.4		242	R 0.2	013	18	27	48
17	JAN	67	16-1	B-58	39.7	1.65		247	R 3.0	017	18	16	[illegible]
17	JAN	67	16-2	XB-70	59.7	1.8		245	R 0.7	017	18	[illegible]	52
17	JAN	67	16-3	F-104	20.6	1.4		250	R 5.0	017	18	41	27
31	OCT	66	17-1	F-104	31.2	1.61		252	R 7.0	304	16	30	14
31	OCT	66	17-2	B-58	48.6	1.61		248	R 4.0	304	16	34	[illegible]
31	OCT	66	18-1	B-58	47.3	1.61		250	L 1.4	304	16	57	27
31	OCT	66	18-2	F-104	31.0	1.65		247	R 1.2	304	16	59	27
31	OCT	66	19-1	F-104	30.5	1.61		250	R 5.0	304	17	59	33
31	OCT	66	19-2	B-58	38.9	1.43		244	L 1.2	304	18	02	54
31	OCT	66	20-1	B-58	43.9	1.52		251	R 2.4	304	18	22	[illegible]
31	OCT	66	20-2	F-104	31.0	1.65		249		304	18	28	[illegible]
8	NOV	66	21-1	B-58	47.6	1.60		244	L 1.3	312	16	22	25
8	NOV	66	21-2	WC135B			1.76						
8	NOV	66	22-1	B-58	47.5	1.65		243	L 2.0	312	16	56	12
8	NOV	66	22-2	WC135B	3.9	250	1.76	68					
8	NOV	66	23-1	B-58	47.8	1.65		246	R 1.4	312	17	14	51
8	NOV	66	23-2	WC135B	3.3	235	1.76	62					
8	NOV	66	24-1	B-58	47.7	1.65		250	R 3.9	312	17	40	35
8	NOV	66	24-2	WC135B	5.4	230	1.76	73	R .1				
8	NOV	66	25-1	B-58	46.8	1.65		247	R 1.0	312	18	02	59
8	NOV	66	25-2	WC135B	3.9	215	1.76	78	R .1				
8	NOV	66	26-1	B-58	47.9	1.50		244		312	18	11	41
8	NOV	66	26-2	WC135B	3.2	222	1.76	77					
8	NOV	66	27-1	WC135B	3.1	245	1.76	73					
8	NOV	66	27-2	B-58	47.4	1.65		247	R .9	312	18	30	07
8	NOV	66	28-1	WC135B	3.9	235	1.76	59	R .1				
8	NOV	66	28-2	B-58	49.0	1.6		248	R 4.1	312	18	37	55
8	NOV	66	29-1	WC135B	5.3	230	1.76	65	R .1				
8	NOV	66	29-2	B-58	47.4	1.65		249	R 2.0	312	18	54	25
8	NOV	66	30-1	WC135B	3.1	245	1.76	65					
8	NOV	66	30-2	B-58	47.5	1.65		254	R 4.0	312	19	17	41
8	NOV	66	31-1	WC135B	3.9	225	1.76	55					
8	NOV	66	31-2	B-58	47.0	1.60		244	L 1.3	312	19	52	41
8	NOV	66	32-1	WC135B	5.2	235	1.76	77	L .1				
8	NOV	66	32-2	B-58	48.0	1.65		242	L 2.3	312	20	20	44

TABLE A-9

MISSION LOG - EDWARDS PHASE II (Continued)

DATE			MSN	A/C	ALT KFT MSL	MACH OR SPD	EPR TKFF (LDG)	HDG	OFF-SET L/R,K	OBS DY	BOOM TME ZULU		
DY	MO	YR									HR	MN	SC
16	NOV	66	33-1	B-58	36.2	1.65		241	L 5.5	320	16	30	18
16	NOV	66	33-2	WC135B	3.2	240	1.76	060	L 0.4	320	16	31	42
16	NOV	66	34-1	B-58	36.0	1.65		240	L 4.2	320	16	58	12
16	NOV	66	34-2	WC135B	4.4	236	1.76	67	L 0.8	320	16	59	33
16	NOV	66	35-1	B-58	36.4	1.63		247	R 1.5	320	17	18	37
16	NOV	66	35-2	WC135B	4.4	238	1.76	066	L 0.2	320	17	19	59
16	NOV	66	36-1	B-58	36.2	1.64		245		320	17	45	38
16	NOV	66	36-2	WC135B	3.2	230	1.76	066		320	17	47	10
16	NOV	66	37-1	B-58	36.0	1.65		248	R 2.1	320	18	09	56
16	NOV	66	37-2	WC135B	3.1	260	1.76	062		320	18	08	15
16	NOV	66	38-1	B-58	35.9	1.64		239	L 8.9	320	18	31	39
16	NOV	66	38-2	WC135B	4.4	244	1.76	072	L 0.2	320	18	30	54
16	NOV	66	39-1	B-58	35.7	1.65		244	R 0.7	320	18	51	56
16	NOV	66	39-2	WC135B	4.3	256	1.76	083	L 0.7	320	18	49	30
16	NOV	66	40-1	B-58	36.2	1.64		248	R 2.2	320	19	01	57
16	NOV	66	40-2	WC135B	3.1	240	1.76	072	L 0.3	320	18	59	22
17	NOV	66	41-1	B-58	36.3	1.65		247	R 3.5	321	18	16	40
17	NOV	66	41-2	WC135B	4.3	257	1.76	077		321	18	17	37
21	NOV	66	42-1	B-58		282				325	19	00	11
21	NOV	66	42-2	WC135B	3.0	262	1.76	063	L 1.2	325	19	01	13
21	NOV	66	43-1	WC135B	3.1		1.76	065	L 0.6	325	19	19	48
21	NOV	66	43-2	B-58	35.9	1.65		245	L 2.9	325	19	23	53
21	NOV	66	44-1	WC135B	4.3		1.76	062	L 0.7	325	19	30	47
21	NOV	66	44-2	B-58	36.4	1.65		250	L 3.5	325	19	31	58
21	NOV	66	45-1	B-58	36,0	1.63		246		325	19	54	19
21	NOV	66	45-2	WC135B	4.3	280	1.76	077	L 1.3	325	19	55	12
21	NOV	66	46-1	B-58	35.9	1.55		246	L 1.6	325	20	37	14
21	NOV	66	46-2	WC135B	3.0		1.76	065	L 0.3	325	20	37	55
21	NOV	66	47-1	WC135B	3.1		1.76	074	L 0.6	325	21	00	26
21	NOV	66	47-2	B-58	35.8	1.62		244	L 2.5	325	21	02	53
21	NOV	66	48-1	WC135B	4.3	250	1.76	083	L 0.8	325	21	13	02
21	NOV	66	48-2	B-58	36.0	1.65		247	L 0.4	325	21	15	01
15	NOV	66	49-1	WC135B	2.8	240	1.76	63	L 0.2	319	18	19	28
15	NOV	66	49-2	F-104	16.6	1.15		246	R 0.3	319	18	21	13
15	NOV	66	50-1	WC135B	3.3	232	1.76	68	L 0.1	319	18	31	46
15	NOV	66	50-2	F-104	16.4	1.22		245	L 0.6	319	18	34	46
29	NOV	66	51-1	WC135B	2.7	255	1.76	72		333	16	32	15
29	NOV	66	51-2	F-104	16.6	1.30		246	R 4.0	333	16	34	06
6	DEC	66	52-1	F-104	17.0	1.30		248	R 6.2	340	17	34	17
6	DEC	66	52-2	WC135B	2.7	270	1.76	74	L 1.7	340	17	34	55
6	DEC	66	53-1	F-104	17.1	1.30		246	R 3,1	340	17	44	23
6	DEC	66	53-2	WC135B	2.4	255	1.76	74	L 1.[illegible]	340	17	45	31
7	DEC	66	54-1	F-104	16.5	1.3		244	L 0.8	341	17	10	18
7	DEC	66	54-2	WC135B	2.9	255	1.76	63	L 2.2	341	17	12	01

TABLE A-9

MISSION LOG - EDWARDS PHASE II (Continued)

DATE			MSN	A/C	ALT KFT MSL	MACH OR SPD	EPR TKFF (LDG)	HDG	OFF-SET L/R,K	OBS DY	ROOM TME ZULU		
DY	MO	YR									HR	MN	SC
21	DEC	66	55-1	F-104	16.9	1.3		243	L 1.9	355	16	33	30
21	DEC	66	55-2	WC135B	2.7	290	1.76	68		355	16	35	38
9	DEC	66	56-1	F-104	16.5	1.28		246	R 2.2	343	18	29	42
9	DEC	66	56-2	WC135B						343	18	30	31
9	DEC	66	57-1	F-104	16.0	1.29		240	R 0.8	343	18	37	54
9	DEC	66	57-2	WC135B	2.5	265	1.76	71	L 0.2	343	18	39	48
20	DEC	66	58-1	WC135B	2.5	315	1.76	73	R 0.2	354	17	40	24
20	DEC	66	58-2	F-104	16.8	1.3		246	R10.8	354	17	41	58
20	DEC	66	59-1	WC135B	3.4		1.76	74		354	17	50	26
20	DEC	66	59-2	F-104	16.6	1.34		247	R 8.0	354	17	50	17
21	DEC	66	60-1	WC135B	2.8	280	1.78	68	L .1	355	16	20	49
21	DEC	66	60-2	F-104	17.1	1.28		245	L .8	355	16	22	31
15	NOV	66	61-1	F-104	29.6	1.65		247	R 3.1	319	16	55	19
15	NOV	66	61-2	WC135B	3.4	242	1.76	61	L 0.3	319	16	56	14
30	NOV	66	62-1	F-104	30.3	1.66		246	R 1.3	334	16	27	50
30	NOV	66	62-2	WC135B	4.2		1.76	72	L .2	334	16	29	22
30	NOV	66	63-1	F-104	29.6	1.62		242	L .9	334	18	32	57
30	NOV	66	63-2	WC135B	6.6		1.76	64	L .6	334	18	34	22
29	NOV	66	64-1	WC135B	6.5	280	1.76	69	L 0.5	333	16	58	31
29	NOV	66	64-2	F-104	29.4	1.65		248	R 3.0	333	16	59	48
6	DEC	66	65-1	WC135B	4.4	260	1.75	68	L 1.2	340	17	27	17
6	DEC	66	65-2	F-104	29.7	1.60		244	L 0.1	340	17	30	17
6	DEC	66	66-1	WC135B	3.4	245	1.76	9	L 1.0	340	17	54	54
6	DEC	66	66-2	F-104	30.1	1.64		245	R 2.2	340	17	57	09
7	DEC	66	67-1	F-104	29.6	1.65		245	L 2.9	341	17	00	26
7	DEC	66	67-2	WC135B	3.3		1.76	70	L 1.8	341	17	02	52
21	DEC	66	68-1	F-104	29.7	1.64		249	R 5.1	355	16	44	18
21	DEC	66	68-2	WC135B	4.0	275	1.76	72	R .2	355	16	46	12
9	DEC	66	69-1	F-104	29.6	1.67		246	R 1.2	343	16	58	08
9	DEC	66	69-2	WC135B	6.2		1.76	70	L 0.9	343	17	00	05
20	DEC	66	70-1	WC135B	6.4	310	1.76	77	R 0.6	354	16	40	56
20	DEC	66	70-2	F-104	29.8	1.65		246		354	16	40	13
20	DEC	66	71-1	WC135B	4.4	285	1.76	74	R 0.2	354	17	02	08
20	DEC	66	71-2	F-104	30.6	1.58		244	L 0.1	354	17	03	53
20	DEC	66	72-1	WC135B	4.5	270	1.76	75		354	17	11	36
20	DEC	66	72-2	F-104	34.3	1.42		245	R 5.1	354	17	15	45
30	NOV	66	73-1	F-104	50.1	1.51		248	R 2.3	334	17	16	24
30	NOV	66	73-2	WC135B	4.2	265	1.76	68		334	17	17	36
15	NOV	66	74-1	F-104	50.5	1.5		247	R 4.2	319	16	27	48
15	NOV	66	74-2	WC135B	6.4	224	1.64	70	L 0.9	319	16	29	49
30	NOV	66	75-1	F-104	49.6	1.5		246	R .9	334	18	41	52
30	NOV	66	75-2	WC135B	11.2		1.76	66	L .8	334	18	42	37

TABLE A-9

MISSION LOG - EDWARDS PHASE II (Continued)

DATE DY MO YR	MSN	A/C	ALT KFT MSL	MACH OR SPD	EPR TKFF (LDG)	HDG	OFF-SET L/R,K	OBS DY	BOOM TIME HR MN SC ZULU
29 NOV 66	76-1	WC135B	10.6		1.76	75	L 0.2	333	18 22 34
29 NOV 66	76-2	F-104	50.4	1.52		245	R 0.9	333	18 26 13
29 NOV 66	77-1	WC135B	6.4		1.76	53	R 0.1	333	18 29 42
29 NOV 66	77-2	F-104	48.8	1.51		244	L 0.6	333	18 33 10
7 DEC 66	78-1	WC135B	4.1	295	1.76	69	L 1.4	341	16 29 11
7 DEC 66	78-2	F-104	50.0	1.5		246	R 1.3	341	16 31 09
7 DEC 66	79-1	F-104	50.4	1.5		246	R 1.8	341	16 45 22
7 DEC 66	79-2	WC135B	4.2	290	1.75	62	L 1.2	341	16 46 38
21 DEC 66	80-1	F-104	49.2	1.5		244	R .2	355	16 53 33
21 DEC 66	80-2	WC135B	6.2	302	1.76	70	L .9	355	16 54 17
21 DEC 66	81-1	F-104	49.4	1.51		245	R .9	355	17 04 14
21 DEC 66	81-2	WC135B	10.4	276	1.76	66	L .6	355	17 05 55
9 DEC 66	82-1	WC135B	10.3	245	1.75	71	R 1.2	343	16 38 05
9 DEC 66	82-2	F-104	50.5	1.5		245	R 3.0	343	16 39 30
20 DEC 66	83-1	WC135B	6.5		1.76	73	R 0.2	354	16 50 00
20 DEC 66	83-2	F-104	50.2	1.5		245	R 1.9	354	16 53 45
21 DEC 66	84-1	WC135B	4.3		1.78	69	L .2	355	16 02 55
21 DEC 66	84-2	F-104	49.5	1.56		247	R 3.2	355	16 06 14
16 NOV 66	85-1	B-58	36.0	1.63		248	R 3.4	320	19 24 59
16 NOV 66	85-2	WC135B	3.1	258	1.76	075	L 0.3	320	19 24 02
16 NOV 66	86-1	B-58	36.1	1.64		251	R 3.3	320	19 44 23
16 NOV 66	86-2	WC135B	3.1		1.76	070		320	19 43 31
17 NOV 66	87-1	B-58	36.4	1.65		246	R 2.5	321	17 29 39
17 NOV 66	87-2	WC135B	3.2	240	1.76	067	L 0.5	321	17 30 33
17 NOV 66	88-1	B-58	36.3	1.65		244	R 5.5	321	17 55 10
17 NOV 66	88-2	WC135B	3.1		1.76	072	L 0.5	321	17 56 27
4 JAN 67	113-1	B-58	39.1	1.65		246	L .7	004	21 04 47
4 JAN 67	113-2	XB-70	60.3	1.8		247	L .1	004	21 05 53
4 JAN 67	113-3	F-104	20.5	1.4		246	R 1.2	004	21 25 44
2 DEC 66	117-1	F-104	[illegible]	1.65		251	R [illegible]	336	17 48 18
2 DEC 66	117-2	B-58	45.0	1.65		244	L 1.0	336	17 48 26
2 DEC 66	118-1	B-58	48.7	1.65		247	R 2.0	336	18 23 22
2 DEC 66	118-2	F-104	36.1	1.60		244	R 4.1	336	18 25 11
7 DEC 66	119-1	F-104	36.4	1.65		249	L 5.0	341	19 00 19

TABLE A-9

MISSION LOG - EDWARDS PHASE II (Continued)

DATE			MSN	A/C	ALT KFT MSL	MACH OR SPD	EPR TKFF (LDG)	HDG	OFF-SET L/R,K	OPS DY	BOOM TME ZULU		
DY	MO	YR									HR	MN	SC
8	NOV	66	121-1	B-58	47.4	1.66		250	R 7.4	312	19	40	28
8	NOV	66	121-2	WC135B	5.2	260	1.76	51	R .1				
8	DEC	66	122-1	B-58	48.6	1.65		244	R 2.2	342	17	10	25
8	DEC	66	122-2	WC135B	3.4	270	1.76	71	L 0.3	342	17	12	32
8	DEC	66	123-1	B-58	47.6	1.51		249	L 4.9	342	17	23	15
8	DEC	66	123-2	WC135B	2.7	255	1.76	68	L 0.6	342	17	25	24
8	DEC	66	124-1	B-58	48.2	1.65		244	L 0.9	342	17	49	36
8	DEC	66	124-2	WC135B	4.2	264	1.76	69	L 0.3	342	17	51	37
8	DEC	66	125-1	B-58	48.2	1.65		242		342	18	04	16
8	DEC	66	125-2	WC135B	3.4	282	1.76	72	L 0.3	342	18	06	40
8	DEC	66	126-1	B-58	50.2	1.65		242	L 4.2	342	18	29	28
8	DEC	66	126-2	WC135B	2.7	288	1.76	66	L 0.3	342	18	31	25
8	DEC	66	127-1	WC135B	2.8	264	1.76	74	L 0.2	342	18	41	43
8	DEC	66	127-2	B-58	49.0	1.65		241	R 3.5	342	18	44	40
8	DEC	66	128-1	WC135B	3.3	278	1.76	69	L 0.3	342	19	08	11
8	DEC	66	128-2	B-58	41.6	1.4		244		342	19	10	06
8	DEC	66	129-1	WC135B	4.1	255	1.76	71	L 0.5	342	19	22	23
8	DEC	66	129-2	B-58	48.8	1.65		244	R 0.8	342	19	24	42
8	DEC	66	130-1	WC135B	2.8	282	1.76	72	L 0.6	342	19	37	26
8	DEC	66	130-2	B-58	49.4	1.65		247	R 1.8	342	19	39	[illegible]
8	DEC	66	131-1	WC135B	3.4	268	1.76	76	L 0.6	342	19	54	43
8	DEC	66	131-2	B-58	48.5	1.65		246	R 1.2	342	19	55	35
8	DEC	66	132-1	WC135B	4.1	288	1.76	75	L 0.6	342	20	18	14
8	DEC	66	132-2	B-58	48.3	1.65		241	L 4.5	342	20	18	26
15	NOV	66	149-1	WC135B	3.0	234	1.76	65	L 0.2	319	17	17	29
15	NOV	66	150-1	WC135B	5.1	226	1.76	67	L 0.3	319	18	00	35
15	NOV	66	161-2	WC135B	3.8	230	1.76	67	L 0.5	319	17	03	48
21	DEC	66	172-1	WC135B	3.3	304	1.76	68	L .5	355	17	22	15
21	DEC	66	172-2	F-104	29.0	1.65		245	R 6.4	355	17	23	18
15	NOV	66	174-2	WC135B	5.3	232	1.76	57	L 0.4	319	16	37	21
8	DEC	66	221-1	B-58	47.2	1.4		246	R 3.9	342	16	43	36
8	DEC	66	221-2	WC135B	4.1	268	1.76	70	L 0.3	342	16	43	38
15	NOV	66	249-1	WC135B	3.0	234	1.76	66	L 0.1	319	17	24	13
15	NOV	66	250-1	WC135B	3.8	227	1.76	63	L 0.2	319	18	03	44
15	NOV	66	261-2	WC135B	3.8	230	1.76	67	L 0.6	319	17	10	48
15	NOV	66	274-2	WC135B	5.3	248	1.76	58	L 1.1	319	16	45	14
15	NOV	66	350-1	WC135B	5.2	247	1.76	60	L 0.8	319	18	39	23
15	NOV	66	450-1	WC135B	2.5	252	1.76	63	L 0.1	319	18	46	23

Note: 31 SR-71 missions were flown in addition to the missions listed above.

TABLE A-10

INSTRUMENT LOCATION LOG

DATE DY MO YR	CHNL	HOUSE INSTR	INST TYPE	LOCATION
15 NOV 66	101	1 MA1	ACOUSTIC	CNTR LR SUSP 6 FT ABV FLR
15 NOV 66	102	1 MA2	ACOUSTIC	CNTR FR-KIT SUSP 6 FT ABV FLR
15 NOV 66	103	1 MA3	ACOUSTIC	CNTR BR1 SUSP 6 FT ABV FLR
15 NOV 66	104	1 MA4	ACOUSTIC	BR1 FRONT OF CLOSET MOVABLE
15 NOV 66	105	1 MA5	ACOUSTIC	FR-KIT FRONT OF RANGE MOVABLE
15 NOV 66	106	1 A3	LF ACCEL	CONC BLK FLR BR1 AXIS VERT
15 NOV 66	107	2 MA1	ACOUSTIC	BTWN LR AND DR SUSP 6 FT ABV FLR
15 NOV 66	108	2 MA2	ACOUSTIC	CNTR KIT SUSP 6 FT ABV FLR
15 NOV 66	109	2 MA3	ACOUSTIC	CNTR BR1 SUSP 6 FT ABV FLR
15 NOV 66	110	2 MA4	ACOUSTIC	CNTR FR
15 NOV 66	111	2 MA5	ACOUSTIC	FR-KIT-DR KIT STOVE
15 NOV 66	112	2 MA6	ACOUSTIC	FR-KIT-DR,DR SUSP 6 FT ABV FLR NR CHINA CLOS
15 NOV 66	113	1 MA7	ACOUSTIC	OUTSIDE SUBJECT GROUP
15 NOV 66	114			IRIG B TIME CODE AND VOICE
DATE DY MO YR	CHNL	HOUSE INSTR	INST TYPE	LOCATION
15 NOV 66	201	1 A5	LF ACCEL	ROOF PLATE LINE E WALL NE CRNR (E-W ACCEL)
15 NOV 66	202	1 A11	LF ACCEL	BR1 E WALL (N-S ACCEL)
15 NOV 66	203	1 A6	LF ACCEL	ROOF PLATE LINE N WALL NE CRNR (N-S ACCEL)
15 NOV 66	204	1 ML3	PRESSURE	BR1 E WALL NEXT TO A11
15 NOV 66	205	1 ML4	PRESSURE	FR-KIT CNTR CLG ATTIC SIDE
15 NOV 66	206	2 SG41	STRAIN	GARAGE WNDW 3RD FROM CNTR
15 NOV 66	207	1 SG3	STRAIN	GARAGE CNTR LARGE WINDOW
15 NOV 66	208	2 SG42	STRAIN	GARAGE WNDW 2ND FROM CNTR
15 NOV 66	209	2 MA8	ACOUSTIC	TRIGGER MIKE
15 NOV 66	210	2 SG43	STRAIN	GARAGE WNDW 1ST FROM CNTR
15 NOV 66	211			SPARE
15 NOV 66	212	2 SG44	STRAIN	GARAGE WNDW CENTER
15 NOV 66	213			SPARE
15 NOV 66	214			IRIG B TIME CODE AND VOICE
DATE DY MO YR	CHNL	HOUSE INSTR	INST TYPE	LOCATION
15 NOV 66	301	2 A1	LF ACCEL	DR FLR CONC BLK AXIS VERT
15 NOV 66	303	2 A3	LF ACCEL	BR1 BED CONC BLK AXIS EAST-WEST
15 NOV 66	302	2 A2	LF ACCEL	FR FLR CONC BLK AXIS VERT BETW KIT AND FR
15 NOV 66	304	1 A1	LF ACCEL	LR FLR CONC BLK AXIS VERT
15 NOV 66	305	1 A2	LF ACCEL	FR-KIT FLR CONC BLK AXIS VERT
15 NOV 66	306	2 A1P	HF ACCEL	FR FLR CONC BLK AXIS VERT
15 NOV 66	307	2 A2P	HF ACCEL	FR-KIT-DR MOVABLE KIT WNDW BETW KIT AND FR
15 NOV 66	308	2 A5P	HF ACCEL	AIR COND DOOR
15 NOV 66	309	2 A6P	HF ACCEL	FR-KIT-DR MOVABLE KIT CABNT DOOR ABV SINK LEFT
15 NOV 66	310	2 A9P	HF ACCEL	BR1 CLOSET DOOR
15 NOV 66	311	2 A10P	HF ACCEL	KIT CABINET
15 NOV 66	312	2 A11P	HF ACCEL	FR-KIT-DR MOVABLE DR CNTR N WINDOW
15 NOV 66	313	2 A12P	HF ACCEL	BR1 EAST WNDW
15 NOV 66	311			IRIG B TIME CODE AND VOICE

TABLE A-10

INSTRUMENT LOCATION LOG (Continued)

DATE DY MO YR	CHNL	HOUSE INSTR	INST TYPE	LOCATION
15 NOV 66	401	2 A5	LF ACCEL	ROOF PLATE LINE N WALL NE CORNER (N-S ACCEL)
15 NOV 66	402	2 A9	LF ACCEL	BR1 CNTR CLG BOTT CHORD ROOF TRUSS
15 NOV 66	403	2 A6	LF ACCEL	ROOF PLATE LINE E WALL NE CORNER (E-W ACCEL)
15 NOV 66	404	2 A11	LF ACCEL	DR E WALL MID HT CNTR STUD
15 NOV 66	405	2 A7	LF ACCEL	2ND FLR PLATE LINE N WALL NE CRNR (N-S ACCEL)
15 NOV 66	406	2 A12	LF ACCEL	BR1 N WALL MID HT CNTR STUD
15 NOV 66	407	2 A8	LF ACCEL	2ND FLR PLATE LINE E WALL NE CRNR (E-W ACCEL)
15 NOV 66	408	2 ML2	PRESSURE	BTWN LR AND DR SUSP 6 FT ABV FLR
15 NOV 66	409	2 ML3	PRESSURE	BR1 ATTIC
15 NOV 66	410	2 ML4	PRESSURE	BR1 CNTR CLG SUSP 2 IN BELOW CLG
15 NOV 66	411	2 D1	DISPL	ADJACENT TO A5 WITH SAME AXIS
15 NOV 66	412	2 D2	DISPL	ADJACENT TO A6 WITH SAME AXIS
15 NOV 66	413			SPARE
15 NOV 66	414			IRIG B TIME CODE AND VOICE

DATE DY MO YR	CHNL	HOUSE INSTR	INST TYPE	LOCATION
15 NOV 66	501	3 A1H	LF ACCEL	TOP STEEL COL INTERIOR OF BLDG E-W RACKING
15 NOV 66	502	3 A2H	LF ACCEL	TOP STEEL COL SOUTH SIDE E-W RACKING
15 NOV 66	503	3 A3H	LF ACCEL	TOP STEEL COL SOUTH SIDE N-S RACKING
15 NOV 66	504	3 A4H	LF ACCEL	TOP STEEL COL WEST SIDE N-S RACKING
15 NOV 66	505	3 A5H	LF ACCEL	CENTER OF ROOF GRDR HORZ ACCEL
15 NOV 66	506			BLANK
15 NOV 66	507	3 S1L	STRAIN	BOTT FLANGE ROOF GIRDER AT CENTERLINE
15 NOV 66	508	3 S2L	STRAIN	BOTT FLANGE ROOF GIRDER AT 1/4 POINT
15 NOV 66	509	3 S3L	STRAIN	BOTT FLANGE ROOF PURLIN AT CENTERLINE
15 NOV 66	510			BLANK
15 NOV 66	511			BLANK
15 NOV 66	512	3 M2	PRESSURE	INTERIOR 3 FT BELOW ROOF
15 NOV 66	513	3 M4	PRESSURE	EXTERIOR ABV ROOF
15 NOV 66	514			IRIG B TIME CODE

DATE DY MO YR	CHNL	HOUSE INSTR	INST TYPE	LOCATION
15 NOV 66	601	2 MLC1	PRESSURE	EAST CORNER CRUCIFORM ARRAY
15 NOV 66	602			BLANK
15 NOV 66	603	2 MLC2	PRESSURE	NORTH CORNER CRUCIFORM ARRAY
15 NOV 66	604			BLANK
15 NOV 66	605	2 MLC3	PRESSURE	WEST CORNER CRUCIFORM ARRAY
15 NOV 66	606			BLANK
15 NOV 66	607	2 MLC4	PRESSURE	SOUTH CORNER CRUCIFORM ARRAY
15 NOV 66	608			BLANK
15 NOV 66	609	2 MLC5	PRESSURE	CENTER BOTTOM MAST CRUC ARRAY
15 NOV 66	610			BLANK
15 NOV 66	611	2 MLC6	PRESSURE	CENTER TOP MAST CRUCIFORM ARRAY
15 NOV 66	612			VOICE
15 NOV 66	613			100 KC REFERENCE SIGNAL
15 NOV 66	614			IRIG B TIME CODE

TABLE A-10

INSTRUMENT LOCATION LOG (Continued)

DATE DY MO YR	CHNL	HOUSE INSTR	INST TYPE	LOCATION
15 NOV 66	801	2 ML15	PRESSURE	OUTSIDE CNTR HIGH ROOF N SIDE
15 NOV 66	802	2 ML16	PRESSURE	OUTSIDE CNTR HIGH ROOF S SIDE
15 NOV 66	803	1 ML1	PRESSURE	OUTSIDE N WALL ABV PLATE
15 NOV 66	804	1 ML2	PRESSURE	OUTSIDE E WALL
15 NOV 66	805	1 ML5	PRESSURE	OUTSIDE W WALL GARAGE AT PLATE LINE
15 NOV 66	806	1 ML6	PRESSURE	OUTSIDE S WALL CNTR ABV PLATE LINE
15 NOV 66	807	2 ML17	PRESSURE	OUTSIDE N WALL MIDDLE-2ND STORY
15 NOV 66	808	2 ML18	PRESSURE	OUTSIDE S WALL MIDDLE 2ND STORY
15 NOV 66	809	2 ML14	PRESSURE	OUTSIDE W WALL GARAGE ABV PLATE LINE
15 NOV 66	810	2 ML13	PRESSURE	OUTSIDE W WALL ABOVE GARAGE ROOF
15 NOV 66	811	2 ML11	PRESSURE	OUTSIDE E WALL MIDDLE OF 2ND STORY
15 NOV 66	812	2 ML12	PRESSURE	OUTSIDE E WALL MIDDLE OF 1ST STORY OUTSIDE DR
15 NOV 66	813			VOICE
15 NOV 66	814			IRIG B TIME CODE (CP-100 REVERSED IRIG HEAD)

The cruciform array analog tapes were digitized using the facilities available at Edwards AFB. The analog to digital conversion (A/D) equipment at Edwards AFB is capable of digitizing six channels of data at a sampling rate of 5000 samples per second per channel. The computer facilities consist of an IBM 7094/44 direct coupled system.

The raw digital tapes are in multiplexed form, and a computer program was developed in order to provide a check of the digital data and to arrange the data in a readily usable form. This program de-multiplexed and arranged the data serially by mission and channel, evaluated the sinusoidal calibrations by a curve fitting and averaging process, edited the digital data so that the final output was one second of data, converted the data to pounds per square foot, located positive and negative peaks and computed the time interval between them, and stored identification information on the tape. A brief description of the format of the digital tapes is given in Appendix A-1.

DIGITIZATION REQUIREMENTS

Structures E-1, E-2 and E-3

Instrument	Tape Recorder Number	Digitization Rate SPS	Filter Cutoff CPS
Low Frequency Accelerometers	TR-2	8000	
" " "	TR-3	2000	
" " "	TR-4	8000	
" " "	TR-5	8000	
High " "	TR-3	10000	
Loading Microphones	TR-2	8000	
" "	TR-4	1600	
" "	TR-5	8000	
" " Chnls 801-807	TR-6	8000	
" " Chnls 808-812	TR-8	1600	
Acoustic "	TR-1	20000	
Strain Gages	TR-2	1600	
Strain Gages	TR-5	1600	
Displacement Meters	TR-4	1600	
Cruciform Array			
Loading Microphones	TR-6	5000	1350

Note: For tape recorders 2, 4, 5, and 8 the time code (tape channel 14) is digitized as a data channel and the sampling rate is 8000 sps.

IV PSYCHOACOUSTIC TESTS

The first step in studying the effects of booms and subsonic aircraft noise upon human reactions was to specify the noise conditions and devise psychological tests to obtain subjective reactions of listeners to booms and aircraft noise in terms of the relative "acceptability" of these sounds to them. The primary test procedure devised was that of paired-comparisons in which the listener must indicate which of a pair of sounds (two booms, or a boom and aircraft noise) is judged to be the more acceptable to him. The two sounds, designated as A and B, were made to occur within one to three minutes or less of each other, and judgments were obtained four separate times for each condition of A and B, twice for A vs. B, and twice in reverse, B vs. A. In addition, the listeners were required to indicate on a scale the acceptability of each boom or aircraft noise.

During Phase I, 173 subjects were selected from Edwards Air Force Base and Lancaster. During Phase II, subjects were not used in the Lancaster test house. Approximately 120 subjects were selected for Phase II from each of three communities: Edwards Air Force Base, Fontana, and Redlands, California, with the majority of the tests conducted with the Edwards Air Force Base personnel. During both Phases, the subjects were distributed inside and outside the test structures at Edwards Air Force Base as follows:

E-1 Bedroom	8 subjects
E-1 Living Room	8 subjects
E-1 Kitchen/Family Room	11 subjects
E-2 Bedroom	10 subjects
E-2 Living Room	9 subjects
E-2 Dining Room	6 subjects
E-2 Kitchen/Family Room	13 subjects
Outside	55 subjects
Total	120 subjects

The subjects were all adults (18 years or older) and were chosen to be as representative as possible of the communities in which they live, including at least 80% housewives. The hearing acuity of the subjects from Edwards was determined by standard audiometric techniques.

In the experiments, at least four evaulators monitored the subjects, notifying them 1-2 minutes in advance of each pair of test flights, and collecting and scoring the answer sheets. The psychological response sheets were scored and the data tabulated on a daily basis. The response data were also entered on punch cards for detailed post-test analyses which would show the percentage of people who preferred the first or the second of the pairs of sonic booms or boom and subsonic aircraft noise, and the distributions of acceptability ratings given to each of the sonic booms or aircraft noises. The data were averaged over all subjects in E-1 and E-2 to represent general "indoor" listening response and averaged over the outdoor listeners to obtain "outside" listening response. In addition, the subjective response data were scored in terms of groups of subjects located in individual rooms within E-1 and E-2 to determine possible differences in room conditions upon subjective response. Data concerning age, sex, occupation, and years of residence in their community were obtained from all of the subjects and correlated with the subjective response data.

The subjective response data were correlated with a number of physical measures of the sonic boom and subsonic aircraft noise to determine possible methods of measurement, and calculations from these measurements, that can be used to predict subjective reactions to sonic booms and subsonic aircraft noise. To this end, the physical measures and indices given on p. A-58 are being obtained for Phase II data. The poor time code on the tapes from Phase I limits the number of computations which will be made from that Phase. Finally, the structural response data will be analyzed and an attempt made to explain, if possible, what role the house structures and components in the houses had in producing the acoustic and vibrational signals to which the subjects responded.

EDWARDS PHASE II DATA REDUCTION

	BOOM				NOISE	
	Inside		Outside			
	Mic.	Acc.	Mic.	Acc.	Inside	Outside
"Peak" PNdB, dB(A), dB(N), loudness (phon-s)	X		X		X	X
"Integrated Average" of above	X		X		X	X
Values of Peak PNdB, dB(A), dB(N), loudness (phon-s) at 1/2 sec. interval	X		X		X	X
Peak Acceleration		X				
ΔP	X		X			
Energy Spectra 0-50 cps	X		X			
0-200	X		X			
0-1000	X		X			
20-1000	X		X			
20-200	X		X			

NOTE: (1) Use 70 msec smoothing time constant for boom analysis.

(2) Use 200 msec smoothing time constant for noise analysis.

(3) Recording instruments to be used.

(a) 5 cruciform-array microphones (booms)

(b) 1 outdoor acoustic microphone (booms and noise)

(c) 8 indoor acoustic microphones (booms and noise)

(d) 8 low-frequency accelerometers (booms)

(4) "Integrated Average" means the accumulated values of smoothed (averaged) samples.

(5) For boom-boom missions → 44 records to be processed.

For boom-noise missions → 31 records to be processed.

Annex A

Appendix A-1

OPERATIONAL SUPPORT PLAN

Prepared by USAF Flight Test Center

Annex A

Appendix A-1

OPERATIONAL SUPPORT PLAN

In general, technical support was required for the sonic boom test program in four areas, defined as follows:

1. Radar control and space positioning data
2. Base timing
3. Data processing
4. Photographic support

Radar vectoring and control determined aircraft position over the instrumented test sites during the recording times.

Base timing provided a time reference for the acoustical information recorded at the test sites.

Data processing digitized and formatted the recorded information in a form (DDPS output tape) acceptable to the AFFTC Data Systems Computing Center.

The operations plan specified the following tasks to achieve the above-listed support:

1. Technical Support by Edwards Air Force Base

Provide radar vectoring and control for all aircraft during sonic boom tests. Analog plots were required for all aircraft during supersonic portion of flight, with no more than two aircraft shown on each plot.

Provide altitude and speed adjustments for aircraft prior to 20 nautical miles from entry point. No correction will be made after the 20 mile point.

Provide countdown from three miles to test site.

Provide deceleration point and turn information to aircraft.

Provide a record of the following information for all supersonic flights:

1. Time of entry point
2. Time supersonic
3. Time at altitude
4. Time on Mach number
5. Time at 20 mile point
6. Time subsonic

Provide digital radar data for all XB-70 and NASA F-104 flights.

Provide analog plots on the WC-135B flights.

Provide a terminal timing unit for installation in the instrumented test site on south base.

Provide one timing van to supply base timing at the bowling alley.

Provide a copy of analog tape recorded at set site.

Provide analog-to-digital conversion for approximately 30 tapes. Each tape will consist of information from as many as 12 sonic boom tests.

The magnetic tape will contain the following information:

1. Six channels of wide band data (54 KC ± 40%)
2. One channel IRIG B timing
3. One channel of 100 KC reference frequency
4. One track audio

The above data channels will be digitized simultaneously and formatted as follows:

1. 5000 samples/second/channel
2. Number of words per record - 920
3. Number of bits per word - 24
4. Bit density - 556 B.P.I.

Pre- and post-calibration information shall also include digitization in conjunction with the data.

Start stop time for the calibration and data will be identified by the requester (contractor).

The programmer (contractor) will merge the digitized tape with the card information (control and test data) in the direct coupled computer system (IBM 7094/44).

Computer output will consist of:

1. tabular
2. three tapes of merged data (copies)

Provide 50 4x5 still photos of instrumented test sites and subjects.

Prepare a 15-to 20-minute silent inhouse engineering briefing film of Phase II of the test program.

Prepare a Staff Film Report on Phase II of the test program.

Provide 10 each 8x10 prints of the still photos (color).

Provide vertical aerial photo (color) of the three test sites as shown in Attachment 4. Area shown is 2000' long by 600' wide.

Provide six each proportional color prints of aerial photos.

2. Flight Operations, Strategic Air Command (SAC) Mission

SAC will provide B-58 aircraft and associated tanker support for the number of booms and overpressure required.

Planning Data

SAC B-58 support for XB-70 aircraft will stage from Edwards AFB to provide back-up capability of the AFSC TB-58 aircraft as well as affording common briefing of all participating aircrews. If back-up is unnecessary, SAC B-58 may be launched after XB-70 force for use in other experiments as required. All B-58 sorties supporting F-104 and WC-135B aircraft may be launched from home base.

Point of supersonic overflight is 34-51-25N 117-54-30W on an inbound track of 245° mag Aircraft will decelerate to subsonic speed on request of SPORT CONTROL, turning right for subsequent runs as necessary. Racetrack pattern will remain within bounds of Edwards SOA.

A maximum of two B-58 aircraft will be in the racetrack pattern at any time. B-58 aircraft will be spaced at opposite ends of the racetrack pattern when two B-58's are needed to meet boom times.

Planned boom time for first aircraft scheduled to cross overflight point on sorties, not involving the XB-70, is 1630Z.

Planned boom times for XB-70 are 1745Z and 1845Z on double boom sorties, and 1745Z on single boom sorties. Boom times for other aircraft supporting the XB-70 will be provided.

Ten additional B-58 supersonic overflights will be required at seismological sites in Arizona and Utah (5 booms each site) upon completion of the experiment at Edwards Air Force Base. Information will be forthcoming when it becomes available.

B-58 aircrews will report actual true heading, Mach number, indicated altitude (29.92), gross weight, and flight conditions, i.e., turbulence or any departure from straight-and-level at time of overflight of designated point.

3. Flight Operations-Military Aircraft Command Mission

MAC will provide WC-135B fanjet subsonic overflights as required.

Planning Data

MAC WC-135B support will be generated to conduct low-level subsonic overflights of varying PNdB noise levels. Altitudes, aircraft configuration and EPR required to produce desired PNdB levels are as indicated at the end of this Appendix.

Flights will be flown over specially constructed instrumented houses and subjects in conjunction with the XB-70, B-58, and F-104 booms.

Weekly flight schedules will be furnished Edwards Center scheduling by 1100 each Wednesday. Daily confirming flight schedules will be furnished by 1100 on the day preceding that schedule.

XB-70 flights will take priority over all other desired data. Coordination of both weekly and daily schedules will be effected by Edwards AFB Center Scheduling with project personnel of the 9th Weather Squadron. Deviations from schedule will occur only as dictated by XB-70 status.

WC-135B aircraft will fly a right-hand racetrack pattern with an inbound heading of 065 degrees over the test site. Space positioning will orbit WC-135B aircraft in the vicinity of Rosamond, California, to establish timing.

All overflights will be conducted at takeoff power setting of 1.76 EPR. Aircraft will be slow-flown on inbound heading to approximately 60 seconds from over site. Aircraft at this time will be configured to enable minimum speed at takeoff power, maintaining constant assigned altitude. Aircraft will maintain altitude and power setting for 30 seconds after passing test site. Pilot will report to tower when on inbound heading. Tower will take action to preclude loss of data due to conflicting engine run up, takeoffs, or landings during overflight of WC-135B. At termination of each run, WC-135B pilot will pass power setting, speed, and altitude to SPORT CONTROL.

ALTITUDE ABOVE SITE	EPR	PNdB
8000'	1.76	85
4000'	1.76	95
2800'	1.76	100
2000'	1.76	105
1800'	1.76	106
1400'	1.76	110
1000'	1.76	113
700'	1.76	117
500'	1.76	119
400'	1.76	121
250'	1.76	125

Annex A

Appendix A-2

INSTRUMENT CALIBRATION PROCEDURES

Annex A

Appendix A-2

INSTRUMENT CALIBRATION PROCEDURES

General

The following general procedures were followed:

1. All equipment was left in the "Power On" condition, except tape recorders which were turned off over weekends only.

2. All instrumentation channels were calibrated prior to and immediately after each day's run. Calibration commenced at 0600 on run days.

3. Use of voice annotations was held to a minimum to maintain IRIG timing on the tapes.

4. On each run day, personnel were informed, prior to calibrating, of values to set on the various channels. Variations in gain settings were recorded on the log sheet for the particular mission.

5. All pertinent data, including unusual conditions or events, were recorded on the appropriate data sheets.

Photocon Microphone Calibration

1. Tune Dynagage
2. Set Dynagage at attenuation of "18."
3. Set Burr Brown Amplifier at 18 dB.
4. Balance Dynagage for "zero output."
5. Install the proper adaptor on the driver unit of the model PC-125 calibrator.

6. Check the battery condition of the PC-125 by turning the function control to "Bat. Check." If the meter reads below the line marked "Bat. Check," recharge the batteries for a minimum of 12 hours. If the meter reads above the "Bat. Check" line, proceed as follows:

7. Set the "dB SPL" control to 120 dB, turn the function control to "operate" and adjust the "SPL ADJ" control until the "SPL" meter reads 0 dB.

8. Adjust Burr Brown amplifier gain to obtain a "2vPP" signal at tape recorder input for SPL of 120 dB.

9. Alternately switch calibrator "on & off" and check balance and gain settings. The system is now ready to make the day's calibration and record on tape. NOTE: After system calibration is on tape, do not retune Dynagage.

10. When flight settings are made, leave Dynagage at "18." Add or subtract as needed in Burr Brown amplifier. (Always stay 1 dB under the assigned level--if the difference is an odd number.)

11. Continually check the Dynagage tuner for dc balance.

12. Do not rebalance system after the command "Recorders On" is given.

13. Only one variable will be used to obtain the desired SPL, if possible.

14. A 2vPP signal will be the equivalent of 120 dB SPL.

NOTE: If the tuning meter should read high throughout the entire tuning range, it indicates that the link circuit is open. If this happens, the transducer cable and its connectors should be inspected. If the meter stays near the middle of the scale during tuning, a short in the transducer cable or in the transducer itself is indicated.

Accelerometer Calibration

1. Set accelerometer voltage at "±28 volts dc."
2. Set accelerometer amplifier voltage at "±15 volts dc."
3. Check output voltage when switch is in "amplifier" position.
4. Balance output to "zero" with balance pot, adjust dc balance, and check with digital voltmeter.
5. Run a current inspection calibrate on the sensitivity range selected for the day's flight, using table below as a guide:

Accelerometer Sensitivity	External Calibrate Box
0.05 g	8 micro amps
0.1 g	16 micro amps
0.2 g	20 micro amps
0.5 g	20 micro amps
1.0 g	20 micro amps

Current Insertion Calibrating Procedure:

1. Insert the phone jack of the external insertion box into front of accelerometer control panel.
2. Record "zero" voltage on data sheet.
3. With the calibrate switch of the external calibrate box in the "positive" position, adjust the balance pot to give the required current level as listed in step 4 above. Record the voltage, then switch to the "negative" calibrate position and record the voltage on your data sheet.
4. Record calibrate 0, +, and - signals on tape recorder.

Strain Gage Calibration

1. Check system for proper sensitivity range card. (Registor Board)
2. Check output voltage (amplifier balance) when switch is in "dummy gage" position. (Should be "zero.")
3. Check calibrate voltages on "dummy bridge" position.
4. If calibrate voltage varies more than 20-millivolts from original calibration, call to attention of project engineer.
5. Switch to "active gage" position and zero active bridge.
6. Check calibrate voltages with digital voltmeter. (Record on data sheet.) Record calibrate signal on tape recorder.

Bruel and Kjaer Microphone Calibration

1. Set Burr Brown Amplifier (Model 9860) at 100 dB.

2. Install the proper adapter on the driver unit of Model PC-125 calibrator (Photocon unit).

3. Check the battery condition of the PC-125 by turning the function control to "Bat. Check." If the meter reads below the line marked "Bat. Check", recharge the batteries for a minimum of 12 hours. If the meter reads above the "Bat. Check" line, proceed as follows:

4. Set the "dB SPL" control to 100 dB, turn the function control to "operate" and adjust the "SPL ADJ" control until the "SPL" meter reads zero dB.

5. Verify that the two 100 dB settings produce a 1.5 volt p-p (±10%) reading on the oscilloscope. (Note: If scope indicates greater than ±10%, set unit's knob to produce 1.5 volts (±10%) and then reset knob, by means of a setscrew, to zero).

6. Verify that oscillograph deflection is approximately 0.5 in. with the two 100 dB settings.

7. For data runs, set amplifier gain knobs in accordance with the published schedule for each individual mission. (Normally, these settings were determined by SRI and were different for each noise and each boom mission The dial settings then become the "calibration" for each mission. (Examples: If dials indicate 117 dB, the 1.5 volt p-p signal of step 5 above equals 117 dB. If dials indicate 83 dB, 1.5 p-p = 83 dB.)

High Frequency Accelerometer Calibration

1. Set oscillator to 1000 Hz (cps).

2. Plug oscillator into "oscillator" terminal on Datacraft calibration panel.

3. Plug scope into "monitor" terminal on Datacraft calibration panel.

4. Set selector switch on Datacraft panel to proper channel and set toggle switch to "input."

5. Adjust amplitude control on oscillator until proper mv/g level is read on scope (400 mv/g accelerometers are being used). Correct input voltages will be assigned each day.

6. Reset toggle switch on calibration panel to "output." Adjust gain control on that panel until output reads 2.0 volts p-p on the scope.

7. Repeat for other channels, turning selector switch to proper channel each time.

Annex A

Appendix A-3

WEATHER STUDIES

Annex A

Appendix A-3

WEATHER STUDIES

ESSA conducted studies concerned with the effects on sonic boom propagation of waves on low-level temperature inversions and with the influence of low-level turbulence on boom characteristics using boom signature measurements from the microphone arrays at E-2 (cruciform), Site 9, and Site 5 (8000-ft linear array) (Figs. 2 and 3), and soundings of temperature, humidity, and wind to at least 10,000 ft above the operating altitudes of aircraft producing the test sonic booms. One sounding release at about 0700 LST and a second at about 1100 LST were calculated to provide the data needed.

ESSA also collected meteorological data from an instrumented, lightweight "pop-up" tower about 85 ft in height located near the center of the Site 9 array. Temperature, total wind vector (expressed in terms of the three components), and fluctuations of these elements were recorded at 10 ft and 85 ft above ground. Data were recorded on 14-channel tape recorders from which spectral analyses of temperature and wind gustiness were performed over a frequency range of from 2 to 0.001 Hz. Dates and periods of operation of the tower are listed in Table A-3-1.

In addition, an instrumented aircraft made concurrent meteorological measurements in the vicinity of any existing low-level (up to 10,000 ft MSL) temperature inversions during the sonic boom missions. During the early part of the test program, a C-131B aircraft associated with the LO-LOCAT project was used when available, while a chartered light plane (Cessna 150) was flown as soon as suitable instrumentation became available in December. Tables A-3-2 and A-3-3 list the dates and times of the missions flown by the C-131B and the Cessna 150, respectively. Figure A-3-1 shows the flight track followed by the latter in relation to the general test area. The C-131B data was taken over the vicinity of the southeastern position of Rogers Dry Lake.

Approximately one hour prior to each sonic boom mission series, as indicated above, the Rawinsonde Section of the Edwards Air Force Base Weather Detachment conducted a special sounding using a modified radiosonde attached to a balloon ascending at about 750 ft/min, which provided a detailed, continuous temperature profile up to 10,000 ft MSL. These data were used operationally to determine the heights of any temperature inversions in the lower atmosphere, and in turn to specify the maximum altitude of the aircraft measurements for each mission. Table A-3-4 lists the dates and times of the low-level soundings taken during the project. Following each of these soundings a normal sounding to high altitudes was taken by Rawinsonde Section for general use by all participants.

Table A-3-1

ESSA METEOROLOGICAL TOWER OPERATIONS
PHASE II-EDWARDS AIR FORCE BASE

DATE	PERIODS OF DATA COLLECTION (LST)
Nov. 16, 1966	0820-1230
" 17 "	0934-1230
" 21 "	0815-1330
" 22 "	1030-1430
" 23 "	0530-0630, 0836-0935
" 29 "	0935-1015, 1245-1515
" 30 "	0750-1000, 1230-1330
Dec. 1 "	0800-0930, 1239-1430
" 2 "	0830-1045
" 8 "	0800-1320
" 9 "	0845-1045
" 12 "	0938-1130, 1439-1600
" 16 "	0719-0824, 1115-1523
" 19 "	0800-0848
" 20 "	0845-1000, 1100-1230
" 21 "	0700-1115
Jan. 4, 1967	0926-1030, 1209-1421
" 9 "	1010-1330

Table A-3-2

C-131B AIRCRAFT OPERATIONS
PHASE II-EDWARDS AIR FORCE BASE

DATE	PERIODS OF DATA COLLECTION (LST)
Nov. 4, 1966	*0900-0920
" 28 "	*0915-0935, 1315-1335
" 29 "	1058-1114
" 30 "	0915-0930
Dec. 1 "	*0915-0931, 1320-1336
" 12 "	1110-1130
" 16 "	0859-0908

* 8000 ft linear microphone array in operation

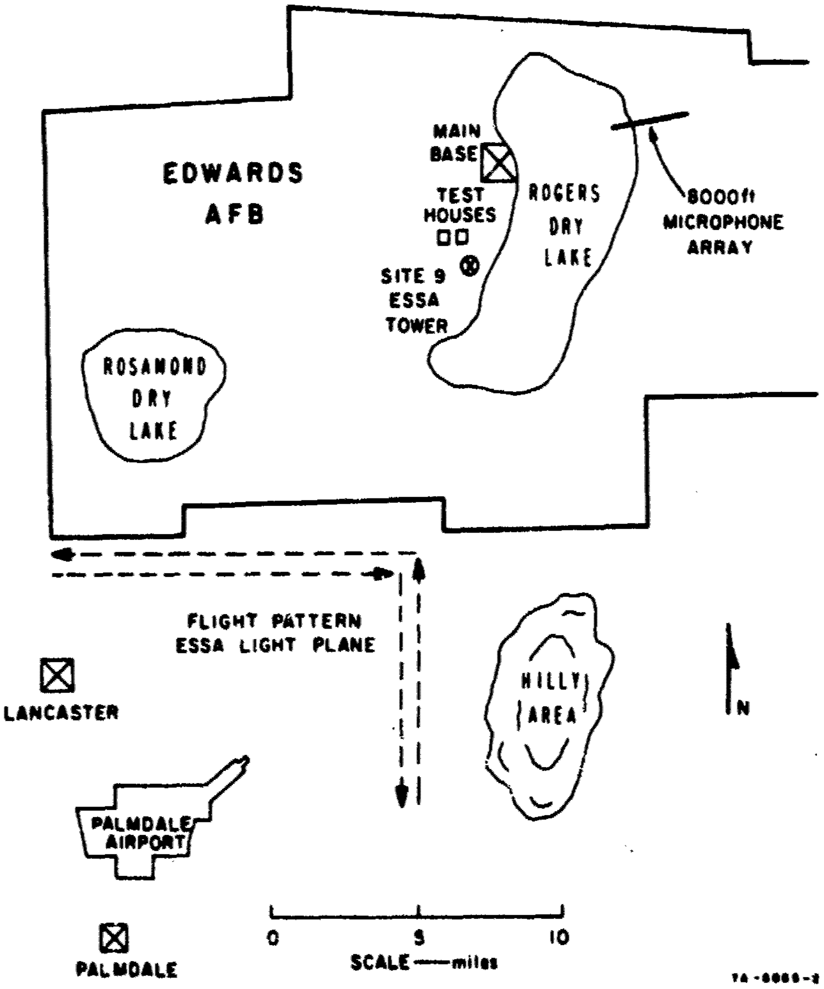


FIG. A-3-1 FLIGHT PATTERN OF ESSA INSTRUMENTED LIGHT AIRCRAFT

Table A-3-4

LOG OF LOW-LEVEL, SLOW-ASCENT TEMPERATURE SOUNDINGS
TAKEN BY EAFB WEATHER DETACHMENT
PHASE II-EDWARDS AIR FORCE BASE

Nov. 4, 1966	1545, 2100
" 8 "	1813
" 9 "	1900
" 10 "	1830, 2200
" 14 "	1608, 2110
" 15 "	1755
" 16 "	1810
" 17 "	1650, 2207
" 18 "	1700, 2000
" 21 "	1800
" 22 "	1850
" 23 "	1947
" 28 "	1600, 1605(?)
" 29 "	1730, 2131
" 30 "	2355
Dec. 1, 1966	1600, 1945
" 2 "	1830
" ? "	?
" 6 "	1600
" 7 "	1830
" 9 "	1730
" 12 "	1630, 2130
" 13 "	1545, 2200
" 14 "	1545
" 15 "	1520
" 16 "	1400
" 19 "	1630
" 20 "	1535
" 21 "	1600
Jan. 4, 1967	1630, 1845
" 5 "	2000
" 6 "	1715, 1950
" 9 "	1815, 2100

Annex A

Appendix A-4

LEGAL

Annex A

Appendix A-4

LEGAL

1. Procedures for Handling Damage Complaints

a. All complaints were received by the Edwards Air Force Base Information Office. The Information Office maintained statistics on all complaints received. All complaints in which damage was reported were recorded on the complaint report furnished by the Air Force Flight Test Center Staff Judge Advocate. Reports of damage complaints were delivered to the Claims Officer, Air Force Flight Test Center, no later than 1500 hours each workday. Damage complaints received on weekends were delivered to the Claims Officer at 0730 hours each Monday. Any report of personal injury was to be reported immediately to the Claims Officer, Air Force Flight Test Center.

b. The Claims Officer, Air Force Flight Test Center, reviewed each complaint of damage, categorized the complaint by type, i.e., Glass, Plaster, Glass and Plaster, Structural, Personal Injury, or Miscellaneous, and delivered the complaint report to the designated representative of John A. Blume and Associates by 1600 hours each day. Damage complaints received on Monday morning were delivered to John A. Blume and Associates by 0830 hours each Monday. The Claims Officer provided the John A. Blume and Associates representative with a supply of Air Force Logistics Command Forms 666 through 670.

c. The Claims Officer, Air Force Flight Test Center, sent directly to potential claimants the necessary claim forms and instructions.

d. John A. Blume and Associates utilized qualified engineers in investigating damage complaints. All damage complaints were investigated.

e. Air Force Logistics Command Form 666 was utilized in investigating glass, bric-a-brac, etc., damage complaints. Air Force Logistics Command Form 667 was utilized in investigating plaster and structural damage complaints. The investigating engineer took photographs depicting the damage and provided diagrams of the damaged areas on Air Force Logistics Command Forms 669 and 670.

f. John A. Blume and Associates recorded data pertaining to the flight causing the damage on Air Force Logistics Command Forms 666 and 667. These data were obtained by John A. Blume and Associates from the Data Requirements and Scheduling Section.

g. All complaints of personal injury were to be investigated immediately by the Claims Officer, Air Force Flight Test Center.

h. All complaints of damage to animals were to be investigated within 24 hours by the Claims Officer and a veterinarian.

2. Procedures for Handling Claims

a. A specific block of claims numbers was assigned to Edwards Air Force Base so that claims generated by this exercise could be readily identified.

b. Upon receipt of a claim, Air Force Form 176 was prepared and the claim was assigned a claim number.

c. Claims resulting from this program were processed through normal claims channels. The Staff Judge Advocate, Air Force Flight Test Center, took final action on all claims filed for $500.00 or less. The Staff Judge Advocate, Sacramento Air Materiel Area, took final action on all claims filed for amounts between $500.00 and $1,000.00. Headquarters, United States Air Force, took action on all claims filed for $1,000.00 or more (such claims will be forwarded through Air Force Logistics Command).

d. All cases involving personal injury were to be evaluated by a medical doctor before final action was taken.

e. All cases involving injury to animals were to be investigated and evaluated by a veterinarian before final action is taken.

f. Claims were finalized when the Claims Officer had all the necessary documentation from the claimant and the report of investigation was complete.

3. Procedures for Handling Appeals

a. Upon receipt of a letter from a claimant expressing dissatisfaction with the decision rendered in his case, a letter was sent to the claimant explaining his appellate rights. At the same time, he was advised that he may present any additional evidence that he would like to have considered.

b. Should the claimant file an appeal, the Staff Judge Advocate reconsidered his previous decision and if he felt that payment was warranted, he might then reverse his previous decision. If he felt that reversal of his previous decision was not warranted, he transmitted the entire file through claims channels to Headquarters, United States Air Force.

4. Funding

Claims were paid out of Air Force funds initially. Standard Form 1034 was annotated to show that payment was made for "Claim paid during the Edwards AFB-National Sonic Boom Evaluation Program-Reimbursable by the Federal Aviation Agency." An extra copy of Standard Form 1034 was prepared and after payment was made by the local finance office, the extra copy was returned to the Office of the Staff Judge Advocate. Every 90 days Standard Form 1080 was dispatched to the Federal Aviation Agency and attached to that form were the supporting Standard Forms 1034 showing that payments had been made by the Department of the Air Force.

5. Reports

a. The Staff Judge Advocate, Air Force Flight Test Center, prepared a weekly report to Headquarters, United States Air Force (AFJALD), with information copies to Headquarters, Air Force Logistics Command (MCJMA) and Sacramento Air Materiel Area (JA). The weekly report was furnished through January 1967. Thereafter, reports were submitted monthly.

b. The Staff Judge Advocate, Sacramento Air Materiel Area prepared a weekly report to Headquarters, United States Air Force (AFJALD), with information copies to Headquarters, Air Force Logistics Command (MCJMA) and Air Force Flight Test Center (JA). The weekly report was furnished through January 1967. Thereafter, reports were submitted monthly.

6. Liaison

a. The Claims Officer, Air Force Flight Test Center maintained liaison with the National Sonic Boom Evaluation Office at Edwards Air Force Base.

b. The Claims Officer, Air Force Flight Test Center, delivered the weekly claims report to Edwards AFB National Sonic Boom Evaluation Office, each week during November and December 1966 and January 1967.

Annex A

Appendix A-5

PUBLIC INFORMATION

Annex A

Appendix A-5

PUBLIC INFORMATION

Public information responsibility for the Edwards Air Force Base Sonic Boom Test Program rested with the Director of Information, National Sonic Boom Evaluation Office (NSBEO).

1. The initial public announcement of tests and any subsequent public information releases were only made in coordination with that office.

2. Proposed public information releases from any of the several cooperating agencies were coordinated with the Director of Information, National Sonic Boom Evaluation Office, prior to release.

3. During operations at Edwards Air Force Base, the senior representative of NSBEO made policy determinations of public information activity at Edwards Air Force Base and responded to news media queries in coordination with the Office of Information, Air Force Flight Test Center, Edwards Air Force Base, California.

4. In the event an NSBEO representative was not available at Edwards Air Force Base, public information questions not answerable within the text of previously released information were referred to the Director of Information, AFRSTS, in Washington, D.C. (A/C 202, Oxford 59664 or Oxford 59665).

Annex B

PSYCHOLOGICAL EXPERIMENTS ON SONIC BOOMS

by

K. D. Kryter, P. J. Johnson, J. R. Young
Stanford Research Institute

Annex B

CONTENTS

ILLUSTRATIONS

ILLUSTRATIONS (continued)

ILLUSTRATIONS (continued)

TABLES

Annex B

PSYCHOLOGICAL EXPERIMENTS ON SONIC BOOMS

I INTRODUCTION

Most of the energy in the typical sonic boom as measured outdoors is in the low-frequency region, giving the boom an audible "thud" characteristic; in addition, there are briefly present significant amounts of energy at the higher frequencies due to the abruptness with which the the wavefront goes from ambient to peak positive pressure and returns to ambient pressure from peak negative pressure. This portion of the boom where the pressure is rapidly changing in intensity gives the boom a sharp audible "crack." For a given change in pressure, the more quickly (rise time) this pressure change takes place, the greater the amount of high-frequency energy and the greater the subjective sharpness of the "crack." If there is sufficient temporal separation between the beginning and end portions (the duration) of the sonic boom and if each of the two portions is of a sufficient intensity, the listener will hear two cracks rather than the one crack due to the initial portion of the wavefront.

The way in which the human auditory system perceives impulse sounds such as the sonic boom has been and is being studied under laboratory conditions at the University of Southhampton in Great Britain and at the Lockheed-California Company in the U.S.A. It has been found in these studies[26*] that subjective intensity (loudness or perceived noisiness) of a simulated outdoor sonic boom pressure signature is to a first approximation determined by the frequency spectrum of the energy in the booms and can therefore be calculated or predicted from knowledge of this spectrum.

Although the effects of the sonic boom upon people outdoors are of considerable interest, the fact remains that people indoors object as

---

*References are listed at end of Annex.

much if not more to the effects of environmental noise, even though the noise itself is generated outdoors and even though the house or building structure attenuates and reduces somewhat the intensity of the sound. This is usually attributed to the fact that people indoors demand and have a greater need for protection against noise because their indoor activities differ from their outdoor activities and perhaps because they spend more time indoors.

In the case of the sonic boom it is possible that the sonic boom and the house will interact in such a way that the interference effects on humans are augmented more than are other externally generated sounds, the reason being that components of the house structure are driven beyond their usual response and make the house "rattle," "creak," etc. In any event, it seems likely that the effects of sonic booms on people indoors will strongly determine human acceptability of the sonic booms.

Research has been conducted previously on this question and other related questions regarding the subjective response of people to noise using the so-called paired-comparison psychological tests in which listeners are asked to express their preference for one of two sounds presented within a brief period of time.[1,3,6,7,8,10,14,16-18,20-25] By means of the paired-comparison tests, one should be able to determine the relative effectiveness upon human response of sonic booms that differ with respect to their duration, rise time, or other signature variations. Such information could serve as design criteria for the development of supersonic aircraft that generate sonic booms that are the most acceptable to people located under or near their flight tracks.

Of more practical importance than knowing the relative acceptability to people of different types of sonic booms is the question of how acceptable these sonic booms will be to people when the booms are judged in terms of their acceptability under everyday living conditions and as a part of commercial aviation. Paired-comparison tests can also serve as a means of indirectly determining how people might accept and what they might do about sonic booms of various sorts when heard in their homes and when the booms were generated by commercial supersonic aircraft. This can be done by having one of the sounds in the pair be a sonic boom and the other be a sound from commercial aircraft for which we know the negative and positive values people hold in terms of political, legal, and social behavior.

It is, of course, to be understood that the paired-comparison tests, particularly involving two sounds that differ, require some validation before they can be accepted with confidence. Fortunately, in the present case this has been done to some extent for the sonic boom (studies at Oklahoma City[4] and France[11]), and particularly for the noise from commercial aircraft near busy metropolitan airports.[9,12,16]

The precision with which the relations between the physical and psychological effects of sonic booms and between sonic booms and the noise from subsonic aircraft can be determined is limited by the availability and characteristics of supersonic aircraft for generating the required sonic booms or of equipment whereby different types of sonic booms under laboratory conditions could be simulated. At the time the psychological experiments to be reported were planned, simulators that could generate sonic booms with complete fidelity were not available, although, as aforementioned, some tests have been conducted in the laboratory with simulations of both indoor and outdoor sonic booms.

With this background of information, the following series of experiments using military supersonic and subsonic jet aircraft were planned for prosecution at Edwards Air Force Base:

1. Paired-comparison tests and absolute ratings of the relative acceptability of sonic booms with the flyover noise from susonic jet aircraft, the subjects being placed both indoors and outdoors during the tests

2. Paired-comparison tests and absolute ratings of the relative acceptability of sonic booms from one type of supersonic aircraft to sonic booms from a second type, and of sonic booms from the same type of aircraft but flown under different operational conditions

3. An attitude survey of the acceptability of the sonic booms to residents in a military community habitually exposed to sonic booms.

II PROCEDURES FOR PSYCHOLOGICAL TESTS

Subjects selected from residents of the communities of Edwards Air Force Base, Fontana, and Redlands, California, were assigned to the various indoor* and outdoor test sites at Edwards Air Force Base (see Table 1). The instruction sheets and answer sheets were discussed with the subjects by the test monitors. One monitor was provided for about 20 subjects in each test room or area.

The aircraft sounds were presented in pairs with approximately one to two minutes between the members of each pair and a minimum of approximately four to five minutes between pairs. Each experimental test condition was repeated four times, twice with sound A of the pair given first in the sequence, and twice with sound B of the pair given first. The schedule of test missions and conditions for all the paired-comparison tests is given in Appendix A.

The subjects' main task was to indicate on an answer sheet which sound of each pair was the more acceptable if heard in or near their homes. They also were required to rate on a 13-point scale the acceptability of each of the sonic booms or sounds heard on certain days. A set of the instructions to the subjects and the answer sheet are in Appendix B.

Approximately one minute before the first sound of each pair, the subjects were advised that a sound would soon occur. The subjects were allowed to chat among themselves, knit, read, etc., but were admonished not to discuss their answers nor were they permitted to engage in loud conversation during the presentation of a pair of sounds. The subjects

---

*The test houses at Edwards designated as "E-1," and "E-2" were centrally air-conditioned and, except for one of the rooms, the door of which was kept closed, the windows and exterior doors of the house were closed during all the tests. The masonry "block house" used for some of the tests was not air-conditioned, but the windows and doors were kept closed.

Table 1

BIOGRAPHICAL DATA FOR THREE GROUPS:
EDWARDS, FONTANA, REDLANDS

	Edwards	Fontana	Redlands
Sex and Marital Status			
Single Male	1%	4%	12%
Married Male	12%	21%	28%
Total Male	13%	25%	40%
Single Female	3%	4%	7%
Married Female	84%	71%	53%
Total Female	87%	75%	60%
Male Occupations			
Air Force	79%	4%	0%
Retired	16%	25%	46%
Other	5%	71%	54%
Female Occupations			
Housewife	94%	92%	75%
Retired	1%	0%	11%
Other	5%	8%	14%
Average Age (years)			
Male	36.9	44.0	50.8
Female	33.7	38.7	49.2
Total	34.2	40.0	49.8
Education (Ave. yrs. Completed)			
Male	12.3	13.1	13.2
Female	11.8	11.9	13.1
Total	11.8	12.2	13.1
Total Biography Cards	142	98	153

were paid $1.50 per hour and appeared to be highly motivated and interested in the tests. The test results indicate that the subjects were attentive and reliable.

In addition to the test subjects, data were obtained from 50 percent of the residences at Edwards Air Force Base regarding their ratings or attitudes on a scale of the "acceptability" of sonic booms, the noise from subsonic aircraft, and street noise at and in their homes. This information was obtained by means of a mail survey conducted after the sonic boom test program was completed. The instructions and questionnaire used for the attitude survey are in Appendix C.

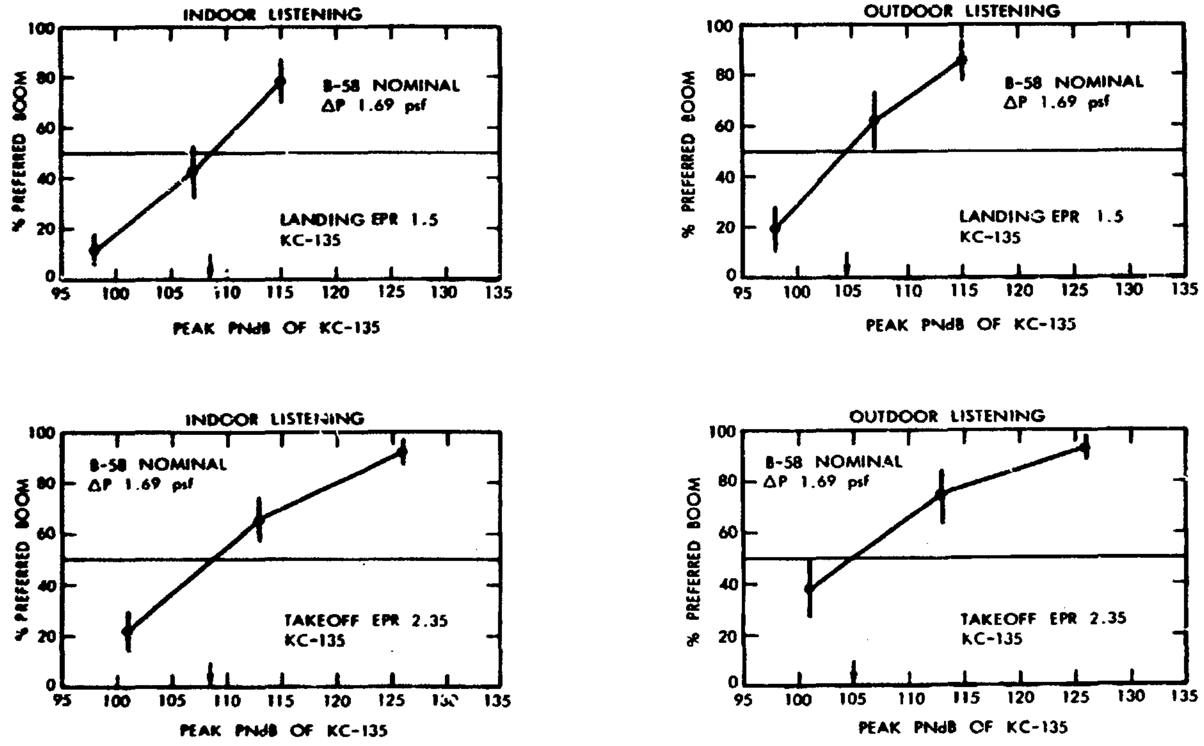
III RESULTS

A. Boom vs. Subsonic Noise

Figure 1 shows a plot of typical results obtained from the judgment tests. The intensity level at which 50 percent of the subjects rated one of the sounds in Fig. 1 (the noise from the KC-135 subsonic jet aircraft) equal in acceptability to the other sound in Fig. 1 (the sonic boom from the B-58 at a nominal peak overpressure of either 1.69 or 2.65 psf) was taken as the point at which the sounds are equally acceptable to the subjects. Table 2 gives the intensity, in PNdB, required for the noise from the subsonic jet aircraft to be judged equal in acceptability to the sonic booms; the data in Table 2 are taken from the graphs in Figs. 1, 2, 3, 4, and 5. Figure 5(a) is derived from Fig. 5 (see subsection E).

The vertical lines drawn through each data point on Figures 1 through 5 represent th 90 percent probability ranges for the data points; the ranges are based on the number of subjects involved and the percentage value of each point.[5] The plotted points represent the average percent of the subjects who preferred the boom on each of two boom vs. noise and two noise vs. boom pairs.

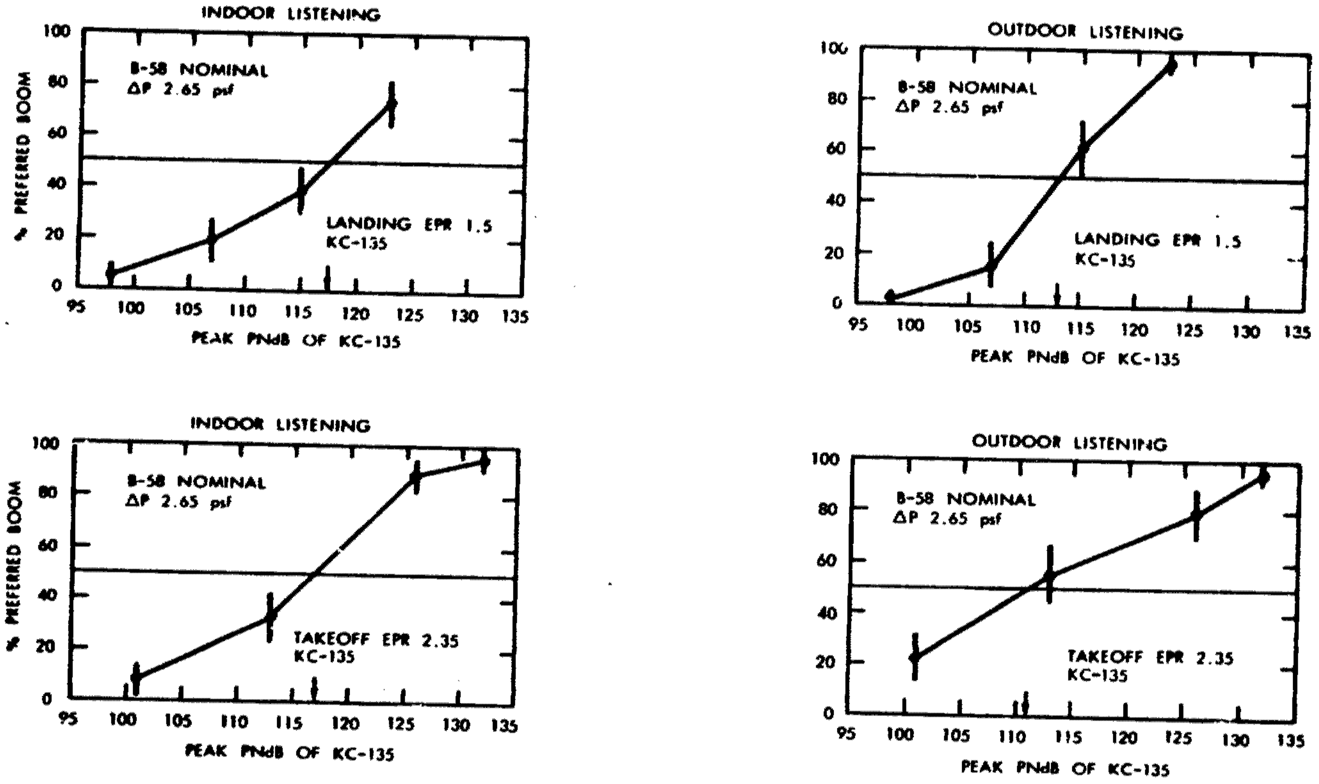
It is to be noticed that some of the data points obtained with the Fontana and Redlands subjects and with the XB-70 tests with Edwards subjects were such that for three conditions (Fontana subjects listening indoors, Redlands subjects listening outdoors, and Edwards subjects



AVERAGE FOR INDOOR LISTENING 109 PNdB

AVERAGE FOR OUTDOOR LISTENING 105 PNdB

FIG. 1 RESULTS OF PAIRED-COMPARISON JUDGMENTS OF SONIC BOOM vs. SUBSONIC NOISE (B-58 nominal ΔP 1.69 psf vs. KC-135). The vertical bars mark the 90% confidence limits of plotted data points. Listeners from Edwards AF Base – Phase I.



AVERAGE FOR INDOOR LISTENING 117 PNdB

AVERAGE FOR OUTDOOR LISTENING 112 PNdB

FIG. 2 RESULTS OF PAIRED-COMPARISON JUDGMENTS OF SONIC BOOM vs. SUBSONIC NOISE (B-58 nominal ΔP 1.69 psf vs. KC-135). The vertical bars mark the 90% confidence limits of plotted data points. Listeners from Edwards AF Base – Phase I.

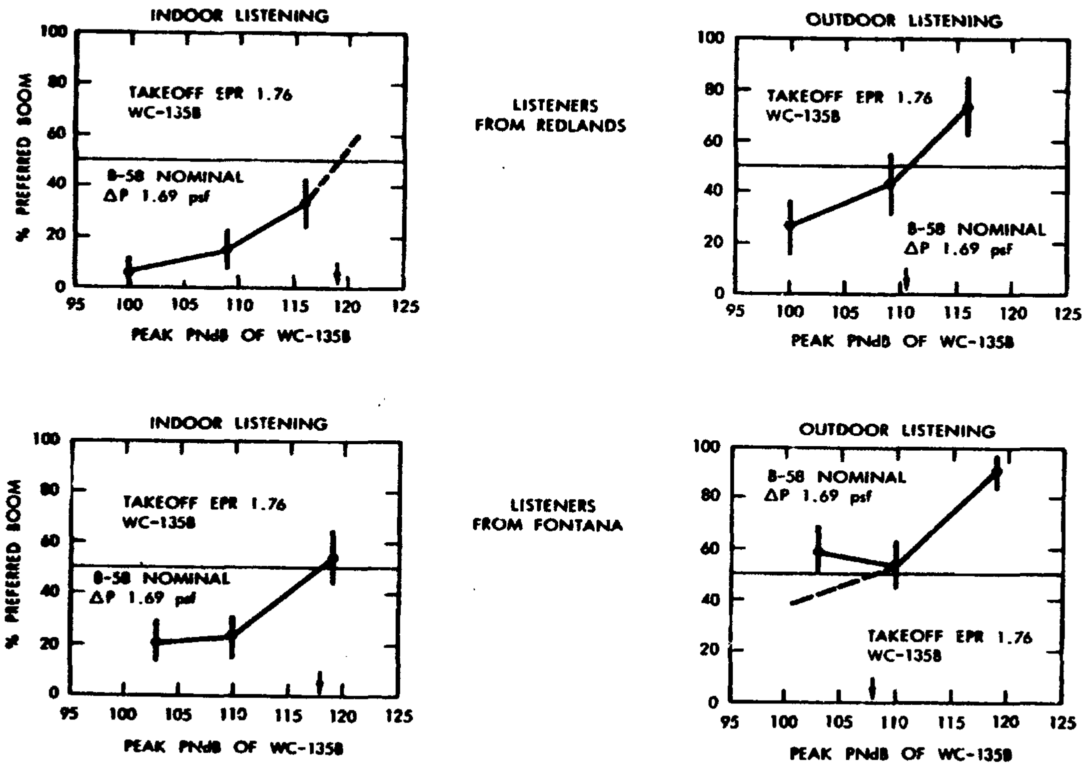


FIG. 3 RESULTS OF PAIRED-COMPARISON JUDGMENTS OF SONIC BOOM vs. SUBSONIC NOISE (B-58 nominal ΔP 1.69 psf vs. KC-135). The vertical bars mark the 90% confidence limits of plotted data points. Listeners from Edwards AF Base – Phase I.

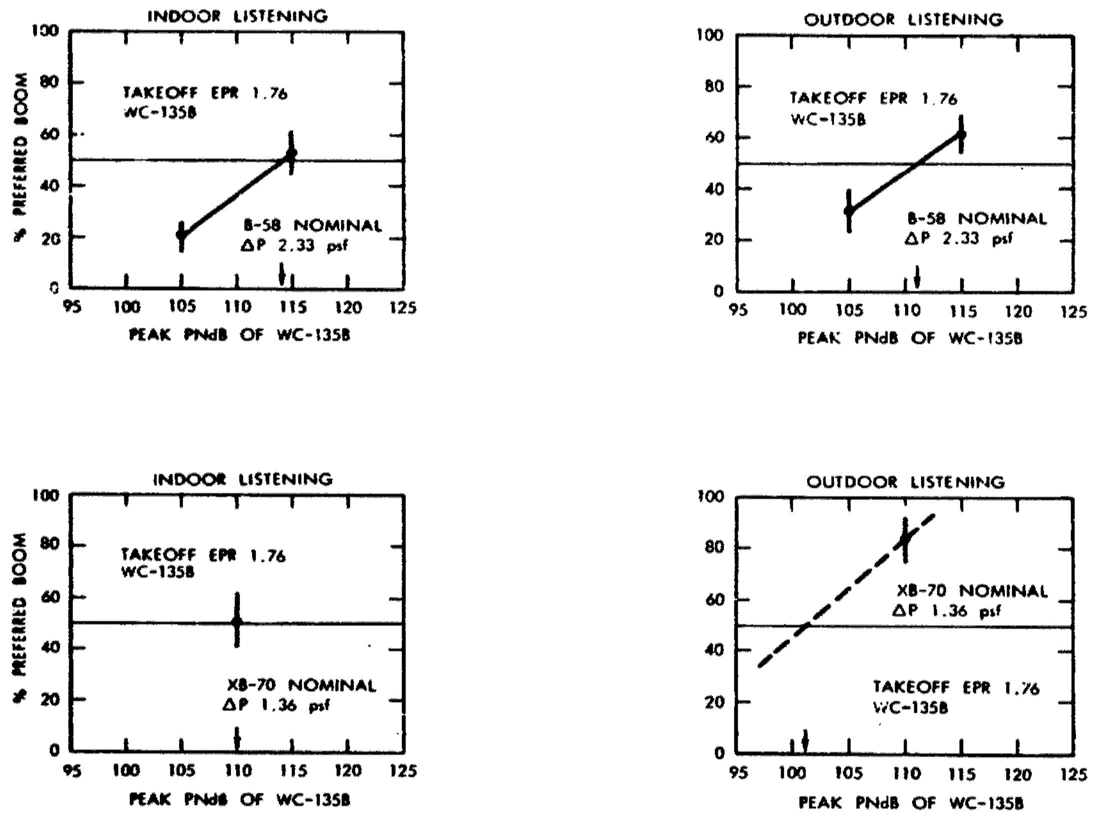


FIG. 4 RESULTS OF PAIRED-COMPARISON JUDGMENTS OF SONIC BOOM vs. SUBSONIC NOISE (B-58 nominal ΔP 2.33 psf vs. WC-135B and XB-70 nominal ΔP 1.36 psf vs. WC-135B). The vertical bars mark the 90% confidence limits of the plotted data points. Listeners from Edwards AF Base – Phase II.

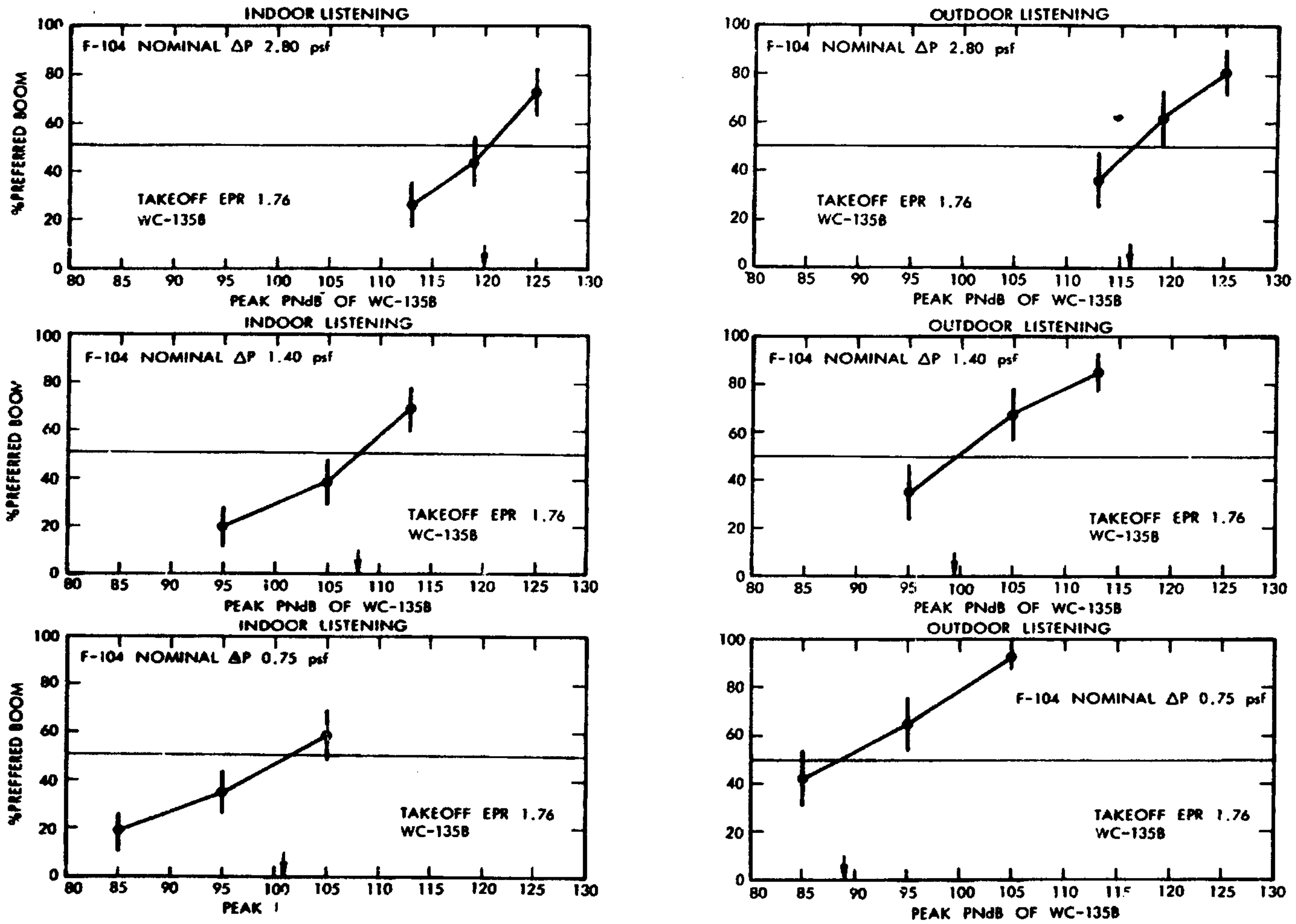


FIG. 5 RESULTS OF PAIRED-COMPARISON JUDGMENTS OF SONIC BOOM vs. SUBSONIC NOISE (B-58 nominal ΔP 1.69 psf vs. KC-135). The vertical bars mark the 90% confidence limits of plotted data points. Listeners from Edwards AF Base – Phase I.

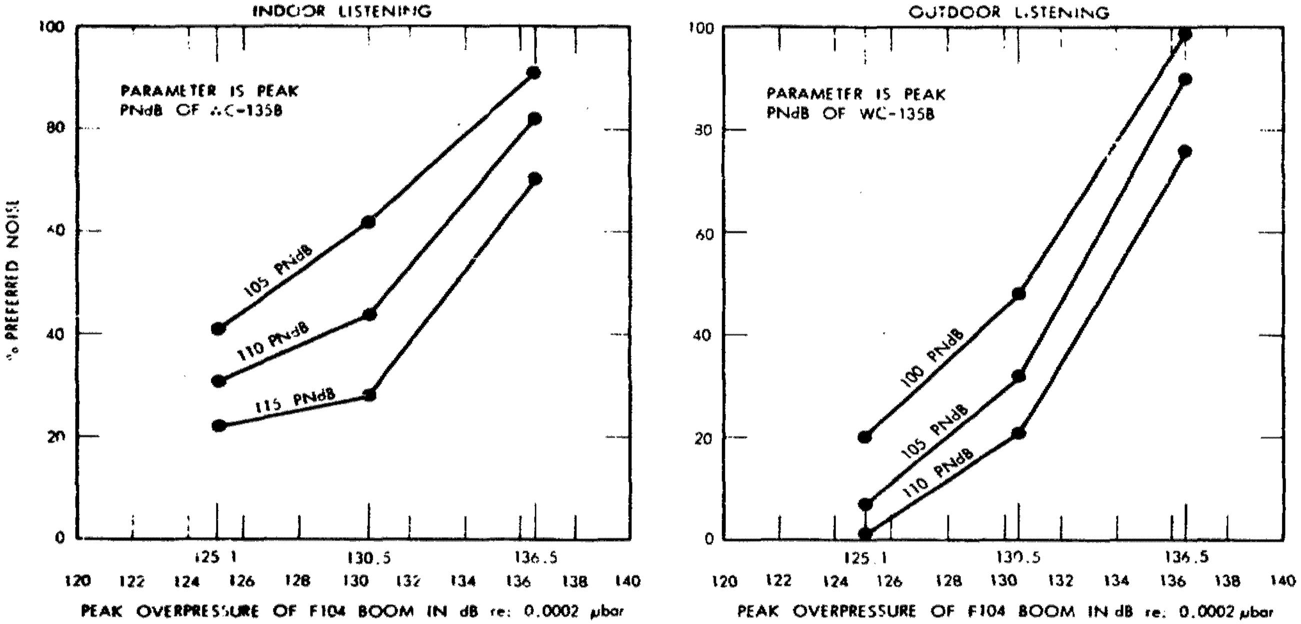


FIG. 5(a) RESULTS OF PAIRED-COMPARISON JUDGMENTS OF F-104 SONIC BOOMS vs. SUBSONIC NOISE (Derived from Fig. 5).

Table 2

RESULTS OF PAIRED-COMPARISON JUDGMENTS OF RELATIVE ACCEPTABILITY OF SONIC BOOMS VS. SUBSONIC AIRCRAFT NOISE

NOTE - All overpressure and energy values for the sonic boom and PNdB levels for subsonic aircraft noise are for outdoor measurements

1	2	3	4		5		6		7	8
Variable	Subjects From	A C	Nominal ΔP		Measured ΔP for N Missions-Median of the Medians of 5 Microphones Over N Missions[4]		Aircraft Noise when Judged Equal to Boom		Number of Subjects	N Missions-Number of Pairs of Booms vs. Noises
							Indoors	Outdoors		
Subjects from Different Communities	Edwards AF Base	+ B-58[1]	1.69 psf*	132.14 dB**	1.94 psf	133.34 dB	109 PNdB	105 PNdB	120	25
	Fontana	B-58[2]	1.69	132.14	1.74	132.39	119	111	98	12
	Redlands	B-58[2]	1.69	132.14	1.73	132.34	118	108	148	12
Different Types of Aircraft	Edwards AF Base	+ B-58[1]	1.69	132.14	1.94	133.34	109	105	120	25
		-F-104[2]	1.40	130.50	1.40	130.50	108	100	120	13
		XB-70[3]	1.36	130.25	1.35	130.19	110	101	120	4
Booms of Different Intensities From Same Aircraft		F-104[2]	0.75	125.08	0.86	126.27	101	89	120	12
		-F-104[2]	1.40	130.50	1.40	130.50	108	100	120	13
		F-104[2]	2.80	136.52	2.77	136.43	120	116	120	12
		+B-58[1]	1.69	132.14	1.94	133.34	109	105	120	25
		B-58[2]	2.33	134.93	2.56	135.74	114	111	120	20
		B-58	2.65	136.05	2.91	136.86	117	112	120	24

+ The data in these three lines are for the same missions.

– " " two " " " "

1. Aircraft were flown on track 5 miles to one side of test facility.
2. Aircraft were flown directly over test facility.
3. Aircraft were flown on track 13 miles to one side of test facility.
4. The five microphones were arranged at the test facility in a cruciform with a spacing of 100 ft between microphones.

* pounds per square foot (psf).

** dB = $10 \log_{10} \frac{p_1^2}{p_o^2}$, and p_o is 0.0002 μbar (0.0002 dyne/cm^2), and p_1 is peak overpressure in bars (or dynes/cm^2).

Table 2 (Continued)

9	10		11		12		13	14
A.C	Difference between Median Measured ΔP and Nominal ΔP (Col.4 minus Col.5)		Average Difference between Median of 5 Microphones for a Single Mission and Nominal ΔP*		Average Difference between Median of 5 Microphones for a Single Mission and Median Measured ΔP for N Missions**		Median Measured Duration	Median Measured Rise Time
+ 5-58^1	0.25 psf	1.20 dB	0.38 psf	1.75 dB	0.33 psf	0.71 dB	0.171 sec	0.007 sec
B-58^2	0.05	0.25	0.23	1.17	0.22	1.30	0.183	0.006
B-58^2	0.04	0.20	0.37	1.60	0.37	1.60	0.197	0.008
+ B-58^1	0.25	1.20	0.38	1.75	0.33	0.71	0.171	0.007
- F-104^2	0	0	0.22	1.38	0.22	1.38	0.079	0.005
XB-70^3	0.01	0.06	0.15	0.88	0.15	0.88	0.277	0.006
F-104^2	0.11	1.19	0.25	2.10	0.21	1.63	0.106	0.006
- F-104^2	0	0	0.22	1.38	0.22	1.38	0.079	0.005
F-104^2	0.03	0.09	0.37	1.08	0.27	1.08	0.080	0.005
+ B-58^1	0.25	1.20	0.38	1.75	0.33	0.71	0.171	0.007
B-58^2	0.23	0.81	0.40	1.28	0.33	1.01	0.160	0.005
B-58^1	0.26	0.81	0.39	1.17	0.31	1.92	0.148	0.009

+ The data in these three lines are for the same missions.
- " " " " two " " " " " " "

* $\frac{1}{N}\sum_{i=1}^{N}\left|X_i - \text{Nominal } \Delta P\right|$: where X_i is the median of 5 microphone measurements for the i^{th} mission, and N is number of missions.

** $\frac{1}{N}\sum_{i=1}^{N}\left|X_i - \text{Median } (X_i)\right|$: where X_i is the median of 5 microphone measurements for the i^{th} mission, and N is number of missions.

Table 2 (Continued)

15	16	17		18		19
Subjects From	A/C	Nominal ΔP		Date	Mission Number	Phase
Edwards AF Base	+ B-58	1.69 psf	132.14 dB	+ 6 June	+71	
				7 June	45R; 46R, 49; 50	I
				8 June	41; 42; 43; 55R; 46R	
				9 June	41S; 42S; 43S; 46S; 56SR; 57SR	
				20 June	43; 54; 59	
				21 June	40; 48; 48; 60; 61; 68	
Fontana	B-58	1.69	132.14	8 Nov	22-32; 121	II
Redlands	B-58	1.69	132.14	8 Dec	122-132; 221	II
Edwards AF Base	+ B-58	1.69	132.14	+See Above	+See Above	I
	-F-104	1.40	130.50	-Var. Days	-61-72;172	II
	XB-70	1.36	130.25	Var. Days	5-8	II
	F-104	0.75	125.08	Var. Days	73-84	II
	-F-104	1.40	132.14	-See Above	-See Above	II
	F-104	2.80	136.52	Var. Days	49-60	II
	+ B-58	1.69	132.14	+See Above	+See Above	I
	B-58	2.33	134.93	Var. Days	33-48; 85-88	I
	B-58	2.65	136.05	6 June	74	
				7 June	76R; 77R; 79; 80	
				8 June	72; 73; 75; 80R; 86R; 87R	
				9 June	72S; 73S; 75S; 80SR; 86SR, 87SR	
				20 June	84; 93	
				21 June	85; 89; 99; 100; 101	

+ The data for this B-58 flight condition are for the same missions.

- The data for this F-104 flight condition are for the same missions.

listening outdoors to XB-70 tests) it was necessary to extrapolate a curve beyond a data point for the curve to cross the 50-percent line from the ordinate.

In the case of the Fontana subjects, the reason for this problem was that the intensity levels of the noises to be judged against the sonic boom from the B-58 were planned on the basis of some of the results obtained with the Edwards subjects. As it turned out, the Fontana subjects found the boom so much more unacceptable, relative to the aircraft noise, than had the Edwards subjects that the data points for the indoor listeners were somewhat lower than desired. Until all the physical data are available for the sonic booms, it is not possible to deduce whether the irregularity of the data for the Redlands outdoor listeners is due to inconsistencies in the subjects for some of the tests or due to deviations of booms from planned, nominal intensities.

The number of flights available from the XB-70 aircraft and the frequency with which the aircraft could be operated (about one flight per week) made it impractical to perform as many tests with the XB-70 as with the B-58 and F-104 aircraft. Accordingly, the XB-70 was operated to provide four booms at an intensity (nominal 1.36 psf) that was estimated, on the basis of the other judgment tests, to be about as equally acceptable when heard indoors as the noise from the subsonic aircraft at about 110 PNdB.* The extrapolation required of the data for the outdoor listeners was based on the general shape of the curves drawn in Figs. 1-5. By this means it was possible to obtain comparative results of the acceptability, relative to the noise from the subsonic aircraft, of the booms from the F-104, B-58, and XB-70 with a minimum number of flights required of the XB-70 aircraft. To achieve this nominal boom intensity from the XB-70, it was necessary that its flight track be offset from the normal track by 13 miles.

---

*PNdB is a unit for expressing the perceived noise level of a sound.[15,19] It is standard practice to measure the sound from subsonic aircraft in terms of perceived noise level in PNdB.[2,13] PNdBs are determined from octave or one-third octave band sound pressure levels made of a noise. In this report the PNdB values are the peak levels reached by the noise when the aircraft flew over the test site.

The nominal[*] peak overpressures were calculated by NASA. The PNdB values for the noise from the subsonic aircraft were determined from spectral analyses of recordings made outdoors at the test site. Figure 6 gives the measured PNdB levels as a function of altitude for a number of flights of the subsonic aircraft. Additional analysis and calculations will be performed on the noise from the subsonic aircraft for purposes of correlation with the results of the judgment tests. It is to be noted, however, that the noise from a given subsonic aircraft flying at a given altitude and power setting does not show as much variation for repeated flights (a median deviation of less than 1.0 dB) as do the booms from repeated flights of a given supersonic aircraft flying at a given altitude, Mach, and weight (a median deviation of about 1.5 dB).

1. Relative Acceptability of Booms of Different Intensities

Figure 1 and Table 2 indicate that for indoor listening the noise from a subsonic aircraft (KC-135) at a level of 109 PNdB was about equally preferred to a sonic boom of a nominal 1.69 psf from a B-58. The results were about the same when the subsonic aircraft was operated with partial takeoff or landing engine power settings. It is interesting to note that for indoor listening when the nominal sonic boom overpressure was increased

---

[*] The theory used herein for the calculation of the nominal peak overpressures takes into account, relative to the generation and propagation of sonic booms, the volume and lift components of the aircraft, temperature, pressure, and density changes in the atmosphere which have some influence on boom propagation along the boom path, and effects of near-field signature characteristics. The theory used herein is the one used, by and large, by the National Aeronautics and Space Administration (NASA) in calculating sonic booms given in most NASA reports subsequent to July 1966. In some previous progress reports on sonic boom research by Stanford Research Institute, and SST Design Objectives of the Federal Aviation Agency, the effects of temperature and some pressure changes (important only to supersonic flights below, usually, 35,000 ft or so) were not included in the calculation of nominal peak overpressures. The net effect is that for sonic booms from supersonic aircraft above 35,000 ft or so, the nominal peak overpressures, according to latest theory (which agree best with actual measured peak overpressures) are about 12% higher than was previously predicted; with aircraft below about 35,000 ft (at least as found with the F-104), the new predicted overpressures are about 20% less (which also agrees best with actual measured overpressures) than those found with calculation procedures used previously for this purpose. These observations are based on the results of the tests conducted at Oklahoma City and Edwards Air Force Base (personal communication with Dominic Maglieri, NASA, Langley Field, Hampton, Virginia).

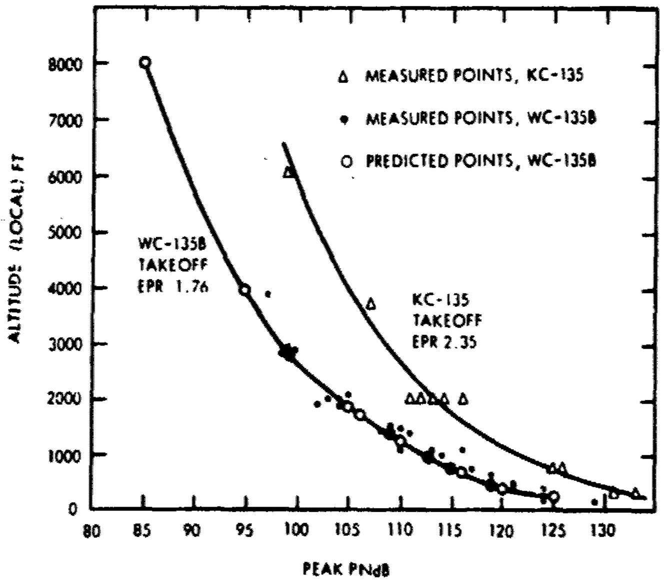


FIG. 6 ALTITUDE PLOTTED AGAINST MEASURED PEAK PNdB FOR WC-135B (Takeoff EPR 1.76) AND KC-135 (Takeoff EPR 2.35). Measurements obtained during Phase I and Phase II.

to 2.65 psf, the PNdB level of the noise from the KC-135 had to be approximately 117 PNdB to be judged as equally acceptable as the boom. This result would perhaps not be expected inasmuch as increasing the overpressure from 1.69 to 2.65 psf represents only a 4-dB increase in physical intensity, whereas, as judged against the noise from the KC-135, there appeared to be an effective increase in subjective noisiness of about 8 PNdB. Likewise, for indoor listening an overall increase of about 12 dB in the physical intensity of the boom from the F-104 (from 0.75 psf to 2.8 psf) required an increase of 19 PNdB in the aircraft noise to maintain equal acceptability of the two sounds.

These results would imply that the subjective objectionableness or noisiness of a sonic boom increases at a greater rate than does the noisiness of the sound from a subsonic jet aircraft when the intensity of the two sounds is increased by an equal amount. Broadbent and Robinson,[7] using a magnetic tape recording (played back via loudspeakers) made inside a structure overflown by a supersonic aircraft, found a somewhat similar but less dramatic difference between the growth (as a function of their intensities) of the unacceptability of sonic booms and aircraft noise.

2. Indoor vs. Outdoor Listening - Relative Judgments

It is clear that the boom heard outdoors is more acceptable relative to the noise of the subsonic jet aircraft (by an amount equivalent to about 5 PNdB) than when the two sounds are heard indoors. That the results between the relative judgments indoors and outdoors should be even this similar is perhaps fortuitous in that the nature of the two sounds is so different outdoors and because the sounds, due to attenuation by the house and vibrations present indoors, further differ from their outdoor counterparts. Apparently, however, the secondary sounds or "rattles" introduced by the nonlinear response of components of the house to the boom contribute substantially to the subjective unacceptability of the boom heard indoors. In a later report, when the physical data are more fully analyzed, the exact physical stimulus present at the listeners' ears will be correlated with the subjective rating data.

It might be noted that in a previous laboratory test by Pearsons and Kryter[23] of the relative acceptability of recorded subsonic aircraft noise and a simulated "indoor" boom, a boom which measured 1.69 psf outdoors was judged to be equal to the noise of a subsonic jet at 113 PNdB measured outdoors. Broadbent and Robinson, using, as aforementioned, a sonic boom and aircraft noise recorded indoors and played back over loudspeakers to listeners, found a 1.69 psf boom to be judged as equally acceptable as an aircraft noise of about 107 to 113 PNdB. These results, we believe, compare well with 109-112 PNdB noise and nominal 1.69 psf booms found in the present study with actual aircraft to be equal subjectively when heard indoors.

3. Indoor vs. Outdoor Listening - Rating Scale

The scores on the acceptability rating scales (see Table 3) demonstrate that the booms heard indoors were on the average slightly more acceptable than the same booms as heard by the subjects outdoors--about 34 percent of the indoor subjects rated the booms as unacceptable when about 47 percent of the outdoor subjects rated the same booms as unacceptable. The noise of the subsonic jet was also rated more acceptable indoors than it was when heard outdoors, but by a slightly larger amount--41 percent vs. 23 percent. Inasmuch as the house structure should attenuate the aircraft noise by an average of 15 to 20 dB and the sonic boom by 5 to 10 dB or so (the major energy in the boom is at lower frequencies where the attenuation of the sound by the house is less than it is for the frequency region occupied by the aircraft noise), it might be expected on first thought that the booms and noise would be much more acceptable indoors than outdoors.

The relatively small improvement in the acceptability of the booms, by virtue of the listeners being indoors and therefore somewhat sheltered from the noise, has been found to be true in previous studies of road traffic and aircraft noise.[3,6,9,22]

Table 3

PERCENTAGE OF PERSONS WHO RATED SONIC BOOMS AND NOISES AS
UNACCEPTABLE (LESS THAN JUST ACCEPTABLE)
LISTENERS FROM EDWARDS AIR FORCE BASE

SOURCES OF BOOMS AND NOISES						LOCATIONS OF PERSONS									
A/C	Nom. Peak Overpressure (psf)	Alt.	EPR	PNdB	Number of* Missions	Out-door	Block-house**	E1&E2 In-door	E1-BR	E1-LR	E1-FK	E2-BR	E2-LR	E2-DR	E2-FK
B-58	1.69				12	33%	23%	27%	15%	25%	17%	39%	46%	28%	24%
B-58	2.06				4	51	--	37	42	68	20	11	28	73	54
B-58	2.33				11	63	--	28	34	44	6	13	51	38	39
B-58	2.52				2	64	--	49	41	67	32	18	83	92	40
B-58	2.65				8	68	55	62	32	70	52	89	73	56	59
	Av. 2.25					Av. 56	--	41	33	55	25	34	56	57	43
F-104	0.70				6	2	--	2	6	0	1	0	0	3	3
F-104	1.36				2	17	--	3	7	0	4	0	0	9	0
F-104	1.40				6	30	--	16	16	12	9	11	9	51	15
F-104	1.50				4	29	--	27	10	29	23	54	43	4	22
F-104	1.69				1	75	--	29	43	38	0	11	22	67	38
F-104	2.00				2	33	--	31	0	7	17	75	57	0	39
F-104	2.80				7	74	--	63	54	50	22	62	89	100	73
F-104	3.30				2	98	--	82	63	75	79	100	79	50	100
	Av. 1.83					Av. 45	--	32	25	26	19	39	36	36	36
XB-70	1.36				2	21	--	28	32	15	11	19	39	74	25
XB-70	2.06				4	53	--	25	33	32	9	6	21	68	27
XB-70	2.52				2	65	--	33	55	53	18	10	39	67	28
	Av. 1.98					Av. 46	--	29	40	33	13	12	33	70	27
WC-135B		8000	1.76	85	2	1	--	1	0	0	4	0	0	9	0
KC-135		3000	1.5	95	4	2	5	2	0	0	2	3	0	0	3
WC-135B		4000	1.76	95	4	3	---	2	7	0	0	0	0	0	2
WC-135B		2000	1.76	105	9	24	--	11	17	11	5	4	4	17	14
KC-135		1000	1.5	107	4	28	33	22	6	30	21	15	16	11	38
WC-135B		1300	1.76	110	2	41	--	14	0	0	27	5	0	44	15
WC-135B		1000	1.76	113	3	70	--	35	25	50	22	33	15	65	44
WC-135B		800	1.76	115	6	77	--	43	44	56	19	47	24	55	49
KC-135		500	1.5	115	2	80	62	49	19	80	50	80	13	33	59
WC-135B		500	1.76	119	2	92	--	51	38	71	40	53	34	91	52
WC-135B		250	1.76	125	2	94	--	70	53	85	54	78	58	90	81
				Av. 111		Av. 47	--	27	19	3.	22	29	15	38	32
Number of Persons per Mission						10-48	9-11	51-70	6-8	5-8	8-11	8-10	6-9	5-6	13-18

*The ratings are only for the first aircraft of a pair.
**Used in Phase I only.

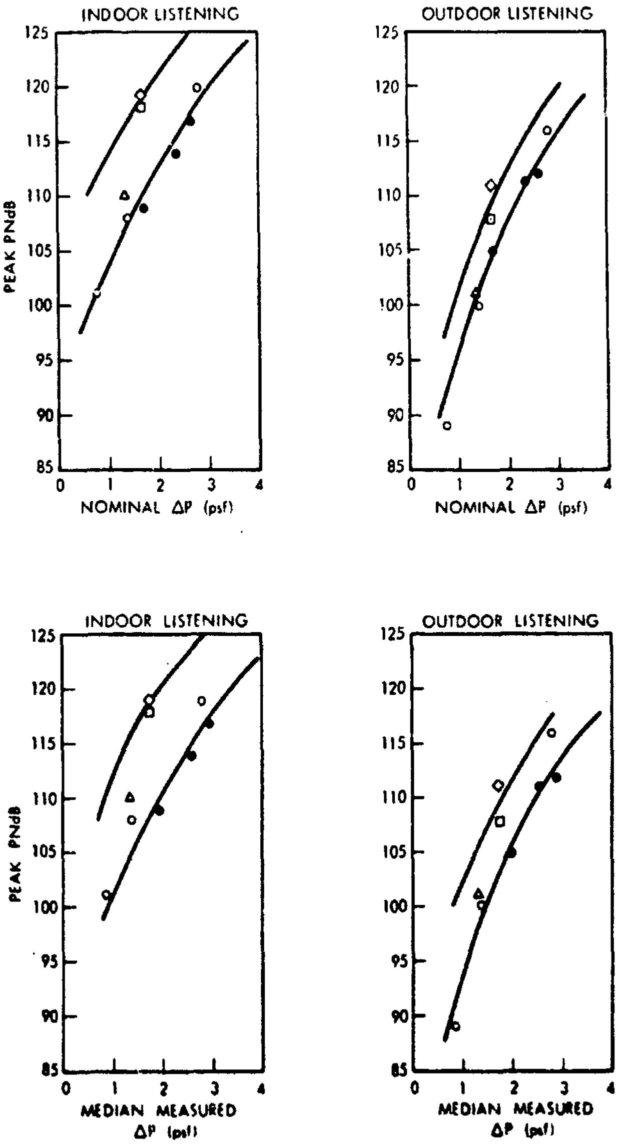
4. Comparisons Among Subjects from Different Communities

Table 2 shows that the subjects from Redlands and Fontana judged the sonic boom from the B-58 relative to the subsonic aircraft noise in much the same way--a noise of 118-119 PNdB was judged equal to the boom at 1.69 psf when heard indoors and to 108-111 PNdB when heard outdoors. Thus to these subjects the boom was much less acceptable than it was to the subjects from Edwards Air Force Base--equivalent to a 10 PNdB change in the noise from the subsonic aircraft when heard indoors and about 5 PNdB when heard outdoors. The difference between the judgments of the subjects from Edwards Air Force Base and those from the relatively "quiet" communities of Fontana and Redlands is illustrated by the extrapolated curves in Fig. 7. Also, Table 3(a) shows that on the average the subjects from Fontana and Redlands, combined, rated on the acceptability scale the aircraft noise and particularly the sonic booms as being more unacceptable than did the subjects from Edwards Air Force Base for comparable booms and noises.

An aircraft noise survey showed that the median peak level of aircraft noise in typical residential neighborhoods in Redlands was about 75 PNdB (maximum peak level of about 95 PNdB), and in Fontana about 85 PNdB (maximum peak level of about 100 PNdB); also, these communities were not under or near usual flight tracks for supersonic military aircraft involved in training or test missions.

An aircraft noise survey of the residential area of Edwards Air Force Base revealed that subsonic aircraft noise reached occasional peak levels of 110 PNdB, this area, however, was subjected to about 4-8 booms per day for the past three years at a median nominal peak overpressure of 1.2 psf (see Table 4 and Fig. 8). The subjects had lived on Edwards Air Force Base an average of two years.

It is to be noted on Table 1 that the subjects from Redlands and Fontana were, on the average, somewhat older than those from Edwards Air Force Base. As a check on the importance of age to the relative judgment of the sonic boom vs. the aircraft noise, the data were divided for the Redlands subjects into two parts--those for the subjects above the median age, and those for the subjects below the median age. It was found that



BOUNDARY	CODE	SONIC BOOM A/C	SUBJECTS
UPPER	◇	B-58	FONTANA
	□	B-58	REDLANDS
LOWER	▲	XB-70	EDWARDS
	○	F-104	
	●	B-58	

FIG. 7 RESULTS OF PAIRED-COMPARISON JUDGMENTS FOR SUBJECTS FROM DIFFERENT COMMUNITIES. Data obtained from Table 2.

Table 3(a)

PERCENTAGE OF PERSONS WHO RATED SONIC BOOMS AND NOISES AS
UNACCEPTABLE (LESS THAN JUST ACCEPTABLE)
LISTENERS FROM FONTANA AND REDLANDS

	SOURCES OF BOOMS AND NOISES						LOCATION OF PERSONS								
Group	A/C	Nom. Peak Overpressure (psf)	Alt.	EPR	PNdB	Number of Missions*	Out-door	In-door	E1-BR	E1-LR	E1-FK	E2-BR	E2-LR	E2-DR	E2-FK
Fontana	B-58	1.69				6	53%	50%	53%	71%	31%	69%	15%	27%	66%
	WC-135B		2800	1.76	100	2	5	1	7	0	0	0	0	0	0
	WC-135B		1400	1.76	109	2	33	1	0	0	0	6	0	0	0
	WC-135B		700	1.76	116	2	86	30	44	44	15	45	7	30	30
					Av. 108		Av. 41	11	17	15	5	17	2	10	10
Redlands	B-58	1.69				6	25	29	9	22	17	33	36	50	40
	WC-135B		1800	1.76	103	2	31	4	0	7	0	0	19	0	4
	WC-135B		1000	1.76	110	2	69	15	0	7	8	22	13	20	27
	WC-135B		400	1.76	120	2	90	33	15	28	19	56	47	50	27
					Av. 111		Av. 63	17	5	14	9	26	26	23	19
Fontana & Redlands Combined	B-58	1.69					Av. 39	40	31	47	24	51	26	39	53
	WC-135B				Av. 110		Av. 52	14	11	15	7	22	14	22	15
	Number of Persons Per Mission - Fontana						35	63	8	8	10	9	8	5	15
	Number of Persons Per Mission - Redlands						86	66	7	8	13	9	8	6	15

* The ratings are only for the first aircraft of a pair.

Table 4

USE OF EDWARDS AIR FORCE BASE SUPERSONIC CORRIDOR
Number of Sonic Booms

1963-1966

MONTH	1963	1964	1965	1966
January	---	161	126	193
February	4	110	102	165
March	11	140	97	287
April	106	162	48	257
May	190	104	109	107
June	139	137	86	289
July	179	82	107	
August	142	58	78	
September	149	54	203	
October	125	60	176	
November	108	65	41	
December	143	56	143	
Total:	**1296**	**1189**	**1316**	**1298**
Daily Average:	**3.9**	**3.3**	**3.6**	**7.2**

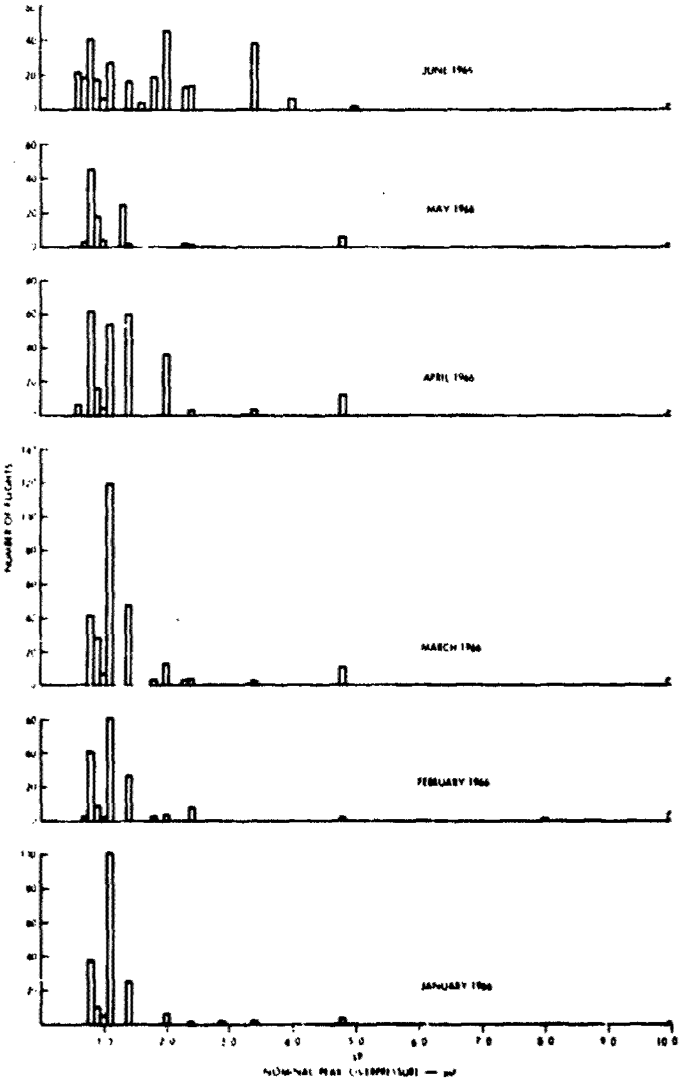


FIG. 8 HISTOGRAM OF NUMBER OF SUPERSONIC FLIGHTS OVER EDWARDS AF BASE PLOTTED AGAINST THE NOMINAL PEAK OVERPRESSURES OF THE BOOMS

the results for these two subgroups of subjects agreed within 1 PNdB of the findings for the total group (see Table 5). Table 6 shows that age and sex were not consistently related to the acceptability rating scores given to sonic booms and the noise from subsonic aircraft.

It is presumed that the lesser acceptability of sonic booms to the subjects from Fontana and Redlands than to the subjects from Edwards Air Force Base may be due to the "adaptation" to the sonic booms enjoyed by the Edwards subjects as the result of an average of two year's previous exposure to sonic booms. It was also found, as will be described more fully later, that the residents of Edwards Air Force Base, in reply to an attitude survey, in general believed that their exposure to sonic booms at Edwards made them more tolerant of the boom.

B. Sonic Booms vs. Sonic Booms

A number of tests were conducted in which the subjects judged the relative acceptability of sonic booms from different supersonic aircraft or from the same type of supersonic aircraft flying in accordance with different or the same operational procedures. The results of these tests are given in Fig. 9 and 9(a). These tests do not show any consistent differences in the acceptability of one type of sonic boom vs. another type of those tested.

Of particular interest is the rate at which the percent preference score changed as a function of a change in peak overpressure. Figures 9 and 9(a) show that a change of 1.5 dB (about 0.25 psf at a boom intensity of 1.69 psf for people indoors and 1.0 dB for people outdoors) can cause an increase of about 12.5 percentage points in the number of people who judge the more intense boom to be less acceptable. This finding indicates that the subjective unacceptability of the sonic boom increases at a relatively rapid rate as its intensity level is increased, and at a somewhat more rapid rate for listeners outdoors compared with listeners indoors. It was noted before that the rate of growth of unacceptability of the sonic boom appears to be greater than is the growth of unacceptability of the noise from subsonic aircraft (a 6-dB increase in the intensity of the sonic boom was found to be equivalent to a 10-PNdB increase in the level of a noise from a subsonic aircraft of equal acceptability).

Table 5

PERCENTAGE OF REDLANDS SUBJECTS (INDOOR LISTENERS) WHO PREFER BOOM (B-58 OF 1.69 PSF NOMINAL PEAK OVERPRESSURE)

Peak PNdB of WC-135B	Age Less than 50 Yrs. (Median 38 Years)	Age Greater than or Equal to 50 Years (Median 65 Years)
103	9%	26%
110	17	27
120	58	53
118	50	--
119	--	50

Table 6

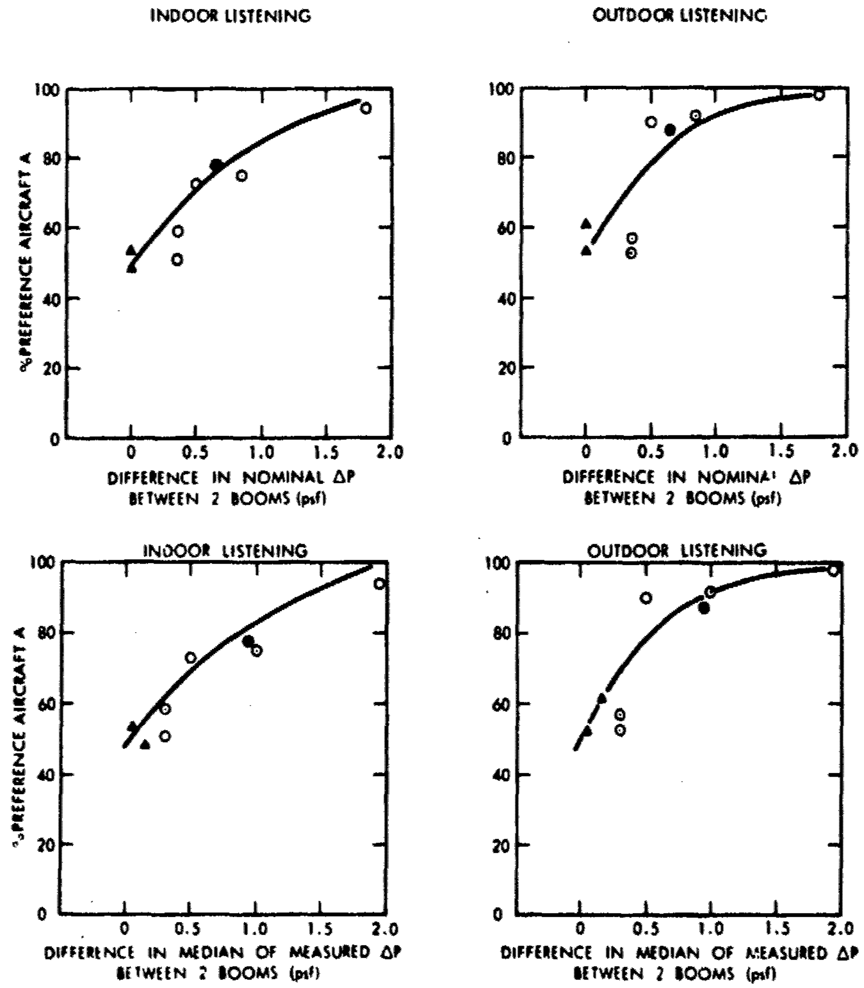
COMPARISON BY AGE AND SEX OF THE PERSONS WHO RATED SONIC BOOMS AND NOISE AS UNACCEPTABLE (LESS THAN JUST ACCEPTABLE)

Group	Median Age	A/C	Number of Flights	Indoor Listening				Outdoor Listening				Critical Value at 10% Level of Significance	Decision
					(See notes for explanation of column headings and cell entries)								
				ML vs. MG	FL vs. FG	ML vs. FL	MG vs. FG	ML vs. MG	FL vs. FG	ML vs. FL	MG vs. FG		
Redlands	49	B-58	6	4/10 5/20 0.71	6/17 4/16 0.41	4/10 6/17 0.06	5/20 4/16 0.10	4/15 3/17 0.38*	8/28 3/14 0.25	4/15 8/28 0.02	3/17 3/14 0.07*	2.71	No Significant Difference in the Ratings
		WC-135B	6	2/10 3/20 0.12*	4/17 2/16 0.67*	2/10 4/17 0.05*	3/20 2/16 0.05*	10/15 11/17 0.01	19/28 10/14 0.06	10/15 19/28 0.01	11/17 10/14 0.16	2.71	
Fontana	38	B-58	6	2/5 3/9 0.06*	14/22 11/25 1.61	2/5 14/22 0.94*	3/9 11/25 0.31	1/2 2/6 0.20*	9/14 6/12 0.54	1/2 9/14 0.15*	2/6 6/12 0.45*	2.71	
		WC-135B	6	1/5 0/9 1.94*	4/22 2/25 1.09*	1/5 4/22 0.00*	0/9 2/25 0.77*	1/2 2/6 0.18*	6/14 5/12 0.00	1/2 6/14 0.04*	2/6 5/12 0.12*	2.71	
Edwards AF Base	32	B-58	9	2/5 3/7 0.01*	5/23 9/26 0.99	2/5 5/23 0.73*	3/7 9/26 0.16*	1/4 1/3 0.06*	8/19 5/21 1.52	1/4 8/19 0.41*	1/3 5/21 0.13*	2.71	
		KC-135	12	1/6 1/7 0.01*	5/25 4/26 0.19	1/6 5/25 0.03*	1/7 4/26 0.01*	1/4 1/3 0.06*	4/20 5/21 0.09	1/4 4/20 0.05*	1/3 5/21 0.13*	2.71	

* Inadequate sample size

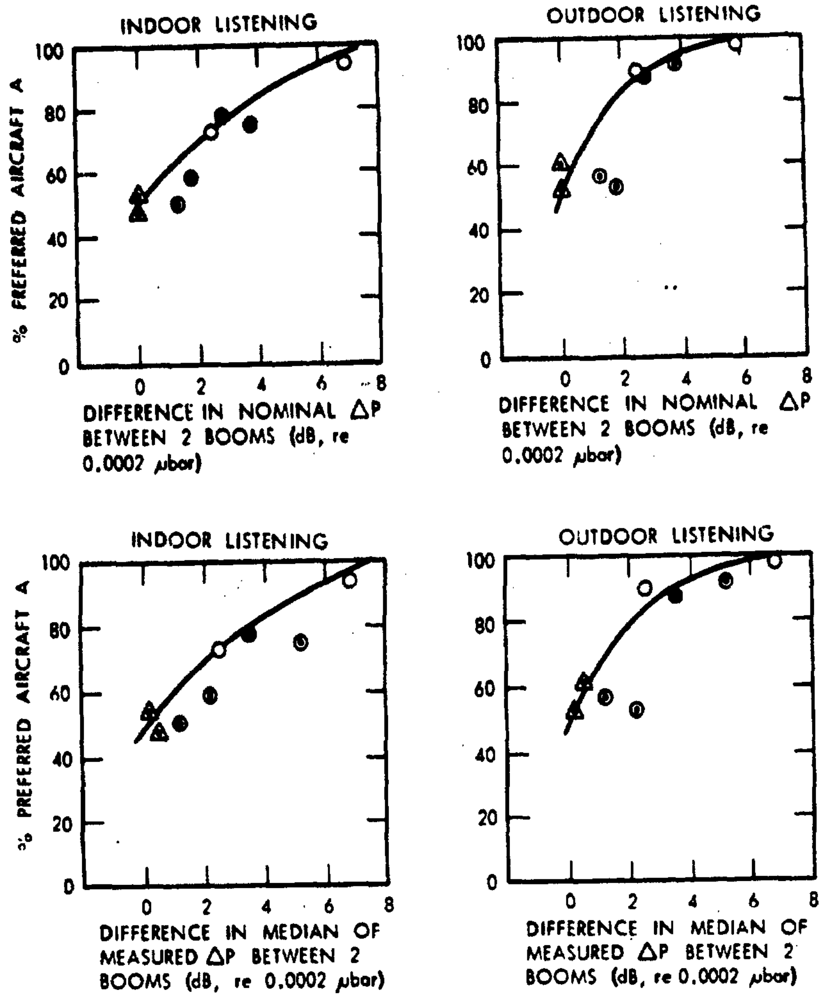
NOTES:

1. The comparisons are based on ratings for the first aircraft of a pair.
2. Symbols for age and sex classification: ML = males whose age is less than the median age; FL = females whose age is less than the median age; MG = Males whose age is greater than or equal to the median age; FG = females whose age is greater than or equal to the median age.
3. Differences in the ratings due to age are tested in the columns headed ML vs. MG and FL vs. FG. Differences in the ratings due to sex are tested in the columns headed ML vs. FL and MG vs. FG.
4. Cell entries: Upper left (or upper right) is a/a+b (or c/c+d) where a (or c) is the average number of unacceptable ratings and b (or d) is the average number of acceptable ratings for the designated class. (a+b (or c+d) is the average number of persons in the class.) The lower entry is the value of the test statistic: $\chi^2 = \frac{(ad - bc)^2(a+b+c+d)}{(a+b)(a+c)(b+d)(c+d)}$. Example: Third row and second column, a = 14, b = 8, c = 11, d = 14; $\chi^2 = \frac{(14^2 - 11 \cdot 8)^2(47)}{(22)(25)(22)(25)} = 1.81$. The adequacy of the sample size depends on the values of a and c in addition to the values of a+b and c+d.
5. Significance test and decision rule: The data are used to determine whether the same percentage of unacceptable ratings occurs for two classes. The hypothesis that the ratings are the same would be rejected if the value of the test statistic equals or exceeds 2.71 at the 10% level of significance (i.e., the probability is 0.10 that the hypothesis is rejected when it is true).
6. Reference 5, Chapter XI, Analysis of Enumeration Data.



	AIRCRAFT A					AIRCRAFT B				
CODE	TYPE A/C	NOMINAL ΔP	MEDIAN OF MEASURED ΔP	% PREFERENCE		TYPE A/C	NOMINAL ΔP	MEDIAN OF MEASURED ΔP	% PREFERENCE	
				INDOOR	OUTDOOR				INDOOR	OUTDOOR
●	B-58	1.69	1.91	78%	88%	B-58	2.33	2.84	22%	12%
○	F-104	1.50	1.52	73	90	F-104	2.00	2.02	27	10
	F-104	1.50	1.63	94	98	F-104	3.30	3.56	6	2
○	F-104	2.00	2.09	51	57	B-58	2.33	2.40	49	43
	F-104	1.36	1.14	59	53	B-58	1.69	1.46	41	47
	F-104	1.50	1.20	75	92	B-58	2.33	2.18	25	8
▲	XB-70	2.06	2.18	48	61	B-58	2.06	2.33	52	39
	XB-70	2.52	2.49	54	53	B-58	2.52	2.55	46	47

FIG. 9 RESULTS OF PAIRED-COMPARISON JUDGMENTS OF SONIC BOOMS (of the same type aircraft or two different types of aircraft) AT THE SAME AND AT DIFFERENT NOMINAL PEAK OVERPRESSURES IN psf. Listeners from Edwards AF Base.



AIRCRAFT A						AIRCRAFT B				
CODE	TYPE A/C	NOMINAL ΔP^*	MEDIAN OF MEASURED ΔP^*	% PREFERENCE		TYPE A/C	NOMINAL ΔP^*	MEDIAN OF MEASURED ΔP^*	% PREFERENCE	
				INDOOR	OUTDOOR				INDOOR	OUTDOOR
●	B-58	132.1	133.2	78	88	B-58	134.9	136.7	22	12
○	F-104	131.1	131.2	73	90	F-104	133.6	133.7	27	10
	F-104	131.1	131.8	94	98	F-104	138.0	138.6	6	2
◉	F-104	133.6	134.0	51	57	B-58	134.9	135.2	49	43
	F-104	130.3	128.7	59	53	B-58	132.1	130.9	41	47
	F-104	131.1	129.2	75	92	B-58	134.9	134.4	25	8
▲	XB-70	133.9	134.4	48	61	B-58	133.9	134.9	52	39
	XB-70	135.6	135.5	54	53	B-58	135.6	135.7	46	47

*IN dB re 0.0002 μbar

FIG. 9(a) RESULTS OF PAIRED-COMPARISON JUDGMENTS OF SONIC BOOMS (of the same type aircraft or two different types of aircraft) AT THE SAME AND AT DIFFERENT NOMINAL PEAK OVERPRESSURES IN dB. Listeners from Edwards AF Base.

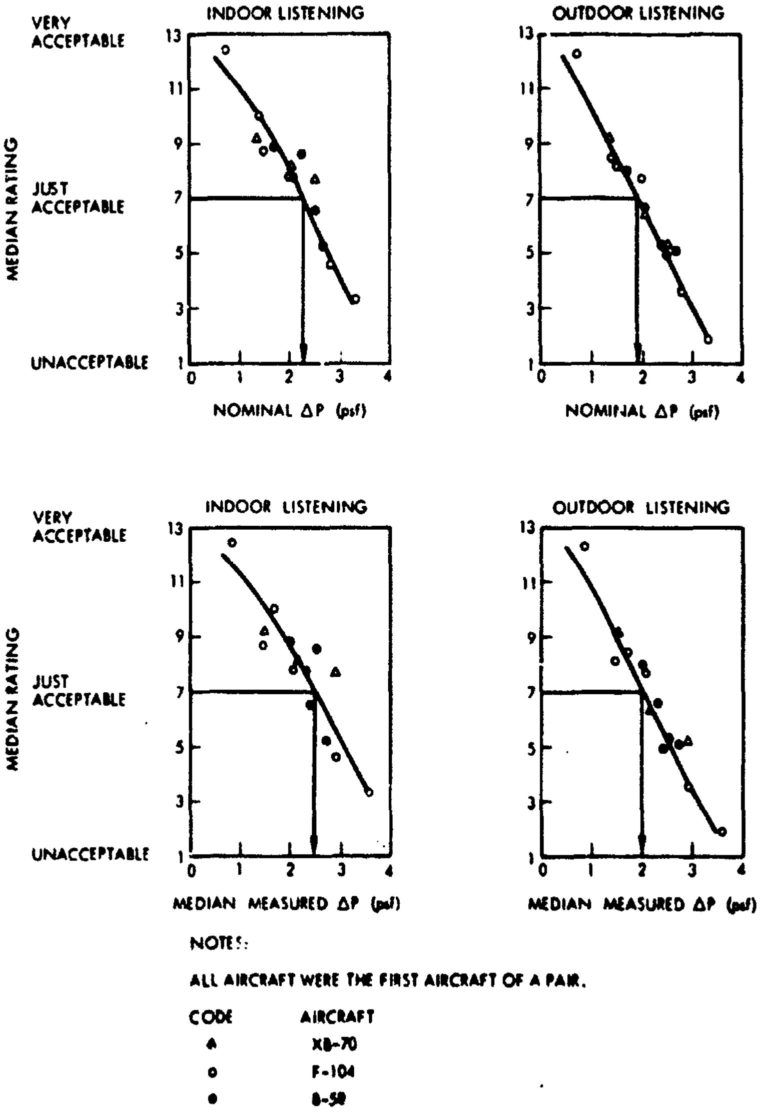
C. Ratings of Sonic Booms

Comparisons can be made between the sonic booms from the F-104, B-58, and XB-70 aircraft on the basis of the scores obtained on the absolute rating scale. Figure 10 shows the results obtained from the ratings given to sonic booms of different nominal peak overpressures from the various aircraft when the particular booms occurred first in a pair for a given mission. (It was necessary to use only the results from the given position in a pair in order to avoid any biases due to the order in which the sounds were presented to the subjects.) On this measure the difference in the unacceptability of the booms from the various aircraft is rather small, if at all present. However, Figures 10 and 10(a) show that the sonic boom, when heard indoors, was somewhat more acceptable than it was when heard outdoors.

D. Subsonic Noise vs. Subsonic Noise

The KC-135 aircraft is powered by nonnoise-suppressed turbojet engines, whereas modern-day commercial jet transports are equipped with either noise-suppressed turbojet or fanjet engines. Inasmuch as one of the purposes of the tests was to be able to relate the acceptability of sonic booms to the noise heard in communities near commercial airports, a series of tests were conducted in which the subjects judged the noise of a KC-135 to the noise from a WC-135B aircraft, the latter being equipped with fanjet engines. The results are shown in Fig. 11. These figures illustrate the PNdB values and approximate altitudes required for the WC-135B when operated at either partial takeoff or landing power setting to be judged equally as acceptable as the noise from a KC-135 operated either at partial takeoff power and an altitude of 2000 feet, or at landing power and an altitude of 800 feet. It is of interest to note that, at least for indoor listening when the WC-135B fanjet had the same PNdB value measured outdoors as the noise from the KC-135, the two noises were judged to be equally acceptable or equally noisy.

The noises from the flights of the KC-135 at takeoff power that were paired with the noises from the WC-135B at landing power averaged 113.0 PNdB, whereas those paired with the WC-135B at takeoff power averaged

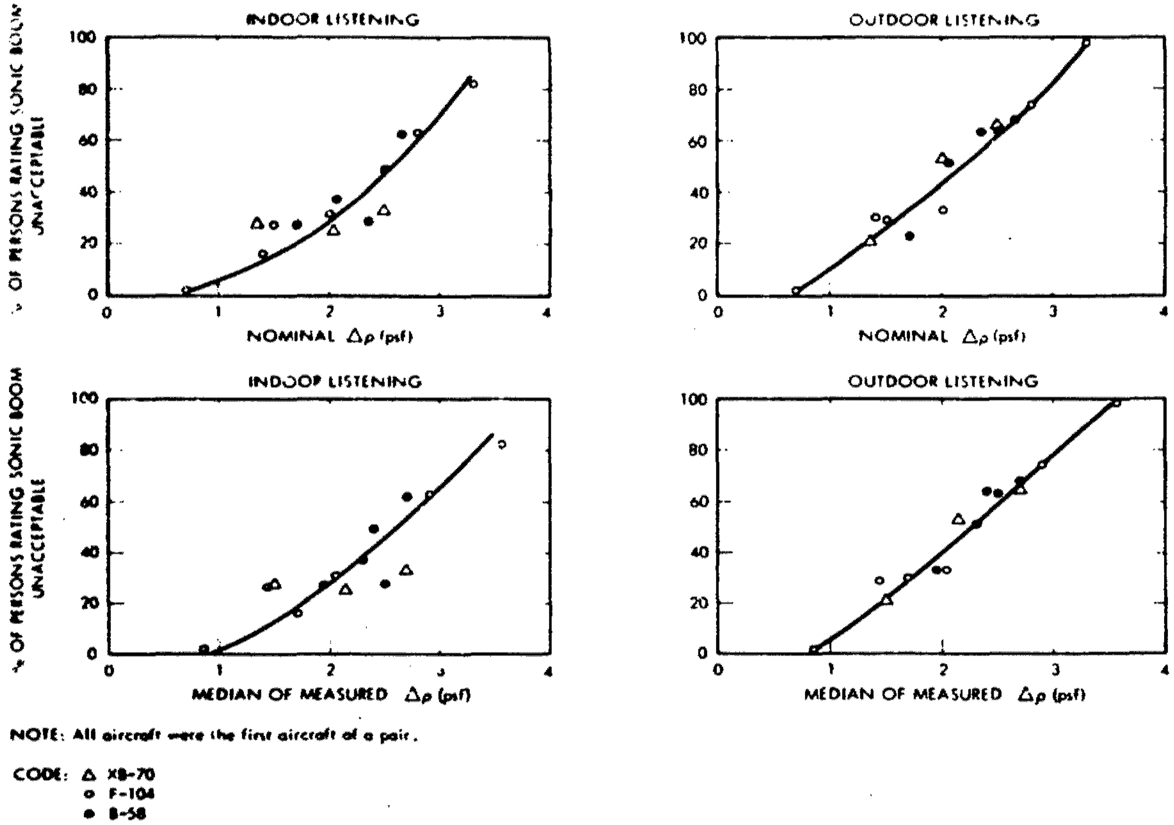


NOTES:

ALL AIRCRAFT WERE THE FIRST AIRCRAFT OF A PAIR.

CODE	AIRCRAFT
▲	XB-70
○	F-104
●	B-58

FIG. 10 MEDIAN RATINGS OF XB-70, F-104, AND B-58 SONIC BOOMS PLOTTED AGAINST NOMINAL PEAK OVERPRESSURE AND MEDIAN OF MEASURED PEAK OVERPRESSURE. Listeners from Edwards AF Base.



NOTE: All aircraft were the first aircraft of a pair.

CODE: △ XB-70
○ F-104
● B-58

FIG. 10(a) PERCENT OF PEOPLE WHO RATED AS UNACCEPTABLE SONIC BOOMS FROM XB-70, F-104, AND B-58 AIRCRAFT. Listeners from Edwards AF Base.

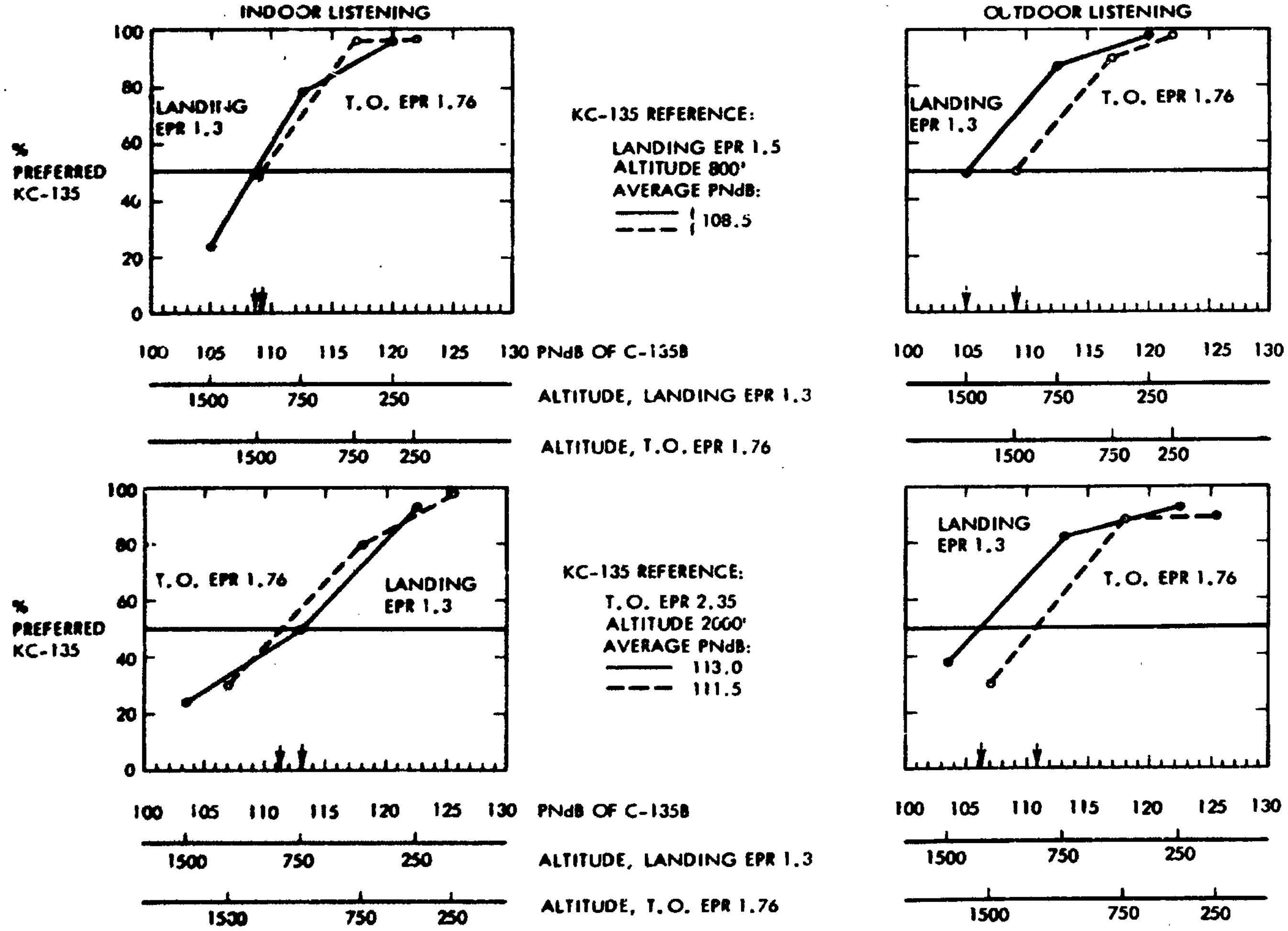


FIG. 11 RESULTS OF PAIRED-COMPARISON JUDGMENTS OF SUBSONIC NOISE (KC-135 vs. WC-135B)
Listeners from Edwards AF Base.

111.5 PNdB. This difference between the average PNdB values for the KC-135 was probably due to variations in power or altitude for the particular flights involved. For the flights of the KC-135 operating with landing power, the perceived noise level of the KC-135 averaged 108.5 PNdB when paired with the WC-135B operating with partial takeoff power and also when paired with the WC-135B operating with landing power.

The outdoor listeners consistently judged the fanjet WC-135B operating at landing power (EPR 1.3) to be about 4 PNdB less acceptable than the WC-135B operating at partial takeoff power (EPR 1.76). One possible explanation is that the increase in the pure-tone whine when the power setting is reduced from takeoff to landing perhaps caused an increase in the subjective noisiness of the sound of the landing power condition that is not adequately evaluated by the PNdB as calculated.

It is also of interest to note the rate of change of the unacceptability of the noise from the subsonic aircraft as a function of its intensity in PNdB as revealed through the judgments made of aircraft noise vs. aircraft noise. Figure 11 shows that about a 2-dB increase in level near the 50-percent point causes an increase of about 12.5 percentage points in the number of people who rate the more intense noise as being more unacceptable, whereas, as mentioned above, a 1-dB increase in intensity of a sonic boom will cause an increase of about 12.5-percentage points in the number of people who rate the more intense boom as being more unacceptable.

E. Criterion of Significant Difference between Boom and Noise Conditions

It is perhaps not unreasonable to suggest that a difference of 12.5 percentage points (from 50% to 62.5%) in the number of people who rate one boom to be relatively more unacceptable than another boom or one subsonic aircraft noise to be relatively more unacceptable than another noise is of practical significance. Using this criterion it follows from Figs. 1 through 5 that on the average two noises that differ by about 4 PNdB when heard indoors, 2 PNdB outdoors, would be significantly different when judged against a sonic boom of a nominal peak overpressure of about 1.69 psf.

The curves on Fig. 5 are replotted on Fig. 5(a) to show the relation between percent of people who preferred the noise at a given intensity as a function of the intensity of the sonic boom. It is seen in Fig. 5(a) that on the average an increase of about 2 dB when heard indoors and 1 dB when heard outdoors in boom intensity would cause a change from 50% to 62.5% of the people who preferred the aircraft noise.

These results--a significant difference when booms were judged against aircraft noise for indoor listening was found with a 4 PNdB change in aircraft noise or a 2 dB change in boom intensity--follow, of course, from the aforementioned greater growth of unacceptability ratings of booms than of aircraft noise as a function of their intensity. However, it is seen in Figs. 9 and 11 that the subjects indoors judged aircraft noise vs. aircraft noise and booms vs. booms as being significantly different, according to the criterion specified above, when they differed in intensity by 2 PNdB and 1 dB, respectively. This increased precision in the relative judgments when the subjects judged aircraft noise vs. aircraft noise and booms vs. booms rather than aircraft noise vs. booms is to be expected from the fact that the accuracy and consistency of the relative judgments of some subjective attribute of two sounds are greater when the two sounds are similar than when they are dissimilar.[17]

Because of the nature of the paired-comparison test and the rather small number of repetitions of each test condition, probability statistics, other than those shown in Figs. 1 through 5, cannot be readily applied to the data at hand. However, in Appendix B-4 an analysis is made of the variability present in these tests.

F. Differences in Responses of Subjects in Different Test Rooms on Vibration Isolation Pads

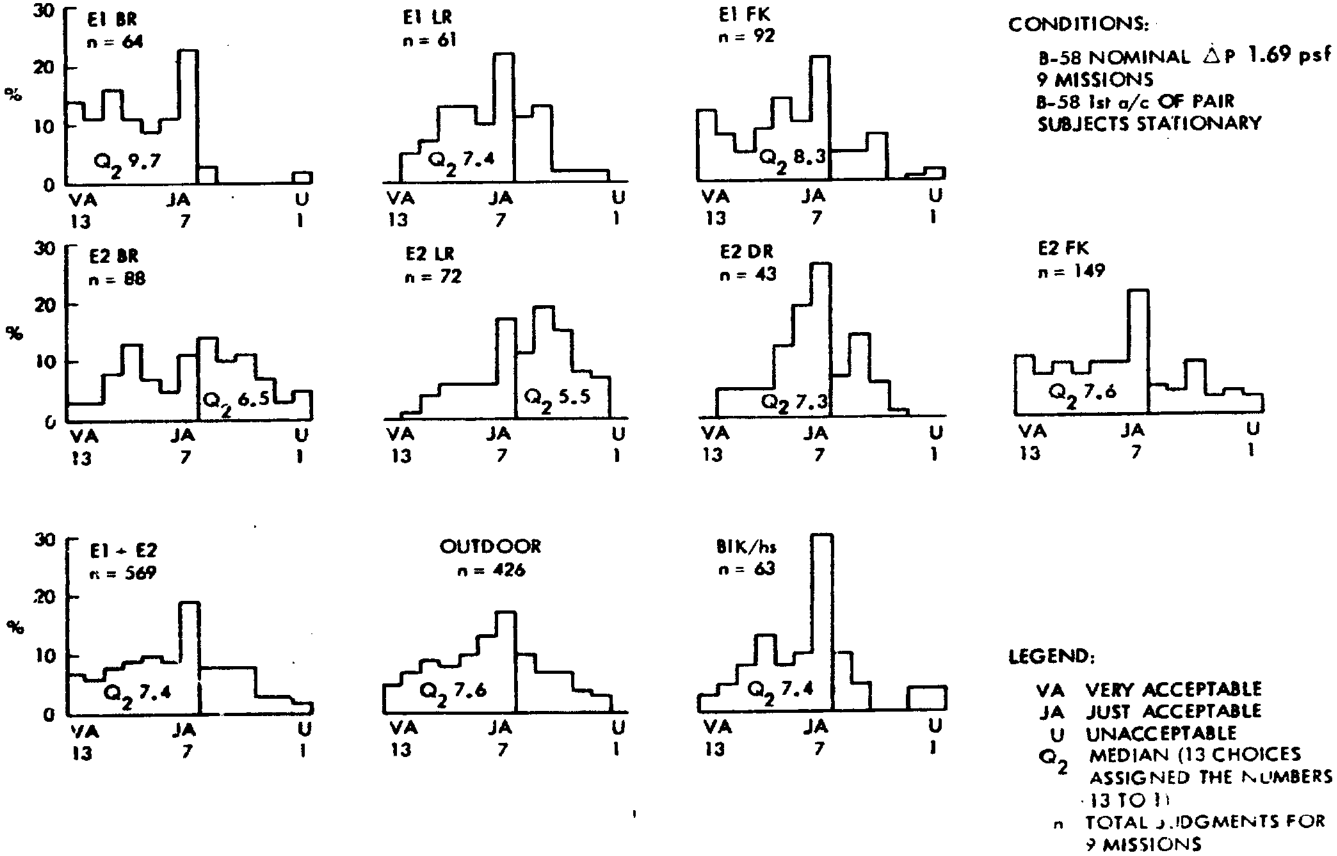
Comparisons between the average subjective ratings made by listeners outdoors, in different houses, and in different rooms of the one-story and two-story "midwest" test houses, can be made by reference to Table 3. In Table 3 the percentage is given of the people in the respective groups who rated the booms and the noise from subsonic aircraft as being unacceptable (less than "just acceptable").

Figures 12 and 13 show histogram distributions of ratings assigned by subjects in the various test locations for B-58 booms having a nominal overpressure of 1.69 psf and 2.65 psf, respectively.

Table 3 shows that there were no clear-cut differences among the averages for the Edwards Air Force Base house built of cement block, the two special frame houses, and for the listener group located out of doors. However, it would appear from Table 3 that either the subjects or the acoustic-vibration stimulation differed significantly among some of the individual rooms in houses "E-1" (the one-story frame house) and "E-2" (the two-story frame house). It is possible, of course, that the subgroups, by room, of the subjects differed significantly in their sensitivity to noise and sonic booms. In view of the relative unimportance of this possibility to the overall results and of the need for the most efficient use of the aircraft and test facilities to meet the objective of the experiments, it was not deemed advisable to "rotate" systematically all the subjects among the various test rooms to find out if the subgroups of subjects would respond similarly when in exactly similar noise-vibration environments.

Examination of the data in Table 3 reveals that the subjects in some rooms rated the boom and the noise from the subsonic aircraft as being less acceptable than did the subjects in other rooms. Some rooms that achieved, on the average, the worst ratings for booms were not necessarily the rooms in which the subjects gave the worst ratings to the noise from subsonic aircraft. Although the subjects were randomly assigned to the chair locations at the beginning of the tests, they kept, except for certain special tests, the same position throughout the tests. Accordingly, it is possible that some of the difference between ratings among the different groups of subjects by their location could be due to inherent differences in the sensitivity of the two groups to sounds.

As a check on this possibility, subjects from one of the rooms that on the average gave the least acceptable ratings and subjects from one of the rooms that gave the most acceptable ratings exchanged their locations for a series of 16 missions. The results given in Fig. 14 indicate



CONDITIONS:

B-58 NOMINAL ΔP 1.69 psf
9 MISSIONS
B-58 1st a/c OF PAIR
SUBJECTS STATIONARY

LEGEND:

VA VERY ACCEPTABLE
JA JUST ACCEPTABLE
U UNACCEPTABLE
Q_2 MEDIAN (13 CHOICES ASSIGNED THE NUMBERS 13 TO 1)
n TOTAL JUDGMENTS FOR 9 MISSIONS

FIG. 12 DISTRIBUTION OF ACCEPTABILITY RATINGS BY LOCATION — PHASE I. Listeners from Edwards AF Base.

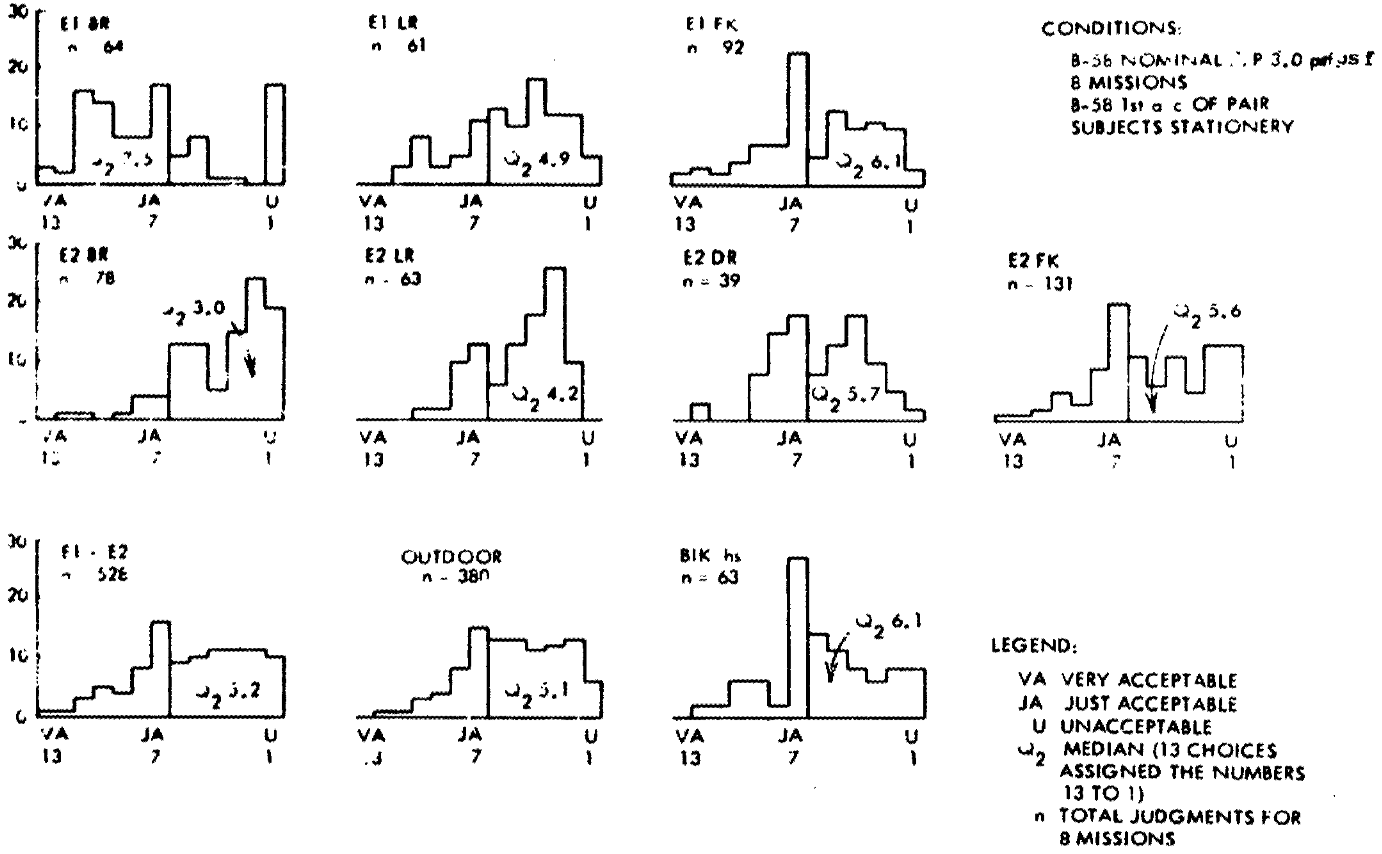
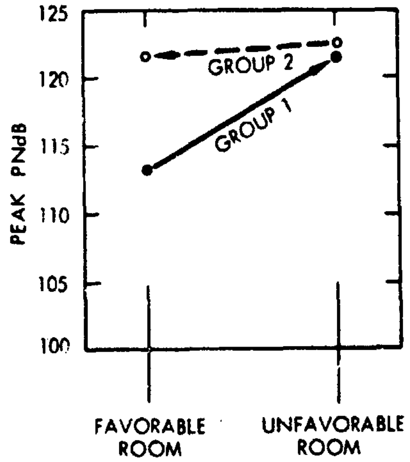


FIG. 13 DISTRIBUTION OF ACCEPTABILITY RATINGS BY LOCATION — PHASE II. Listeners from Edwards AF Base.



GROUP	NORMAL LOCATION	FAVORABLE ROOM	UNFAVORABLE ROOM	NET CHANGE
1	FAVORABLE ROOM	113.5 PNdB	121.5 PNdB	8 PNdB
2	UNFAVORABLE ROOM	121.5 PNdB	122.5 PNdB	1 PNdB
Average		117.5 PNdB	122 PNdB	4.5 PNdB

FIG. 14 RESULTS OF PAIRED-COMPARISON JUDGMENTS SHOWING HOW JUDGMENTS CHANGED FOR THE SAME SUBJECTS WHEN MOVED TO DIFFERENT ROOMS
Data are Peak PNdB levels of subsonic aircraft noise judged to be as acceptable as B-58 boom of 2.33 psf nominal peak overpressure. Listeners from Edwards AF Base.

that at least some of the differences among the ratings given in the test rooms were indeed due to room and not subject differences.

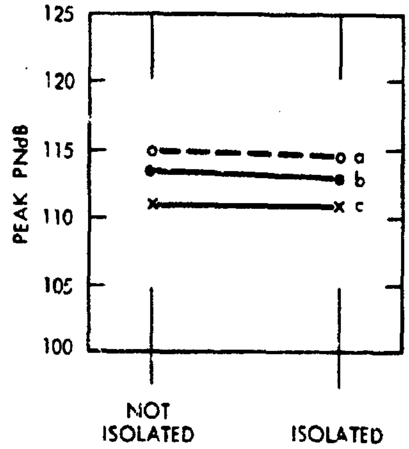
When all the physical data are available, it is planned to correlate the average subject responses obtained with the acoustical-vibrational environment as determined from the various microphones and gauges present in the test structures. Positive correlation, if found, would presumably indicate that the differences in the physical envirommcnt are responsible for the measured differences in the subjective responses present in the different rooms.

From a practical point of view, it is the ratings taken over all types of houses and listening conditions that are important in evaluating the reaction of people in homes to sonic booms and to the noise from subsonic aircraft. It is to be expected in real life that not only will people and given rooms in houses differ in their responses to sonic booms and noise from subsonic aircraft, but also that the interaction between these sounds and given rooms or structures will differ, depending on the angle of incidence of the sounds with the structure.

1. Vibration Isolation

For one series of 16 missions about half the subjects in houses E-1 and E-2 and about half the subjects outdoors sat on chairs placed on a piece of plywood that was isolated from the ground or the floor by an air-inflated pad 1-12 inches in diameter (the floors were carpeted in all rooms but the kitchen, where the flooring was covered with vinyl tile). Each subject sat on a vibration-isolated chair during half the tests, and on a normal, nonvibration-isolated chair during the other half.

Figure 15 shows that the vibration isolation had no significant effects on the ratings given to the booms or the aircraft noise, although there is a slight statistically insignificant improvement in the acceptability of the boom when the subjects were indoors and on the vibration-isolation pads. This finding is perhaps somewhat unexpected because in many locations within the house the subjects and the experimenter could "feel" the floor shake when the house was subjected to sonic booms; at



GROUP	NOT ISOLATED	ISOLATED	NET CHANGE
a (INDOORS)	115.0 PNdB	114.5 PNdB	-0.5 PNdB
b (INDOORS)	113.5 PNdB	113.0 PNdB	-0.5 PNdB
c (OUTDOORS)	111.0 PNdB	111.0 PNdB	0 PNdB

FIG. 15 RESULTS OF PAIRED-COMPARISON JUDGMENTS SHOWING INSIGNIFICANT ISOLATION EFFECTS. Data are Peak PNdB levels of subsonic aircraft noise judged to be as acceptable as B-58 boom of 2.33 psf nominal peak overpressure.

the same time, however, they could hear the sounds made in the house as the result of its being vibrated by the boom. It would appear that the auditory component was nearly as or perhaps slightly more effective than the actual vibrations as felt by the subjects in determining their response to the sonic booms and noise from the subsonic aircraft.

2. House Loading

When all the subjects (62) were in place, more than the normal number of persons (three to six) were present in the test houses. To test whether the weight of 62 people so loaded the structures that the houses did not respond to the booms in a normal manner, one series of tests was run with only 16 subjects in each test house. The results were essentially the same for comparable boom and noise exposures when 16 subjects or when 32 subjects were in the house.

G. Mail Survey Ratings of Sonic Booms, Aircraft Noise, and Street Noise by Residents of Edwards Air Force Base

Residents of Edwards Air Force Base were asked on 1 July 1966 to rate several noise conditions present in or around their homes on a scale similar to that used by the test subjects: (1) during the month of June when the special sonic boom tests were being conducted and (2) for the months prior to June. It is estimated that the average daily number of sonic booms at Edwards during the month of June 1966 was about ten (the residents estimated six). It is seen in Table 7 that 26 percent of the people who answered the mail survey felt that the sonic boom environment at Edwards during the month of June was unacceptable.

Street noise and the noise of subsonic aircraft would appear to be no significant problem to the residents at Edwards Air Force Base. It should be borne in mind that although occasionally the noise of low-flying subsonic aircraft reaches the residential area at Edwards, the normal takeoff and approach paths to the runways avoid the residential area and the flight path of the subsonic aircraft used in the sonic boom evaluation tests did not pass over the residential area. Figure 16 shows distributions for the ratings of different environmental noises by a sample of the residents of Edwards Air Force Base.

Table 7

MAIL SURVEY DATA: PERCENTAGE OF PERSONS WHO RATED SONIC BOOMS AND NOISE AS UNACCEPTABLE (LESS THAN "JUST ACCEPTABLE")

Type	Response Total	Male	Female	Age				Time-on-Base			
				<25	25-34	35-44	>44	<0.5	0.5-1	1-5	>5
Street Noise, June	7%	9%	5%	6%	6%	8%	5%	7%	5%	8%	4%
Aircraft Noise, June	6	6	6	10	6	4	7	5	7	5	7
Aircraft Noise, Prior	3	3	4	5	3	3	3	1	5	3	0
Sonic Boom, June	26	25	27	37	25	25	21	28	27	25	20
Sonic Boom, Prior	14	13	15	16	13	11	18	13	17	11	16
Number of Persons Who Responded	783*	353	397	90	366	238	78	109	249	371	46

* Includes 33 families with no designation of male or female response. Age was not reported for 11 responses. Time-on-base was not reported for eight responses.

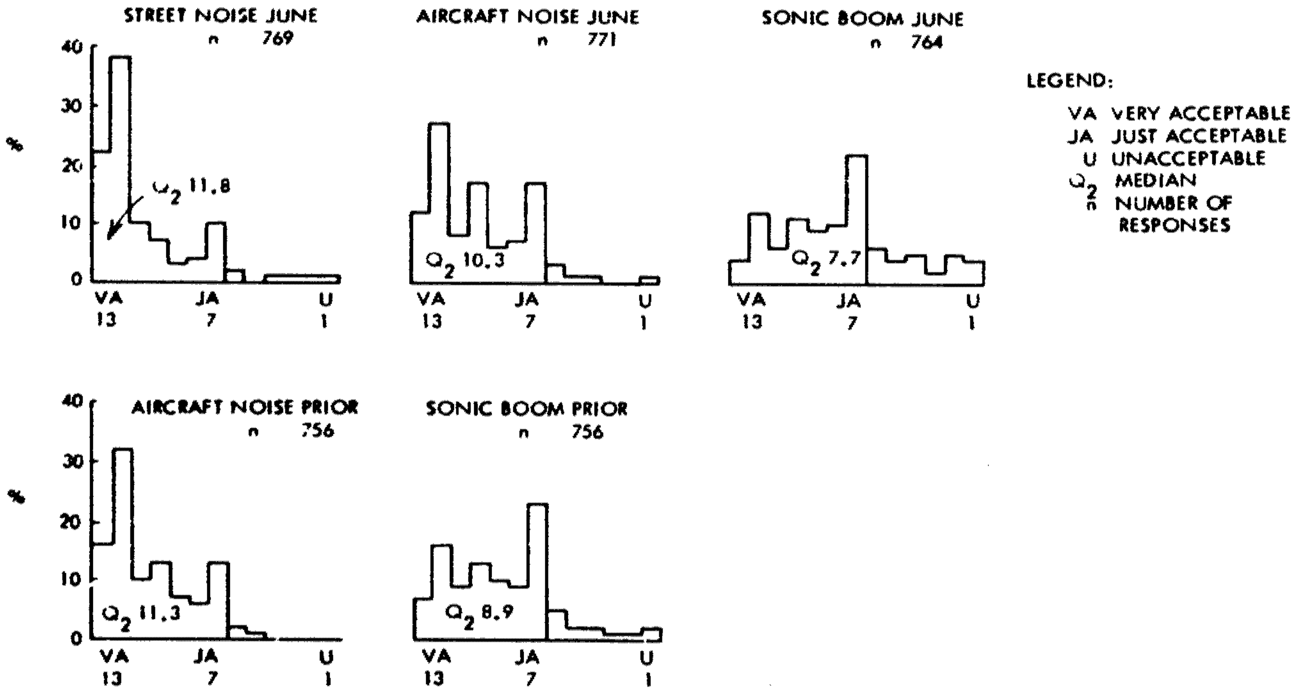


FIG. 16 DISTRIBUTION OF ACCEPTABILITY RATINGS OBTAINED BY MAIL SURVEY

Figure 17 depicts the acceptability ratings of environmental noises made by residents of Edwards Air Force Base as a function of their age and years of residence at Edwards. It would appear from this figure that, particularly with respect to sonic booms, the older the person and the longer he or she had lived there, the more acceptable were the noises. Age and years of residence are obviously not independent of each other, and an analysis of the data by years of residence, keeping age constant, showed no consistent influence of age upon the ratings of sonic booms. (See Table 7.) No significant difference was found between the results of paired-comparison tests for different age groups of subjects. (See Tables 5 and 6.)

The respondents rated the sonic boom as the least acceptable noise condition at Edwards as follows:

Least Acceptable Condition	No. Replies	Percent
Sonic Boom	553	71
Street Noise	135	17
Airplane Noise	90	12

These data obviously substantiate the displacement between the curves for these various noise conditions shown in Fig. 17.

Some adaptation, as mentioned above, to the sonic booms is evident from data given in Fig. 17. This is further demonstrated by the answers (tabulated below) to the question, "Do you think living at Edwards Air Force Base and being regularly exposed to sonic booms in your homes up to 1 June 1966 has tended to make sonic booms when heard in your home to be:"

Living at Edwards Made Boom:	No. Replies	Percent
More acceptable	456	60
No change	246	33
Less acceptable	53	7

At the same time it should be noted, as shown in Table 7, that about 14 percent of the people who replied to the mail questionnaire rated in

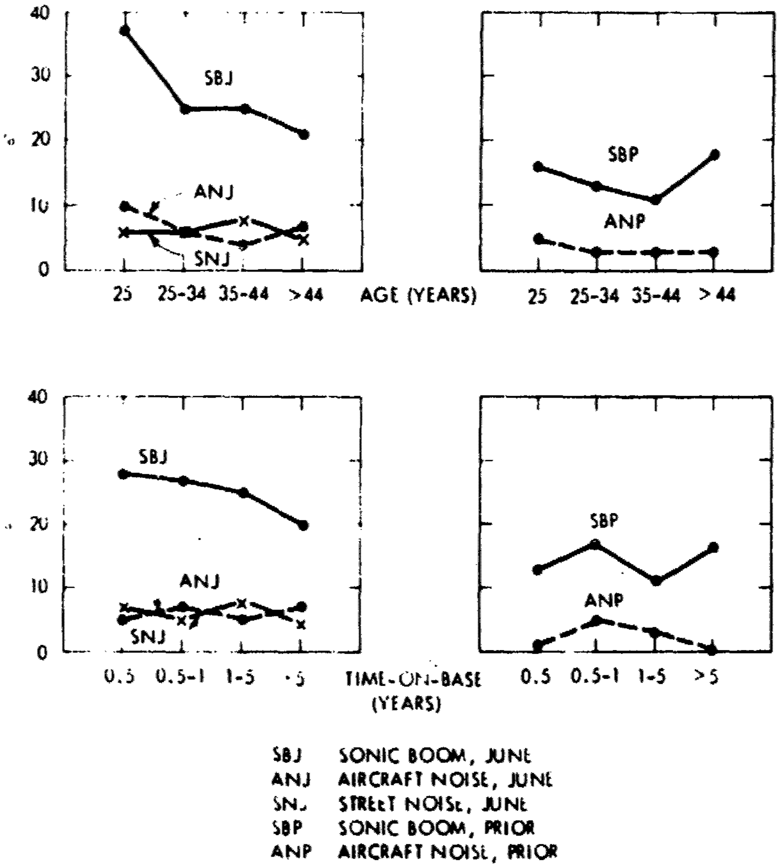


FIG. 17 PERCENTAGE OF PERSONS WHO RATED SONIC BOOMS AS UNACCEPTABLE (Less than just acceptable)

retrospect the sonic boom conditions prior to the month of June as being unacceptable, compared to 26 percent who rated the booms heard during June as being unacceptable. Part of the explanation for this difference undoubtedly was due to the difference in boom exposures during this period (see Table 4). The average nominal peak overpressure of sonic booms during a typical operational month prior to June 1966 in the residential area of Edwards is about 1.2 psf and the average frequency about 4-8 per day. During the month of June, however, about 289 booms were created, giving a daily average of about ten and a median nominal peak overpressure of about 1.69 psf.

IV SUMMARY OF FINDINGS

To date the major findings from analysis of the results obtained for the subjects and listening conditions involved in these experiments are as follows:

1. <u>Sonic Boom from B-58 Judged against Noise from Subsonic Aircraft</u>

    (a) When indoors, subjects from Edwards Air Force Base judged booms from the B-58 at 1.69 psf nominal peak overpressure outdoors to be as acceptable as the noise from a subsonic jet at an intensity of 109 PNdB* measured outdoors.

    (b) When indoors, subjects from the towns of Fontana and Redlands judged the boom from the B-58 at 1.69 psf nominal peak overpressure outdoors to be as acceptable as the noise from a subsonic jet at an intensity of 118 to 119 PNdB** measured outdoors.

    (c) The booms heard outdoors from the B-58 at 1.69 nominal peak overpressure were judged to be as acceptable as the noise heard outdoors from a subsonic jet at 105 PNdB, 111 PNdB, and 108 PNdB by subjects from Edwards Air Force Base, Fontana, and Redlands, respectively.

    (d) When indoors, 27 percent of the subjects from Edwards and 40 percent of the subjects from Fontana and Redlands combined rated the B-58 booms of nominal peak overpressure of 1.69 psf as being between less than "just acceptable" to "unacceptable."

---

*Noises having these PNdB values would be generated on the ground directly under the flight path of a turbofan aircraft at an altitude of 800 or 1400 ft, depending on whether landing or takeoff engine power settings were used.

**Noises having these PNdB values would be generated on the ground directly under the flight path of a turbofan aircraft at an altitude of 300 or 600 ft, depending on whether landing or takeoff engine power settings were used.

(e) When outdoors, 33 percent of the subjects from Edwards and 39 percent of the subjects from Fontana and Redlands, combined, rated the B-58 booms of nominal peak overpressure of 1.69 psf as being between less than "just acceptable" to "unacceptable."

(f) Residents of Edwards AF Base who served as subjects had been in residence there for an average of two years and had been exposed during that period to about 4-8 booms per day of median nominal peak overpressure of 1.2 psf and to subsonic aircraft noise having peak PNdB levels of about 110 PNdB. The towns of Fontana and Redlands, on the other hand, were not under or near the flight track of supersonic aircraft and were occasionally exposed to noise of subsonic aircraft at a peak level of about 95-100 PNdB.

2. Acceptability of Sonic Booms from Different Military Aircraft

(a) When of approximately equal nominal or measured peak overpressure and when heard indoors and judged against the aircraft noise, the boom from the XB-70 was slightly less acceptable than the booms from the F-104 or B-58 aircraft. When heard outdoors and judged against aircraft noise, the boom from the B-58 was slightly less acceptable than the booms from the XB-70 and F-104 aircraft.

(b) When one type of boom was judged against another type of boom at equal nominal peak overpressure, no significant difference in their acceptability was measured in these tests.

3. Acceptability of Booms and Aircraft Noise as a Function of Their Intensity

The unacceptability of sonic booms, as a function of intensity, increases at about half again as fast a rate as does the unacceptability of the noise from subsonic aircraft; i.e., in terms of judged unacceptability, an increase of 10 PNdB in intensity of a noise from a subsonic aircraft was equivalent to about a 6 dB increase (from 1 psf to 2 psf) in the intensity of a sonic boom.

4. Acceptability of Booms or Noises for Indoor Listening Compared to Outdoor Listening

The results averaged over all tests indicates that the booms and particularly the noise were rated slightly more unacceptable by the listeners outdoors than by the listeners indoors. Also, the precision of the judgments and rate of growth of unacceptability as a function of the intensity of the booms or noise was about 50-percent greater for listeners outdoors than indoors.

5. Subsonic Aircraft Noise

The results obtained when sonic booms were judged against the noise from either turbojet or turbofan subsonic aircraft were comparable, provided the aircraft noise had about the same peak PNdB value. Also, noise from turbojet aircraft was generally judged to be equal in acceptability to noise from turbofan aircraft when the noises had the same PNdB value, except when landing power was used and the listeners were outdoors.

6. Discrimination of Intensity Differences in Booms and Subsonic Aircraft Noise

(a) On the average, two booms were judged to be significantly different in acceptability when their nominal or measured peak overpressures differed by about 1 dB, and by about 2 dB when the two booms were compared against a reference aircraft noise.

(b) On the average, two aircraft noises were judged to be significantly different in acceptability when they differed by about 2 PNdB, and by about 4 PNdB when the two aircraft noises were compared against a reference boom.

7. Differences in Judgments of Subjects Located in Different Rooms and When on Vibration Isolation Pads

Systematic differences were found among some of the subgroups of subjects located in different rooms in the test houses. When some of the subjects were exchanged among rooms, it was found that some of the differences were due to the test rooms and not to the subjects.

Placing the indoor and outdoor subjects on vibration isolation pads did not significantly change their judgments of the sonic booms relative to the noise from the subsonic aircraft.

8. Attitude Survey

An attitude survey of residents (15 percent of whom served as subjects in these experiments) at Edwards Air Force Base revealed that 26 percent rated the boom environment as being between less than "just acceptable" to "unacceptable" for the month of June, when there was an average of about 10 booms per day at a median nominal peak overpressure of about 1.69 psf. Fourteen percent of the residents also rated the boom environment prior to June as being between less than "just acceptable" to "unacceptable." During this previous period, there were about 4 to 8 booms per day at a median nominal boom level of 1.2 psf. Six percent rated the ambient daily aircraft noise and seven percent rated the street noise as being between less than "just acceptable" to "unacceptable."

9. Age and Sex of Subjects

Within the adult population studied, age and sex are not statistically significant factors in the ratings or paired-comparison of the unacceptability of sonic booms or the aircraft noises.

REFERENCES

1. Andrews, B. and D. M. Finch, "Truck Noise Measurement," Proc. Highways Research Board (U.S.A.), 456-465, December 1951

2. ARP 865, "Definitions and Procedure for Computing the Perceived Noise Level of Aircraft Noise," Society of Automotive Engineers, New York, N.Y. (1965)

3. Bishop, D. E., "Judgments of the Relative and Absolute Acceptability of Aircraft Noise," J. Acoust. Soc. Am. 40, 108-122 (1966)

4. Borsky, P. N., "Community Reactions to Sonic Booms in the Oklahoma City Area," (Parts I and II), Wright-Patterson AFB, AMRL-TR-65-37 (1965) AD 613 620

5. Bowker, C. H. and Lieberman, G. J., Engineering Statistics, Prentice-Hall Inc., Englewood Cliffs, New Jersey (1959)

6. Bowsher, J. M., D. R. Johnson, and D. W. Robinson, "A Further Experiment on Judging the Noisiness of Aircraft in Flight," Acustica 17, 246-267 (1966)

7. Broadbent, D. E. and D. W. Robinson, "Subjective Measurements of the Relative Annoyance of Simulated Sonic Bangs and Aircraft Noise," J. Sound Vibration 1, 162-174 (1964)

8. Cohen, A. and R. F. Scherger, "Correlation of Objectionability Ratings of Noise with Proposed Noise-Annoyance Measures," U.S. Department of Health, Education, and Welfare, Public Health Service, Division of Occupational Health Report RR-3, May 1964

9. Committee on the Problem of Noise; Final Report, "Noise," Cmdn. 2056, Her Majesty's Stationery Office, London (1963)

10. Copeland, W. C. T., I. M. Davidson, T. J. Hargest, and D. W. Robinson, "A Controlled Experiment on the Subjective Effects of Jet Engine Noise," J. Royal Aeron. Soc. 64, 33-36, January 1960

11. deBrisson, Lt. Colonel, "Opinion Study on the Sonic Bang," Centre de 'etudes et d'instruction psychologiques de l'armee de l'air; Study No. 22 (1966); Royal Air Est. Lib. Trans. No. 1159 (1966); AD 483 066

12. Galloway, W. J. and H. E. von Gierke, "Individual and Community Reaction to Aircraft Noise; Present Status and Standardization Efforts," London Noise Conference, November 1966

13. ISO Recommendation R506, "Procedure for Describing Aircraft Noise Around an Airport," U.S.A. Standards Institute, New York, N.Y. (1967)

14. Johnson, D. R. and D. W. Robinson, "On the Subjective Evaluation of Sonic Bangs," National Physical Laboratory, Applied Physics Division, Great Britain. Report Prepared for Ministry of Aviation, AP 25, GC 1147/66/1, November 1966

15. Kryter, K. D., "Scaling Human Reactions to the Sound from Aircraft," J. Acoust. Soc. Am. 31, 1415-1429 (1959)

16. Kryter, K. D., "Psychological Reactions to Aircraft Noise," Science 151, 1346-1355 (1966)

17. Kryter, K. D. and K. S. Pearsons, "Judgment Tests of the Sound from Piston, Turbojet, and Turbofan Aircraft," Sound 1, No. 2, 24-31, March-April 1962

18. Kryter, K. D. and K. S. Pearsons, "Some Effects of Spectral Content and Duration on Perceived Noise Level," J. Acoust. Soc. Am 35, No. 6, 866-883 (June 1963)

19. Kryter, K. D. and K. S. Pearsons, "Modification of Noy Tables," J. Acoust. Soc. Am. 36, 394-397 (1964)

20. Kryter, K. D. and K. S. Pearsons, "Judged Noisiness of a Band of Random Noise Containing an Audible Pure-Tone," J. Acoust. Soc. Am. 38, 106-112 (1965)

21. Little, J. W., "Human Response to Jet Engine Noises," Noise Control 7, No. 3, 11-13 (1961)

22. Mills, C. H. B. and D. W. Robinson, "The Subjective Rating of Motor Vehicle Noise," Engineer 211, 1070-1074 (1961)

23. Pearsons, K. S. and K. D. Kryter, "Laboratory Tests of Subjective Reactions to Sonic Boom," NASA Contractor Report No. CR-187 (1964)

24. Pearsons, K. S. and K. D. Kryter, "The Effects of Duration and Background Noise Level on Perceived Noisiness," FAA ADS-78, April 1966

25. Robinson, D. W., J. M. Bowsher, and W. C. Copeland, "On Judging the Noise from Aircraft in Flight," Acustica 13, 324-330 (1963)

26. Zepler, E. E. and J. R. P. Harel, "The Loudness of Sonic Booms and Other Impulsive Sounds," J. Sound Vibration 2, No. 3, 249-256 (1965)

Annex B

Appendix B-1

MISSIONS FOR PSYCHOLOGICAL TESTS

Table B-1-1

EDWARDS - PHASE I

Experiment 1: BOOM vs BOOM
B-58 versus B-58
F-104 versus F-104
B-58 versus F-104

Missions*	A/C	Altitude kft. MSL**	MACH	Lat. Dist. Miles	Nominal Peak Overpressure (POP) (psf)
18-A, 21-A, 29-B, 32-B	B-58	36	1.65	0	2.33
18-B, 21-B, 29-A, 32-A	B-58	48	1.65	0	1.69
1X-A, 4X-A, 2X-B, 3X-B	F-104	13	1.3	0	3.30
1X-B, 4X-B, 2X-A, 3X-A	F-104	28	1.65	0	1.5
26-A, 26(R)-A, 37-A, 38-B, 27-B	F-104	20	1.4	0	1.85
26-B, 26(R)-B, 37-B, 38-A, 27-A	F-104	28	1.65	0	1.5
17-A, 28-A, 31-A, 20-B, 36-B	B-58	36	1.65	0	2.33
17-B, 28-B, 31-B, 20-A, 36-A	F-104	20	1.4	0	1.85
19-A, 30-A, 23-B	B-58	36	1.65	0	2.33
19-B, 30-B, 23-A	F-104	28	1.65	0	1.5
24-A, 35-A, 25-B	B-58	42	1.65	5.	1.69
24-B, 35-B, 25-A	F-104	20	1.40	0	1.85
22-A, 34-A, 33-B	F-104	28	1.65	0	1.5
22-B, 34-B, 33-A	B-58	42	1.65	5.	1.69

* A is first aircraft of pair; B flown second.
** Local altitude is 2300 ft.
(R) Indicates the mission was repeated with the same number.

Table B-1-1 (cont d)

EDWARDS - PHASE I

Experiment 2: BOOM vs NOISE
B-58 vs KC-135

Missions*	A C	Alt Kft MSL**	MACH	Lat. Dist Miles	Nom. POP (psf)	Alt Kft MSL**	EPR	Est. PNdB
9-A, 55R-B, 55SR-B	B-58	42	1.65	5	1.69			
9-B, 55R-A, 55SR-A	KC-135					10.3	1.5	88
10-A, 10(R)-A, 18-A, 18(R)-A, 56R-B, 56SR-B	B-58	42	1.65	5	1.69			
10-B, 10(R)-B, 18-B, 18(R)-B, 56R-A, 56SR-A	KC-135					5.3	1.5	98
11-A, 11(R)-A, 11S-A, 57R-B, 57SR-B	B-58	42	1.65	5	1.69			
11-B, 11(R)-B, 11S-B, 57R-A, 57SR-A	KC-135					3.3	1.5	108
12-A, 12(R)-A, 12S-A, 12S(R)-A, 58-B, 66-B	B-58	42	1.65	5	1.69			
12-B, 12(R)-B, 12S-B, 12S(R)-B, 58-A, 66-A	KC-135					2.8	1.5	114
13-A, 13(R)-A, 13S-A, 59-B	B-58	42	1.65	5	1.69			
13-B, 13(R)-B, 13S-B, 59-A	KC-135					14.3	2.35	95
50-A, 14R-A, 60-B, 60(R)-B, 68-B	B-58	42	1.65	5	1.69			
50-B, 14R-B, 60-A, 60(R)-A, 68-A	KC-135					8.3	2.35	101
19-A, 53-A, 61-B, 69-B	B-58	42	1.65	5	1.69			
19-B, 53-B, 61-A, 69-A	KC-135					1.3	2.35	111
16S-A, 18(R)-A, 54-A, 45R-B, 46R-B	B-58	42	1.65	5	1.69			
16S-B, 18(R)-B, 54-B, 45R-A, 46R-A	KC-135					3.0	2.35	121

* A is first aircraft of pair, B is flown second.
** Local altitude is 2300 ft.
(R) Indicates the mission was repeated with the same number.

Table B-1-1 (cont'd)

EDWARDS - PHASE I

Experiment 2: BOOM vs NOISE
(continued) B-58 vs KC-135

Missions*	A/C	Alt. kft. MSL**	MACH	Lat. Dist. Miles	Nom. POP (psf)	Alt. kft. MSL**	EPR	Est. PNdB
70-A, 86R-B, 86SR-B	B-58	30	1.5	0	2.65			
70-B, 86R-A, 86SR-A	KC-135					5.3	1.5	98
71-A, 79-A, 87R-B, 87SR-B	B-58	30	1.5	0	2.65			
71-B, 79-B, 87R-A, 87SR-A	KC-135					3.3	1.5	108
72-A, 72(R)-A, 72S-A, 72S(R)-A, 80R-B, 80SR-B	B-58	30	1.5	0	2.65			
72-B, 72(R)-B, 72S-B, 72S(R)-B, 80R-A, 80SR-A	KC-135					2.8	1.5	114
73-A, 73(R)-A, 73S-A, 89-B	B-58	30	1.5	0	2.65			
73-B, 73(R)-B, 73S-B, 89-A	KC-135					2.55	1.5	120
74-A, 90-B, 98-B	B-58	30	1.5	0	2.65			
74-B, 90-A, 98-A	KC-135					8.3	2.35	101
75-A, 75(R)-A, 81(RR)-A, 75S-A, 76R-B, 99-B	B-58	30	1.5	0	2.65			
75-B, 75(R)-B, 81(RR)-B, 75S-B, 76R-A, 99-A	KC-135					4.3	2.35	111
80-A, 81-A, 77R-B, 100-B	B-58	30	1.5	0	2.65			
80-B, 81-B, 77R-A, 100-A	KC-135					3.0	2.35	121
79-A, 85-A, 85(R)-A, 93-B, 101-B	B-58	30	1.5	0	2.65			
79-B, 85-B, 85(R)-B, 93-A, 101-A	KC-135					2.6	2.35	128

* A is first aircraft of pair, B is flown second.

** Local altitude is 2300 ft.

(R) Indicates the mission was repeated with the same number.

Table B-1-1 (concluded)

EDWARDS - PHASE I

Experiment 3: **NOISE vs NOISE**

KC-135 vs WC-135B

Missions*	A/C	Alt. kft. MSL**	EPR	Est. PNdB
1-A, 12-B	KC-135	3.1	1.5	108
1-B, 12-A	WC-135B	2.55	1.3	121
2-A, 11-B	KC-135	3.1	1.5	108
2-B, 11-A	WC-135B	3.05	1.3	113
3-A, 10-B	KC-135	3.1	1.5	108
3-B, 10-A	WC-135B	3.8	1.3	104
6-A, 7-B	KC-135	3.1	1.5	108
6-B, 7-A	WC-135B	2.55	1.76	125
5-A, 8-B	KC-135	3.1	1.5	108
5-B, 8-A	WC-135B	3.05	1.76	117
4-A, 9-B	KC-135	3.1	1.5	108
4-B, 9-A	WC-135B	3.8	1.76	108
15-A, 22-B	KC-135	4.3	2.35	112
15-B, 22-A	WC-135B	2.55	1.3	121
14-A, 23-B	KC-135	4.3	2.35	112
14-B, 23-A	WC-135B	3.05	1.3	113
13-A, 24-B	KC-135	4.3	2.35	112
13-B, 24-A	WC-135B	3.8	1.3	104
16-A, 21-B	KC-135	4.3	2.35	112
16-B, 21-A	WC-135B	2.55	1.76	125
17-A, 20-B	KC-135	4.3	2.35	112
17-B, 20-A	WC-135B	3.05	1.76	117
18-A, 19-B	KC-135	4.3	2.35	112
18-B, 19-A	WC-135B	3.8	1.76	108

* A is first aircraft of pair; B is flown second.

** Local altitude is 2300 ft.

Table B-1-2

EDWARDS - PHASE II

Experiment 1: **BOOM VS BOOM**
XB-70 versus B-58
F-104 versus B-58

Missions*	A/C	Altitude kft MSL**	MACH	Lat. Dist. Miles	Nominal Peak Overpressure (POP) (psf)
1-A, 2-A, 3-B, 4-B	XB-70	37	1.5	0	2.52
1-B, 2-B, 3-A, 4-A	B-58	32	1.5	0	2.52
9-A, 10-A, 11-B, 12-B	XB-70	60	2.5	0	2.06
9-B, 10-B, 11-A, 12-A	B-58	40	1.65	0	2.06
13-B, 113-B, 14-A, 15-A, 16-B	XB-70	60	1.8	0	2.06
13-A, 113-A, 14-B, 15-B, 16-A	B-58	40	1.65	0	2.06
17-A, 18-B, 19-A, 20-B	F-104	30.5	1.65	0	1.69
17-B, 18-A, 19-B, 20-A	B-58	48	1.65	0	1.69
117-A, 118-B	F-104	26.1	1.65	0	1.69
117-B, 118-A	B-58	48	1.65	0	1.69

* A is first aircraft of pair; B is flown second.

** Local altitude is 2300 ft.

Table B-1-2 (cont'd)

EDWARDS - PHASE II

Experiment 2 **BOOM VS NOISE**

F-104 vs C-135B
XB-70 vs C-135B

Missions*	A-C	Alt. kft. MSL**	MACH	Lat. Dist. Miles	Nom. POP (psf)	Alt. kft. MSL**	EPR	Est. PNdB
52-A, 57-A, 51-B, 58-B	F-104	16.3	1.3	0	2.8			
52-B, 57-B, 51-A, 58-A	C-135B					2.65	1.76	125
54-A, 55-A, 49-B, 60-B	F-104	16.3	1.3	0	2.8			
54-B, 55-B, 49-A, 60-A	C-135B					2.9	1.76	119
53-A, 56-A, 50-B, 59-B	F-104	16.3	1.3	0	2.8			
53-B, 56-B, 50-A, 59-A	C-135B					3.4	1.76	113
61-A, 67-A, 66-B, 172-B	F-104	29.5	1.65	0	1.4			
61-B, 67-B, 66-A, 172-A	C-135B					3.4	1.76	113
62-A, 68-A, 65-B, 71-B, 72-B	F-104	29.5	1.65	0	1.4			
62-B, 68-B, 65-A, 71-A, 72-A	C-135B					4.4	1.76	105
63-A, 69-A, 64-B, 70-B	F-104	29.5	1.65	0	1.4			
63-B, 69-B, 64-A, 70-A	C-135B					6.4	1.76	95
73-A, 79-A, 78-B, 84-B	F-104	50	1.5	0	0.7			
73-B, 79-B, 78-A, 84-A	C-135B					4.4	1.65	105
74-A, 80-A, 77-B, 83-B	F-104	50	1.5	0	0.7			
74-B, 80-B, 77-A, 83-A	C-135B					6.4	1.76	95
75-A, 81-A, 76-B, 82-B	F-104	50	1.5	0	0.7			
75-B, 81-B, 76-A, 82-A	C-135B					10.4	1.76	85
5-A, 6-A, 7-B, 8-B	XB-70	60	2.5	13	1.36			
5-B, 6-B, 7-A, 8-A	C-135B					3.7	1.76	110

* A is first aircraft of pair; B is flown second.

** Local altitude is 2300 ft.

Table B-1-2 (cont'd)

EDWARDS - PHASE II

Experiment 3: **BOOM VS NOISE**
B-58 vs C135-B

Response of Non-Air Force Base Subjects

Missions*	A/C	Altitude kft. MSL**	MACH	Lat.Dist. Miles	Nom.PCP (psf)	Alt. kft. MSL**	EPR	Est. PNdB
			FONTANA					
21-A,121-A , 24-A, 29-B, 32-B	B-58	48	1.65	0	1.67			
21-B,121-B , 24-B, 29-A, 32-A	C135-B					5.2	1.76	101
22-A, 25-A, 28-B, 31-B	B-58	48	1.65	0	1.67			
22-B, 25-B, 28-A, 31-A	C135-B					3.8	1.76	109
23-A, 26-A, 27-B, 30-B	B-58	48	1.65	0	1.67			
23-B, 26-B, 27-A, 30-A	C135-B					3.1	1.76	116
			REDLANDS					
221-A, 124-A, 129-B, 132-B	B-58	48	1.65	0	1.67			
221-B, 124-B, 129-A, 132-A	C135-B					4.2	1.76	106
122-A, 125-A, 128-B, 131-B	B-58	48	1.65	0	1.67			
122-B, 125-B, 128-A, 131-A	C135-B					3.4	1.76	113
123-A, 126-A, 127-B, 130-B	B-58	48	1.65	0	1.67			
123-B, 126-B, 127-A, 130-A	C135-B					2.8	1.76	120

* A is first aircraft of pair; B is second.

** Local altitude is 2300 ft.

Table B-1-2 (cont'd)
EDWARDS - PHASE II

Experiment 4: BOOM VS NOISE
Isolation, Exchange, and Loading
B-58 versus C-135B

Missions*	A C	Altitude kft. MSL**	MACH	Lat. Dist. Miles	Nom. POP (psf)	Alt. kft MSL**	EPR	Est. PNdB
(1) 33-A, 36-A, 37-B, 40-B (2) 42-A, 46-A, 43-B, 47-B (3) 87-A, 88-A, 85-B, 86-B	B-58	36	1.65	0	2.33			
(1) 33-B, 36-B, 37-A, 40-A (2) 42-B, 46-B 43-A, 47-A (3) 87-B, 88-B, 85-A, 86-A	C-135B					3.2	1.76	115
(1) 34-A, 35-A, 38-B, 39-B (2) 41-A, 45-A, 44-B, 48-B	B-58	36	1.65	"	2.33			
(1) 34-B, 35-B, 38-A, 39-A (2) 41-B, 45-B, 44-A, 48-A	C-135B					4.4	1.76	105

CONDITIONS

Normal Location of Group	(1)	(2)	(3)
E1 Bedroom (1B)	In 2L	Normal	Approx. 1/3 indoor, remainder outdoor
E1 Living Room (1L)	Approx. half on isolation pads	Normal for Mission 41*	
E1 Kitchen (1K)	Outdoors	Normal	
E2 Bedroom (2B)	Approx. half on isolation pads	Normal for Mission 41*	**
E2 Living Room (2L)	In 1B	Normal	
E2 Dining Room (2D)	Approx. half on isolation pads	Normal for Mission 41*	
E2 Family Kitchen (2K)	Approx. half on isolation pads	Normal for Mission 41*	
Outdoor (T1 and T2)	Part of group in 1K. Approx. half of remainder on isolation pads.	Normal	Normal

Changes in Experimental Design

None for aircraft requirements.

---

*Approximately one-half the people in 1L, 2B, 2D, and 2K (those not isolated under condition (1) were placed on isolation pads for Missions 42-48.

**Due to an oversight, the entire 2B group was indoors for Missions 87 and 88.

Annex B

Appendix B-2

INSTRUCTIONS TO SUBJECTS

Annex B

Appendix B-2

SONIC BOOM JUDGMENT TESTS

It is anticipated that in the not too distant future supersonic transports, which create sonic booms, will be placed into commercial operation. The study in which you are participating is being conducted to determine what kinds of sonic booms, if any, are the most acceptable to people.

As you know, special supersonic aircraft operate from Edwards Air Force Base. These aircraft occasionally generate "sonic booms" with which you are familiar. Because you are somewhat familiar with sonic booms and because they are generated as a matter of everyday operation at Edwards Air Force Base, we would like you to make certain judgments about the relative acceptability of the sonic booms that you will hear during this study.

The sonic booms you will hear will be of the intensity that normally occur at or near Edwards Air Force Base during everyday operations and are levels which will presumably be present in communities when the anticipated commercial supersonic aircraft fly across the United States.

There is nothing secret or classified about these tests. However, we ask that you do not attempt to give opinions about the results of the tests inasmuch as the results will not be analyzed or understood until the study is completed and all data are given proper consideration. Also, you should not discuss, in particular, your reactions to these sounds with your fellow observers inasmuch as we want your own opinions, and we expect people to differ in their judgments. There are no right or wrong answers.

These tests are being conducted jointly by the Air Force, the National Aeronautics and Space Administration, and the Federal Aviation Agency, and are part of the program for the development of a commercial supersonic transport. Your concientious participation in this program is greatly appreciated. Any requests for additional information should be addressed to: Public Information Officer, Edwards Air Force Base.

LAST NAME ☐☐☐☐☐☐☐☐☐☐☐☐☐☐ INITIAL ☐

P DATE ☐☐ MONTH ☐☐☐ LOC. ☐☐ ISO. ☐

INSTRUCTIONS:

The primary purpose of the tests being conducted is to determine, if possible, how people feel about the *relative* acceptability of one type or level of aircraft noise when compared with a second type or level of aircraft noise.

You will hear a series of sounds from aircraft. Some of the sounds will be sonic booms and some will be the sound made by a subsonic jet aircraft. The sounds will occur in "pairs" and your task is to judge which sound in each pair you think would be more acceptable to you if heard in or near your home during the day and/or evening when you are engaged in typical, awake activities.

After you have heard each pair of sounds please quickly decide which of the two you feel would be more acceptable to you. If you think the second sound of a pair would be more acceptable, circle **B** for that particular pair. If you think the first sound in the pair would be more acceptable to you than the second, circle **A**.

Please concentrate on the judgment at hand and give an answer even though the two sounds may seem approximately equal in acceptability to you. If you feel that there is absolutely no real difference in terms of acceptability of the two sounds, please circle either **A** or **B**, giving the best guess you can, and put a question mark after that pair.

There are no "right" or "wrong" answers, nor do we expect people to agree with each other. We are interested in how you feel about the sounds and how people differ in their judgments of the acceptability of these aircraft sounds.

An announcement will be made before each pair of sounds is to occur. The sounds of a pair may be separated in time by several minutes; usually, however, they will occur within a single minute. During this period we ask that you be quiet and attentive. Give us your best judgment and imagine, if you will, that you are listening to these sounds in or near your own home.

CIRCLE A IF FIRST SOUND IS MORE ACCEPTABLE.
CIRCLE B IF SECOND SOUND IS MORE ACCEPTABLE.

1. A B
2. A B
3. A B
4. A B
5. A B
6. A B
7. A B
8. A B
9. A B
10. A B
11. A B
12. A B
13. A B
14. A B
15. A B
16. A B
17. A B
18. A B
19. A B
20. A B

LAST NAME INITIAL

R DATE MONTH LOC. ISO.

For each aircraft noise you hear, indicate with an X in the corresponding box how you would
* feel if you heard this noise in or near your home 10 15 times throughout the day and evening.

1.	A													
	B													
		VERY ACCEPTABLE						JUST ACCEPTABLE						UNACCEPTABLE
2.	A													
	B													
		VERY ACCEPTABLE						JUST ACCEPTABLE						UNACCEPTABLE
3.	A													
	B													
		VERY ACCEPTABLE						JUST ACCEPTABLE						UNACCEPTABLE
4.	A													
	B													
		VERY ACCEPTABLE						JUST ACCEPTABLE						UNACCEPTABLE
5.	A													
	B													
		VERY ACCEPTABLE						JUST ACCEPTABLE						UNACCEPTABLE
6.	A													
	B													
		VERY ACCEPTABLE						JUST ACCEPTABLE						UNACCEPTABLE
7.	A													
	B													
		VERY ACCEPTABLE						JUST ACCEPTABLE						UNACCEPTABLE
8.	A													
	B													
		VERY ACCEPTABLE						JUST ACCEPTABLE						UNACCEPTABLE
9.	A													
	B													
		VERY ACCEPTABLE						JUST ACCEPTABLE						UNACCEPTABLE
10.	A													
	B													
		VERY ACCEPTABLE						JUST ACCEPTABLE						UNACCEPTABLE
11.	A													
	B													
		VERY ACCEPTABLE						JUST ACCEPTABLE						UNACCEPTABLE
12.	A													
	B													
		VERY ACCEPTABLE						JUST ACCEPTABLE						UNACCEPTABLE

NAME

LAST NAME

FIRST NAME

MIDDLE INITIAL

SOCIAL SECURITY NUMBER — —

PLACE OF PRESENT RESIDENCE (Circle One)

B	N
On Base	Off Base

MARITAL STATUS (Circle One)

M	S
Married	Not Married

SEX (Circle One)

M	F
Male	Female

AGE

OCCUPATION (Circle One)

H	A	R	O
Housewife	Air Force Employee	Retired	Other

HUSBAND EMPLOYED BY (Circle One) Military Civilian

IF MILITARY, STATE RANK ______________________

TIME IN AREA TO THE NEAREST YEAR (Circle One)

L	1	2	3	4	5	6
Less than 6 months	1 yr	2 yrs	3 yrs.	4 yrs.	5 yrs.	6 yrs. or more

ADDRESS

STREET ADDRESS

C a l i f

ZIP CODE

Annex B

Appendix B-3

ATTITUDE SURVEY

Annex B
Appendix B-3
ATTITUDE SURVEY

DEPARTMENT OF THE AIR FORCE
HEADQUARTERS AIR FORCE FLIGHT TEST CENTER (AFSC)
EDWARDS AIR FORCE BASE CALIF 93523

OFFICE OF
THE COMMANDER

7 June 1966

SUBJECT: Sonic Boom Testing Program

TO: All Occupants, Base Housing

1. Edwards AFB has been chosen as a place to study some of the reactions and feelings people have to the noise of subsonic aircraft and to sonic booms. Edwards was chosen because it is a base where people are exposed to the noise of aircraft and to sonic booms.

2. These studies are a joint Air Force, NASA and FAA project with Stanford Research Institute assisting as a government contractor. The studies are an important step to finding out which types of sonic booms and other noises are bothersome to people. The program is directly related to design and development of commercial supersonic transport aircraft. Sonic booms created by these aircraft must be socially acceptable to the people of the United States.

3. There are obviously no "right" or "wrong" answers to the questions on the enclosed sheet. It is your opinion and first reaction to each question that is wanted. It is expected that people will differ widely in their opinions.

4. The individual (not joint) opinions of the husband and of the wife, to be given separately on the enclosed answer sheets, are requested. If one of you cannot fill out the answer sheet, or objects to doing so, please send in at least one answer sheet completed. The answer sheets are numbered to aid in data analysis, but the identification of persons filling out the answer sheets will not be used in any way or kept. You will also be asked to complete answer sheets like the enclosed one once or possibly twice again later this summer.

5. This is a voluntary service we are asking you to perform. The program has the full endorsement of the Air Force and is important. For these reasons, your willing cooperation and participation will be appreciated.

Hugh B. Manson
HUGH B. MANSON
Brigadier General, USAF
Commander

Please check one point on each of the lines below which indicates most closely how you felt on the average in your present home during the past few weeks or month about the kinds of various sounds indicated.

a. The sounds, as heard in your home during the day and night for the past few weeks or month, of aircraft flying overhead or nearly so shortly after taking off or during approach to landing were on the average:

Very Acceptable | Just Acceptable | Unacceptable

b. The sonic booms, as heard in your home during the day and night for the past few weeks or month, were on the average:

Very Acceptable | Just Acceptable | Unacceptable

c. Street noises, as heard in your home during the day and night for the past few weeks or month, were on the average:

Very Acceptable | Just Acceptable | Unacceptable

Please check what you think was the number of occurences of the following sounds, as heard in your home during the average day and night, for the past several weeks or month:

a. The sounds of aircraft flying overhead or nearly so shortly after taking off or during approach to landing.

Approximate Average No. of Daily Occurences

1 or Less	2 - 5	6 - 10	11 - 20	21 - 30	30 or More

b. Sonic Booms

Approximate Average No. of Daily Occurences

1 or Less	2 - 5	6 - 10	11 - 20	21 - 30	30 or More

Please place a circle around the condition which in your present home is the most bothersome or least acceptable to you:

a. general airplane noise b. sonic booms c. street noise

How long have you lived at Edwards Air Force Base? ____________ Your age? ________

Please check: husband ________ wife ________

The previous page was concerned with your reaction to sonic booms during the first three weeks or so of the month of June 1966. The questions below are about how you felt about sonic booms and aircraft noise at Edwards Air Force Base before 1 June 1966.

- -

1. Do you think that the sounds of aircraft flying overhead shortly after taking off or during approach to the landing you have heard in your home, up to about 1 June 1966, while living at Edwards Air Force Base were, on the average:

Very Acceptable　　　　Just Acceptable　　　　Unacceptable

- -

2. Do you think that the sonic booms you have heard in your homes, up to about 1 June 1966, while living at Edwards Air Force Base were, on the average:

Very Acceptable　　　　Just Acceptable　　　　Unacceptable

- -

3. Do you think that living at Edwards Air Force Base and being regularly exposed in your homes to sonic booms up to about 1 June 1966 has tended to make sonic booms when heard in your home to be:

   a) more acceptable ☐
   b) no change ☐　　　(Please check one box)
   c) less acceptable ☐

- -

4. Do you think that living at Edwards Air Force Base and being regularly exposed in your homes to the sounds of aircraft flying overhead shortly after taking off or during landing up to about 1 June 1966 has tended to make these sounds when heard in your home to be on the average:

   a) more acceptable ☐
   b) no change ☐　　　(Please check one box)
   c) less acceptable ☐

- -

Please return this answer sheet, along with the attached sheet, within a few days in the enclosed, addressed envelope.

Attach.

Annex B

Appendix B-4

VARIABILITY IN PAIRED-COMPARISON TESTS

Appendix B-4

VARIABILITY IN PAIRED-COMPARISON TESTS

The following factors are considered to be possible major sources of unwanted variability in the present tests:

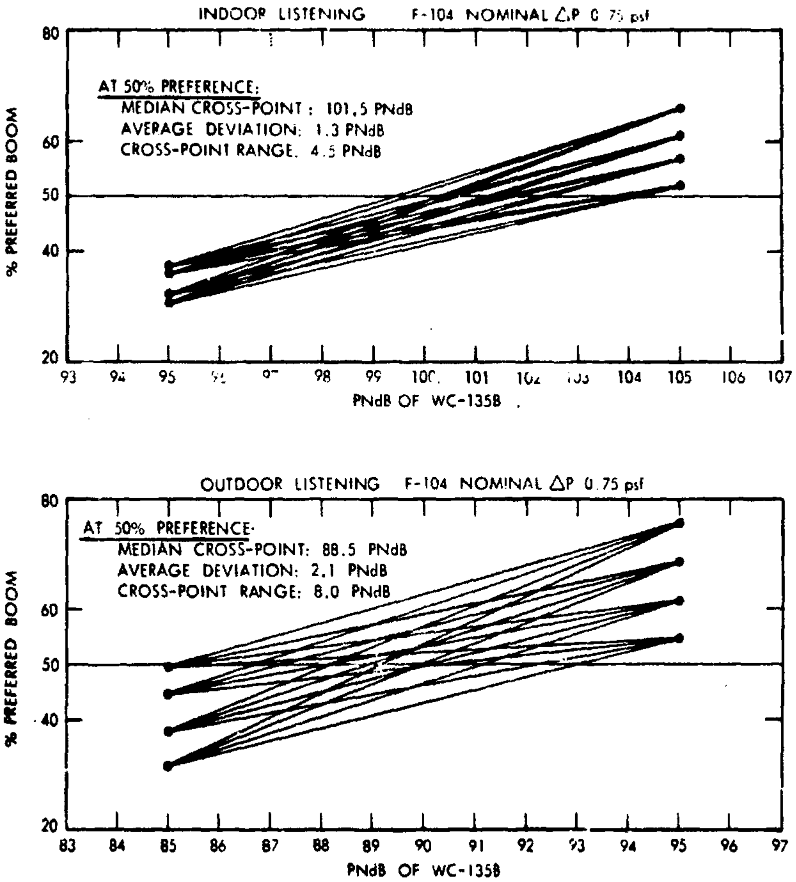
1. Variations in the attentiveness and attitudes of the subjects from moment to moment
2. Chance variation in the physical conditions, such as the aircraft being slightly off flight course or prescribed power setting, or effects of weather conditions on the booms, the presence of extraneous noises, etc.
3. The fact that, at the intensity levels used in these tests, the second sound to be judged in a pair is usually found to have a somewhat stronger psychological effect on a person than the first sound, even though they are physically equal (the so-called "time-error" in judgment tests).

The tests were designed to reduce to a practical minimum the effects of these factors on the results by having the subjects judge each pair of sounds four times: twice in the order of sound A followed by sound B, and twice in the order sound B followed by sound A. In addition, the sequencing of pairs for any one test condition was randomized insofar as flight operations would permit among all test conditions and testing days. The average of the results taken over the four judgments for any two sounds that were compared with each other represents then the best estimate possible of the relative subjective acceptability of the two sounds, taking into account the error-factors outlined above.

An estimate can be made of the variability that would be expected had only one set of A-B and B-A pairs been given for each test condition. This can be done by finding the 50-percent crossing points for the various test conditions from curves based on each possible A-B and B-A data point, rather than on the average of all four pairs, as was done in

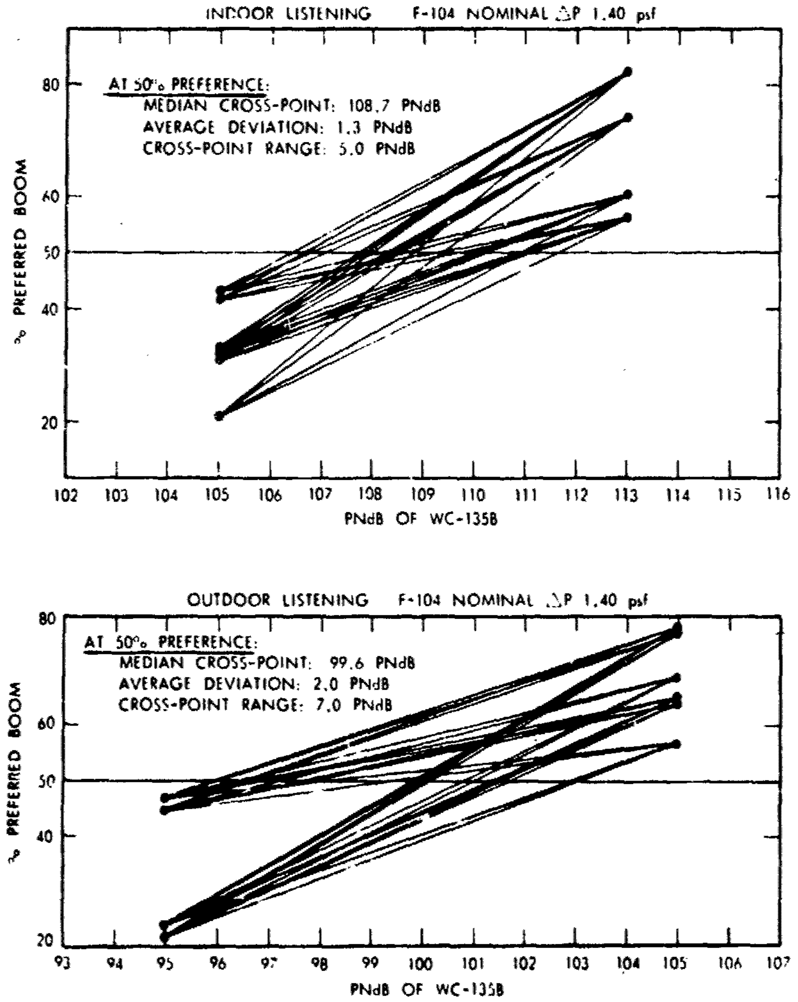
Figures 1 through 5 in the text of Annex B. Figures B-4-1 through B-4-3 show the data for the F-104 vs. WC-135B pairs plotted in this way.

Table B-4-1 gives the average range of the deviations of all possible cross-points for each of the major experimental conditions tested and shows that, in general, the average of the differences between the median of the crossing points (Figs. 1-5 in the text of Annex B) and crossing points for any curve drawn between any two data points is about 1 PNdB for any test condition or group of subjects. The total range of the differences among the crossing points for any test condition or group of subjects averages about 4 PNdB.



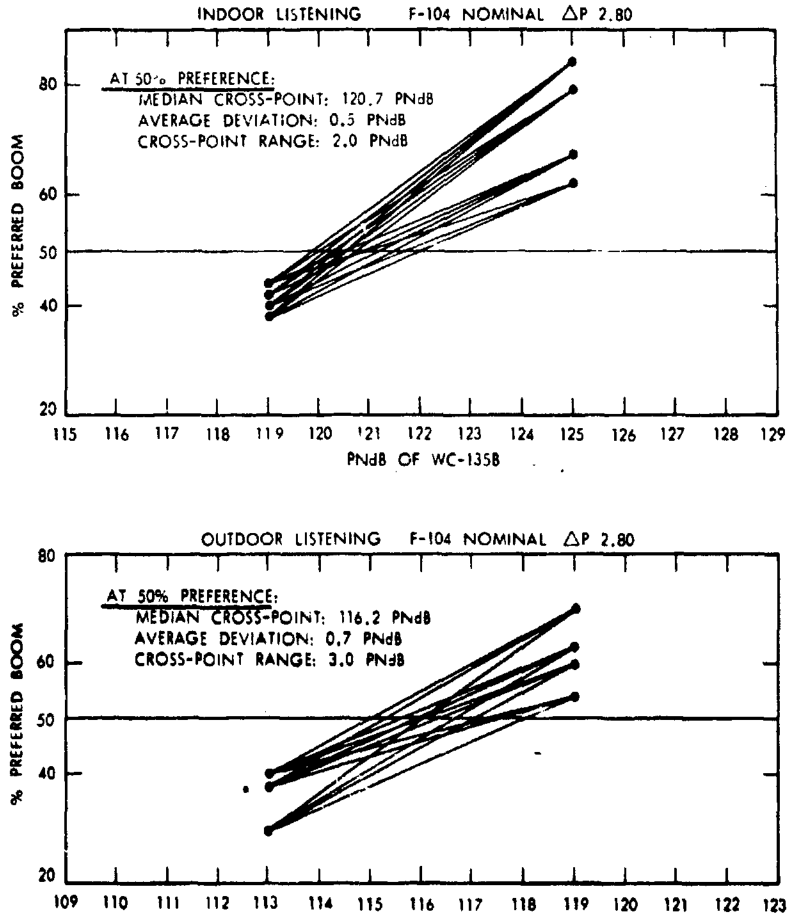
NOTES: Each data point is the average preference for two missions; one mission being a Boom-Noise mission and the other a Noise-Boom mission. From four [illegible] (Boom-Noise Test, Boom-Noise Retest, Noise-Boom Test and Noise-Boom Retest) four data points can be formed. With one set of four points above the 50% line and another set of four points below the 50% line, sixteen lines will intersect the 50% preference line. The average deviation is $1/N \sum_{i=1}^{N} \left| x_i - \text{median cross-point} \right|$ where N is the number of cross-points and x_i is the value of the i^{th} cross-point.

FIG. B-4-1 VARIATION OF PAIRED-COMPARISON JUDGMENTS (F-104 nominal ΔP 0.75 psf vs. WC-135B). Listeners from Edwards AF Base.



NOTES: See Fig. B-4-1 for general notes.
*Two Boom-Noise missions and three Noise-Boom missions were flown, consequently, six data points can be formed.

FIG. B-4-2 VARIATION OF PAIRED-COMPARISON JUDGMENTS (F-104 nominal ΔP 1.40 psf vs. WC-135B). Listeners from Edwards AF Base.



NOTES: See Fig. B-4-1 for general notes.
*Three Boom-Noise missions and one Noise-Boom mission were flown, consequently, only three data points can be formed.

FIG. B-4-3 VARIATION OF PAIRED-COMPARISON JUDGMENTS (F-104 nominal ΔP 2.80 psf vs. WC-135B). Listeners from Edwards AF Base.

Table B-4-1

VARIATION OF PAIRED-COMPARISON JUDGMENTS FOR SONIC BOOM VS SUBSONIC NOISE PAIRS

	Aircraft Identification				Indoor Listening		Outdoor Listening		
Listeners	Sonic Boom A/C	Nominal ΔP (psf)	Subsonic Noise A/C	Power	Average* Deviation (PNdB)	Range* (PndB)	Average* Deviation (PNdB)	Range* (PNdB)	Comment
Edwards AF Base	F-104	0.75	WC-135B	Takeoff	1.3	4.5	2.1	8.0	Fig. B-4-1
	F-104	1.10	"	Takeoff	1.3	5.0	2.0	7.0	Fig. B-4-2
	F-104	2.80	"	Takeoff	0.5	2.0	0.7	3.0	Fig. B-4-3
	B-58	1.69	KC-135	Landing	0.3	1.1	1.0	5.0	Missions where the B-58 exceeded deviation criteria (for altitude, mach or lateral distance) were excluded from the analysis.
	B-58	1.69	"	Takeoff	1.0	2.7	1.6	6.3	
	B-58	2.65	"	Landing	0.5	1.6	0.8	2.7	
	B-58	2.65	"	Takeoff	2.1	4.0	1.0	2.0	
				Av.	1.0	Av. 3.0	Av. 1.3	Av. 4.9	
Fontana	B-58	1.69	WC-135B	Takeoff	1.1	4.2	0.9	3.4	Average deviation value and range value for indoor listening were estimated at the 20% preference line instead of the 50% preference line. (See Fig. 3, Annex B).
Redlands	B-58	1.69	WC-135B	Takeoff	1.5	5.8	1.0	3.5	Average deviation value and range value for outdoor listening were estimated at the 70% preference line instead of the 50% preference line. (See Fig. 3, Annex B).

* See Figure B-4-1 for additional notes and illustration of crosspoints

The average deviation is $\frac{1}{N}\sum_{i=1}^{N} | X_i - \text{median crosspoint} |$ where [illegible], the number of crosspoints and X_i is the value of the i^{th} crosspoint.

Annex C

MEASUREMENTS OF SONIC BOOMS

Part I - SUMMARY OF VARIATIONS OF SONIC BOOM SIGNATURES RESULTING FROM ATMOSPHERIC EFFECTS

D. J. Maglieri, D. A. Hilton, and N. J. McLeod
National Aeronautics and Space Administration
Langley Research Center
Langley Field, Virginia
February 1967

Part II - PRELIMINARY RESULTS OF XB-70 SONIC BOOM FIELD TESTS DURING NATIONAL SONIC BOOM EVALUATION PROGRAM

D. J. Maglieri, V. Huckel, H. R. Henderson, and T. Putman
National Aeronautics and Space Administration
Langley Working Paper No. 382
Langley Research Center
Langley Field, Virginia
March 9, 1967

Part III - SUMMARY OF CRUCIFORM DATA

National Aeronautics and Space Administration
Langley Research Center
Langley Field, Virginia

Part IV - FULL-RANGE AND AUDIO PRESSURE MEASUREMENTS

D. R. Grine
Stanford Research Institute

Annex C

Part I - SUMMARY OF VARIATIONS OF SONIC BOOM SIGNATURES RESULTING FROM ATMOSPHERIC EFFECTS

D. J. Maglieri, D. A. Hilton, and N. J. McLeod
National Aeronautics and Space Administration
Langley Research Center
Langley Field, Virginia
February 1967

Annex C
Part I

SUMMARY OF VARIATIONS OF SONIC BOOM SIGNATURES RESULTING FROM ATMOSPHERIC EFFECTS

ABSTRACT

Data based on about 5000 overpressure measurements are presented to illustrate atmospheric induced sonic boom signature variations for supersonic aircraft varying in gross weight from about 20,000 to 450,000 pounds and from about 60 ft to 185 ft in length, respectively. Descriptions are included of several special flight test experiments performed to define quantitatively some of these atmospheric effects.

The experience derived from several flight test programs regarding sonic boom signature variations has been summarized. Variations were noted to occur in the peak overpressure, the impulse function, the time duration, and the bow wave rise time. Such variations are noted to be induced by the atmosphere. That portion of the atmosphere below about 2000 ft is shown to be most influential although in some cases the higher portions may also be important. Aircraft motions, in the form of perturbations about the normal flight track, are shown not to contribute significantly to observed sonic boom signature variations at the ground.

INTRODUCTION

It is a matter of record that substantial variations occur in sonic boom signature shapes (see refs. 1, 2, and 3). These variations involve such quantities as the peak overpressure, the time duration, impulse, etc. Such variations are thought to be largely due to atmospheric and weather effects although the exact cause and effect relationship has not been definitely established up to this time. The purpose of this paper is to present some recent sonic boom measurement results which illustrate the nature of the atmospheric effects problem and which define quantitatively some of these effects.

Figure 1 contains examples of wave shapes observed for three different types of aircraft. At the left of the figure are tracings of measured waves for the F-104 aircraft for which the time duration is about .10 of a second. It is seen that the waves vary from sharply peaked to gently rounded. Similar signature tracings are shown at the right side of the figure for the B-58 and the XB-70, respectively. The B-58 signatures are roughly .20 of a second in duration and those of the XB-70 are approximately .30 of a second in duration. The main differences between waves for a given aircraft are noted to occur at the times of the rapid compressions. The largest overpressure values are generally associated with the sharply peaked waves.

NATURE OF SIGNATURE SHAPE VARIATIONS

In the following discussions, reference will be made to variations in those quantities which are defined in Fig. 2. Shown in Fig. 2 is an example tracing of an N-wave signature. The quantities peak positive overpressure ΔP, the positive impulse I, the total time duration of the wave Δt, and the rise time τ, are illustrated. Rise time always refers to the bow wave and is usually defined as the elapsed time between the onset of pressure and the occurrence of its maximum value (see ref. 4).

There has been considerable discussion about the frequency response requirements of measuring equipment and whether differences in frequency response would markedly change the observed patterns of signature variation. In order to provide some information in this regard, FM magnetic tape records were processed by playback through a series of low pass filters. Figure 3 contains examples of traced wave forms resulting from playback of one particular record through various filters varying in band width from about 5000 Hz down to about 200 Hz. For the case illustrated, it is seen that the narrower band width systems noticeably affect the wave shape particularly with regard to the peak overpressure and rise time. About 200 data records were processed as indicated in Fig. 3 to provide data for the histograms of Fig. 4.

The data of Fig. 4 relate to B-58 flights at an altitude of about 31,000 ft and a Mach number of 1.5. In the figure the number of events

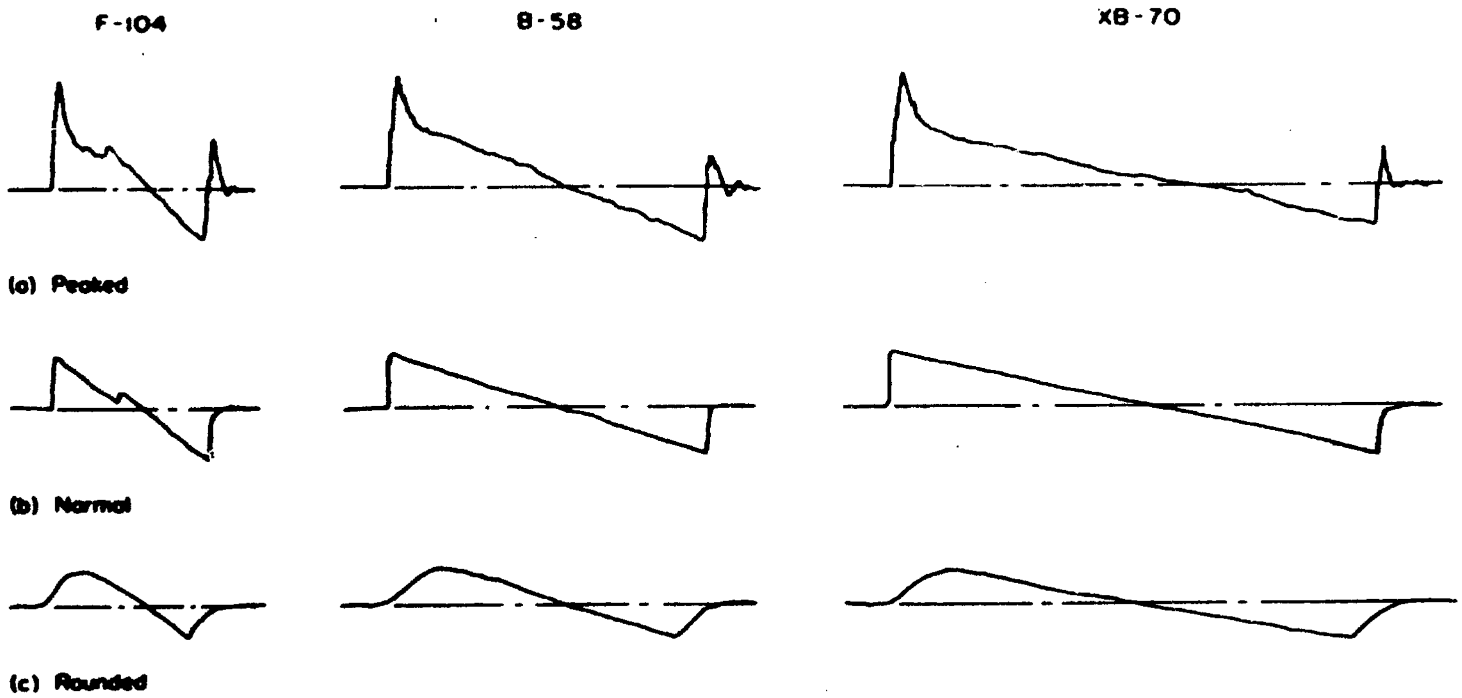


FIG. 1 VARIATION OF MEASURED SONIC BOOM PRESSURE SIGNATURES AT GROUND LEVEL FOR SMALL, MEDIUM, AND LARGE AIRCRAFT IN STEADY LEVEL FLIGHT

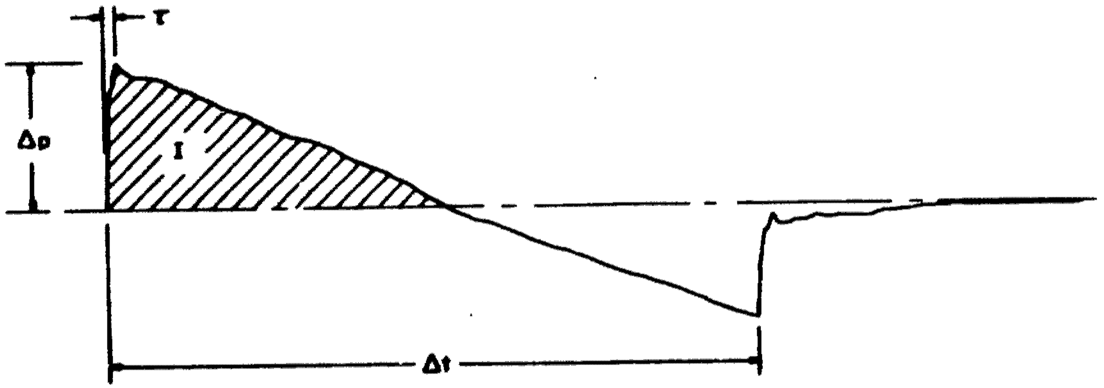
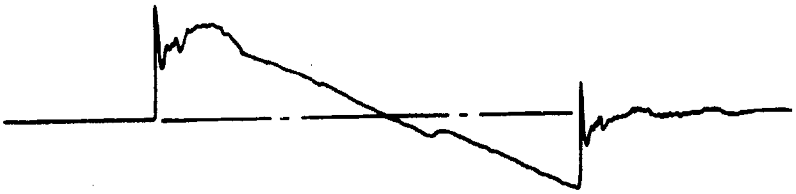
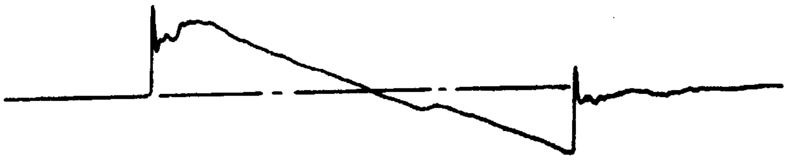


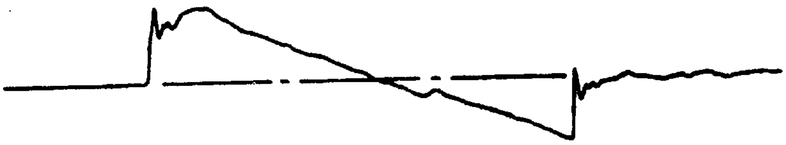
FIG. 2 DEFINITIONS OF QUANTITIES



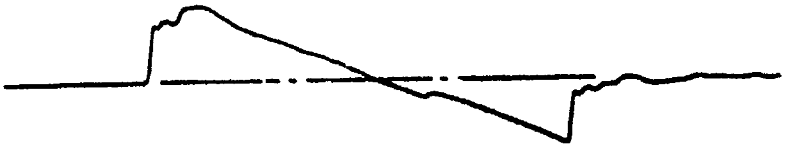
(a) 0.02-5,000 Hz



(b) 0.02-2,000 Hz



(c) 0.02-500 Hz



(d) 0.02-200 Hz

FIG. 3 EFFECTS OF INSTRUMENT FREQUENCY RESPONSE ON SONIC BOOM SIGNATURE SHAPES. Data are for B-58 aircraft at an altitude of 31,000 ft. and a Mach number of 1.5

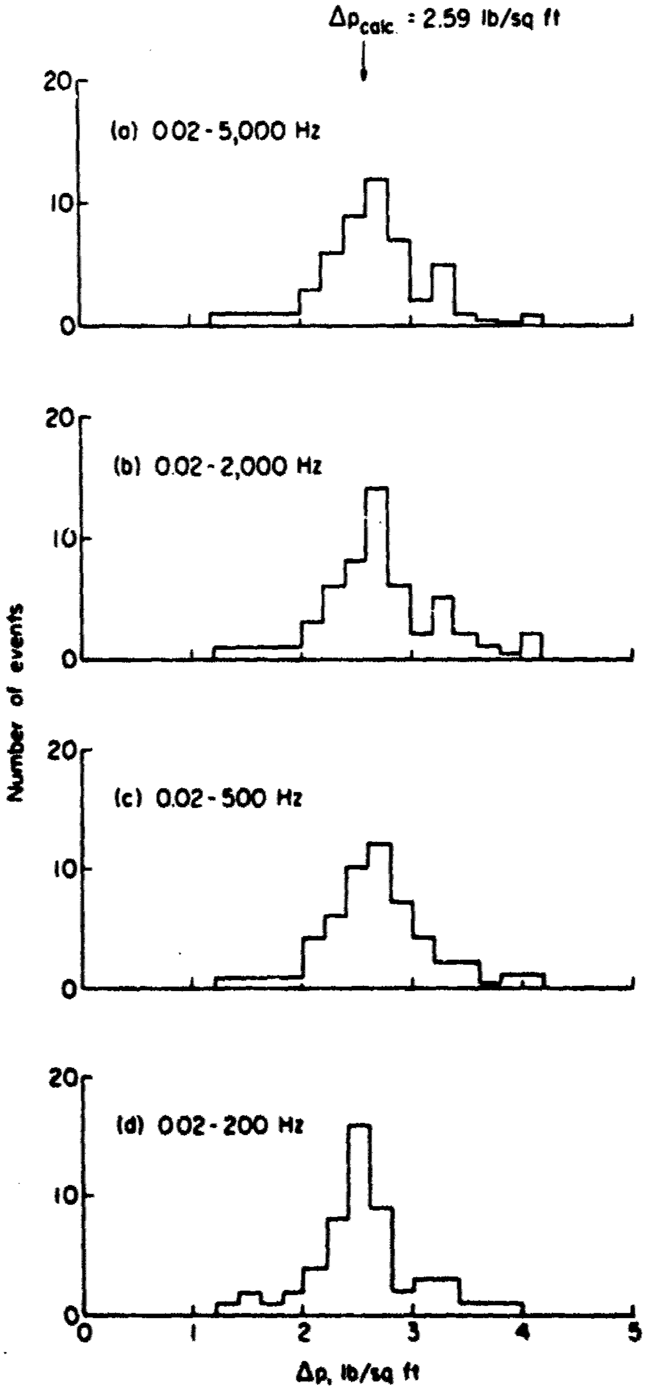


FIG. 4 VARIATION OF PEAK POSITIVE OVERPRESSURE FROM SONIC BOOM SIGNATURES ANALYZED AT VARIOUS FREQUENCY RESPONSE RANGES. Data are for B-58 aircraft at an altitude of 31,000 ft. and a Mach number of 1.5

is plotted as a function of the overpressure values in histogram form for the four different filter band widths of Fig. 3. The data of Fig. 4 relate to a variety of wave form shapes on the original records such as those illustrated in Fig. 1. It can be seen from the inspection of Fig. 4 that the histograms do not vary markedly as a function of filter band width. There is, however, a general shift to lower peak overpressure values as filter band width is reduced. The point can be made that the average peak overpressure values obtained for the smaller filter band width are more nearly in agreement with the calculated values than are those obtained with the larger filter band widths. For all the data subsequently presented in this paper, the instrument frequency responses are essentially .02-5,000 Hz and thus the effects noted in Figs. 3 and 4 will not apply.

Shown in Fig. 5 are probability plots of the ratios of measured to calculated overpressure for the B-58 and XB-70 aircraft. The ordinate is the probability of equalling or exceeding a given abscissa value. Three sets of data are included. The square data points for the XB-70 and the triangle data points for the B-58 were obtained from measurements of a 7000 ft linear microphone array, whereas the circle B-58 data points were obtained for a small cruciform microphone array having dimensions of 200 ft. It should be noted that the data would fit on a straight line if the variation corresponded to a normal distribution. The slope of this line would indicate the amount of variability of the data, a vertical line indicating no variability. With the exception of the highest and lowest valued points, all three sets of data generally follow a normal distribution line and the variability is about the same in each case. These results are similar to those obtained in other programs as, for instance, in references 1 and 2, and the implication is that the type and size of the airplane are not significant factors regarding variability.

Although no data on the positive impulse function of the waves are included in this paper, the point can be made that the same general trends exist as for the overpressure data of Fig. 5. The only exception is that the variability is generally less for the impulse function for

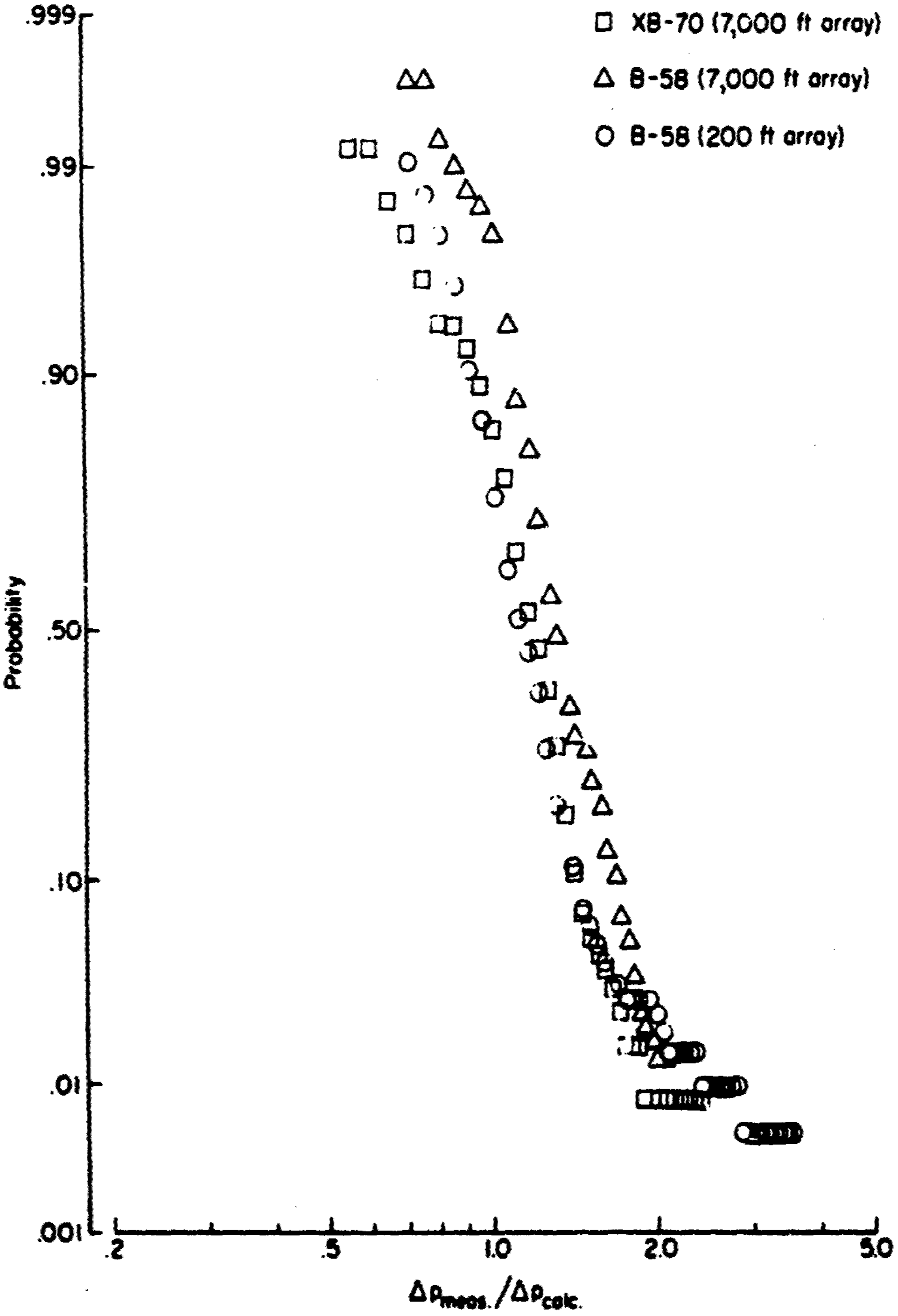


FIG. 5 PROBABILITY OF EQUALING OR EXCEEDING A GIVEN VALUE OF THE RATIO OF MEASURED TO CALCULATED OVERPRESSURES FOR TWO DIFFERENT AIRCRAFT. (Data are plotted on log normal probability paper)

a given set of flight and atmospheric conditions than for the overpressure function.

Some variations in the sonic boom signature time durations which are important for structural responses have been observed. The data of Fig. 6 illustrate these latter variations for the B-58 aircraft for two different flight conditions. Results are based on about 200 data points measured at a fixed location for approximately 50 flights over a period of about three weeks. The histograms at the top of the figure are for an overhead flight track for an airplane altitude of 31,000 ft and for a Mach number of 1.5. The histogram at the bottom of the figure relates to a flight track five miles distant from the measuring station and for an airplane altitude of 43,000 ft and a Mach number of 1.65. It can be seen that the time periods are longer for the off-the-track condition, but that variability does exist in the durations of the waves at both locations. This variability is probably due to differences in the propagation rates of the bow and tail waves which travel along somewhat different ray paths from the aircraft to the ground.

Also of interest is the variation in bow wave rise time as defined in Fig. 2, since it is believed that this quantity is important from a subjective reaction standpoint. The data of the histograms of Fig. 7 have been normalized on the horizontal scale to indicate the rise time per unit overpressure. These data are for a B-58 aircraft for an altitude of approximately 31,000 ft and a Mach number of 1.5 for an overhead flight condition. The two histograms of the figure relate to the same measured data but result from different interpretations of that data. For instance, the histogram of solid lines is based on the rise time definition of Fig. 2. The dashed line histogram, on the other hand, is based on the determination of the ΔP values associated with the first peak in the wave even though that may not be the highest peak. This latter definition may be the more appropriate one for subjective evaluation whereas the definition of Fig. 2 is a commonly accepted one. In either case, it can be seen that considerable variations in rise times are encountered regardless of the manner in which rise time is defined. It is significant to note that rise times of less than a

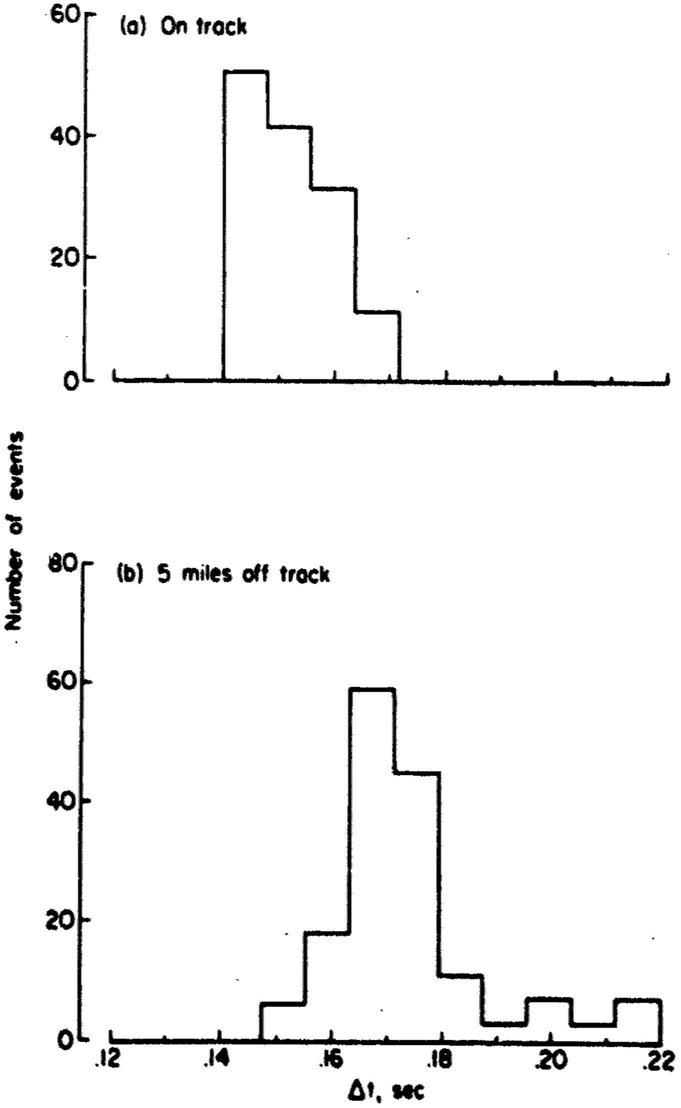


FIG. 6 VARIATIONS OF SONIC BOOM SIGNATURE TIME DURATIONS FOR TWO DIFFERENT FLIGHT CONDITIONS OF THE B-58 AIRCRAFT

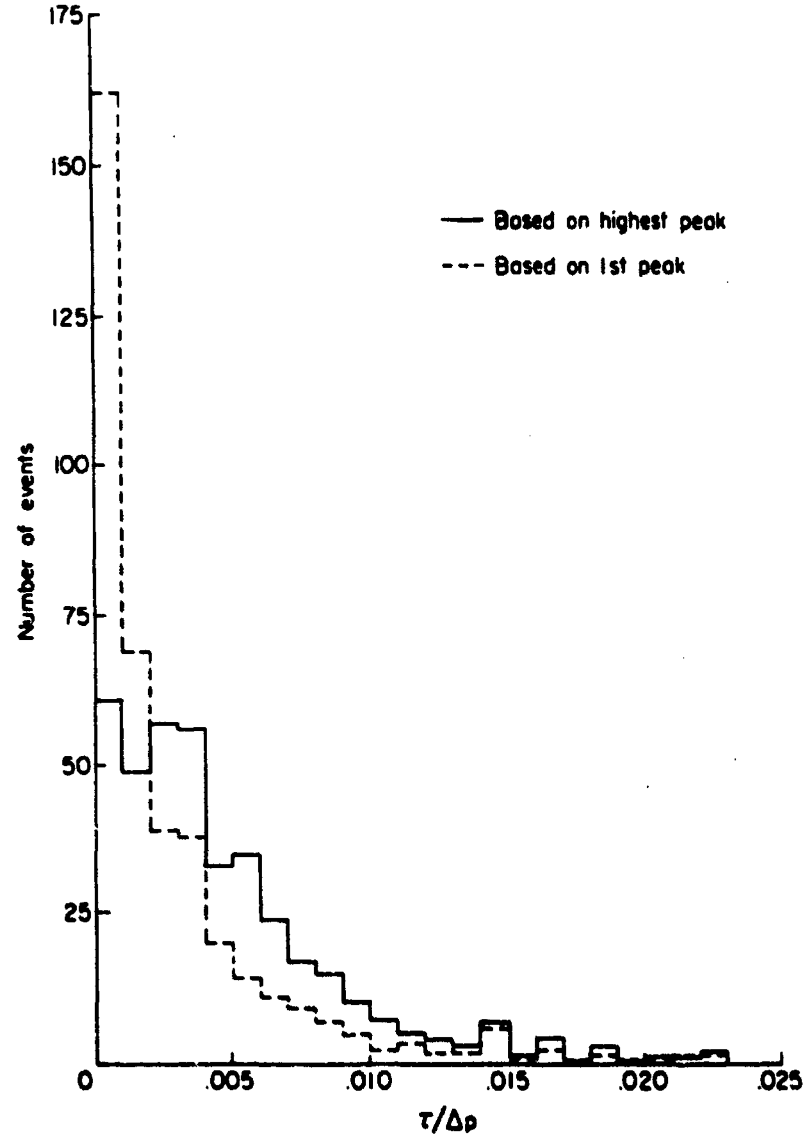


FIG. 7 VARIATIONS OF BOW WAVE RISE TIME FOR THE B-58 AIRCRAFT AT A MACH NUMBER OF 1.5 AND AN ALTITUDE OF 31,000 FT

millisecond are commonly encountered for the initial peak of the wave.

PROPAGATION STUDIES IN THE LOWER ATMOSPHERE

Previous studies of atmospheric effects on sonic boom signatures have suggested that the lower layers of the atmosphere exert the greatest influence (see ref. 3.). In order to better define the region of the atmosphere most effective in distorting the sonic boom signatures, several special experiments have been performed by NASA and USAF personnel. The first two of these were conducted at the NASA Wallops Station and are illustrated schematically in Figs. 8 and 9. Flights were made over an instrumented range consisting of a linear microphone array on the ground and extending about 1500 ft in combination with a vertical array on an instrumented tower extending to about 250 ft above the ground surface. The generating aircraft was flown at an altitude of 40,000 ft and at a Mach number of 1.5 for a variety of weather conditions. The objective of the studies was to correlate the sonic boom measurements with the extensive meteorological data obtained on the instrumented tower.

In situations where wave form distortion was noted to exist, it was found that similar wave shapes were measured both at the ground surface and on the instrumented tower. A particularly interesting and significant result of these studies is illustrated by the wave form tracings of Fig. 8 which suggest that similar types of distortions exist at points along given ray paths. Such a result was obtained along a ray path extending from a measuring station on the tower to the ground and also on a reflected path from the ground back up to a station on the tower.

This leads to the conclusion that for these particular tests the 250 ft layer of the atmosphere near the surface of the ground did not appreciably affect the signature shapes. Thus, correlation studies involving only the lower surface layers would probably not produce conclusive results. It follows then that the portion of the atmosphere above 250 ft was important for the conditions of this experiment regarding wave shape distortions.

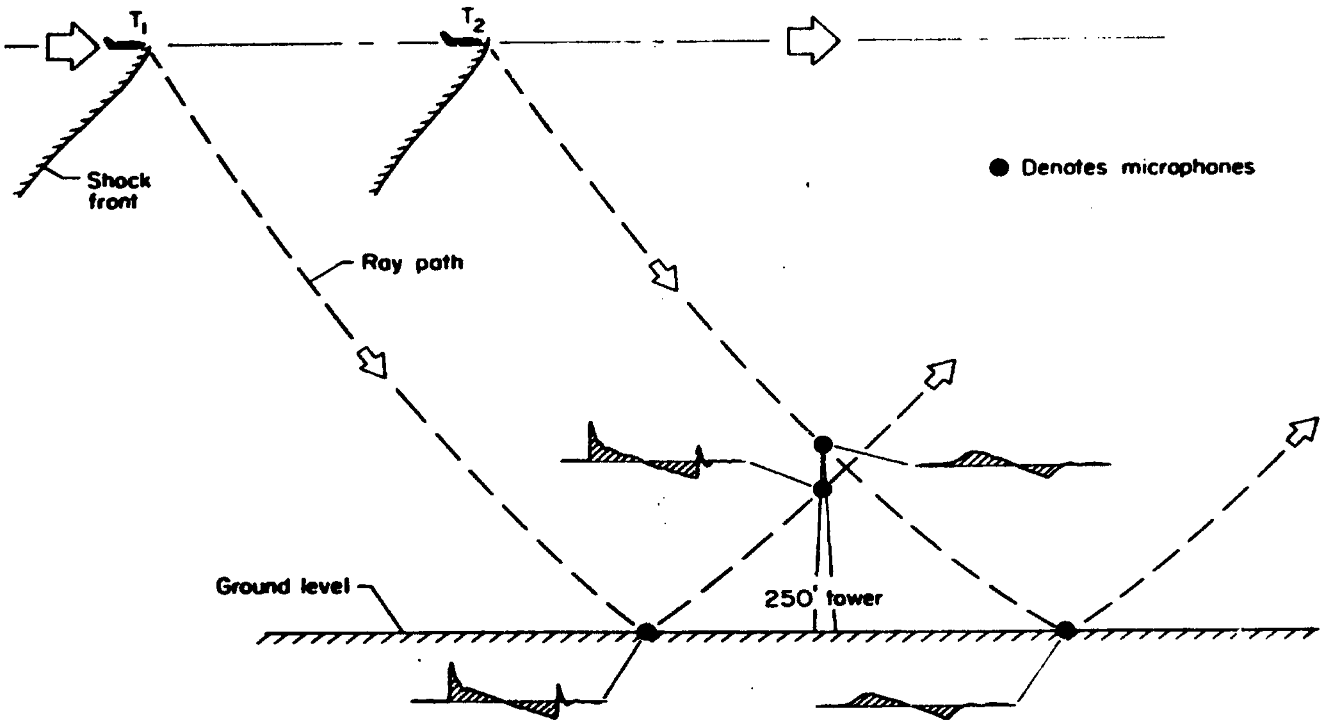
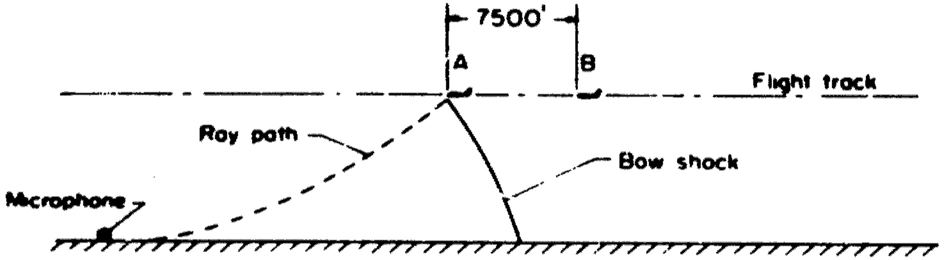
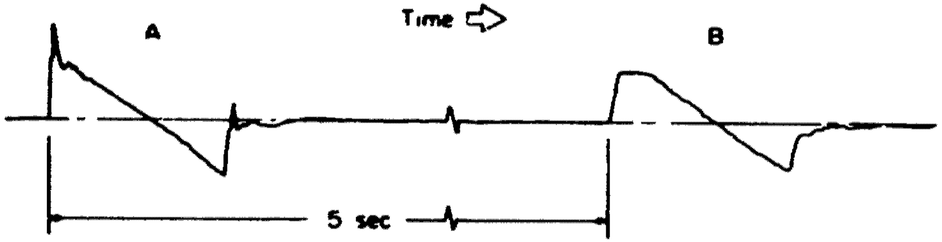


FIG. 8 SCHEMATIC DIAGRAM OF TEST SETUP AT THE NASA WALLOPS STATION, VIRGINIA, FOR EVALUATING ATMOSPHERIC EFFECTS ON SONIC BOOM WAVE PROPAGATION IN THE SURFACE LAYER (250 ft. depth) OF THE ATMOSPHERE. Generating aircraft was an F-106 at 40,000 ft. altitude and a mach number of 1.5



(a) Schematic of shock front and ray path



(b) Sonic boom ground pressure signatures

FIG. 9 SCHEMATIC DIAGRAM OF TEST ARRANGEMENTS AT NASA WALLOPS STATION, VIRGINIA, FOR MEASURING SONIC BOOM SIGNATURES FROM TWO AIRCRAFT AT THE SAME FLIGHT CONDITIONS AND FOR A VERY SHORT TIME INTERVAL

As a follow-up to the ray path experiments of Fig. 8, another experiment was performed to investigate the effects of time with regard to atmospheric distortion effects. This experiment was performed with the aid of two airplanes of the same type which were flown at the same altitude and Mach number and on the same nominal flight track and about 5 seconds apart. By means of a ground microphone array, it was possible to measure sonic boom signatures which travelled along essentially the same ray path from high altitude to the ground for a distance of approximately 15 miles but at slightly different times. One of the results of the experiment is illustrated by the signature tracings at the bottom of Fig. 9. It can be seen that quite different wave shapes are associated with measurements at times a few seconds apart. Such a result suggests that the integrated effects of changes in the atmospheric conditions along a given ray path may be significant even for such a small difference in time.

Further experiments relating to atmospheric effects on sonic boom propagation were performed recently by NASA and USAF personnel in the Edwards, California, area. One of these experiments was performed with the aid of the Goodyear airship, Mayflower, as illustrated schematically in Fig. 10. For some cases, as illustrated in the figure, the incident signature was essentially undistorted, whereas the ground measurements and the reflected signature measurements at the airship showed evidence of distortion. This would suggest that the 2000 ft surface layer of the atmosphere was responsible for all such distortion. On the other hand, some other measurements indicate distortion of the incident wave, thus indicating the portion of the atmosphere above 2000 ft may for some cases be important.

None of the above experiments produced evidence of direct correlation between signature distortion and identifiable local disturbances in the atmosphere. The last special experiment to be described was performed particularly to achieve such a correlation. Use was made of a large subsonic aircraft to generate wing tip vortices in the test area in such a manner that the shock wave to be measured would pass through these vortex disturbances (see ref. 5). The resulting measurements of

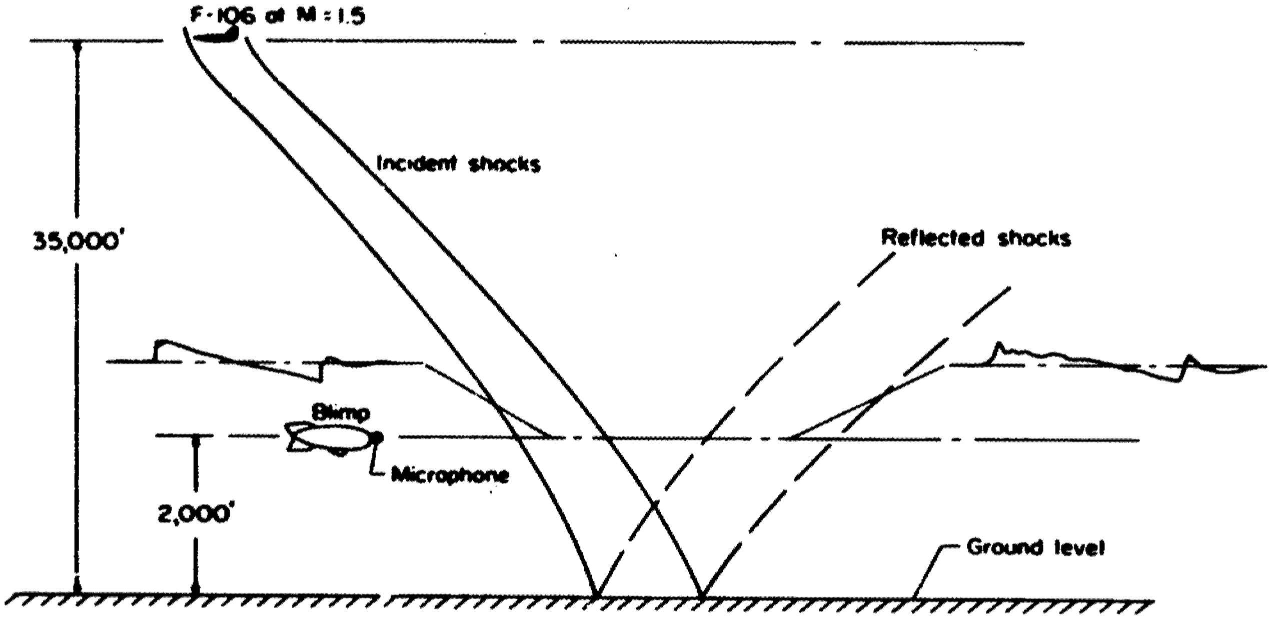


FIG. 10 SCHEMATIC DIAGRAM OF TEST ARRANGEMENTS AT EDWARDS, CALIFORNIA, FOR EVALUATING ATMOSPHERIC EFFECTS ON SONIC BOOM WAVE PROPAGATION IN THE LOWER LAYER (2,000 ft. depth) OF THE ATMOSPHERE. Generating aircraft was an F-106 at 33,000 ft. altitude and a Mach number of 1.5

peak overpressure values from the microphones in the ground array are shown at the bottom of Fig. 11. Of particular interest are the data points at distances from 5200 to 5600 ft along the ground track where markedly larger overpressure values were recorded. These latter measurements were believed to have been affected by the presence of the wing tip vortices, but no significant changes were noted in the signature shapes. Some further analyses and more definitive experimental studies are planned to improve the understanding of these latter interaction phenomena.

EVALUATION OF AIRCRAFT MOTION EFFECTS

It is recognized that measurements of sonic boom signatures on the ground may be affected by variations in the aircraft operating conditions as well as by the atmosphere. An experiment has thus been performed in an attempt to evaluate the effects on measured signatures of perturbations of the aircraft about its normal flight path. In order to accomplish this study use was made of the test setup in Fig. 12. The aircraft was flown at a given altitude and Mach number and on a given heading directly over and along a 7000 ft long array of 40 microphones. The aircraft, which was specially instrumented to record its motions, was flown both in steady level flight and in "porpoising" flight. All flights were accomplished at an altitude of 35,000 ft and a Mach number of 1.5 with an F-106 aircraft. For the porpoising flight, the pilot caused the airplane to deviate from the nominal flight track by cycling the controls to produce a ±0.5 g normal acceleration at the center of gravity of the aircraft. These induced motions have a period of about one second and thus the wave lengths of the motion were about 1600 ft for these particular flight conditions.

Ground overpressure measurements for the two types of flights are shown in Fig. 13. The data points for three steady flights and for four porpoising flights were obtained from individual microphones located at various stations along the ground track as indicated schematically in Fig. 12. It can be seen from Fig. 13 that approximately the same ranges of overpressure were measured for each of the flight conditions.

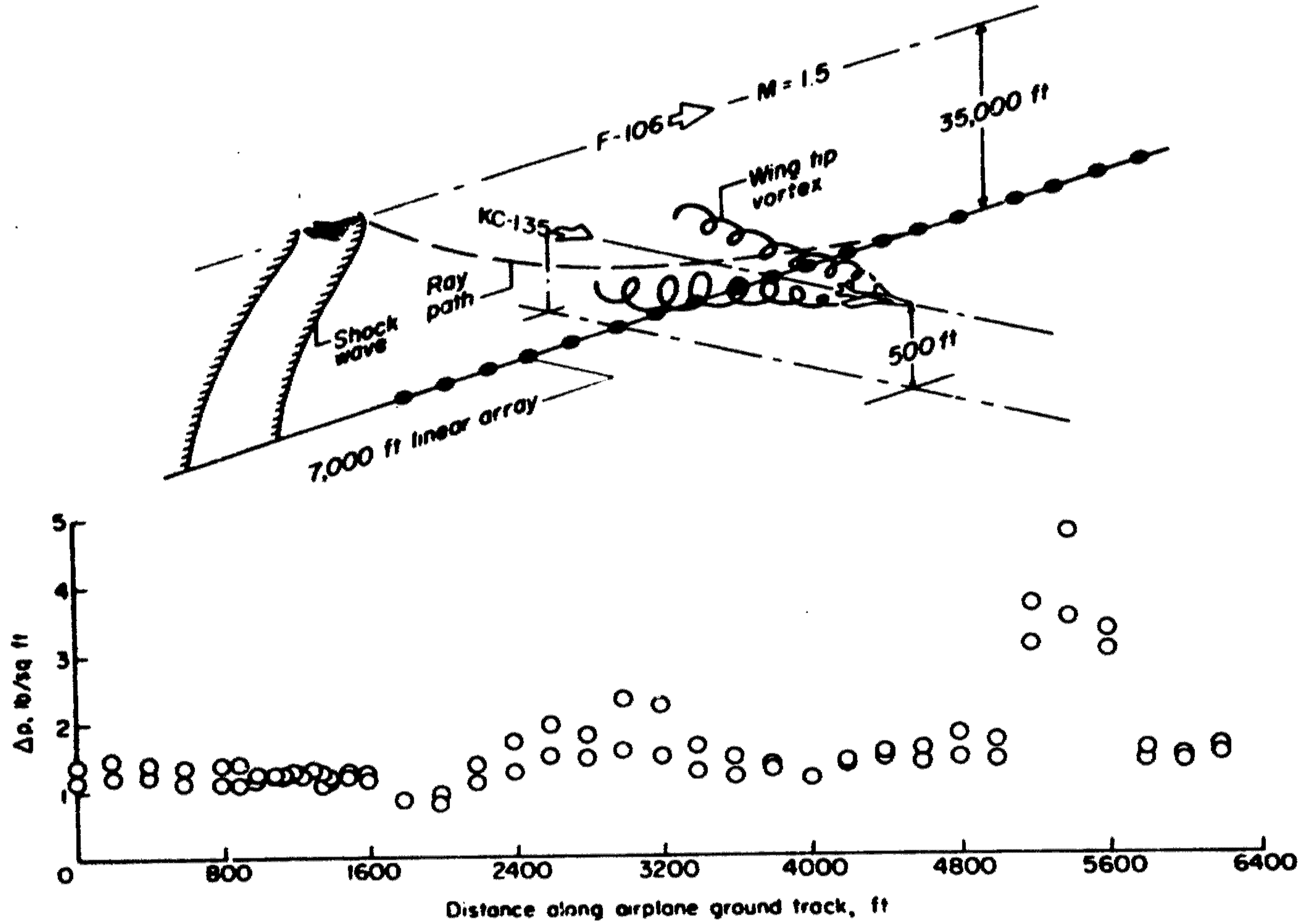


FIG. 11 SCHEMATIC DIAGRAM OF TEST ARRANGEMENTS IN THE EDWARDS, CALIFORNIA, AREA FOR STUDYING THE PHENOMENON OF SHOCK WAVE-VORTEX INTERACTIONS

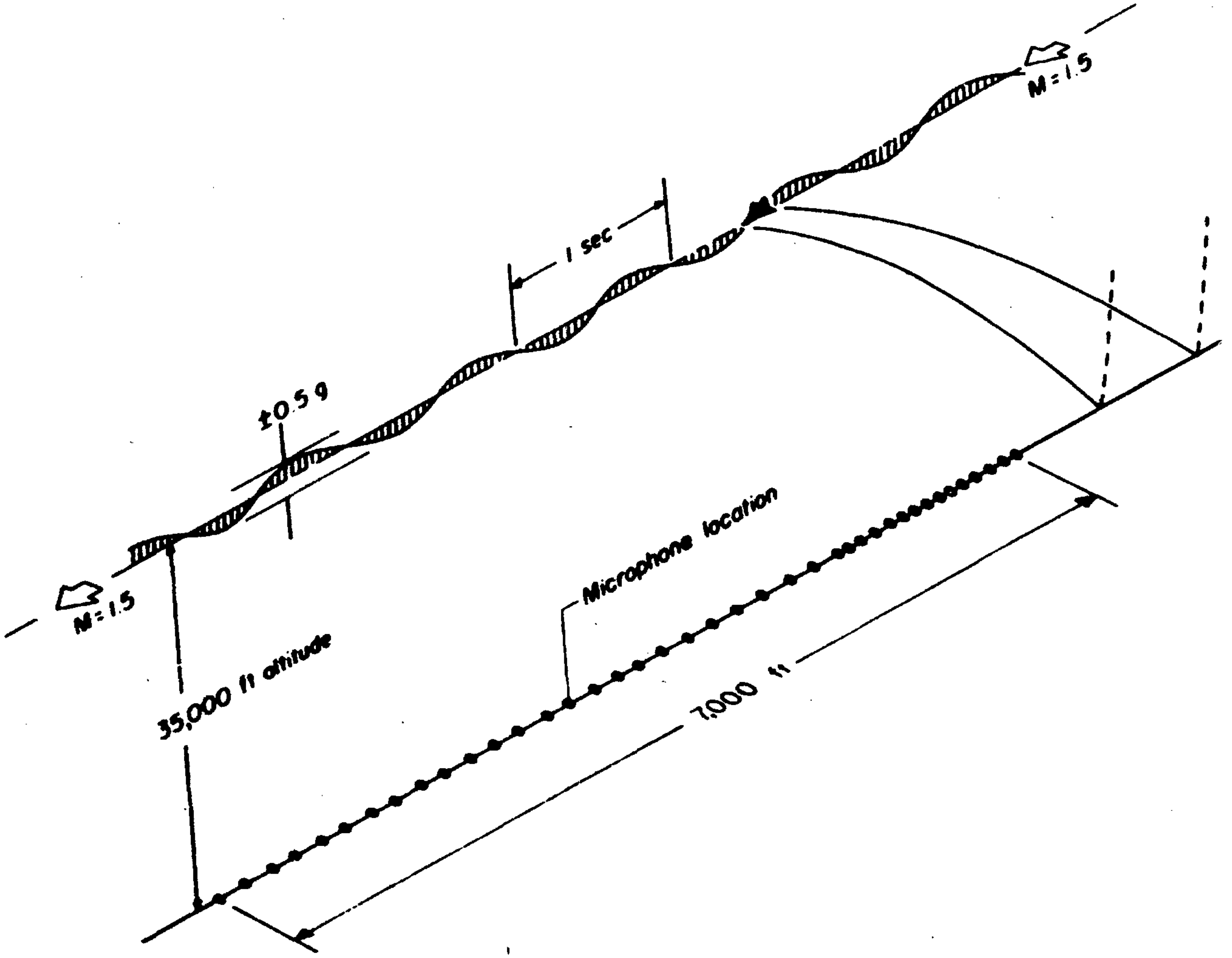


FIG. 12 SCHEMATIC DIAGRAM OF TEST ARRANGEMENTS IN THE EDWARDS, CALIFORNIA, AREA FOR EVALUATING THE EFFECTS OF AIRPLANE MOTIONS ON SONIC BOOM SIGNATURES AT THE GROUND

Furthermore, an inspection of the data of Fig. 13 suggests the occurrence of cyclic variations of the overpressures for both flight conditions. Such cyclic variations have been documented during this and other flight research programs (see ref. 1). It is significant to note, however, that cyclic variations that occur during the steady flights seem to have wave lengths that vary considerably. Since it is believed that the porpoising flight condition might produce a cyclic variation of overpressure at a preferred wave length on the ground, the data of several such flights were analyzed in such a manner as to accentuate this effect if it existed. These results are shown in Fig. 14.

The individual histograms of Fig. 14 represent variations in the absolute values of the differences in the overpressures measured at pairs of points which are separated by the distances indicated. If the effects of the airplane motion were faithfully transmitted to the ground, it is reasonable to expect that smaller differences in overpressure values would be obtained at some separation distances than at others. The sample data of Fig. 14 represent separation distances varying from 100 ft to 1600 ft for comparison. In order to better define the trend of the variations of Fig. 14 the data are presented in a more convenient form in Fig. 15.

In Fig. 15 the quantity $\sigma_{\Delta\tau}$, which is the root mean square overpressure difference, is plotted as a function of separation distance for the distances for which data are available. The curve of Fig. 15 seems to represent generally the variation of $\sigma_{\Delta\tau}$ as a function of distance for both the steady and porpoising flight cases. Both sets of data are seen to increase monotonically as a function of separation distance. Such a result strongly suggests that perturbations about the flight track of the order of those illustrated in Fig. 12 do not propagate faithfully to the ground from high altitude. It is thus believed that the variations discussed previously in this paper are due mainly to atmospheric effects rather than to effects of aircraft motion.

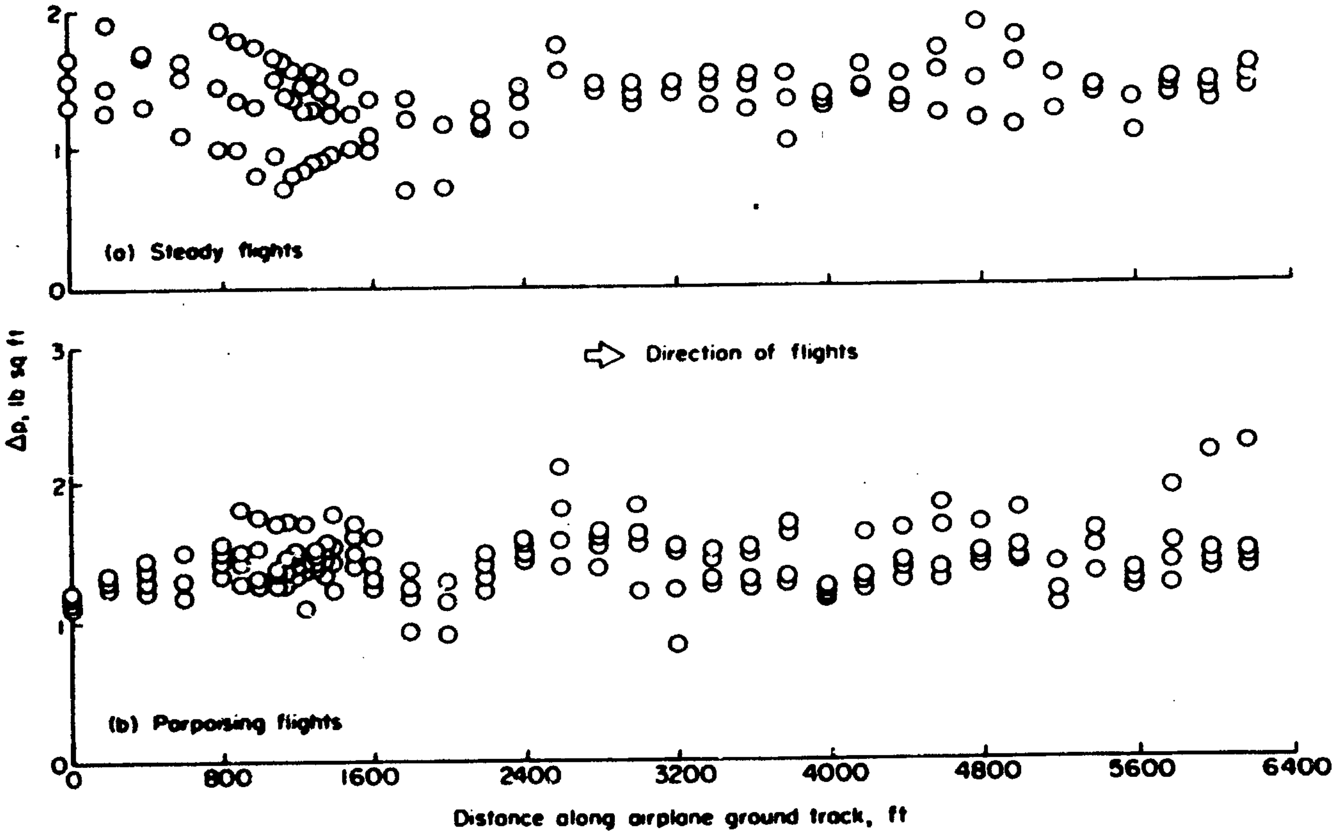


FIG. 13 MEASURED PEAK OVERPRESSURES AT SEVERAL STATIONS ALONG THE GROUND FOR BOTH STEADY AND PORPOISING FLIGHTS OF AN F-106 AIRCRAFT AT 35,000 FT. ALTITUDE AND A MACH NUMBER OF 1.5

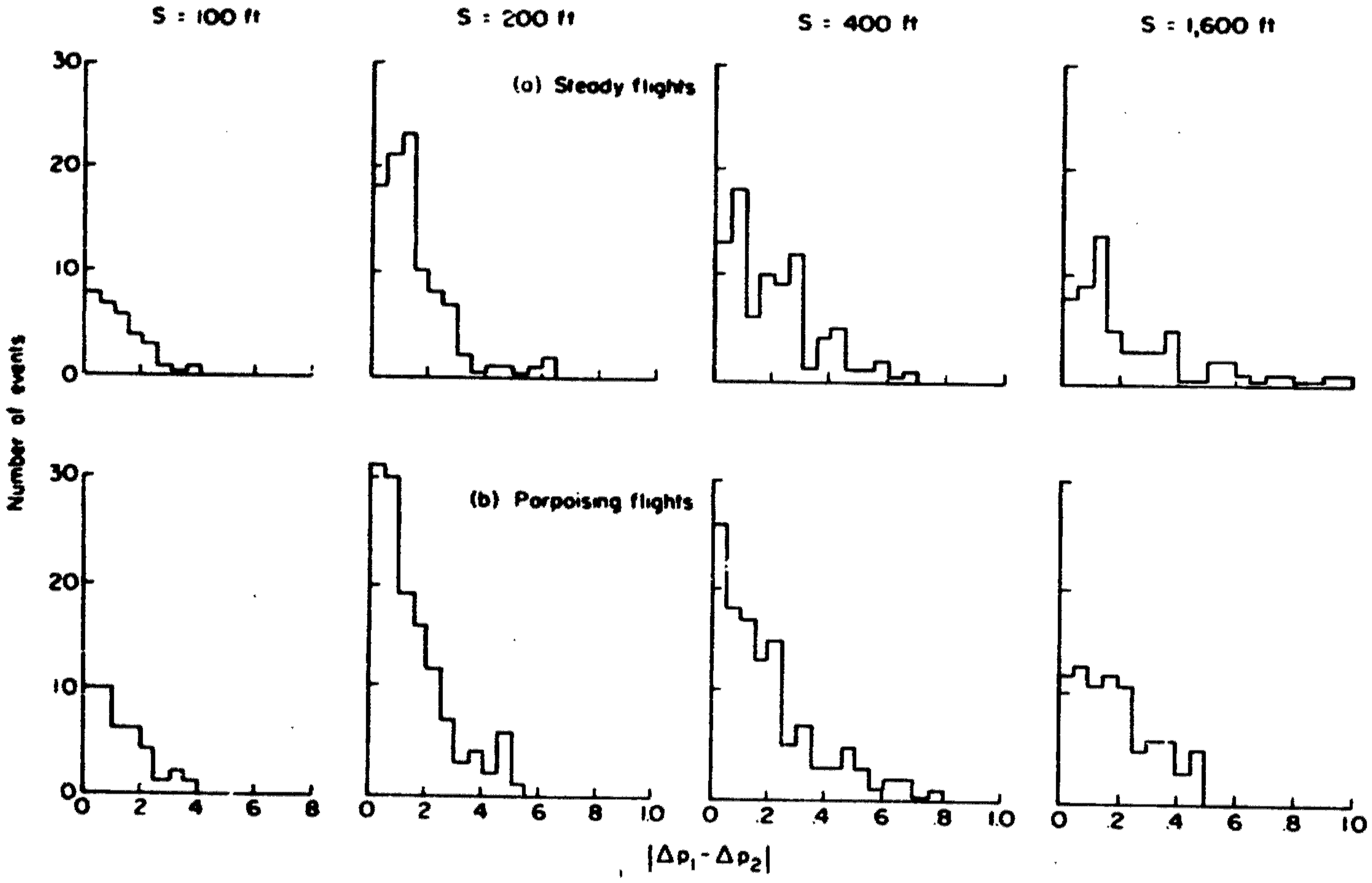


FIG. 14 HISTOGRAMS OF THE ABSOLUTE VALUES OF THE DIFFERENCES BETWEEN PEAK OVERPRESSURES AT POINTS SEPARATED IN DISTANCE FROM 100 TO 1,600 FT., FOR BOTH STEADY AND PORPOISING FLIGHTS

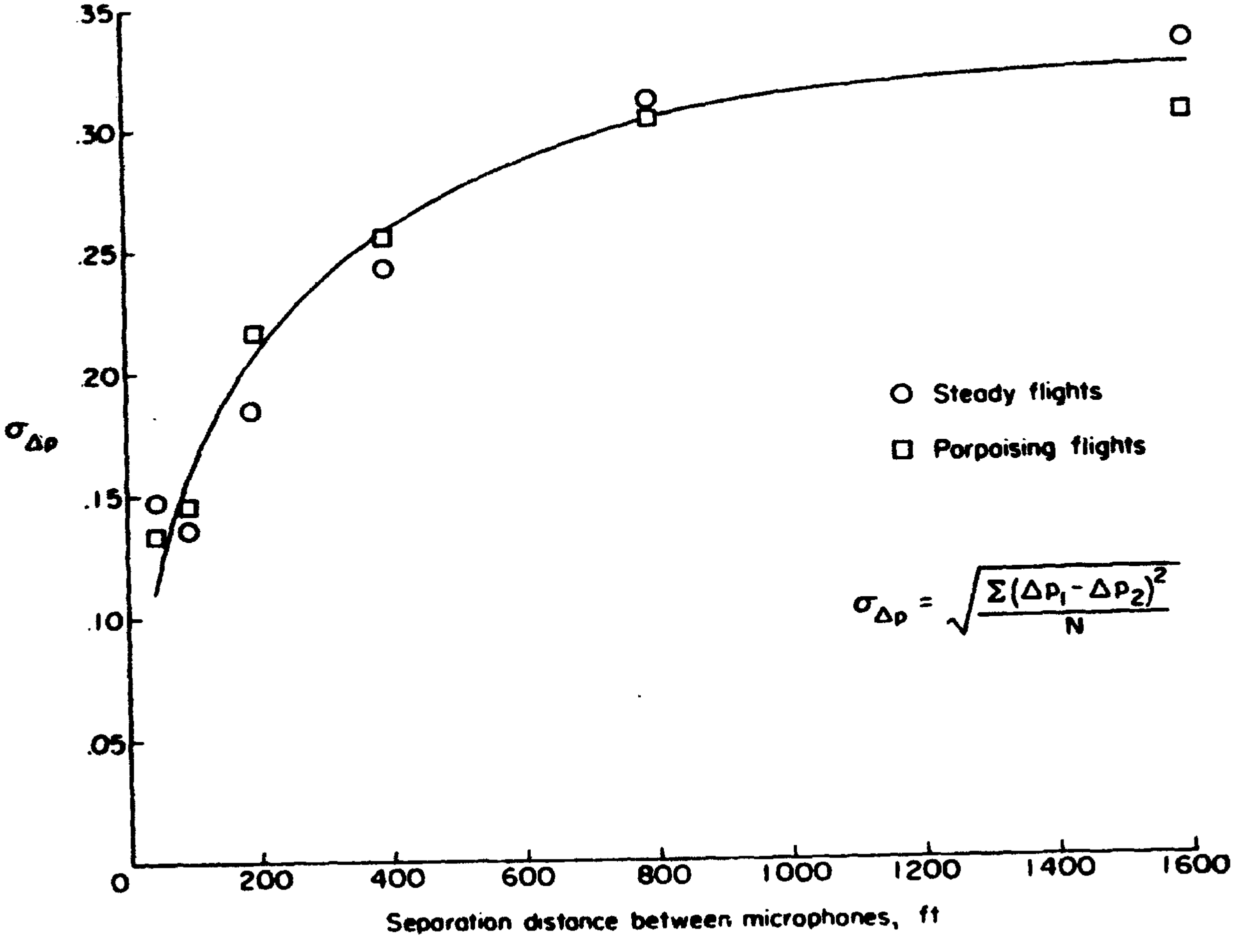


FIG. 15 ROOT MEAN SQUARE DIFFERENCES IN OVERPRESSURES AS A FUNCTION OF SEPARATION DISTANCE FOR BOTH STEADY AND PORPOISING FLIGHT

CONCLUDING REMARKS

The experience derived from several flight test programs regarding sonic boom signature variations has been summarized. Variations were noted to occur in the peak overpressure, the impulse function, the time duration, and the bow rise time. Such variations are noted to be induced by the atmosphere. That portion of the atmosphere below about 2000 ft is shown to be most influential although in some cases the higher portions may also be important. Aircraft motions, in the form of perturbations about the normal flight track, are shown not to contribute significantly to observed sonic boom signature variations.

REFERENCES

1. Hilton, David A.; Huckel, Vera; Steiner, Roy; and Maglieri, Domenic J.: Sonic-Boom Exposures During FAA Community-Response Studies Over a 6-Month Period in the Oklahoma City Area. NASA TN D-2539, 1964.

2. Hilton, David A.; Huckel, Vera; and Maglieri, Domenic J.: Sonic-Boom Measurements During Bomber Training Operations in the Chicago Area. NASA TN D-3655, 1966.

3. Hubbard, Harvey H.; Maglieri, Domenic J.; Huckel, Vera; and Hilton, David: Ground Measurements of Sonic-Boom Pressures for the Altitude Range of 10,000 to 75,000 Feet. NASA TR R-198, 1964.

4. Maglieri, Domenic J.; Parrott, Tony L.; Hilton, David A.; and Copeland, William L.: Lateral-Spread Sonic-Boom Ground-Pressure Measurements from Airplanes at Altitudes to 75,000 Feet and at Mach Numbers to 2.0. NASA TN D-2021, 1963.

5. Wetmore, Joseph W.; and Reeder, John P.: Aircraft Vortex Wakes in Relation to Terminal Operations. NASA TN D-1777, 1963.

Annex C

Part II - PRELIMINARY RESULTS OF XB-70 SONIC BOOM FIELD TESTS DURING NATIONAL SONIC BOOM EVALUATION PROGRAM

D. J. Maglieri, V. Huckel, H. R. Henderson, and T. Putman
National Aeronautics and Space Administration
Langley Working Paper No. 382
Langley Research Center
Langley Field, Virginia
March 9, 1967

Annex C
Part II

PRELIMINARY RESULTS OF XB-70 SONIC BOOM FIELD TESTS DURING NATIONAL SONIC BOOM EVALUATION PROGRAM

INTRODUCTION

This write-up has been prepared for the purpose of documenting some of the physical measurement results to date from XB-70 sonic boom flight tests of Phase I and Phase II of the Edwards, California, Sonic Boom Program conducted in June, November, and December 1966, and January 1967. Included are brief descriptions of the test area, the instrumentation deployment plan, the flight track, and aircraft operating conditions, as well as presentations of sample data and preliminary conclusions from the data analyses to date.

The objectives of the above flight tests involving the XB-70 airplane were to verify the available sonic boom overpressure and signature shape prediction methods for large aircraft of the supersonic transport class and to evaluate the effects of the atmosphere on the sonic boom signatures for such a large airplane.

TEST CONDITIONS

Data were obtained for a series of 20 flights of the XB-70 airplane for the Mach number range 1.38 to 2.94, for the altitude range from 31,000 to 72,000 ft, and for a gross weight range of about 300,000 to 420,000 lbs. Measurements were made of the sonic boom signatures at the ground level (EAFB elevation is approximately 2300 ft above sea level) over an extended area using about 65 ground microphones and of the flow field near the airplane with the aid of an instrumented probe aircraft. The nine ground measuring stations were positioned as shown in Fig. 1 in order to obtain a large number of measurements on or near the ground track of the airplane and also to define the lateral exposure patterns to distances of about 25 miles to each side of the flight track.

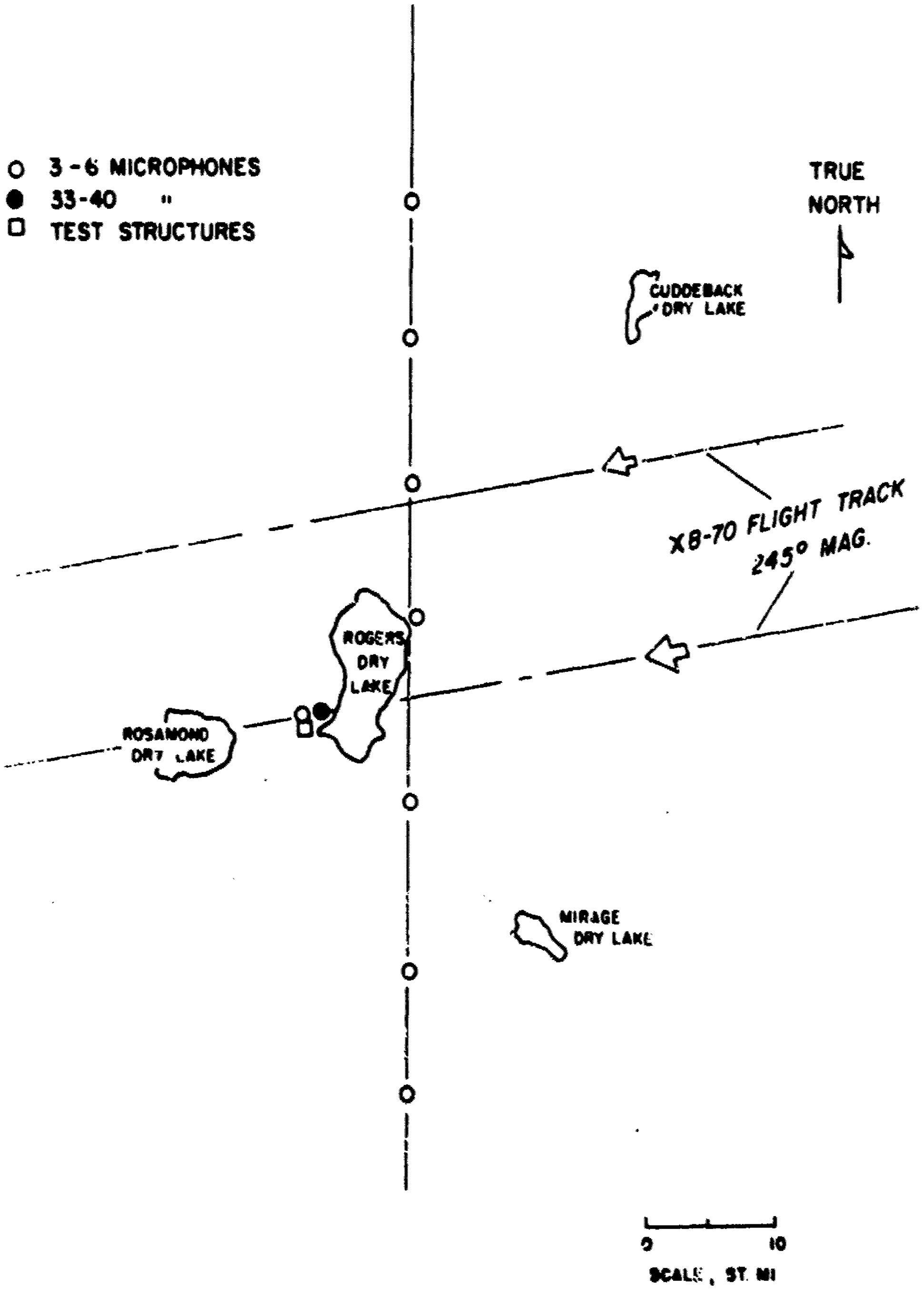


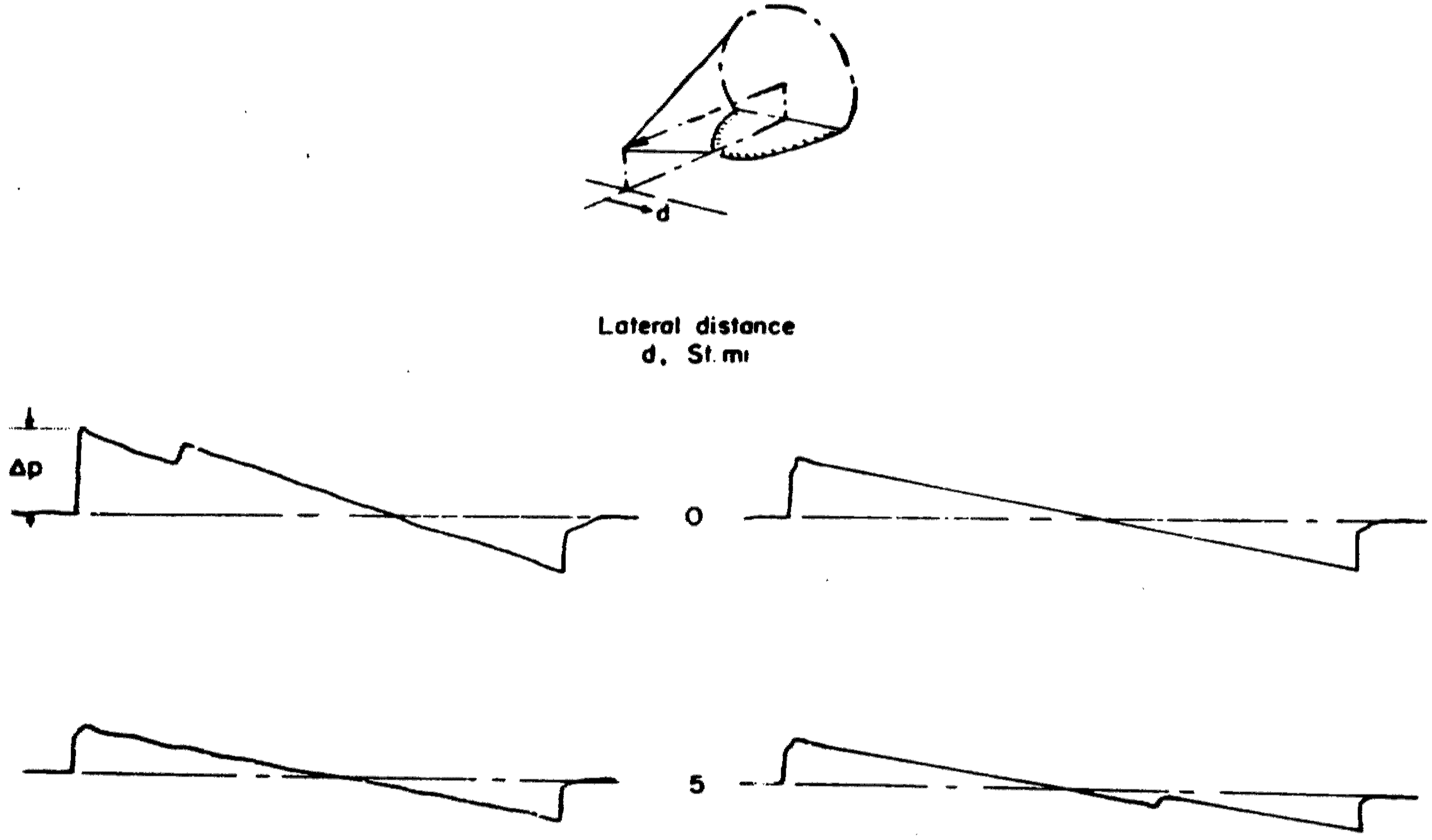
FIG. 1 SCHEMATIC DIAGRAM OF TEST AREA SHOWING GROUND MICROPHONE MEASUREMENT STATIONS AND AIRCRAFT FLIGHT TRACKS

The airplane was flown under radar control generally over the main Edwards Base on a heading of 245° magnetic for most of the flights, and on a parallel track displaced about 13 miles laterally for the remaining flights.

GROUND MEASUREMENTS

Samples of the measured signatures and illustrations of the main findings to date from the ground measurements are presented in Figs. 2 through 8. Figure 2 presents tracings of typical sonic boom signatures measured at two different lateral distances and for two different flight conditions of the airplane. These data are believed to be representative of those observed for relatively quiescent conditions of the atmosphere. The signatures on the left relate to flights at Mach numbers of about 1.5 and altitudes of about 37,000 ft. It can be seen that the signature measured on the ground track is of the so-called near-field variety, that is, it is more complex than the conventional N-wave. Near-field signatures of the type observed are predicted for these flight conditions bv Mr. L. McLean using the generalized theory of reference 1. The lateral distance data as illustrated by the bottom tracing of the signature, do assume the characteristic N-wave form. The data on the right hand side of the figure relate to altitudes of 60,000 ft and a Mach number range of 1.8 to 2.5. For these latter conditions the characteristic N-wave form is observed on the track, whereas at lateral distances in excess of five miles there is evidence of near-field effects. The reason for the existence of an additional relatively weak shock wave for these latter observer locations is not fully understood at present, but it may be associated with the variable geometry features of the airplane.

From data such as those of Fig. 2,the overpressure values, as defined in the figure, were determined for a large number of measurements at various lateral distances and are presented in Fig. 3. The data at the top of the figure relate to four flights made at 37,000 ft and a Mach number of 1.5. The data at the bottom relate to 13 flights at conditions of 60,000 ft altitude and the Mach number range 1.8 to 2.5.



(a) 37,000 ft, M = 1.5

(b) 60,000 ft., M = 1.8 - 2.5

FIG. 2 SONIC BOOM SIGNATURES FROM THE XB-70 AIRPLANE FOR TWO DIFFERENT FLIGHT CONDITIONS FOR QUIESCENT ATMOSPHERIC CONDITIONS

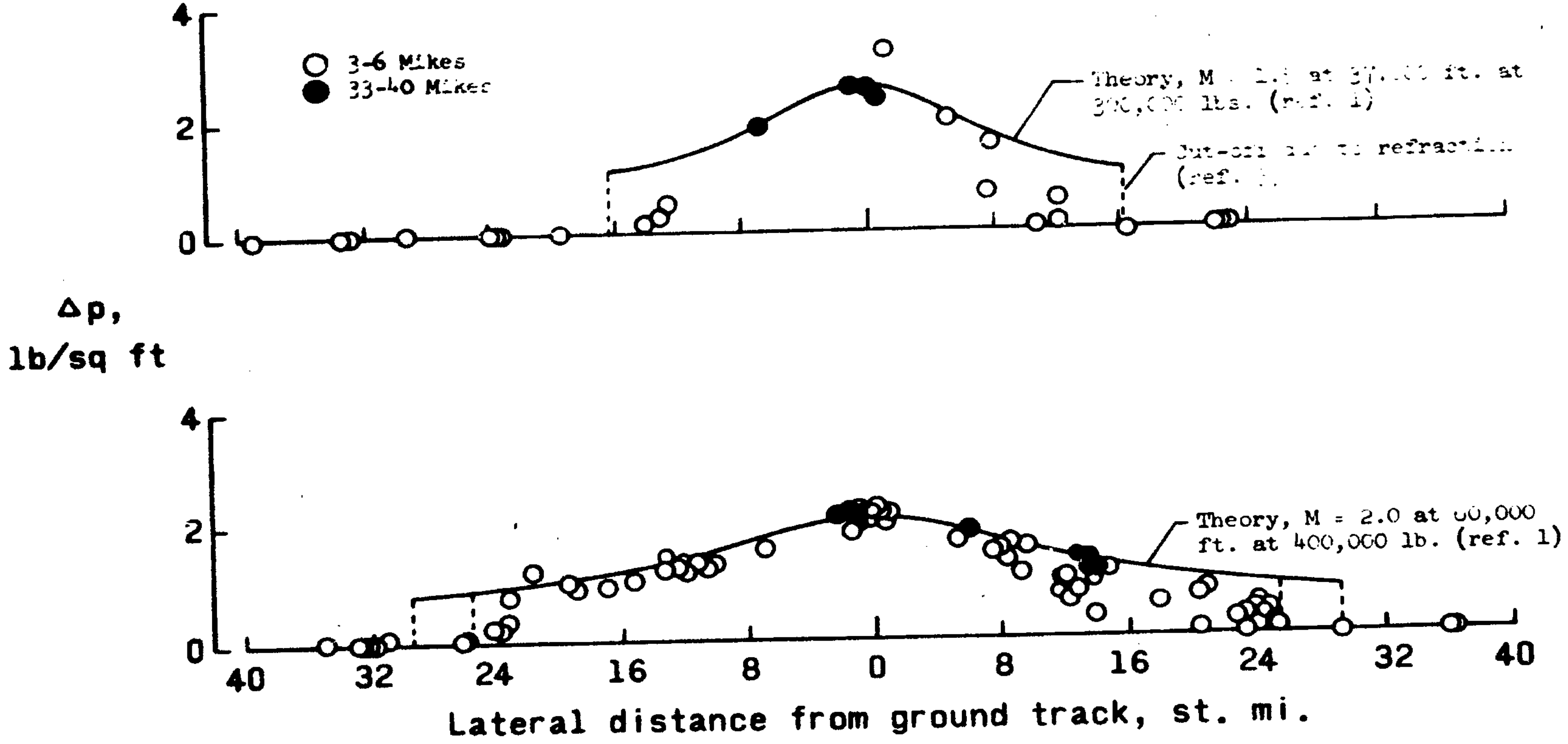


FIG. 3 SONIC BOOM OVERPRESSURES FOR THE XB-70 AIRPLANE AS A FUNCTION OF LATERAL DISTANCE FOR TWO DIFFERENT FLIGHT CONDITIONS

The data points are coded to represent the averages of from 3 to 40 microphones as indicated on the figure. Also shown are calculated curves by McLean using the generalized theory of reference 1 corrected to a standard atmosphere using Fig. 13 of reference 2. The cut-off points due to atmospheric refractions, as calculated by the method of reference 3, are shown as vertical dashed lines. It can be seen that the overpressures are a maximum on the track and decrease with increasing lateral distance as predicted generally by theory. The measured and calculated values of overpressure are in good agreement with the exception of the region near the lateral cut-off where the measured data are seen to fall below the theory.

The data points of Fig. 3 are in all cases averages of several individual readings which for some flights varied considerably from one measuring point to another. The type of variation observed is illustrated by the tracings of the sample data records of Fig. 4. It can be seen that the waveforms vary from the conventional N-wave shape to include, in some cases, peaked wave forms as indicated at the top and, in other cases, rounded-off wave forms as illustrated at the bottom. These sample variations are very similar to those previously observed for other aircraft which were smaller in size and weight (see references 4 and 5). Varying wave shapes such as those illustrated in Fig. 4 have associated with them variations in the overpressure ΔP, time duration Δt, and impulse functions I_o. These latter data have been tabulated for a large number of flights and their variability is illustrated in Figs. 5 through 8.

In Fig. 5 are shown probability plots for the overpressure and impulse data obtained in the three flights of June 1966, at the on-track (0 to about 4 miles) measurement stations. These flights were conducted at $M = 1.38$ at 31,850 ft, $M = 1.81$ at 52,920 ft, and $M = 2.94$ at 72,000 ft. In each case the probability of equalling or exceeding a given value of the ratio of measured to calculated quantities is plotted. It can be seen that the impulse data have generally less variability than the overpressure data. This finding is consistent with those of references 4 and 5. It should be noted that the ordinate is

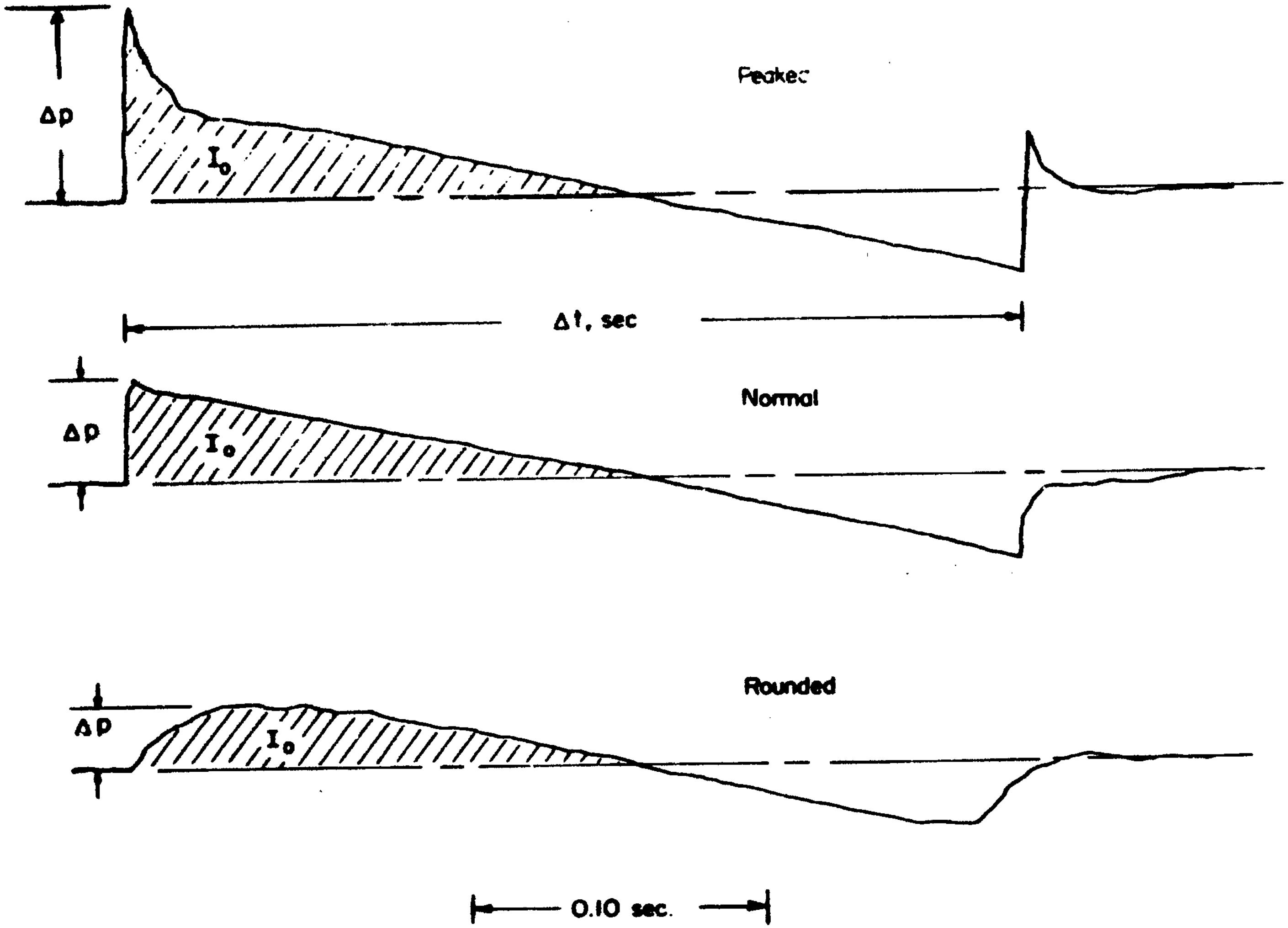


FIG. 4 TYPES OF SONIC BOOM SIGNATURES OBSERVED AT THE GROUND FROM THE XB-70 AIRCRAFT DUE TO THE EFFECTS OF THE ATMOSPHERE

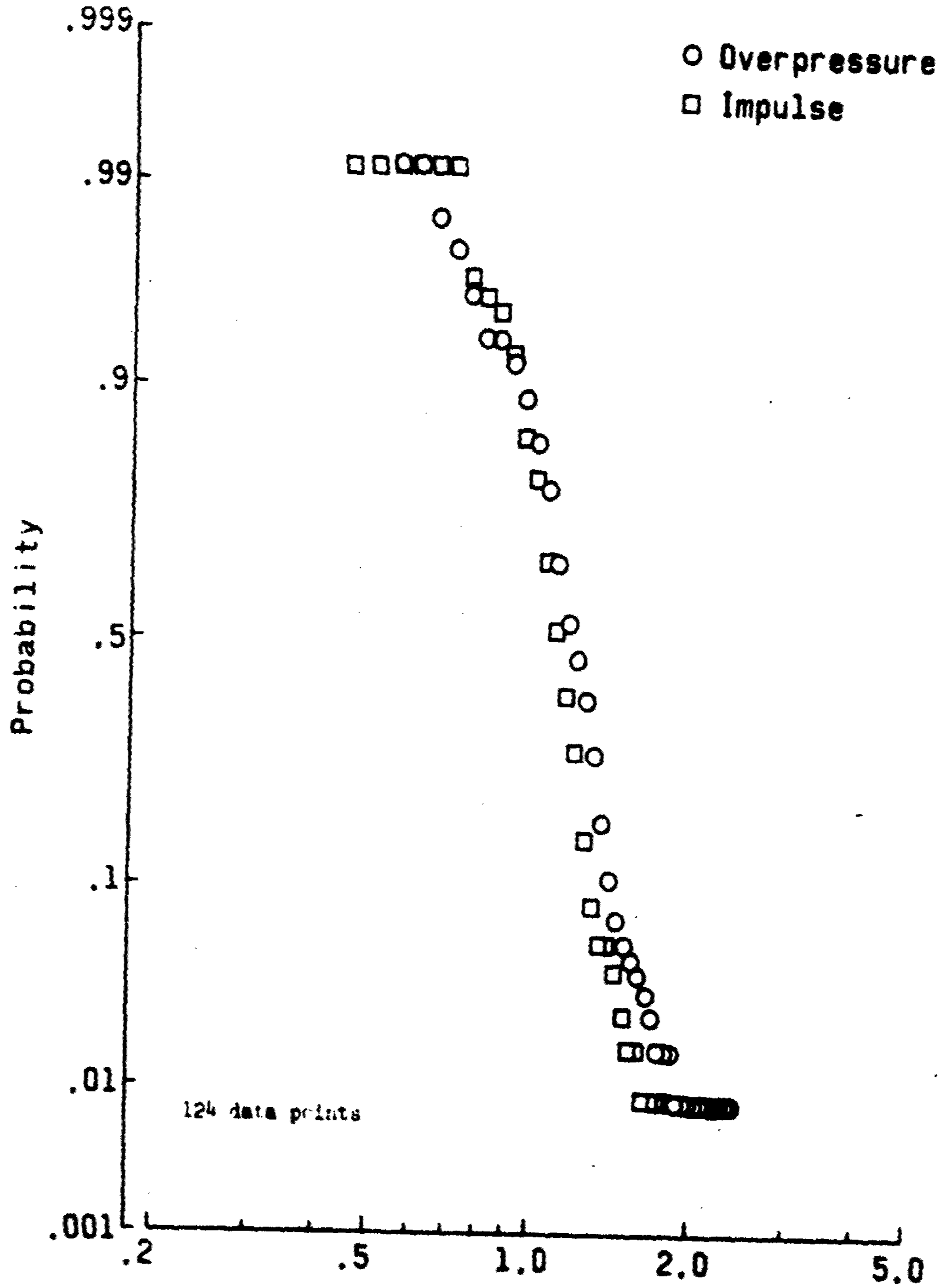


FIG. 5 PROBABILITY OF EQUALLING OR EXCEEDING GIVEN VALUES OF THE RATIOS OF MEASURED TO CALCULATED OVERPRESSURES AND POSITIVE IMPULSES FOR XB-70. Data are for the June 1966 time period

a cumulative function and hence, care should be taken in interpretation of the significance of the multiple data points at the extremes. Data points plotted at .05 psf increments represent the cumulative probability of all events having values equal to or exceeding the value at which the point is plotted.

During the flight tests it was noted that the amount of variability of the data differed depending on the time of year of the measurements. This is illustrated for the on-track locations (0 to about 2 miles) in Fig. 6 for the overpressures. The circle data points relate to the June 1966 time period, whereas the square data points relate to the November 1966 to January 1967 time period. The latter data relate to four flights at $M = 1.5$ at 37,000 ft and 14 flights on the Mach number range 1.8 to 2.5 at 60,000 ft. It is obvious that the latter data have markedly less variability. It is believed that this is due to the fact that the atmosphere is more stable during this latter time period, due, at least in part, to the reduced convective heating in the lower layers.

The opportunity was also taken to document the variability of the overpressures for a given set of flight conditions, but for locations at some distance from the flight track as well as for those on the flight track, and these results are given in Fig. 7. Data for measurement locations about 13 miles off the flight track (diamond symbols) are compared with those on the track (circle symbols) for conditions of 60,000 ft altitude and Mach number 1.8 to 2.5 and for the November 1966 to January 1967 time period. In addition to the probability curves histograms are also shown for information. It can be seen that the probability distribution for the measurements obtained at distances out to 13 miles show larger variability. This is consistent with results of other flight tests (see reference 4) and is believed to be due to the longer ray paths traveled by the waves in the lower layers of the atmosphere in order to reach the lateral stations.

The data records available for the flights at 60,000 ft at $M = 1.8$ to 2.5 have also been analyzed to evaluate the variability in the time duration of the waves since this is of obvious importance in the struc-

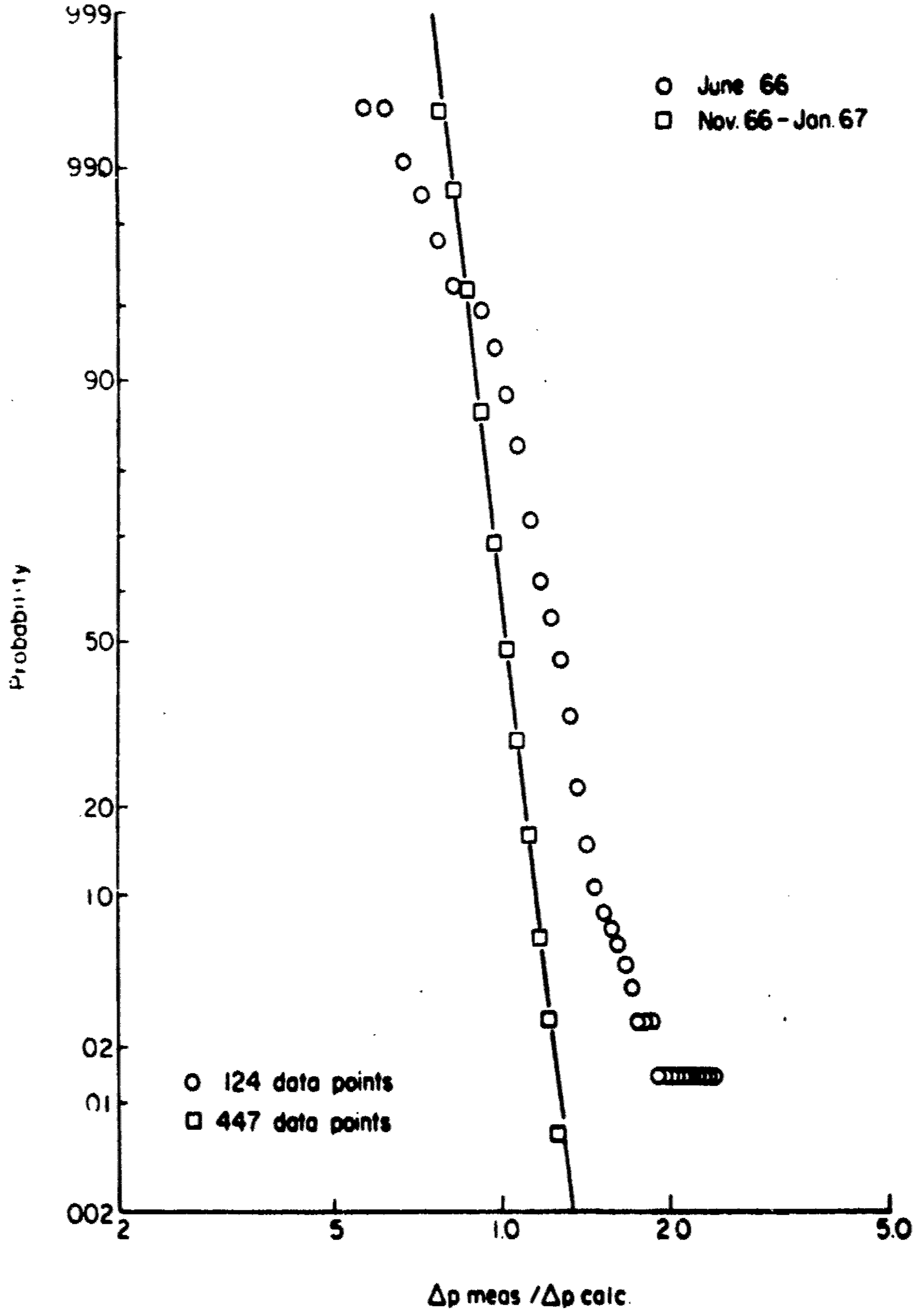


FIG. 6 PROBABILITY OF EQUALLING OR EXCEEDING GIVEN VALUES OF THE RATIOS OF MEASURED TO CALCULATED GROUND OVERPRESSURES FOR THE XB-70 AIRCRAFT FOR THE TWO DIFFERENT TIME PERIODS

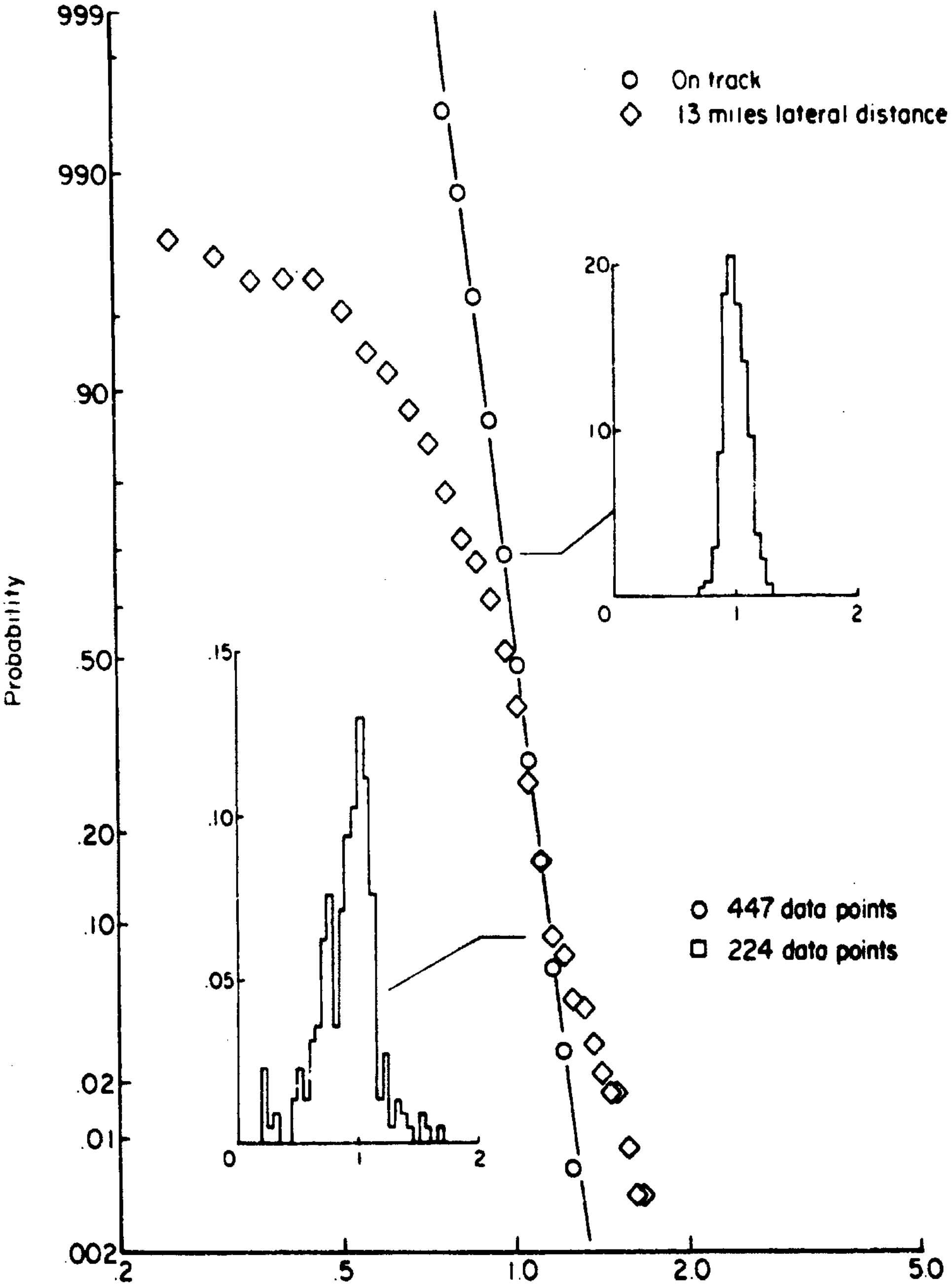


FIG. 7 PROBABILITY OF EQUALLING OR EXCEEDING GIVEN VALUES OF THE RATIOS OF MEASURED TO CALCULATED GROUND OVERPRESSURES FOR THE XB-70 AIRCRAFT FOR MEASURING STATIONS ON THE TRACK AND AT A LATERAL DISTANCE OF 13 MILES

tural response problem. The results of these analyses are given in Fig. 8. The data at the top of the figure relate to the on-track condition, whereas the data at the bottom are for the 13-mile offset condition. The Δt increment selected was .008 sec. It can be seen that variations in the time duration values from about .26 to .32 seconds were observed for both measurement conditions. These amounts of variability are generally consistent with those noted previously for smaller aircraft (ref. 6).

IN-FLIGHT MEASUREMENTS

In order to obtain data for a critical test of the generalized theory for predicting sonic boom wave forms, the opportunity was taken to make in-flight flow field measurements for conditions where atmospheric effects are minimized. The XB-70 flow field was probed with an instrumented NASA F-104 aircraft using an instrument system of the same type as was used in reference 7 at separation distances from 2000 to 5000 ft above and below the generating aircraft. These were accomplished on the four XB-70 flights which were conducted at a Mach number of 1.5 at an altitude of 37,000 ft. Sample in-flight wave forms measured for these tests are presented in Fig. 9 along with the corresponding ground pressure signature for comparison. It can be seen that more complex signatures are measured close to the aircraft and that the individual shock waves from the aircraft tend to coalesce as distance from the aircraft increases. It can also be seen that the shock wave signature above the airplane differs markedly from that below the airplane at a comparable distance. This result is at least partly due to the differences in the detailed geometry of the airplane and in the manner in which the volume and lift components interact. The analyses of these latter data have not been completed as yet; however, it is planned to compare them with comparable theoretical calculations involving the known operating conditions of the airplane. Particular attention will be given to the comparable cases above and below the airplane where the lift and volume components combine in a markedly different manner.

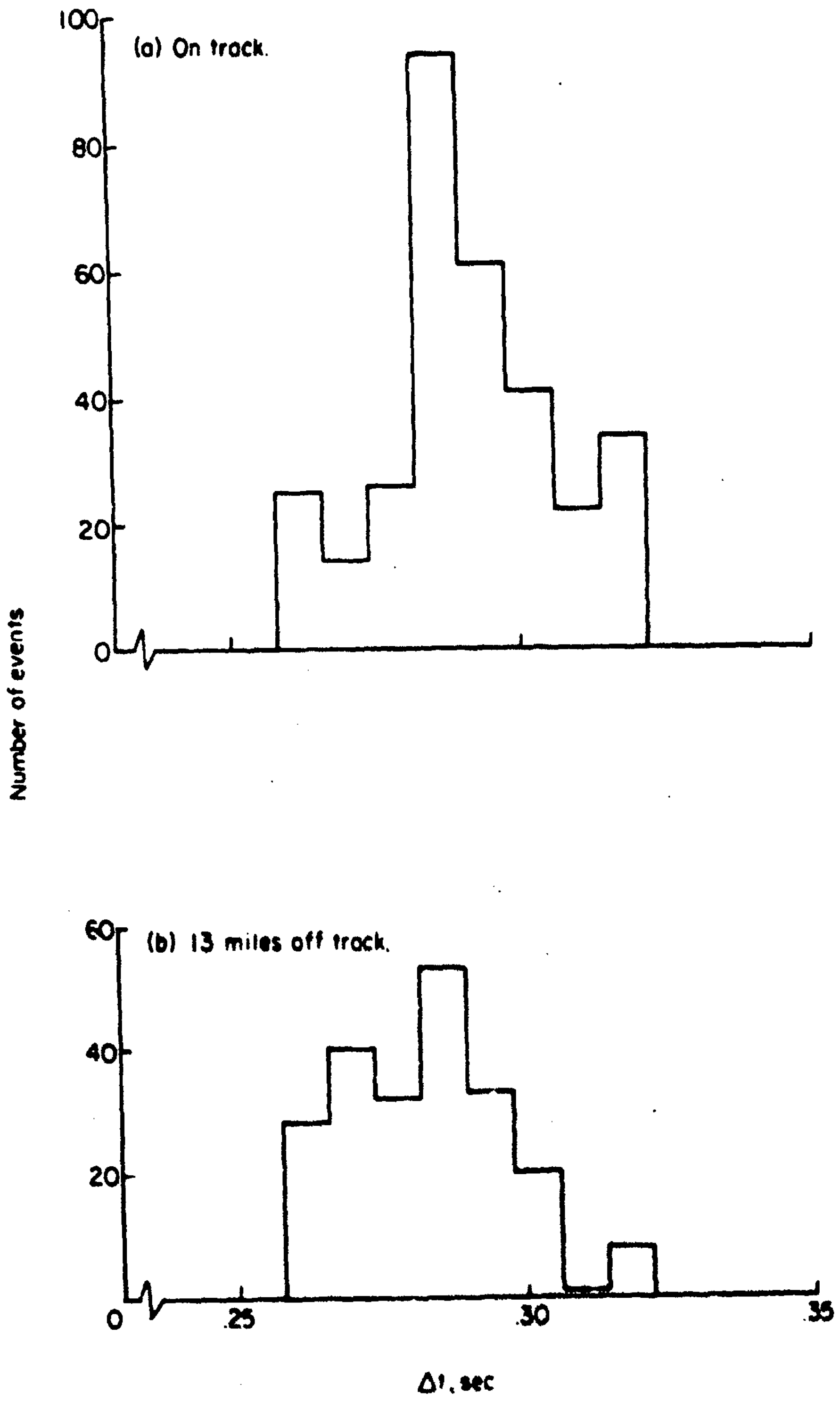


FIG. 8 HISTOGRAMS SHOWING THE VARIABILITY OF THE TIME DURATION VALUES OF THE SONIC BOOM SIGNATURES OF THE XB-70 AIRPLANE AT TWO LOCATIONS RELATIVE TO THE GROUND TRACK

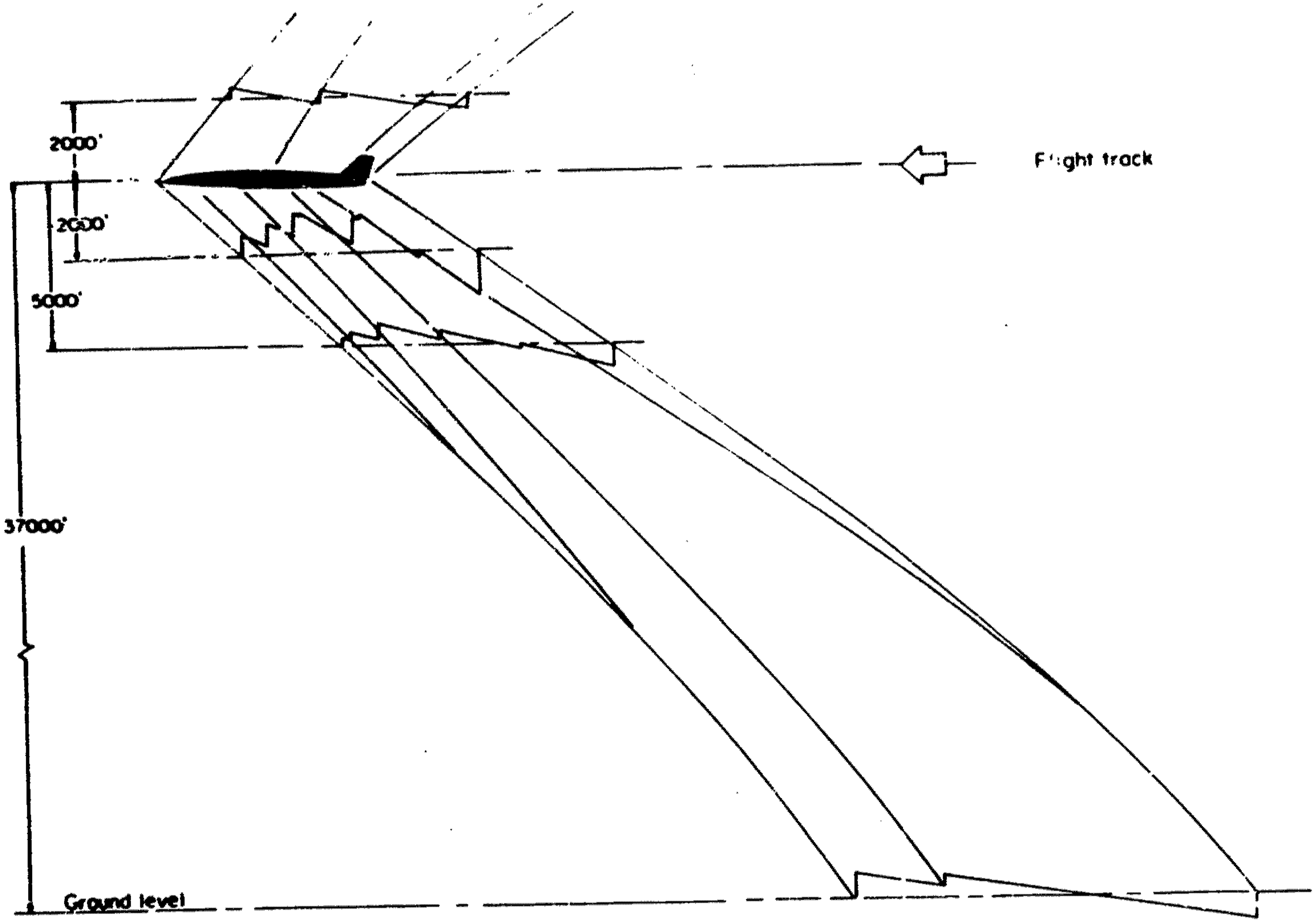


FIG. 9 SCHEMATIC DIAGRAM SHOWING THE SIGNATURES MEASURED IN CLOSE PROXIMITY TO THE XB-70 AIRCRAFT IN FLIGHT COMPARED TO A GROUND SIGNATURE FOR THE SAME FLIGHT CONDITIONS

CONCLUDING REMARKS

The signature shape variations and the associated variations in overpressures, impulses,and time durations are similar in nature to those observed previously for smaller airplanes. Variability in the above quantities was markedly greater in June than in the November-January time period and is thus believed to be related to atmospheric effects. For cases where a large number of overpressure data points are available, the average measured values correlate well with current theory.

REFERENCES

1. Middleton, Wilbur D.; and Carlson, Harry W.: A Numerical Method for Calculating Near-Field Sonic-Boom Pressure Signatures. NASA TN D-3082, November 1965.

2. Carlson, Harry W.: Correlation of Sonic-Boom Theory with Wind-Tunnel and Flight Measurements. NASA TR R-213, December 1964.

3. Randall, D. G.: Methods for Estimating Distributions and Intensities of Sonic Bangs. R. & M. No. 3113, British A.R.C., 1959.

4. Hilton, David A.; Huckel, Vera; Steiner, Roy; and Maglieri, Domenic J.: Sonic-Boom Exposures During FAA Community-Response Studies Over a 6-Month Period in the Oklahoma City Area. NASA TN D-2539, December 1964.

5. Hilton, David A.; Huckel, Vera; and Maglieri, Domenic J.: Sonic-Boom Measurements During Bomber Training Operations in the Chicago Area. NASA TN D-3655, October 1966.

6. Maglieri, Domenic J.; Hilton, David A.; and McLeod, Norman J.: Summary of Variations of Sonic Boom Signatures Resulting from Atmospheric Effects. Presented at the 5th Meeting of the (FAUSST) French Anglo-Saxon United States Supersonic Transport Committee, Washington, D.C., February 27 through March 3, 1967.

7. Maglieri, Domenic J.; Ritchie, Virgil S.; and Bryant, John F., Jr.: In-Flight Shock-Wave Pressure Measurements Above and Below a Bomber Airplane at Mach Numbers from 1.42 to 1.69. NASA TN D-1968, October 1963.

Annex C

Part III - SUMMARY OF CRUCIFORM DATA

National Aeronautics and Space Administration
Langley Research Center
Langley Field, Virginia

Annex C
Part III

SUMMARY OF CRUCIFORM DATA

Table C-III-1 for Phase I of the Edwards experiments and Table C-III-2 for Phase II give the listing of measured quantities in order of mission number for each of the cruciform microphones. The map of the cruciform is Fig. A-2. The quantities measured are illustrated in Fig. A-5.

Table C-III-1

SUMMARY OF CRUCIFORM DATA, EDWARDS PHASE 1

Date	Mission No.	Aircraft	Altitude ft	Mach No.	Microphone No.	Δp lb/ft^2	Δt sec.	Rise Time sec.
6-1-66	11	XB-70	52,920	1.81	MLC-1	2.37	.250	.0125
					MLC-5	--	--	--
					MLC-6	1.36	--	--
					MLC-2	2.59	.250	.007
					MLC-3	2.72	.250	.006
					MLC-4	2.42	.250	.0035
6-6-66	22	XB-70	72,000	2.83	MLC-1	1.65	.3175	.0055
					MLC-5	1.64	.3175	.007
					MLC-6	.814	--	--
					MLC-2	1.53	.3175	.005
					MLC-3	1.68	.3175	.005
					MLC-4	1.70	.3175	.007
6-8-66	1	XB-70	31,850	1.38	MLC-1	Noise	--	--
					MLC-5	2.35	.233	.03
					MLC-6	2.10	--	--
					MLC-2	2.28	.234	.032
					MLC-3	2.08	.233	.03
					MLC-4	2.38	.234	.028
6-6-66	39		No Boom					
	70	B-58	43,900	1.6	MLC-1	1.97	.185	.005
					MLC-5	1.88	.185	.024
					MLC-6	1.01	--	--
					MLC-2	2.23	.185	.002
					MLC-3	1.72	.185	.007
					MLC-4	1.98	.1845	.023
	40	B-58	31,400	1.48	MLC-1	3.55	.1575	.010
					MLC-5	3.36	.157	.0115
					MLC-6	1.78	--	--
					MLC-2	3.21	.157	.007
					MLC-3	3.63	.157	.0065
					MLC-4	3.52	.157	.015
	71	B-58	41,200	1.59	MLC-1	1.65	.179	.012
					MLC-5	1.88	.179	.017
					MLC-6	.930	--	--
					MLC-2	1.72	.179	.012
					MLC-3	1.76	.179	.006
					MLC-4	1.78	.179	.016
	41	B-58	31,440	1.45	MLC-1	2.49	.154	.016
					MLC-5	2.56	.154	.017
					MLC-6	1.24	--	--
					MLC-2	2.33	.154	.015
					MLC-3	2.43	.154	.018
					MLC-4	2.64	.1535	.016
	72	B-58	43,920	1.55	MLC-1	1.51	.172	.006
					MLC-5	2.64	.172	.005
					MLC-6	1.63	--	--
					MLC-2	2.09	.174	.007
					MLC-3	2.02	.172	.003
					MLC-4	1.78	.171	.005

Table C-III-1 (Continued)

Date	Mission No.	Aircraft	Altitude ft	Mach No.	Microphone No.	Δp lb/ft^2	Δt sec.	Rise Time sec.
6-6-66	43	B-58	Missed Boom					
	74	B-58	32,440	1.3	MLC-1	3.16	.195	.014
					MLC-5	3.20	.194	.010
					MLC-6	1.67	--	--
					MLC-2	3.12	.194	.001
					MLC-3	3.33	.1945	.006
					MLC-4	3.09	.194	.009
	44	B-58	43,400	1.57	MLC-1	1.58	.197	.007
					MLC-5	1.96	.196	.0005
					MLC-6	1.16	--	--
					MLC-2	1.53	.196	.006
					MLC-3	1.65	.195	.0005
					MLC-4	1.90	.1955	.004
	75	B-58	31,840	1.46	MLC-1	2.67	.157	.006
					MLC-5	3.00	.1575	.004
					MLC-6	2.02	--	--
					MLC-2	3.02	.157	.001
					MLC-3	4.94*/3.33	.157	.0005*/.001
					MLC-4	3.05	.1575	.0035
	42	B-58	43,300 10 N. mi East	1.53	MLC-1	1.83	.1835	.0065
					MLC-5	1.80	.183	.0065
					MCL-6	.930	--	--
					MCL-2	1.58	.183	.007
					MLC-3	1.65	.1825	.011
					MLC-4	1.98	.1835	.0065
	73	B-58	31,860	1.43	MLC-1	2.95	.160	.006
					MLC-5	5.41*/3.72	.160	.0005*/.001
					MLC-6	2.29	--	--
					MLC-2	3.12	.160	.0005
					MLC-3	3.03	.160	.006
					MLC-4	3.25	.160	.004
6-7-66	76-A	B-58	31,560	1.48	MLC-1	2.88	.164	.0065
					MLC-5	2.81	.1635	.006
					MLC-6	1.61	--	--
					MLC-2	3.10	.164	.008
					MLC-3	4.51	.164	.0015
					MLC-4	3.47	.1635	.004
	45-B	B-58	43,660	1.70	MLC-1	1.75	.1715	.005
					MLC-5	2.01	.172	.0085
					MLC-6	1.06	--	--
					MLC-2	2.29	.171	.001
					MLC-3	2.27	.172	.0055
					MLC-4	1.96	.171	.009
	77-B	B-58	31,680	1.51	MLC-1	2.18	.156	.011
					MLC-5	2.75	.156	.010
					MLC-6	1.48	--	--
					MLC-2	3.26	.155	.005
					MLC-3	3.24	.156	.005
					MLC-4	2.71	.1565	.027

Table C-III-1 (Continued)

Date	Mission No.	Aircraft	Altitude ft	Mach No.	Microphone No.	Δp lb/ft^2	Δt sec.	Rise Time sec.
6-7-66	46-B	B-58	13,720	1.65	MLC-1	1.35	.1715	.0005
					MLC-5	1.62	.172	.011
					MLC-6	.84	---	--
					MLC-2	1.40	.171	.003
					MLC-3	1.81	.170	.006
					MLC-4	1.71	.172	.006
	18-A		No Boom					
	79-A	B-58	31,600	1.52	MLC-1	2.57	.170	.028
					MLC-5	2.49	.1695	.029
					MLC-6	1.16	--	--
					MLC-2	2.45	.169	.027
					MLC-3	2.45	.1695	.014
					MLC-4	2.66	.169	.017
	49-A	B-58	13,340	1.43	MLC-1	1.41	.211	.040
					MLC-5	1.49	.212	.032
					MLC-6	1.42	--	--
					MLC-2	1.33	.2075	.024
					MLC-3	1.39	.212	.045
					MLC-4	1.59	.2115	.035
	80-A	B-58	31,600	1.53	MLC-1	2.59	.156	.0085
					MLC-5	2.59	.1555	.0115
					MLC-6	1.35	--	--
					MLC-2	3.10*/2.48	.1555	.001/.003
					MLC-3	2.60	.1565	.019
					MLC-4	3.11	.1555	.014
	50-A	B-58	43,340	1.43	MLC-1	.930	.197	.0105
					MLC-5	.938	.192	.020
					MLC-6	.183	--	--
					MLC-2	1.02	.197	.045
					MLC-3	.908	.1995	.023
					MLC-4	1.15	.196	.049
	81-A	B-58	31,400	1.49	MLC-1	1.75	.151	.053
					MLC-5	2.07	.1505	.042
					MLC-6	.516	--	--
					MLC-2	1.80	.150	.050
					MLC-3	1.97	.151	.034
					MLC-4	2.29	.150	.047
6-8-66	13-A	B-58	42,380	1.62	MLC-1	--	--	--
					MLC-5	1.70	.177	.015
					MLC-6	1.53	--	--
					MLC-2	1.74	.174	.012
					MLC-3	1.73	.176	.014
					MLC-4	1.63	.175	.012
	75-A	B-58	31,200	1.44	MLC-1	--	--	--
					MLC-5	3.52	.156	.0055
					MLC-6	1.75	--	--
					MLC-2	3.18	.156	.0115
					MLC-3	3.37	.1565	.009
					MLC-4	3.15	.157	.007

Table C-III-1 (Continued)

Date	Mission No.	Aircraft	Altitude ft	Mach No.	Microphone No.	Δp lb/ft^2	Δt sec.	Rise Time sec.
6-8-66	42-A	B-58	43,260	1.67	MLC-1	--	--	--
					MLC-5	2.09	.179	.009
					MLC-6	1.18	--	--
					MLC-2	2.73	.179	.006
					MLC-3	2.34	.179	.0035
					MLC-4	2.06	.179	.008
	73-A	B-58	31,200	1.5	MLC-1	--	--	--
					MLC-5	2.35	.147	.0155
					MLC-6	1.23	--	--
					MLC-2	2.23	.147	.011
					MLC-3	2.16	.146	.014
					MLC-4	2.23	.147	.016
	41-A	B-58	43,200	1.6	MLC-1	--	--	--
					MLC-5	1.74	.166	.006
					MLC-6	.963	--	--
					MLC-2	3.03	.166	.005
					MLC-3	1.82	.166	.006
					MLC-4	1.91	.167	.006
	72-A	B-58	31,200	1.49	MLC-1	--	--	--
					MLC-5	2.96	.144	.006
					MLC-6	1.58	--	--
					MLC-2	2.88	.145	.004
					MLC-3	3.21	.144	.002
					MLC-4	2.55	.145	.004
	57-RB	B-58	37,600	1.66	MLC-1	--	--	--
					MLC-5	1.78	.161	.023
					MLC-6	.832	--	--
					MLC-2	2.18	.162	.003
					MLC-3	1.51	.163	.030
					MLC-4	1.67	.162	.0085
	80-RB	B-58	31,300	1.46	MLC-1	--	--	--
					MLC-5	2.52	.161	.005
					MLC-6	1.31	--	--
					MLC-2	2.58	.160	.014
					MLC-3	2.64	.160	.0075
					MLC-4	3.15	.161	.0025
	56-RB	B-58	43,040	1.64	MLC-1	--	--	--
					MLC-5	2.61	.171	.004
					MLC-6	1.40	--	--
					MLC-2	2.08	.171	.0135
					MLC-3	1.90	.169	.006
					MLC-4	2.06	.171	.0065
	87-RB	B-58	31,440	1.49	MLC-1	--	--	--
					MLC-5	3.09	.148	.0175
					MLC-6	1.66	--	--
					MLC-2	4.27	.148	.001
					MLC-3	2.81	.148	.006
					MLC-4	3.19	.148	.017

Table C-III-1 (Continued)

Date	Mission No.	Aircraft	Altitude ft	Mach No.	Microphone No.	Δp lb/ft^2	Δt sec.	Rise Time sec.
6-8-66	55-RB	B-58	43,200	1.64	MLC-1	--	--	--
					MLC 5	2.18	.170	.003
					MLC-6	1.71	--	--
					MLC-2	2.63	.169	.0125
					MLC-3	2.68	.166	.0015
					MLC-4	2.06	.169	.0055
	86-RB	B-58	31,360	1.49	MLC-1	--	--	--
					MLC-5	2.87	.144	.009
					MLC-6	1.62	--	--
					MLC-2	2.63	.144	.011
					MLC-3	3.03	.144	.0055
					MLC-4	2.48	.144	.006
6-9-66	86-SRB	B-58	31,000	1.5	MLC-1	3.82	.153	.0055
					MLC-5	3.72	.153	.005
					MLC-6	1.94	--	--
					MLC-2	4.09	.153	.0045
					MLC-3	5.32	.152	.005
					MLC-4	3.31	.1525	.004
	55-SRB	B-58	35,720	1.69	MLC-1	1.42	.1395	.032
					MLC-5	1.46	.1395	.030
					MLC-6	.74	--	--
					MLC-2	1.43	.1405	.030
					MLC-3	1.75	.1395	.0085
					MLC-4	1.56	.1405	.031
	87-SRB	B-58	31,000	1.53	MLC-1	3.02	.147	.015
					MLC-5	2.93	.146	.006
					MLC-6	1.58	--	--
					MLC-2	3.12	.1455	.005
					MLC-3	3.72	.1465	.006
					MLC-4	1.02	.146	.001
	56-SRB	B-58	43,600	1.72	MLC-1	3.11	.1605	.002
					MLC-5	2.61	.161	.003
					MLC-6	1.31	--	--
					MLC-2	2.46	.1615	.0035
					MLC-3	2.98	.162	.0075
					MLC-4	2.63	.161	.004
	80-SRB	B-58	31,000	1.53	MLC-1	2.79	.1405	.006
					MLC-5	3.12	.140	.007
					MLC-6	2.18	-	-
					MLC-2	2.46	.140	.021
					MLC-3	3.61	.140	.003
					MLC-4	2.63	.1405	.024
	57-SRB	B-58	43,200	1.70	MLC-1	1.60	.1505	.0085
					MLC-5	1.36	.1495	.0035
					MLC-6	.838	--	--
					MLC-2	1.99	.150	.012
					MLC-3	2.12	.150	.004
					MLC-4	1.94	.150	.018

Table C-III-1 (Continued)

Date	Mission No.	Aircraft	Altitude ft	Mach No.	Microphone No.	Δp lb/ft^2	Δt sec.	Rise Time sec.
6-9-66	41-SA	B-58	42,920	1.52	MLC-1	1.75	.180	.011
					MLC-5	2.93	.1805	.001
					MLC-6	1.74	--	--
					MLC-2	1.79	.1805	.005
					MLC-3	2.23	.181	.0045
					MLC-4	2.19	.1805	.002
	73-SA	B-58	31,720	1.50	MLC-1	3.05	.156	.017
					MLC-5	2.83	.1555	.0045
					MLC-6	1.47	--	--
					MLC-2	2.69	.155	.0045
					MLC-3	3.61	.155	.014
					MLC-4	2.76	.155	.018
	42-SA	B-58	43,060	1.52	MLC-1	1.99	.1755	.015
					MLC-5	2.04	.176	.018
					MLC-6	1.21	--	--
					MLC-2	2.23	.176	.005
					MLC-3	2.49	.176	.0175
					MLC-4	2.08	.176	.0015
	75-SA	B-58	31,680	1.55	MLC-1	3.68	.149	.003
					MLC-5	4.01*/3.34	.1485	.001*/.005
					MLC-6	1.81	--	--
					MLC-2	2.99	.1488	.003
					MLC-3	4.24	.1485	.012
					MLC-4	3.78	.149	.004
			Note	72-SA Aborted				
	43-SA	B-58	43,000	1.68	MLC-1	3.50	.157	.003
					MLC-5	2.35	.1565	.001
					MLC-6	1.17	--	--
					MLC-2	2.99	.157	.004
					MLC-3	2.31	.157	.001
					MLC-4	3.01	.157	.002
	42-SA	B-58	43,300	1.70	MLC-1	1.87	.1645	.007
					MLC-5	2.07	.165	.011
					MLC-6	1.01	--	--
					MLC-2	1.06	.1645	.017
					MLC-3	2.05	.1655	.011
					MLC-4	1.81	.1685	.013
	46-SA	B-58	42,900	1.68	MLC-1	1.69	.156	.022
					MLC-5	1.69	.1555	.008
					MLC-6	.972	--	--
					MLC-2	2.26	.1565	.007
					MLC-3	3.03	.156	.006
					MLC-4	1.97	.1565	.0205
	72-SA	B-58	31,320	1.53	MLC-1	2.19	.1455	.0145
					MLC-5	2.29	.145	.016
					MLC-6	1.17	-	-
					MLC-2	1.89	.145	.0095
					MLC-3	2.37	.145	.017
					MLC-4	2.16	.1455	.019

Table C-III-1 (Continued)

Date	Mission No.	Aircraft	Altitude ft	Mach No.	Microphone No.	Δp lb/ft^2	Δt sec.	Rise Time sec.
6-13-66	18-A	B-58	37,740	1.64	MLC-1	2.59	.1605	.005
					MLC-5	3.36*/2.77	.1605	.0004/.0008
					MLC-6	1.85	--	--
					MLC-2	2.71	.160	.0035
					MLC-3	2.83	.160	.0003
					MLC-4	2.78	.160	.004
	18-B	B-58	49,600	1.66	MLC-1	2.16	.1955	.0005
					MLC-5	1.96	.1955	.005
					MLC-6	1.04	--	--
					MLC-2	1.88	.195	.0055
					MLC-3	2.00	.1955	.007
					MLC-4	2.31	.1955	.0035
	21-A	B-58	37,840	1.69	MLC-1	3.00	.1455	.0005
					MLC-5	2.55	.146	.0065
					MLC-6	1.34	--	--
					MLC-2	2.76	.146	.0035
					MLC-3	2.98	.146	.004
					MLC-4	2.94	.146	.005
	21-B	B-58	49,160	1.72	MLC-1	1.83	.195	.0045
					MLC-5	1.84	.195	.004
					MLC-6	.936	--	--
					MLC-2	1.83	.1945	.0045
					MLC-3	1.98	.195	.004
					MLC-4	2.03	.195	.0045
	29-A	B-58	49,300	1.67	MLC-1	1.85	.195	.0055
					MLC-5	2.01	.195	.0035
					MLC-6	1.04	--	--
					MLC-2	1.73	.1955	.004
					MLC-3	2.03	.195	.0055
					MLC-4	1.84	.1955	.013
	29-B	B-58	38,140	1.67	MLC-1	3.56*/2.93	.156	.0002*/.001
					MLC-5	3.07	.156	.0015
					MLC-6	1.52	--	--
					MLC-2	2.58	.1555	.0035
					MLC-3	3.66	.156	.009
					MLC-4	3.33*/3.22	.156	.0002*/.001
	32-A	B-58	49,820	1.64	MLC-1	1.85*/1.80	.1825	.0002*/.005
					MLC-5	1.91	.1825	.005
					MLC-6	1.10	--	--
					MLC-2	1.91	.1825	.004
					MLC-3	1.91	.182	.004
					MLC-4	1.93	.1825	.004
	32-B	B-58	38,080	1.67	MLC-1	2.35	.149	.015
					MLC-5	2.10*/2.50	.149	.0002*/.001
					MLC-6	1.31	--	--
					MLC-2	2.98	.149	.004
					MLC-3	2.39	.149	.005
					MLC-4	2.56	.149	.0035

Table C-III-1 (Continued)

Date	Mission No.	Aircraft	Altitude ft	Mach No.	Microphone No.	Δp lb/ft^2	Δt sec.	Rise Time sec.
6-20-66	48-A	B-58	41,300	1.55	MLC-1	2.71	.179	.005
					MLC-5	2.61	.179	.004
					MLC-6	1.40	--	--
					MLC-2	2.52	.1785	.005
					MLC-3	2.66	.179	.005
					MLC-4	2.93	.1775	.005
	79-A	B-58	32,100	1.45	MLC-1	2.57	.1535	.002
					MLC-5	2.52	.1535	.004
					MLC-6	1.37	--	--
					MLC-2	2.27	.1535	.006
					MLC-3	2.54	.1535	.005
					MLC-4	2.50	.1535	.005
	53-A	B-58	42,700	1.59	MLC-1	1.49	.1755	.020
					MLC-5	1.49	.1755	.020
					MLC-6	.588	--	--
					MLC-2	1.39	.1755	.021
					MLC-3	1.54	.175	.023
					MLC-4	1.43	.1755	.021
	84-A	B-58	31,220	1.43	MLC-1	2.68	.1445	.0015
					MLC-5	2.58	.1445	.017
					MLC-6	1.37	--	--
					MLC-2	2.36	.1445	.004
					MLC-3	2.66	.144	.0155
					MLC-4	2.59	.1445	.019
	54-A	B-58	43,000	1.59	MLC-1	1.28	.164	.0065
					MLC-5	1.31	.1635	.0075
					MLC-6	.718	--	--
					MLC-2	1.36	.164	.005
					MLC-3	1.42	.1645	.0055
					MLC-4	1.49	.1645	.0065
	59-B	B-58	43,360	1.41	MLC-1	2.31	.2175	.007
					MLC-5	2.31	.2176	.010
					MLC-6	1.01	--	--
					MLC-2	2.21	.218	.005
					MLC-3	2.21	.218	.0075
					MLC-4	2.17	.2175	.0045
	98-B	B-58	31,340	1.50	MLC-1	3.27	.1545	.0025
					MLC-5	3.04	.1535	.005
					MLC-6	1.50	--	--
					MLC-2	2.71	.1545	.004
					MLC-3	3.25	.1545	.006
					MLC-4	2.96	.1545	.004
	60-B		No Boom					
	90-B	B-58	31,000	1.35	MLC-1	2.74	.145	.016
					MLC-5	2.76	.145	.0135
					MLC-6	1.31	-	--
					MLC-2	2.68	.1455	.004
					MLC-3	1.16	.145	.002
					MLC-4	2.62	.1455	.011

Table C-III-1 (Continued)

Date	Mission No.	Aircraft	Altitude ft	Mach No.	Microphone No.	Δp lb/ft^2	Δt sec.	Rise Time sec.
6-20-66	85-A	B-58	32,320	1.45	MLC-1	2.22	.143	.016
					MLC-5	2.37	.142	.0115
					MLC-6	1.27	--	--
					MLC-2	2.33	.1435	.0145
					MLC-3	2.66	.142	.011
					MLC-4	2.38	.1435	.016
	93-B	B-58	32,140	1.55	MLC-1	2.48	.1415	.005
					MLC-5	2.86	.1410	.008
					MLC-6	1.47	--	--
					MLC-2	2.84	.1415	.013
					MLC-3	2.92	.141	.006
					MLC-4	3.52	.1405	.0045
6-21-66	89-B	B-58	31,760	1.46	MLC-1	2.84	.151	.018
					MLC-5	2.65	.1515	.007
					MLC-6	1.46	--	--
					MLC-2	3.00	.152	.014
					MLC-3	2.67	.151	.013
					MLC-4	2.98	.1515	.012
	58-B	B-58	13,600	1.67	MLC-1	1.93	.175	.006
					MLC-5	2.20	.1745	.002
					MLC-6	1.26	--	--
					MLC-2	1.55	.175	.012
					MLC-3	1.79	.1745	.002
					MLC-4	1.91	.175	.0075
	99-B	B-58	31,700	1.47	MLC-1	2.66	.1485	.025
					MLC-5	3.54*/3.16	.149	/.007
					MLC-6	1.78	--	--
					MLC-2	2.71	.1485	.003
					MLC-3	3.19	.1485	.0015
					MLC-4	3.89	.148	.004
	66-B	B-58	39,860	1.59	MLC-1	1.18	.167	.025
					MLC-5	1.16	.1675	.006
					MLC-6	.575	--	--
					MLC-2	1.08	.1675	.0125
					MLC-3	1.14	.167	.025
					MLC-4	1.19	.1665	.030
	100-B	B-58	31,760	1.46	MLC-1	3.55	.147	.0025
					MLC-5	2.96	.1465	.004
					MLC-6	1.39	--	--
					MLC-2	2.46	.1465	.005
					MLC-3	2.48	.146	.010
					MLC-4	3.54	.1465	.005
	68-B	B-58	14,080	1.62	MLC-1	1.32	.1675	.005
					MLC-5	1.41	.167	.007
					MLC-6	.732	--	--
					MLC-2	1.28	--	.012
					MLC-3	1.55	.167	.004
					MLC-4	1.41	.1665	.004

Table C-III-1 (Continued)

Date	Mission No.	Aircraft	Altitude ft	Mach No.	Microphone No.	Δp lb/ft^2	Δt sec.	Rise Time sec.
6-21-66	69-B	B-58	39,440	1.39	MLC-1	1.59	.1855	.023
					MLC-5	1.59	.186	.008
					MLC-6	.837	--	--
					MLC-2	1.58	.1855	.018
					MLC-3	1.60	.1855	.016
					MLC-4	1.66	.1855	.013
	48-A	B-58	43,140	1.60	MLC-1	1.45	.178	.003
					MLC-5	1.57	.1775	.026
					MLC-6	.785	--	--
					MLC-2	1.16	.1775	.011
					MLC-3	1.81	.177	.002
					MLC-4	1.44	.1775	.022
	40-A	B-58	43,840	1.65	MLC-1	1.55	.171	.012
					MLC-5	1.77	.171	.006
					MLC-6	1.05	--	--
					MLC-2	1.87	.171	.005
					MLC-3	1.88	.1705	.009
					MLC-4	1.96	.171	.0065
	60-B	B-58	43,940	1.64	MLC-1	1.55	.165	.007
					MLC-5	1.46	.165	.013
					MLC-6	.759	--	--
					MLC-2	2.24	.1655	.004
					MLC-3	1.43	.1655	.017
					MLC-4	1.82	.165	.0095
	61-B	B-58	43,260	1.62	MLC-1	2.46	.1825	.018
					MLC-5	2.05	.1815	.011
					MLC-6	1.10	--	--
					MLC-2	3.32	.1815	.0025
					MLC-3	1.93	.1805	.020
					MLC-4	2.38	.181	.007
	101-B	B-58	31,700	1.5	MLC-1	2.68	.1485	.019
					MLC-5	2.68	.1485	.015
					MLC-6	1.39	--	--
					MLC-2	2.49	.148	.019
					MLC-3	2.72	.149	.001
					MLC-4	2.76	.1485	.020
	85-A	B-58	31,700	1.5	MLC-1	2.23	.146	.023
					MLC-5	3.74	.146	.020
					MLC-6	1.57	--	--
					MLC-2	2.64	.1455	.009
					MLC-3	2.55	.146	.005
					MLC-4	3.12	.1455	.007
6-22-66	28-A	B-58	37,000	1.63	MLC-1	2.26	.162	.013
					MLC-5	2.73	.162	.0115
					MLC-6	1.45	--	--
					MLC-2	2.36	.163	.0245
					MLC-3	3.29	.1625	.008
					MLC-4	2.62	.162	.017

Table C-III-1 (Continued)

Date	Mission No.	Aircraft	Altitude ft	Mach No.	Microphone No.	Δp lb/ft²	Δt sec.	Rise Time sec.
6-22-66	19-A	B-58	37,200	1.64	MLC-1	2.30	.1555	.0155
					MLC-5	2.02	.156	.015
					MLC-6	1.08	--	--
					MLC-2	2.20	.156	.026
					MLC-3	1.78	.1565	.0085
					MLC-4	2.04	.156	.0135
	6-X	B-58	43,560	1.60	MLC-1	2.48	.167	.006
					MLC-5	3.36	.167	.0115
					MLC-6	2.48	--	--
					MLC-2	1.79	.1665	.0245
					MLC-3	5.06	.167	.0055
					MLC-4	4.12	.167	.016
	30-A	B-58	37,400	1.65	MLC-1	2.21	.163	.008
					MLC-5	1.92	.1635	.032
					MLC-6	1.01	--	--
					MLC-2	1.98	.163	.0185
					MLC-3	2.10	.163	.0295
					MLC-4	1.93	.1625	.0045
	31-B	B-58	43,400	1.61	MLC-1	1.44	.169	.018
					MLC-5	1.36	.170	.024
					MLC-6	.800	--	--
					MLC-2	1.74	--	.0105
					MLC-3	1.59	.170	.003
					MLC-4	1.44	.170	.0165
	21-A	B-58	43,300	1.6	MLC-1	1.58	No	.021
					MLC-5	1.59	time.	.031
					MLC-6	1.34	Could	--
					MLC-2	1.28	not	.022
					MLC-3	1.17	read.	.016
					MLC-4	1.55		.0225
	35-A	B-58	43,400	1.6	MLC-1	1.45	.165	.0225
					MLC-5	1.19	.165	.0175
					MLC-6	1.01	--	--
					MLC-2	.989	.165	.0365
					MLC-3	1.57	.1645	.0155
					MLC-4	1.35	.165	.028
	25-B	B-58	43,220	1.59	MLC-1	1.69	.179	.0135
					MLC-5	1.67	.1795	.0165
					MLC-6	.852	--	--
					MLC-2	1.23	.180	.009
					MLC-3	1.66	.1785	.0175
					MLC-4	1.44	.1795	.010
	24-B	B-58	37,440	1.63	MLC-1	2.73	.157	.0055
					MLC-5	2.45	.158	.009
					MLC-6	1.21	--	--
					MLC-2	2.05	.157	.0075
					MLC-3	2.30	.158	.0145
					MLC-4	2.40	.157	.0125

Table C-III-1 (Continued)

Date	Mission No.	Aircraft	Altitude ft	Mach No.	Microphone No.	Δp lb/ft²	Δt sec.	Rise Time sec.
6-23-66	17-A	B-58	37,600	1.64	MLC-1	2.38	.1625	.0035
					MLC-5	2.24/2.37	.162	.005/.0065
					MLC-6	1.17	--	--
					MLC-2	2.17/2.22	.162	.010/.014
					MLC-3	2.35	.162	.0045
					MLC-4	2.92	.162	.001
	22-B	B-58	43,360	1.67	MLC-1	1.13/1.43	.1685	.0025/.016
					MLC-5	1.46	.168	.0065
					MLC-6	.859	--	--
					MLC-2	1.53/1.87	.168	.0025/.0055
					MLC-3	.877/1.60	.168	.002/.010
					MLC-4	1.76	.168	.0055
	31-A	B-58	37,480	1.64	MLC-1	1.11/1.92	.155	.0025/.016
					MLC-5	1.80 1.95	.155	.007/.011
					MLC-6	.990	--	--
					MLC-2	2.12	.155	.006
					MLC-3	2.03	.154	.008
					MLC-4	1.79 1.90	.155	.0015/.015
	33-A	B-58	43,200	1.64	MLC-1	1.20	.163	.005
					MLC-5	1.20 1.28	.164	.004/.007
					MLC-6	.755	--	--
					MLC-2	1.03 1.26	.162	.0055/.013
					MLC-3	.701 1.25	.163	.002/.013
					MLC-4	1.30	.164	.006
	20-B	B-58	37,400	1.65	MLC-1	1.67 1.93	.159	.006/.019
					MLC-5	1.88	.159	.005
					MLC-6	1.07	--	--
					MLC-2	1.97 2.27	.159	.003/.013
					MLC-3	2.26	.1595	.007
					MLC-4	3.17	.159	.0095
	36-B	B-58	37,460	1.66	MLC-1	4.37	.160	.015
					MLC-5	5.11	.1605	.006
					MLC-6	2.69	--	--
					MLC-2	4.21	.160	.0025
					MLC-3	7.65	.1595	.005
					MLC-4	6.12	.160	.005
	6X-2	B-58	43,520	1.67	MLC-1	1.61	.168	.019
					MLC-5	1.52	.168	.019
					MLC-6	--	--	--
					MLC-2	2.27	.168	.006
					MLC-3	1.51	.1675	.0135
					MLC-4	2.04	.168	.0125
6-1-66	2	F-104	No Tracking		MLC-1	1.19	.087	
					MLC-5	1.16	.087	
					MLC-6	.022	--	
					MLC-2	1.30	.087	
					MLC-3	1.26	.087	
					MLC-4	1.01	.087	

Table C-III-1 (Continued)

Date	Mission No.	Aircraft	Altitude ft	Mach No.	Microphone No.	Δp lb/ft^2	Δt sec.	Rise Time sec.
6-13-66	26-A	F-104	21,200	1.4	MLC-1	1.75	.0735	.0055
					MLC-5	1.74	.073	.0055
					MLC-6	.883	--	--
					MLC-2	1.88	.0735	.0035
					MLC-3	1.88	.0735	.0035
					MLC-4	1.93	.074	.0035
	26-B	F-104	29,660	1.6		Missed Boom		
6-14-66	26-A	F-104	No Tracking		MLC-1	2.10	.072	
					MLC-5	2.28	.072	
					MLC-6	1.03	--	
					MLC-2	1.72	.0715	
					MLC-3	2.15	.072	
					MLC-4	2.15	.0725	
	26-B	F-104	29,920	1.54	MLC-1	1.61	.080	.0065
					MLC-5	1.43	.0795	.0055
					MLC-6	.814	--	--
					MLC-2	1.48	.079	.013
					MLC-3	1.45	.0795	.007
					MLC-4	1.43	.079	.006
	38-A	F-104	No Tracking		MLC-1	2.07	.074	.004
					MLC-5	2.10	.074	.0055
					MLC-6	1.08	--	--
					MLC-2	1.94	.0735	.006
					MLC-3	1.94	.074	.004
					MLC-4	2.35	.074	.0045
	38-B	F-104	29,700	1.52	MLC-1	1.19	.0795	.019
					MLC-5	1.36	.0785	.0135
					MLC-6	.788	--	--
					MLC-2	1.63	.079	.0085
					MLC-3	1.36	.0795	.0095
					MLC-4	1.62	.0795	.0115
	37-A	F-104	29,700	1.49	MLC-1	1.30	.079	.009
					MLC-5	1.19	.0795	.004
					MLC-6	.788	--	--
					MLC-2	1.41	.079	.004
					MLC-3	1.28	.079	.008
					MLC-4	1.56	.0795	.007
	37-B	F-104	21,080	1.39	MLC-1	3.21*/2.93	.0755	.0005* .002
					MLC-5	2.60	.075	.004
					MLC-6	1.34	--	--
					MLC-2	2.67	.075	.0015
					MLC-3	--	--	--
					MLC-4	2.99	.075	.004
6-15-66	18-A	F-104	11,080	1.21	MLC-1	4.21	.080	.0005
					MLC-5	3.75	.0795	.0015
					MLC-6	1.99	--	--
					MLC-2	3.17	.080	.0035
					MLC-3	4.10	.080	.0005
					MLC-4	3.46	.0795	.004

Table C-III-1 (Continued)

Date	Mission No.	Aircraft	Altitude ft.	Mach No.	Microphone No.	Δp lb/ft^2	Δt sec.	Rise Time sec.
6-15-66	1X-B	F-104	28,140	1.5	MLC-1	1.32	.079	.009
					MLC-5	1.50	.079	.005
					MLC-6	.831	--	--
					MLC-2	1.62	.0785	.0005
					MLC-3	1.36	.079	.0055
					MLC-4	1.52	.0785	.0055
	2X-A	F-104	29,700	1.32	MLC-1	1.62	.090	.014
					MLC-5	1.63	.090	.0115
					MLC-6	--	--	--
					MLC-2	1.55	.0905	.007
					MLC-3	1.69	.090	.009
					MLC-4	1.76	.0905	.0125
	2X-B	F-104	14,080	1.20	MLC-1	4.27	.079	.0035
					MLC-5	4.44	.079	.004
					MLC-6	2.13	--	--
					MLC-2	4.30	.079	.004
					MLC-3	4.40	.0795	.004
					MLC-4	4.30	.079	.0035
	3X-A	F-104	29,100	1.58	MLC-1	1.15	.075	.0135
					MLC-5	1.19	.0755	.0105
					MLC-6	.631	--	--
					MLC-2	1.39	.0745	.0105
					MLC-3	1.20	.0755	.008
					MLC-4	1.23	.075	.0095
	3X-B	F-104	14,200	1.15	MLC-1	2.35	.077	.006
					MLC-5	2.28	.077	.006
					MLC-6	1.20	--	--
					MLC-2	2.10	.077	.0115
					MLC-3	2.29	.077	.010
					MLC-4	2.17	.0775	006
	4X-A	F-104	14,060	1.28	MLC-1	3.38	.0675	.0015
					MLC-5	3.28	.0685	.0055
					MLC-6	1.69	--	--
					MLC-2	3.20	.0675	.0035
					MLC-3	3.19	.0675	.0035
					MLC-4	3.49	.0675	.0035
	4X-B	F-104	29,880	1.62	MLC-1	3.29/2.56	.078	.0005/.004
					MLC-5	2.41	.0765	.0045
					MLC-6	1.20	--	--
					MLC-2	2.26	.077	.0045
					MLC-3	2.44	.077	.005
					MLC-4	2.46	.0775	.0035
6-16-66	27-A	F-104	29,300	1.65	MLC-1	1.28	.075	.0055
					MLC-5	1.48	.075	.004
					MLC-6	.797	--	--
					MLC-2	1.54	.075	.001
					MLC-3	1.45	.075	.0055
					MLC-4	1.52	.075	.004

Table C-III-1 (Continued)

Date	Mission No.	Aircraft	Altitude ft.	Mach No.	Microphone No.	Δp lb/ft^2	Δt sec.	Time Rise sec.
6-16-66	27-B	F-104	20,540	1.4	MLC-1	1,63	.074	.003
					MLC-5	1,61	.0735	.004
					MLC-6	.897	--	--
					MLC-2	1,95	.0735	.0035
					MLC-3	1,56	.0735	.005
					MLC-4	1,58	.0735	.0035
	5-X	F-104	29,700	1,65	MLC-4	1,93	.072	.005
					MLC-5	1,79	.072	.0045
					MLC-6	.964	--	--
					MLC-2	1,64	.071	.003
					MLC-3	1,71	.0715	.0045
					MLC-4	1,71	.072	.0045
6-22-66	28-B	F-104	20,820	1,35	MLC-1	2,65	.0775	.0135
					MLC-5	2,20	.078	.0085
					MLC-6	1,34	--	--
					MLC-2	2,15	.077	.0105
					MLC-3	3,46	.078	.0065
					MLC-4	2,98	.0775	.0085
	19-B	F-104	29,500	1.42	MLC-1	1.51	.0885	.0175
					MLC-5	2,05	.089	.0025
					MLC-6	1,03	--	--
					MLC-2	1,50	.0885	.008
					MLC-3	1,94	.0885	.0095
					MLC-4	1,99	.089	.0085
	30-B	F-104	29,720	1,37	MLC-1	1,01	.093	.0215
					MLC-5	.985	.094	.0255
					MLC-6	.139	--	--
					MLC-2	.724	.092	.0385
					MLC-3	.958	.0935	.0265
					MLC-4	1,02	.093	.0290
	41-A	F-104	29,600	1,39	MLC-1	1,31	.096	.018
					MLC-5	1,29	.0965	.0225
					MLC-6	.981	--	--
					MLC-2	1,45	.0945	.0215
					MLC-3	1,07	.0985	.011
					MLC-4	1,30	.0945	.021
	24-B	F-104	20,860	1,36	MLC-1	1,76	.0785	.012
					MLC-5	2,37* 1,69	.0775	.0005* .0135
					MLC-6	1,06	--	--
					MLC-2	1,76	.077	.007
					MLC-3	1,99	.078	.007
					MLC-4	2,90	.0775	.0025
	35-B	F-104	27,060	1,28	MLC-1	3,02	.0815	.005
					MLC-5	3,85	.082	.0035
					MLC-6	1,42	--	--
					MLC-2	2,24	.0825	.007
					MLC-3	2,50	.0815	.007
					MLC-4	1,82	.0805	.0045

Table C-III-1 (Continued)

Date	Mission No.	Aircraft	Altitude ft.	Mach No.	Microphone No.	Δp lb/ft²	Δt sec.	Rise Time sec.
6-22-66	25-A	F-104	21,900	1.39	MLC-1	1.21	.075	.007
					MLC-5	1.36	.075	.0065
					MLC-6	.719	--	--
					MLC-2	1.12	.078	.0095
					MLC-3	1.75	.075	.0014
					MLC-4	1.16	.075	.012
	23-A	F-104	29,725	1.51	MLC-1	.993	.083	.036
					MLC-5	.985	.084	.0195
					MLC-6	.901	-	--
					MLC-2	2.17	.084	.0045
					MLC-3	1.01	.083	.0225
					MLC-4	1.24	.0845	.0135
6-23-65	17-B	F-104	21,600	1.4	MLC-1	2.31	.076	.0015
					MLC-5	1.33/2.03	.0755	.002/.007
					MLC-6	.938	--	--
					MLC-2	1.43/1.48	.076	.002/.005
					MLC-3	1.93	.076	.0055
					MLC-4	1.82	.076	.002
	22-A	F-104	29,260	1.4	MLC-1	1.39/1.80	.083	.001/.0085
					MLC-5	1.22/1.51	.083	.0045
					MLC-6	.781	--	--
					MLC-2	1.55	.0825	.010
					MLC-3	1.28/1.43	.083	.0015/.006
					MLC-4	1.71*/1.52	.082	.001/.0045
	31-B	F-104	21,260	1.39	MLC-1	2.17	.076	.006
					MLC-5	1.02/2.08	.076	.0015/.013
					MLC-6	.547	--	--
					MLC-2	1.72/1.97	.076	.003/.0095
					MLC-3	1.93	.076	.013
					MLC-4	1.63/2.49	.076	.001/.006
	33-B	F-104	29,840	1.49	MLC-1	1.43	.084	.012
					MLC-5	1.61	.084	.011
					MLC-6	.885	--	--
					MLC-2	2.41	.084	.004
					MLC-3	1.85	.084	.010
					MLC-4	1.82/1.92	.084	.0085/.011
	20-A	F-104	21,520	1.37	MLC-1	1.86	.078	.011
					MLC-5	1.61/1.97	.080	.007/.012
					MLC-6	1.07	--	--
					MLC-2	.985/1.74	.079	.0025/.020
					MLC-3	2.14	.080	.003/.0095
					MLC-4	1.83	.079	.012
	36-A	F-104	20,860	1.39	MLC-1	1.93	.077	.002
					MLC-5	2.24	.077	.005
					MLC-6	1.28	--	-
					MLC-2	1.97/2.12	.077	.001/.0055
					MLC-3	1.85/2.14	.0765	.0045/.007
					MLC-4	1.70/2.04	.077	.003/.005

Table C-III-1 (Concluded)

Date	Mission No.	Aircraft	Altitude ft.	Mach No.	Microphone No.	Δp lb/ft^2	Δt sec.	Rise Time sec.
6-23-66	7-X	F-104	29,640	1.55	MLC-1	1.99	.081	.008
					MLC-5	1.70	.081	.016
					MLC-6	.806	--	--
					MLC-2	3.33	.082	.0075
					MLC-3	1.27/1.56	.0815	.009/.0205
					MLC-4	1.70	.081	.0135

* Moved into backyard of concrete blockhouse after June 6, 1966.

Table C-III-2

SUMMARY OF CRUCIFORM DATA - PHASE II

MSN	CHNL	HOUSE INSTR		TYPE	PEAK AMPLITUDES POSITIVE P1	P2	P3	NEGATIVE P1	P2	RISE TIME T1	T2	PER-IOD	WAVE ANGLE	GND SPD
-1	601	2	MLC1	2			3.06	2.29	2.50		.0015	.229	58.9	1342
1-1	603	2	MLC2	2			2.91	2.34	2.67		.0065	.229		
1-1	605	2	MLC3	2			2.78	2.22	2.39		.005	.229		
1-1	607	2	MLC4.	2			2.86	2.18	2.64		.002	.230		
1-1	609	2	MLC5	2			2.94	2.37	2.84		.003	.231		
1-1	611	2	MLC6				1.44							
1-3	601	2	MLC1	2			2.99	1.72	2.25		.005	.165	66.5	1242
1-3	603	2	MLC2	6		3.57	3.37	2.51	2.44	.0005	.005	.165		
1-3	605	2	MLC3	2			2.86	1.94	2.22		.003	.165		
1-3	607	2	MLC4	2			2.93	1.96	2.52		.007	.165		
1-3	609	2	MLC5	2			3.24	2.27	2.44		.005	.165		
1-3	611	2	MLC6				1.59							
1-4	601	2	MLC1	2			2.75	3.06	2.57		.0015	.082	58.7	1351
1-4	603	2	MLC2	6		3.51	3.07	3.67	2.81	.0005	.004	.081		
1-4	605	2	MLC3	4			3.85	4.29	2.62		.0005	.081		
1-4	607	2	MLC4	2			3.21	3.58	2.96		.003	.081		
1-4	609	2	MLC5	2			3.34	3.81	2.97		.0035	.081		
1-4	611	2	MLC6				1.78							
2-1	601	2	MLC1	2			2.37	1.96	1.38		.005	.237	79.4	1250
2-1	603	2	MLC2	3			2.23	1.97	1.48		.008	.237		
2-1	605	2	MLC3	4			2.82	2.11	1.30		.004	.236		
2-1	607	2	MLC4	3			2.25	1.75	1.45		.008	.237		
2-1	609	2	MLC5	4			3.09	2.32	1.63		.006	.237		
2-1	611	2	MLC6				1.52							
2-3	601	2	MLC1	3			2.15	1.62	2.30		.014	.153	50.9	1626
2-3	603	2	MLC2	3			2.21	1.61	2.15		.017	.153		
2-3	605	2	MLC3	3			2.32	1.83	2.14		.0075	.153		
2-3	607	2	MLC4	8		2.10	2.40	1.52	2.30	.001	.008	.153		
2-3	609	2	MLC5	3			2.52	1.43	2.40		.012	.153		
2-3	611	2	MLC6				0.99							
2-4	601	2	MLC1	4			3.96	4.22	2.76		.001	.079	54.3	1439
2-4	603	2	MLC2	4			3.71	4.12	2.79		.0005	.078		
2-4	605	2	MLC3	2			3.02	3.70	2.66		.004	.079		
2-4	607	2	MLC4	4			3.47	3.95	2.90		.002	.078		
2-4	609	2	MLC5	2			3.41	3.93	2.93		.002	.079		
2-4	611	2	MLC6				1.69							

Table C-III-2 (Continued)

MSN	CHNL	HOUSE INSTR	TYPE	PEAK AMPLITUDES POSITIVE P1	P2	P3	NEGATIVE P1	P2	RISE T1	TIME T2	PER-IOD	WAVE ANGLE	GND SPD
3-1	601	2 MLC1	2			2.66	2.08	1.75		.005	.153	53.6	1476
3-1	603	2 MLC2	2			2.46	1.99	1.89		.0055	.153		
3-1	605	2 MLC3	2			2.39	1.96	1.67		.005	.153		
3-1	607	2 MLC4	2			2.68	2.23	1.92		.0035	.153		
3-1	609	2 MLC5	2			2.56	2.10	1.90		.0055	.152		
3-1	611	2 MLC6				1.30							
3-2	601	2 MLC1	2			2.57	2.27	2.50		.005	.234	56.7	1384
3-2	603	2 MLC2	2			2.42	1.79	2.39		.005	.233		
3-2	605	2 MLC3	2			2.39	2.10	2.25		.005	.234		
3-2	607	2 MLC4	2			2.47	2.13	2.51		.0045	.234		
3-2	609	2 MLC5	2			2.53	2.23	2.63		.004	.234		
3-2	611	2 MLC6				1.30							
3-4	601	2 MLC1	A6	2.79		2.47	2.86	2.40	.001	.004	.077	56.1	1413
3-4	503	2 MLC2	2			2.32	2.76	2.36		.005	.077		
3-4	605	2 MLC3	2			2.25	2.79	2.32		.005	.077		
3-4	607	2 MLC4	2			2.34	2.68	2.37		.004	.077		
3-4	609	2 MLC5	2			2.42	2.76	2.33		.004	.077		
3-4	611	2 MLC6				1.26							
4-1	601	2 MLC1	3			2.30	1.87	2.04		.0135	.149	50.9	1476
4-1	603	2 MLC2	3			2.29	1.83	2.01		.015	.149		
4-1	605	2 MLC3	3			2.20	1.87	1.87		.014	.149		
4-1	607	2 MLC4	3			2.25	1.90	2.11		.014	.149		
4-1	609	2 MLC5	3			2.19	1.81	2.02		.0125	.149		
4-1	611	2 MLC6				.91							
4-2	601	2 MLC1	2			2.57	2.24	2.27		.005	.232	55.0	1399
4-2	503	2 MLC2	2			2.57	2.32	2.29		.005	.232		
4-2	605	2 MLC3	2			2.49	2.23	2.02		.005	.232		
4-2	607	2 MLC4	2			2.39	2.11	2.29		.006	.232		
4-2	609	2 MLC5	2			2.43	2.12	2.22		.005	.232		
4-2	611	2 MLC6				1.17							
5-1	601	2 MLC1	3			.70	.42	.62		.014	.173	75.5	1481
5-1	603	2 MLC2	3		.60	.70	.40	.67	.0005	.015	.173		
5-1	505	2 MLC3	3		.60	.67	.42	.60	.001	.015	.173		
5-1	607	2 MLC4	2			.67	.45	.67		.0045	.173		
5-1	609	2 MLC5	3			.67	.35	.64		.0165	.173		
5-1	611	2 MLC6				.32							

Table C-III-2 (Continued)

MSN	CHNL	HOUSE	INSTR	TYPE	PEAK AMPLITUDES POSITIVE P1	P2	P3	NEGATIVE P1	P2	RISE T1	TIME T2	PER-IOD	WAVE ANGLE	GND SPD
5-2	601	2	MLC1	2			1.25	.62	.81		.005	.283	52.0	2235
5-2	603	2	MLC2	2			1.16	.60	.93		.006	.284		
5-2	605	2	MLC3	2			1.14	.62	.76		.005	.283		
5-2	607	2	MLC4	2			1.24	.62	.89		.004	.283		
5-2	609	2	MLC5	2			1.20	.59	.82		.0045	.293		
5-2	611	2	MLC6				.61							
6-1	601	2	MLC1	3			1.29	.75	1.13		.021	.157	57.1	1533
6-1	603	2	MLC2	3			1.35	.83	1.21		.015	.157		
6-1	605	2	MLC3	3			1.30	.61	1.06		.015	.157		
6-1	607	2	MLC4	3			1.29	.70	1.21		.016	.158		
6-1	609	2	MLC5	3			1.31	.76	1.15		.014	.159		
6-1	611	2	MLC6				.532							
6-2	601	2	MLC1	2			1.67	.95	.97		.007	.284	52.3	2129
6-2	603	2	MLC2	2			1.75	.98	1.00		.0065	.284		
6-2	605	2	MLC3	2			1.91		.98		.0045	.284		
6-2	607	2	MLC4	2			1.39	1.03	1.05		.006	.284		
6-2	609	2	MLC5	2			1.69	.97	1.03		.0055	.284		
6-2	611	2	MLC6				.874							
7-1	601	2	MLC1										56.7	1630
7-1	603	2	MLC2	2			1.79	.91	1.30		.0055	.147		
7-1	605	2	MLC3	2			1.78	.91	1.20		.0055	.147		
7-1	607	2	MLC4											
7-1	609	2	MLC5	2			1.67	.91	1.23		.005	.147		
7-1	611	2	MLC6				.887							
7-3	601	2	MLC1										41.3	2273
7-3	603	2	MLC2	5		1.17	1.33	.51	.86	.0005	.006	.264		
7-3	605	2	MLC3	5		1.24	1.34	.56	.78	.001	.004	.264		
7-3	607	2	MLC4											
7-3	609	2	MLC5	2			1.29	.65	.85		.0045	.264		
7-3	611	2	MLC6				.679							
8-1	601	2	MLC1	2			2.44	2.14	2.25		.005	.163	45.0	1802
8-1	603	2	MLC2	2			2.50	2.23	2.32		.0055	.164		
8-1	605	2	MLC3	2			2.58		2.17		.0045	.164		
8-1	607	2	MLC4	2			2.12	2.00	2.34		.0075	.165		
8-1	609	2	MLC5	2			2.33	2.02	2.27		.005	.165		
8-1	611	2	MLC6				1.25							

Table C-III-2 (Continued)

MSN	CHNL	HOUSE INSTR	TYPE	PEAK AMPLITUDES POSITIVE P1	P2	P3	NEGATIVE P1	P2	RISE T1	TIME T2	PER-IOD	WAVE ANGLE	GND SPD
8-3	601	2 MLC1	3			1.39		.875		.008	.269	42.3	2439
8-3	603	2 MLC2	3			1.43		.930		.013	.270		
8-3	605	2 MLC3	3			1.37		.808		.013	.270		
8-3	607	2 MLC4	3			1.37		1.03		.008	.270		
8-3	609	2 MLC5	3			1.37		.866		.012	.269		
8-3	611	2 MLC6				.696							
9-1	601	2 MLC1	7	2.10	1.65	1.94	0.83	1.13	.0005	.005	.275	30.9	2381
9-1	603	2 MLC2	2			2.10	0.84	1.22		.0015	.276		
9-1	605	2 MLC3	5		2.03	2.24	0.79	1.24	.002	.005	.275		
9-1	607	2 MLC4	2			2.06	0.89	1.25		.0035	.272		
9-1	609	2 MLC5	2			2.10	1.06	1.30		.0035	.273		
9-1	611	2 MLC6				0.99							
9-2	601	2 MLC1	2			2.11	1.81	1.71		.003	.175	48.5	1538
9-2	603	2 MLC2	5		1.81	2.41	1.98	1.77	.0015	.005	.174		
9-2	605	2 MLC3	6		4.51	4.16	3.32	1.70		.0005	.174		
9-2	607	2 MLC4	2			2.34	2.06	1.94		.005	.174		
9-2	609	2 MLC5	2			2.51	2.20	1.87		.002	.174		
9-2	611	2 MLC6				1.32							
9-3	601	2 MLC1	2			1.60	1.92	1.58		.0055	.085	59.0	1333
9-3	603	2 MLC2	2			1.71	1.85	1.48		.0065	.085		
9-3	605	2 MLC3	3			1.41	1.66	1.39		.009	.084		
9-3	607	2 MLC4	2			1.37	1.69	1.47		.0075	.084		
9-3	609	2 MLC5	2			1.61	1.75	1.59		.0085	.085		
9-3	611	2 MLC6				0.75							
10-1	601	2 MLC1	2			2.32	1.01	1.54		.004	.262	28.4	2469
10-1	603	2 MLC2	2			2.41	1.17	1.70		.005	.263		
10-1	605	2 MLC3	2			2.33	1.07	1.54		.005	.263		
10-1	607	2 MLC4	2			2.47	1.11	1.75		.004	.263		
10-1	609	2 MLC5	2			2.52	1.19	1.75		.0035	.263		
10-1	611	2 MLC6				1.20							
10-2	601	2 MLC1	3			3.16	2.10	2.35		.0135	.185	73.8	1163
10-2	603	2 MLC2	2			3.29	2.26	2.65		.0055	.185		
10-2	605	2 MLC3	3			3.03	2.30	2.68		.017	.185		
10-2	607	2 MLC4	3			3.44	2.03	2.69		.016	.185		
10-2	609	2 MLC5	3			3.42	2.18	2.65		.014	.185		
10-2	611	2 MLC6				1.47							

Table C-III-2 (Continued)

MSN	CHNL	HOUSE INSTR	TYPE	PEAK AMPLITUDES POSITIVE P1	P2	P3	NEGATIVE P1	P2	RISE TIME T1	T2	PER- IOD	WAVE ANGLE	GND SPD
11-1	601	2 MLC1	2			2.12	2.47	2.12		.004	.073	50.2	1515
11-1	603	2 MLC2	2			1.98	2.35	2.01		.005	.073		
11-1	605	2 MLC3	5		1.72	1.89	2.26	1.95	.002	.0045	.073		
11-1	607	2 MLC4	2			1.96	2.32	2.04		.0045	.074		
11-1	609	2 MLC5	2			2.09	2.42	2.04		.0045	.074		
11-1	611	2 MLC6				.93							
11-2	601	2 MLC1	3			1.94	1.57	1.83		.005	.171	47.4	1533
11-2	603	2 MLC2	3			1.84	1.54	1.79		.005	.171		
11-2	605	2 MLC3	3			1.80	1.49	1.66		.005	.170		
11-2	607	2 MLC4	3			1.97	1.51	1.96		.0045	.170		
11-2	609	2 MLC5	2			1.97	1.52	1.76		.0045	.171		
11-2	611	2 MLC6				.84							
11-3	601	2 MLC1	2			2.23	1.33	1.59		.0045	.278	28.4	2381
11-3	603	2 MLC2	2			2.04	1.23	1.59		.005	.278		
11-3	605	2 MLC3	2			2.12	1.29	1.52		.0045	.278		
11-3	607	2 MLC4	2			2.12	1.34	1.59		.0045	.278		
11-3	609	2 MLC5	2			1.95	1.19	1.60		.0045	.278		
11-3	611	2 MLC6				.99							
12-1	601	2 MLC1	2			2.40	1.57	1.85		.006	.171	47.3	1538
12-1	603	2 MLC2	2			2.32	1.51	1.88		.0055	.172		
12-1	605	2 MLC3	5		2.21	2.43	1.54	1.84	.002	.005	.172		
12-1	607	2 MLC4	2			2.32	1.60	2.08		.006	.171		
12-1	609	2 MLC5	A5	2.92	2.07	2.51	1.40	1.87	.001	.004	.172		
12-1	611	2 MLC6				1.28							
12-2	601	2 MLC1	2			2.21	1.41	1.71		.0045	.290	27.9	2439
12-2	603	2 MLC2	2			2.14	1.51	1.71		.005	.289		
12-2	605	2 MLC3	2			2.29	1.57	1.73		.005	.289		
12-2	607	2 MLC4	2			2.28	1.65	1.72		.005	.290		
12-2	609	2 MLC5	2			2.04	1.46	1.66		.005	.290		
12-2	611	2 MLC6				.98							
12-3	601	2 MLC1	2			1.88	1.99	1.85		.0045	.076	51.2	1460
12-3	603	2 MLC2	A5	1.88	1.74	1.88		2.00	.0005	.006	.076		
12-3	605	2 MLC3	5		2.00	2.16	2.51	2.00	.001	.0055	.076		
12-3	607	2 MLC4	2			2.16	2.30	2.01		.005	.076		
12-3	609	2 MLC5	A6		2.19	2.01	2.13	1.93	.001	.005	.076		
12-3	611	2 MLC6				1.01							

Table C-III-2 (Continued)

MSN	CHNL	HOUSE	INSTR	TYPE	PEAK AMPLITUDES POSITIVE P1	POSITIVE P2	P3	NEGATIVE P1	NEGATIVE P2	RISE TIME T1	T2	PER-IOD	WAVE ANGLE	GND SPD
13-1	601	2	MLC1	3			2.31	1.59	1.82		.006	.159	47.7	1581
13-1	603	2	MLC2	2		1.92	2.17			.001	.005	.160		
13-1	605	2	MLC3	5		2.04	2.19	1.41	1.67	.0015	.005	.159		
13-1	607	2	MLC4	2			2.25	1.48	1.93		.004	.158		
13-1	609	2	MLC5	2			2.11	1.50	1.93		.0045	.158		
13-1	611	2	MLC6				1.08							
13-2	601	2	MLC1	3			2.00	1.21	1.59		.0075	.286	43.7	1778
13-2	603	2	MLC2	3			1.92				.0055	.286		
13-2	605	2	MLC3	2			2.17	1.25	1.54		.005	.287		
13-2	607	2	MLC4	3			1.95	1.19	1.73		.015	.287		
13-2	609	2	MLC5	3			1.97	1.17	1.69		.0065	.287		
13-2	611	2	MLC6				1.03							
13-3	601	2	MLC1	2			1.87	2.16	1.92		.0055	.074	56.0	1498
13-3	603	2	MLC2	2			2.05	2.42	2.07		.0055	.074		
13-3	605	2	MLC3	2			2.01	2.22	1.83		.005	.075		
13-3	607	2	MLC4	2			2.15	2.37	1.95		.0045	.074		
13-3	609	2	MLC5	2			1.95	2.25	1.97		.006	.075		
13-3	611	2	MLC6				0.98							
14-1	601	2	MLC1	3			2.02	1.22	1.65		.013	.312	43.7	1674
14-1	603	2	MLC2	3			2.01	1.25	1.68		.018	.312		
14-1	605	2	MLC3	2			2.17	1.41	1.64		.006	.311		
14-1	607	2	MLC4	2			2.26	1.36	1.79		.0045	.311		
14-1	609	2	MLC5	2			2.11	1.29	1.78		.005	.311		
14-1	611	2	MLC6				.933							
14-2	601	2	MLC1	6		3.36	2.70	1.62	1.82	.0005	.0035	.156	54.6	1423
14-2	603	2	MLC2	2			2.53	1.59	1.86		.005	.156		
14-2	605	2	MLC3	2			2.61	1.53	1.67		.005	.156		
14-2	607	2	MLC4	2			2.75	1.73	2.01		.0035	.156		
14-2	609	2	MLC5	2			2.62	1.56	1.87		.0035	.156		
14-2	611	2	MLC6				1.26							
14-3	601	2	MLC1	2			2.02	2.48	2.08		.005	.086	58.8	1347
14-3	603	2	MLC2	6		2.47	2.04	2.38	2.13	.0005	.002	.086		
14-3	605	2	MLC3	2			1.97	2.35	2.14		.005	.086		
14-3	607	2	MLC4	2			1.85	2.16	2.19		.002	.086		
14-3	609	2	MLC5	2		2.17	2.20	2.62	2.23	.0005	.004	.086		
14-3	611	2	MLC6				.963							

Table C-III-2 (Continued)

MSN	CHNL	HOUSE	INSTR	TYPE	PEAK AMPLITUDES POSITIVE P1			NEGATIVE P1		RISE T1	TIME T2	PER-IOD	WAVE ANGLE	GND SPD
					P1	P2	P3	P1	P2					
15-1	601	2	MLC1	2			2.32	1.64	1.78		.0055	.296	40.4	1739
15-1	603	2	MLC2	2			2.23	1.62	1.83		.005	.296		
15-1	605	2	MLC3	2			2.13	1.49	1.74		.006	.296		
15-1	607	2	MLC4	2			2.10	1.49	1.86		.004	.295		
15-1	609	2	MLC5	2			2.14	1.54	1.84		.0035	.295		
15-1	611	2	MLC6				1.05							
15-2	601	2	MLC1	2			2.29	1.81	2.01		.004	.163	45.7	1626
15-2	603	2	MLC2	2			2.32	1.91	2.03		.005	.163		
15-2	605	2	MLC3	2			2.32	1.85	1.96		.004	.162		
15-2	607	2	MLC4	2			2.38	1.83	2.10		.004	.163		
15-2	609	2	MLC5	2			2.38	1.90	2.08		.0045	.162		
15-2	611	2	MLC6				1.14							
15-3	601	2	MLC1	2			2.29	2.49	2.01		.004	.073	45.9	1550
15-3	603	2	MLC2	5		2.23	2.29	2.44	2.09	.0005	.005	.073		
15-3	605	2	MLC3	2			2.51	2.76	2.15		.004	.073		
15-3	607	2	MLC4	6		2.32	2.07	2.20	2.07	.0005	.002	.074		
15-3	609	2	MLC5	2			2.38	2.65	2.11		.004	.074		
15-3	611	2	MLC6				1.20							
16-1	601	2	MLC1	3			2.12	1.73	2.04		.007	.169	48.3	1550
16-1	603	2	MLC2	2			2.52	1.93	2.15		.005	.170		
16-1	605	2	MLC3	2			2.16	1.65	1.92		.0045	.170		
16-1	607	2	MLC4	2			2.17	1.73	2.32		.0045	.170		
16-1	609	2	MLC5	2			2.29	1.83	2.04		.0045	.170		
16-1	611	2	MLC6				1.10							
16-2	601	2	MLC1	2			2.29	1.41	1.70		.005	.298	41.5	1739
16-2	603	2	MLC2	2			2.24	1.47	1.93		.0055	.299		
15-2	605	2	MLC3	2			2.26	1.49	1.77		.0055	.298		
16-2	607	2	MLC4	2			2.27	1.46	1.88		.005	.299		
16-2	609	2	MLC5	2			2.41	1.56	1.92		.004	.299		
16-2	611	2	MLC6				1.13							
16-3	601	2	MLC1	2			1.95	2.06	1.81		.004	.076	54.4	1429
16-3	603	2	MLC2	2			2.09	2.06	1.87		.0005	.076		
16-3	605	2	MLC3	2			1.98	2.07	1.93		.004	.076		
16-3	607	2	MLC4	2			1.90	2.00	1.83		.004	.076		
16-3	609	2	MLC5	2			2.16	2.20	1.89		.001	.076		
16-3	611	2	MLC6				1.10							

Table C-III-2 (Continued)

MSN	CHNL	HOUSE INSTR	TYPE	PEAK AMPLITUDES					RISE TIME		PER-IOD	WAVE ANGLE	GND SPD
				POSITIVE			NEGATIVE						
				P1	P2	P3	P1	P2	T1	T2			
17-1	601	2 MLC1	3			1.04	0.87	1.04		.0065	.076	45.0	1667
17-1	603	2 MLC2	8		0.95	1.10	0.80	1.12	.0025	.006	.076		
17-1	605	2 MLC3	3			1.08		1.01		.006	.076		
17-1	607	2 MLC4	2			1.21		1.02		.004	.076		
17-1	609	2 MLC5	5		1.00	1.09		1.00	.0015	.006	.075		
17-1	611	2 MLC6				.60							
17-2	601	2 MLC1	3			1.59		1.38		.009	.188	48.7	1527
17-2	603	2 MLC2	3			1.70				.0065			
17-2	605	2 MLC3	3			1.59		1.46		.015	.188		
17-2	607	2 MLC4	3			1.66		1.39		.008	.189		
17-2	609	2 MLC5	8		1.23	1.64		1.46	.001	.0075	.189		
17-2	611	2 MLC6				.91							
18-1	601	2 MLC1	3			1.19		1.21		.015	.172	43.6	1535
18-1	603	2 MLC2	2			1.32				.0065	.173		
18-1	605	2 MLC3	3			1.30		1.24		.014	.173		
18-1	607	2 MLC4	3			1.25		1.25		.0085	.173		
18-1	609	2 MLC5	3			1.30		1.30		.008	.172		
18-1	611	2 MLC6				.70							
18-2	601	2 MLC1	2			1.14	1.12	1.00		.001	.072	44.4	1702
18-2	603	2 MLC2	2			1.19	1.46	1.15		.005	.073		
18-2	605	2 MLC3	2			1.19	1.37	1.06		.004	.072		
18-2	607	2 MLC4	2		1.02	1.15		1.07	.0005	.004	.073		
18-2	609	2 MLC5	2		1.14	1.16	1.27	1.11	.0015	.0045	.072		
18-2	611	2 MLC6				.68							
19-1	601	2 MLC1	2			1.47		1.21		.0045	.074	49.3	1639
19-1	603	2 MLC2	2			1.44		1.29		.005	.074		
19-1	605	2 MLC3	2			1.44	1.30	1.09		.0045	.075		
19-1	607	2 MLC4	2			1.71	1.64	1.39		.005	.075		
19-1	609	2 MLC5	2			1.42		1.23		.0045	.074		
19-1	611	2 MLC6				.74							
19-2	601	2 MLC1	3			2.03		1.72		.007	.155	52.6	1455
19-2	603	2 MLC2	3			2.19		1.76		.006	.154		
19-2	605	2 MLC3	7	2.41	2.12	2.24	1.37	1.68	.001	.005	.154		
19-2	607	2 MLC4	3			1.55	1.06	1.45		.005	.154		
19-2	609	2 MLC5	2			2.18		1.79		.0035	.154		
19-2	611	2 MLC6				1.02							

Table C-III-2 (Continued)

MSN	CHNL	HOUSE INSTR	TYPE	PEAK AMPLITUDES POSITIVE P1	POSITIVE P2	P3	NEGATIVE P1	NEGATIVE P2	RISE TIME T1	T2	PER-IOD	WAVE ANGLE	GND SPD
20-1	601	2 MLC1	3			1.77	1.16	1.40		.005	.161	52.3	1470
20-1	603	2 MLC2	5		1.75	1.92	1.11	1.38	.0015	.0055	.161		
20-1	605	2 MLC3	2			1.70	1.16	1.42		.005	.161		
20-1	607	2 MLC4	3			1.98		1.77		.005	.161		
20-1	609	2 MLC5	3			1.82	1.23	1.47		.004	.161		
20-1	611	2 MLC6				.92							
20-2	601	2 MLC1	3			1.24		1.28		.005	.074	47.0	1695
20-2	603	2 MLC2	3			1.24		1.44		.005	.073		
20-2	605	2 MLC3	2			1.27		1.27		.005	.073		
20-2	607	2 MLC4	2			1.45		1.52		.0045	.074		
20-2	609	2 MLC5	1			1.32		1.40		.005	.074		
20-2	611	2 MLC6				.68							
21-1	601	2 MLC1	3			1.08	0.43	0.90		.013	.182	51.2	1471
21-1	603	2 MLC2	8		0.84	1.00	0.40	0.84	.003	.032	.189		
21-1	605	2 MLC3	8		0.62	0.875	0.54	0.76	.002	.0055	.189		
21-1	607	2 MLC4	3			0.929	0.51	0.91		.0075	.189		
21-1	609	2 MLC5	8		0.76	0.907	0.47	0.74	.0025	.014			
21-1	611	2 MLC6				0.53							
22-1	601	2 MLC1	5		1.01	1.66	1.25	1.10	.0015	.006	.173	47.6	1587
22-1	603	2 MLC2	3			1.48	1.27	1.12		.011	.173		
22-1	605	2 MLC3	2			1.53	1.16	1.04		.0075	.173		
22-1	607	2 MLC4	2			1.73	1.47	1.15		.002	.174		
22-1	609	2 MLC5	5		1.35	1.56	1.21	1.15	.0025	.0075	.174		
22-1	611	2 MLC6				0.82							
23-1	601	2 MLC1	3			1.44	1.07	1.45		.0065	.190	49.8	1538
23-1	603	2 MLC2	2			1.77	1.38	1.57		.0025	.190		
23-1	605	2 MLC3	3			1.55		1.46		.020	.190		
23-1	607	2 MLC4	3			1.62	1.02	1.51		.015	.190		
23-1	609	2 MLC5	3			1.50	1.07	1.44		.017	.190		
23-1	611	2 MLC6				0.69							
24-1	601	2 MLC1	2			1.22	0.76	0.92		.004	.177	45.0	1667
24-1	603	2 MLC2	2			1.53	1.03	1.09		.010	.177		
24-1	605	2 MLC3	2			1.26	0.74	0.94		.0055	.176		
24-1	607	2 MLC4	2			1.39	0.94	1.15		.005	.176		
24-1	609	2 MLC5	2			1.33	0.89	1.00		.0075	.176		
24-1	611	2 MLC6				0.69							

Table C-III-2 (Continued

MSN	CHNL	HOUSE	INSTR	TYPE	PEAK AMPLITUDES POSITIVE P1	P2	P3	NEGATIVE P1	P2	RISE T1	TIME T2	PER-IOD	WAVE ANGLE	GND SPD
25-1	601	2	MLC1	3			1.74	1.07	1.25		.012	.186	45.0	1600
25-1	603	2	MLC2	7	2.00	1.77	1.91	1.38	1.55	.0005	.0135	.185		
25-1	605	2	MLC3	3			1.62	1.14	1.41		.014	.186		
25-1	607	2	MLC4	7	2.16	1.63	2.05	1.60	1.44	.0005	.0135	.186		
25-1	609	2	MLC5	4			2.21		1.36		.001	.185		
25-1	611	2	MLC6				0.93							
26-1	601	2	MLC1	2	2.08	1.83	2.08		1.54	.0005	.005	.196	53.7	1471
26-1	603	2	MLC2	2			2.15	1.41	1.58		.0025	.196		
26-1	605	2	MLC3	5		1.87	2.27	1.18	1.53	.0015	.004	.196		
26-1	607	2	MLC4	2			2.31	1.60	1.75		.0015	.196		
26-1	609	2	MLC5	2			2.28		1.70		.0045	.196		
26-1	611	2	MLC6				1.27							
27-2	601	2	MLC1	2			1.39	1.07	1.30		.003	.174	48.6	1600
27-2	603	2	MLC2	2			2.19	1.38	1.62		.005	.174		
27-2	605	2	MLC3	2			1.58	0.94	1.31		.003	.174		
27-2	607	2	MLC4	2			2.05	1.28	1.76		.008	.175		
27-2	609	2	MLC5	5		1.80	2.03	0.91	1.47	.0025	.006	.175		
27-2	611	2	MLC6				1.00							
28-2	601	2	MLC1	3			1.25	0.70	1.15		.004	.175	45.9	1613
28-2	603	2	MLC2	8		1.34	1.45	0.81	1.40	.002	.0075	.175		
28-2	605	2	MLC3	8		1.16	1.25	0.74	1.21	.002	.015	.175		
28-2	607	2	MLC4	5		1.65	1.67		1.38	.0005	.004	.174		
28-2	609	2	MLC5	8			1.33	0.76	1.18		.002	.174		
28-2	611	2	MLC6				0.84							
29-2	601	2	MLC1	2			1.65	1.36	1.22		.0055	.195	46.4	1587
29-2	603	2	MLC2	5		1.60	1.67	1.41	1.48	.0045	.015	.195		
29-2	605	2	MLC3	2			1.50	1.35	1.25		.005	.195		
29-2	607	2	MLC4	3			1.57	1.59	1.28		.008	.195		
29-2	609	2	MLC5	2			1.56	1.37	1.28		.005	.195		
29-2	611	2	MLC6				0.84							
30-2	601	2	MLC1	4			2.03	1.83	1.47		.0035	.186	43.9	1660
30-2	603	2	MLC2	5		2.17	3.16	2.34	1.51	.0005	.002	.186		
30-2	605	2	MLC3	4			1.70	1.21	1.38		.005	.186		
30-2	607	2	MLC4	4			2.96	2.51	1.45		.0015	.187		
30-2	609	2	MLC5	2			1.77	1.56	1.44		.012	.187		
30-2	611	2	MLC6				0.92							

Table C-III-2 (Continued)

MSN	CHNL	HOUSE INSTR	TYPE	PEAK AMPLITUDES POSITIVE P1	PEAK AMPLITUDES POSITIVE P2	PEAK AMPLITUDES POSITIVE P3	PEAK AMPLITUDES NEGATIVE P1	PEAK AMPLITUDES NEGATIVE P2	RISE TIME T1	RISE TIME T2	PER-IOD	WAVE ANGLE	GND SPD
31-2	601	2 MLC1	2			1.73	0.92	1.47		.0025	.187	48.6	1600
31-2	603	2 MLC2	3			1.86	1.07	1.72		.025	.187		
31-2	605	2 MLC3	3			1.58	1.01	1.52		.022	.187		
31-2	607	2 MLC4	3			1.73		1.51		.010	.187		
31-2	609	2 MLC5	5		1.74	1.78	0.94	1.51	.001	.022	.187		
31-2	611	2 MLC6				1.37							
32-2	601	2 MLC1	5		1.76	1.73	1.13	1.34	.001	.013	.179	49.0	1581
32-2	603	2 MLC2	5		1.34	1.74	0.91	1.58	.001	.0075	.179		
32-2	605	2 MLC3	2			1.77		1.36		.011	.178		
32-2	607	2 MLC4	2			2.00		1.55		.0025	.180		
32-2	609	2 MLC5	5		1.36	1.78	1.24	1.44	.0015	.005	.179		
32-2	611	2 MLC6				0.92							
33-1	601	2 MLC1	3			2.61	1.39	2.06		.0125	.168	50.0	1460
33-1	603	2 MLC2	3			2.26	1.48	2.17		.0175	.169		
33-1	605	2 MLC3	2			2.48	1.93	2.01		.007	.169		
33-1	607	2 MLC4	2			2.80	2.41	2.29		.0075	.168		
33-1	609	2 MLC5	3			2.29	1.54	2.11		.0155	.168		
33-1	611	2 MLC6				1.26							
34-1	601	2 MLC1	3			2.97	2.31	1.98		.011	.155	50.4	1504
34-1	603	2 MLC2	5		3.23	3.38	2.26	2.05	.001	.0055	.155		
34-1	605	2 MLC3	2			4.20	2.96	2.04		.0035	.154		
34-1	607	2 MLC4	2			3.44	2.50	2.35		.003	.154		
34-1	609	2 MLC5	2			3.62	2.41	2.05		.004	.154		
34-1	611	2 MLC6				1.79							
35-1	601	2 MLC1	3			2.68	1.29	1.98		.0165	.163	50.0	1527
35-1	603	2 MLC2	5		1.87	2.56	1.39	1.99	.0005	.005	.162		
35-1	605	2 MLC3	6		2.99	2.41	1.20	1.75		.001	.162		
35-1	607	2 MLC4	2			2.77	1.40	2.13		.005	.163		
35-1	609	2 MLC5	2			2.53	1.15	1.96		.003	.163		
35-1	611	2 MLC6				1.36							
36-1	601	2 MLC1	99	NO DATA FAILURE OF RECORDER									
36-1	603	2 MLC2	99	NO DATA FAILURE OF RECORDER									
36-1	605	2 MLC3	99	NO DATA FAILURE OF RECORDER									
36-1	607	2 MLC4	99	NO DATA FAILURE OF RECORDER									
36-1	609	2 MLC5	99	NO DATA FAILURE OF RECORDER									
36-1	611	2 MLC6	99	NO DATA FAILURE OF RECORDER									

Table C-III-2 (Continued)

MSN	CHNL	HOUSE	INSTR	TYPE	PEAK AMPLITUDES POSITIVE			NEGATIVE		RISE T1	TIME T2	PER-IOD	WAVE ANGLE	GND SPD
					P1	P2	P3	P1	P2					
37-1	601	2	MLC1	6		3.78	2.83	2.20	1.98		.0005	.162	50.4	1504
37-1	603	2	MLC2	5		2.20	2.65	1.51	1.99	.001	.005	.163		
37-1	605	2	MLC3	3			2.26	1.64	1.75		.007	.163		
37-1	607	2	MLC4	2			2.44	1.65	2.01		.004	.162		
37-1	609	2	MLC5	3			2.32	1.66	1.87		.004	.162		
37-1	611	2	MLC6				1.23							
38-1	601	2	MLC1	2			3.45	2.94	2.28		.004	.159	54.3	1439
38-1	603	2	MLC2	2			3.98	3.53	2.29		.003	.159		
38-1	605	2	MLC3	5		2.85	3.98	2.92	2.23	.001	.004	.158		
38-1	607	2	MLC4	2			3.41	3.02	2.38		.008	.158		
38-1	609	2	MLC5	2			3.71	3.32	2.32		.003	.159		
38-1	611	2	MLC6				2.39							
39-1	601	2	MLC1	3			2.90	2.24	1.87		.005	.158	52.3	1470
39-1	603	2	MLC2	5		2.90	3.08	2.41	2.05	.0025	.0055	.158		
39-1	605	2	MLC3	2			2.66	1.86	1.75		.008	.158		
39-1	607	2	MLC4	2			3.08	2.44	2.10		.007	.158		
39-1	609	2	MLC5	2			3.02	2.44	2.08		.004	.158		
39-1	611	2	MLC6				1.46							
40-1	601	2	MLC1	2			3.75	2.61	2.28		.002	.160	49.0	1538
40-1	603	2	MLC2	2			2.99		2.20		.0025	.160		
40-1	605	2	MLC3	2			3.10	2.23	1.86		.005	.160		
40-1	607	2	MLC4	6		4.39	3.84	2.77	2.47	.0005	.001	.160		
40-1	609	2	MLC5	2			3.74	2.53	2.26		.001	.160		
40-1	611	2	MLC6				1.69							
41-1	601	2	MLC1	2			2.74	1.68	1.59		.0015	.157	51.1	1538
41-1	603	2	MLC2	2			2.42		1.90		.005	.157		
41-1	605	2	MLC3	2			2.30		1.77		.004	.157		
41-1	607	2	MLC4	2			2.45	1.81	2.00		.0055	.158		
41-1	609	2	MLC5	2			2.67	1.92	1.96		.001	.158		
41-1	611	2	MLC6				1.44							
42-1	601	2	MLC1	2			2.60	1.35	1.96		.007	.168	50.2	1515
42-1	603	2	MLC2	2			2.33	1.75	2.02		.006	.168		
42-1	605	2	MLC3	6		3.32	2.56	1.93	1.69	.001	.0025	.168		
42-1	607	2	MLC4	2			2.24	1.57	2.03		.0055	.168		
42-1	609	2	MLC5	3			2.32	1.57	1.91		.013	.168		
42-1	611	2	MLC6				1.18							

Table C-III-2 (Continued)

MSN	CHNL	HOUSE INSTR	TYPE	PEAK AMPLITUDES POSITIVE P1	POSITIVE P2	P3	NEGATIVE P1	NEGATIVE P2	RISE TIME T1	T2	PER- IOD	WAVE ANGLE	GND SPD
43-2	601	2 MLC1	5		3.04	3.28	2.03	1.93	.001	.0055	.155	49.1	1504
43-2	603	2 MLC2	4			3.59	1.56	1.87		.0005	.156		
43-2	605	2 MLC3	2			2.33	1.06	1.59		.0055	.155		
43-2	607	2 MLC4	2			2.74	1.78	1.96		.007	.156		
43-2	609	2 MLC5	2			2.92		1.87		.0055	.156		
43-2	611	2 MLC6				1.42							
44-2	601	2 MLC1	2			2.74	1.82	2.13		.006	.167	49.9	1527
44-2	603	2 MLC2	3			2.40	1.60	2.02		.0135	.166		
44-2	605	2 MLC3	2			2.36	1.63	1.73		.005	.167		
44-2	607	2 MLC4	2			2.71	1.75	2.10		.002	.167		
44-2	609	2 MLC5	A5	2.73	2.02	2.62	1.87	2.06		.0005	.167		
44-2	611	2 MLC6				1.28							
45-1	601	2 MLC1	2			2.64	1.76	2.03		.012	.165	50.4	1504
45-1	603	2 MLC2	4			2.86	1.53	1.98		.001	.166		
45-1	605	2 MLC3	2			2.19	1.53	1.66		.005	.165		
45-1	607	2 MLC4	5		2.17	2.46	1.21	2.14	.0035	.0135	.165		
45-1	609	2 MLC5	2			2.54	1.80	2.02		.004	.165		
45-1	611	2 MLC6				1.28							
46-1	601	2 MLC1	3			2.50	1.55	1.79		.012	.166	58.7	1351
46-1	603	2 MLC2	2			2.44	1.53	1.75		.0075	.166		
46-1	505	2 MLC3	4			3.39	2.16	1.73		.0015	.166		
46-1	607	2 MLC4	2			3.06	2.10	1.99		.004	.167		
46-1	609	2 MLC5	5		2.58	2.66	1.50	1.87	.001	.0045	.167		
46-1	611	2 MLC6				1.62							
47-2	601	2 MLC1	2			2.64	1.62	1.76		.006	.158	48.7	1527
47-2	603	2 MLC2	2			2.48	1.60	1.79		.006	.158		
47-2	605	2 MLC3	3			1.93	1.20	1.53		.006	.157		
47-2	607	2 MLC4	3			2.28	1.42	1.85		.008	.158		
47-2	609	2 MLC5	2			2.25	1.53	1.80		.005	.158		
47-2	611	2 MLC6				1.28							
48-2	601	2 MLC1	3			2.33	1.39	2.06		.007	.165	52.3	1471
48-2	603	2 MLC2	2			2.71	1.98	2.06		.004	.166		
48-2	605	2 MLC3	2			2.86	1.86	1.79		.004	.166		
48-2	607	2 MLC4	2			2.78	1.99	2.21		.004	.166		
48-2	609	2 MLC5	2			2.73	2.39	2.10		.0045	.166		
48-2	611	2 MLC6				1.59							

Table C-III-2 (Continued)

MSN	CHNL	HOUSE	INSTR	TYPE	PEAK AMPLITUDES POSITIVE P1	P2	P3	NEGATIVE P1	P2	RISE TIME T1	T2	PER-IOD	WAVE ANGLE	GND SPD
49-2	601	2	MLC1	5		2.70	2.70	3.02	2.86	.001	.004	.100	76.6	1190
49-2	603	2	MLC2	3			2.74	3.08	2.68		.005	.099		
49-2	605	2	MLC3	5		2.47	2.53	2.91	2.72	.0015	.005	.100		
49-2	607	2	MLC4	2			2.46		2.80		.0065	.100		
49-2	609	2	MLC5	2			2.70	3.08	2.77		.0055	.100		
49-2	611	2	MLC6				1.36							
50-2	601	2	MLC1	2			3.08	3.47	2.76		.002	.085	68.4	1290
50-2	603	2	MLC2	2			3.14	3.29	2.80		.0025	.086		
50-2	605	2	MLC3	5		2.35	3.07	3.22	2.72	.0005	.0045	.085		
50-2	607	2	MLC4	5		3.52	3.80	4.11	3.02	.0005	.004	.086		
50-2	609	2	MLC5	5		2.80	2.92	3.14	2.83	.001	.005	.086		
50-2	611	2	MLC6				1.46							
51-2	601	2	MLC1	2			3.48	4.26	3.09		.006	.078	55.5	1375
51-2	603	2	MLC2	5		3.38	3.55	4.68	3.31	.0025	.006	.077		
51-2	605	2	MLC3	4			4.10	4.90	3.12		.0025	.077		
51-2	607	2	MLC4	2			3.36	3.71	3.13		.005	.078		
51-2	609	2	MLC5	4			4.07	4.78	3.25		.004	.078		
51-2	611	2	MLC6				1.91							
52-1	601	2	MLC1	5		3.14	3.51	4.62	3.14	.007	.014	.084	68.8	1290
52-1	603	2	MLC2	5		3.91	4.83	6.20	3.50	.0025	.0115	.084		
52-1	605	2	MLC3	3			2.67		2.84		.0055	.084		
52-1	607	2	MLC4	2			2.69	2.65	2.96		.0045	.084		
52-1	609	2	MLC5	5		2.86	3.20	3.45	3.23	.004	.018	.084		
52-1	611	2	MLC6				2.87							
53-1	601	2	MLC1	4			5.43	6.50	3.25		.0075	.085	70.3	1303
53-1	603	2	MLC2	2			3.15	3.75	3.46		.0105	.085		
53-1	605	2	MLC3	2			3.18	3.55	2.70		.013	.085		
53-1	607	2	MLC4	2			3.39	4.17	3.19		.006	.085		
53-1	609	2	MLC5	4			3.73	4.06	2.93		.0105	.085		
53-1	611	2	MLC6				4.27							
54-1	601	2	MLC1	2			4.07	4.72	3.81		.003	.079	53.7	1399
54-1	603	2	MLC2	2			4.17	4.52	4.10		.003	.079		
54-1	605	2	MLC3	2			3.55	4.00	3.34		.007	.079		
54-1	607	2	MLC4	2			3.88	4.48	3.79		.0025	.079		
54-1	609	2	MLC5	2			3.75	4.32	3.78		.004	.079		
54-1	611	2	MLC6				1.71							

Table C-III-2 (Continued)

MSN	CHNL	HOUSE	INSTR	TYPE	PEAK AMPLITUDES POSITIVE P1	PEAK AMPLITUDES POSITIVE P2	PEAK AMPLITUDES POSITIVE P3	PEAK AMPLITUDES NEGATIVE P1	PEAK AMPLITUDES NEGATIVE P2	RISE TIME T1	RISE TIME T2	PER-IOD	WAVE ANGLE	GND SPD
55-1	601	2	MLC1	2			2.82	3.30	2.96		.006	.076	52.3	1404
55-1	603	2	MLC2	5		2.62	2.81	3.51	2.92	.002	.0065	.077		
55-1	605	2	MLC3	A6		4.10	2.92	3.56	2.78	.0005	.006	.077		
55-1	607	2	MLC4	2			2.99	3.30	2.80		.0015	.077		
55-1	609	2	MLC5	2			2.84	3.44	2.88		.0035	.077		
55-1	611	2	MLC6				1.40							
56-1	601	2	MLC1	2			2.60	3.05	2.57		.0055	.081	59.2	1325
56-1	603	2	MLC2	2			2.92	3.09	2.51		.001	.081		
56-1	605	2	MLC3	2			2.50	2.94	2.46		.0025	.081		
56-1	607	2	MLC4	2			2.70	3.03	2.74		.004	.081		
56-1	609	2	MLC5	2			2.58	2.99	2.68		.003	.081		
56-1	611	2	MLC6				1.42							
57-1	601	2	MLC1	2			2.73	2.96	2.47		.002	.080	58.9	1342
57-1	603	2	MLC2	2			2.68	3.16	2.72		.0015	.080		
57-1	605	2	MLC3	2			2.42	2.86	2.50		.002	.079		
57-1	607	2	MLC4	2			2.49	2.74	2.63		.004	.079		
57-1	609	2	MLC5	2			2.89	3.33	2.68		.001	.079		
57-1	611	2	MLC6				1.46							
58-2	601	2	MLC1	2			2.15	2.22	2.04		.004	.076	60.6	1408
58-2	603	2	MLC2	A5	2.61	2.07	2.30	2.38	2.11	.0005	.005	.075		
58-2	605	2	MLC3	2			2.29	2.36	2.14		.005	.076		
58-2	607	2	MLC4	2			2.45	2.61	2.18		.005	.076		
58-2	609	2	MLC5	2			2.43	2.50	2.16		.004	.076		
58-2	611	2	MLC6				1.17							
59-2	601	2	MLC1	A5	2.87	2.47	2.58	2.87	2.33	.0005	.005	.075	59.3	1399
59-2	603	2	MLC2	2			2.46	2.84	2.50		.002	.075		
59-2	605	2	MLC3	2			2.62	2.96	2.40		.0045	.075		
59-2	607	2	MLC4	2			2.76	2.99	2.41		.0045	.075		
59-2	609	2	MLC5	2			2.65	2.88	2.39		.0035	.075		
59-2	611	2	MLC6				1.25							
60-2	601	2	MLC1	2			2.58		2.61		.005	.082	56.1	1347
60-2	603	2	MLC2	2			2.59	2.96	2.62		.005	.082		
60-2	605	2	MLC3	A6		4.06	2.60	2.85	2.46	.0005	.005	.082		
60-2	607	2	MLC4	2			2.54		2.69		.005	.082		
60-2	609	2	MLC5	2			2.54	2.69	2.62		.0035	.082		
60-2	611	2	MLC6				1.36							

Table C-III-2 (Continued)

MSN	CHNL	HOUSE	INSTR	TYPE	PEAK AMPLITUDES POSITIVE P1	P2	P3	NEGATIVE P1	P2	RISE TIME T1	T2	PER-IOD	WAVE ANGLE	GND SPD
61-1	601	2	MLC1	3			1.16		1.36		.005	.078	46.4	1587
61-1	603	2	MLC2	3			1.18		1.32		.0055	.077		
61-1	605	2	MLC3	2			1.26	1.38	1.28		.004	.078		
61-1	607	2	MLC4	2			1.26		1.41		.004	.078		
61-1	609	2	MLC5	2			1.21		1.39		.005	.078		
61-1	611	2	MLC6				0.59							
62-1	601	2	MLC1	2			1.81		1.76		.005	.079	41.7	1660
62-1	603	2	MLC2	2			1.83		1.79		.005	.079		
62-1	505	2	MLC3	2			1.79		1.73		.005	.079		
62-1	607	2	MLC4	2			1.73	1.69	1.79		.005	.079		
62-1	609	2	MLC5	2			1.85		1.83		.004	.079		
62-1	611	2	MLC6				.89							
63-1	601	2	MLC1	2			1.79	1.67	1.70		.005	.080	44.8	1613
63-1	603	2	MLC2	2			1.85	1.77	1.83		.005	.080		
63-1	605	2	MLC3	2			1.69	1.59	1.65		.005	.079		
63-1	607	2	MLC4	2			1.75	1.63	1.79		.005	.080		
63-1	609	2	MLC5	2			1.81	1.73	1.85		.005	.080		
63-1	611	2	MLC6				.87							
64-2	601	2	MLC1	2			1.55	1.91	1.72		.007	.077	47.7	1515
64-2	603	2	MLC2	2			1.55	1.91	1.78		.0025	.078		
64-2	605	2	MLC3	2			1.50	1.76	1.57		.0055	.078		
64-2	607	2	MLC4	3			1.51	1.81	1.63		.008	.077		
64-2	609	2	MLC5	3			1.49		1.62		.007	.078		
64-2	611	2	MLC6				.746							
65-2	601	2	MLC1	3			1.09	.62	.83		.016	.084	73.6	1471
65-2	603	2	MLC2	3			.96	.48	.94		.010	.084		
65-2	605	2	MLC3	3			1.21	.52	.99		.018	.083		
65-2	607	2	MLC4	3			1.19	.66	1.04		.0165	.085		
65-2	609	2	MLC5	3			1.01	.31	.80		.013	.085		
65-2	611	2	MLC6				1.13							
66-2	601	2	MLC1	3			1.17	.91	.76		.023	.078	71.4	1498
66-2	603	2	MLC2	3			1.00	.92	.76		.0185	.078		
66-2	605	2	MLC3	3			.88	.73	.69		.015	.078		
66-2	607	2	MLC4	3			1.00	.83	.70		.022	.079		
66-2	609	2	MLC5	2			1.07	.70	.66		.0205	.078		
66-2	611	2	MLC6				.375							

Table C-III-2 (Continued)

MSN	CHNL	HOUSE	INSTR	TYPE	PEAK AMPLITUDES					RISE TIME		PER-IOD	WAVE ANGLE	GND SPD
					POSITIVE			NEGATIVE		T1	T2			
					P1	P2	P3	P1	P2					
67-1	601	2	MLC1	5		1.47	1.75	1.67	1.51	.005	.0095	.082	43.3	1633
67-1	603	2	MLC2	2			1.93	1.75	1.54		.0055	.083		
67-1	605	2	MLC3	2			1.38	1.29	1.43		.0080	.083		
67-1	607	2	MLC4	4			2.08	1.89	1.72		.005	.083		
67-1	609	2	MLC5	2			1.68	1.47	1.53		.006	.083		
67-1	611	2	MLC6				.71							
68-1	601	2	MLC1	A6		1.71	1.63		1.56	.001	.005	.082	45.8	1619
68-1	603	2	MLC2	2			1.56		1.49		.005	.081		
68-1	605	2	MLC3	5		1.39	1.62	1.48	1.71	.002	.0065	.082		
68-1	607	2	MLC4	5		1.53	1.75	1.70	1.58	.0015	.005	.081		
68-1	609	2	MLC5	2			1.68	1.65	1.53		.005	.081		
68-1	611	2	MLC6				.765							
69-1	601	2	MLC1	2			1.16	1.36	1.26		.005	.078	42.8	1660
69-1	603	2	MLC2	2			1.19	1.39	1.30		.0055	.078		
69-1	605	2	MLC3	2			1.18	1.44	1.25		.0055	.078		
69-1	607	2	MLC4	2			1.25	1.48	1.36		.0045	.078		
69-1	609	2	MLC5	2			1.20	1.39	1.31		.004	.077		
69-1	611	2	MLC6				.56							
70-2	601	2	MLC1	2			1.36		1.47		.005	.074	42.2	1695
70-2	603	2	MLC2	2			1.28		1.40		.0055	.074		
70-2	605	2	MLC3	2			1.40	1.68	1.45		.005	.075		
70-2	607	2	MLC4	2			1.40	1.52	1.42		.005	.074		
70-2	609	2	MLC5	2			1.36	1.48	1.43		.005	.074		
70-2	611	2	MLC6				.598							
71-2	601	2	MLC1	2			1.42	1.31	1.56		.005	.083	44.8	1613
71-2	603	2	MLC2	2			1.43		1.57		.0055	.083		
71-2	605	2	MLC3	2			1.40		1.52		.006	.083		
71-2	607	2	MLC4	2			1.40	1.47	1.54		.006	.083		
71-2	609	2	MLC5	2			1.41	1.27	1.32		.006	.082		
71-2	611	2	MLC6				.670							
72-2	601	2	MLC1	3			1.18	1.40	1.22		.014	.092	55.2	1389
72-2	603	2	MLC2	3			1.14	1.40	1.26		.014	.091		
72-2	605	2	MLC3	3			1.14	1.40	1.28		.014	.091		
72-2	607	2	MLC4	3			1.18	1.42	1.32		.013	.090		
72-2	609	2	MLC5	3			1.17	1.31	1.24		.013	.091		
72-2	611	2	MLC6				.550							

Table C-III-2 (Continued)

MSN	CHNL	HOUSE	INSTR	TYPE	PEAK AMPLITUDES POSITIVE P1	POSITIVE P2	POSITIVE P3	NEGATIVE P1	NEGATIVE P2	RISE TIME T1	RISE TIME T2	PER-IOD	WAVE ANGLE	GND SPD
73-1	601	2	MLC1	3			.762	.58	.67		.007	.103	55.2	1389
73-1	603	2	MLC2	3			.761	.64	.72		.007	.103		
73-1	605	2	MLC3	3			.756	.60	.68		.0065	.104		
73-1	607	2	MLC4	3			.776	.64	.78		.008	.104		
73-1	609	2	MLC5	3			.761	.62	.73		.0065	.103		
73-1	611	2	MLC6				.374							
74-1	601	2	MLC1	2			0.91	0.91	0.85		.002	.115	62.2	1316
74-1	603	2	MLC2	2			0.98	0.88	0.80		.007	.115		
74-1	605	2	MLC3	2			1.06	0.97	0.86		.005	.113		
74-1	607	2	MLC4	2			1.02	0.93	0.91		.0035	.115		
74-1	609	2	MLC5	2			0.97	0.94	0.84		.004	.114		
74-1	611	2	MLC6				0.48							
75-1	601	2	MLC1	3			.817	.63	.78		.007	.103	55.6	1370
75-1	603	2	MLC2	3			.866	.70	.83		.007	.103		
75-1	605	2	MLC3	2			.828	.67	.83		.006	.103		
75-1	607	2	MLC4	NO DATA										
75-1	609	2	MLC5	2			.877	.71	.90		.0045	.103		
75-1	611	2	MLC6				.406							
76-2	601	2	MLC1	3			.845	.54	.78		.015	.106	62.4	1307
76-2	603	2	MLC2	3			.801		.80		.015	.105		
76-2	605	2	MLC3	8		.542	.754	.57	.71	.002	.008	.105		
76-2	607	2	MLC4	3			.839		.84		.0135	.105		
76-2	609	2	MLC5	3			.821		.79		.013	.105		
76-2	611	2	MLC6				.418							
77-2	601	2	MLC1	2			1.10	.81	.91		.0045	.116	62.5	1299
77-2	603	2	MLC2	2			1.15	.88	.92		.008	.115		
77-2	605	2	MLC3	2			1.05	.77	.85		.0065	.115		
77-2	607	2	MLC4	2			1.04	.81	.98		.007	.115		
77-2	609	2	MLC5	2			1.10	.79	.98		.004	.115		
77-2	611	2	MLC6				.48							
78-2	601	2	MLC1	5		1.96	2.19	2.06	1.25	.011	.0125	.110	63.2	1262
78-2	603	2	MLC2	4			2.40	2.02	1.28		.0105	.110		
78-2	605	2	MLC3	4			2.20	2.31	1.36		.0065	.109		
78-2	607	2	MLC4	4				3.06	1.53			.110		
78-2	609	2	MLC5	4			2.71	2.71	1.41		.0105	.111		
78-2	611	2	MLC6				1.32							

Table C-III-2 (Continued)

MSN	CHNL	HOUSE INSTR	TYPE	PEAK AMPLITUDES POSITIVE P1	P2	P3	NEGATIVE P1	P2	RISE T1	TIME T2	PER-IOD	WAVE ANGLE	GND SPD
79-1	601	2 MLC1	8		.51	.52	.33	.46	.0075	.0175	.114	53.1	1307
79-1	603	2 MLC2	3			.54	.26	.48		.027	.115		
79-1	605	2 MLC3	3			.54	.37	.50		.015	.114		
79-1	607	2 MLC4	3			.60	.39	.54		.0105	.115		
79-1	609	2 MLC5	3			.54	.32	.48		.023	.115		
79-1	611	2 MLC6											
80-1	601	2 MLC1	2			.870	.79	.70		.005	.108	54.7	1413
80-1	603	2 MLC2	2			.806	.70	.67		.006	.108		
80-1	605	2 MLC3	2			.867	.72	.65		.0065	.108		
80-1	607	2 MLC4	2			.863		.72		.0045	.108		
80-1	609	2 MLC5	2			.864		.67		.0045	.108		
80-1	611	2 MLC6				.407							
81-1	601	2 MLC1	2			.815	.72	.62		.005	.103	51.1	1465
81-1	603	2 MLC2	A5	.865	.701	.760	.70	.57	.0005	.006	.103		
81-1	605	2 MLC3	4			.878	.69	.56		.001	.103		
81-1	607	2 MLC4	5		.803	.803	.66	.62	.0015	.0045	.103		
81-1	609	2 MLC5	2			.876	.73	.62		.005	.103		
81-1	611	2 MLC6				.419							
82-2	601	2 MLC1	2			.92	.83	.71		.005	.104	53.5	1408
82-2	603	2 MLC2	2			.92	.75	.68		.0055	.103		
82-2	605	2 MLC3	2			.87	.75	.67		.0055	.104		
82-2	607	2 MLC4	2			.89	.74	.74		.006	.103		
82-2	609	2 MLC5	2			.95	.77	.72		.004	.104		
82-2	611	2 MLC6				.45							
83-2	601	2 MLC1	2			.839	.63	.77		.0065	.106	53.1	1418
83-2	603	2 MLC2	2			.862	.68	.80		.006	.105		
83-2	605	2 MLC3	2			.911	.72	.81		.006	.106		
83-2	607	2 MLC4	2			.889	.67	.82		.005	.106		
83-2	609	2 MLC5	2			.695	.50	.62		.005	.106		
83-2	611	2 MLC6				.527							
84-2	601	2 MLC1	2			.783	.60	.65		.0065	.102	54.5	1428
84-2	603	2 MLC2	2			.736	.56	.67		.006	.102		
84-2	605	2 MLC3	5		.755	.822	.56	.70	.001	.0055	.103		
84-2	607	2 MLC4	2			.755	.56	.70		.0045	.103		
84-2	609	2 MLC5	2			.745	.54	.67		.005	.102		
84-2	611	2 MLC6				.419							

Table C-III-2 (Continued)

MSN	CHNL	HOUSE	INSTR	TYPE	PEAK AMPLITUDES POSITIVE P1	POSITIVE P2	POSITIVE P3	NEGATIVE P1	NEGATIVE P2	RISE TIME T1	RISE TIME T2	PER-IOD	WAVE ANGLE	GND SPD
85-1	601	2	MLC1	2			2.24	1.39	1.80		.0025	.156	51.0	1563
85-1	603	2	MLC2	2			2.29	1.48	1.94		.0015	.156		
85-1	605	2	MLC3	3			2.04	1.24	1.69		.006	.155		
85-1	607	2	MLC4	2			2.44	1.52	1.95		.0035	.156		
85-1	609	2	MLC5	7	2.32	1.93	2.08	1.27	1.84	.0003	.013	.157		
85-1	611	2	MLC6				1.03							
86-1	601	2	MLC1	2			2.94	2.02	1.84		.0055	.157	50.1	1521
86-1	603	2	MLC2	5		2.84	2.78	2.05	1.90	.0005	.006	.157		
86-1	605	2	MLC3	3			2.30	1.42	1.61		.010	.157		
86-1	607	2	MLC4	2			2.56	1.77	1.98		.003	.157		
86-1	609	2	MLC5	2			2.59		1.81		.0075	.157		
86-1	611	2	MLC6				1.30							
87-1	601	2	MLC1	3			2.31	1.82	2.05		.004	.169	50.3	1509
87-1	603	2	MLC2	8		2.05	2.12	1.49	2.12	.001	.0055	.170		
87-1	605	2	MLC3	3			2.23	1.73	2.00		.005	.170		
87-1	607	2	MLC4	3			2.32	1.91	2.38		.007	.170		
87-1	609	2	MLC5	3			2.07	1.62	2.15		.005	.170		
87-1	611	2	MLC6				1.17							
88-1	601	2	MLC1	2			2.41	1.49	1.92		.004	.160	51.0	1470
88-1	603	2	MLC2	3			2.19	1.41	1.90		.0075	.160		
88-1	605	2	MLC3	2			2.53	1.57	1.96		.005	.160		
88-1	607	2	MLC4	3			2.19		1.97		.02	.161		
88-1	609	2	MLC5	2			2.26	1.36	1.88		.004	.161		
88-1	611	2	MLC6				1.10							
113-1	601	2	MLC1	A6		3.09	2.60	2.21	1.93	.0005	.0045	.164	50.6	1493
113-1	603	2	MLC2	2			2.64	1.25	1.97		.005	.164		
113-1	605	2	MLC3	5		2.43	2.64	1.48	2.02	.001	.005	.163		
113-1	607	2	MLC4	2			2.44	1.40	2.01		.0015	.164		
113-1	609	2	MLC5	5		2.57	2.71	1.66	1.90	.0015	.004	.164		
113-1	611	2	MLC6				1.49							
113-2	601	2	MLC1	2			2.26	1.55	1.77		.005	.313	41.8	1717
113-2	603	2	MLC2	2			2.29	1.57	1.88		.0055	.313		
113-2	605	2	MLC3	5		1.89	2.21	1.32	1.84	.001	.0055	.313		
113-2	607	2	MLC4	2			2.13	1.48	1.94		.004	.313		
113-2	609	2	MLC5	2			2.10	1.43	1.81		.004	.313		
113-2	611	2	MLC6				1.07							

MSN	CHNL	HOUSE INSTR	TYPE	PEAK AMPLITUDES POSITIVE P1	P2	P3	NEGATIVE P1	P2	RISE TIME T1	T2	PER-IOD	WAVE ANGLE	GND SPD
113-3	601	2 MLC1	8		1.60	1.74	1.66	1.82	.001	.0065	.079	57.6	1408
113-3	603	2 MLC2	5		1.88	1.94	2.06	1.91	.001	.005	.078		
113-3	605	2 MLC3	A6		2.21	2.10	2.43	2.00	.0005	.005	.078		
113-3	607	2 MLC4	2			1.91	1.96	1.89		.002	.078		
113-3	609	2 MLC5	2			2.04	2.13	1.84		.004	.078		
113-3	611	2 MLC6				1.07							
117-1	601	2 MLC1	6		3.72	3.02	3.94	2.16		.001	.077	46.2	1575
117-1	603	2 MLC2	7	2.97	2.06	2.[illegible]3	3.13	2.23	.0015	.0035	.077		
117-1	605	2 MLC3	5		1.23	2.25	2.50	1.79	.002	.009	.077		
117-1	607	2 MLC4	4			2.55	2.89	1.90		.003	.077		
117-1	609	2 MLC5	4			2.78	2.91	2.02		.0025	.078		
117-1	611	2 MLC6				1.25							
117-2	601	2 MLC1	2			1.97	1.35	1.47		.006	.194	53.9	1460
117-2	603	2 MLC2	A3			1.94		1.43		.018	.193		
117-2	605	2 MLC3	3			1.65		1.31		.014	.193		
117-2	607	2 MLC4	2			2.02		1.48		.007	.193		
117-2	609	2 MLC5	A3			1.78	1.26	1.41		.0175	.193		
117-2	611	2 MLC6				.92							
118-1	601	2 MLC1	2			2.20	1.01	1.72		.007	.185	50.7	1550
118-1	603	2 MLC2	4			2.39	1.07	1.68		.005	.185		
118-1	605	2 MLC3	4			2.29	1.02	1.60		.009	.185		
118-1	607	2 MLC4	2			2.32	1.29	1.81		.007	.186		
118-1	609	2 MLC5	4			2.60	1.69	1.15		.005	.186		
118-1	611	2 MLC6				1.29							
118-2	601	2 MLC1	6		2.15	1.78	1.55	1.89		.001	.074	44.5	1626
118-2	603	2 MLC2	2			1.97	1.90	2.10		.005	.075		
118-2	605	2 MLC3	2			1.83		1.85		.007	.075		
118-2	607	2 MLC4	3			1.64	1.10	1.79		.016	.075		
118-2	609	2 MLC5	2			1.67	1.58	1.93		.0055	.074		
118-2	611	2 MLC6				.81							
119-1	601	2 MLC1	7	2.55	1.79	2.22	1.12	.87	.002	.0085	.078	44.8	1681
119-1	603	2 MLC2	2			2.28	1.01	.82		.006	.077		
119-1	605	2 MLC3	6		2.24	2.04	.84	.81		.0025	.077		
119-1	607	2 MLC4	5		1.51	2.21	1.17	.94	.003	.015	.077		
119-1	609	2 MLC5	5		1.77	2.32	1.12	.84	.0025	.0135	.077		
119-1	611	2 MLC6				.92							

Table C-III-2 (Continued)

[illegible]	CHNL	HOUSE INSTR	TYPE	PEAK AMPLITUDES POSITIVE P1	P2	P3	NEGATIVE P1	P2	RISE T1	TIME T2	PER-IOD	WAVE ANGLE	GND SPD
121-1	601	2 MLC1	2			1.45	1.41	1.24		.005	.175	47.1	1619
121-1	603	2 MLC2	4			1.81	1.33	1.52		.001	.175		
121-1	605	2 MLC3	2			1.62	1.20	1.33		.005	.175		
121-1	607	2 MLC4	4			1.97	1.63	1.60		.0065	.174		
121-1	609	2 MLC5	4			1.75	1.42	1.47		.0075	.174		
121-1	611	2 MLC6				0.93							
122-1	601	2 MLC1	2			1.43	1.00	1.14		.008	.182	53.5	1481
122-1	603	2 MLC2	2			1.46	.84	1.16		.016	.183		
122-1	605	2 MLC3	3			1.23		1.11		.016	.182		
122-1	607	2 MLC4	3			1.31		1.28		.0185	.183		
122-1	609	2 MLC5	3			1.36		1.05		.020	.183		
122-1	611	2 MLC6				.75							
123-1	601	2 MLC1	4			1.90	1.24	1.38		.004	.214	55.6	1370
123-1	603	2 MLC2	2			1.38	1.02	1.30		.007	.215		
123-1	605	2 MLC3	2			1.54		1.29		.004	.215		
123-1	607	2 MLC4	2			1.66	1.26	1.45		.005	.215		
123-1	609	2 MLC5	2			1.75	1.03	1.24		.002	.216		
123-1	611	2 MLC6				.98							
124-1	601	2 MLC1	2			2.38	1.85	1.52		.006	.200	52.1	1413
124-1	603	2 MLC2	6		2.25	2.07	1.26	1.52	.001	.005	.199		
124-1	605	2 MLC3	5		1.67	1.95		1.47	.001	.005	.199		
124-1	607	2 MLC4	2			1.91	1.24	1.64		.006	.200		
124-1	609	2 MLC5	2			2.06	1.34	1.48		.006	.199		
124-1	611	2 MLC6				1.12							
125-1	601	2 MLC1	8		1.16	1.85	.83	1.64	.001	.013	.204	57.8	1399
125-1	603	2 MLC2	3			2.05		2.05		.015	.204		
125-1	605	2 MLC3	5		2.06	2.29	1.59	1.52	.003	.014	.205		
125-1	607	2 MLC4	3			1.84	1.22	1.76		.015	.205		
125-1	609	2 MLC5	2			1.94	1.43	1.55		.010	.205		
125-1	611	2 MLC6				1.12							
126-1	601	2 MLC1	3			1.79	.93	1.51		.018	.200	53.3	1418
126-1	603	2 MLC2	3			1.63	1.10	1.50		.010	.200		
126-1	605	2 MLC3	8		1.37	1.59	.77	1.54	.0025	.015	.199		
126-1	607	2 MLC4	3			1.67		1.62		.016	.200		
126-1	609	2 MLC5	3			1.62		1.47		.019	.199		
126-1	611	2 MLC6				.83							

Table C-III-2 (Continued)

MSN	CHNL	HOUSE	INSTR	TYPE	PEAK AMPLITUDES POSITIVE P1	PEAK AMPLITUDES POSITIVE P2	PEAK AMPLITUDES POSITIVE P3	PEAK AMPLITUDES NEGATIVE P1	PEAK AMPLITUDES NEGATIVE P2	RISE TIME T1	RISE TIME T2	PER-IOD	WAVE ANGLE	GND SPD
127-2	601	2	MLC1	3			1.54	1.06	1.54		.021	.198	55.5	1374
127-2	603	2	MLC2	3			1.44	1.02	1.50		.016	.198		
127-2	605	2	MLC3	3			1.48	.88	1.45		.023	.198		
127-2	607	2	MLC4	3			1.43	1.03	1.65		.008	.198		
127-2	609	2	MLC5	3			1.44	.95	1.47		.023	.198		
127-2	611	2	MLC6				.70							
128-2	601	2	MLC1	2			2.42	1.89	2.13		.0065	.184	58.9	1338
128-2	603	2	MLC2	5		2.26	2.68	1.78	1.99	.002	.0085	.184		
128-2	605	2	MLC3	2			2.60	1.92	1.98		.006	.184		
128-2	607	2	MLC4	5		2.70	2.70	1.91	2.14	.002	.0055	.184		
128-2	609	2	MLC5	2			2.68	2.01	2.11		.0065	.184		
128-2	611	2	MLC6				1.91							
129-2	601	2	MLC1	2			1.94	1.56	1.59		.008	.190	50.9	1476
129-2	603	2	MLC2	2			1.84	1.50	1.59		.0075	.190		
129-2	605	2	MLC3	2			1.73	1.37	1.56		.006	.190		
129-2	607	2	MLC4	3			1.65	1.58	1.69		.0145	.190		
129-2	609	2	MLC5	2			1.80	1.39	1.62		.006	.190		
129-2	611	2	MLC6				.90							
130-2	601	2	MLC1	2			2.12	1.51	1.81		.006	.192	52.3	1470
130-2	603	2	MLC2	2			2.01	1.36	1.76		.0065	.192		
130-2	605	2	MLC3	3			1.87	1.59	1.91		.0125	.192		
130-2	607	2	MLC4	3			1.95	1.36	1.75		.009	.192		
130-2	609	2	MLC5	3			1.88	1.44	1.88		.0105	.191		
130-2	611	2	MLC6				.99							
131-2	601	2	MLC1	2			3.25	2.19	2.85		.005	.195	54.5	1428
131-2	603	2	MLC2	A6		3.77	3.52	1.48	1.08		.0015	.195		
131-2	605	2	MLC3	2			3.37	2.17	3.37		.0025	.194		
131-2	607	2	MLC4	2			2.68	2.30	2.24		.007	.195		
131-2	609	2	MLC5	2			3.14	2.70	2.24		.008	.195		
131-2	611	2	MLC6				1.67							
132-2	601	2	MLC1	2			1.49	.93	1.49		.015	.191	54.1	1449
132-2	603	2	MLC2	2			1.78		1.57		.014	.192		
132-2	605	2	MLC3	2			1.65	1.10	1.45		.006	.191		
132-2	607	2	MLC4	3			1.49	.86	1.54		.0155	.191		
132-2	609	2	MLC5	3			1.59	.77	1.23		.017	.191		
132-2	611	2	MLC6				.77							

Table C-III-2 (Concluded)

MSN	CHNL	HOUSE INSTR	TYPE	PEAK AMPLITUDES POSITIVE P1	P2	P3	NEGATIVE P1	P2	RISE TIME T1	T2	PER-IOD	WAVE ANGLE	GND SPD
172-2	601	2 MLC1	6		1.95	1.43	1.65	1.41	.0005	.0015	.077	45.8	1619
172-2	603	2 MLC2	5		1.28	1.33	1.49	1.33	.002	.005	.077		
172-2	605	2 MLC3	5		1.35	1.42	1.57	1.46	.002	.006	.077		
172-2	607	2 MLC4	5		1.43	1.55	1.77	1.43	.001	.0045	.078		
172-2	609	2 MLC5	A6		1.70	1.49	1.65	1.39	.0005	.005	.078		
172-2	611	2 MLC6				.956							
221-1	601	2 MLC1	10			2.07							
221-1	603	2 MLC2	10			1.46							
221-1	605	2 MLC3	10			1.47							
221-1	607	2 MLC4	10			1.80							
221-1	609	2 MLC5	10			1.58							
221-1	611	2 MLC6				1.76							

NOTE: Data for 31 SR-71 missions are not available for release at this time.

Annex C

Part IV - FULL-RANGE AND AUDIO PRESSURE MEASUREMENTS

D. R. Grine
Stanford Research Institute

Annex C
Part IV

FULL-RANGE AND AUDIO PRESSURE MEASUREMENTS

The waveforms of Figures 1 and 2, provided by NASA-Langley, show several phenomena related to the expected response of people to sonic booms heard outdoors. The following comments on these waveforms are based on a presentation by Mr. Harvey Hubbard of the NASA Langley Research Center.

NASA-Langley used a B&K microphone with a direct record card to give the 200-Hz to 10-kHz response shown in the second waveform from the top in Fig. 1. We shall refer to this microphone as the audio mike. The audio mike was mounted on a stand 5 ft above the ground within a few inches horizontally of the loading microphone MLC-3 that was used to record the top wave form in Fig. 1. The time scales are the same on both of these waveforms from Mission No. 7-3. The beginning of the audio record is coincident with the bow shock on the full-range waveform. Note that the start of the audio record has two sharp peaks: the first is from the incident shock and the second is from the bow shock reflected from the ground. No measurable audio pressure coincides with the relatively slow pressure rise just after the zero crossing on the full-range waveform. The audio pressure from the tail shock is about one-third that from the bow shock. This difference is partially due to the difference in amplitude of the bow and tail shock noted on the figure. There may also be a difference in rise times of the bow and tail shock. On the bottom two waveforms of Fig. 1 from Mission No. 8-3, the rise time of the bow shock is 13 milliseconds longer than the 4 milliseconds for Mission No. 7-3 at the top of the figure. The audio peak for Mission 8-3 is considerably smaller than it was for Mission 7-3 as one would expect since the longer rise time corresponds to less high-frequency energy. Note that the noticeable rise near the middle of the waveform from Mission No. 8-3 shows no corresponding audio peak. The tail shock from

Mission No. 8-3 shows a very small audio peak. This peak would probably not be heard by an outdoor observer. Although two distinguishable bangs from an outdoor sonic boom are usually heard, it is possible that on some occasions only the bow shock may be heard. Particularly for the B-70 the tail shock is likely to have a longer rise time and therefore a lower audio peak.

In Fig. 2, waveforms from an F-104 and the XB-70 are compared for Mission 16-2 and 16-3 flown a few minutes apart. The effect of reflection from the ground on the full-range waveform is shown for both aircraft by the waveform from the microphone at 20-ft elevation, MLC-6. Note that the audio peaks for the F-104 are very nearly equal in size for the bow and tail shocks. The bow and tail shocks on MLC-3 for the full-wave waveform have very nearly the same amplitude and rise time for this airplane. The audio record for the bow shock of the XB-70 is slightly smaller than the audio record for the F-104 even though the full-range waveform has a larger amplitude for the XB-70. The slight difference is probably caused by a slight difference in rise times, 4 milliseconds for the F-104 and 5.5 milliseconds for the XB-70. Note that the audio record for the tail shock on the XB-70 is considerably smaller than that for the bow shock as in Fig. 1.

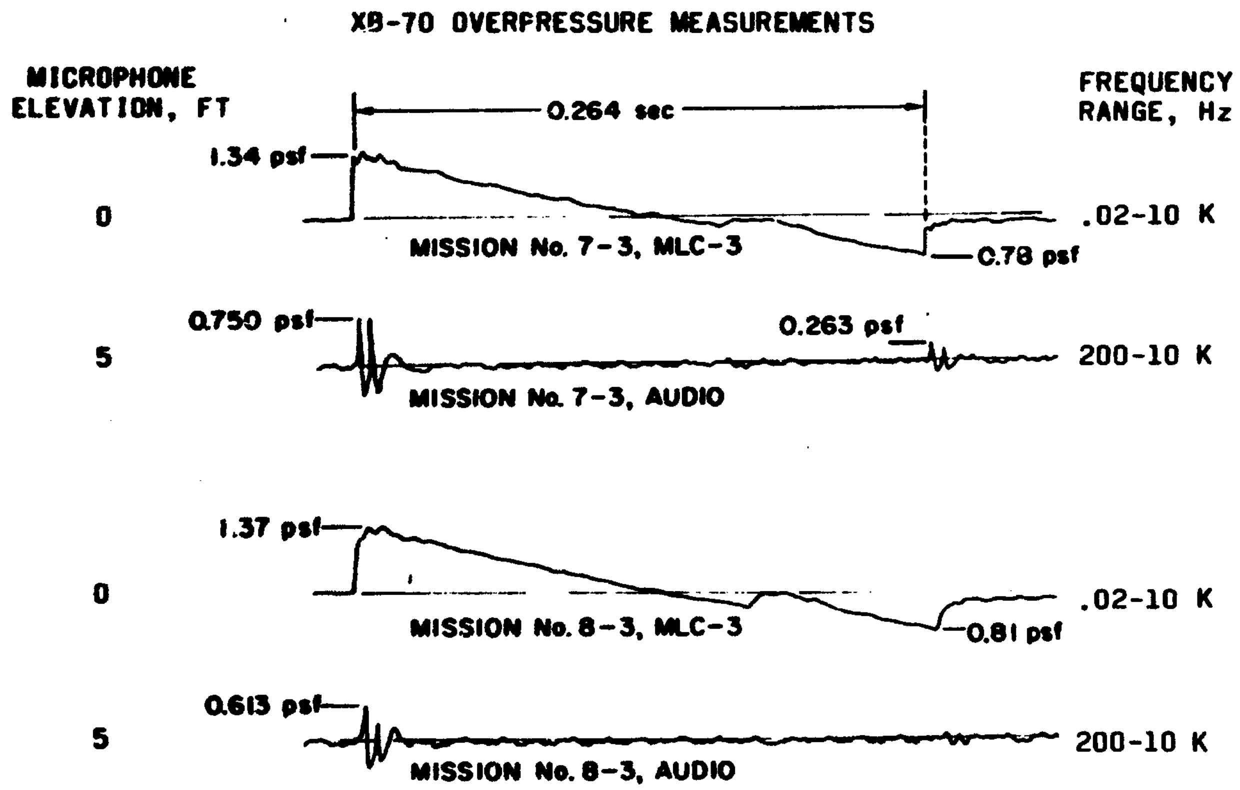


FIG. C-IV-1 XB-70 OVERPRESSURE MEASUREMENTS

MEASURED OVERPRESSURE SIGNATURES

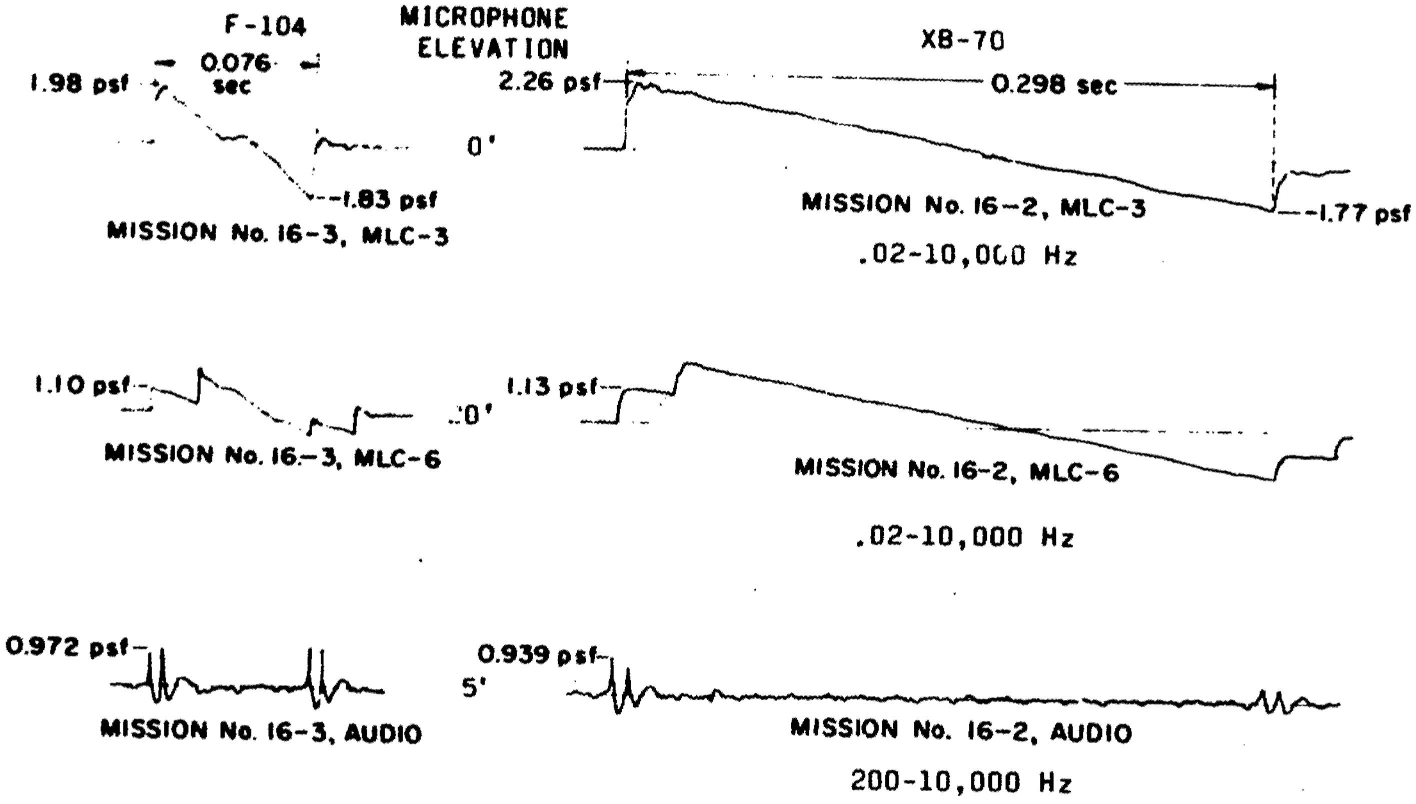


FIG. C-IV-2 MEASURED OVERPRESSURE SIGNATURES

Annex D

METEOROLOGICAL INVESTIGATIONS
ENVIRONMENTAL SCIENCE SERVICES ADMINISTRATION

SUMMARY RESULTS

Following the Phase I Edwards Tests, ESSA was asked to participate in the planning and execution of the follow-up Phase II Tests to the extent that leadtime and recognition of the basic problems permitted. The program that was developed is outlined in Annex A, Operational Test Plan, and essentially covers a minimal effort to obtain: (1) detailed, low-level (10 and 90 feet above the ground) turbulence statistics in the immediate area of the surface overpressure measurements (Site 9 array); (2) data on the existence of waves on lower troposphere inversion surfaces, as a possible mechanism for selective focussing of sonic booms, and (3) the area distribution and variability of overpressure by means of microphone grid arrays of two different intervals of spacing (50 and 200 feet). In addition, it was planned to make use of the routine deep atmospheric soundings, as well as special, more detailed, low-level (to 10,000 feet MSL) soundings taken by the Air Weather Detachment on request in connection with the inversion-wave study. Also in connection with the latter study, use was to be made of overpressure data from the 8000-foot linear microphone array.

While the majority of the meteorological data acquired by ESSA has been or is being processed, the bulk of the overpressure data needed for correlation has not yet become available. The following will summarize the results or the state of progress in the various areas of study being pursued by ESSA.

A. Inversion-Wave Investigation

This study resulted from attempts to explain the frequently observed large horizontal variations in sonic boom overpressure, believed to be associated with low-level atmospheric inhomogeneities. Some observations suggested a periodicity or wavelength in maximum overpressure on the order of 3000 feet or more.

Limited meteorological observations have indicated the occurrence of waves of similar wavelength on temperature inversion surfaces in the lower troposphere (below 10,000 feet MSL). It was therefore theorized that a boom shock wave passing through such an inversion, would undergo differential refraction with a resulting alternating focussing and defocussing of the sonic boom (energy) at the ground. A computer model was devised using basic ray tracing concepts and reasonable inversion and wave structures, and did indeed produce results indicating alternate maxima and minima of sonic boom intensity at the surface commensurate with the intensity of the inversion and the amplitude and wavelength of the waves on the inversion.

On the basis of these findings, a program of observations was undertaken during the Edwards Phase II Tests that would determine the presence of such inversion surfaces and the detailed structure of existing wave patterns, in an attempt to relate them directly with any periodicity in overpressure values observed by means of the 8000-foot linear microphone array. Inversion surfaces (height and intensity) were detected initially by means of special, low-level temperature soundings. During the first portion of the Phase II Tests the inversions were probed for temperature variations (indicative of wave structure) by an instrumented C-131B Air Force aircraft, on loan from another project. When it was recognized that the definition of temperature structure was insufficient for the purpose, a chartered light plane (Cessna 150) was specially instrumented and used instead.

In all, nine flights were made by the C-131B, five of which were made on three days when the 8000-foot microphone array was in operation; eighteen flights were made by the Cessna 150, six of which were made on three days when the 8000-foot array was being used. Because the expected wavelength of inversion undulations was on the order of 3000 feet or more, it is of primary interest to compare results with those obtained from the 8000-foot array. This, however, was only in operation on a total of eight days during the program. For remaining flights, comparison will be attempted with the data from the Site 9 microphone array, in which the longest dimension was 1800 feet.

The flight track of the Cessna 150 within the inversion layer consisted of two orthogonal legs, east-west (the general orientation of both the boom aircraft and the microphone arrays), and north-south, in order to discern the orientation of existing wave structure. Figure 1 shows an example of the temperature trace obtained along these tracks on December 16. The primary wavelength of temperature oscillations is of the order of 5000 feet. The presence of oscillations only along the east-west legs indicates, in this case, an essentially north-south orientation of the wave pattern.

These data are being analyzed for wavelength and amplitude of the oscillations and inversion depth and intensity, and will be used in the basic model to compare results of computed variability of overpressures with observed values when the latter are available.

B. Boundary Layer Turbulence Study

Another observed characteristic of surface overpressure values is the often considerable (by factors of more than two) and apparently random variation in intensity within relatively short distances of the order of 10 - 1000 feet. Such variation has generally been ascribed to the presence of turbulent eddies in the lower or planetary boundary layer of the atmosphere (the lower 3000 or so feet); and although limited, indirect evidence to this effect has been noted, no direct measurements or correlations have been made.

Within the constraints of time available, ESSA personnel conducted a limited observational program during the Edwards Phase II Tests designed to define the spectrum of turbulence near the surface as a first approximation to the probable turbulence spectrum in the boundary layer. Very detailed, rapid-response measurements of wind and temperature fluctuations were made at heights of 4 and 28 meters (13 and 92 feet) above the dry lake bed in close proximity to the Site 9 array of overpressure microphones. In addition, 18 extra microphones were placed within the basic cruciform array in checker-board fashion with spacing initially 200 feet and later 50 feet, in order to provide a two-dimensional picture of the distribution and variation of overpressures.

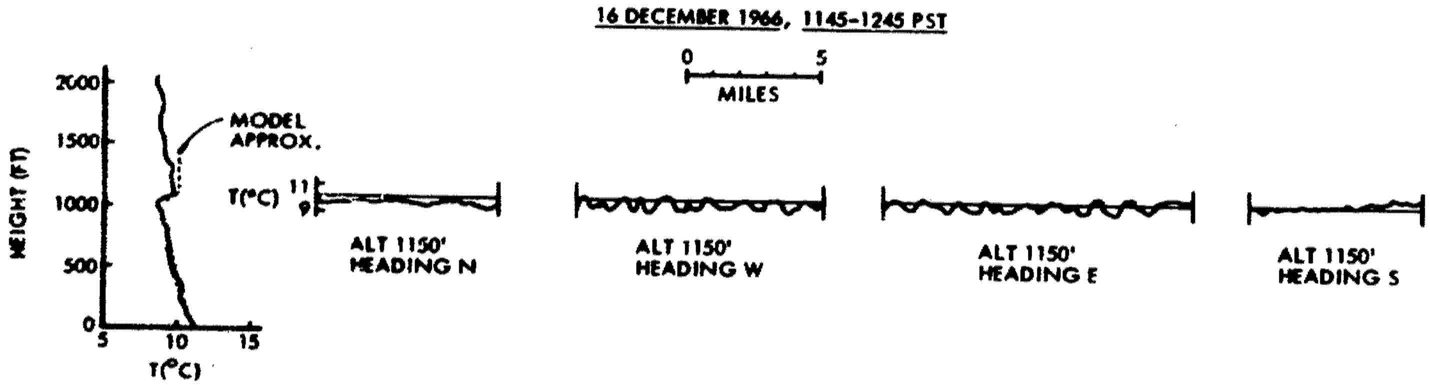

16 DECEMBER 1966, 1145-1245 PST

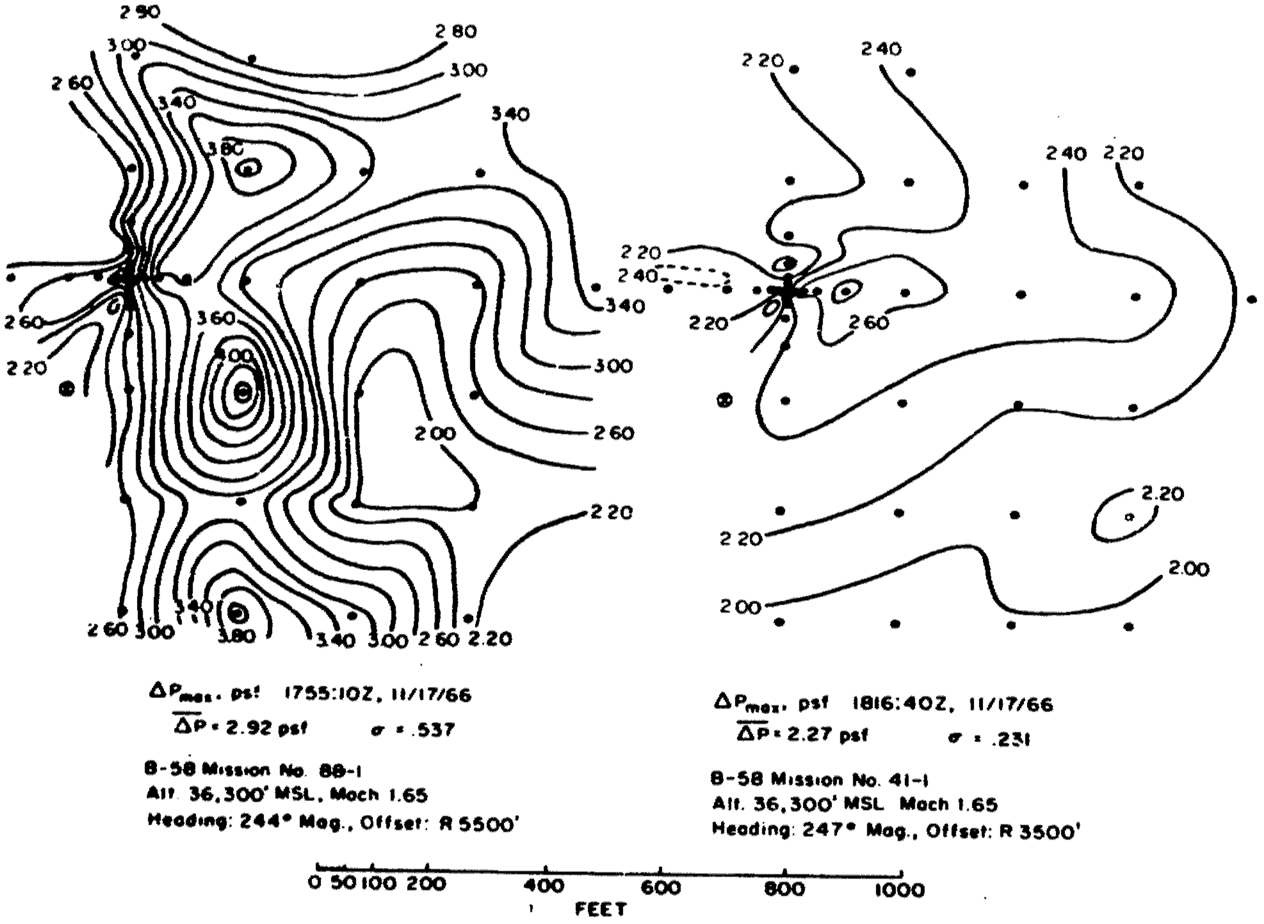
FIG. 1 EXAMPLE OF TEMPERATURE TRACE

The turbulence data is based on wind speeds, inclination angles and temperatures which were recorded on analog tapes in frequency modulation and digitized for computer use. Approximately 50 hours of data were collected in conjunction with 96 sonic booms on 18 days. About a third of these data will probably be unusable because the air movement was below the threshold of the sensing instrumentation, i.e., essentially calm. To date, statistical (power spectra) analyses have been completed for seven days (16, 17, 21 and 23 November and 12, 16 and 20 December), covering 33 sonic boom missions.

The comparison of these data, which are in a time-scale, with the spatial variation of observed overpressures requires a transformation to a length scale based on the mean wind speed. The length-scale domain of the meteorological data ranges from 4 to 2000 feet, while that of the overpressure data ranges from 12.5 to 1800 feet. Although no direct comparisons have as yet been made, Fig. 2 illustrates, for the 200-foot grid array, the size, intensity, and distribution of overpressure patterns involved, and particularly the change of these patterns and gradients within a 22-minute period under almost identical sonic boom flight conditions. Figure 3 shows the detail of comparable overpressure patterns for the 50-foot grid array.

C. Study of Atmospheric Effects on Overpressures by Means of Computer Program

Past efforts in evaluating the overall effects of the atmosphere (i.e., wind and temperature variations, assuming horizontal homogeneity) between the aircraft and the ground, on the value of overpressures measured on the ground, have used realistic types of atmospheres to determine limiting ranges of corrections which can be applied to overpressures computed by simpler means for the case of the Standard Atmosphere with no wind. In general, for aircraft speeds of more than about Mach 1.3, the factors due to such ranges of both wind and temperature conditions have been found to be no more than ±5 percent, indicating that the effect of the atmosphere as a whole was essentially negligible for higher Mach numbers.



ΔP_{max}, psf 1755:10Z, 11/17/66

$\overline{\Delta P}$ = 2.92 psf σ = .537

B-58 Mission No. 88-1
Alt. 36,300' MSL, Mach 1.65
Heading: 244° Mag., Offset: R 5500'

ΔP_{max}, psf 1816:40Z, 11/17/66

$\overline{\Delta P}$ = 2.27 psf σ = .231

B-58 Mission No. 41-1
Alt. 36,300' MSL Mach 1.65
Heading: 247° Mag., Offset: R 3500'

FIG. 2 DISTRIBUTION OF OVERPRESSURE PATTERNS FOR MISSIONS 88-1 AND 44-1, 200-ft GRID ARRAY

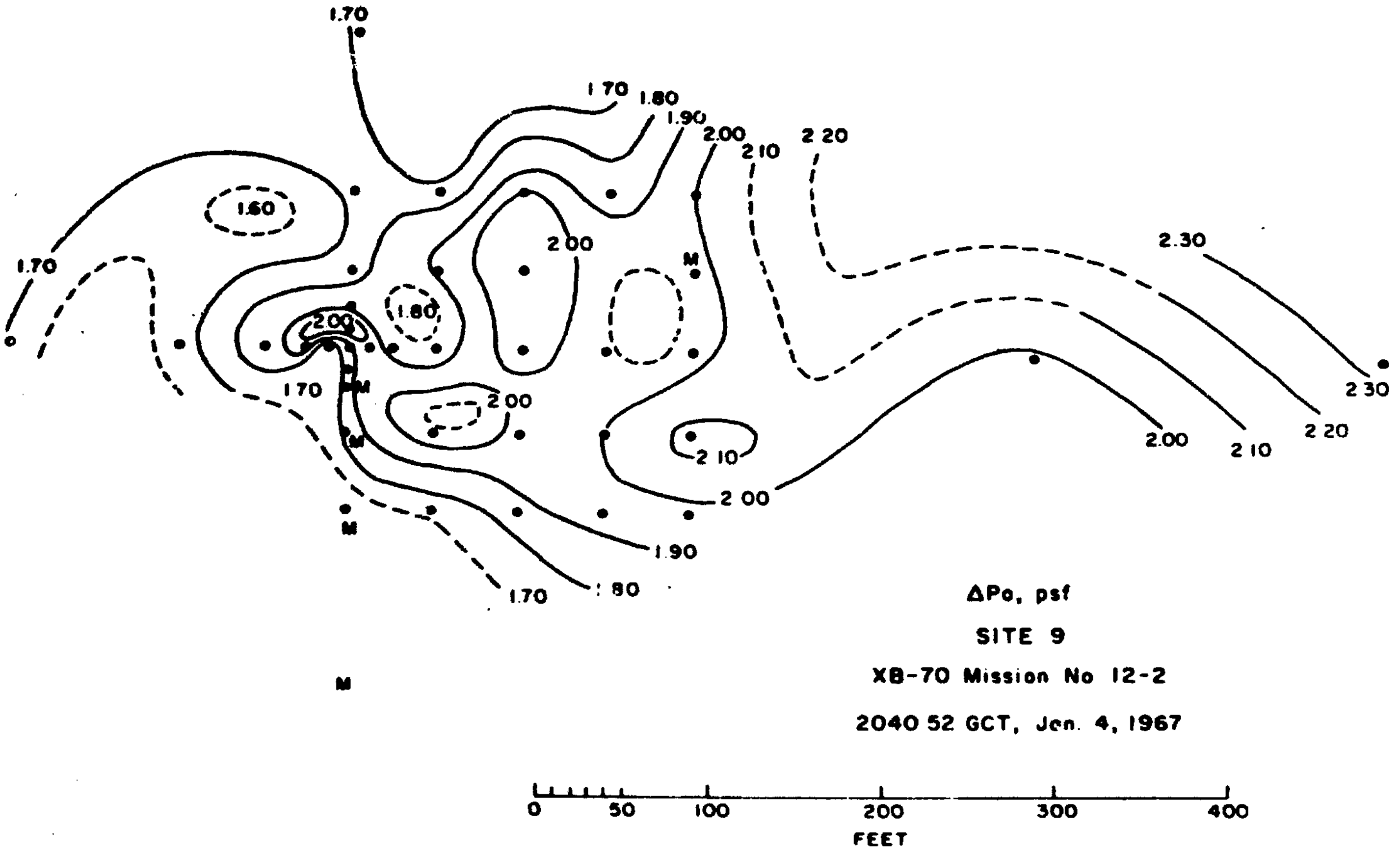


FIG. 3 DISTRIBUTION OF OVERPRESSURE PATTERNS FOR MISSION 87-1 50-ft GRID ARRAY

In considering the possible ranges of overpressure variability to be expected from a given aircraft under given flight conditions in the probable spectrum of real atmospheric conditions, it was felt that additional investigation was warranted. This was possible by means of the computer program developed for NASA by M. P. Friedman, which incorporates the determination of both the initial aircraft pressure disturbance input and the manner in which it is transmitted through any given atmosphere from source to ground. In practice, however, it was learned that it is necessary to apply a correction factor to the output of the program, based on the more sophisticated handling of the aircraft input data by a program developed by NASA.

The program, with appropriate correction, has been used initially in the computation of surface overpressures for 14 selected cases of B-58 flights made at Edwards Air Force Base during Phase I, June 1966, in order to initially test the validity of the program and the reasonableness of its results. Computed overpressures were compared with the mean of the observed overpressures for the basic cruciform network, and in all cases the observed (mean) overpressures were greater than the computed values. The ratio of observed to computed overpressures, $\Delta P_o/\Delta P_c$, varied from 1.02 to 1.69 with a mean of 1.34 and a standard deviation of .19. A similar comparison was made with overpressures computed for the Standard Atmosphere with no wind; and, except for two cases, the observed values were also greater than those computed. In all cases, however, the Standard Atmosphere with no wind gave results closer to the observed values than those for the real atmosphere. For the conditions of temperature and wind profiles and Mach numbers involved in these cases, this latter result is diametrically opposed to the findings of other investigators.[1]

The program was also used on the same 14 cases to look into the relative effects of temperature and wind separately on the value of the computed overpressure by considering only the observed temperatures with

---

[1] Proceedings of the Sonic Boom Symposium, November 1965, pp. S26-30.

no wind, and also by using the observed winds with the Standard Atmosphere. It was found that while both temperature and wind are influential in increasing the ratio of observed to computed overpressure, wind is considerably more important in these cases.

The program is presently being run for a complete range of wind profiles (headwinds and tailwinds) and Mach numbers, and for the several temperature lapse rates previously used, as well as for the Standard Atmosphere with and without wind, in an attempt to check out the earlier findings.

D. Statistical Study of the Effects of the Atmosphere on Overpressure Variability

Another approach to the determination of the effects of atmospheric conditions between the aircraft and the ground, on the variability of overpressures was statistically to relate the observed variability with such specific factors as low-level turbulence, the level of the maximum wind, the height of the tropopause, and the mean temperature and wind. Data used were taken from the B-58 flights of the Edwards Air Force Base Phase I Tests in June 1966, the deep rawinsonde observations provided by the Air Weather Service Detachment, and the peak overpressures recorded at the test house cruciform.

1. Low-Level Turbulence

The possible influence of low-level turbulence was examined in several ways, among them the standard deviations of observed overpressures (of the five stations) for individual booms versus the time of day and versus the depth of the mixing layer. Both can be considered possible measures of low-level turbulence, reaching a maximum in the warmest part of the day. Plots of both showed a tendency for the standard deviation (and therefore the variability) to increase somewhat from 0800 to 1200, local time, and as the mixing layer depth increased from 4000 to 9000 feet; but the extreme scatter of values was overshadowing in both cases.

Table I summarizes the results of examining other properties of the atmosphere in terms of the mean standard deviations of peak overpressures within the cruciform array (in lb./ft.^{2}) and standard errors of the mean.

Table D-1

ANALYSIS OF SONIC BOOM OVERPRESSURE VARIABILITY AS A FUNCTION OF ATMOSPHERIC CONDITIONS

Flight, Relative to:	Number of Flights	Standard Deviation of Peak Overpressure (lb./ft.^{2}), and Standard Errors of the Mean
Maximum Wind Layer		
Above	10	.27 ± .10
Within	53	.26 ± .03
Below	27	.24 ± .03
Tropopause		
Above	27	.21 ± .03
Within Layers	31	.25 ± .05
Below	32	.32 ± .04
Mean Temperature		
Warm Days (5)	46	.24 ± .04
Cool Days (5)	45	.25 ± .03
Mean Wind		
Strong (40-50 k.)	18	.27 ± .05
Moderate (25-40 k.)	29	.25 ± .05
Weak (10-25 k.)	45	.22 ± .02

2. Maximum Wind Layer

There is a slight indication that overpressure variability is greatest when flights are above the level of maximum wind, and least when they are below it.

3. Tropopause

Flights below the tropopause result in greater variability of overpressures than flights above or within the tropopause, possibly because individual variations in the near-field disturbance are smoothed out in passing through the tropopause. It was also noted that the mean overpressures resulting from flights in the troposphere (i.e., below the tropopause, or about 35,000 feet, MSL) were twice as large as those for flights in or above the tropopause, which is again generally consistent with other findings relating greater attenuation with longer ray path lengths.

4. Temperature

Although the atmosphere was warmer than standard on all days, it was considerably warmer on five days and only slightly warmer on five other days. Comparison of the mean observed overpressure variability for these two groups indicated very little effect of overall temperature departures from standard.

5. Wind

Analysis of the mean wind between aircraft and the surface (on the average, headwinds) indicated a fairly pronounced tendency for stronger mean winds to have a greater effect on the variability of mean observed overpressures. This is in agreement with theory and past findings.

These results are not conclusive, due mainly to the extreme scatter or variability in the peak overpressures within the network for any given boom. Trends are indicated, however, and are generally consistent with earlier findings. Although continued, similar examination of the Phase II data should be pursued to validate and possibly clarify these trends, it would appear that the overall effects of the atmosphere cannot be entirely neglected in the determination of overpressure variability.

Annex E

SEISMIC EFFECTS OF SONIC BOOMS

by

J. C. Cook and T. Goforth

GEOTECH, a Teledyne Company
Farland, Texas

Technical Note
Preliminary Data for
NASA Langley Research Center
Under Contract NAS1-6342

Annex E

SEISMIC MEASUREMENTS OF SONIC BOOMS[1]

I INTRODUCTION

As a part of the current Government program to study the hazards and annoyances which may be imposed upon the population by sonic booms, Geotech has begun a study of the seismic effects associated with sonic booms. This paper will include a brief introduction to the science of seismology, and will give examples of the results obtained in field experiments, to date, together with their preliminary interpretation.

II PHENOMENA AND METHODS OF SEISMOLOGY

Some human activities, such as blasting, produce noticeable ground motion. Because of the importance of monitoring and controlling these activities, studies have been conducted by the U. S. Bureau of Mines, the Liberty Mutual Insurance Company, and others, to establish criteria defining the level at which ground motions may damage buildings. Three criteria have been developed. The oldest criterion on which structural damage threshold is based is the peak acceleration of the ground during passage of seismic waves. Accelerations exceeding 0.1g (980 mm/second^2) in the frequency range between 1 and 20 cps are considered to be above the safe range. A newer criterion in the "energy ratio," defined as $\left[\frac{\text{peak acceleration}}{\text{frequency}}\right]^2$. The energy ratio damage threshold is defined as 3 [feet/second]^2. The latest criterion and the criterion currently recommended by the U. S. Bureau of Mines [Duvall and Fogelson, 1962] defines the upper limit of safe ground particle velocity as 2.0 inches/second; that is, 50,800 microns/second [μ/sec]. This new criterion agrees very well with the earlier energy ratio criterion. At this level of ground velocity, damage may begin in the weakest part of a structure; that is, plaster may crack. If the measured ground motion is below this level, courts in many states may reject damage claims.

---

[1] Preliminary data for NASA Langley Research Center under Contract NAS1-6342.

[2] The main difference is that the surface particles revolve in a vertical retrograde orbit in Rayleigh waves, but in a vertical prograde orbit in ocean gravity waves.

Figure 1 shows some portable seismographic instruments similar to those used in the sonic boom program. Seismometers operating both in the vertical and horizontal orientations are used to measure all the components of ground motion. Data are recorded on a visual recorder and on magnetic tape to permit later analysis by computer. Means of electrically calibrating to seismometers are provided. Calibration is performed daily in the field to check small variations in system sensitivity caused, for example, by temperature changes. Field calibration is performed by sending a known amount of electric current through the seismometer coil or an auxiliary coil, producing a known motion of the inertial mass, which is then registered by the recording apparatus. Such electrical calibration is, in turn, standardized at the laboratory with a precision shake table having optical indicators, the calibration of which is, in turn, traceable to the U. S. Bureau of Standards.

Figure 2 shows one of several kinds of deep-well seismometers [Shappee, 1964] currently in use at Government seismic observatories [Gudzin and Holle, 1962]. This instrument is protected by a pressure case so that it can be lowered into inactive oil wells for monitoring motions of the earth as far as 10,000 feet below the surface. The deep-well instrument is coupled firmly to the well casing by means of the electrically controlled wedging lock shown protruding from its side. Using such instruments, we plan to measure the effect of sonic booms upon ground motion at various depths in the earth, to obtain a better understanding of the types of waves involved and how they travel through the ground.

III SEISMIC WAVES FROM SONIC BOOMS

Figure 3 illustrates, in a simplified manner, the conical shock wave developed at the nose of a supersonic aircraft, and its interaction with the ground [the tail shock has been omitted for simplicity]. Such a shock wave is reflected from the ground like any other acoustic wave, and over 99 percent of the energy returns to the atmosphere, because of the large density and velocity contrast between earth and air. In instances where the density and seismic velocities of the ground are high, as in hard rock, less energy is coupled into the ground than in instances in which the earth is soft, of low density, and low velocity. Hence, we can expect to find a dependence of the seismic effects of sonic booms upon local geology.

As shown in figure 3, the pressure exerted by the sonic boom shock wave produces a moving vertical force and may also generate a horizontal force if the ground is rough or irregular. Theory indicates that a moving vertical force should generate a surface wave moving at the same speed as the aircraft, of a frequency determined by the vertical velocity distribution in the earth. The amplitude of the surface wave may be especially large if the aircraft speed and the fundamental frequency of its N wave happen to match the local geology. This possibility is under study.

Secondarily, as the shock wave travels along the surface, irregularities and variations in density and ground hardness which it encounters may become local sources of seismic waves which radiate in all directions.

Figure 4 illustrates a plan view of the shock cone intersecting the ground in a hyperbola. Only one of the two shocks of the "N wave" has been shown for simplicity. In this diagram, it can be seen that the seismic waves generated by local sources along the hyperbola that move backward from the two branches of the hyperbola could reinforce one another as they cross the flight trace. This type of seismic "focusing," if it exists, may result in twice as much ground motion along the flight trace as elsewhere.

Seismic waves traveling forward from the hyperbola at a rate faster than the airplane would arrive before the sonic boom. Such "precursor waves" do indeed exist, as shown by the seismogram in figure 5. This seismogram was taken at a large Government seismic observatory and the position of the flight trace with respect to the instruments was not know. On the three "low-gain" traces near the top of the record, and some others, the precursor can be clearly seen to exceed the level of the background noise about 4 seconds before the arrival of the sonic boom at the same location, as indicated by the microbarograph.

IV PRELIMINARY EXPERIMENTAL RESULTS

Between October 1966 and January 1967, numerous Government supersonic tests were flown at Edwards Air Force Base, California. Among the ground-level measurements made during these flights were seismic measurements made by Geotech under NASA Contract NAS 1-6342.

Figure 6 shows the location of the three seismic stations [shown as dark spots] with relation to the general flight track of the aircraft [indicated by an arrow]. The center station, on the edge of the dry lake bed, includes a vertical seismometer, a horizontal in line with the flight track, and a horizontal transverse to the track. The two outlying stations employ vertical seismometers; one is on an area of thicker lake [playa clay] sediments and the other is on an outcrop of hard rock [quartz monzonite], giving a comparison of two different geological environments. All seismometers are buried to depths of about 3 feet.

Figure 7 shows a seismogram of a typical F-104 overflight. The aircraft was flying at an altitude of 31,000 feet and a speed of Mach 1.65. The top trace or channel [VI] represents the output from the vertically oriented seismometer and the second and third channels are the radial [R1] and transverse [T1], seismograms, respectively, at the center station. Channel 4 [V31] is the output of the vertical seismograph located nearer the center of the dry lake, and channel 5 [VX] is that of the vertical seismometer situated on the rock outcrop. Channels 4 and 5 have been shifted in time so that all channels can be shown in one illustration. The peak positive air overpressure recorded at each site and the resulting first downward peak of ground velocity are noted above and below the proper channel. Two distinct frequencies can be readily identified. A frequency of about 60-70 cps corresponds in time to the passage of the bow and stern shock waves. A damped sinusoidal wave of lower frequency can be seen best on channel 4 "underlying" the high frequency motion and arriving at the same time as the boom. The "precursor" waves are present in the magnetic-tape recording but cannot be seen in figure 8 because of the low amplification used to display the main peaks without distortion.

The lower-frequency motion is tentatively identified as the theoretically predicted, shock-coupled, fundamental Rayleigh wave. The nature of the higher frequency motion is not fully understood at this time. It may be either; [1] the movement of the ground due to the direct application of the shock waves, or [2] a higher mode shock-coupled Rayleigh wave. In all flights recorded, a larger ground velocity is observed in the lake bed clay than in the hard rock, for a given overpressure.

Figure 8 shows a typical sismogram of a B-58 overflight. The aircraft passed overhead at an altitude of 43,000 feet and a speech of Mach 1.55. The chief difference between this seismogram and the F-104 seismogram [figure 7] is the larger time interval between the two onsets of high frequency motion for the B-58, corresponding to the increased time interval between the arrival of the bow and stern shock waves.

Figure 9 shows a typical seismogram of an XB70 overflight. The aircraft was flying at an altitude of 60,000 feet and a speed of Mach 1.80. Again, the chief difference from the preceding records is the larger time interval between the two onsets of high frequency motion.

Figure 10 shows the relation of peak positive overpressure to first peak ground velocity recorded by instruments located on the dry lake bed, and figure 11 shows a similar relation for the station on the rock outcorp. These preliminary results indicate a linear relationship between maximum positive overpressure and first peak ground velocity for both the clay and the rock. Figures 7, 8, 9, and 10 also show that the ground motion for a given overpressure is consistently greater in the lake sediments than in the rock, as predicted by theory.

Figure 12 shows the relation of maximum positive overpressure to the maximum ground velocity associated with the lower frequency motion tentatively identified as a coupled Rayleigh wave. These preliminary data were obtained from instruments located on the lake sediments. They also indicate a linear increase of ground motion with overpressure, and show that the low-frequency ground velocity is less than one-third as large as the high-frequency ground velocity.

The values of ground velocity obtained for the rather limited range of overpressures available are small compared with the most reliable estimates of the damage threshold. The maximum value of ground velocity which has been recorded and analyzed to date is 320 microns/second [at 60 cps] from an overpressure of 2.0 lb/sq ft. This is less than 1.0 percent of the damage threshold criterion now recommended by the U. S. Bureau of Mines.

It should be emphasized that the results presented here are based on incomplete analysis of perhaps 10 percent of the total data, and should be regarded as extremely preliminary.

V STUDIES IN PROGRESS

From a thorough analysis of the data obtained at Edwards Air Force Base, and a seismic refraction survey of the local geology, we hope to obtain a more complete understanding of the mechanism by which seismic motion is produced in the ground by air shock waves, and on the relation of aircraft operating conditions to the amplitude and frequency of the induced seismic motion.

We will also record a limited number of supersonic flights at the Tonto Forest Seismological Observatory in Arizona and at the Uinta Basin Seismological Observatory in Utah [Gudzin and Holle, 1962]. The near-surface geologic structure at each recording site will be determined by a seismic refraction survey. The extensive seismometer array available at the Arizona observatory will provide data from which we can evaluate possible focusing effects of reflections from geologic features and of propagation backward from the hyperbolic intersection of the shock cone and the ground. The Utah observatory has a vertical array of six borehole seismometers extending to a depth of 8000 feet. These will provide data from which we can determine the depth to which the seismic disturbance penetrates. In addition, the observatories will provide two different geologic environments for comparison. Instrumentation at the observatories will be modified to give the same recording characteristics as the field system currently being used at Edwards Air Force Base. The field unit will be used to supplement instrumentation at each of the observatories.

REFERENCES

Duvall, W. I., and Fogelson, D. C., 1962, Review of criteria for estimating damage to residences from blasting vibrations: U. S. Dept. of the Interior, Bureau of Mines, TN 23.U7, No. 5963

Gudzin, M. G., and Holle, E. G., 1962, Seismological observatories: Proc. Inst. of Radio Engrs., v. 50, p. 2216-2224

Richter, C. F., 1958 Elementary seismology: San Francisco, W. H. Freeman and Co., p. 137 and 338

Shappee, R. M., 1964, Deep-well variable-reluctance seismometer: Am. Inst. of Elect. & Electron. Engrs., Trans. on Geoscience Electronics, v. GE-2, p. 2-5

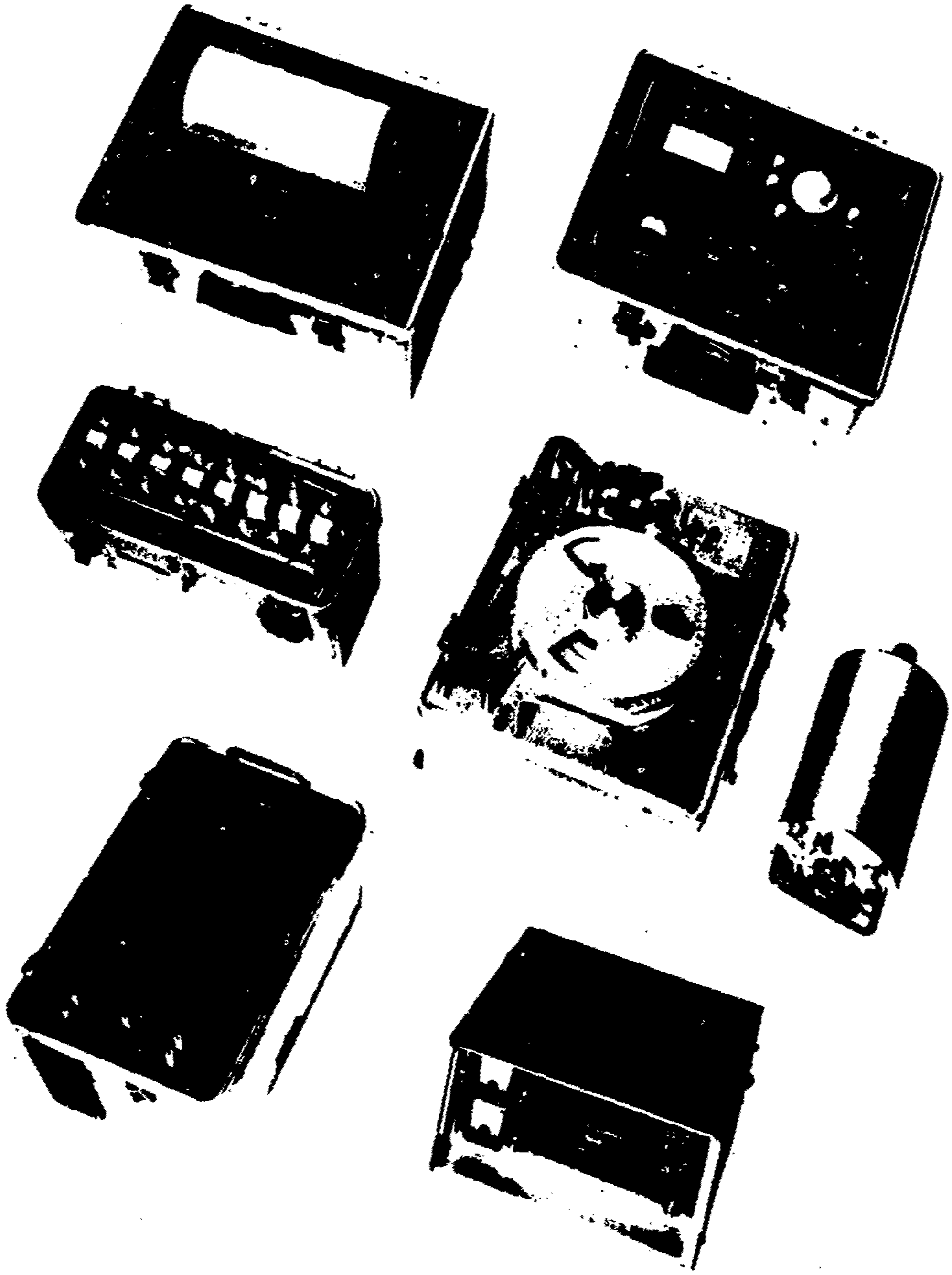


FIG. 1 SOME ELEMENTS OF A HIGH QUALITY PORTABLE SEISMOGRAPH SYSTEM

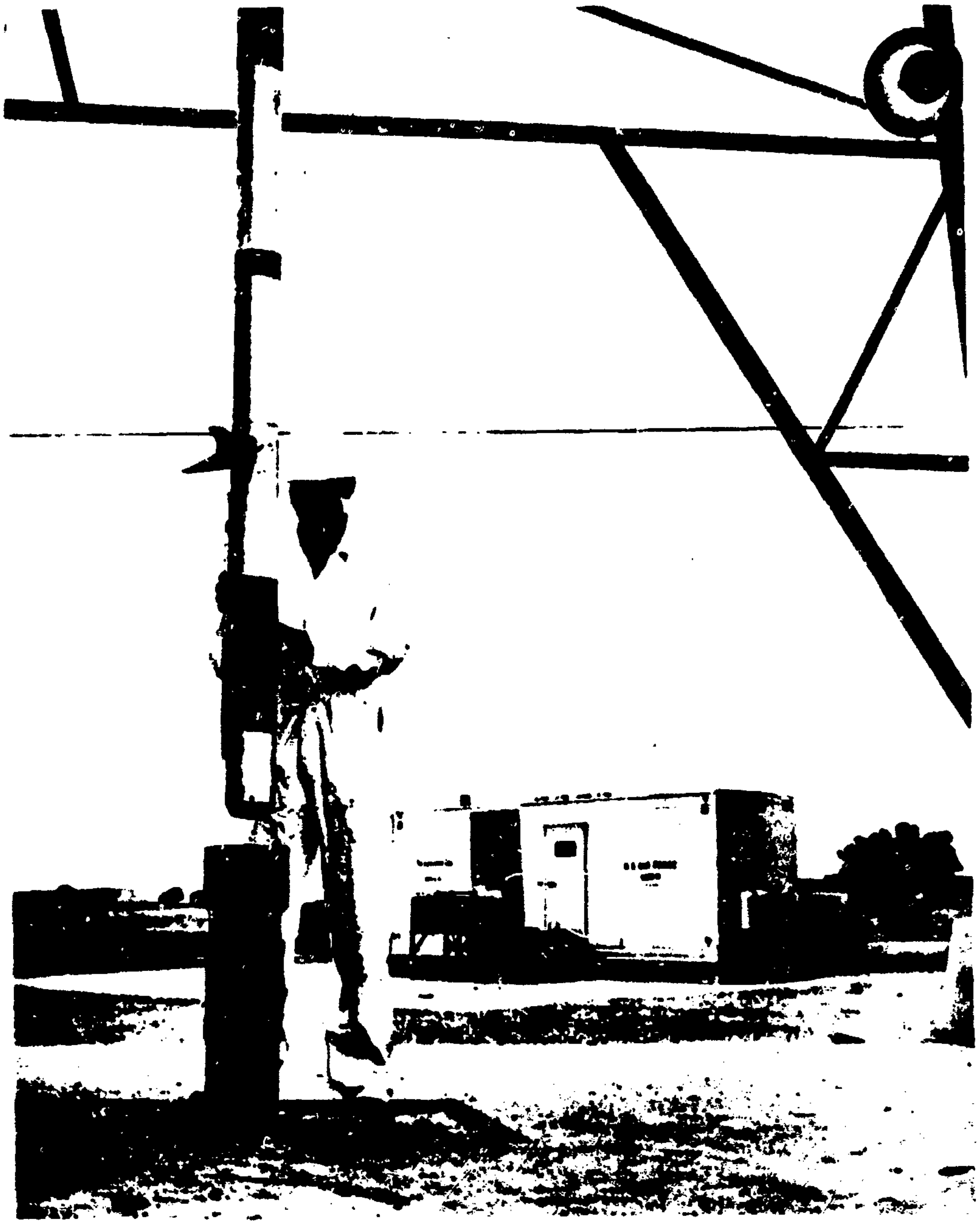


FIG. 2 INSTALLING A SENSITIVE DEEP-WELL SEISMOMETER

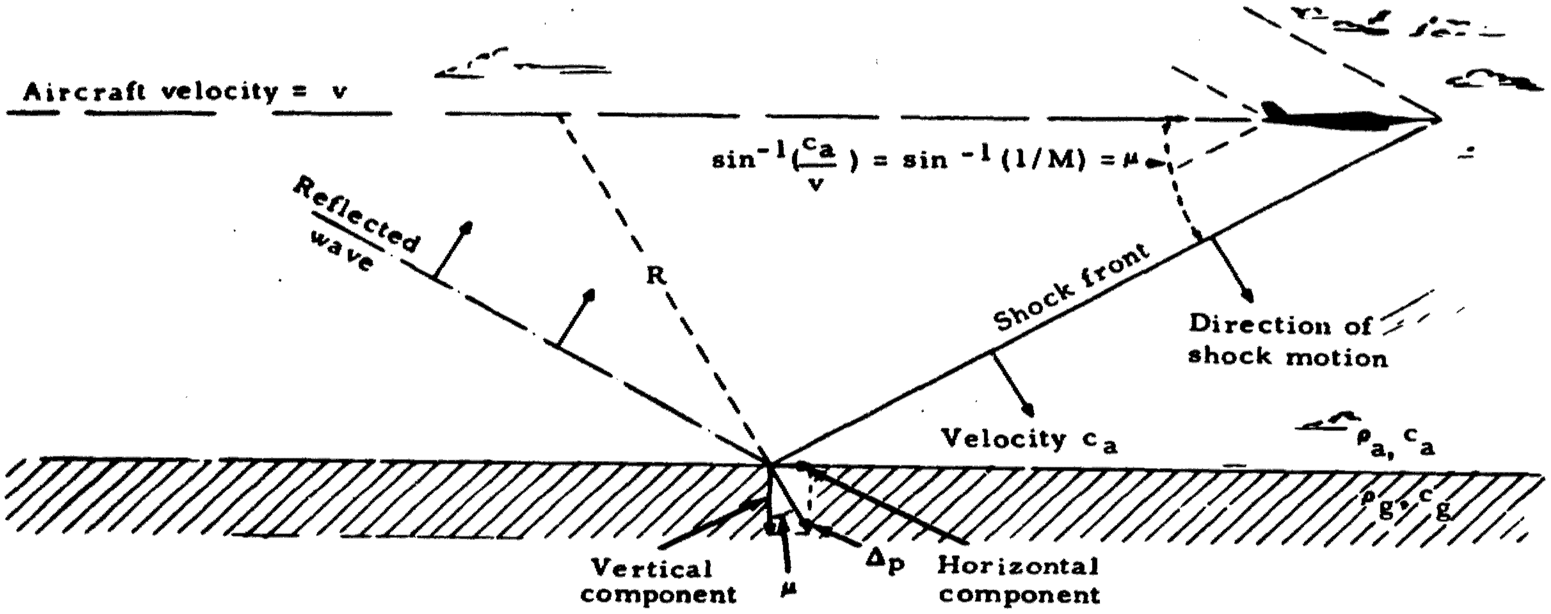


FIG. 3 VERTICAL SECTION OF A SHOCK WAVE INTERACTING WITH THE GROUND

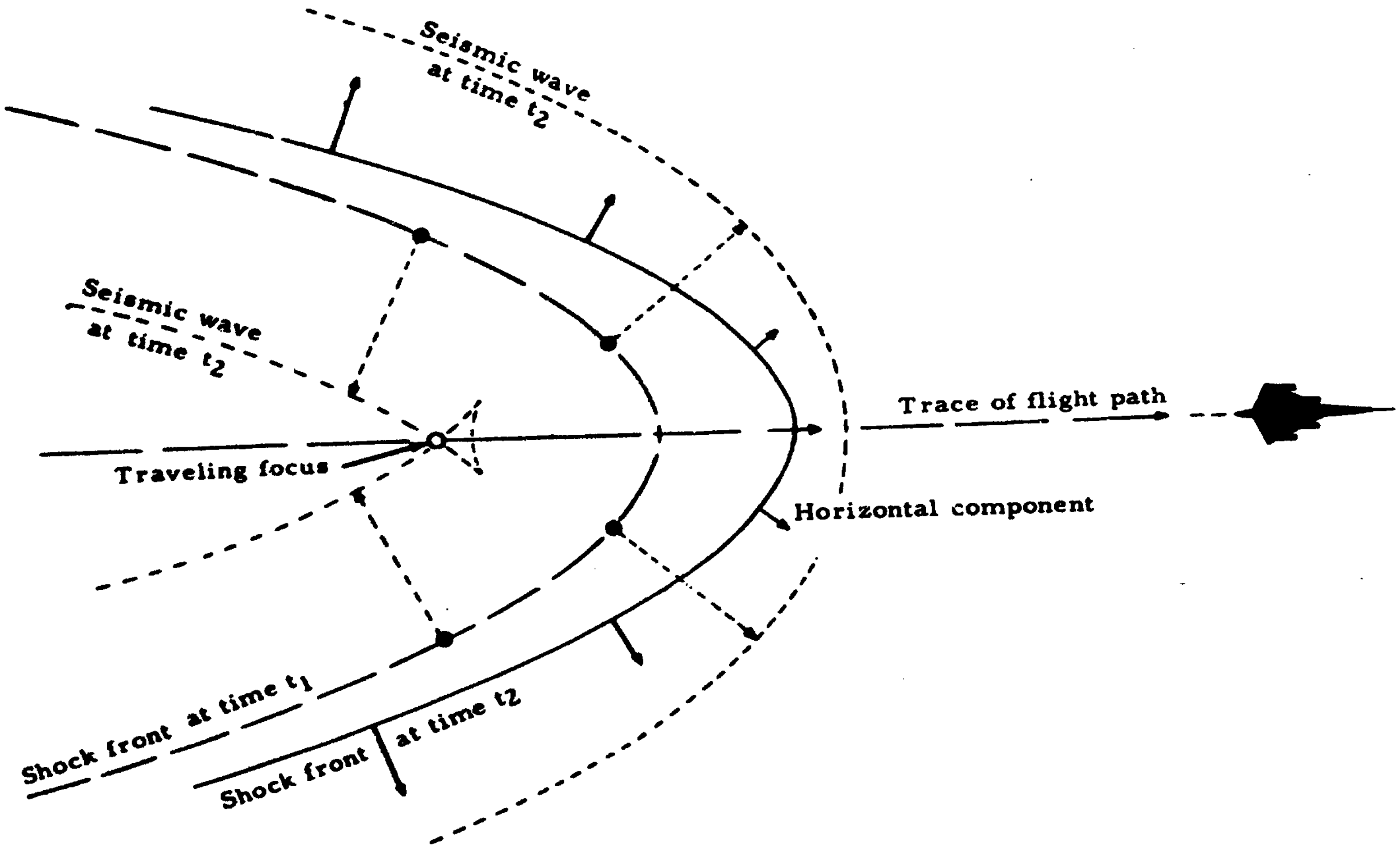


FIG. 4 PLAN VIEW OF SHOCK CONE INTERSECTING THE GROUND

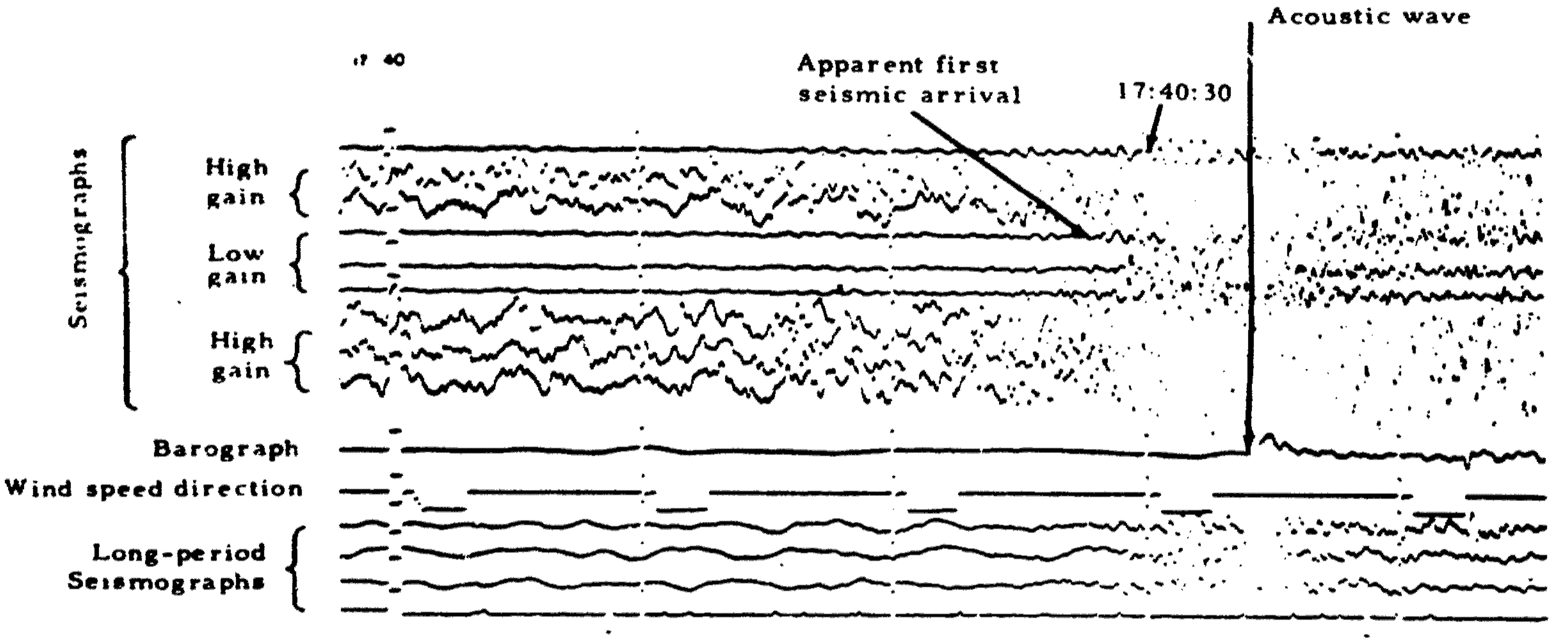


FIG. 5 OBSERVATORY SEISMOGRAM SHOWING "PRECURSOR" WAVES

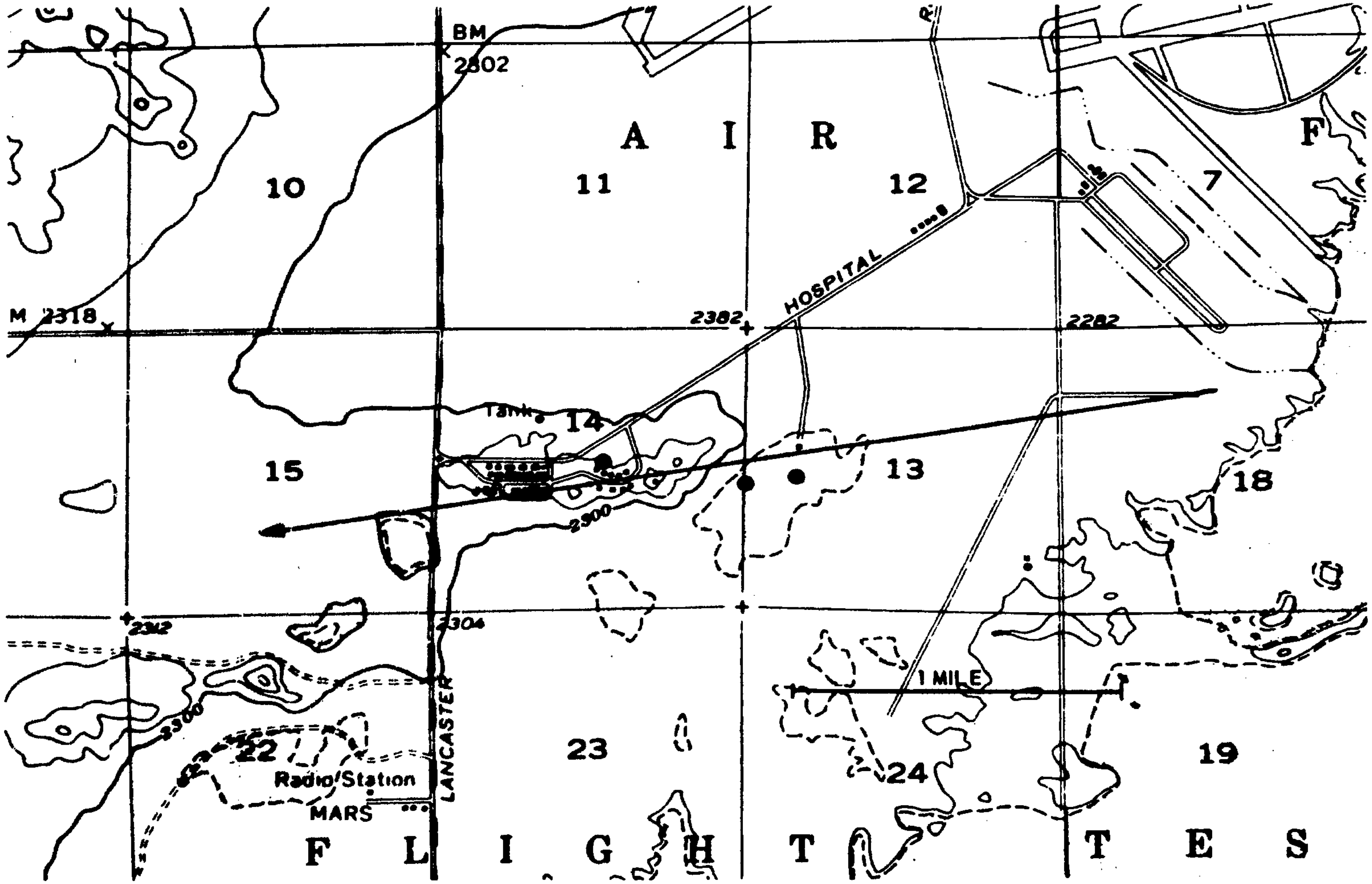


FIG. 6 AIRCRAFT FLIGHT PATH AND LOCATION OF THE SEISMOGRAPH STATIONS (round spots) AT EDWARDS AFB, CALIFORNIA

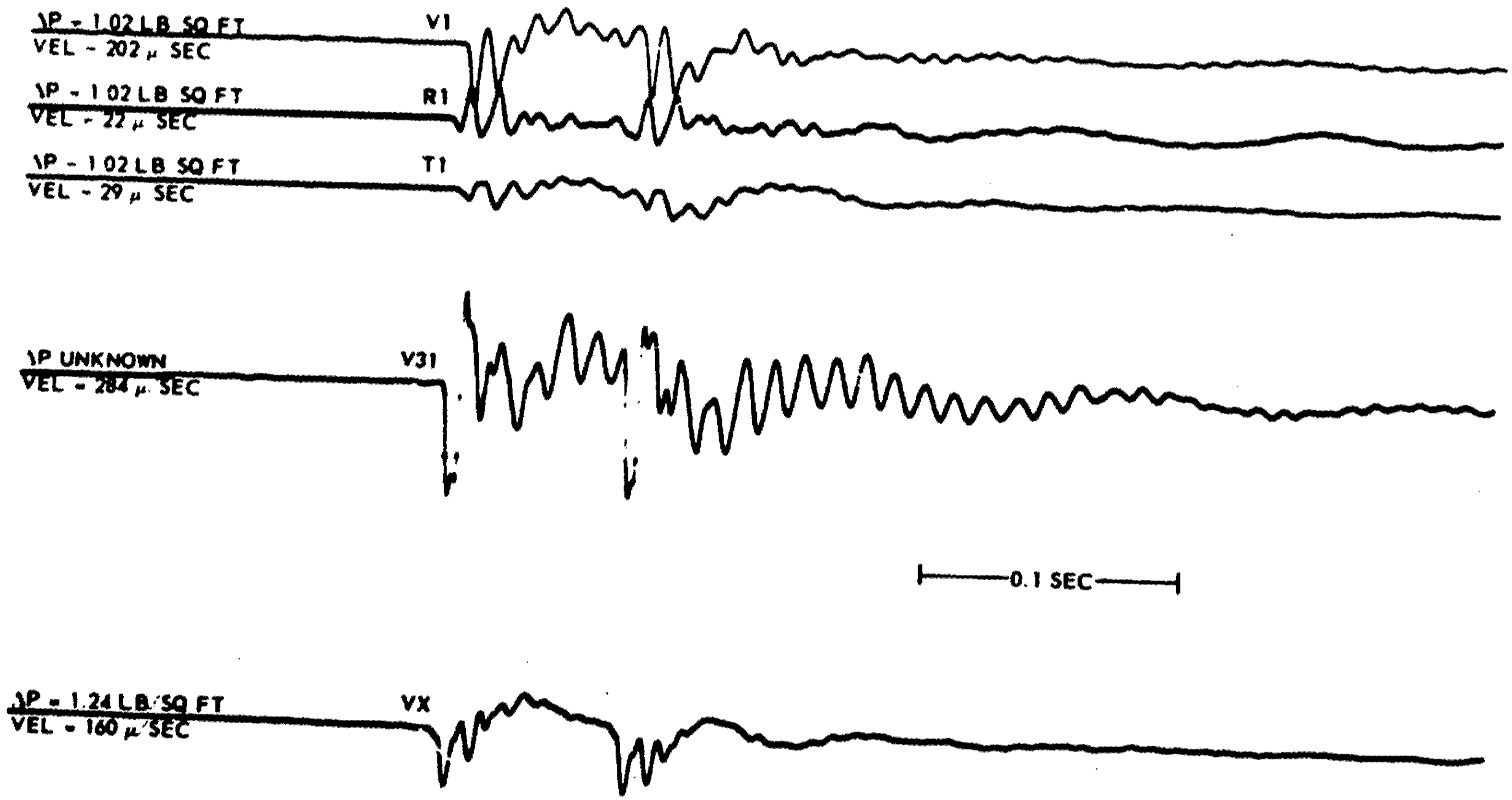


FIG. 7 COMPOSITE GROUND VELOCITY SEISMOGRAM OF MISSION 20-2 TYPICAL OF F-104 OVERFLIGHTS
(altitude 31,000 ft, mach 1.65)

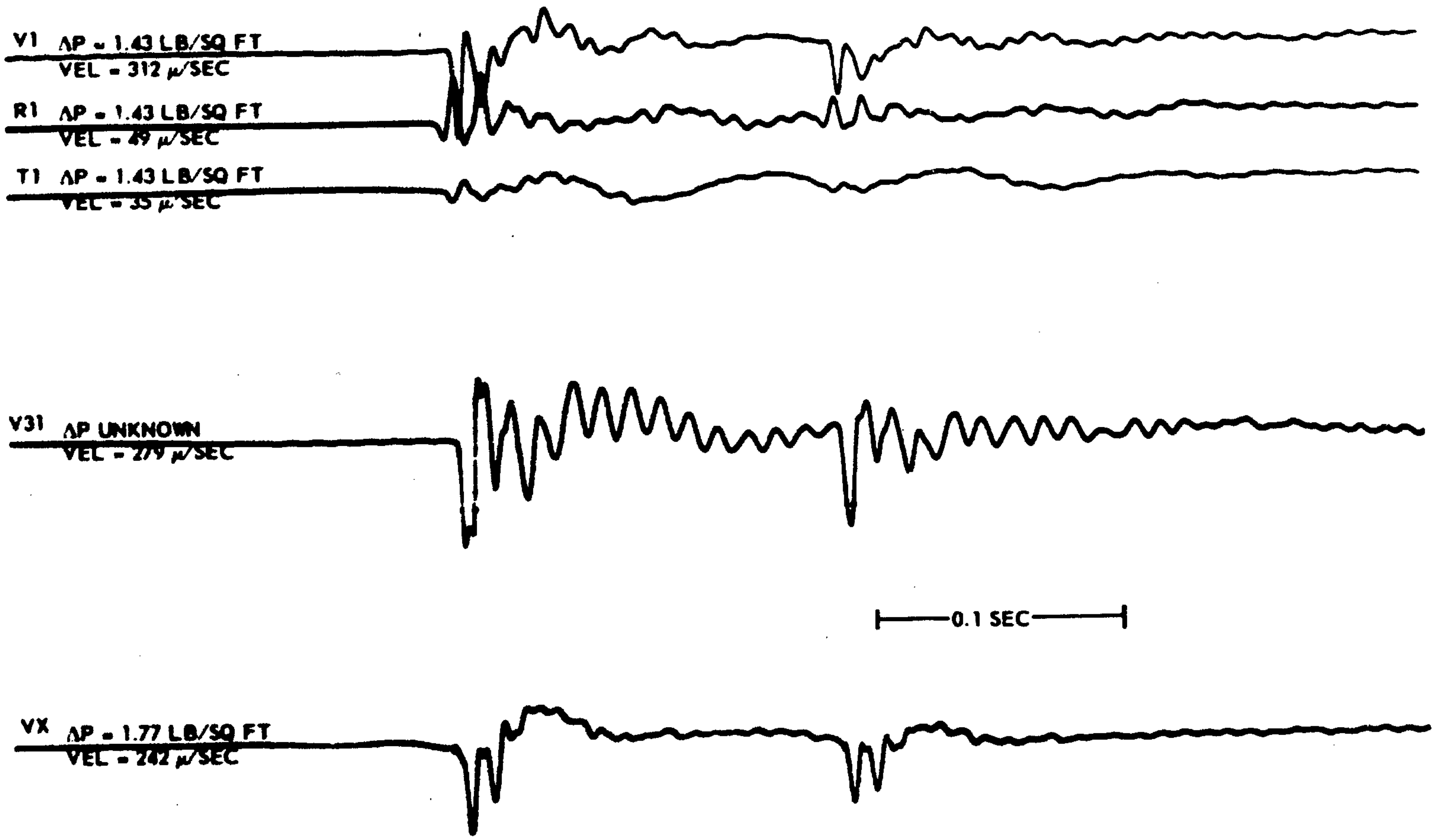


FIG. 8 COMPOSITE GROUND VELOCITY SEISMOGRAM OF MISSION 20-1 TYPICAL OF B-58 OVERFLIGHTS
(altitude 43,000 ft, mach 1.55)

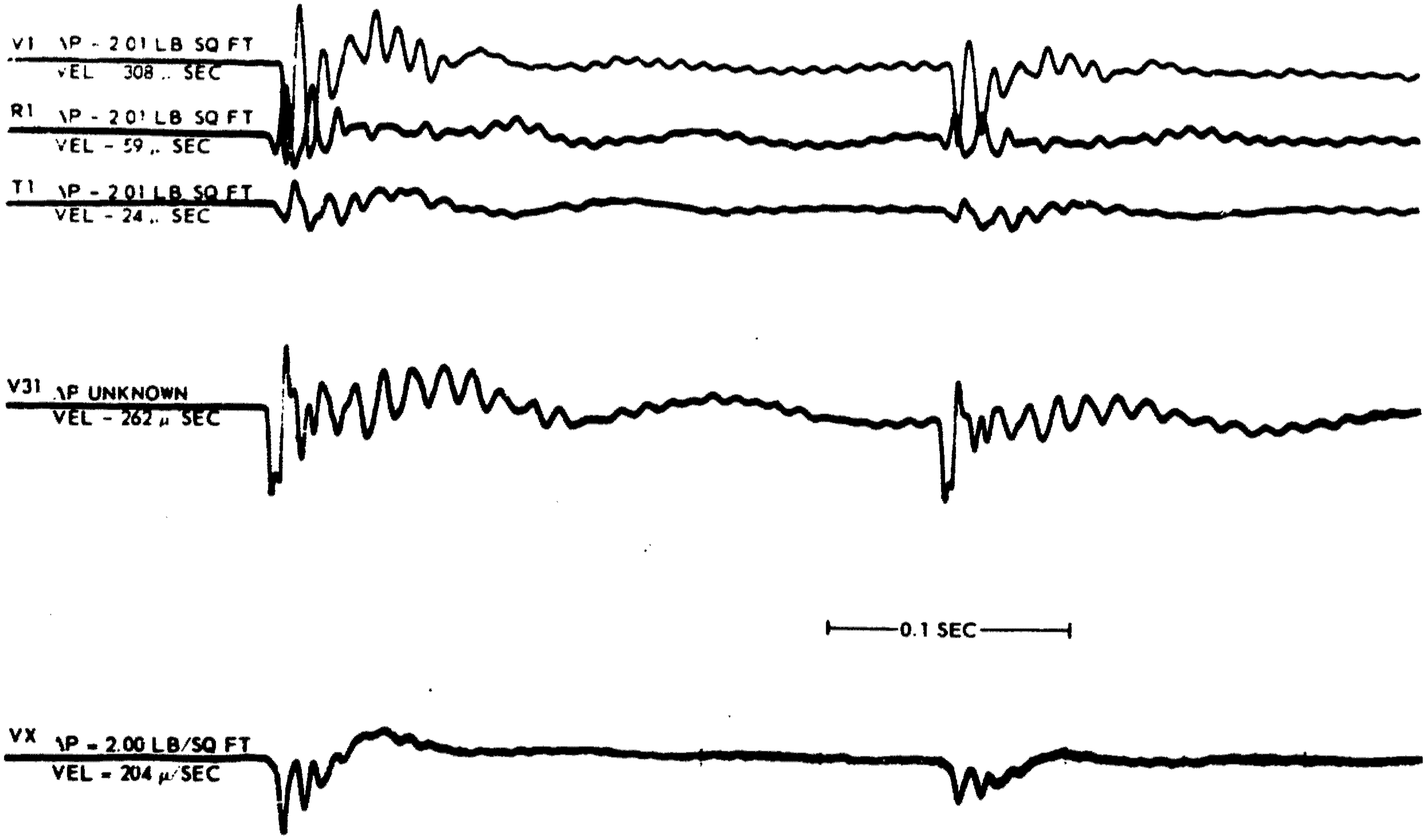


FIG. 9 COMPOSITE GROUND VELOCITY SEISMOGRAM OF MISSION 13-2 TYPICAL OF XB70 OVERFLIGHTS
(altitude 60,000 ft, mach 1.80)

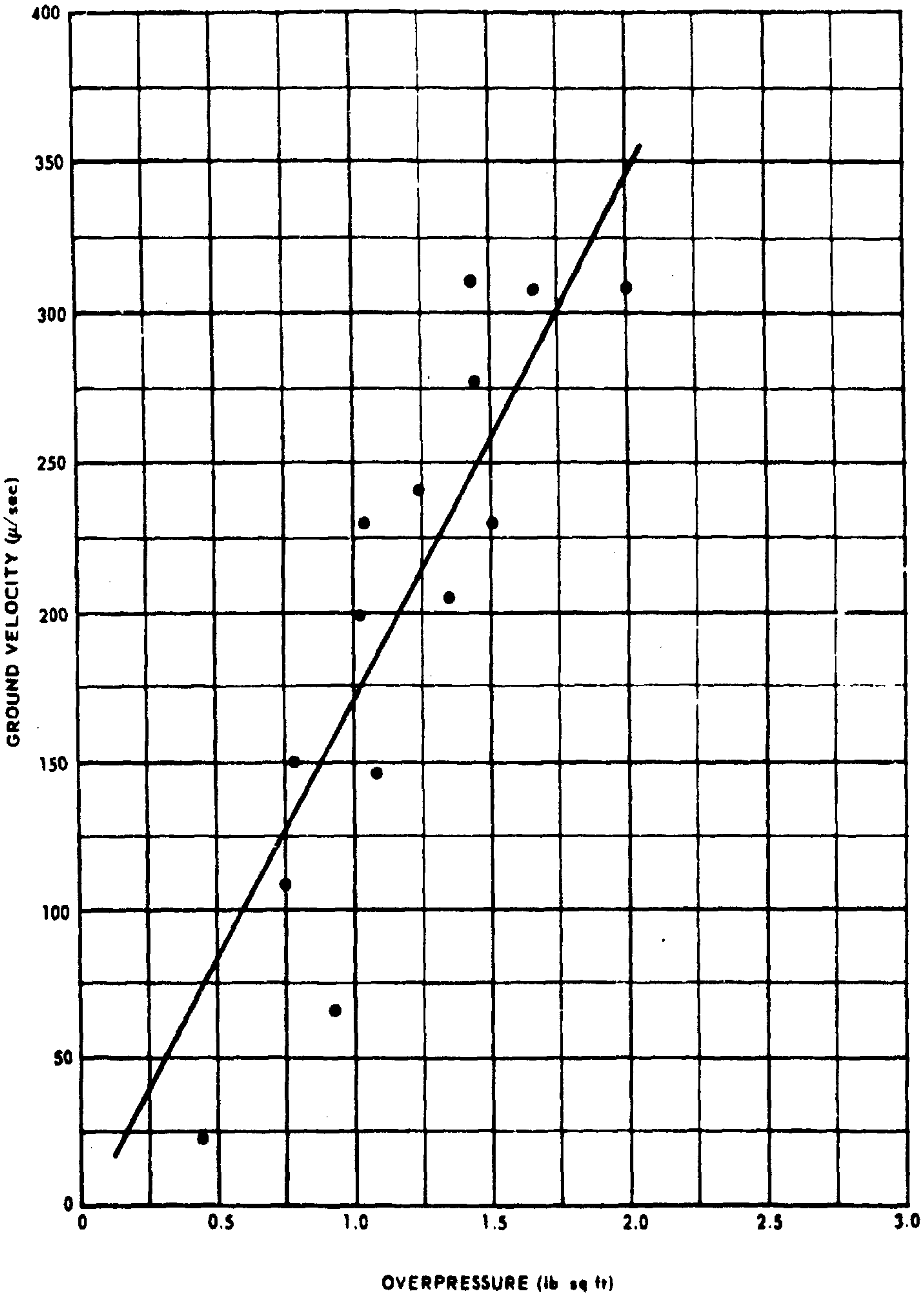


FIG. 10 RELATION OF PEAK POSITIVE OVERPRESSURE TO FIRST PEAK GROUND VELOCITY RECORDED BY A SEISMOMETER LOCATED ON PLAYA CLAY (microphone 1)

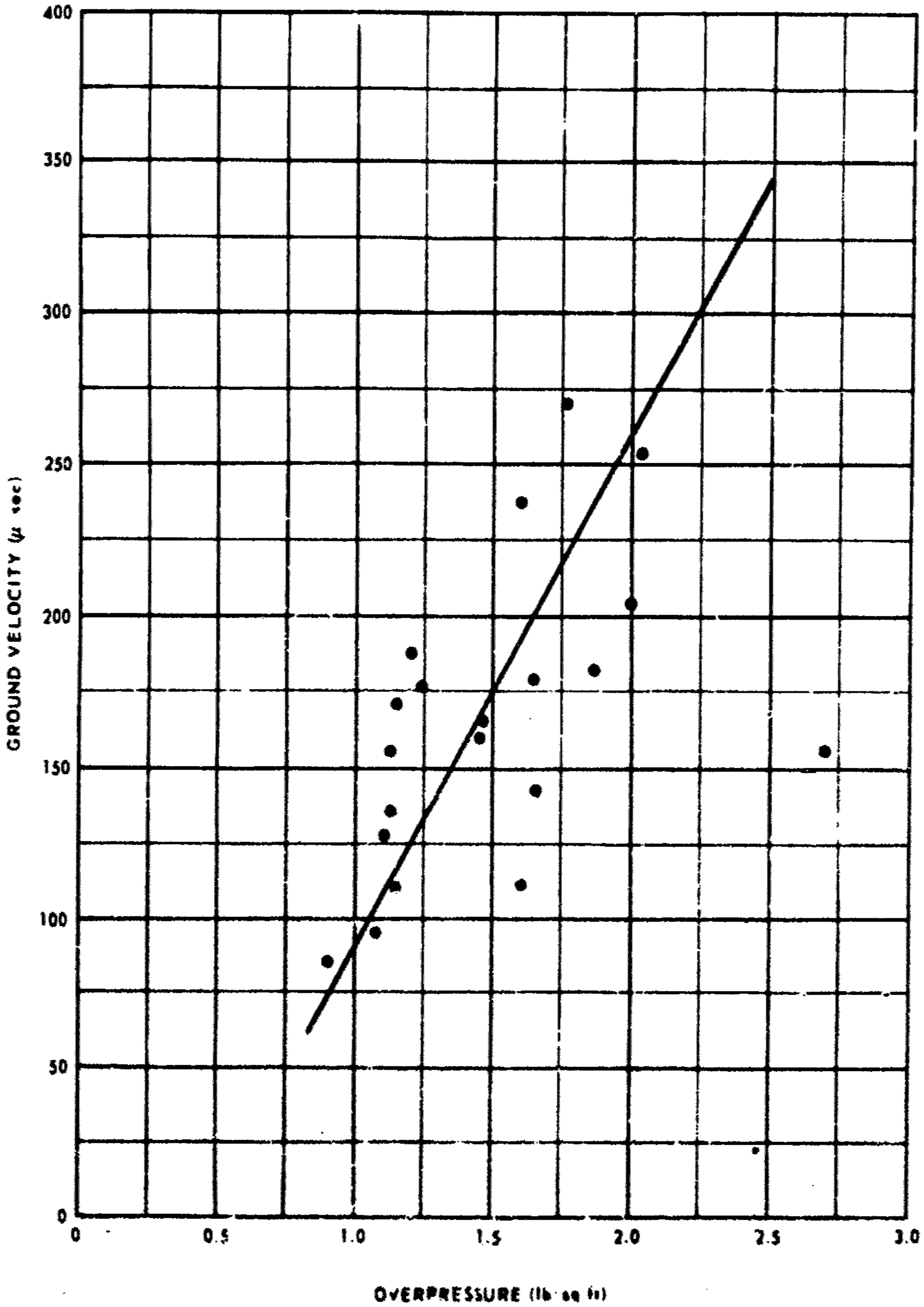


FIG. 11 RELATION OF PEAK POSITIVE OVERPRESSURE TO FIRST PEAK GROUND VELOCITY RECORDED BY A SEISMOMETER LOCATED ON QUARTZ MONZONITE (microphone 1, cruciform array

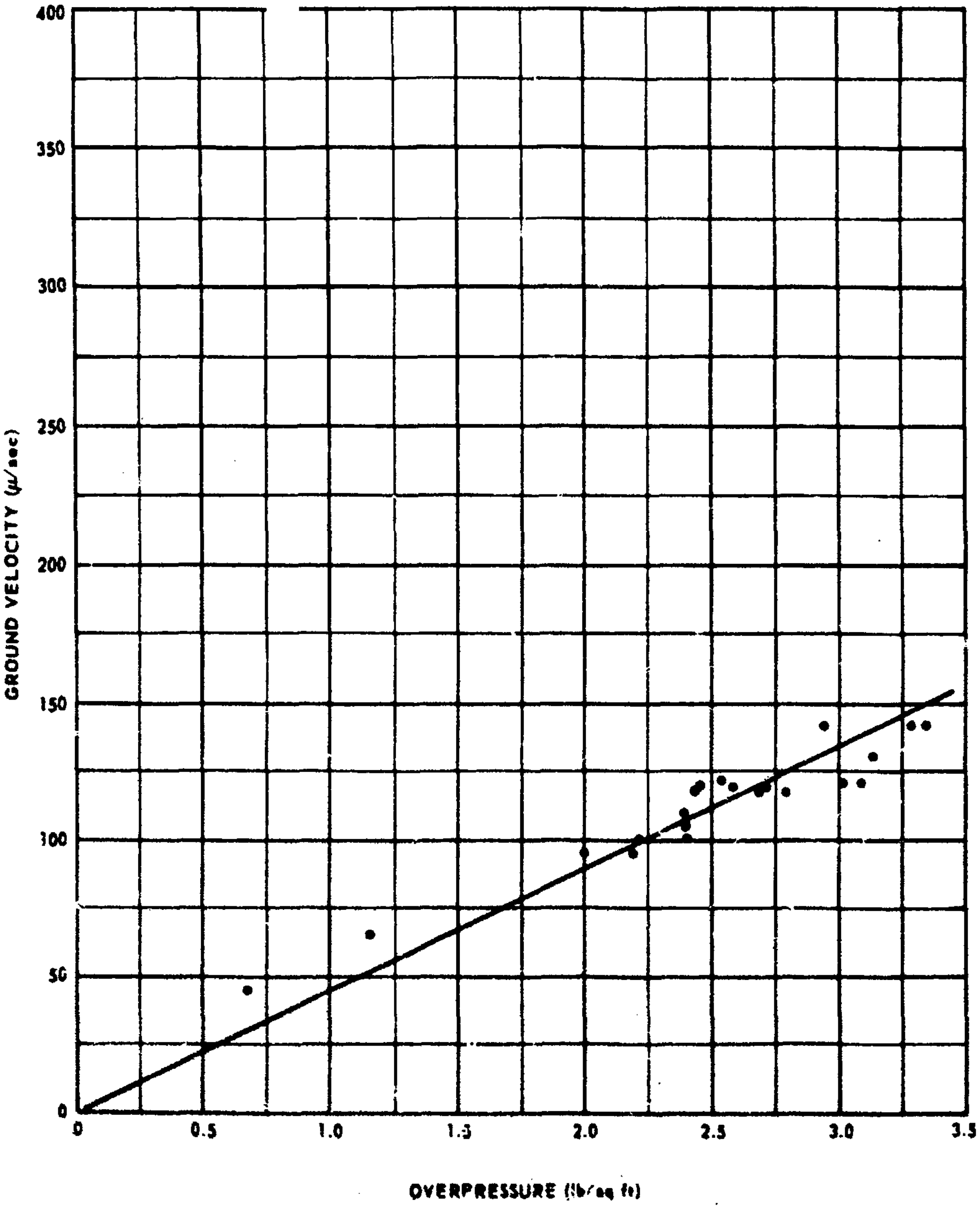


FIG. 12 RELATION OF PEAK POSITIVE OVERPRESSURE TO THE MAXIMUM VELOCITY ASSOCIATED WITH SEISMIC ENERGY PROPAGATING WITHIN THE FREQUENCY RANGE 5-10 cps RECORDED BY A SEISMOMETER LOCATED ON PLAYA CL/Y (microphone 31)

Annex F

ENERGY SPECTRAL DENSITY OF SOME SONIC BOOMS

by

J. R. Young, P. J. Johnson, K. D. Kryter, and W. A. Aron
Stanford Research Institute

Annex F

CONTENTS

ILLUSTRATIONS

TABLES

Annex F

ENERGY SPECTRAL DENSITY OF SOME SONIC BOOMS

I CONCEPT AND DEFINITION OF ENERGY SPECTRAL DENSITY

In previous work,[1*] energy spectral density (ESD) has been proposed as a method for representing the frequency-intensity properties of the sonic boom. The definition of the ESD function as used heretofore is:

$$|P(\omega)|^2 = \left|\int_{-\infty}^{+\infty} p(t)\, \epsilon^{-i\omega t}\, dt\right|^2 \qquad -\infty < \omega < +\infty \quad , \tag{1}$$

where p(t) is a real-valued time-varying pressure associated with a transcient phenomenon, such as the sonic boom, and ω is angular velocity ($2\pi f$). To calculate the physically measurable energy $E(\omega_1, \omega_2)$ in a specified frequency band between frequencies f_1 and f_2 the following integration is performed:

$$E(\omega_1,\omega_2) = 4 \int_{\omega_1 = 2\pi f_1}^{\omega_2 = 2\pi f_2} |P(\omega)|^2\, d\omega \qquad 0 < \omega_1 < \omega_2 \quad . \tag{2}$$

For the ideal N-wave, with duration D and amplitude ΔP, as shown in Fig. 1, spectral asymptotes have been calculated.[1] These asymptotes, when applied to the relation in Eq. (2) are:

$$A_{low} = \frac{\Delta P^2\, D^4\, \omega^2}{9} \tag{3}$$

$$A_{med} = \frac{16\, \Delta P^2}{\omega^2} \tag{4}$$

A typical spectrum of $E(\omega)$ for the ideal N-wave is sketched in log-log form, with asymptotes indicated thereon, in Fig. 2. The low-frequency and medium frequency asymptotes have slopes of +6 dB/octave and −6dB/octave, respectively.

---

*J. R. Young, "Energy Spectral Density of the Sonic Boom," J. Acoust. Soc. Am. 40, 496-498 (1966)

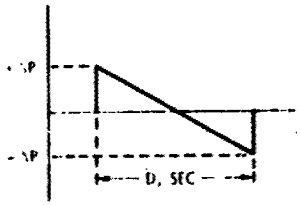


FIG. 1 IDEAL N-WAVE

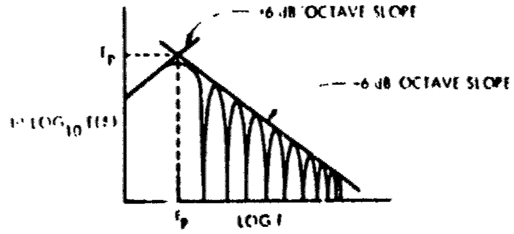


FIG. 2 SPECTRUM OF IDEAL N-WAVE

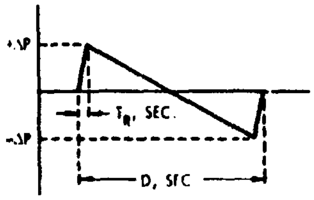


FIG. 3 N-WAVE WITH NONZERO RISE TIME, T_r

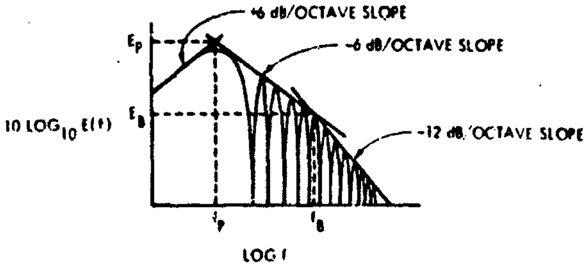


FIG. 4 SPECTRUM OF N-WAVE WITH RISE TIME, T_r

If the sonic boom is assumed to have a nonzero rise time, T_r, as in Fig. 3, further analysis shows that a third asymptote must be calculated to account for the high-frequency behavior of $E(\omega)$ or $|P(\omega)|^2$. This asymptote has been found to be, for $E(\omega)$

$$A_{high} = \frac{64 \quad \Delta P^2}{T_r^{\ 2} \ \omega^4} \quad . \tag{5}$$

Thus, for the wave illustrated in Fig. 3, the corresponding plot of $E(\omega)$ is that in Fig. 4, where the high-frequency asymptote has a slope of -12 dB/octave and the remaining two asymptotes have ±6 dB/octave slopes as before.

By equating the relations for asymptotes, two intersections can be solved for, one of which is the frequency, f_p, and intensity of $E(\omega)$ at its peak, E_p, the other being the frequency, f_b, and intensity, E_b, at which the spectrum begins to roll off at -12 dB/octave. These relations are:

$$\text{Peak frequency,} \quad f_p = \frac{0.552}{D} \tag{6}$$

$$\text{Peak intensity,} \quad E_p = \frac{2}{3} \Delta P^2 \ D^2 \quad . \tag{7}$$

In Eq. (7) an extra factor of 2 is implicit. This factor takes into account the realization that the asymptotic solution at the frequency f_p yields an energy that is twice the actual energy calculated by using an exact expression for $E(\omega)$.

$$\text{Breakpoint frequency,} \quad f_b = \frac{1}{\pi \ T_r} \quad . \tag{8}$$

$$\text{Breakpoint intensity,} \quad E_b = 4 \ \Delta P^2 \ T_r^{\ 2} \ . \tag{9}$$

II SPECTRA OBTAINED FROM EXPERIMENTAL DATA

Figure 5 shows three sample spectra and associated pressure-time plots for Missions 15-1, -2, and -3, which were flown by XB-70, B-58, and F-104 aircraft, respectively.

The raw data from these spectra and all others referred to later were obtained by digitizing analog FM tapes of NASA cruciform microphone outputs at 5000 samples/second. Each sample was converted to a binary number 11 bits in length. A low pass presampling filter was used with its cutoff frequency set to about 1350 Hz.

Table 1 summarizes the values of peak overpressure, ΔP, and rise time, T_r, as read by NASA personnel from time-amplitude tracing recordings at the Edwards test site. The table also contains calculated values for ΔP and T_r, designated ΔP_c, and $T_{r,c}$. These values were obtained by using E_p and f_b from computed energy spectra as follows:

$$\Delta P_c = \frac{1}{D} \sqrt{\frac{3}{2} E_p} \tag{10}$$

$$T_{r,c} = \frac{1}{\pi f_b} \tag{11}$$

Implicit in the calculation of ΔP_c and $T_{r,c}$ is a smoothing of the computed spectra by ideal asymptotes that, in turn, are used to define E_p and the break-frequency f_b.

Table 1

COMPARISON OF SONIC BOOM PARAMETERS MEASURED FROM TIME-AMPLITUDE TRACINGS AND THOSE CALCULATED FROM ENERGY SPECTRA IN FIG. 5

	Values Obtained From Time-Amplitude Tracings (NASA)		Values Calculated from Computed Energy Spectra Using Eqs. (10) and (11)	
Aircraft	ΔP	T_r	ΔP_c	$T_{r,c}$
F-104	2.29 psf	0.0040 sec	2.32 psf	0.0047 sec
B-58	2.29 psf	0.0040 sec	2.49 psf	0.0041 sec
XB-70	2.32 psf	0.0055 sec	2.19 psf	0.0051 sec

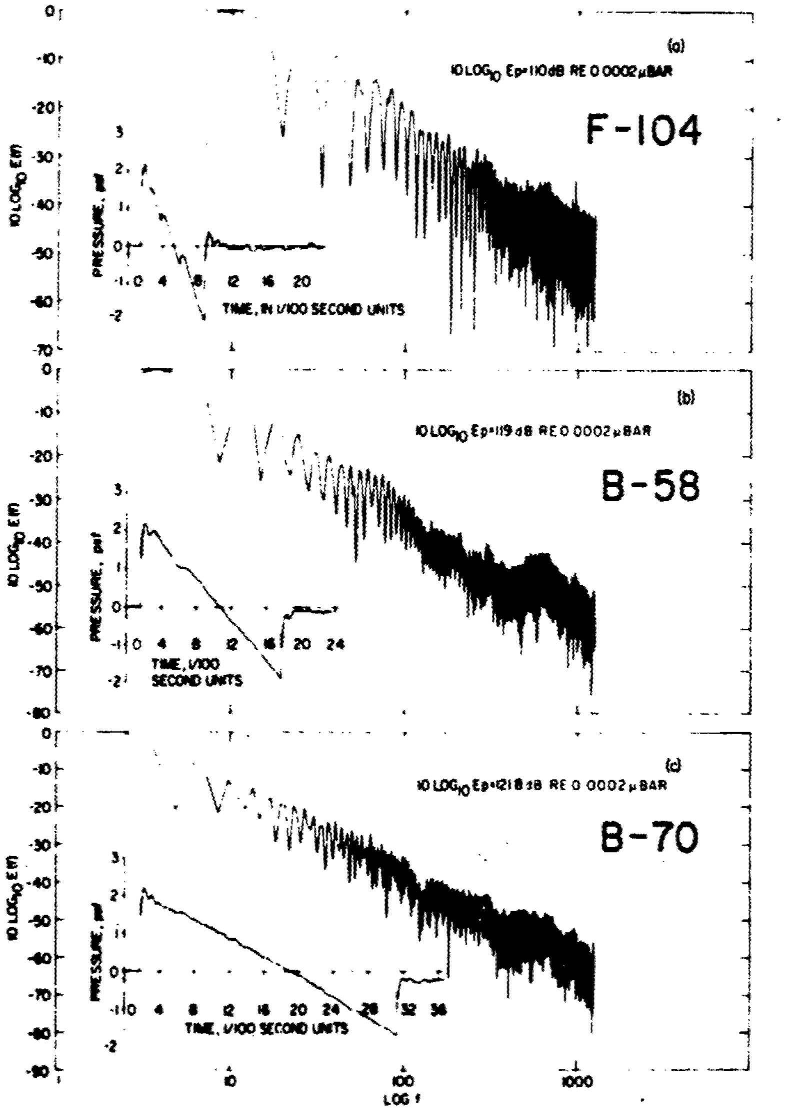


FIG. 5 PRESSURE-TIME AND E(f) PLOTS FOR THREE AIRCRAFT, F-104, B-58, AND XB-70

For this limited number of cases fair agreement and consistency appear between pressure-time parameters extracted directly from a time-amplitude plot and the same parameters calculated from computed energy spectra of the same time-amplitude plot. Particularly in the case of the values ΔP_c, it appears that wave-rounding and spiking at the N-wave peaks seem to be smoothed and an "effective" value of ΔP is obtained. General agreement between T_r and $T_{r,c}$ is apparent, though grossness of these particular energy plots does not permit a precise measure of f_b. Moreover, the spectra fail, as expected, to follow exactly the regular theoretical asymptotes, and this creates uncertainty in defining an exact f_b. Nevertheless, agreement between T_r and $T_{r,c}$ seems reasonably good.

Figure 6 shows five pressure-time and energy spectrum plots for Mission 123-1, which was flown by a B-58 aircraft at 47,600 ft MSL, Mach 1.51, and offset left of the prescribed track 4900 ft. The basic data were also derived from five microphones in the NASA cruciform array. The figure tends to indicate variabilities in pressure waveforms and spectra that may be expected for a single nominal event or flight when monitored by five closely spaced microphones (the arms of the cruciform were 200 ft long, with microphones spaced 100 ft apart). For this case, the range and average deviation from the median for ΔP, as read by NASA, measured 3.22 dB and 1.163 dB, respectively; for energy in the band 0-50 Hz, 2.14 dB and 0.694 dB, respectively; and for energy in the band 20-200 Hz, 4.92 dB and 1.34 dB, respectively. The other energy measures for this event lie within the upper and lower limits of the energy statistics quoted.

III ANALYSIS OF TOTAL ENERGY IN CERTAIN FREQUENCY BANDS

Energy spectra have been determined for 16 B-58 missions (four on 8 December 1966 and 12 on 8 November 1966) and for four missions (2 XB-70, 1 B-58, and 1 F-104) on 3 January 1967. For each mission the five NASA cruciform microphone channels were analyzed by finding total energy for each channel and each sonic boom, and total energy in each of six frequency bands: 0-50 Hz, 10-30 Hz, 0-200 Hz, 0-1000 Hz, 20-200 Hz, and 20-1000 Hz.

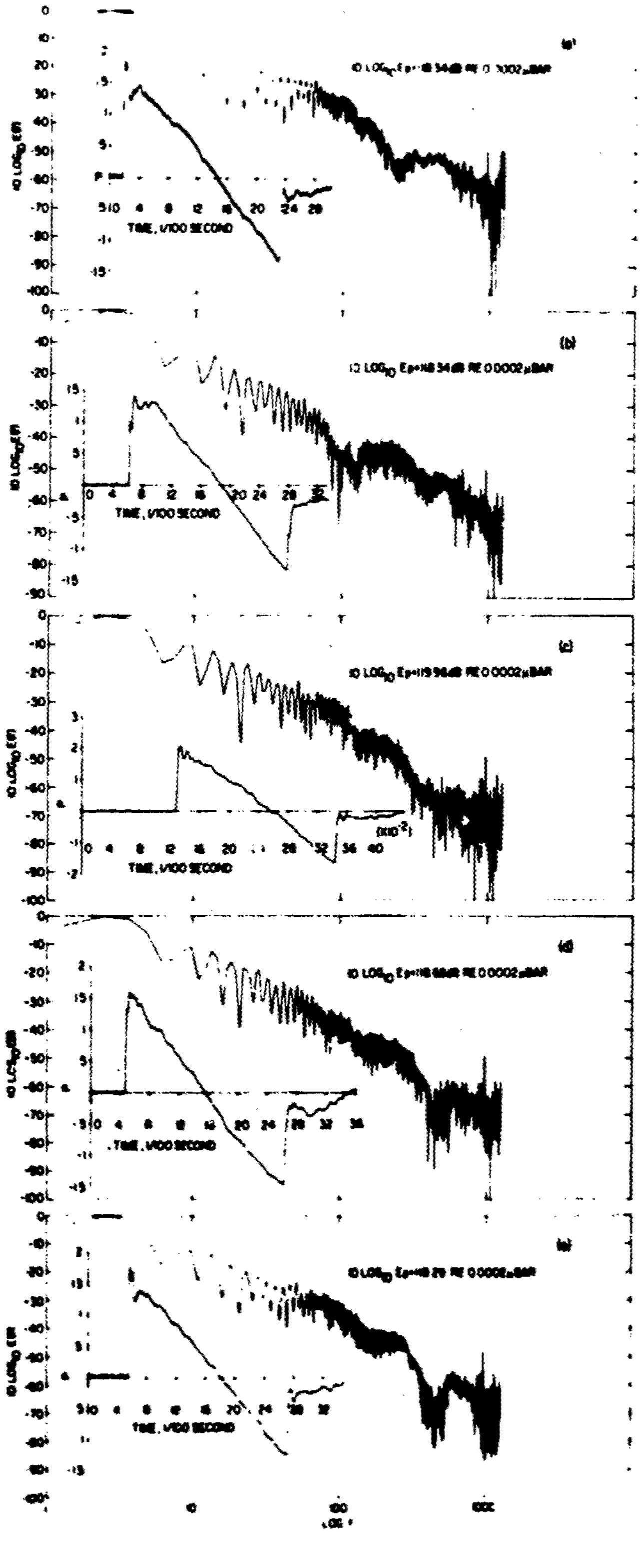


FIG. 6 PRESSURE-TIME PLOTS AND ENERGY SPECTRA FOR FIVE MICROPHONE RECORDINGS OF MISSION 123-1 FLOWN BY B-58 AIRCRAFT

By way of checking the accuracy of the energy spectral computations, total energy was derived in two ways: first by direct computation using

$$E_t = \int_I p^2(t)\,dt \quad , \quad \text{(I is a time interval containing the sonic boom)} \tag{12}$$

and second, by

$$E_t = \int_{f_{min}}^{f_{max}} E(f)\,df \tag{13}$$

where f_{min} and f_{max} were the extreme frequencies for which the spectra could be calculated owing either to sample length (approximately 0.80 sec) or sampling rate (5000 samples/second). These independent estimates of total energy agreed to five significant decimal places for all examples calculated by using Eq. (2) with the appropriate frequencies included as integral limits. The energy density at zero frequency was adjusted to zero in all cases.

A third check of the approximate total energy in any particular N-wave can be obtained by assuming that the wave is an ideal wave with negligible rise time and with ΔP and D as measured.

$$E_t = \Delta P^2 \frac{D}{3} \quad . \tag{14}$$

For the cases considered here this estimate is, and should be, consistently higher than actual values by 10 to 20 percent. Nevertheless, Eq. (14) can be used as a rough check for more precise values.

Table 2 contains summary statistics for 16 B-58 flights whose nominal flight parameters were 48,000 ft altitude, Mach 1.65, on a track directly over the NASA cruciform array. Only slight deviations from these parameters on a mission-to-mission basis were found from examination of the official log of the Edwards Experiment, and it is felt that the flights were sufficiently close to nominal conditions to permit summarizing the data as shown.

Table 2

SUMMARY STATISTICS OF 16 B-58 FLIGHTS ON 8 NOVEMBER 1966 AND 8 DECEMBER 1966, FIVE MICROPHONE CHANNELS PER FLIGHT*

Parameter	Average of Median Values for Each Flight for the Five Microphones	Range Over 16 Flights of Median Values of 5 Microphones per Flight	Average Range	Ave. Deviation of Medians for Five Microphones for Each Flight from Median 16 Flights
ΔP	1.75 psf	5.146 dB	2.045 dB	0.705 dB
$E_{0-50\ Hz}$	119.46 dB	4.120 dB	1.240 dB	0.423 dB
E_{0-200}	119.53 dB	4.170 dB	1.305 dB	0.422 dB
E_{0-1000}	119.63 dB	4.171 dB	1.305 dB	0.422 dB
$E_{20-1000}$	106.44 dB	7.930 dB	2.640 dB	0.890 dB
E_{20-200}	106.32 dB	8.340 dB	2.620 dB	0.890 dB
E_{10-30}	109.81 dB	5.240 dB	1.610 dB	0.590 dB
E_{total}	119.54 dB	4.171 dB	1.246 dB	0.370 dB

* Energies were computed by converting ΔP in units of psf to units of 0.0002 μBar.

In Table 2 each measure was determined for each of five microphone channels for each flight, and medians of dB readings for each flight were used to compile the statistics. The average deviation from the median, listed in the extreme right column, is thus the quantity

$$\text{Average deviation} = \frac{1}{16} \sum_{1}^{16} \sum_{1}^{5} \frac{|X_i - X_3|}{4} \qquad (15)$$

where X_i is one of four measures of a parameter expressed in dB different from the median, and X_3 is the median expressed in dB of the five channels for the flight and parameter under consideration. ΔP is the peak overpressure obtained from the digital records used for computation. The range of median values is taken as being across all flights and all channels, and the average range is that for all flights on a flight-by-flight basis.

The data seem to indicate that ΔP and the energy bands containing high frequencies vary considerably more than does the total energy associated primarily with low-frequency content.

Table 3 was computed to try to establish correlations between the pressure-time parameters ΔP and T_r and the various parameters associated with the energy spectrum. Data from microphone No. 3 are used here; the other microphone data are similar and consistent with these results.

Table 3

CORRELATIONS BETWEEN ΔP AND T_r AND ENERGY SPECTRUM MEASURES FOR CHANNEL 605 OF THE NASA CRUCIFORM ARRAY, USING THE SPEARMAN RANK CORRELATION COEFFICIENT, r

Parameter	ΔP Correlations, N=16		T_r Correlations, N=15	
	r	Significance of r	r	Significance of r
E_{0-50}	0.7873	$\lvert r_{.95}\rvert = 0.426$	-0.4464	$\lvert r_{.95}\rvert = 0.441$
E_{0-200}	0.8529	$\lvert r_{.975}\rvert = 0.497$	-0.4964	$\lvert r_{.975}\rvert = 0.514$
E_{0-1000}	0.8529	$\lvert r_{.99}\rvert = 0.574$	-0.4964	$\lvert r_{.99}\rvert = 0.592$
$E_{20-1000}$	0.9132	$\lvert r_{.995}\rvert = 0.623$	-0.7460	$\lvert r_{.995}\rvert = 0.641$
E_{20-200}	0.9221	$\lvert r_{.9995}\rvert = 0.742$	-0.7460	$\lvert r_{.9995}\rvert = 0.760$
E_{10-30}	0.8441		-0.4929	
E_{total}	0.8529		-0.4964	

In Table 3 r is a statistical measure of the dependence of an energy parameter and ΔP or T_r. Higher values of r indicate a greater dependence or correlation, and lower values indicate a lesser dependence or correlation. Subscripted r values indicate the confidence level of the measure for specific values of r. For example, $r_{.95} = 0.426$ implies that a value of r equal to 0.426 or greater could occur by chance when two variables are actually uncorrelated or independent five times in 100 trials of sampling the paired variables 16 times. In the table, 16 pairs are available for ΔP correlations, and 15 pairs for T_r; hence, the r values have different interpretations as shown.

Though all the energy measures are highly correlated with ΔP ($r \cdot r_{.9995}$), the highest correlation occurs in the energy band $E_{20-1000}$ and E_{20-200}. Correlations of energies with T_r are considerably less, though still quite high except for E_{0-50}, where r is but slightly greater than $r_{0.95}$. Again, however, the highest correlations occur with T_r and E_{20-200} or $E_{20-1000}$, which is not surprising in view of the analysis and results presented previously in Sections I and II. The relatively high correlation between T_r and E_{0-50} is somewhat surprising until the also high correlation between ΔP and T_r is computed, -0.6107 for $N = 15$.

Table 4 summarizes data obtained from Missions 7-1, 15-1,-2, and -3. These data permit some preliminary comparisons between different aircraft with regard to energy spectral parameters.

The last three missions in the table are comparable with regard to ΔP and its statistics and allow some comparisons between the XB-70 and either the F-104 or the B-58 . Though the data are limited in quantity it would appear that the results are consistent with theory and other available data. It is interesting to note that for E_{10-30} the F-104 aircraft has a higher value than either the XB-70 or the B-58. Upon examination of several energy spectra samples, this result seems to be due to the spectral lobe distribution patterns of these aircraft and is probably a consistent difference, other things (such as ΔP) being equal.

IV SUMMARY AND CONCLUSIONS

Energy spectra have been computed and summarized for 16 B-58 flights on 8 November 1966 and 8 December 1966, and for four flights on 3 January 1967 involving XB-70, B-58, and F-104 aircraft. For each flight, spectra were measured for each of five microphones in the NASA cruciform array. Thus, a total of 100 energy spectra was obtained and summarized.

Table 4

COMPARISON OF DIFFERENT AIRCRAFT BY ENERGY SPECTRUM PARAMETERS
AMONG FIVE MICROPHONES*

Mission & A/C	ΔP			E_{0-50}			E_{0-200}			E_{0-1000}			$E_{20-1000}$			E_{20-200}			E_{10-30}			E_{total}		
	Med. psf	Rng. dB	Dev dB	Med. dB	Rng. dB	Dev. dB	Med. dB	Rng. dB	Dev. dB	Med. dB	Rng. dB	Dev. dB	Med. dB	Rng. dB	Dev. dB	Med. dB	Rng. dB	Dev. dB	Med. dB	Rng. dB	Dev. dB	Med. dB	Rng. dB	Dev. dB
7-3 XB-70	1.63	4.8	2.1	117.1	2.334	0.669	117.34	2.384	0.64	117.36	2.339	0.63	106.54	3.63	1.06	106.27	3.79	1.62	106.92	2.65	0.77	117.36	2.340	0.63
15-3 F-104	2.267	3.1	0.9	117.35	2.468	0.687	118.64	2.514	0.70	117.68	2.499	0.52	111.76	3.34	0.96	111.58	3.26	0.96	114.52	2.55	0.66	117.69	2.497	0.70
15-1 XB-70	2.234	2.4	0.8	123.47	2.344	0.638	123.51	2.331	0.75	123.52	2.326	0.63	109.42	2.18	0.61	109.28	2.23	0.69	112.12	2.83	0.78	123.52	2.326	0.63
15-2 B-58	2.300	2.70	0.8	121.54	2.275	0.641	121.63	2.261	0.63	121.65	2.258	0.78	110.23	2.40	0.71	110.09	2.43	0.52	112.80	2.03	0.61	121.65	3.258	0.66

* Energies were computed by converting ΔP in units of psf to units of 0.0002 μBar.

Theoretical properties of the energy spectral density function of the sonic boom have been compared to properties obtained from spectra computed from actual booms, and good agreement and consistency have been found. In general, the experimental data indicate that all parts of the energy spectrum are correlated with observed variations of the peak overpressure ΔP; the best correlations of ΔP occur in the energy measures E_{20-200} and $E_{20-1000}$; E_{0-50} is most independent of variations in ΔP for a series of 16 nominally similar events. Correlations of energy band content with rise time are poorer, though still significant; E_{20-200} and $E_{20-1000}$ correlate best with rise time, and E_{0-50} correlates least with rise time.

For three comparable flights of XB-70, B-58, and F-104 aircraft, the energy band content for all bands, except the 10-30 Hz band rank downward in the order listed. In the 10-30 Hz band, the F-104 aircraft has the highest energy content by what appears to be something in excess of 2 dB relative to the XB-70. This particular result is consistent with the energy-spectral-lobe patterns of the sonic boom spectra of these aircraft, that in turn is associated with the differing sonic boom duration parameters.

The least variability among the five microphones is observed in the energy measures E_{0-50}, E_{0-200}, E_{0-1000}, and E_{total}; the greatest variability is observed in ΔP and the energy measures E_{20-200} and $E_{20-1000}$.

Annex G

Part I

RESPONSE OF STRUCTURES TO SONIC BOOMS

John A. Blume & Associates Research Division

Part II

VIBRATION RESPONSES OF TEST STRUCTURES NOS. 1 AND 2 DURING PHASE I OF THE SONIC BOOM EXPERIMENTS AT EDWARDS AIR FORCE BASE

NASA, Langley Research Center

Annex G

Part I

RESPONSE OF STRUCTURES TO SONIC BOOMS

by

J. A. Blume, R. L. Sharpe, J. Proulx, and E. G. Kost
John A. Blume & Associates Research Division

Annex G

Part I

RESPONSE OF STRUCTURES TO SONIC BOOM

INTRODUCTION

The purpose of this report is to present a summary of the status of the structural response, damage investigation and damage prediction work resulting from the experiments at Edwards Air Force Base. The primary objectives of the structural response portion of the Edwards Test Program were to:

1. Determine the response or reaction of structures to sonic booms generated by XB-70, B-58, and F-104 aircraft.
2. Evaluate damage resulting from these sonic booms.
3. Develop a means of predicting structure response and possible damage from sonic booms generated by the SST based on data from present aircraft.

To fulfill these objectives an overflight program was designed to subject instrumented structures to sonic booms from F-104, B-58, and XB-70 aircraft. The overflight program provided for different levels of overpressure as well as overhead and offset flights.

Two wood frame test house structures were built at Edwards AFB; one was a two-story house and the other a one-story house, each with wood framed floors. They were both built in accordance with plans obtained from a large housing contractor and are representative of typical contemporary mid-western construction. Each of the test houses was instrumented to record the loading on and the response of the houses and certain of their structural elements. The arrangement of the instruments was modified after the first few weeks of the program in order to increase the effectiveness of the information obtained.

In addition to the two test houses, the Bowling Alley on the Base was selected as a structure with a representative long-span roof. Instruments were installed to measure the response of the roof structure and the building frame to sonic boom.

For the first few weeks of the program, a two-story house identical to the two-story test structure at Edwards was leased in Lancaster, California. Instruments were installed to measure the effect of sonic boom loading from an aircraft at a large lateral distance from the test structure. Measurements were not recorded after the first few weeks because of the minimal information obtained. Due to the large lateral displacement of the aircraft and generally prevailing windy conditions, the boom intensities and structural reactions were often masked by natural phenomena.

The report presented in the following pages briefly discusses the instrumentation used, data reduction procedures, methods of structural analysis and typical results, types of damage complaints received and results of investigations, and methods of damage prediction. The text terminates with a summary of preliminary findings.

Appendices G-1, G-2, and G-3 are reports covering the construction of the test structures, sonic boom damage complaints received and investigated, and the results of a pre-test flight survey of glass windows at Edwards AFB.

Three basic types of sensing instruments (transducers) were installed: microphones, accelerometers, and strain gages. Microphones were used to measure overpressures at ground level near the instrumented structures (free field signatures) and to measure exterior and interior overpressures on structural elements (loading signatures). Accelerometers and strain gages were used to measure the response or reaction of the structures and selected structural elements. Each instrument was selected to be compatable with the characteristics (frequency response and size) of the structural element. Annex A, Test Operations Plan, presents a detailed description of the instrumentation.

The signals generated by these transducers when subjected to sonic booms were recorded on analog magnetic tape by precision FM tape recorders. The recordings were reviewed shortly after each mission and minor modifications were made in the instrumentation when required.

DATA REDUCTION

In order to evaluate and analyze the data, the instrument data on the analog tapes were recorded on photo-sensitive paper. The recordings on paper were a visual record of the pressures, accelerations, etc., produced by the booms and were used to make comparative judgments of the different instrument measurements. Measurements were made from these oscillographic records of rise time (time required for boom overpressure to reach a peak positive value), peak positive and negative overpressures, and boom duration. A more detailed discussion of preliminary data reduction procedures is presented in the Test Operations Plan. The analog data were also converted to digital form so that they could be processed by digital computers. Several different computer programs have been developed and are presently being used as aids in the analysis of data.

STRUCTURAL ANALYSIS

There are two basic types of loading to which a structure can be subjected. The first is a static load, such as a warehouse floor load, where the intensity or pressure of the load does not vary for long periods of time, and the second is the dynamic load, such as a sonic boom, where the intensity varies greatly over a very short period of time. A given structure or element of a structure will, in general, respond or react quite differently to dynamic and static loads. The deformation of or stresses in a structure element due to a static load can be calculated by conventional procedures, whereas similar calculations for a dynamic load are considerably more complex.

To facilitate the calculation of reaction to dynamic loads, the concept of an equivalent static load has often been used. In this concept, dynamic loads acting on a structure are replaced by equivalent static loads that produce the same deformations or stresses as the dynamic loads. Once these equivalent static loads have been determined, the stresses and deformations of the structure can be calculated.

The relationship between a dynamic load and its equivalent static load can be determined from structural models that represent in mathematical form the properties and response of the structure and the applied load. These models are based on the assumption that the structure can be represented by an idealized single degree of freedom-damped system; the response of this system is then corrected for the participation of the other vibrational modes.

The structural model described above is used with sonic boom loading to determine the relationship between the dynamic load and an equivalent static load. This relationship is expressed as the ratio of the equivalent static load to the dynamic load, or Dynamic Amplification Factor (DAF). DAF is a dimensionless ratio and for a given structural element depends upon the element's natural frequency, stiffness, damping, and the type of applied loading.

DAF is often plotted as a spectrum, see Figure G-1. These curves represent the values of DAF calculated for structural elements with 2% critical damping with a range of natural frequencies from 0.5 to 50 Hz (cps) when subjected to an applied loading of a sonic boom N-wave. Note that as the duration of the sonic boom increases, the DAF spectrum curve is shifted to the left on the graph. Since larger aircraft produce sonic booms of greater duration than do smaller aircraft, it can be seen that sonic booms from large aircraft such as the XB-70 and future SST will affect a greater range of structural elements than will smaller aircraft. The DAF spectrum curves in Figure G-1 were determined from free field signatures for a number of overhead flights of the XB-70, B-58, and F-104 aircraft flown during Phase II. The curves are drawn as envelopes of the DAF for each aircraft, that is, all of the DAF curves for the overhead missions listed in Table G-1 were plotted and then curves drawn through the maximum and minimum values for each aircraft. The DAF spectrum for overhead XB-70 flights flown at Mach 2.5 closely corresponds

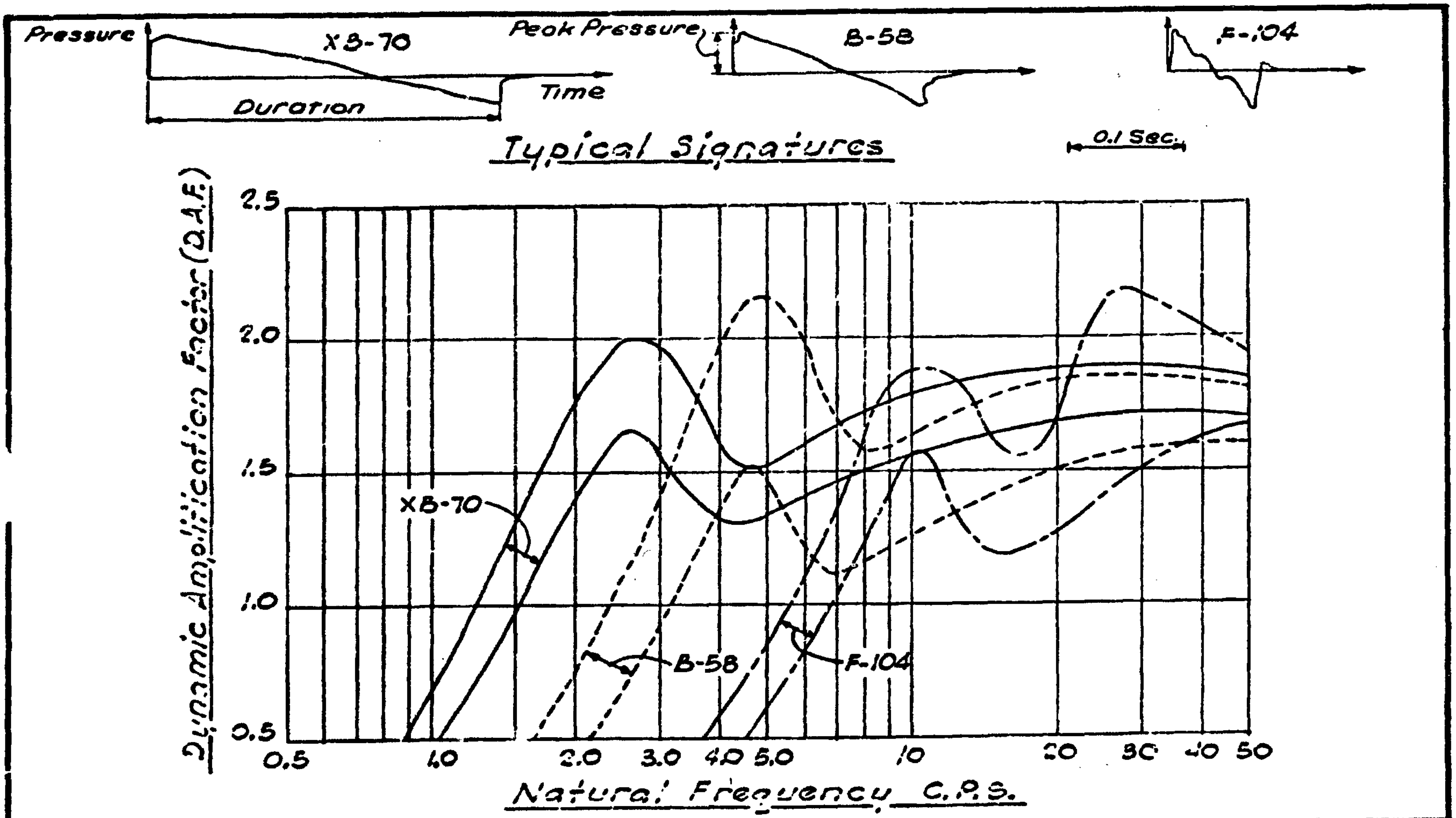


FIG. G-1

ENVELOPES OF RESPONSE OF 2% DAMPED SYSTEMS TO FREE FIELD LOADING

FIG. G-1

Table G-1

AIRCRAFT AND MISSIONS INVOLVED IN FIGS. G-1, G-3, G-4, AND G-5 PHASE II TEST FLIGHTS

Aircraft	Mission	Altitude (1000 ft)	Mach	Offset (1000 ft)	Fig.G-1	Fig.G-3	Fig.G-4	Fig.G-5
XB-70	13-2	60.2	1.80	R6.4	X	X		X
	15-1	60.6	1.80	R9.5	X			
	16-2	59.7	1.80	R0.7	X			
	113-2	60.3	1.80	L0.1	X	X	X	
	12-2	60.3	2.50	L0.2		X		
B-58	8-1	35.5	1.65	L3.3	X			
	9-2	40.4	1.65	R1.7	X			
	11-2	40.4	1.65	R0.8	X			
	12-1	39.2	1.65	L2.1	X	X		
	13-1	35.9	1.65	L2.5	X	X		X
	15-2	39.6	1.65	0.0	X			
	16-1	39.7	1.65	R3.0	X			
	113-1	39.1	1.65	L0.7	X	X	X	
F-104	11-1	20.8	1.40	L1.5	X			
	12-3	22.0	1.42	R6.7	X	X		
	13-3	20.0	1.40	R3.4	X	X		X
	15-3	20.2	1.40	R012	X			
	113-3	20.6	1.40	R1.2	X	X	X	

to the envelope for the XB-70 in Figure G-1. The concept of DAF provides a ready means for comparing the response of structures to sonic booms generated by aircraft of different size and for predicting structure response from larger aircraft such as the SST.

Figure G-2 shows a schematic perspective of Test Structure E-2 and the Phase II location of six of the pressure loading microphones. The relation of the free-field-loading microphones to House E-2 is shown in the Plot Plan. Figure G-3 shows DAF spectrum curves determined from loading signatures recorded on the exterior of the east wall of the dining room of the two-story house, E-2. Note that the curves are very similar to those plotted for the free-field signatures, and that the curves fall generally within or slightly below the envelopes plotted in Figure G-1. This would be expected as the shapes of these loading signatures are very similar to the free-field signatures except for the notch at the beginning and end of the loading signature. Figure G-4 shows typical pressure signatures in and around House E-2 for flights of XB-70, B-58, and F-104 aircraft. Note the variation in signature shape for the various areas in the house.

Figure G-5 presents DAF spectrum curves for the net overpressure loading on the east wall of the Dining Room in House E-2 for the missions noted in Table G-1. Net overpressure on an element is determined by subtracting the inside overpressure signature from the exterior overpressure signature. For the east wall of the Dining Room a loading microphone was suspended on the exterior wall and another microphone was suspended in the room. If Figures G-1, G-3, and G-3 are compared it can be seen that near the natural frequency of the Dining Room wall (20 Hz) the DAF spectrum curves for the free field signature, exterior loading on the house and the net overpressure on the wall are in general agreement. For natural frequencies of 3 to 8 Hz, the DAF spectrum for net overpressure indicates greater amplification of the overpressure produced by the B-58 and the DAF spectrum for the XB-70 shows a similar hump for the frequency range of 2.5 to 4 Hz. The DAF spectrum for F-104 net loading also shows a similar hump for the frequency range of 20 to 40 Hz. The lower frequency ranges are important because the natural frequencies

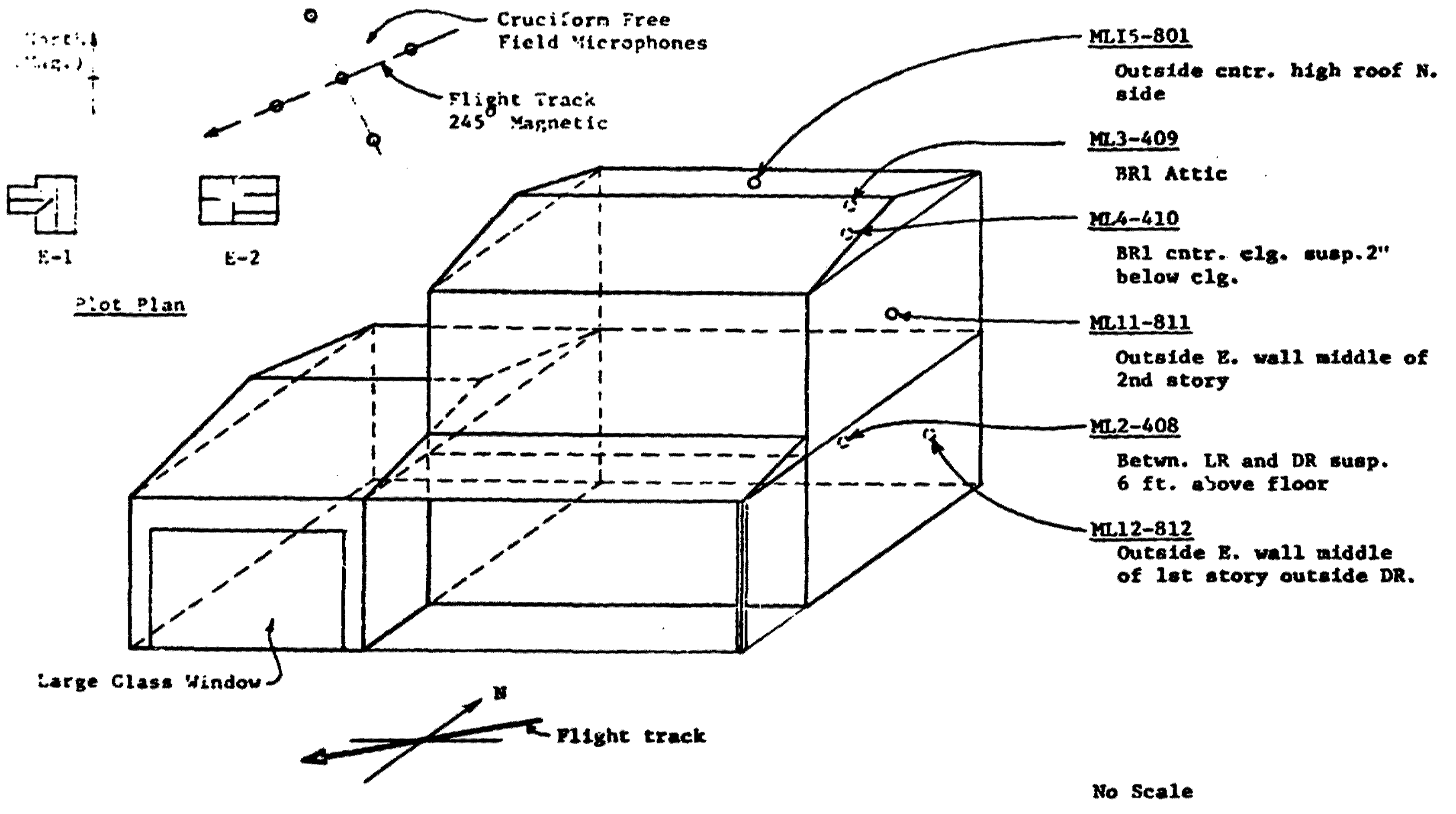


FIG. G-2

INSTRUMENT LOCATIONS
HOUSE E-2

FIG. G-2

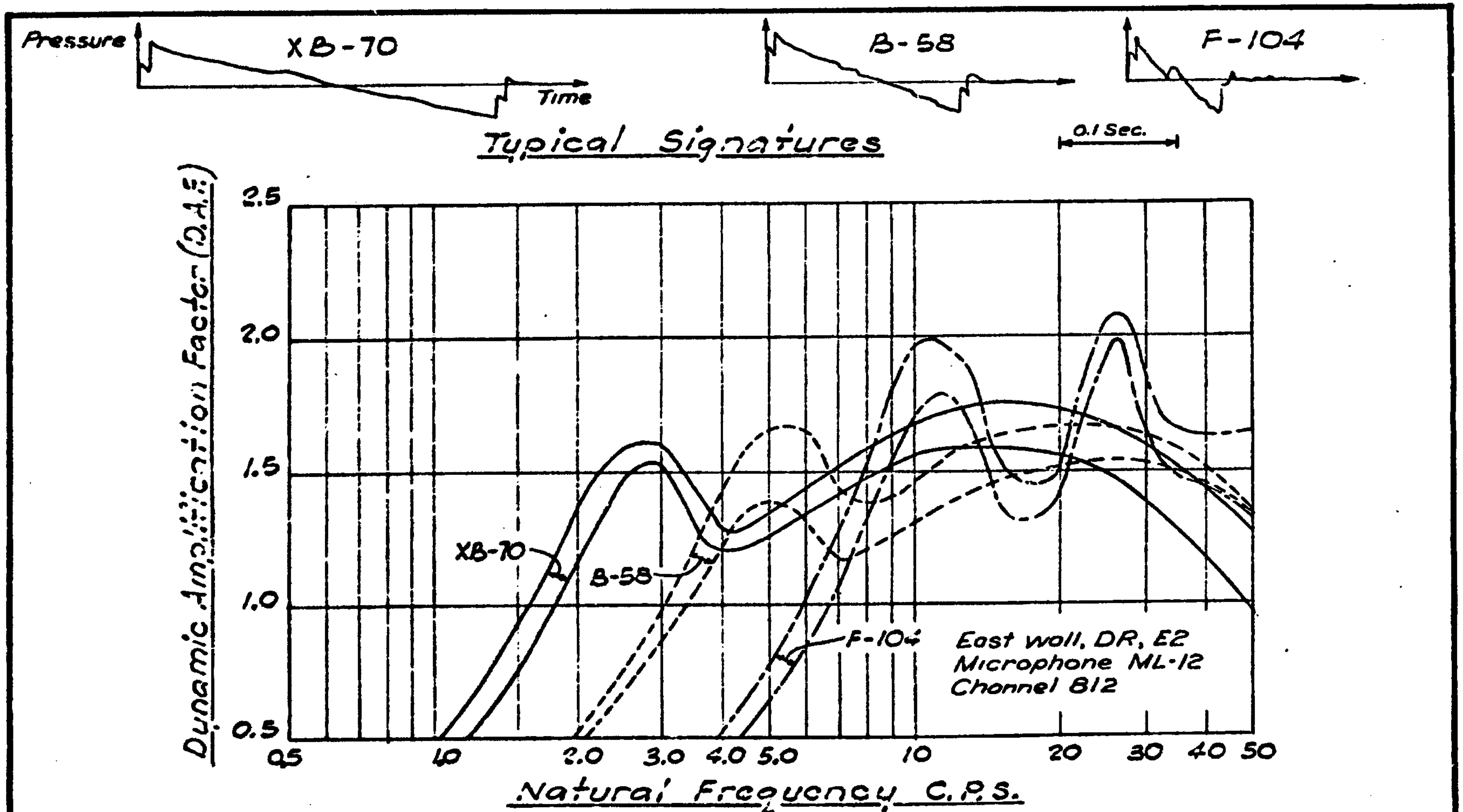


FIG. G-3

ENVELOPES OF RESPONSE OF 2% DAMPED SYSTEMS TO EXTERIOR WALL LOADING

FIG. G-3

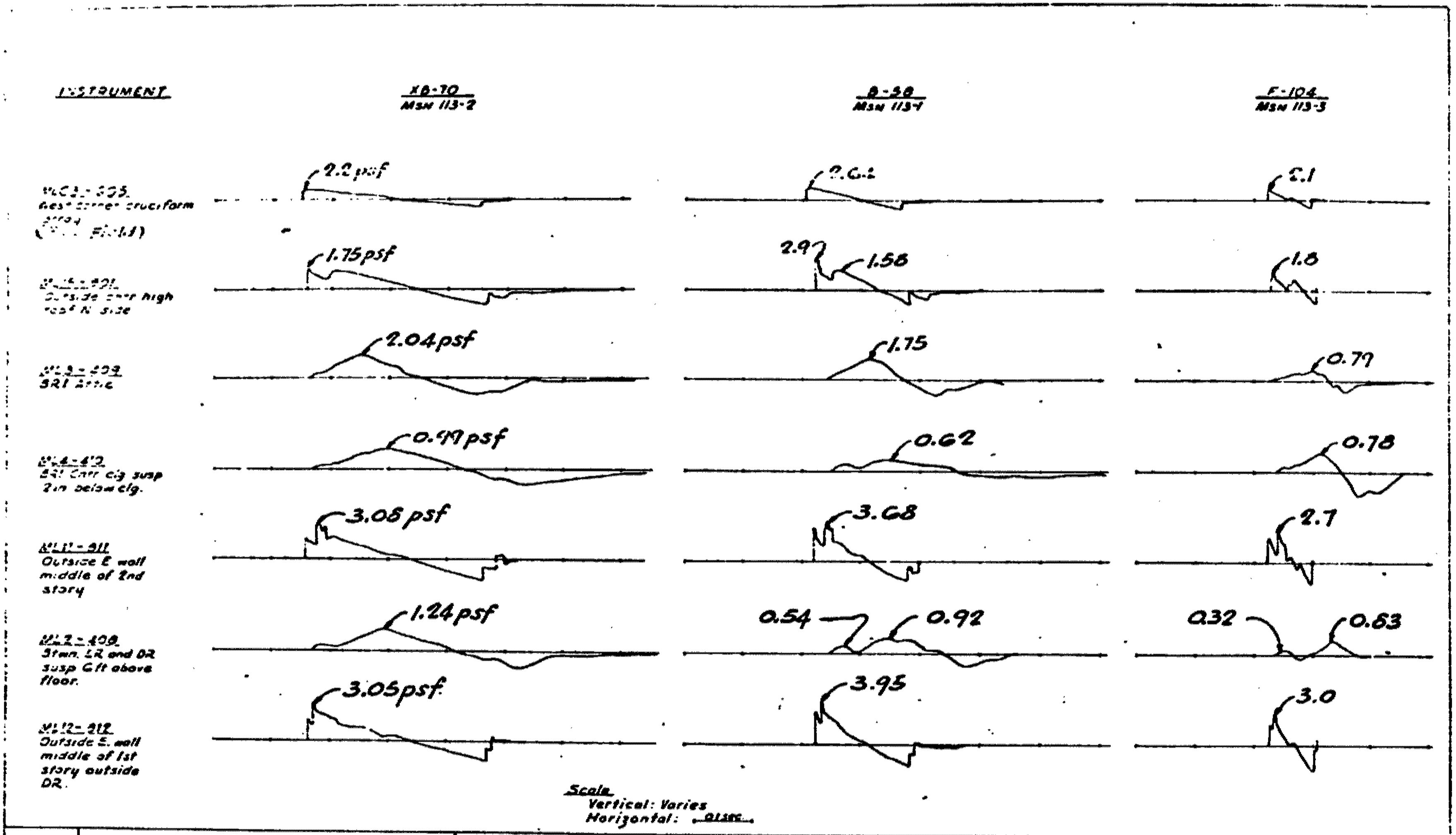
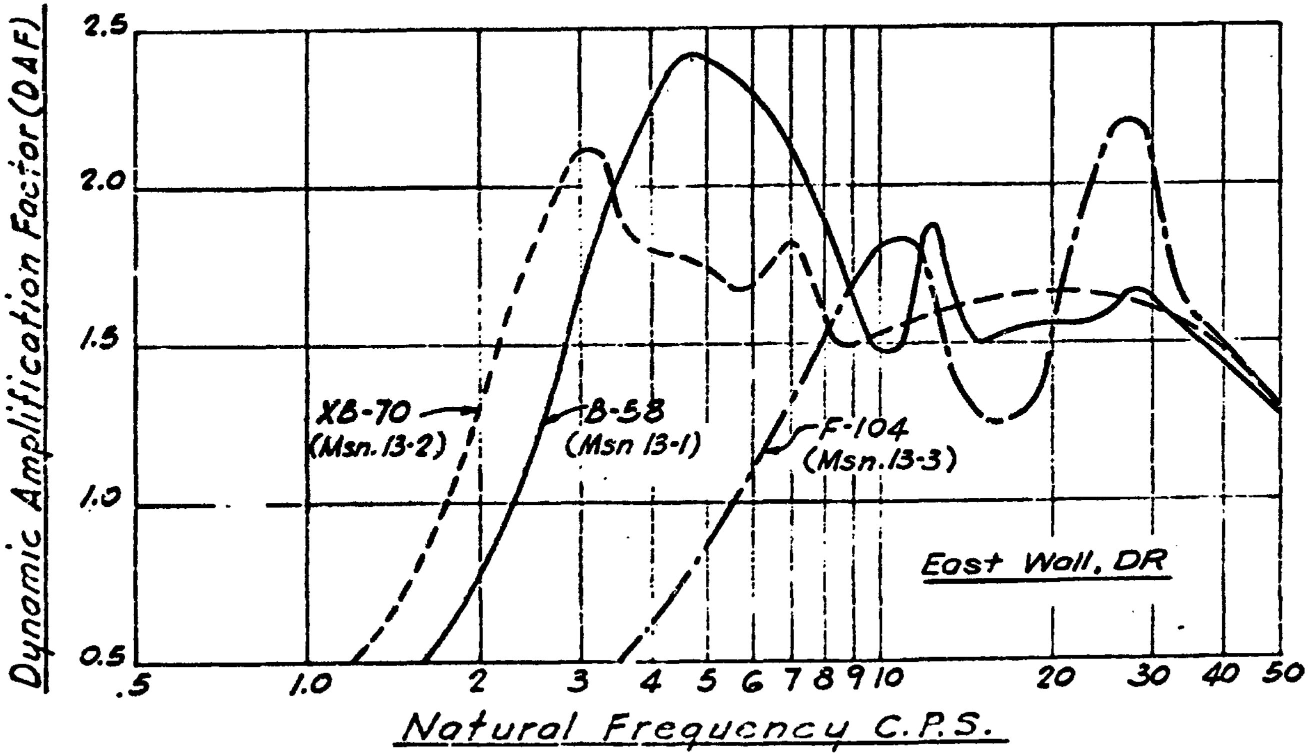


FIG. G-4

TYPICAL SIGNATURES
IN AND AROUND HOUSE E-2

FIG. G-4

Net Pressure = Outside pressure − Inside pressure.
Outside pressure from channel 812, microphone on exterior East wall, Dining Room.
Inside pressure from channel 408, microphone between Living Room and Dining Room, suspended 6' above floor.



RESPONSE OF 2% DAMPED SYSTEMS TO NET LOADING, HOUSE E2

FIG. G-5

FIG. G-5

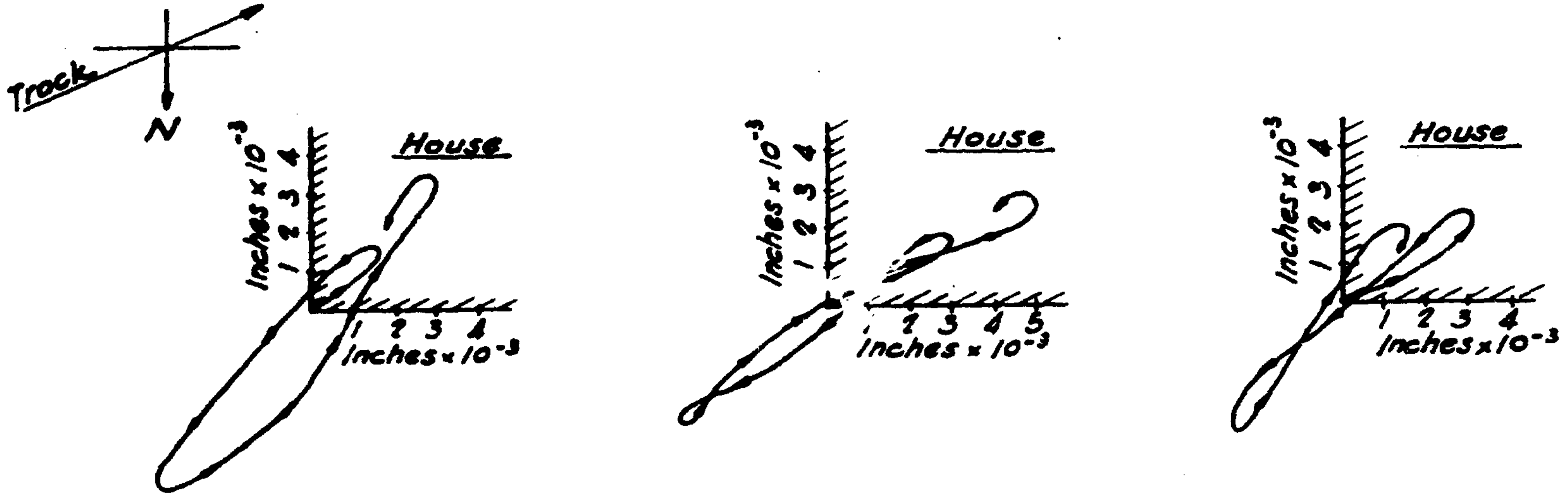
of large windows sometimes fall in these ranges.

As noted previously accelerometers were mounted on the exterior of Houses E-1 and E-2 at the northeast corners to measure racking displacements of the two structures. The racking movement of E-2 at the eave line, in response to a typical flight of the XB-70, B-58, and F-104 aircraft during Phase II, is shown in Figure G-6. Figure G-7 shows comparative racking displacements for the XB-70, B-58, and F-104 during Phase I.

Accelerometers were also located on the east wall of the Dining Room and north wall of Bedroom BR-1 in House E-2. Both rooms are located at the northeast corner of E-2, the Dining Room is on the first floor and BR-1 is on the second floor immediately above. An accelerometer was also mounted on the east wall of Bedroom BR-1 in House E-1. Figures G-8 through G-13 show accelerometer records and corresponding displacements for typical XB-70, B-58, and F-104 missions for the east wall of the Dining Room in E-2. Figures G-14 through G-16 show outside, inside, and net loading pressure signatures on this wall for these missions. The acceleration and displacement records for the east wall of BR-1 in E-1 are similar in shape but slightly less in magnitude because the E-1 wall is smaller and therefore less flexible than the corresponding wall in E-2. The displacements of the north wall of BR-1 in E-2 are also similar to those for the Dining Room. Figure G-17 shows the displacement of the center of the north wall of BR-1 in E-2 for XB-70 and F-104 flights during Phase I and the displacement of the east wall of the Dining Room in E-2 due to a B-58 boom during Phase I. Table G-2 lists the maximum displacements of the Dining Room east wall in E-2 and BR-1 east wall in E-1 for a number of Phase II overhead flights.

TYPICAL RESULTS

The measured values of wall displacements were compared with values predicted by using values of DAF taken from spectra curves determined from free field signatures and net pressure signatures on the E-2 Dining

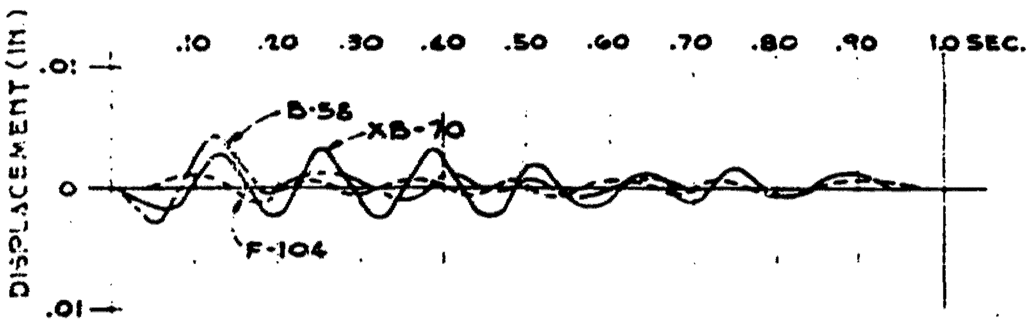


Aircraft	F-104	B-58	XB-70
Mission	13-3	13-1	13-2
Avg. Peak Pressure	2.01 psf	2.21 psf	2.00 psf
Ave. Rise Time	0.0053 sec.	0.0049 sec.	0.0079 sec.

FIG. G-6

RACKING DISPLACEMENT AT ROOF LINE OF NORTHEAST CORNER OF TWO STORY HOUSE E-2

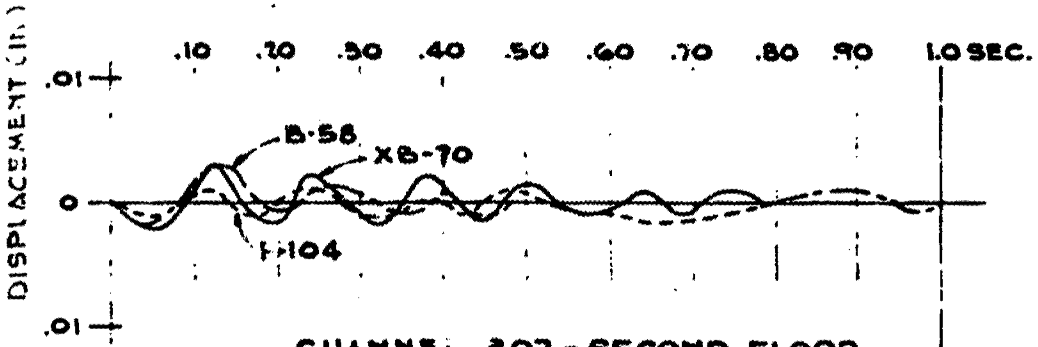
FIG. G-6



CHANNEL 305 - ROOF

PHASE I FLIGHTS

MSN	A/C	ALT	MACH
14	F-104	35.6K	1.70
46RB	B-58	43.7K	1.65
13	XB-70	52.9K	1.81



CHANNEL 307 - SECOND FLOOR

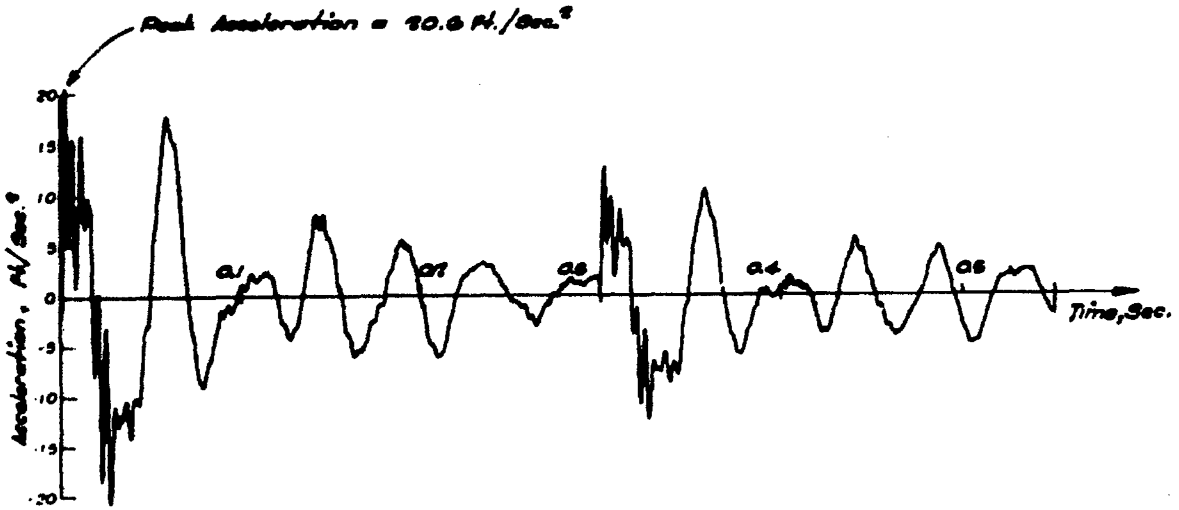
PHASE I FLIGHTS

MSN	A/C	ALT	MACH
14	F-104	35.6K	1.70
46RB	B-58	43.7K	1.65
13	XB-70	52.9K	1.81

FIG. G-7

RACKING DISPLACEMENTS
N-S E-2

FIG. G-7

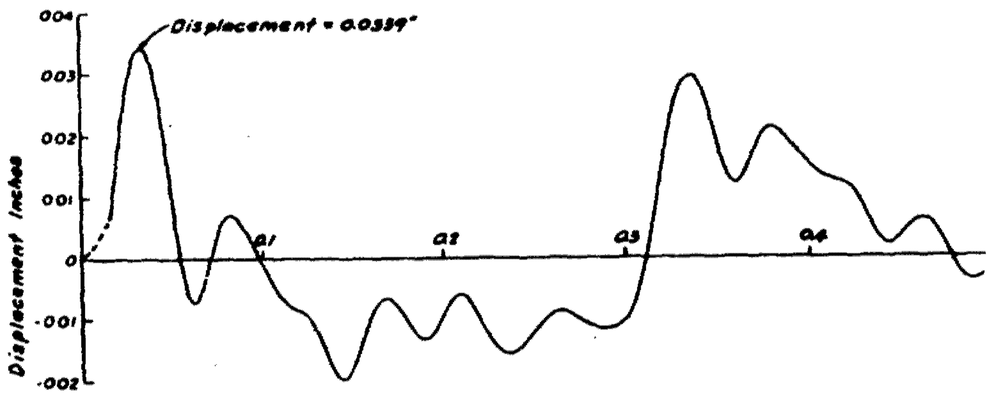


XB-70 Msn. 16-2

Average free field positive overpressure = 2.27 p.s.f.

PLATE ACCELERATION
EAST WALL DINING ROOM E-2
(CHANNEL 404)

G-8

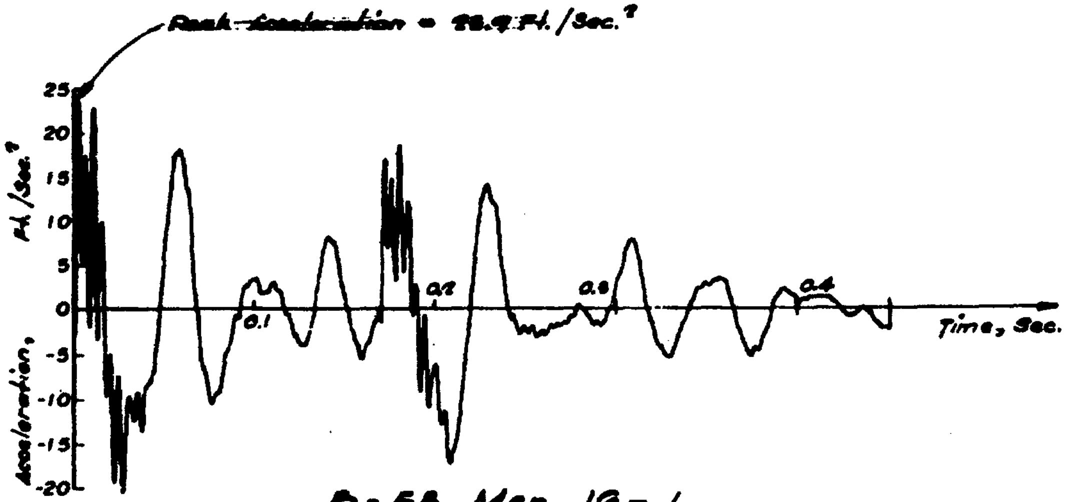


XB-70 Msn. 16-2

Average free field positive overpressure = 2.29 p.s.f.

PLATE DISPLACEMENT
EAST WALL DINING ROOM E-2
(CHANNEL 404)

G-9



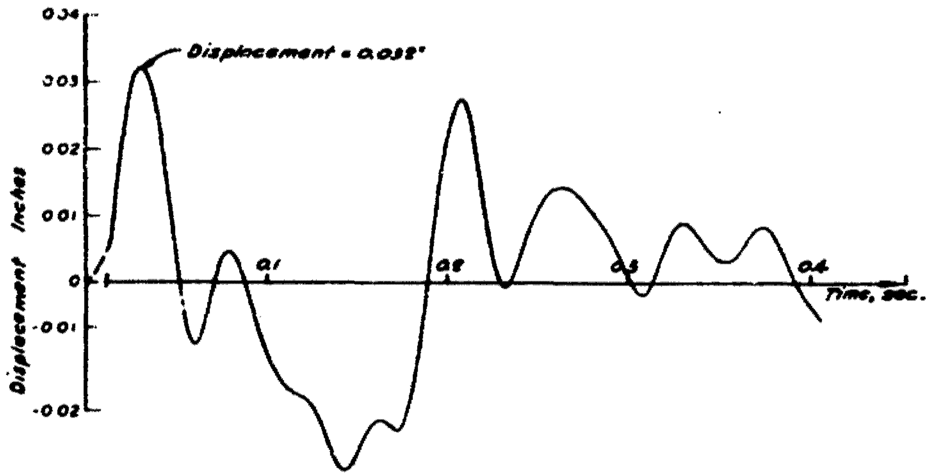
B-58 Men. 16-1

Average free field positive overpressure = 2.26 p.s.i.

PLATE ACCELERATION
EAST WALL DINING ROOM E-2
(CHANNEL 404)

G-10

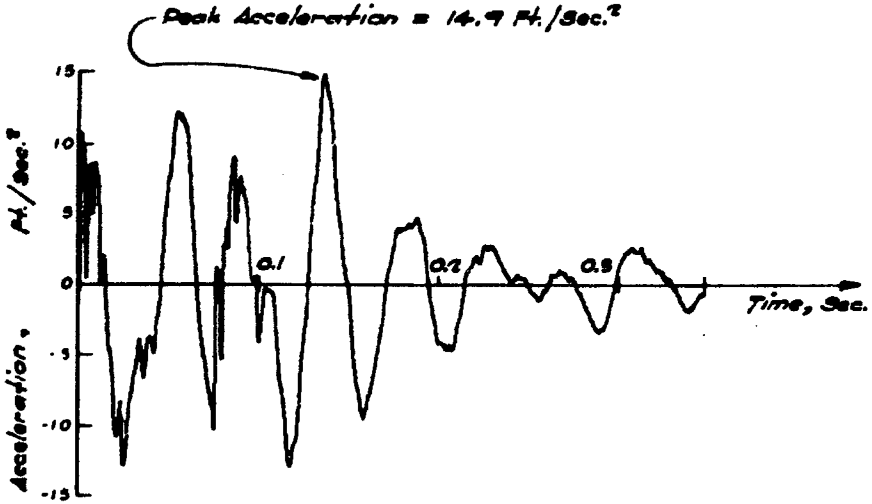
G-10



B - 58 Msn. 16-1

Average free field positive overpressure = 2.25 p.s.i.

-11		PLATE DISPLACEMENT EAST WALL DINING ROOM E-2 (CHANNEL 404)		G-11

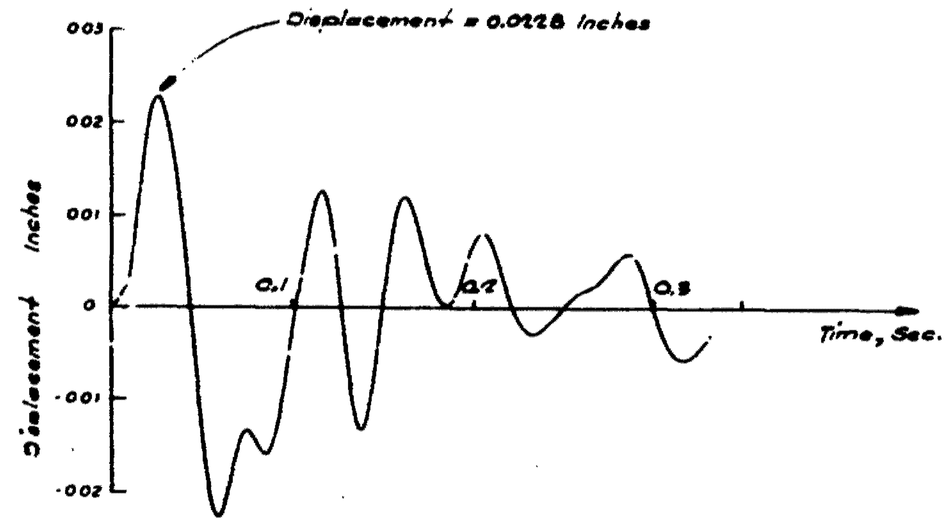


F - 104 Man. 1G - 3

Average free field positive overpressure = 2.02 p.s.f.

PLATE ACCELERATION
EAST WALL DINING ROOM E-2
(CHANNEL 404)

G-12

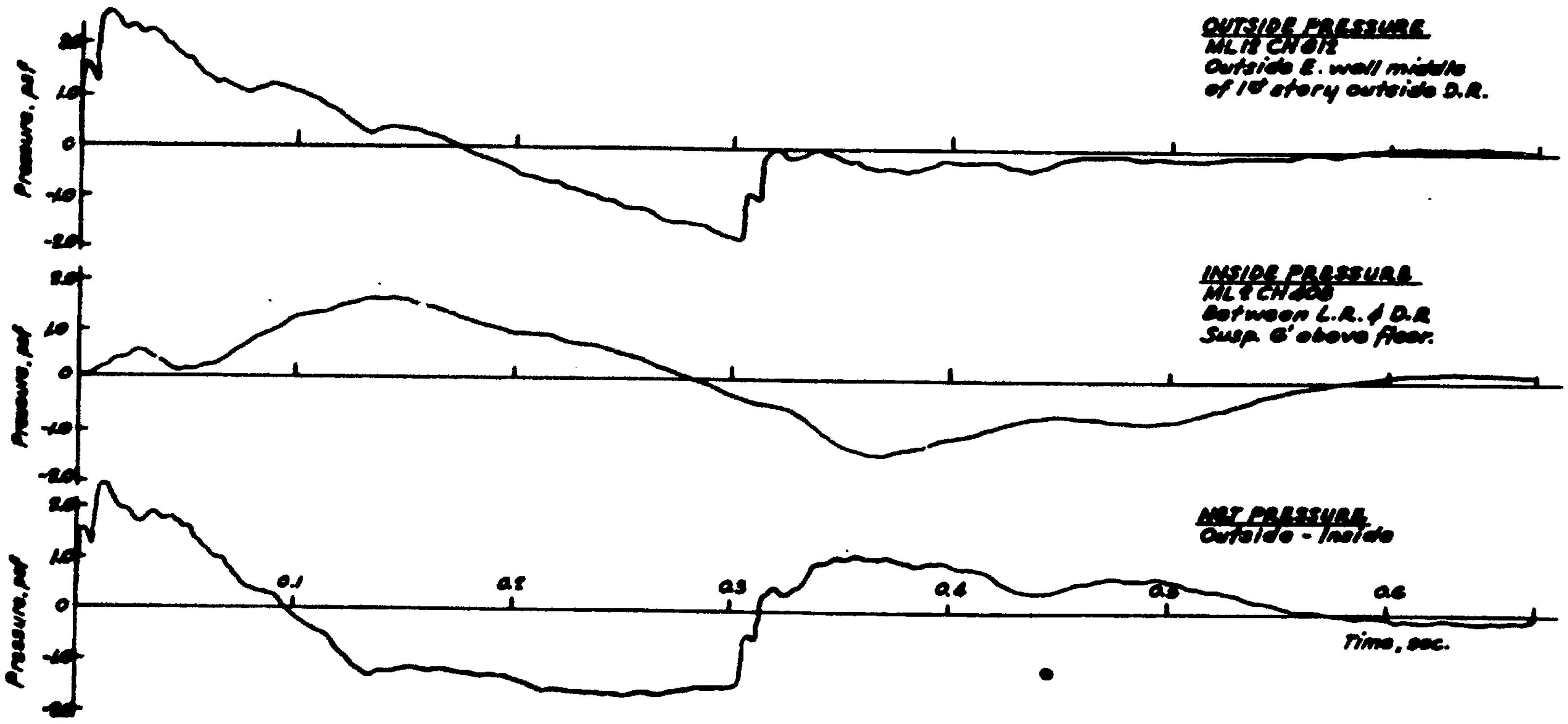


F - 104 Man. 16 - 5

Average free field positive overpressure = 2.02 p.s.f.

PLATE DISPLACEMENT
EAST WALL DINING ROOM E-2
(CHANNEL 404)

G-13



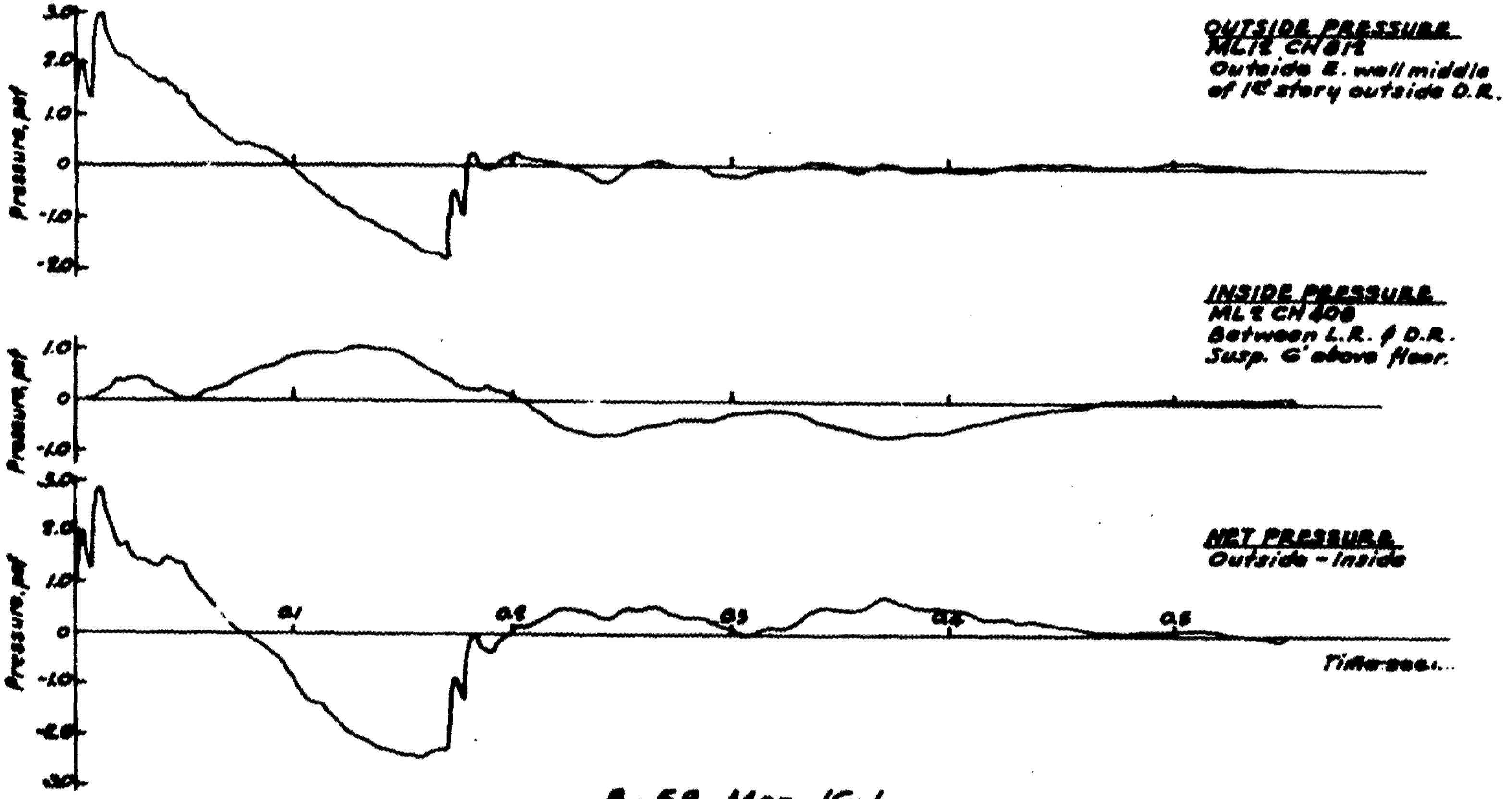
XB-70 Msn. 16-2

G-14

PRESSURE SIGNATURES

E. WALL DINING ROOM, E-2

G-14



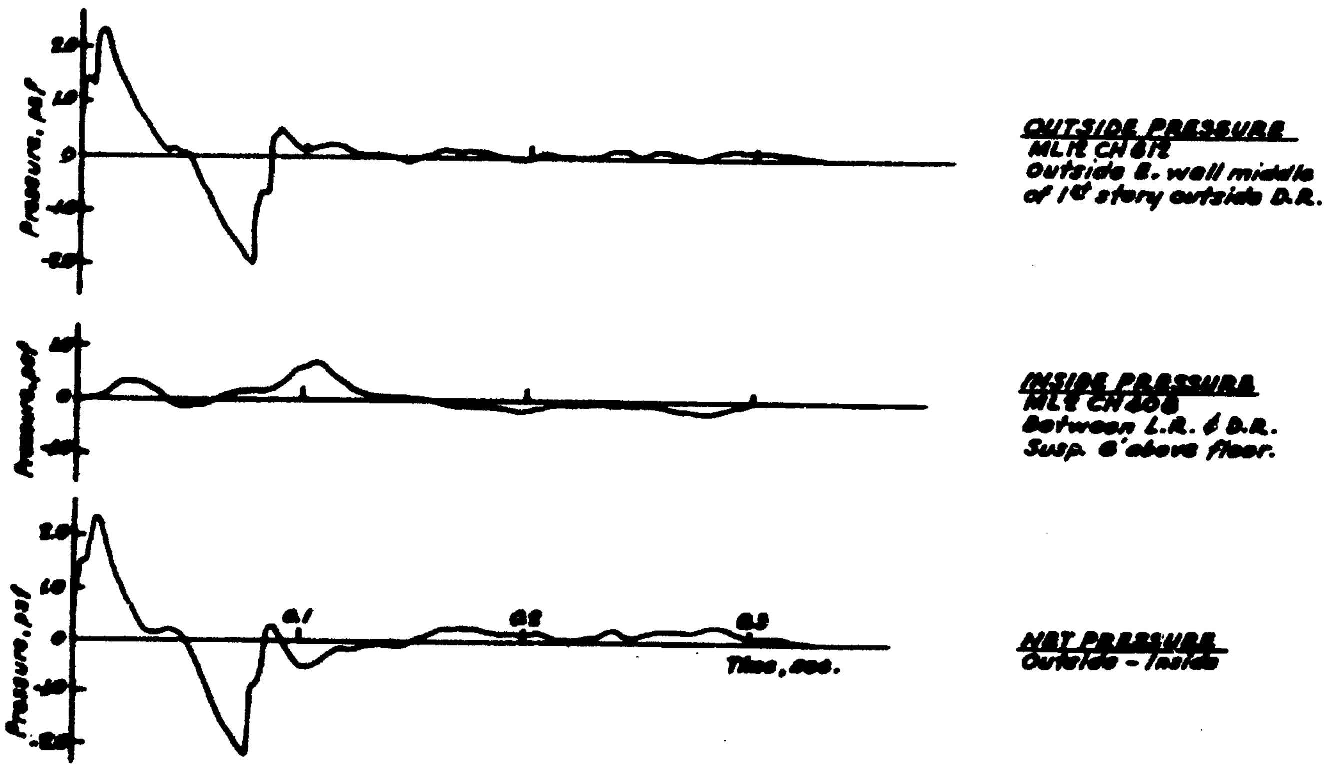
B-58 Msn. 16-1

G-15

PRESSURE SIGNATURES

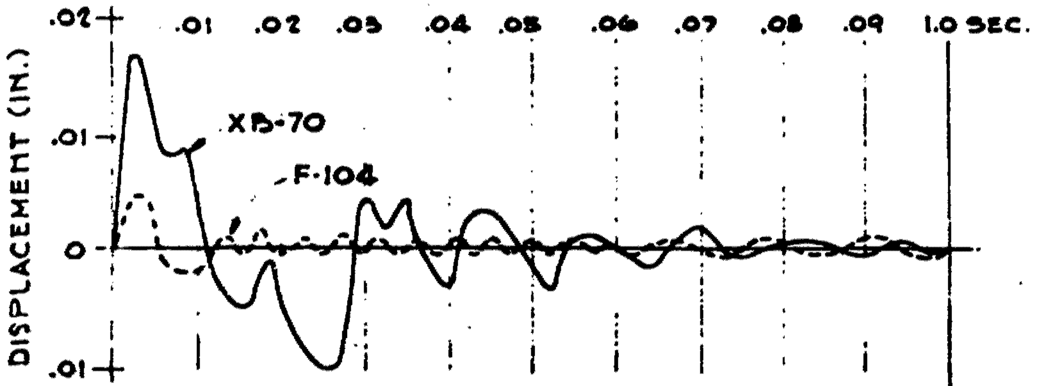
E. WALL DINING ROOM, E-2

G-15



F-104 Msn. 16-3

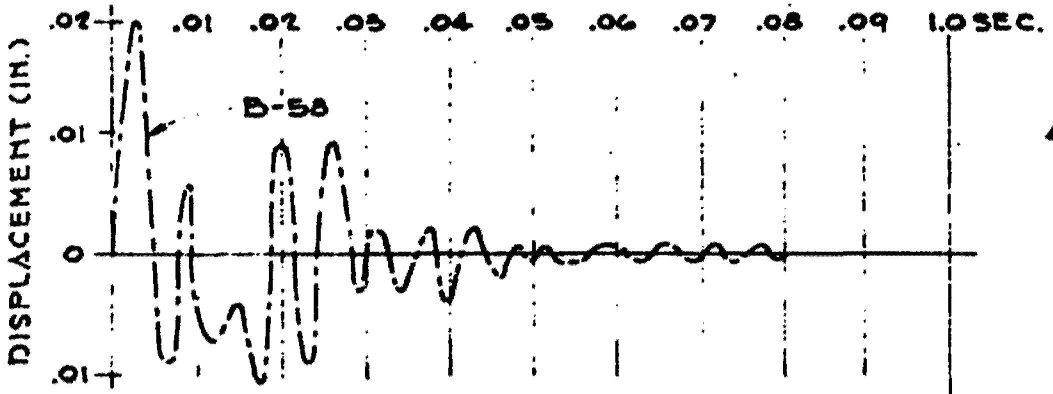
PRESSURE SIGNATURES
E.WALL DINING ROOM, E-2



CHANNEL 304 BRI N. WALL, E-2

PHASE I FLIGHTS

MSN	A/C	ALT	MACH
14	F-104	35.6K	1.70
13	XB-70	52.9K	1.81



CHANNEL 311 DR E. WALL, E-2

PHASE I FLIGHTS

MSN	A/C	ALT	MACH
46RB	B-58	43.7K	1.65

FIG. G-17

PLATE DISPLACEMENTS

FIG. G-17

Table G-2

MAXIMUM PLATE DEFLECTIONS FOR OVERHEAD FLIGHTS

Channel 202: E. Wall, BR-1, E-1
Channel 404: E. Wall, DR, E-2

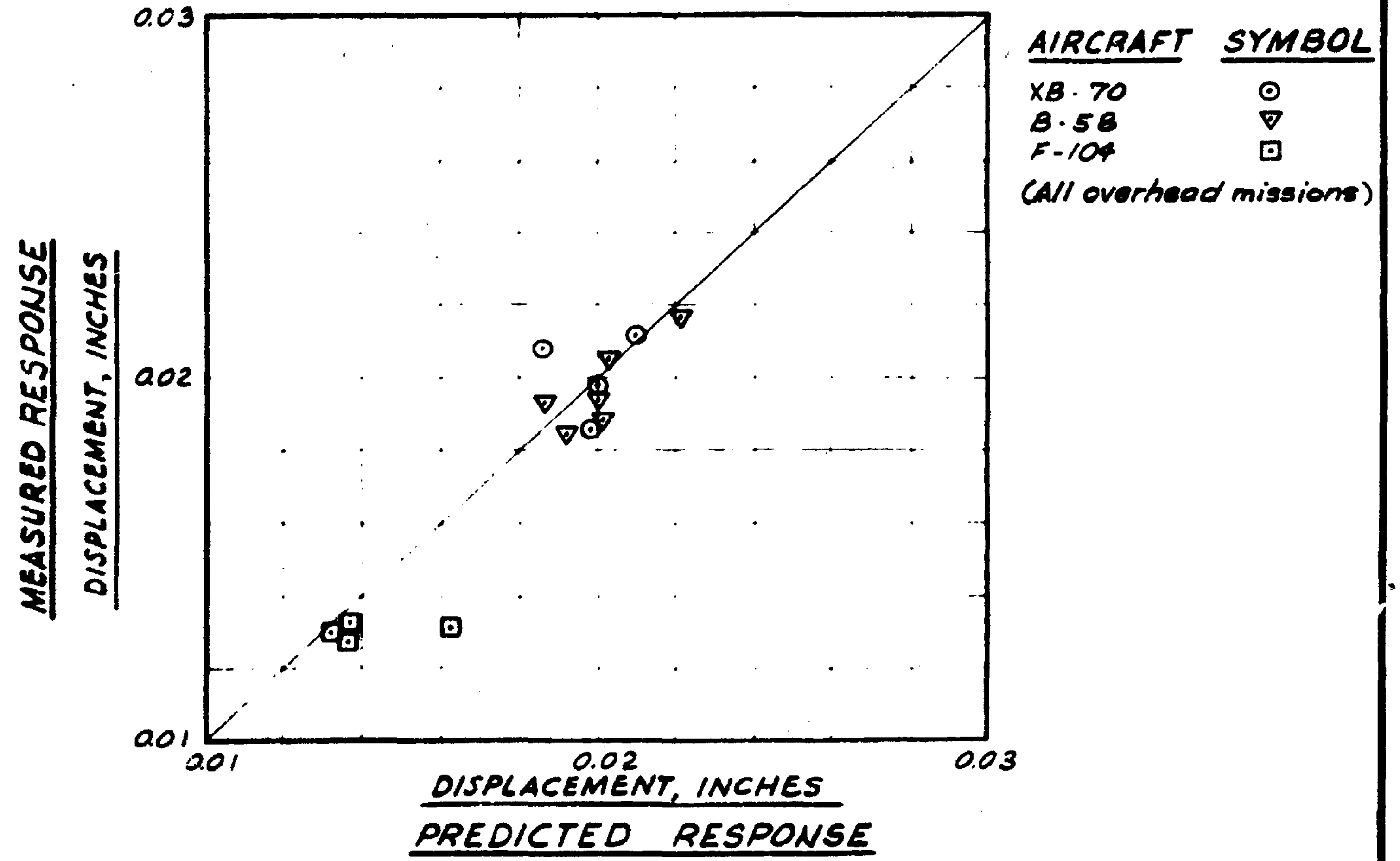
Aircraft	Mission	Average Free Field Peak Overpressure psf	Deflection, Inches Channel 202	Deflection, Inches Channel 404
XB-70	13-2	2.00	0.0208	0.0298
	15-1	2.18	0.0187	0.0313
	16-2	2.29	0.0211	0.0339
	113-2	2.20	0.0198	--
B-58	13-1	2.21	0.0193	0.0311
	15-2	2.34	0.0188	0.0323
	16-1	2.25	0.0184	0.0320
	113-1	2.61	0.0216	--
F-104	13-3	2.01	0.0129	0.0215
	15-3	2.31	0.0131	0.0231
	16-3	2.02	0.0121	0.0228
	113-3	1.95	0.0132	--

Room and BRI, E-1 walls[1]. The comparison of predicted versus measured displacements are shown in Figures G-18, G-19, G-20 and G-21 (see Table G-3 for missions analysed). The displacements predicted using DAF values determined from free field signatures and peak positive overpressures from these signatures compare very well with the measured values.

In order to study the plate response of large windows, loading microphones were placed to measure inside and outside pressures on the large glass window in the garage of E-1 for a number of XB-70/B-58/F-104 flights, see Table G-3. A strain gage was located at the center of the window, see Figure G-22. Strain displacements at the center of the window and the corresponding pressure signatures for three typical missions are shown in Figures G-23, G-24, and G-25. It is evident from the strain records that the window response to sonic booms from the flights was primarily in the first mode of vibration. On the strain records for the F-104 and XB-70 missions the second symmetrical mode, which corresponds to two vertical nodal lines at the third points of the window, was also present (Figure G-26). The amplitude of the second mode strain was less than ±20 percent of the first mode strain which means that the corresponding displacement amplitude was 2.2 percent of the first mode displacement.

Predicted deflections of the window were plotted versus measured deflections in Figure G-27. The predicted deflections were calculated using DAF values from spectra curves derived from free field signatures together with the corresponding free field peak positive overpressures. As the large window was located on the side of structure away from the inbound boom pressure wave, a trailing vector factor was used in the calculations to reduce the free field peak overpressure values.[1]

Racking displacements at the roof lines were negligible (less than 0.005") when E-1 and E-2 were subjected to booms in the order of 2 psf. The racking displacements caused by F-104 and B-58 missions with similar peak overpressures were generally larger than those due to XB-70 missions. Several factors caused this trend in response; signature duration, aircraft speed, and building length, all of which affect the net pressure



MEASURED RESPONSE vs. PREDICTED RESPONSE
BASED ON FREE FIELD SIGNATURES EAST WALL BR1, HOUSE E-1

FIG. G-18

FIG. G-18

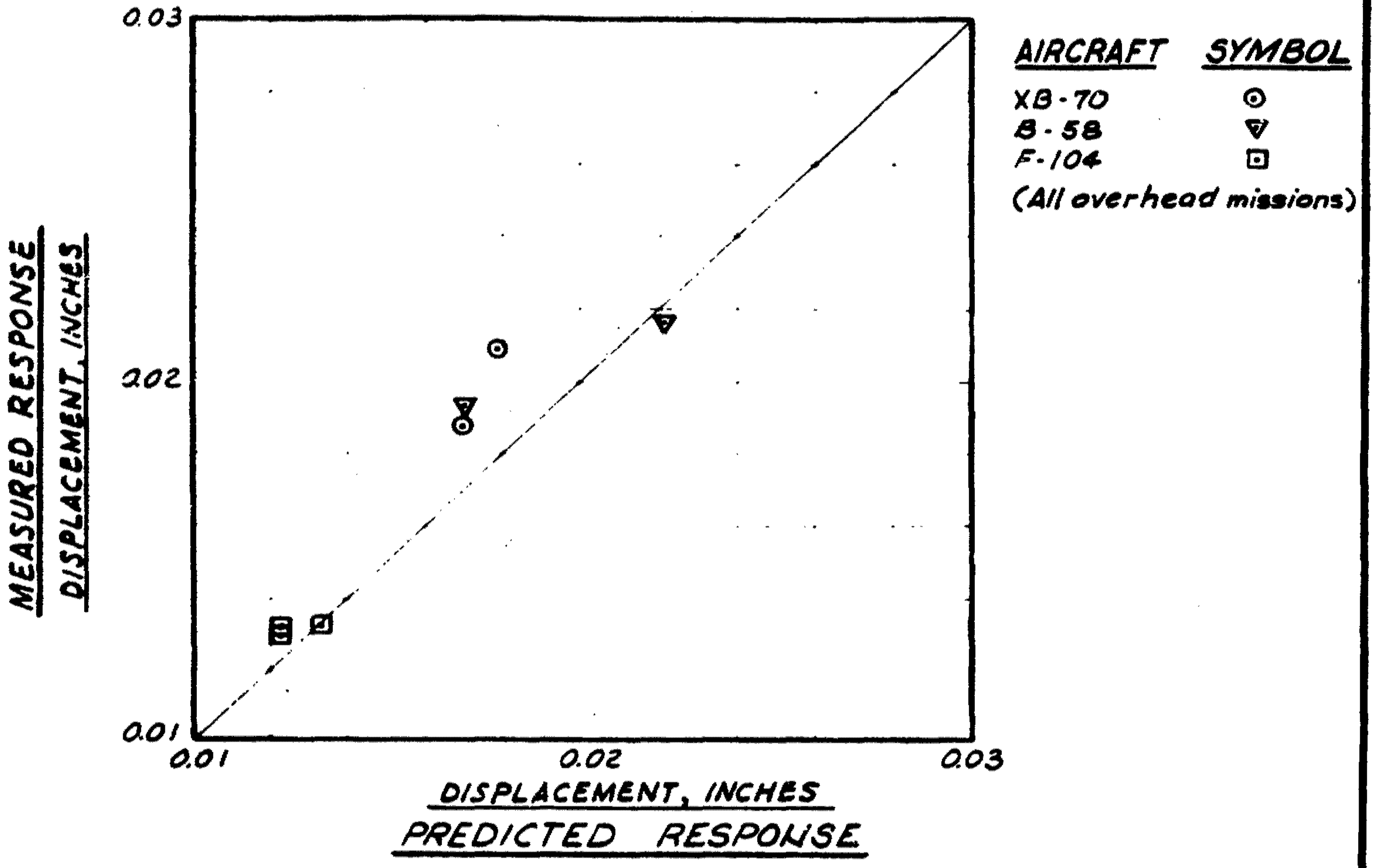
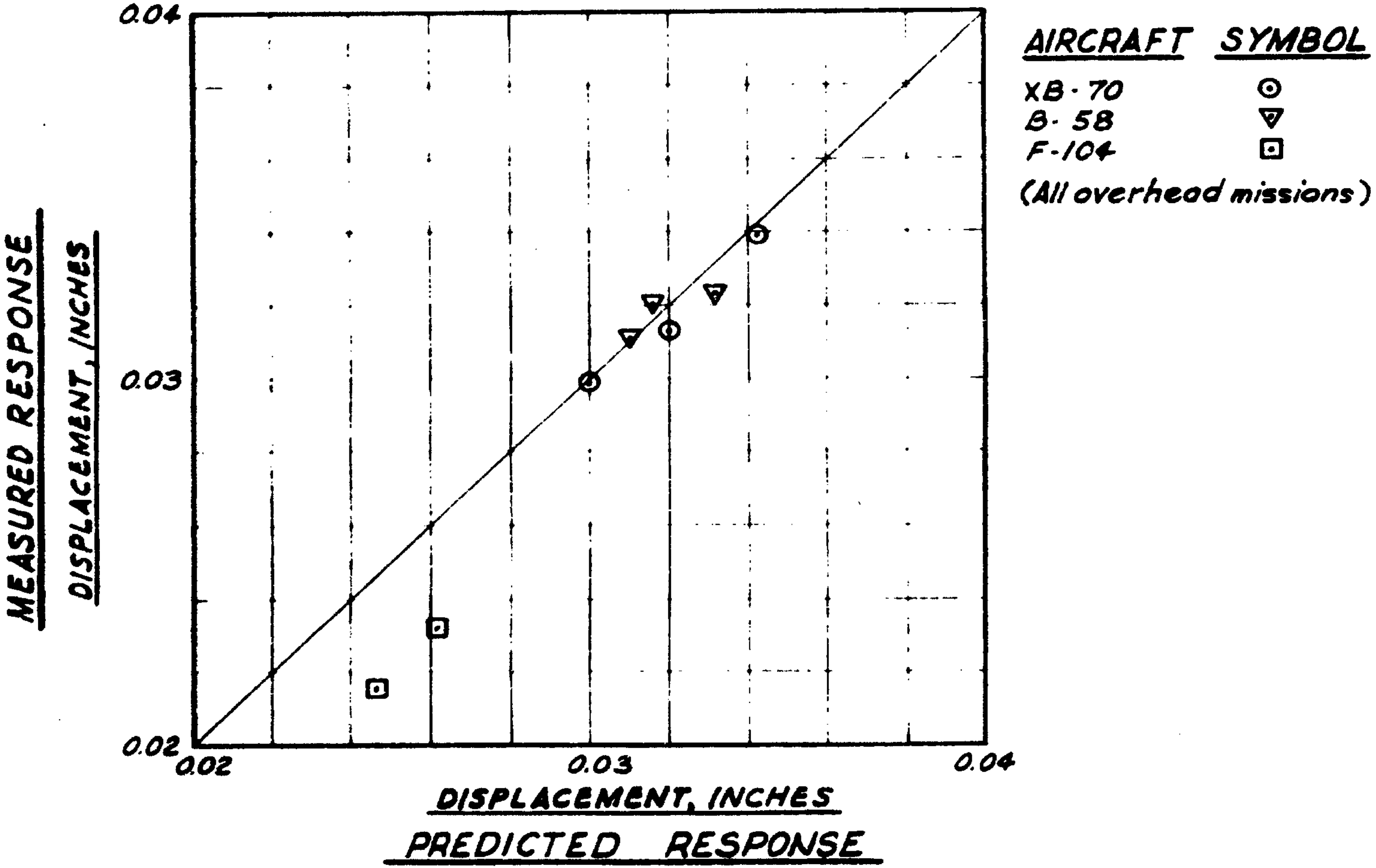


FIG. G-19

MEASURED RESPONSE vs. PREDICTED RESPONSE BASED ON NET SIGNATURES, EAST WALL BR1, HOUSE E-1

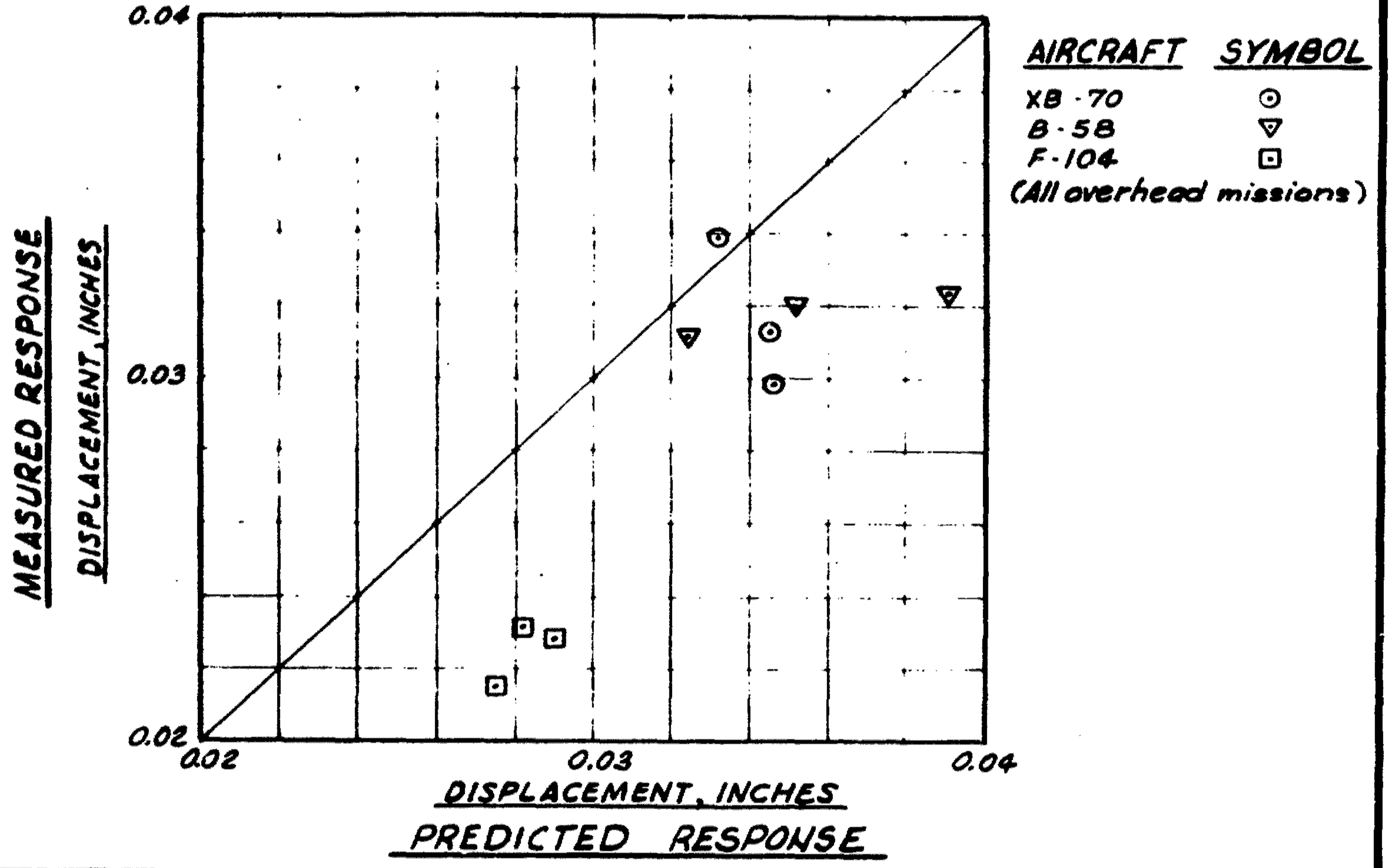
FIG. G-19



MEASURED RESPONSE vs. PREDICTED RESPONSE BASED ON FREE FIELD SIGNATURES, EAST WALL DR, HOUSE E-2

FIG. G-20

F'G. G-20



MEASURED RESPONSE vs. PREDICTED RESPONSE BASED ON NET SIGNATURES, EAST WALL DR, HOUSE E-2

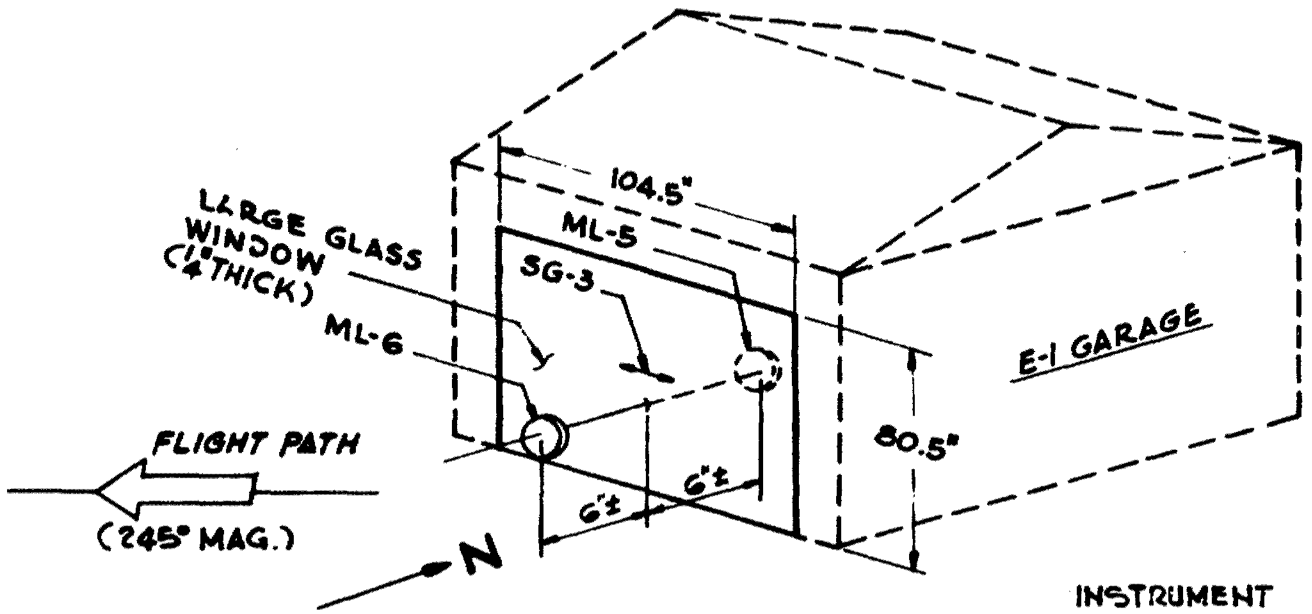
FIG. G-21

FIG. G-21

Table G-3

AIRCRAFT AND MISSIONS INVOLVED IN FIGS. G-18, G-19, G-20, G-21, G-27

Aircraft	Mission	Altitude (1000 ft.)	Mach	Offset (1000 ft.)	Fig. G-18	Fig. G-19	Fig. G-20	Fig. G-21	Fig. G-27
XB-70	4-2	38.6	1.50	0.0					X
	5.2	59.1	2.49	R12.9					X
	8-3	60.0	2.50	R68.2					X
	11-3	59.4	2.50	0.0					X
	12-2	60.3	2.50	L0.2					X
	13-2	60.2	1.80	L26.4	X	X	X	X	
	15-1	60.6	1.80	R9.5	X	X	X	X	
	16-2	59.7	1.80	R0.7	X		X	X	X
	113-2	60.3	1.80	L0.1	X				X
B-58	3-1	32.4	1.50	R7.8					X
	4-1	32.0	1.50	R1.9					X
	5-1	36.3	1.65	R63.3					X
	8-1	35.5	1.65	L3.3	X				X
	11-2	40.2	1.65	R0.8					X
	12-1	39.2	1.65	L2.1	X				X
	13-1	35.9	1.65	L2.5	X	X	X	X	
	15-2	39.6	1.65	0.0	X		X	X	
	16-1	39.7	1.65	R3.0	X		X	X	X
	113-1	39.1	1.65	L0.7	X	X			X
F-104	3-4	17.8	1.30	L2.3					X
	12-3	22.0	1.42	R6.7	X				X
	13-3	20.0	1.40	R3.4	X	X	X	X	
	15-3	20.2	1.40	R0.2	X	X	X	X	
	16-3	20.6	1.40	R5.0				X	
	113-3	20.6	1.40	R1.2	X	X			X



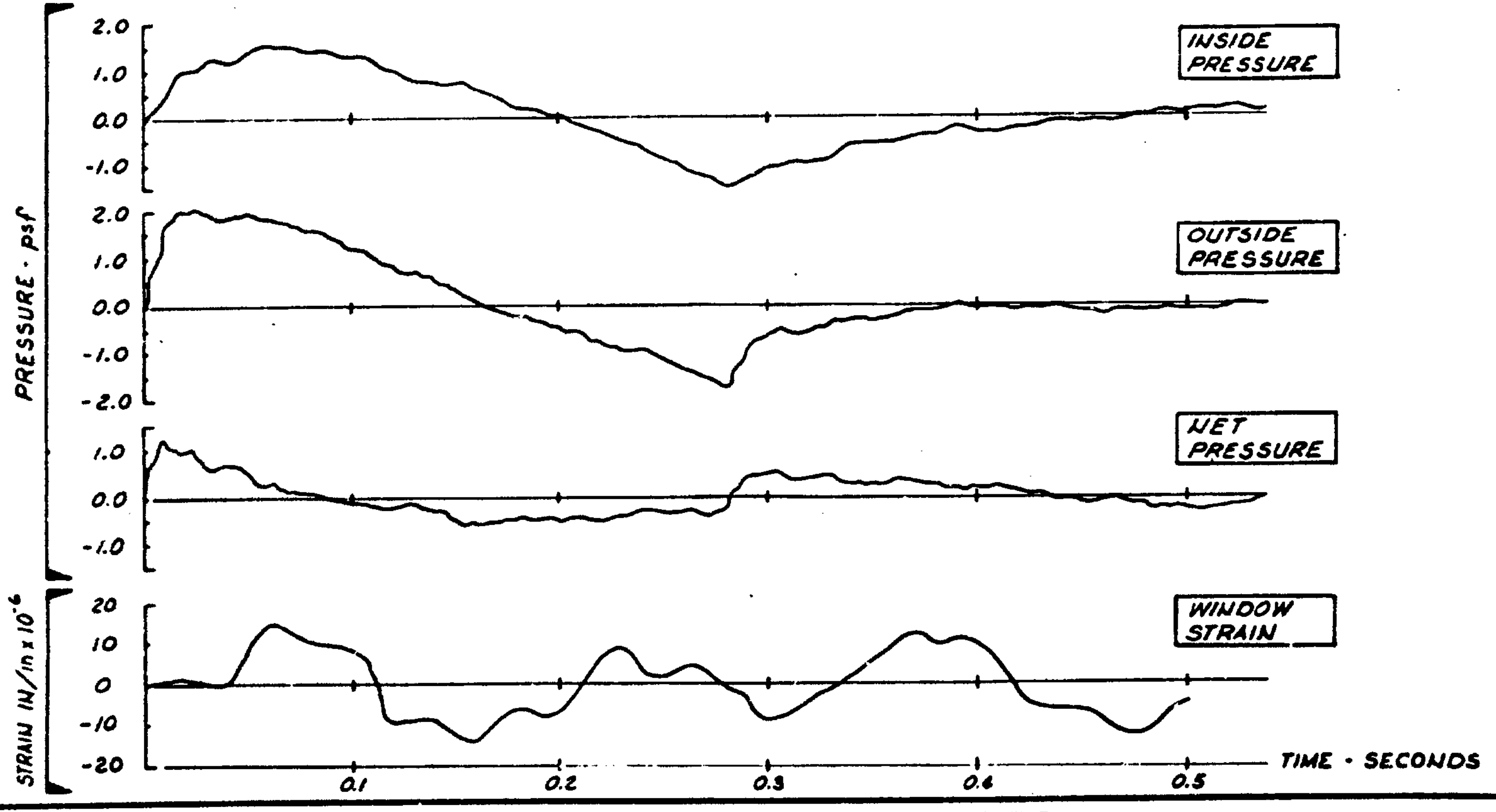
INSTRUMENT	CHANNEL
SG-3	207
ML-5	805
ML-6	806

INSTRUMENT LOCATION
GARAGE WINDOW ~ HOUSE E-1

FIG.
G-22

FIG.
G-22

XB-70 MSN. 11-3



PRESSURE SIGNATURES ON LARGE GLASS WINDOW HOUSE E-1

FIG. G-23

B-58 MSN. 11-2

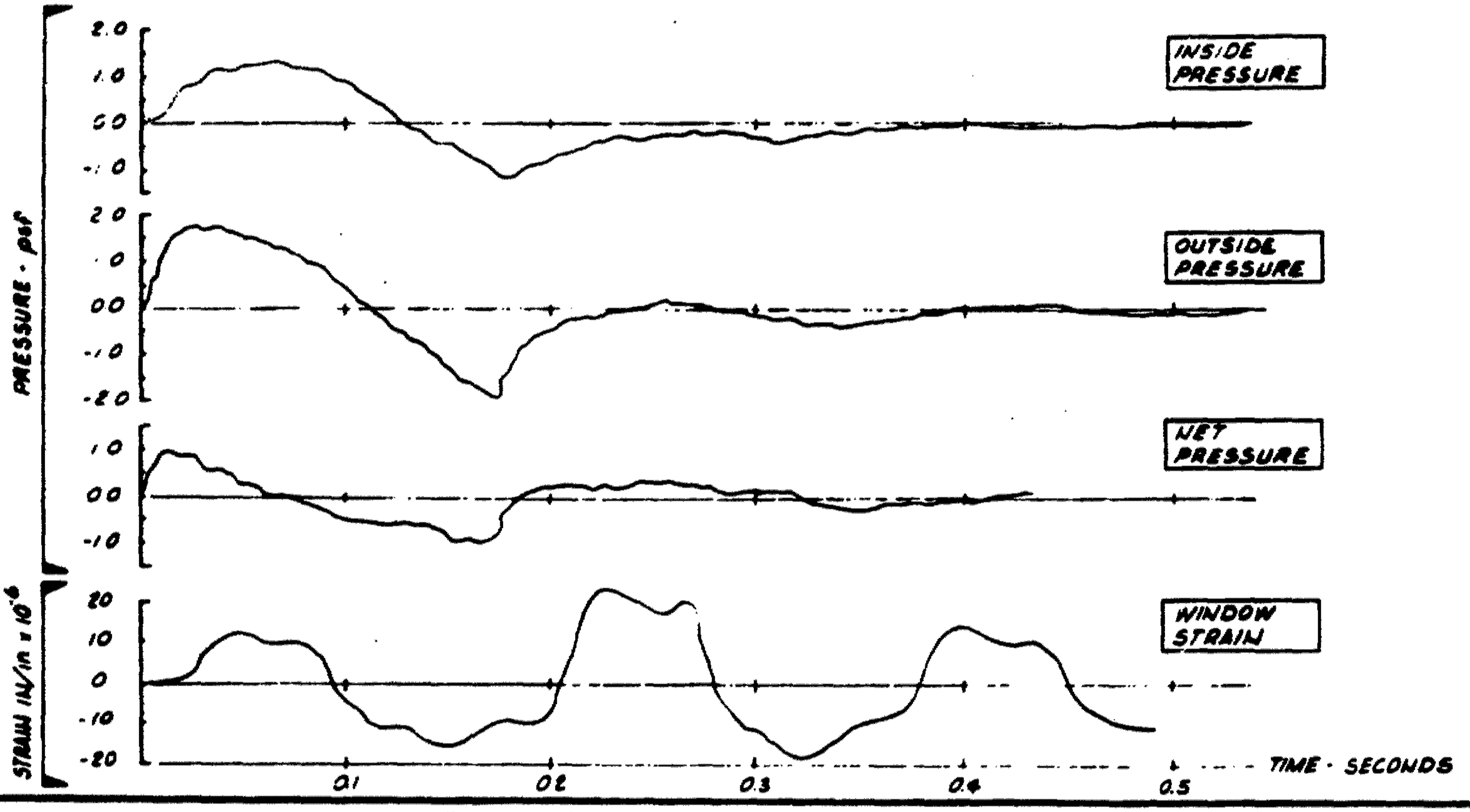
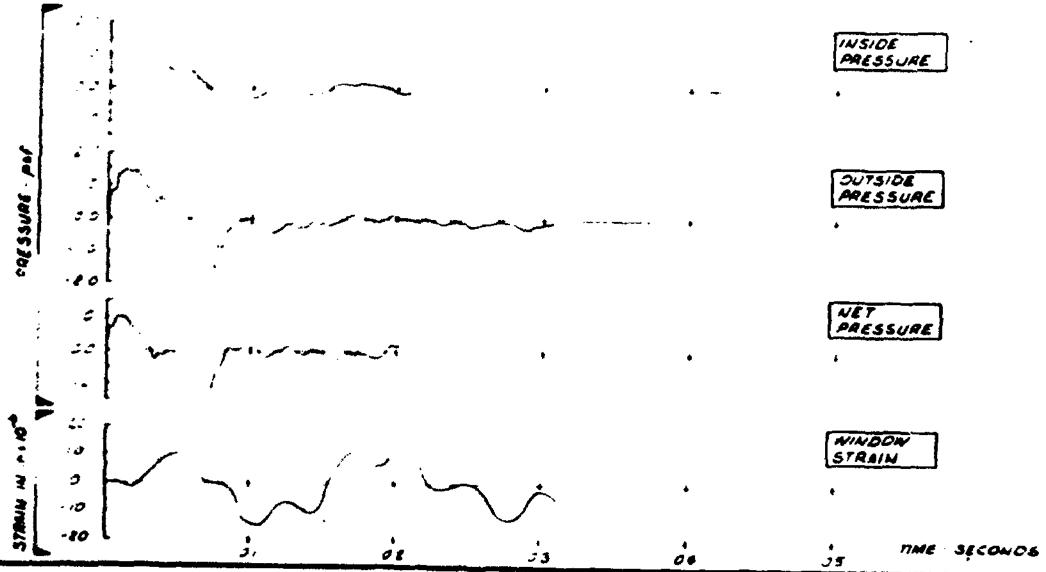


FIG G-24

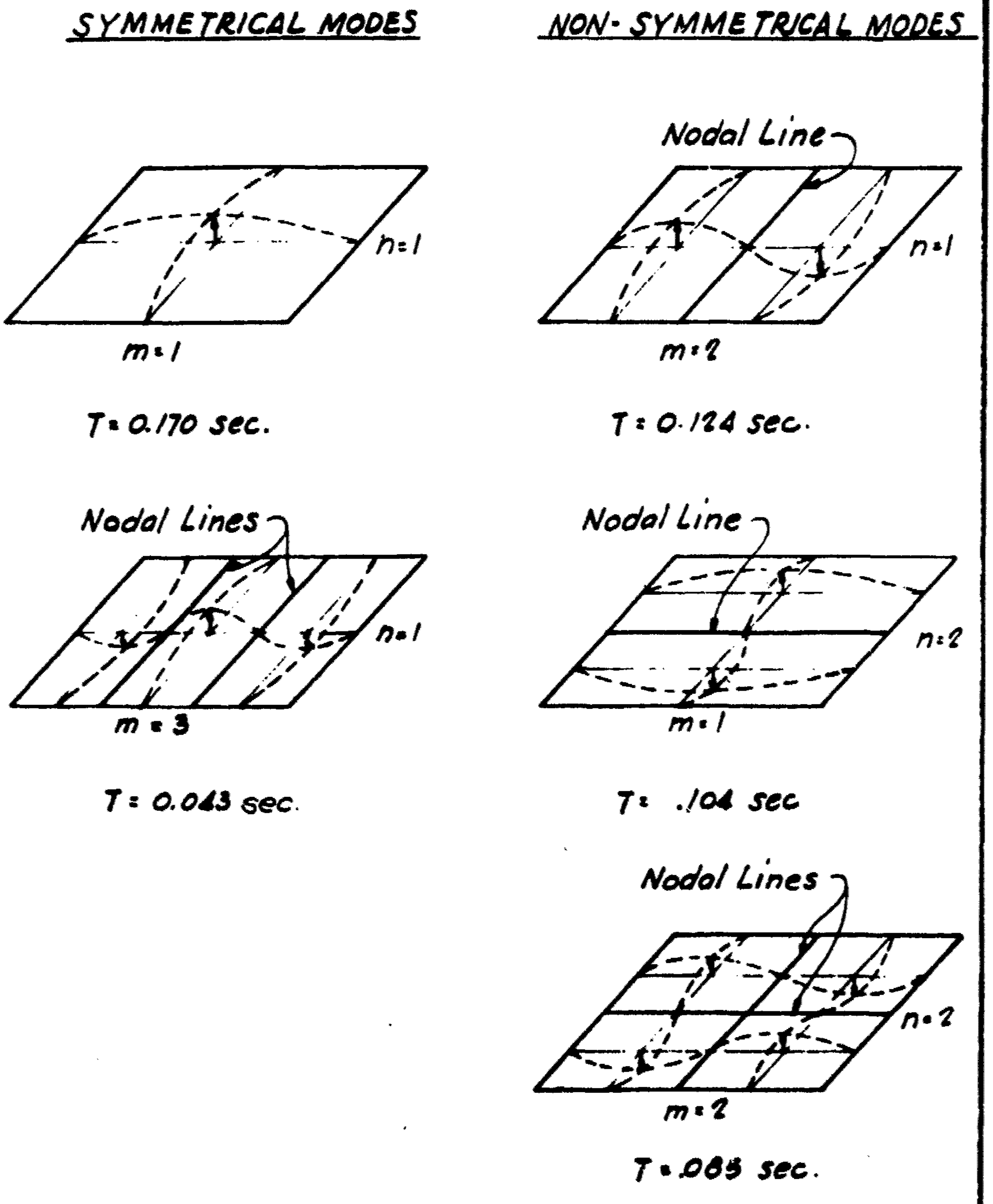
PRESSURE SIGNATURES
ON LARGE GLASS WINDOW HOUSE E-1

FIG G-24

F-104 MSN. 11-1

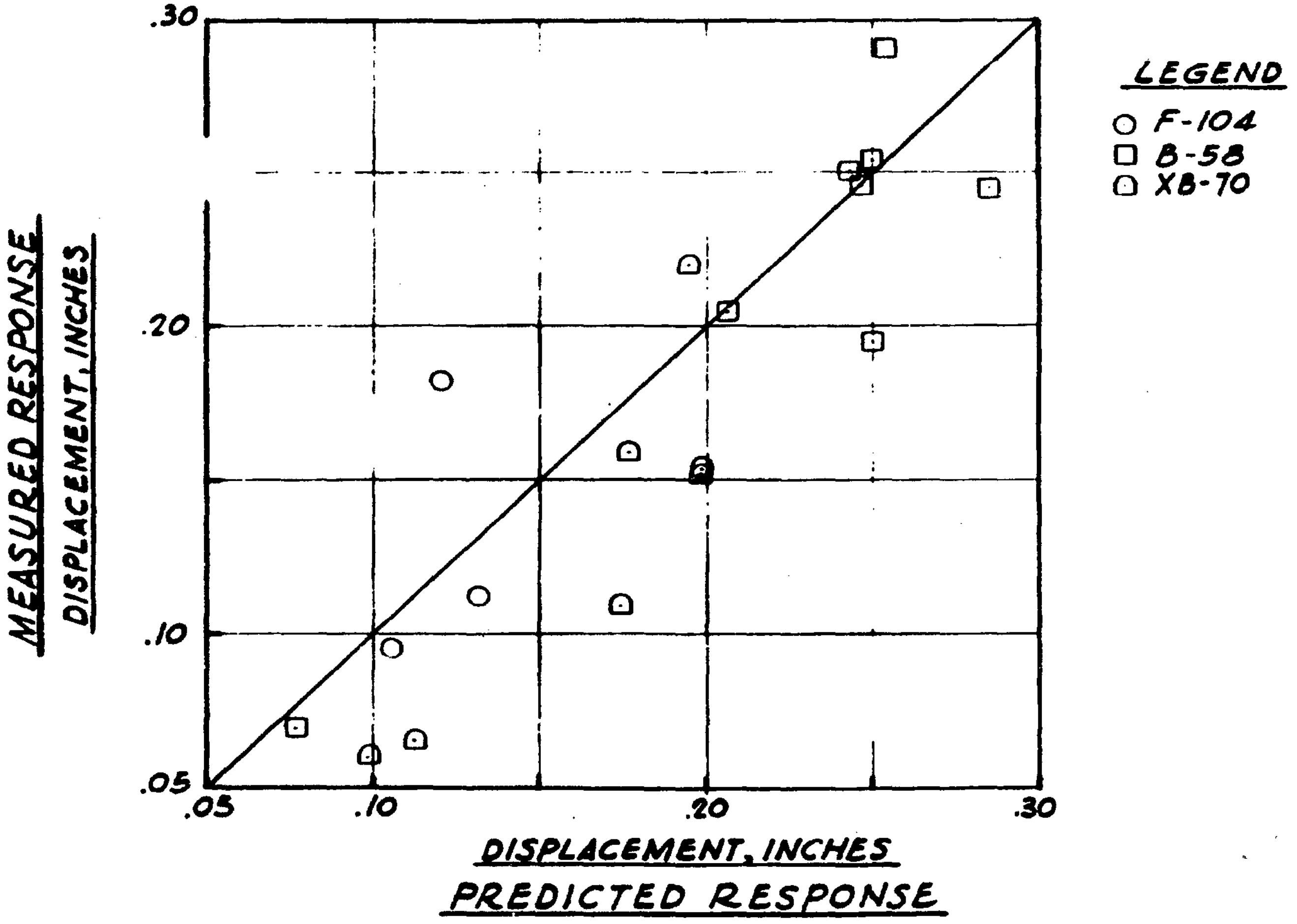


PRESSURE SIGNATURES
ON LARGE GLASS WINDOW HOUSE E-1



NATURAL PERIODS AND CORRESPONDING MODE SHAPES FOR E-I WINDOW

FIG. G-26



MEASURED RESPONSE vs. PREDICTED RESPONSE BASED ON FREE FIELD SIGNATURES, LARGE WINDOW HOUSE E-I

FIG. G-27

FIG. G-27

signatures on the houses. Pressure signatures for the east wall and west wall and net pressure on the structure for typical east to west overhead flights of XB-70/B-58/F-104 aircraft are shown in Figures G-28, G-29, and G-30. For the missions shown, the time lag between the start of the boom on the east wall and the west wall (building length divided by the speed of the aircraft) was 0.027, 0.031 and 0.033 seconds for the XB-70, B-58, and F-104 respectively.

Investigation of the net pressure signatures indicated why the response was greater for the B-58 and F-104. For these two aircraft, the net pressure signature was a distorted N-wave. However, the XB-70 net pressure signature was greatly changed and was reduced to two very short pulses separated by approximately 0.25 sec. This net pressure signature produced considerably smaller deflections, as would be expected.

In the light of these facts, it is reasonable to expect that the future SST, with a faster speed and a pressure signature of longer duration, will produce racking deflections of a typical house that will be of the same order of magnitude, or more probably smaller, than those produced by the XB-70 for comparable overpressures. However, the magnitude of deflections caused by booms of 2 psf overpressure were extremely small for all aircraft, and were below levels where damage could be expected to occur.[1]

DAMAGE COMPLAINTS AND INVESTIGATIONS

Edwards AFB is located near a number of small cities such as Lancaster, Rosamond, Tehachapi, and Mojave. It was anticipated that the aircraft while flying test program missions at supersonic speeds would overfly some of these populated areas in addition to personnel housing and other buildings at Edwards. Therefore, provisions were made to have an engineering investigator inspect each complaint. In addition, a survey was made of all glass windows in structures at Edwards AFB prior to start of test flights in order to establish a fairly reliable basis for determining what glass damage was caused by sonic booms produced by the test program.

There are 49,730 window panes, including glass doors, in the residential structures and 60,660 panes of glass in the other buildings on

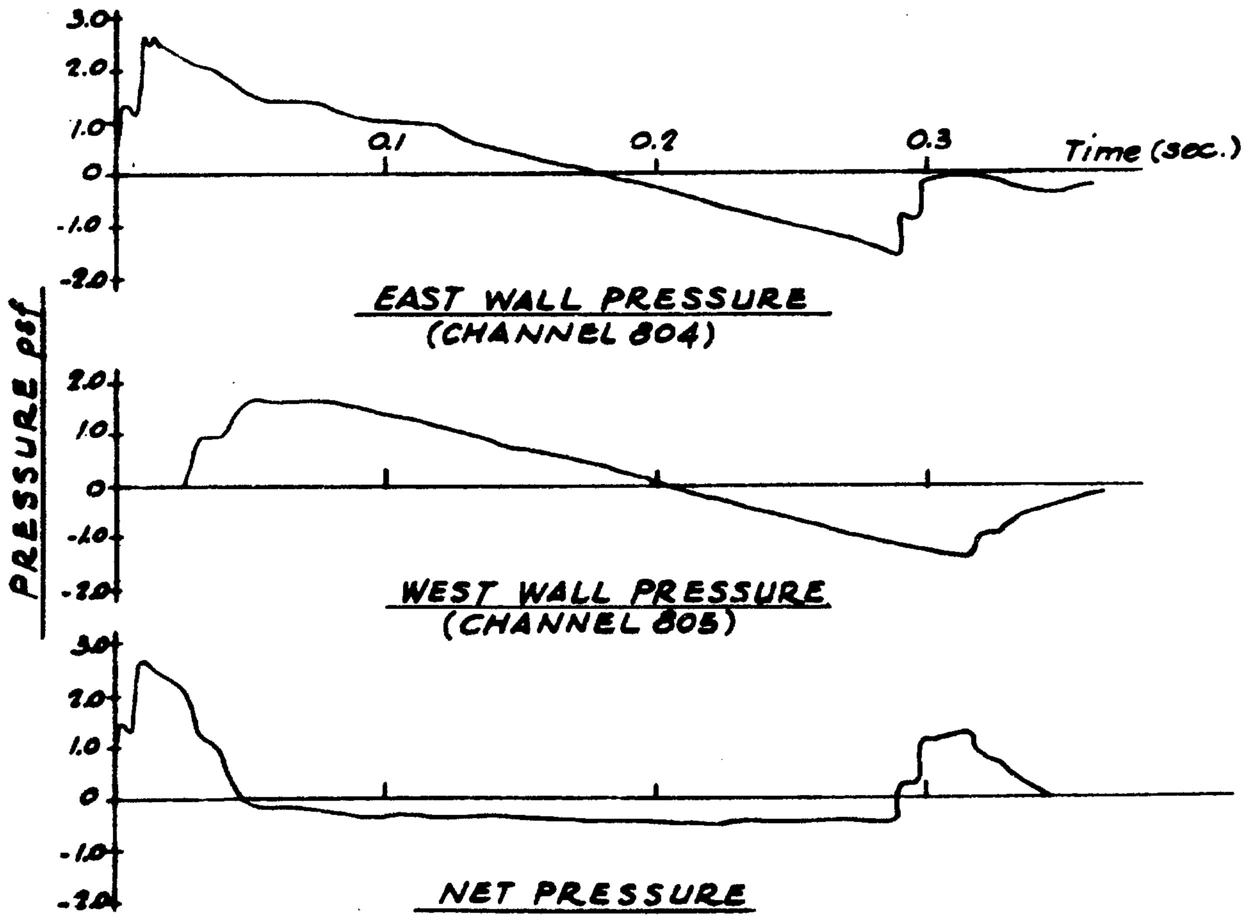
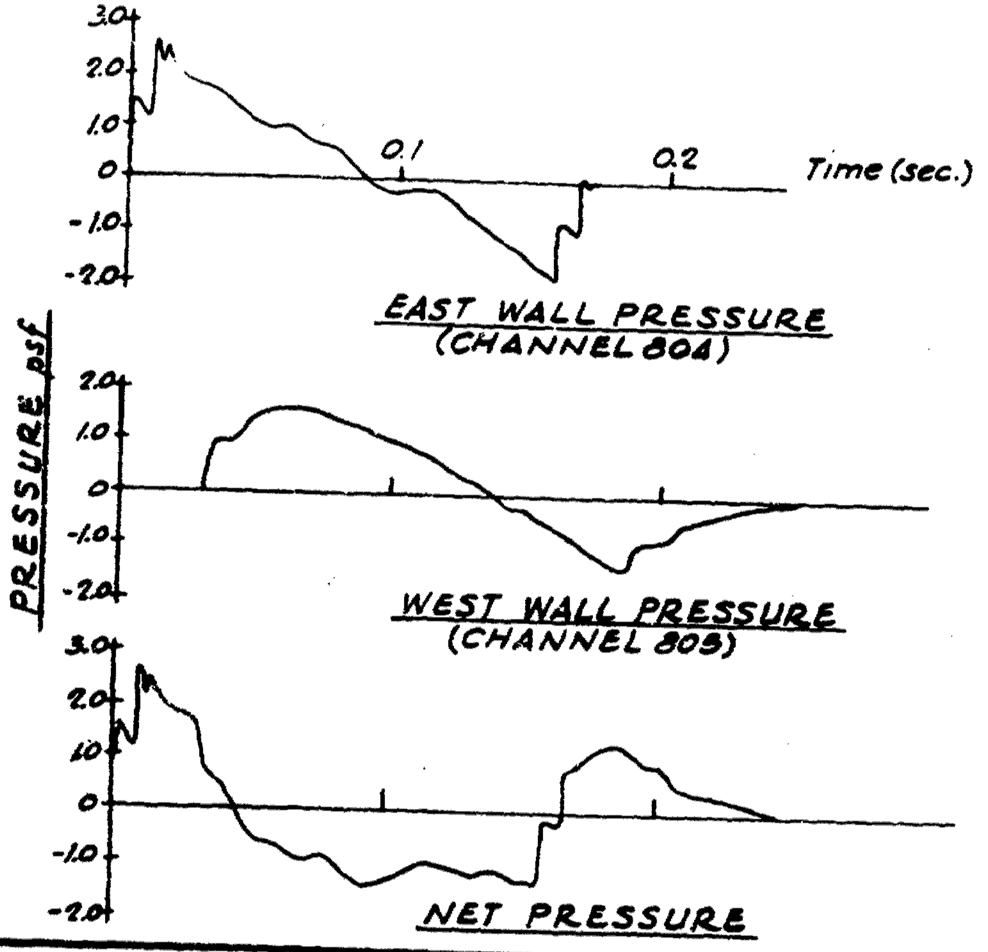


FIG. G-28

PRESSURE SIGNATURES, HOUSE E-1
XB-70 Mach = 1.80, Duration = 0.287 sec., Mission 13-2

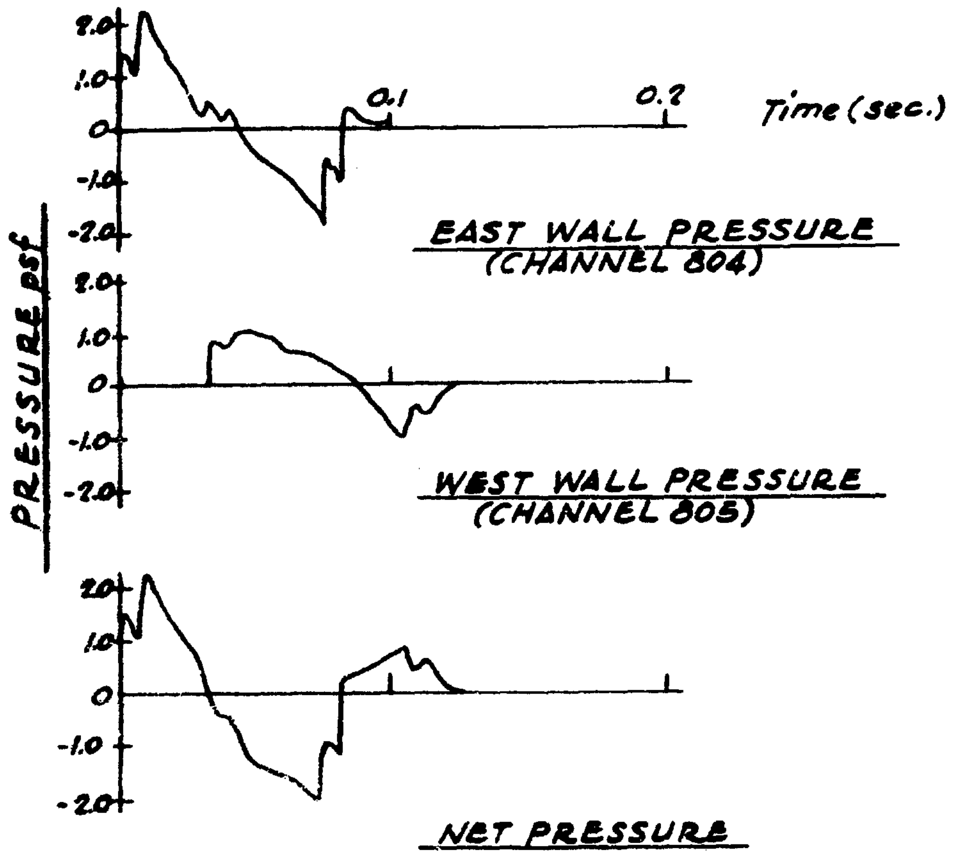
FIG. G-28



PRESSURE SIGNATURES, HOUSE E-1
B-58 Mach. = 1.65 Duration = 0.159sec., Mission 13-1

FIG
G-29

FIG.
G-29



PRESSURE SIGNATURES, HOUSE E-1

F-104 Mach = 1.40, Duration = 0.074 sec., Mission 13-3

FIG. G-30

the Base. A total of 400 cracked panes were reported in the residential structures during the pre-test survey. During the test program, only three broken windows were reported that could be attributed to the test flights. A total of 269 cracked panes and 25 broken or missing panes were reported for the other buildings during the pretest survey. No complaints of glass damage to these buildings were received during the test program.

During the June 1966 overflights all B-58 supersonic flights were flown in a racetrack pattern, that is, the craft made two 180° turns at supersonic speeds after completing the run over the test structures. Of necessity, this racetrack pattern caused sonic booms to be produced over several cities that are located south and west of Edwards AFB. A total of 50 complaints of damage that could be attributed to the test program were received. Thirty-three of these complaints after investigation appeared to be for damage that could have been caused by sonic booms. About 59% of all complaints received were for alleged glass damage, 17% for stucco damage, 12% for structural damage, 9% for bric-a-brac, and 3% for bothersome noise. No damage was observed in the two test house structures constructed on the Base or in the leased structure in Lancaster.

During the 31 October to 17 January portion of the program, ten complaints of alleged damage were received. Of these, four were for glass damage, four for bric-a-brac, none for stucco or plaster, one for structural damage, and one was unknown as the caller did not specify the type of damage. After investigation, seven of the complaints appeared to be for damage triggered by a sonic boom with two bric-a-brac complaints apparently caused by SR-71 flights that occurred on days when no test program flights were flown. The structural damage complaint and the one for glass damage did not appear to be for damage that could have been caused by a sonic boom. It seems reasonable that the major reason for the decrease of damage complaints during the latter phase of the program is the fact that only the XB-70 flights continued at supersonic speed after passing over the test structures on the Base. All B-58 and F-104 flights slowed to subsonic speeds shortly after passing over the test structures. No discernible damage from sonic booms was observed in the test structures on the Base.

Appendix G-2 discusses in detail all complaints received during Phases I and II of the Edwards Program, the results of investigations and the number of claims paid. Appendix G-3 describes the pretest flight window survey at Edwards and the complaints of window damage received due to test flight booms.

DAMAGE PREDICTION

The prediction of damage to a structure or structural elements from a sonic boom involves the consideration of many factors, some of which are quite complex. It presently appears possible to predict the response of a structural element to a sonic boom. If a response, for example, displacement, of a structural element is known, the stresses in the element can be calculated. In order to predict the magnitude of a boom from a specified aircraft that will cause a crack in a given structural element, the average displacement to cause a probable first crack has to be calculated. From this displacement, the equivalent static load required to cause this displacement can be calculated. This static load in pounds per square foot can then be compared with the applicable DAF to obtain the average magnitude of boom required to cause damage.

Prediction includes an element of uncertainty. However, when statistical methods are used in predictions, this uncertainty is expressed as a probability. To obtain this probability, the strength of the structural element as well as the loading on the element must be regarded as random variables. The randomness of the loading can be obtained from observations made during the test program. Little is known, however, about the strength and the randomness of the strength of older in-place materials. To use statistical methods in such a case, a distribution of the strength must be derived in accordance with available data. In order to predict damage, much more data are needed on the strengths of in-place structural materials and the characteristics of the structures and structural elements. Structures and structural elements need to be classified as a function of size, materials, age, natural frequency, and damping. There are little data available about the in-place strength or capacity of each type of structural element in each classification.

SUMMARY OF RESULTS

The analysis of structural response data and the investigation of the methods for predicting structural damage are in progress. The preliminary findings are as follows:

1. Sonic booms from large aircraft such as the XB-70 and the future SST will affect a greater range of structural elements than will smaller aircraft such as the B-58 and F-104; these results are predictable from a knowledge of the characteristics of the boom signature and the response characteristics of the structural elements.

2. No damage was observed in the test structures during these experiments that could be attributed to sonic booms; however, some damage was alleged to have been caused by sonic booms in houses in the vicinity of EAFB during the period of these tests; a total of 57 complaints of damage were received which resulted in the filing of 19 claims against the government for alleged sonic boom damage.

3. A pretest survey of some 110,390 panes of glass on Edwards AFB revealed that 694 were cracked, broken, or missing. During the test program, only three complaints of glass damage were reported that could be attributed to sonic booms from the test flights.

REFERENCES

1. RESPONSE OF STRUCTURES TO SONIC BOOMS PRODUCED BY XB-70, B-58 AND F-104 AIRCRAFT, Blume, Sharpe, Kost and Proulx, Final Report to National Sonic Boom Evaluation Office, Department of the Air Force by John A. Blume & Associates Research Division, Contract No. AF 49 (638)-1739. (To be published).

Annex G, Part I

Appendix G-1

CONSTRUCTION OF TEST STRUCTURES FOR SONIC BOOM EXPERIMENTS AT EDWARDS AIR FORCE BASE

by

John A. Blume & Associates Research Division

Annex G, Part I

Appendix G-1

CONSTRUCTION OF TEST STRUCTURES FOR SONIC BOOM EXPERIMENTS AT EDWARDS AIR FORCE BASE

The types of test structures to be constructed and instrumented were selected after review of many different house plans. Two houses were selected, National Homes Model 8603, a two-story house and Model 9855, a one-story house. These two models have been mass produced and constructed in the mid-west. A survey of the midwest area indicated that these homes were typical of contemporary midwestern construction.

Model 8603 is a two-story home with four bedrooms, two and one-half baths, living room, dining room, kitchen and family room with a total living area of 1,905 square feet. Model 9855 is a one-story home with three bedrooms, two baths, living room and kitchen dining-family room with a total living area of 1,205 square feet.

Upon receipt of approval of the Contracting Officer a Notice to Proceed with construction of the two structures to be built on Edwards Air Force Base was issued on 24 April 1966. The contractor began work on the following day. The leased structure in Lancaster was built to specifications identical to the two-story structure at Edwards Air Force Base and construction started 1 May.

Blume representatives were assigned to Edwards Air Force Base and Lancaster to monitor the construction of test structures. Photographs were taken periodically of each structure to record construction techniques and progress. The basic construction materials are listed in Attachment A. The construction of the houses at Edwards AFB included the required extensions of sewer, water and butane gas services, construction of concrete driveways and sidewalks, and other minor work necessary for installation and operation of test equipment. All test house construction was completed on 1 June 1966.

Drawings of Model 8603 at reduced scale are included in Attachment B. These drawings represent the "As-Built" condition of the structure. Please note that Model 8603, structures E-2 and L-2 were actually constructed opposite hand to the drawings. In other words, with the front of Model 8603 facing south the garage is on the west side of the structure.

ATTACHMENT A

CONSTRUCTION MATERIALS USED

Mud Sills	Pressure Treated Foundation Grade Redwood
Floor Joists	Douglas Fir Construction Grade
Sub Floor	5/8" Plyscore Plywood
Trusses	2" x 4" "Gangnail" Wood Trusses
Wallboard	1/2" U.S. Gypsum
Studding	Standard and Better Douglas Fir
Roof Sheathing	1" x 6" Standard and Better Douglas Fir
Glass	Double Strength Libby-Owens-Ford and Pittsburg Plate Glass
Insulation	3 1/2" Owens-Corning Fiberglass with Aluminum Foil One Face
Roof Shingles	Asphalt 235#, U.S. Gypsum
All Concrete	Local Aggregate 5 Sacksof Cement per Yard
Siding	Ship-Lap Redwood

ATTACHMENT B

MODEL 8603

WINDOW SCHEDULE (AREAS IN SQ. FT.)

CODE	LGT.	VENT	CODE	LGT.	VENT	CODE	LGT.	VENT	CODE	LGT.	VENT
TW	6.5	3.1	ZG	46.0	9.0	AU	12.9	5.2	VW	47.6	5.2
NW	11.0	5.4	XN	32.0	15.6	EL	21.6	10.6	VL	47.6	5.2
[illegible]	16.1	7.9	VN	35.0	22.0	UW	25.1	8.5	1-LT.DR.	6.2	17.5
NY	19.6	11.1	UU	8.2	4.0	QW	25.7	8.5			
UT	13.0	6.2	BU	10.0	4.4	WJ	15.7	2.5			
WN	22.1	10.9	UC	14.1	7.0	VV	31.9	5.2			
ZV	24.0	6.0	UB	17.2	8.5	VL	31.9	5.2			

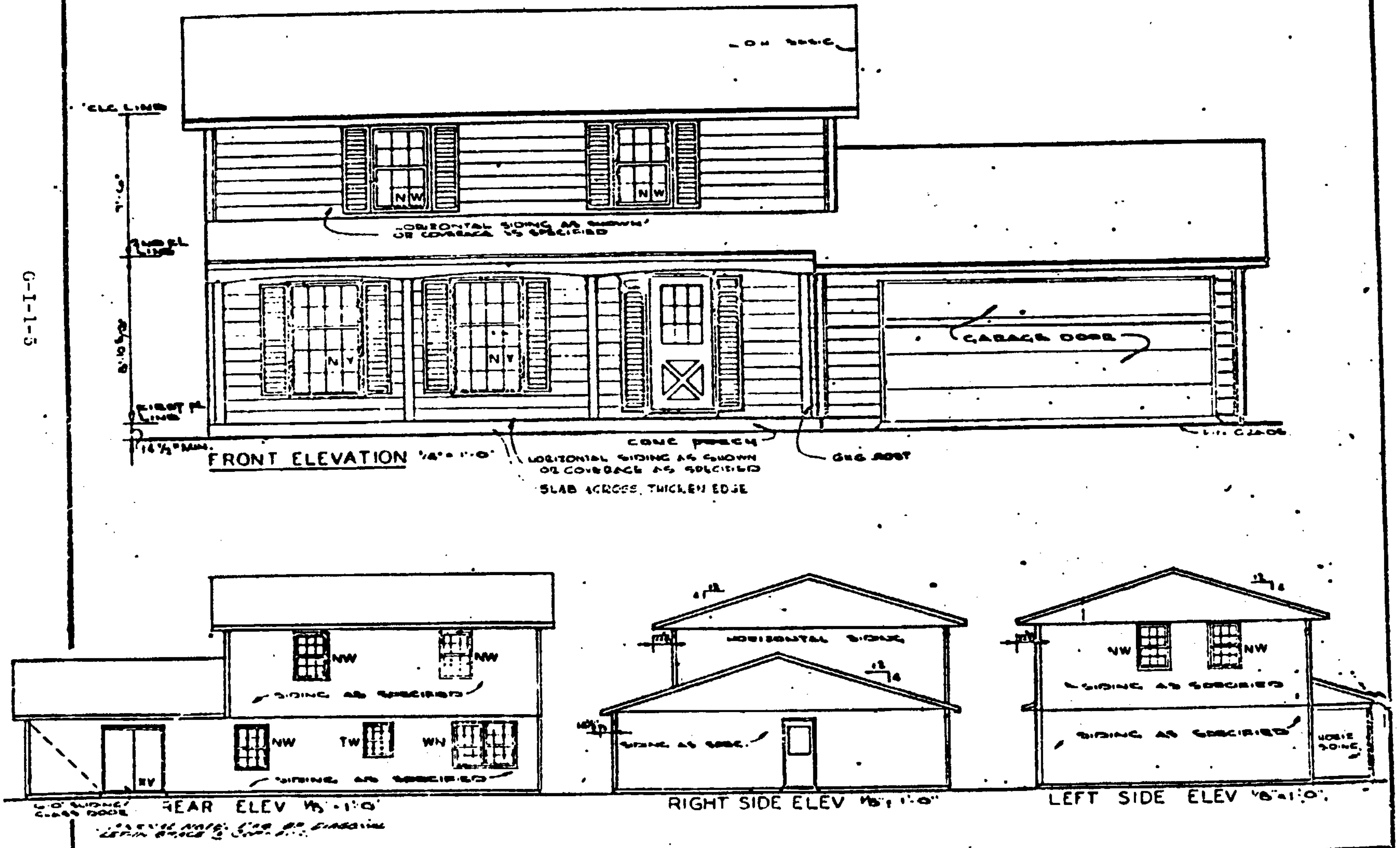
SIDEWALL FINISH CHECK FIN. TO BE USED	ROOF FINISH CHECK FIN. TO BE USED
☐ Brick Veneer	☑ Seal Down Shingles
☐ Alum. Vert Siding W/Battens 12" O.C.	☐ Asphalt thick Butt Shingles
☑ WD. Horiz. Siding	
☐ Others	

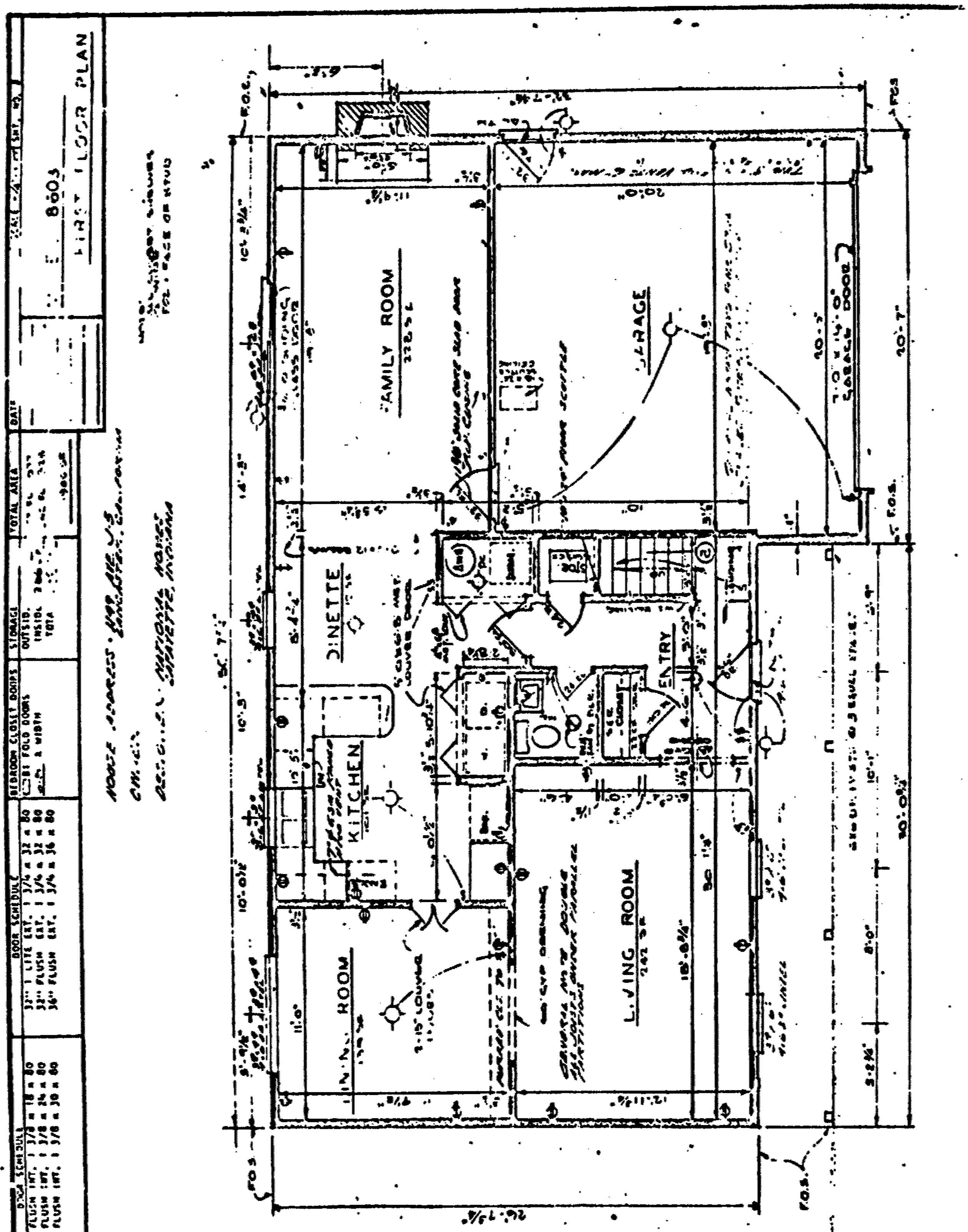
DATE

SCALE-SHOWN | SHT. NO. 10

MODEL 8603
ELEVATION

NOTE: FLUE AS SPECIFIED



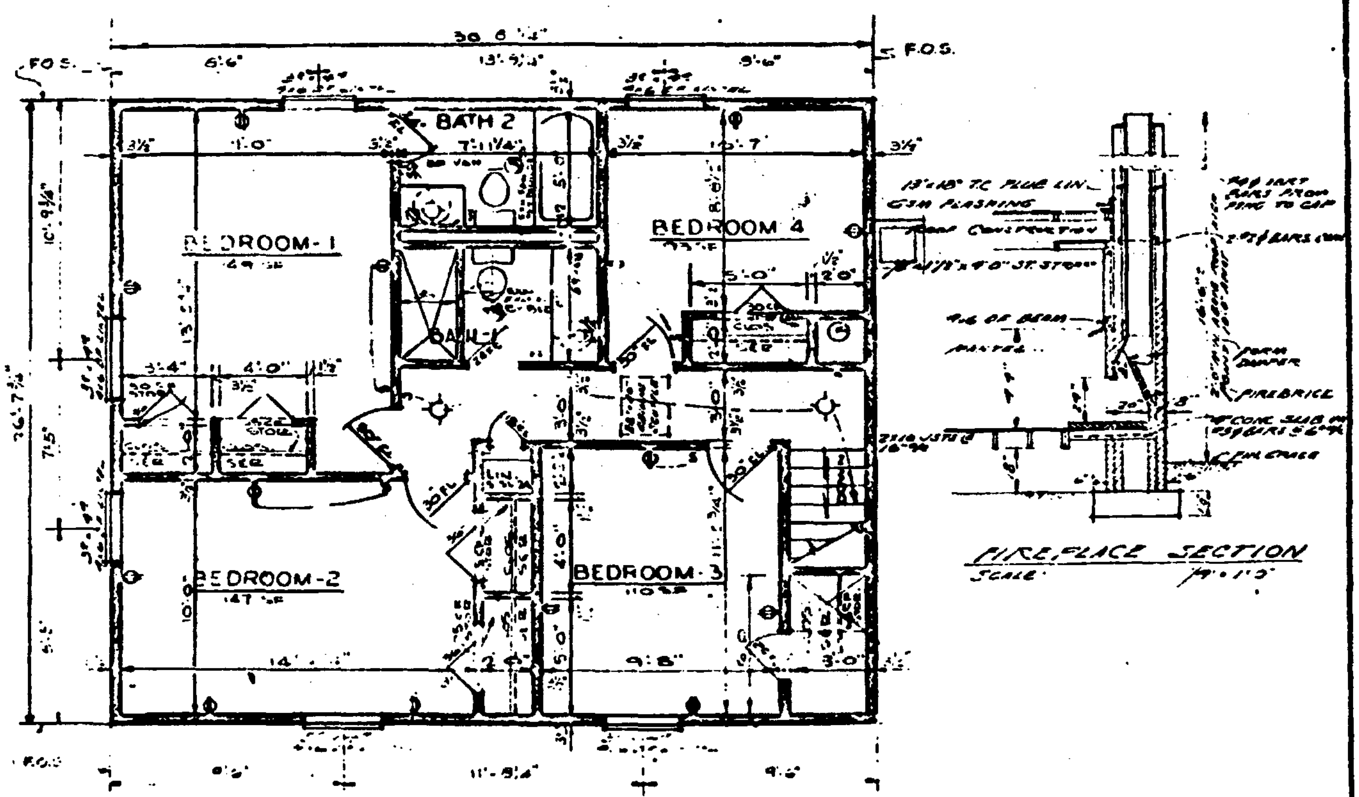

FIRST FLOOR PLAN
FAMILY ROOM
GARAGE
DINETTE
KITCHEN
ENTRY
LIVING ROOM
ROOM
DOOR SCHEDULE
BEDROOM CLOSET DOORS
STORAGE
TOTAL AREA
DATE

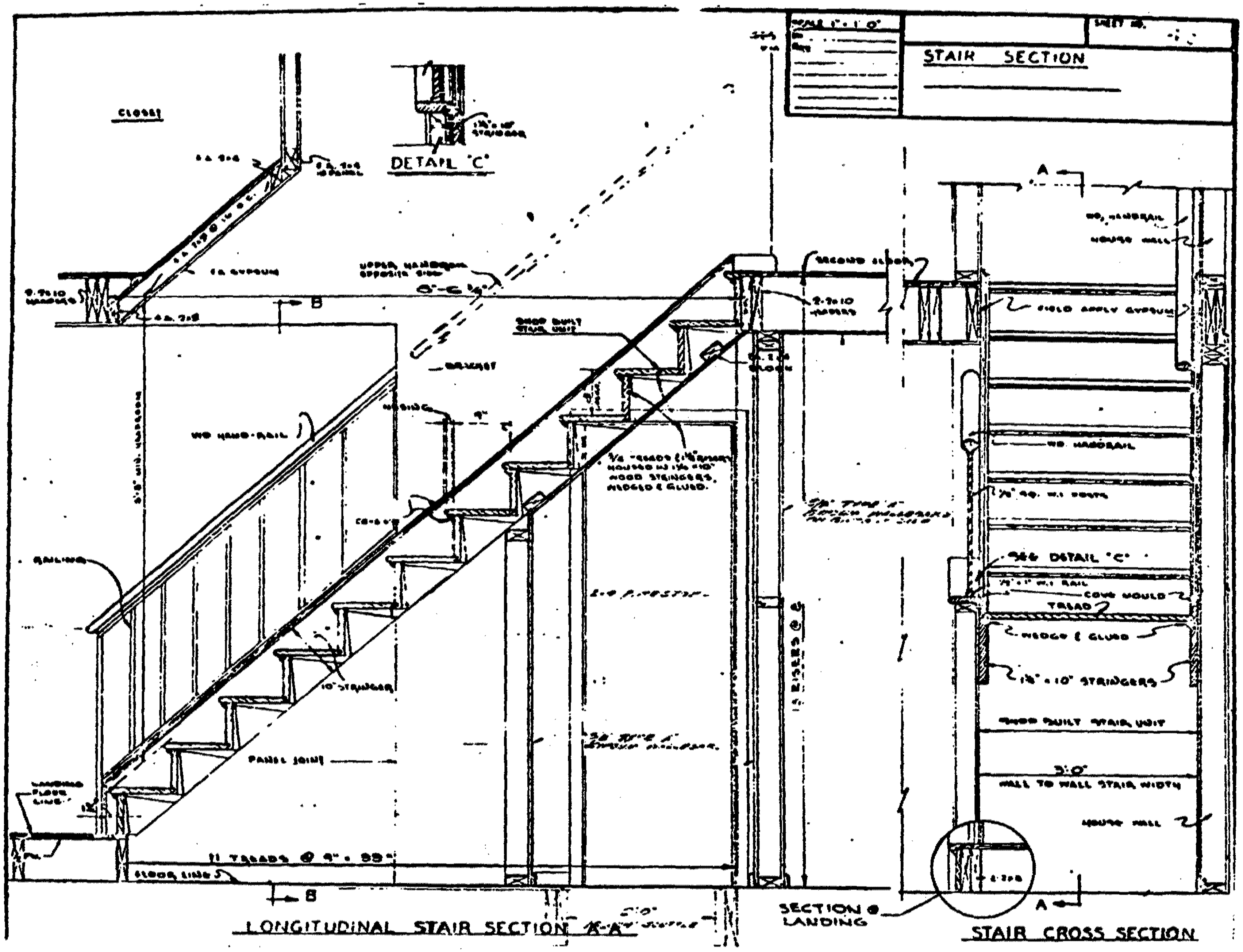
DOOR SCHEDULE	DOOR SCHEDULE	BEDROOM CLOSET DOORS	STORAGE	TOTAL AREA
18" FLUSH INT. 1 3/8 x 18 x 80	32" 1 LITE EXT. 1 3/4 x 32 x 80	BI FOLD DOORS	OUTSIDE	[illegible]
24" FLUSH INT. 1 3/8 x 24 x 80	32" FLUSH EXT. 1 3/4 x 32 x 80	6' x WIDTH	INSIDE	
30" FLUSH INT. 1 3/8 x 30 x 80	36" FLUSH EXT. 1 3/4 x 36 x 80		TOTAL	

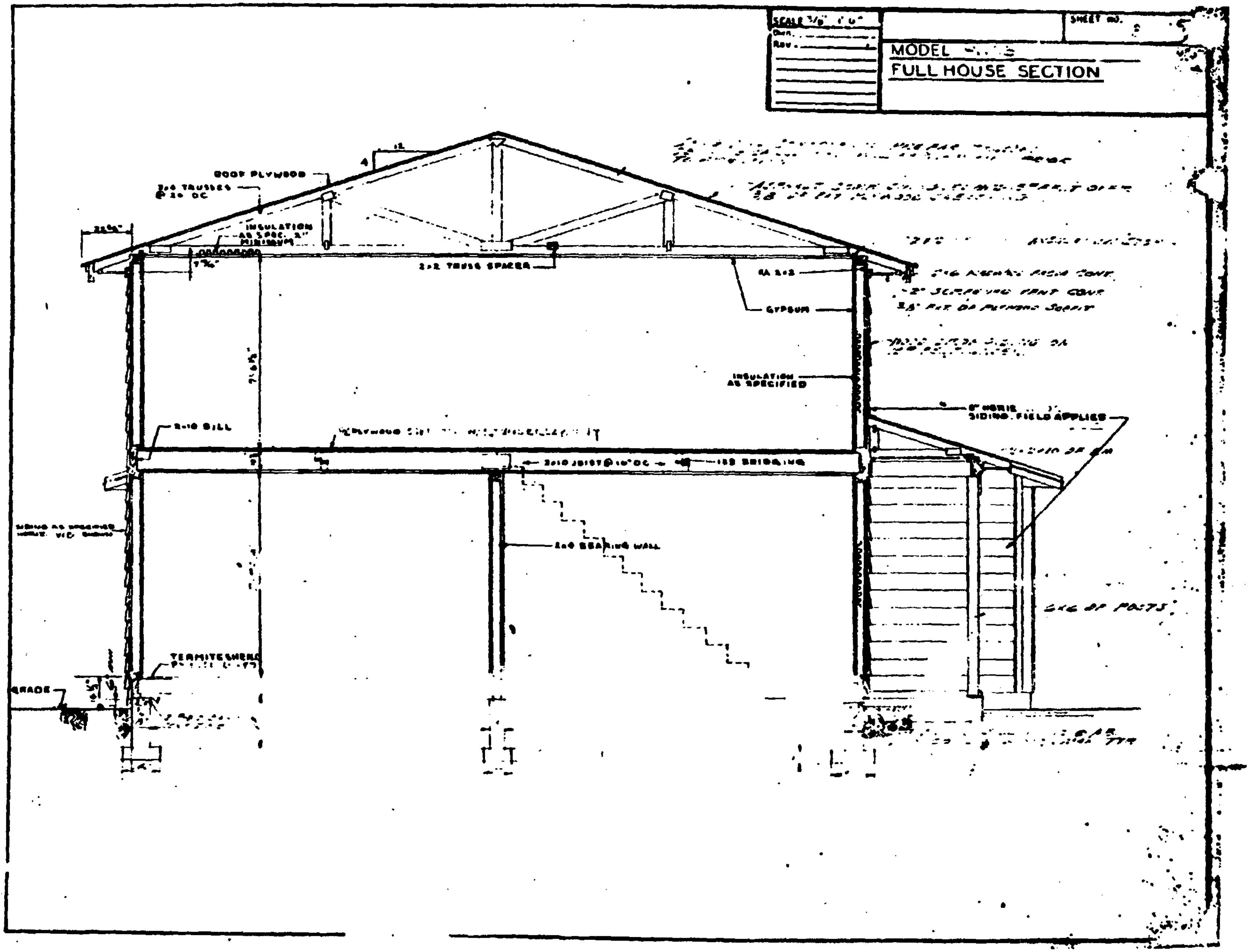
SCALE · SHT. NO. 2

MODEL 8603
SECOND FLOOR PLAN

NOTE: ALL CLOSET SHELVES 2' WIDE



SCALE 1" = 1' 0"
STAIR SECTION
SHEET NO.
CLOSET
DETAIL "C"
1½" x 10" STRINGERS
UPPER HANDRAIL OPPOSITE SIDE
6'-6 ¾"
B
SHOP BUILT STAIR UNIT
BRACKET
WD HAND-RAIL
NOSING
9"
3'-0" MIN. HEADROOM
¾ TREADS 1¾" RISERS HOUSED IN 1½" x 10" WOOD STRINGERS, WEDGED & GLUED.
RAILING
PANEL JOINT
10" STRINGER
LANDING FLOOR LINE
11 TREADS @ 9" = 99"
FLOOR LINE
LONGITUDINAL STAIR SECTION "A-A"
SECOND FLOOR
2-2x10 HEADERS
2-2x4 BLOCK
12 RISERS @
SECTION @ LANDING
A
WD. HANDRAIL
HOUSE WALL
FIELD APPLY GYPSUM
WD. HANDRAIL
SEE DETAIL "C"
COVE MOULD
TREAD
WEDGE & GLUED
1½" x 10" STRINGERS
SHOP BUILT STAIR UNIT
3'-0"
WALL TO WALL STAIR WIDTH
HOUSE WALL
STAIR CROSS SECTION


SCALE 1/8" = 1'-0"
Dwn.
Rev.
SHEET NO.
MODEL
FULL HOUSE SECTION
ROOF PLYWOOD
2x4 TRUSSES @ 24" OC
INSULATION AS SPEC. 2" MINIMUM
2x2 TRUSS SPACER
2x4 TRUSSES
GYPSUM
INSULATION AS SPECIFIED
2" SCREENING VENT CONT.
3/8" EXT. DF PLYWOOD SOFFIT
2x10 SILL
2x10 JOIST @ 16" OC
1x3 BRIDGING
2x4 BEARING WALL
SIDING, FIELD APPLIED
2x6 DF POSTS
TERMITE SHIELD
GRADE
4
12
7'-6 5/8"

Annex G, Part I

Appendix G-2

COMPLAINTS RECEIVED AND RESULTS OF INVESTIGATIONS OF COMPLAINTS CAUSED BY SONIC BOOM EXPERIMENTS AT EDWARDS AIR FORCE BASE

by

John A. Blume & Associates Research Division

Appendix G-2

COMPLAINTS RECEIVED AND RESULTS OF INVESTIGATIONS OF COMPLAINTS

JABARD was assigned the responsibility to investigate all claims and major complaints of sonic boom damage resulting from the Edwards AFB-Lancaster test flights. Complaints were received by the Base Claims Office with daily summaries furnished to JABARD personnel during the test flight period. Base Civil Engineering also received complaints from personnel occupying residential housing on the Base. The total number of complaints received and initially attributed to the Edwards Test Program are as follows:

OFFICE RECEIVING COMPLAINT	NUMBER OF COMPLAINTS	
	Phase I	Phase II
Edwards AFB - Claims	51	12
Edwards AFB - Civil Engineering	8	
Air Force Plant 42, Palmdale	2	
	61	

PHASE I COMPLAINTS

Table G-2.1 lists all complaints received during Phase I of the Test Program. The date each complaint was received, and the date and time of day alleged damage occurred are given. Ten of the 61 complaints received were either information calls (just worried that damage might occur), complaints about sonic boom noise, or damage that occurred prior to the program or from other causes such as shot from a boy's B-B gun. Of the remaining fifty-one complaints, thirty-three after investigation appeared to be valid damage complaints. It should be noted that in many cases of glass complaints repairs had been made prior to the arrival of the engineer-investigator, or the cause of the cracks in the glass could not be definitely established to be from causes other than sonic boom.

TABLE G-2.1

SUMMARY OF COMPLAINTS ATTRIBUTED TO PHASE I

BY LOCATION, DATE, AND TIME

Complaint Number	Location	Date of Receipt of Complaint	Time of Occurrence of Alleged Damage	
			Date	Time of Day
61	Lancaster	1 August	6 June	1000-1030
1	Tehachapi	6 June	6 June	1000-2000
3	Lancaster	6 June	6 June	1000-2000
6	Rosamond	9 June	6 June	0900-1100
57	EAFB	--	6 June	--
7	Barstow	9 June	6 June	am
55	EAFB	--	6 June	--
22	Tehachapi	20 June	6 June	am
52	EAFB	--	6 June	--
2	Barstow	7 June	7 June	0930-1030
6	Rosamond	9 June	7 June	0900-1100
7	Barstow	9 June	7 June	am
22	Tehachapi	20 June	7 June	am
4	EAFB	8 June	8 June	0908
6	Rosamond	9 June	8 June	0900-1100
7	Barstow	9 June	8 June	am
46	Barstow	27 June	8 June	0930
6	Rosamond	9 June	9 June	0900-1100
7	Barstow	9 June	9 June	am
8	Lancaster	10 June	9 June	am
12	Tehachapi	13 June	9 June	0930
58	Barstow	9 June	Prior to Program	--
13	EAFB	9 June	9 June	1400
9	Palmdale	13 June	13 June	am
10	Lancaster	13 June	13 June	0953
14	Tehachapi	14 June	13 June	am
15	Lancaster	20 June	13 June	1000-1200
11	Rosamond	13 June	13 June	--
31	Lancaster	21 June	14 or 15 June	0915
60	Lancaster	24 June	14 June	1200
50	EAFB	--	15 June	1600-1615
34	Lancaster	22 June	16 June	--
16	Tehachapi	20 June	20 June	1030-1100
19	Tehachapi	21 June	20 June	1022
21	Tehachapi	20 June	20 June	1043
23	Tehachapi	20 June	20 June	1044
24	Lancaster	20 June	20 June	1000
26	Lancaster	14 July	20 June	--
27	Quartz Hill	21 June	20 June	am
3	Quartz Hill	20 June	20 June	1045
17	Tehachapi	22 June	20 June	1015
45	Tehachapi	6 July	20 June	--
25	Quartz Hill	20 June	20 June	0910

Complaint Number	Location	Date of Receipt of Complaint	Time of Occurrence of Alleged Damage	
			Date	Time of Day
33	Lancaster	20 June	20 June	0910
37	Quartz Hill	24 June	20 June	am
38	Lake Isabella	20 June	20 June	0915
42	Quartz Hill	21 June	20 June	am
34	Lancaster	22 June	20 June	--
20	Tehachapi	21 June	21 June	am
30	Lancaster	21 June	21 June	1315
40	Lancaster	23 June	21 June	--
41	Quartz Hill	22 June	21 June	0905
42	Quartz Hill	21 June	21 June	am
46	Tehachapi	1 July	21 June	0910
48	Quartz Hill	21 June	21 June	--
54	EAFB	--	21 June	--
49	Lake Hughes	21 June	21 June	0905-0945
51	EAFB	--	22 June	--
53	EAFB	--	23 June	--
24	EAFB	23 June	23 June	0845
58	Tehachapi	24 June	23 June	0955
23	Tehachapi	23 June	23 June	0855
35	Palmdale	23 June	23 June	0912-1256
56	EAFB	--	1965	--
5	Lancaster	21 June	Week of 6 June	
32	Lancaster	22 June	17 - 11 June	
18	Tehachapi	17 June	?	
36	Lancaster	22 June	?	
39	Quartz Hill	22 June	?	
43	Palmdale	27 June	?	
47	Lancaster	7 July	?	

All of the fifty-one "valid" complaints were investigated except one which was classified as an information call. For each complaint, AFLC Forms 666, 669, and 670 were used for recording the facts found during the engineer's investigation. In addition, special note was made of the physical orientation of the damaged item in each structure. Complaints were classified as to whether they involved glass, plaster or stucco, bric-a-brac, structural elements or noise.

DESCRIPTION OF FLIGHTS

Two primary headings were flown by most of the aircraft during the three weeks of testing. From 3 June through 12 June flights were flown from east to west on a heading of 245° magnetic. Flights from 13 June through 23 June were flown east to west at 233° magnetic. Figure G-2.1 shows the scheduled supersonic "racetrack" course flown by B-58 aircraft from 3 June through 12 June with the location and type of complaint received plotted thereon. The B-58 aircraft maintained essentially constant speed throughout the "racetrack" pattern. Radar plots indicate that some aircraft did not follow the radius of turn indicated. Some flights were not plotted after the aircraft started the turn to the north. Note that the least distance from the flight track to the Lancaster test structure, L-2, is about 13 miles. A total of 52 B-58 flights at Mach 1.5 to 1.65 were flown over this racetrack course. Table G-2.2 lists the number of flights for each aircraft flown supersonically as part of the test program during the 3 June to 12 June period.

Figure G-2.2 shows the scheduled supersonic "racetrack" course flown by B-58 aircraft from 13 June through 23 June with the location and type of complaint plotted thereon. The least distance from the flight track to the Lancaster test structure for the 233° magnetic track is about 8 miles. A total of 47 B-58 flights at speeds of Mach 1.5 to 1.65 were flown over this course. Table G-2.3 lists the number of flights for each aircraft flown supersonically as part of the test program from 13 June through 23 June.

SONIC BOOM DAMAGE COMPLAINTS

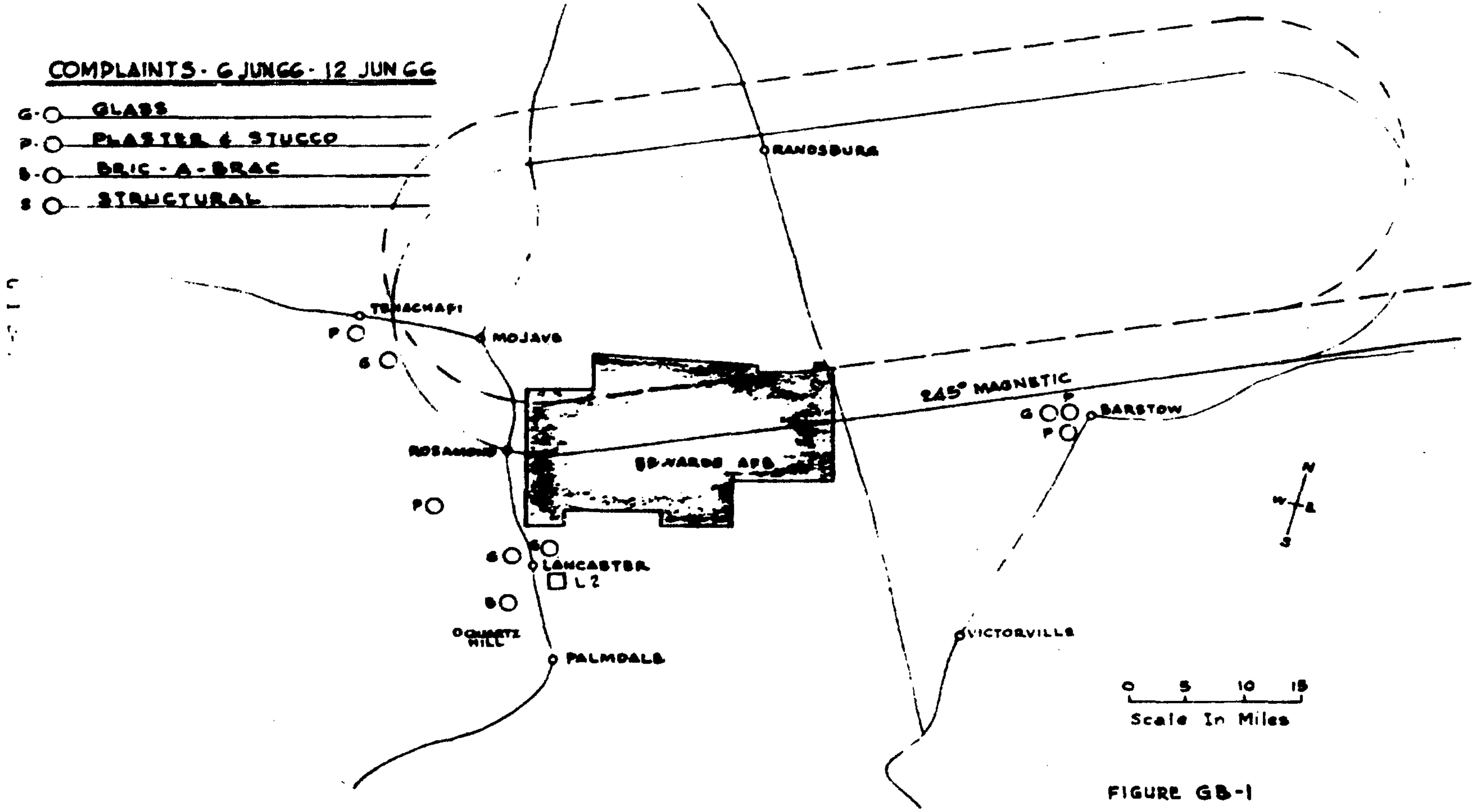


FIGURE GB-1

TABLE G-2.2

AIRCRAFT FLIGHTS 3 JUNE THROUGH 12 JUNE

Aircraft	No. of Flights	Primary Heading	Comments
B-58	52	245° M	Racetrack Course
XB-70	3	245° M (1 @ 262° M)	Straight Course
F-104	3	--	Straight Course
F-106	18	--	Straight Course
SR-71	1	--	Straight Course

TABLE G-2.3

AIRCRAFT FLIGHTS 13 JUNE THROUGH 23 JUNE

Aircraft	No. of Flights	Primary Heading	Comments
B-58	48	233° M	Racetrack Course
F-104	34	233° M	Straight Course
SR-71	2	--	Straight Course
YF-12	2	--	Straight Course

SONIC BOOM DAMAGE COMPLAINTS

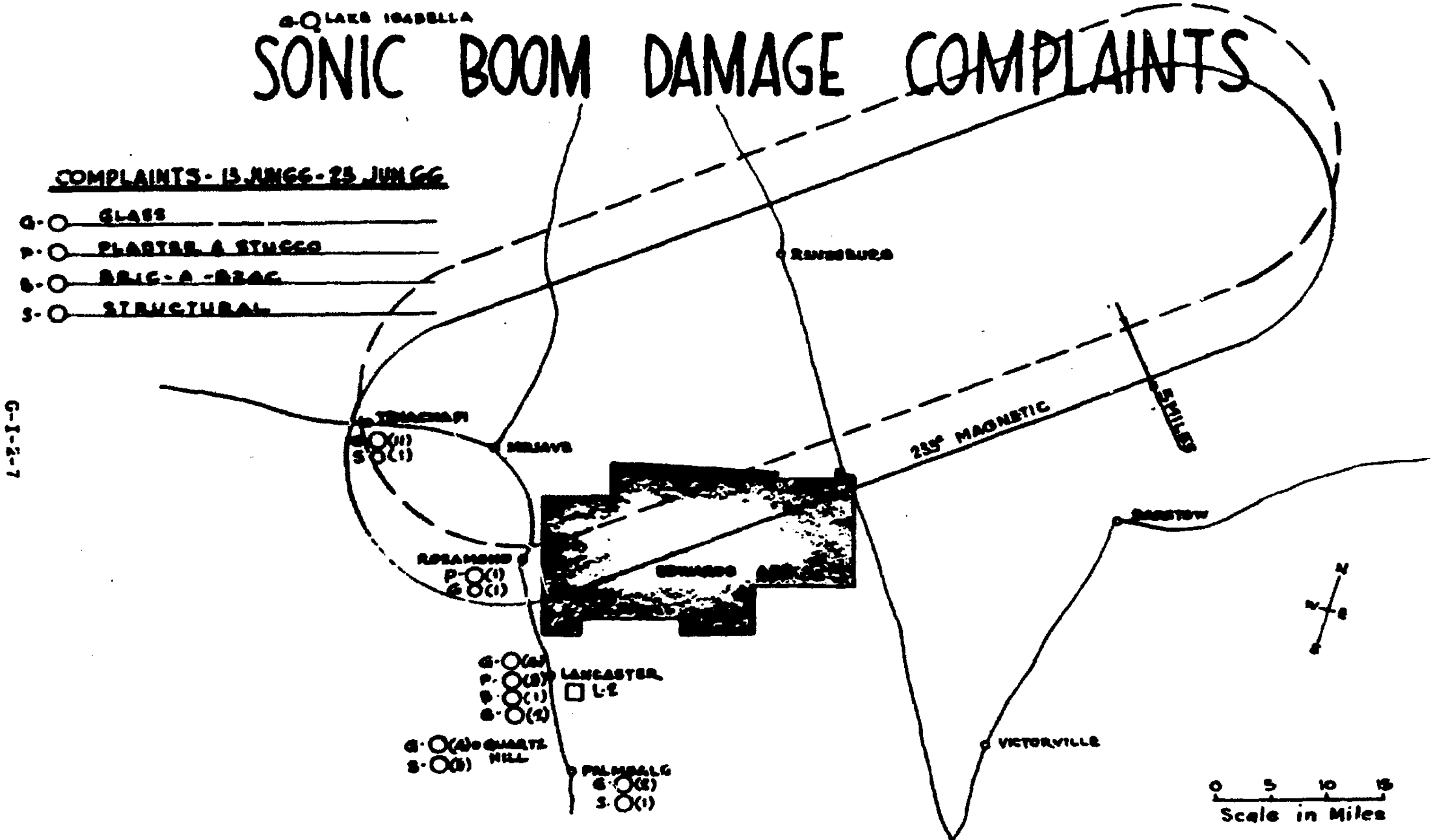


FIGURE GB-2

LOCATION AND TYPES OF DAMAGE

The engineer's investigation reports were analyzed in conjunction with the log of actual flights and radar plots to determine if the type and speed of the aircraft and the location of the flight path could be correlated with the alleged damage. With the number of flights flown daily and the short time interval between flights, it was difficult to pinpoint a specific boom as the cause of damage at a particular location. The major problem was that persons filing complaints could, as a rule, give only an estimate of the time of the boom which caused the damage. This time estimate often spanned an hour, occasionally a whole morning. In addition, many of the radar plots did not show the entire supersonic track of each aircraft. A few of the plots started before the aircraft reached Barstow. Many plots stopped at the "turn" point of the race-track course.

3 June through 12 June

The complaints received were classified as to type; glass, plaster or stucco, bric-a-brac, structural elements or noise. Table G-2.4 lists all complaints attributable to the 3 June - 12 June flights. Of the 14 complaints received, five appear not to be valid, i.e., information call, damage occurred at a time other than during test flights or damage was due to causes other than sonic boom.

In two instances during the 3 to 12 June period, specific booms can be related to damage.

> Barstow - 7 June - A large window was reported broken at about 0930. The radar plot started some distance to the east and shows a B-58 aircraft maneuvering to get on the track heading at about this time. It appears that Barstow was less than five miles off the track of this incoming aircraft.
>
> Edwards AFB Housing - 8 June - A bric-a-brac complaint was received from the Base housing area claiming damage to a figurine that fell from a shelf at 0908. The flight log data show a boom at 0908 at Radar Control which is not far removed from the housing area. This was a flight displaced 5 miles north of the flight track over the test structures or almost over the Base housing area; it was recorded as a 3.17 psf boom at the test house location on the Base.

TABLE G-2.4 - COMPLAINTS RECEIVED

(3 June - 12 June 1966 Track at 245° Mag)

1.	Tehachapi - 0	Glass	D - May not file claim
2.	Barstow - R	Glass (large plate)	A - Claim filed
3.	Lancaster - 0	Bric-A-Brac and Glass	A - Will not file claim
4.	EAFB - R	Bric-A-Brac	A - Claim filed and paid
5.	Lancaster - 0	Glass	No damage - just worried
6.	Rosamond - 0	Plaster and Stucco	D
7.	Barstow - 0	Stucco	D
8	Lancaster - ?	Bric-A-Brac	Information call, did not investigate
12.	Tehachapi - 0	Plaster	A
13.	EAFB - R	Glass (porch light)	D - Time reported does not coincide with program flights
44.	Barstow - 0	Stucco	D
52.	EAFB	Glass	A - Possibly caused by program insufficient data available
55.	EAFB - R	Glass	Insufficient data available
57.	EAFB - R	Glass	D - Window broken by B-B gun
59.	Barstow - 0	Glass	D - Damage occurred prior to program
61.	Lancaster - 0	Glass	No claim filed.

TOTALS BY TYPE (One complaint involves two types of damage)

Glass	Plaster and Stucco	Bric-A-Brac
10	4	3

COMPLAINTS - AREA TOTALS

EAFB	5
Tehachapi	2
Barstow	4
Lancaster	4
Rosamond	1

* A - Recommend approval of payment if claim is filed.
D - Recommend denial of payment if claim is filed.
0 - Owner
R - Renting
? - 0 or R information not available

13 June through 23 June

The number of complaints increased markedly with the change in flight heading, however, nearly half of the complaints occurred on two days. Table G-2.5 lists all complaints received which are attributable to the 233° magnetic heading. Nineteen incidents of damage in eighteen complaints were reported on 20 and 21 June. Included in these two days are all complaints from the Quartz Hill area, one from Lake Isabella, four from Lancaster and six from Tehachapi. Both days included a number of flights with 3 psf nominal overpressures. Average overpressures recorded at Edwards AFB show three booms over 3 psf, eight over 2.5 psf, four over 2.0 psf, all other except two flights over 1.5 psf. The radar plots show an aircraft at 0935 on 20 June descending before reaching Rosamond. Complaints from Quartz Hill and Lancaster give estimates of damage occurring both before and after this time. The radar plots also show several aircraft, which can not be identified by time, in descent on both 20 and 21 June in the vicinity of Tehachapi. No complaints were received for booms on the 15th and 16th of June and only one was received for damage occurring on the 14th. The maximum average overpressure recorded at Edwards Test Structure E-2 for these three days was 3.75 psf at 0915 on 15 June 1966.

Tables G-2.6 and G-2.7 list complaints by type and aircraft heading, and by location and aircraft heading respectively.

For flights flown on a 233° magnetic heading, two specific flights can be related to damage:

> Tehachapi - 20 June - The Postmistress happened to be looking at a clock opposite her desk at the time a boom (1) broke a window in the U.S. Post Office and (2) extended cracks and broke a window in a department store in the same building. The time was noted as 1043, the radar plot indicates a B-58 aircraft at that time had just turned onto the easterly leg of the track a short distance beyond Tehachapi.
>
> Lake Isabella - 20 June - A window was reported broken at approximately 0915. The radar plot shows a B-58 aircraft in a supersonic turn in the vicinity of Lake Isabella at 0900. This is approximately 30 miles north of the return leg of the track.

TABLE G-2.5 - COMPLAINTS RECEIVED

(13 June - 23 June 1966, Track 233° Mag)

	Location	Type	Results of Investigation
9.	Palmdale - 0	Glass	A
10.	Lancaster - 0	Glass	A - Claim filed and paid
11.	Rosamond - 0	Bric-a-brac and plaster	A - Bric-a-brac D - Plaster
14.	Tehachapi - 0	Glass	A - Claim Filed
15.	Lancaster - 0	Structural (Exposed ceiling, beams twisted)	D
16.	Tehachapi - 0	Glass	A
17.	Tehachapi - 0	Glass	A - Claim filed and paid
18.	Tehachapi - 0	Glass	D - Old paint in crack
19.	Tehachapi - 0	Glass (2 complaints on consecutive days)	A - Claim filed and paid
20.	Tehachapi - 0	Glass	A - Claim filed and paid
21.	Tehachapi - 0	Glass (large plate)	A - Claim filed and paid, building leased by U.S. Post Office.
22.	Tehachapi - R	Glass (large plate - 3)	A - Claim filed and paid, same bldg. as U. S. Post Office.
23.	Tehachapi - R	Glass (large plate)	A - Claim filed and paid
24.	EAFB - 0	Glass (Windshield)	Complaint withdrawn.
25.	Lancaster - R	Glass	A - 75%
26.	Lancaster - 0	Glass (2 large, laminated tinted plate)	A - Negotiate settlement,
27.	Quartz Hill - 0	Structural (Light fixture fell)	D
28.	Quartz Hill - 0	Glass	A
29.	Quartz Hill - 0	Glass	A
30.	Lancaster - 0	Structural and Plaster	A - Will not file claim.
31.	Lancaster - 0	Bric-a-brac	A
32.	Lancaster - 0	Glass (T.V.)	D - Probably will not file claim
33.	Lancaster - 0	Glass	A - Claim filed and paid
34.	Lancaster - 0	Stucco	D - Probably will not file claim
35.	Palmdale - R	Glass	A - Partial payment, inspected by Sgt. Talley
36.	Lancaster - 0	Plaster and Stucco	D - Will not file claim
37.	Quartz Hill - 0	Glass	A
38.	Lake Isabella - 0	Glass	A - Claim filed, partial pay. one pane broken before program
39.	Quartz Hill - 0	Structural (Irrig. piping)	Information call, will not file claim
40.	Lancaster - 0	Plaster	A - 50% claim filed and paid
41	Quartz Hill - 0	Structural (Attic access cover)	Information call, will not file claim
42.	Quartz Hill	Glass	A
43.	Palmdale - 0	Structural (Reservoir crack)	D - Will not file claim
45.	Tehachapi - 0	Structural (Brick column)	D - Will not file claim

TABLE G-2.5 Continued

	Location	Type	Results of Investigation
46.	Tehachapi - O	Glass	A
47.	Lancaster - O	Glass and Tile	A - Glass D - Tile
48.	Quartz Hill - ?	Noise	Complaint thru AF Plant 42. no damage reported
49.	Lake Hughes - ?	Noise	Complaint thru AF Plant 42 no damage reported
50.	EAFB - R	Glass	A
51.	EAFB - R	Glass	A
53.	EAFB - R	Glass	D - Insufficient data available
54.	EAFB - R	Glass	D - Insufficient data available
56.	EAFB - R	Glass	D - Window broken in 1965.
58.	Tehachapi - R	Glass	A
60.	Lancaster - ?	Light Fixture	

TOTALS BY TYPE (Several involve more than one type of damage)

Glass	Plaster and Stucco	Bric-A-Brac	Structural	Noise
31	6	2	7	2

COMPLAINTS - AREA TOTALS

EAFB	6
Tehachapi	12
Rosamond	1
Lancaster	13
Quartz Hill	8
Palmdale	3
Lake Isabella	1
Lake Hughes	1

*A - Recommend approval of payment if claim is filed
D - Recommend denial of payment if claim is filed
O - Owner
R - Renting
? - O or R information not available.

TABLE G-2.6 - COMPLAINTS BY TYPE AND AIRCRAFT HEADING

Track and Dates	Glass	Plaster and Stucco	Bric-a-Brac	Structural	Noise	Total
245° Mag 3-12 June	7	4	3	0	0	14
233° Mag 13-23 June	31	6	2	7	2	48

*4 Complaints involved two types of damage

TABLE G-2.7 - COMPLAINTS BY LOCATION AND AIRCRAFT HEADING

AREA	245° Mag 3-12 June	233° Mag 13-23 June	Total
EAFB	5	6	11
Tehachapi	2	12	14
Rosamond	1	1	2
Barstow	4	0	4
Lancaster	4	13	17
Quartz Hill	0	8	8
Palmdale	0	3	3
Lake Isabella	0	1	1
Lake Hughes	0	1	1
TOTALS	16	45	61

A complaint was received from a high school district claiming a row of light fixtures had fallen due to sonic booms during the morning of 20 June 1966 at their high school. The school is located approximately nine miles south of the flight track and approximately 7.5 miles SW from the test house L-2 in Lancaster. The maximum average overpressure recorded at L-2 on the 20th of June was 1.77 psf for Mission 98B at time 1016. The fixtures involved were eight-foot long industrial, fluorescent, two-tube fixtures, mechanically connected to form one row. They were hung with five lengths of "S" type chain approximately five feet long which were fastened to the metal roof decking. At approximately 1300 on 20 June the fixtures were found on the floor partly draped across a chair. Investigation showed that many of the chain links supporting the fixtures had been, at some unknown time, opened sufficiently (the links were almost L-shaped) for the chain to come apart, thus allowing the fixtures to fall. Static loading tests were conducted on pieces of the fixture chain and on pieces of almost identical new chain. These tests showed the supporting chain to have a separating strength of 125 pounds; the fixtures had a dead load weight of 70 pounds. Under normal conditions this difference between the dead weight load and the ultimate strength of the supporting chains would imply an inadequate margin of safety. Nevertheless, even when extreme conditions of sonic boom loading were assumed it was not possible to predict loads exceeding the 125 pound ultimate strength of the supporting chains. After this detailed investigation it was concluded that sonic booms could not and did not cause the chain links to deform and the fixtures to fall.

Of the total "valid" complaints received, 35 were made by owners of the structures involved. A total of 16 claims have been filed with the Edwards AFB Claims Office. Fifteen of these claims for a total of $1,359.93 have been paid. One claim is still pending.

The combined population of Palmdale, Lancaster, Rosamond, Quartz Hill and Tehachapi is about 45,000. Assuming 19 window panes per person,[1] a

---

[1] Southwest Research Institute Report, Evaluation of Window Pane Damage Intensity in San Antonio Resulting from Explosion at Medina Facility of November 13, 1963.

total of about 850,000 panes were subjected to sonic boom. Assuming 11 panes per person (based on the total number of window panes at Edwards AFB) a total of 495,000 panes of all sizes were subjected to sonic boom. A total of 30 complaints of glass pane damage was received for the 13 to 23 June period. Forty-seven B-58 flights were flown resulting in an average of 0.64 complaints per flight or about one cracked pane per 0.77 to 1.33 million exposures.

PHASE II COMPLAINTS

Table G-2.8 lists complaints received that could be attributed to flights during Phase II (31 October 1966 through 17 January 1967). Three of the complaints were for alleged damage that occurred on days when no Test Program flights were flown.

Five glass damage, four bric-a-brac, and two structural damage complaints were recorded. After investigation seven of the complaints were recommended for payment if claims are filed; five could be assigned to test program flights. As of April 10, 1967, three claims have been filed and $40.00 has been paid for one approved claim. Two claims are still unsettled. Table G-2.9 presents a summary of claims received during Phase II.

SUMMARY OF FINDINGS

The above text has presented the status of complaints and claims as of 10 April 1967. Overpressure measurements are not available for the major complaint areas.

The following comments can be made:

1. No sonic boom damage was observed in the test structures prior to or after the test flights. There were minor shrinkage cracks in the test structures prior to start of test flights. However, no discernible extension or widening of these cracks was observed although observations were made and recorded daily.
2. Alleged glass damage represents 63 percent of all complaints received, 14 percent for plaster or stucco, 12 percent for structural, 8 percent for bric-a-brac, and 3 percent for bothersome noise.

TABLE G-2.8

SUMMARY OF COMPLAINTS ATTRIBUTED TO PHASE II BY DATE, LOCATION AND TIME

Complaint Number	Location	Date of Receipt of Complaint	Time of Occurrence of Alleged Damage Date	Time of Day
62	Lancaster	11/10/66	11/10/66	Unknown
63	Mojave	11/16/66	11/16/66	1150
64	Lancaster	11/25/66	11/23/66	1035
69	Lancaster	11/28/66	11/23/66	1004 & 1150
65	EAFB	12/1/66	12/1/66	1040
66	EAFB	12/1/66	12/1/66	0130 - 1515
67	Rosamond	12/8/66	12/8/66	1230
68	Rosamond	12/8/66	12/8/66	1239
70	Mojave	12/15/66	12/8/66	1200
71	Lancaster	1/3/67	Damage not related to any boom.	
72	Lamont	1/17/67	1/17/67	1015 - 1020

TABLE G-2.9

SUMMARY OF COMPLAINTS AND RESULTS OF INVESTIGATION

Complaint Number	Location	Type of Damage	Results of Investigation
62 - O	Lancaster	Glass	A - XB-70 - 8 miles south of designed track.
63 - R	Mojave	Glass	A - B-58 turning over Mojave
64 - O	Lancaster	Bric-A-Brac	A - XB-70 approximately 1.25 miles north of residence.
65 - R	Edwards AFB	Bric-A-Brac	A - Not Caused by program flights.
66 - R	Edwards AFB	Bric-A-Brac	A - Not Caused by program flights.
67 - O	Rosamond	Glass	D - B-58 over Rosamond 12/8/66.
68 - O	Rosamond	Bric-A-Brac	D - Not caused by program flight.
69 - R	Lancaster	Structural	D - Not boom damage.
70 - O	Mojave	Glass	A - B-58 over Mojave
71 - O	Lancaster	Structural	D - Not boom damage
72 - O	Lamont	Glass	A - XB-70 turning over Lamont (approx. 7 mi. south of Bakersfield)

O - Owner
R - Renting
A - Recommend approval of payment if claim is filed
D - Recommend denial of payment if claim is filed

GLASS	**STRUCTURAL**	**BRIC-A-BRAC**
5	2	1
XB-70 - 2 B-58 - 3	2 not boom damage	XB-70 - 1

3. The glass panes damaged ranged in size from 1.3 square feet to 82.5 square feet (Barstow store front). See Table G-2.10.
4. Glass damage was often repaired before the engineer could investigate the alleged damage and hence, the validity of all glass claims could not be definitely established.
5. The large decrease in number of complaints during Phase II can be attributed to two factors; (a) the B-58 aircraft made turns and other maneuvers at supersonic speed over several cities during Phase I, and (b) during Phase II only the XB-70 flew supersonically over cities near to Edwards AFB.

TABLE G-2.10

SIZES OF DAMAGED GLASS

Location	Previous Condition	Sq.Ft.	Size of Glass in Feet	Frame	Orientation
Tehachapi	Cracked	17.2	2.75 x 6.25P (Sliding Door)	Al.	South
Barstow	Good	82.5	8.5 x 9.7P (Store Front)	Al.	Southeast
Palmdale	Cracked	6.0	1.5 x 4W (Fixed)	Al.	South
Palmdale	Good	6.0	1.5 x 4W (Crank out)	Al.	South
Lancaster	Good	9.9	3 x 3.3W (Sliding)	Al.	East
Tehachapi	Good	16.2	3.6 x 4.5W (Fixed)	Wood	West
Tehachapi	Good	10.8	3 x 3.6W (Fixed)	Al.	North
Tehachapi	Good	6.25	2.5 x 2.5W (Vert. sliding)	Wood	East
Tehachapi	Good	9.0	3 x 3W (Fixed)	Al.	West
Tehachapi	Good	9.0	3 x 3W (Fixed)	Al.	West
Tehachapi	Good	4.2	5.6 x 7.5P (Store front)	Al.	East
Tehachapi	Good	62.0	6.75 x 9.2P (Store front)	Al.	East
Tehachapi	Good	23.5	2.25 x 9.2P (Store front)	Al.	East
Tehachapi	Good	20.25	6.75 x 3P (Store door)	Al.	East
Quartz Hill	Good	5.0	2 x 2.5W (Hor. sliding)	Al.	West
(Lancaster) Quartz Hill	Good	4.4	2.2 x 2W (Vert. sliding)	Wood	East
Palmdale	Small crack	63.0	7 x 9P (Store Front)	Al.	North
Lake Isabella	Good	7.6	2 x 3.8W (Hor. sliding)	Al.	East
Lake Isabella	Good	1.3	1 x 1.3W (Hor. sliding)	Al.	North
Tehachapi	Good	23.75	3.75 x 6.3W (Fixed)	Al.	South
Lancaster	Good	6.0	1.5 x 4W (Crankout)	Al.	South
Lancaster	Good	4.5	1.5 x 3W (Crankout)	Al.	South (Same House)
Quartz Hill	Good	9.0	3 x 3W (Fixed)	Al.	East
Quartz Hill	Good	9.0	3 x 3W (Fixed)	Al.	East (Same House)
Tehachapi	Good	3.0	1.5 x 2.5W (Vert.sliding)	Wood	East
Tehachapi	Good	5.0	2 x 2.5W (Vert.sliding)	Wood	East (Same House)
Lancaster	Cracked (1")	27.0	6 x 4.5W (Vert.sliding door)	Al.	West

Location	Previous Condition	Sq. Ft.	Size of Glass in Feet	Frame	Orientation
Quartz Hill	Good	2.0	1 x 2W (Vert.sliding)	Wood	North
Quartz Hill	Good	4.0	2 x 2W (Fixed)	Wood	North (Same House)
Lancaster	Good	8.0	2 x 4W (Crankout)	Al.	South
Lancaster	Good	4.5	1.5 x 3W (Crankout)	Al.	South
Lancaster	Good	4.5	1.5 x 3W (Crankout)	Al.	South (Same bldg.)
Lancaster	Good	32.0	4 x 8W (Fixed 3 layer Laminated)	Wood	West
Lancaster	Good	24.0	3 x 8W (Fixed 3 layer Laminated)	Wood	West (Same House
Lancaster	Good	7.0	1.83 x 3.83W(Fixed)	Al.	East
Mojave	Good	6.8	1.75 x 3.9W(Crankout)	Al.	East
Rosamond	Poor	24.3	3.83 x 6.33P (Hor. Sliding)	Al.	South
Mojave	Good	47.1	4.67 x 10.1P(Fixed)	Al.	West
Lamont	Good	6.9	1.83 x 3.75W (Hor. Sliding)	Al.	South

Note:

Al. - denotes aluminum sash

P - denotes plate glass

W - denotes window glass

Annex G, Part I

Appendix G-3

SURVEY OF GLASS WINDOWS AT EDWARDS AIR FORCE BASE

by

John A. Blume & Associates Research Division

Appendix G-3

SURVEY OF GLASS WINDOWS AT EDWARDS AIR FORCE BASE

Prior to the test program a survey was conducted of all window glass panes in structures located at Edwards AFB. The letter shown in Figure G-3.1a and the Survey Form, Figure G-3.1b were sent to all occupants of Base housing on 25 May 1966 via the Daily Bulletin published by the Base. There were 2,226 residential units on the Base. Of these, 567 or about 25 percent of the residents returned completed forms. A total of 101 cracked window panes were reported by the residents who returned forms for a probable total of about 400 cracked panes in the population of 49,730 window panes (including glass doors) in the base residential housing.

In addition to the residential units, all buildings and facilities used for Base operations were surveyed. The letter shown in Figure G-3.2a together with the form in Figure G-3.2b were sent to the custodians of the 2,912 buildings located on the Base. All forms were returned representing a total of 60,660 panes of glass. Two hundred and sixty-nine cracked panes and 25 broken or missing panes were reported.

Table G-3.1 lists the number of housing and building units, the total number of window panes, and the number of broken and missing panes. A total of 110,390 glass panes was exposed to sonic booms during the test program. Of the eight glass damage complaints received, three appear to be damage that could have been caused by sonic booms produced by aircraft in the test program.

Assuming an average of about 4 persons per residential unit or a total resident population of 10,000 people, there was an average of 11 window panes per person, all buildings on Base, or an average of five panes in residential housing per person. Based on a total of 288 supersonic test flights over the Base during Phase I and II, there was an average of one cracked pane per 10.6 million exposures (total panes on Base) or one cracked pane per 4.77 million exposures of residential glass. It should be realized that Base buildings have been exposed to sonic booms of highly varying frequency and intensity over the past several years.

TABLE G-3.1

TABULATION OF WINDOW GLASS SURVEY

BASE OPERATION BUILDINGS AND FACILITIES

2,912 units
60,660 window panes total
269 cracked panes
25 broken or missing panes

BASE HOUSING (25 percent reported)

2,226 units total determined from base housing plans
49,730 window panes total including glass door
101 cracked panes (404 based on 25% reporting 101 panes)
0 broken or missing panes

COMPLAINTS OF DAMAGE

110,390 total panes of glass
8 broken windows reported to Base Civil Engineer Office

Of the eight complaints of window damage received, three could be attributed to sonic booms, one had been broken for about a year, one was broken by a B-B gun, one location had a new occupant, one was in a vacant house and at one house the investigator was unable to contact anyone.

Several locations were checked that had reported cracked panes in the glass survey made before the test program began. None of the occupants reported observing any change in these panes during the test flights.

HEADQUARTERS, 6510TH AIR BASE GROUP (AFSC)
EDWARDS AIR FORCE BASE, CALIF. 93523

REPLY TO ATTN OF: FTB

SUBJECT: Sonic Boom Testing Program

25 May 1966

TO: All Occupants, Base Housing

1. A sonic boom testing program, as part of the National Sonic Boom Evaluation Program, will be conducted at Edwards Air Force Base. This base was selected for the test site because of its inventory of high performance aircraft, availability of 2300 family housing units, weather conditions, and the already existing Air Force, NASA, and Federal Aviation Agency centers.

2. As part of this program it is necessary to record the type and the condition of the window glass in all the buildings on the base.

3. Please complete the attached form by inserting the correct number or checking the appropriate box. Completed forms must be returned to Base Housing Office (FTBSH) not later than Tuesday, 7 June 1966. Sponsors may return forms by means of the mail and distribution system or deliver them in person.

4. The cooperation of all personnel is solicited.

Donald E. Ewing
DONALD E. EWING
Colonel, USAF
Base Commander

FIGURE G-3.1a

GLASS SURVEY

EDWARDS AIR FORCE BASE HOUSING

Date: May 31, 1966

1. House Number 5372 Lupine Ct.
(Address)

2. Number of Fixed Windows ~~[illegible]~~ 19
(Panes of glass which can not be opened)

3. Number of Movable Windows 12
(Panes of glass which can be opened by sliding or are hinged)

4. Number of Window Panes larger than 20 square feet (4 ft. x 5 ft.)
(Include doors) 2

5. Number of Window Panes that are presently cracked, broken or missing
[✓ 0] 1 2 3 4 5 or ________ (number)
(Circle correct number of window panes)

FIGURE G-3.1

DEPARTMENT OF THE AIR FORCE
HEADQUARTERS, 6510TH AIR BASE GROUP (AFSC)
EDWARDS AIR FORCE BASE, CALIF. 93523

REPLY TO
ATTN OF: FTB

25 May 66

SUBJECT: National Sonic Boom Evaluation Program Glass Survey

TO: All Building Custodians

1. A portion of subject program is soon to be conducted at Edwards Air Force Base. Included in the program is a survey of all window glass on the base; therefore, it is requested that the inclosed form be completed and returned to FTYAA-2 no later than 6 June 1966.

2. A compass orientation, such as N., N.E. or E., etc., should be listed in the proper column and the window panes can then be tallied by their orientation.

3. Under unusual conditions, list the existence of exceptionally large windows (over 100 sq. ft.), wire glass, unusual mounting, etc. These windows should be included in the regular tally. If partitions with glass are located within the building, it should be noted, but not included in the tally.

[illegible] E. EWING
Colonel, USAF
Base Commander

1 Atch
Survey Form

FIGURE G-3.2a

GLASS SURVEY
EDWARDS AIR FORCE BASE
BASE OPERATIONS BUILDINGS

1. Building Number ______________________________

2. Type of Construction ______________________________
(e.g. concrete block, steel frame, metalclad, etc.)

3.

Orientation	0 - 2 Sq. Ft.	2 - 9 Sq. Ft.	9 - 40 Sq. Ft.	Over 40 Sq. Ft.	Remarks
TOTALS					

4. List location of cracked, broken or missing window panes.

5. Comment on unusual conditions.

FIGURE G-3.2b

Annex G

Part II

VIBRATION RESPONSES OF TEST STRUCTURES NO. 1 AND 2 DURING PHASE I OF THE SONIC BOOM EXPERIMENTS AT EDWARDS AIR FORCE BASE

This report is extracted from Langley Working Papers LWP-259 prepared by D. S. Findley, V. Huckel, and H. Hubbard, and LWP-288 prepared by D. S. Findley, V. Huckel, and H. Henderson, of the Langley Research Center of the National Aeronautics and Space Administration.

Annex G

Part II

VIBRATION RESPONSES OF TEST STRUCTURES NO. 1 AND NO. 2 DURING PHASE I OF THE SONIC BOOM EXPERIMENTS AT EDWARDS AIR FORCE BASE

I INTRODUCTION

In order to evaluate reaction of people to sonic booms of varying overpressures and time duration, a series of closely controlled and systematic flight test studies were conducted by the USAF in the vicinity of Edwards, California, from 3 June to 23 June 1966. As a part of these studies and in direct support of them, the NASA has measured the dynamic responses of several building structures. The purpose of this paper is to present in brief summary form the measurements made in a one-story residence structure (Edwards test structure No. 1) and a two-story residence structure (Edwards test structure No. 2).

Included herein are sample acceleration and strain recordings from F-104, B-58, and XB-70 sonic-boom exposures, along with tabulations of the maximum acceleration and strain values measured for each one of about 140 flight tests. These data are compared with similar mersurements for engine noise exposures of the building during simulated landing approaches and takeoffs of KC-135 aircraft.

Description of the test conditions, aircraft, aircraft positioning, weather observations, test structures, and instrumentation are presented in Annex A.

II RESULTS AND DISCUSSION

A. Inputs to the Structures

One of the main objectives of the test studies was to evaluate the responses of the structure to sonic boom inputs of varying wave lengths.

In order to accomplish this, controlled flight tests were performed using F-104, B-58, and XB-70 aircraft. Sample sonic boom waveforms as measured from these aircraft are illustrated in Fig. 1. The main differences in the sonic boom signatures from the above three aircraft were in the time durations of the waves. The F-104 aircraft produced a signature having a time duration generally less than 0.1 sec. The B-58 signature had a time duration of about 0.2 sec, and the XB-70 produced a time duration as long as 0.3 sec. The experiments were obtained in such a way that the overpressure ΔP was comparable for the various aircraft.

In addition to the sonic boom inputs a series of flight tests were conducted with the KC-135 airplane in order to simulate both takeoff and landing noise conditions. During these latter noise flights, similar building response measurements were made for direct comparison with the sonic-boom-induced responses.

The average ΔP_o, Δt, and vertical wave angle values have been measured and these are included in Langley Working Papers LWP-259 and LWP-288. The noise level conditions outside the building for the KC-135 aircraft flight conditions, and the associated building response data are also reported in LWP-259.

B. Building Vibration Responses

1. House No. 1

For each data flight, acceleration levels were measured at 9 points in test structure No. 1 and strain levels were measured at 3 points as described in Table I; the results are given in Table II. A quantitative picture of the type of time history records obtained during the sonic boom exposure flights is given by the tracings of sample records in Figs. 2 and 3.

Figure 2 contains tracings of strain time histories recorded during Mission 80 RB for three different windows of house No. 1. The trace of Fig. 2(b) represents a small window having a period of vibration only a fraction of that of the sonic boom wave. The traces of Fig. 2(a) and 2(c), on the other hand, represent windows for which the periods are comparable to that of the sonic boom wave.

Figure 3 includes acceleration time history responses from 8 transducer locations on the building for a B-58 boom exposure (see Mission 18 B). Each of these transient signals last less than 1.0 sec, but they differ widely in their detailed appearance. For instance, the time history illustrated in Fig. 3(a) exhibits a nearly single frequency vibration at about 20 Hz which is believed to be the first natural frequency of the main floor joists. Similar results are given in Figs. 3(b) and 3(c) for other floor locations. The tracings of Figs. 3(f) and 3(g) represent ceiling accelerations and contain some higher frequency content (100-200 Hz) superposed on the lower framing frequencies. The tracings of Figures 3(d), 3(e), and 3(h) exhibit a sizeable contribution at even higher frequencies (several hundred cps) which are superposed on the lower framing or racking mode frequencies respectively.

Included in Figure 4 are tracings of the acceleration responses of the bedroom east wall (Channel 111) due to excitation from sonic booms from three aircraft. The top trace was obtained for an F-104, the middle one for a B-58, and the bottom one for the XB-70. They are generally low frequency responses with higher frequencies of relatively lower amplitude superposed. One distinguishing feature of these records is the high frequency bursts at time intervals corresponding approximately to the rapid compressions of the sonic boom waves of Figure 1.

Similar data are shown for Channel 111 in Figure 5. These traces represent the responses of one portion of the building to sonic booms from different missions of the B-58 aircraft. Here again the high frequency bursts occur at the times of passage of the waves. It can be seen that the records are similar in their gross features but differ markedly in their small details.

The peak acceleration amplitudes as determined from traces such as those of Figures 3, 4, and 5 are plotted as a function of sonic boom overpressure in Figure 6. The acceleration amplitudes are either positive or negative, whichever is the largest, from Channel 111. The sonic boom overpressure value is the average of all ground overpressures measured for that particular flight by the microphone array.

Data are shown in Figure 6 for the F-104, B-58, and XB-70 airplanes. By means of the coding the data obtained from overhead flights can be differentiated from those associated with flights displaced about 5 miles laterally. It can be seen that acceleration amplitudes vary from about 0.10 g to about 0.7 g and that despite considerable scatter there is a general trend of increased acceleration level with increased overpressure. The closed symbol data points seem to be in good agreement with the open symbol points. There is thus the suggestion that the possible differences in wave angle and rise time due to the offset distance were not significant with regard to this particular measurement of building response. As noted in Reference 1, the F-104 induced accelerations tend to be somewhat higher in amplitude than those of the B-58 for given overpressure values.

Although no samples of the noise induced structural responses and inside acoustic measurement traces are included herein, the maximum values have been determined from the records and are tabulated in Langley Working Paper 259. In general the same qualitative results were obtained as are illustrated in Reference 2.

2. House No. 2

For each data flight, accelerative levels were measured at 11 points in test structure No. 2 as described in Table III; the results are given in Table IV. A quantitative picture of the type of time history records obtained during the sonic boom exposure flights is given by the tracings of sample records in Figures 7, 8, and 9.

Figure 7 includes acceleration time history responses from four transducer locations on the building for a B-58 sonic boom exposure see Mission 27A . Each of these transient signals last approximately 0.7 second, but they differ widely in their detailed appearance. For instance, the time history illustrated in Figure 7 a exhibits a nearly single frequency vibration at about 20 cps which is believed to be the first natural frequency of the main floor joists. The traces of

Figures 7(b) and 7(c) represent accelerations of the ceiling joists of the bedroom and of the downstairs wall studs respectively. It can be seen that superposed on the main framing frequencies are higher frequencies which happen to be in the audible frequency range. The trace of Figure 7(d) represents the accelerations of the frame of the house as measured on the outside surface at the second story floor line. Here also is a case where audible frequency noise is superposed on a much lower frequency component. This low frequency component of relatively low amplitude is believed to be the racking frequency of the house.

Figure 8 contains tracings of strain time histories recorded during the same flight tests as the acceleration traces of Figure 7. Figure 8(a) represents the strain response of a 7 ft. x 12 ft. plate glass window whereas the trace of Figure 8(b) represents the strain time history of a pane of glass with an area of one square foot in one of the upstairs double hung windows. The large plate glass window had a natural period of about 0.25 second which is somewhat longer than the period of the B-58 sonic boom wave. The response results are very similar to those obtained in Reference 1 for the case where the period of the sonic boom signature is less than the period of the structure. The natural frequency of the small pane of glass is very much higher, and its period is only a fraction of the B-58 wave. The result is characteristic of that obtained in Reference 1 for the response of the single degree of freedom system for the case where the period of the N-wave is several times as long as the period of the structure.

For direct comparison with the sonic boom induced response described above, some special experiments were performed to measure similar response data for the case where the building structure is excited by noise from the engines of an aircraft flying overhead. A sample pair of response records are shown for purposes of illustration in Figure 9. Figure 9(a) represents the tracing of a B-58 sonic boom induced building response for Mission No. 75A. The tracing of Figure 9(b on the other hand represents the same transducer at the same gain setting for the engine noise situation during aircraft flyover. It can be seen in the sonic boom case that high frequency responses are superposed on lower frequency response modes. In the case of the engine noise the low frequency modes are not excited and the high frequencies dominate. It should be noted that the response to the sonic boom is a transient having about 0.5 to 1.0 second time duration whereas the engine noise induced vibrations are detectable for a time interval from 10 to 20 seconds. The dominant noise induced responses occur at about 150 to 200 Hz and are believed to be associated with the vibration of wall panels between the vertical studs. This same frequency is also detectable on the comparable sonic boom induced response records but is of a relatively low amplitude.

This latter result can be illustrated further with the aid of the acceleration response record tracings of Figure 10. These time history data are comparable with the record of Figure 9(a) and represent three different test runs as indicated in the figure. The top trace was obtained for an F-104, the middle one for a B-58 mission different than for Figure 9(a), and the bottom one for the XB-70. Note that all are generally low frequency responses with higher frequencies of relatively lower amplitude superposed. One distinguishing feature of these records is the high amplitude bursts at time intervals corresponding approximately to the rapid compressions of the sonic boom waves of Figure 1. In the case of the XB-70 the acceleration response to the bow wave nearly dies out before the tail wave arrives. Two separate responses can also be observed for the B-58 whereas they are not so obvious for the shorter time duration signature of the F-104.

The peak acceleration amplitudes as determined from traces such as those illustrated in Figure 10 are plotted as a function of sonic boom overpressure in Figure 11. The acceleration amplitudes are either positive or negative whichever is the largest from acceleration channel 311. It should be noted that channel 311 relates to an accelerometer mounted on one of the studs near the center of the dining room east wall. The sonic boom overpressure value is the average of all ground overpressures measured for that particular flight by the microphone array.

Data are shown in Figure 11 for the F-104, B-58, and the XB-70 airplanes. The largest number of data points are for the B-58 aircraft.

and these are noted to scatter widely for given values of sonic boom overpressure. Corresponding data for the B-104 airplane also exhibit scatter but seem to have generally higher acceleration amplitudes than the B-58 for given overpressure values. The limited data for the XB-70 fall generally within the range of the B-58 data. Although there is a general trend of increased peaked acceleration amplitudes with an increase in sonic boom overpressure, this trend is not well defined by the data points. A result such as this suggests that the wall acceleration response may be a function of parameters other than sonic boom overpressure and these are not properly accounted for in the figure.

A plot of peak strain amplitudes (either positive or negative) as a function of overpressure values are plotted in Figure 12 for the three different aircraft of the tests. The peak strain values were measured by channel 312 which represents a strain gage located at the quarter point of the diagonal of the large plate glass window in the front of the garage. The sensitive axis of the strain gage was perpendicular to the diagonal line of the window. It can be seen from the figure that a wide range of strain levels were measured for given sonic boom overpressure values. Although generally higher strain values are associated with higher overpressures, the data points do not define a clear trend nor are there differences according to aircraft size.

CONCLUDING REMARKS

Various acceleration and strain responses of a one-story residence and a two-story residence structure were measured for sonic boom exposures from F-104, B-58 and XB-70 airplanes and for engine noises during low altitude flyovers of a KC-135 airplane. The sonic boom induced vibration responses were generally less than one second in duration and contained frequencies associated with both primary and secondary structural components. Wall acceleration amplitudes increased generally as a function of the sonic boom overpressure, and the F-104 seemed to induce the largest amplitudes for a given overpressure. Strains in a large window also increased generally as overpressure increased with no particular trend as a function of airplane size. Considerable variation in peak response amplitudes is noted for the same nominal flight conditions. Engine noise induced vibration responses have durations of 10 to 20 seconds, and the dominant frequencies are those of the secondary structural components. The acoustic pressures inside the rooms of the structure had frequency contents very similar to those of the corresponding wall vibration responses.

REFERENCE

1. Mayes, William H.; and Newman, James W., Jr.: An Analytical Study of the Response of a Single-Degree-of-Freedom System to Sonic-Boom-Type Loadings, LWP No. 154, February 1966.
2. Findley, Donald S.; Huckel, Vera; and Hubbard, Harvey H.: Vibration Responses of Test Structure No. 2 During the Edwards Air Force Base Phase of the National Sonic Boom Program, LWP No. 259, August 1966.
3. Findley, Donald S.; Huckel, Vera; and Henderson, Herbert R.: Vibration Responses of Test Structure No. 1 During the Edwards Air Force Base Phase of the National Sonic Boom Program, LWP No. 288, September 1966.

Table I

Edwards Test House No. 1

IDENTIFICATION, TYPE, LOCATION AND DESCRIPTION OF THE VARIOUS VIBRATION RESPONSE AND PRESSURE TRANSDUCERS FOR WHICH DATA ARE INCLUDED (LWP-288)

Item	Channel No.	Type	Date	Location	Description
A	101	Accelerometer	6/3-6/23	Center of Living Room Floor	Mounted on Concrete Block Sensitive Axis Vertical
B	102	Accelerometer	6/3-6/23	Center of Family Room Floor	Mounted on Concrete Block Sensitive Axis Vertical
C	103	Accelerometer	6/3-6/23	Center of Bedroom No. 1 Floor	Mounted on Concrete Block Sensitive Axis Vertical
D	104	Accelerometer	6/3-6/14	Non Operational	
			6/15-6/20	Outside Between S. and W. Arms of Cruciform Array, On Ground	Mounted on Concrete Block Sensitive Axis Vertical
			6/21-6/23	In House No. 2, Center of Family Room Floor	Mounted on Concrete Block Sensitive Axis Vertical
E	105	Accelerometer	6/3-6/23	Outside, E. Wall, N.E. Corner, Roof Line	Mounted on Stud, Sensitive Axis Horizontal
F	106	Accelerometer	6/3-6/23	Outside, N. Wall, N.E. Corner, Roof Line	Mounted on Stud, Sensitive Axis Horizontal
G	107	Accelerometer	6/3-6/5	Non Operational	
			6/6-6/23	Outside, on Concrete Patio	Mounted on Concrete Block Sensitive Axis Horizontal
H	109	Accelerometer	6/3-6/23	Center of Family Room Ceiling	Mounted on Gyp Board Panel Sensitive Axis Vertical
I	110	Accelerometer	6/3-6/23	Center of Bedroom No. 1 Ceiling	Mounted on Gyp Board Panel Sensitive Axis Vertical
J	111	Accelerometer	6/3-6/23	Bedroom No. 1, Center of E. Wall	Mounted on Stud Sensitive Axis Horizontal
K	201	Audio Mike	6/3-6/23	Center of Living Room	Shock Suspended, Diaphragm 6 Ft. Above Floor
L	202	Audio Mike	6/3-6/23	Center of Family Room	Shock Suspended, Diaphragm 6 Ft. Above Floor
M	203	Audio Mike	6/3-6/23	Center of Bedroom No. 1	Shock Suspended, Diaphragm 6 Ft. Above Floor
N	205	Audio Mike	6/3-6/5	Outside, 90 Ft. From House No. 1	Mounted 3 Ft. Above Ground, Diaphragm Pointing E., No Wind Screen
			6/6-6/14	Outside, 100 Ft. From House No. 1	Mounted 6 Ft. Above Ground, Diaphragm Pointing N., Wind Screened
			6/15-6/23	House No. 2, Center of Family Room	Shock Suspended, Diaphragm 6 Ft. Above Floor
O	207	Full Range Mike	6/3-6/7	Center of Family Room	Shock Suspended, Diaphragm 6 Ft. Above Floor Pointing Down
			6/8-6/23	Center of Family Room	Shock Suspended, Diaphragm 2 In. Below Ceiling, Pointed Up
P	208	Full Range Mike	6/3-6/7	In Attic Above Center of Family Room	Shock Suspended, Diaphragm 8 In. Above Ceiling Joist, Pointed Up
			6/8-6/23	In Attic Above Center of Family Room	Shock Suspended, Diaphragm 3 In. Above Ceiling Joist, Pointed Up
Q	210	Strain Gage	6/3-6/23	On Stationary Side of Sliding Door in Family Room	Center of Glass, Sensitive Axis Vertical
R	211	Strain Gage	6/3-6/23	Bedroom No. 1, On Stationary Pane of Window in East Wall	Center of Window, Sensitive Axis Vertical
S	212	Strain Gage	6/3-6/23	On Large Window in Garage	Center of Window, Sensitive Axis Horizontal

Table II

SONIC BOOM INDUCED ACCELERATION AND STRAIN RESPONSES OF TEST STRUCTURE NO. 1 FOR A RANGE OF B-58 FLIGHT CONDITIONS

Date	Mission No.	Altitude msl ft.	Mach No.	Lateral Dist. Naut. mi.	Mag. Hdg. deg.	Boom Time Z	Peak Amplitude: Accelerometer Channels g's 101	102	103	104	105	106	107	109	110	111	112	Strain Gage μ, in./in. 210	211	212	ΔP_I lb/ft² 207	208	Cruciform ΔP_O Avg. lb/ft²	Cruciform Δt Avg. sec.	Vert. Wave Angle deg.
6-6-66	39	31,400	1.25	1.61 N	235.0	1600.0	--	--	--	Not in Use	--	--	--	--	--	--	Not in Use	--	--	--	--	--	No Boom	--	--
	70	13,900	1.60	.55 N	245.0	1608.57	.129	-.096	.166		-.098	.106	.020	-.103	.405	-.270		9.64	8.45	18.77	1.04	1.73	2.00	0.183	48.4
	10	31,400	1.48	.20 N	246.0	1618.40	.191	.147	.146		-.156	.191	.035	-.147	--	-.391		14.88	12.23	-31.42	1.41	2.25	3.44	.156	51.2
	71	41,200	1.59	5.00 N	245.3	1630.0	-.191	.077	-.146		.110	.117	.018	.099	.331	-.359		9.43	9.79	-14.11	.69	1.38	1.71	.177	52.1
	11	31,380	1.45	.17 N	246.7	1631.44	--	.155	.141		-.131	.177	.024	.154	—	-.378		12.79	14.01	25.13	1.16	1.99	2.50	.152	50.4
	72	13,920	1.55	1.85 N	244.5	1643.55	.127	.051	-.088		-.042	.062	.020	-.074	-.206	-.025		8.38	5.45	-12.50	.66	1.30	1.99	.171	60.1
	74	32,440	1.30	.72 S	242.5	1701.32	--	-.100	-.168		-.160	.176	.046	-.145	.436	--		13.62	13.34	-23.72	1.25	2.12	3.16	.193	73.0
	14	13,400	1.57	5.00 N	245.0	1711.00	.138	.060	-.097		.068	.074	-.020	.078	.210	-.330		8.38	6.01	-11.54	.58	1.21	1.70	.195	63.1
	75	31,840	1.46	0	248.0	1717.00	--	.145	.165		-.193	.194	.026	-.187	--	--		11.74	13.90	24.83	1.14	2.16	3.18	.156	56.7
	12	13,300	1.53	0	245.0	1724.10	.180	.072	-.128		.084	.065	.007	.072	-.212	.283		8.38	6.01	-12.50	.63	1.25	1.78	.182	--
	73	31,800	1.44	.25 N	247.0	1731.30	--	.138	.170		-.225	.225	.033	.164	--	--		12.37	14.46	26.64	1.19	1.99	3.54	.159	53.2
6-7-66	76 A	31,500	1.48	1.09 S	241.5	1610.10	-.159	-.139	.171		.169	-.253	-.028	-.157	.194	.153							3.27	.163	59.1
	15 B	13,660	1.70	4.95 N	244.5	1623.50	-.216	.098	.182		.122	-.297	-.031	-.189	-.223	-.181							2.01	.171	53.1
	77 B	31,680	1.51	.10 S	241.5	1633.12	.172	-.124	-.158		.163	-.297	.033	.162	-.361	.153							2.91	.156	53.2
	16 B	13,720	1.65	5.42 N	246.5	1640.05	-.186	-.077	.133		.259	--	.028	-.152	-.182	.181							1.63	.171	56.7
	18 A	38,700	1.31	5.23 N	245.5	1711.20	.038	.026	.029		.018	-.032	.017	.025	.029	-.035							No Boom	--	--
	79 A	31,600	1.52	.12 N	241.5	1722.20	-.172	-.103	.137		-.088	-.170	.040	-.140	-.141	.141							2.48	.169	53.0
	19 A	13,340	1.43	4.68 N	252.5	1728.15	-.071	-.041	-.056		-.031	.085	.028	.056	.094	.070							1.44	.211	72.8
	80 A	31,600	1.53	.25 N	241.5	1738.45	.189	-.119	-.161		-.148	-.184	-.038	.130	-.261	-.138							2.72	.156	51.6
	[illegible] A	13,310	1.43	5.00 N	245.5	1747.37	.068	-.041	.051		-.039	-.046	-.019	.051	.059	.093							1.01	.196	72.8
	81 A	31,400	1.49	.06 S	245.0	1756.25	-.087	.051	-.075		.042	.136	.017	.064	-.085	-.091							1.95	.150	53.6
6-8-66	43 A	42,380	1.62	5.24 N	245.0	1600.22	.186	-.072	.148		-.049	-.053	-.014	-.169	-.147	-.267		9.94	5.62	-10.90	.64	1.44	1.70	.175	58.7
	75 A	31,200	1.44	.23 N	244.5	1606.45	-.224	-.171	-.182		-.103	.087	-.072	--	--	.372		12.82	14.31	31.06	1.08	2.02	3.17	.156	50.0
	42 A	43,260	1.67	4.83 N	246.7	1614.50	-.203	-.094	.150		.075	-.085	.018	.220	-.216	-.315		8.95	8.17	-10.90	.62	1.24	2.06	.179	57.9
	73 A	31,200	1.50	.10 N	245.0	1624.20	.186	-.130	-.137		-.089	.074	-.024	.302	-.384	.247		10.90	8.86	27.25	.92	1.82	2.22	.147	52.9
	41 A	43,200	1.60	5.32 N	246.0	1630.10	-.128	-.056	.084		.059	-.081	-.021	-.220	-.342	-.237		8.01	6.81	15.80	.55	1.11	1.92	.166	59.0
	72 A	31,200	1.49	.16 N	245.0	1638.45	.196	-.137	-.159		-.169	.167	-.038	--	--	.385		13.14	14.48	- 3.24	1.01	1.83	2.85	.144	49.0
	57 RB	37,600	1.66	5.90 N	248.5	1705.10	-.103	-.045	.082		-.035	-.031	-.017	-.097	-.096	-.166		8.98	4.09	-10.90	.58	1.24	1.76	.162	52.2
	80 RB	31,300	1.46	.14 N	246.6	1712.30	-.156	-.112	-.137		.148	-.154	.060	-.348	--	.387		10.90	10.05	27.79	1.06	2.09	2.63	.161	60.4
	56 RB	43,010	1.61	5.14 N	244.0	1721.22	-.152	-.072	.105		-.038	-.053	-.006	.107	-.180	.214		8.98	4.77	-10.90	.64	1.31	2.09	.170	55.3
	87 RB	31,440	1.49	.40 N	245.4	1728.30	-.238	-.189	-.162		-.087	-.127	-.029	--	--	--		13.46	11.07	34.88	1.01	1.96	3.23	.148	48.9
	55 RB	43,200	1.64	5.16 N	244.0	1736.10	-.294	-.137	.246		-.101	-.151	-.020	--	--	--		11.54	11.92	22.59	.58	1.14	2.17	.169	58.4
	86 RB	31,360	1.47	0	221.0	1745.00	-.221	-.187	-.168		.232	.166	-.011	--	--	--		13.78	14.99	37.06	1.06	1.83	2.70	.144	48.9

Table II (Continued)

Date	Mission No.	Altitude msl ft.	Mach No.	Lateral Dist. Naut. mi.	Mag. Hdg. deg.	Boom Time Z	Peak Amplitude														Δp_I		Cruciform		Vert. Wave Angle deg.
							Accelerometer channels g's											Strain Gage μ, in./in.			lb/ft²		Δp_0 Avg. lb/ft²	Δt Avg. sec.	
							101	102	103	104	105	106	107	109	110	111	112	210	211	212	207	208			
6-9-66	86 SRB	31,000	1.50	.25 N	246.2	1608.30	.250	-.229	-.223		.390	.216	-.032	-.395	--	.722	Not in Use	15.39	18.87	34.68	1.13	1.92	4.00	.153	51.1
	55 SRB	35,720	1.69	5.17 N	244.5	1619.20	-.111	-.049	.077		-.066	-.072	-.014	-.188	-.207	.168		9.62	6.08	14.86	.53	1.22	1.60	.140	55.5
	87 SRB	31,000	1.53	.08 S	244.0	1625.58	.231	-.177	-.187		-.151	-.157	-.025	-.426	--	-.401		4.75	15.30	32.70	1.08	1.86	3.44	.146	19.2
	56 SRB	43,300	1.72	4.70 N	242.6	1634.50	-.205	-.083	.140		.066	.099	-.059	.298	-.398	.302		9.62	10.27	18.33	.54	1.28	2.77	.161	51.0
	80 SRB	31,000	1.53	.06 N	245.2	1641.40	.146	-.120	-.119		-.140	.162	-.020	.478	--	.420		10.90	11.32	29.23	.97	1.73	2.95	.140	48.0
	57 SRB	43,100	1.70	5.23 N	244.0	1649.10	-.156	-.068	.102		.129	-.151	-.014	.282	-.395	-.228		8.98	7.97	15.85	.47	1.15	1.94	.150	54.3
	41 SA	42,920	1.52	4.87 N	240.0	1707.52	-.121	-.052	.077		-.066	.088	.033	.141	.117	-.173		9.30	5.45	11.89	.73	1.28	2.28	.180	60.4
	73 SA	31,720	1.50	.49 S	243.4	1716.15	-.180	-.185	-.176		.077	.106	-.031	-.382	--	-.354		10.90	11.11	29.23	1.11	1.80	3.03	.155	54.4
	42 SA	43,060	1.32	4.69 N	241.2	1723.52	-.232	-.101	.172		.081	-.110	.024	-.308	-.395	.445		10.26	5.15	15.85	.64	1.41	2.25	.176	63.6
	75 SA	31,680	1.55	0	246.5	1731.23	.201	-.161	.168		.121	-.130	-.039	.329	--	-.385		11.22	10.45	28.24	.99	1.67	3.80	.149	48.4
	43 SA	43,000	1.68	4.62 N	213.5	1739.0	-.146	-.052	.098		.092	-.173	-.032	.211	-.270	-.212		9.62	6.71	16.84	.52	1.22	2.84	.157	51.6
	42 SA	43,300	1.70	4.92 N	241.5	1757.00	-.146	-.062	.095		.044	-.058	.020	.164	-.198	-.181		7.37	8.80	12.88	.64	1.22	1.98	.165	37.1
	46 SA	12,900	1.68	4.74 N	216.0	1811.10	-.135	-.065	.077		.063	-.097	.018	.243	-.354	.243		8.96	7.13	14.37	.59	1.09	2.16	.156	57.7
	72 SA	31,320	1.53	.63 N	218.5	1822.10	-.132	-.094	-.090		.052	-.070	.015	.227	-.321	.185		10.58	7.13	30.72	.92	1.67	2.26	.115	50.0
6-13-66	18 A	37,710	1.64	[illegible]	231.0	1646.13	-.202	-.109	-.132		.160	-.153	-.072	-.188	--	.191		11.92	15.22	20.65	1.05	1.30	2.82	.160	42.2
	18 B	49,600	1.66	.28 S	231.0	1649.22	-.142	.115	-.107		.019	-.076	-.034	-.125	.390	-.128		8.52	9.87	13.19	.84	1.30	2.07	.196	45.7
	21 A	37,810	1.69	.21 S	230.0	1700.16	-.213	-.148	-.157		.207	.168	-.058	-.225	--	.226		12.26	14.40	22.95	1.05	1.42	2.86	.146	44.0
	21 B	49,160	1.72	.35 S	231.3	1702.48	-.147	.122	-.109		.087	-.101	-.036	-.148	.105	.131		8.17	9.46	14.92	.82	1.30	1.88	.195	42.4
	29 A	49,300	1.67	.03 N	232.8	1806.25	-.152	-.104	-.096		-.092	-.145	-.040	.148	.405	.133		7.83	7.81	13.19	.79	1.30	1.87	.195	46.6
	29 B	38,110	1.67	.11 S	232.0	1807.35	-.178	-.106	-.137		.186	.166	-.085	-.175	--	.174		10.90	10.08	22.95	.99	1.42	3.42	.156	45.6
	32 A	49,820	1.64	.53 N	235.0	1820.25	-.161	.090	-.100		.052	.165	-.057	.130	-.369	.131		9.20	6.99	17.21	.75	1.18	1.93	.182	47.3
	32 B	38,000	1.67	0	233.0	1821.10	.196	-.124	-.123		.103	.166	-.055	-.170	--	.153		9.88	9.25	20.08	.90	1.36	2.30	.149	43.4
6-20-66	48 A	41,300	1.55	2.20 N	232.0	1554.50	-.209	-.101	.131		.082	-.152	-.025	.325	-.378	A-11 Transducer in Ch. #112	-.338	13.08	12.37	18.69	.89	.90	2.67	.179	51.8
	79 A	32,100	1.45	1.90 S	232.0	1608.00	-.117	-.106	-.123		-.080	-.082	-.020	-.305	--		.327	8.28	13.83	26.16	1.21	.83	2.46	.153	54.1
	53 A	42,700	1.59	5.00 N	232.0	1618.52	.131	-.066	-.086		-.033	-.046	-.011	.123	-.179		-.189	9.16	6.71	13.08	.71	.60	1.47	.175	53.7
	84 A	31,220	1.43	0	235.6	1627.10	--	.162	-.137		-.106	.098	-.051	.522	--		.109	13.08	17.10	28.65	1.30	1.05	2.58	.144	49.4
	54 A	43,000	1.59	4.87 N	230.4	1635.20	-.133	-.071	.082		-.038	-.076	-.017	.177	-.208		.176	8.28	6.92	12.46	.62	.68	1.47	.164	55.1
	59 B	43,360	1.41	5.00 N	233.2	1710.0	-.214	-.102	.143		.113	-.144	.016	-.285	-.352		.529	12.43	10.48	11.51	1.09	.94	2.34	.218	68.7
	98 R	31,340	1.50	0	233.0	1715.15	-.231	.153	-.155		.195	.170	-.051	.472	--		.534	13.95	16.14	26.78	1.33	1.13	3.04	.154	50.5
	90 B	31,800	1.55	.17 S	230.5	1732.0	-.186	.142	-.146		-.127	-.151	-.034	.463	--		.487	13.08	13.83	28.65	1.21	1.02	2.80	.115	52.2
	85 A	32,320	1.45	4.35 N	231.4	1740.0	--	--	--		--	--	--	--	--		--	13.95	9.85	23.67	.77	.87	2.39	.143	60.1
	93 B	32,140	1.55	.17 S	231.4	1747.52	-.214	-.135	-.162		-.094	-.101	-.069	.374	--		-.338	13.52	13.83	30.52	1.24	1.05	2.90	.141	52.2

Table II (Continued)

Date	Mission No.	Altitude msl ft.	Mach. No.	Lateral Dist. Naut. mi.	Mag. Hdg. deg.	Boom Time Z	Peak Amplitude															Δp_I lb/ft²		Cruciform		Vert. Wave Angle deg.
							Accelerometer Channels g's											Strain Gage –, in./in.					Δp_0 Avg. lb/ft²	Δt Avg. sec.	
							101	102	103	104	105	106	107	109	110	111	112	210	211	212	207	208			
6-21-66	59 C	31,760	1.16	.12 N	232.0	1601.55	--	.142	-.155	In House #2	.213	.193	.054	.249	--	A-11 Transducer--In Channel #112 on those days	.300	14.99	10.90	26.64	0.98	2.08	2.81	.151	49.2
	58 B	43,600	1.67	5.12 N	232.6	1611.02	.154	-.086	.111		-.032	-.059	.0095	.148	-.171		-.206	8.17	6.26	-13.32	.51	1.15	1.95	.175	53.3
	99 B	31,700	1.17	.17 N	233.0	1617.05	--	.160	-.175		.191	.169	.049	.123	--		--	16.35	18.17	-26.64	1.91	2.00	3.22	.145	57.0
	66 B	39,860	1.59	5.00 N	233.0	1625.17	.114	-.053	.070		-.028	-.024	-.020	.064	-.123		-.121	7.49	4.44	9.69	.49	.92	1.22	.137	59.0
	100 B	31,760	1.16	.14 S	231.8	1630.23	.191	.093	-.107		.103	-.122	-.021	.290	--		.243	12.60	9.69	-23.01	.88	1.77	3.03	.146	49.2
	68 B	41,080	1.62	4.83 N	232.0	1639.49	.133	.067	.086		.074	-.132	-.020	.157	-.218		.160	6.81	5.85	-9.69	.47	.92	1.51	.167	54.5
	69 B	39,440	1.39	5.00 N	232.8	1729.35	-.157	-.075	.109		.053	.169	-.0095	-.241	-.179		.257	10.56	5.45	-13.93	.64	1.35	1.65	.186	72.0
	18 A	43,140	1.60	5.00 N	231.6	1744.12	.159	-.082	.105		-.037	-.097	-.011	.172	-.282		.223	10.22	5.65	-12.11	.69	1.31	1.51	.177	62.8
	40 A	43,840	1.65	5.40 N	235.0	1756.55	.141	-.069	.100		-.058	-.106	.024	.187	-.276		.227	9.20	6.06	-11.51	.54	1.15	1.88	.171	57.1
	60 B	43,940	1.64	5.16 N	233.2	1808.59	.141	-.058	.091		-.039	-.094	.021	.128	-.123		.160	7.83	4.04	12.11	.49	1.04	1.73	.165	58.9
	61 B	43,260	1.62	4.76 N	232.5	1937.19	.093	-.053	.052		.045	.169	.029	.084	-.085		-.185	9.54	3.83	-14.53	.59	1.35	2.49	.181	59.0
	101 B	31,700	1.50	0	232.8	1951.15	--	.106	.141		.096	.147	-.019	.344	-.388		.267	13.62	9.49	-24.22	.91	1.92	2.67	.148	52.2
	85 A	31,700	1.50	.22 N	233.7	2005.50	--	.140	-.161		-.109	-.153	-.017	-.433	--		.298	14.31	9.49	21.80	.83	1.65	2.84	.146	50.9
6-22-66	28 A	37,000	1.63	.18 N	234.5	1613.27	.187	.126	-.143		-.276	.262	-.024	-.518	1.25		--	14.11	17.82	22.75	1.01	1.76	2.66	.162	50.5
	19 A	37,200	1.64	.24 N	233.5	1628.15	.125	.073	-.093		.068	-.091	-.023	.267	.433		.235	9.94	8.65	18.48	.77	1.53	2.06	.154	47.7
	6 X	43,569	1.60	1.31 S	259.0	1648.24	-.135	-.146	.197		-.106	.126	.010	.326	.621		--	7.69	10.03	25.59	.94	1.42	3.44	.167	50.9
	30 A	37,400	1.65	.20 S	229.8	1743.34	-.132	-.073	-.093		-.064	.102	-.019	-.237	.357		-.234	11.86	5.88	-21.33	.86	1.59	2.04	.163	47.5
	34 B	43,100	1.61	4.00 N	230.0	1757.06	-.104	.053	.061		.038	.063	.018	.163	.235		-.141	6.73	3.81	-9.48	.58	.90	1.48	.169	56.2
	24 A	43,300	1.60	5.06 N	233.0	1810.37	-.128	-.060	.072		.053	-.041	.010	.148	.179		-.164	8.66	4.50	12.32	.58	1.07	1.44	--	--
	35 A	43,400	1.60	.92 S	225.3	1821.21	-.083	-.043	.061		-.026	-.039	-.0055	.104	-.113		-.110	7.05	2.77	9.48	.45	.88	1.15	.165	--
	25 B	43,220	1.59	4.89 N	233.0	1837.59	.156	-.066	.136		-.045	.076	-.017	.222	-.207		-.237	8.01	5.36	10.43	.55	1.08	1.42	.179	56.4
	23 B	37,440	1.63	.50 N	232.5	1852.05	.156	-.096	-.118		.076	-.089	-.017	.281	-.433		.239	11.22	7.96	18.96	.79	1.50	2.31	.157	48.0
6-23-66	17 A	37,600	1.64	.39 N	231.5	1546.08	-.165	-.100	-.111		.121	.219	-.026	-.370	.461		.240	10.90	10.55	27.25	.78	1.62	2.40	.162	46.1
	22 B	43,360	1.67	4.25 N	229.2	1600.40	-.162	-.086	.097		.044	.067	.0082	.420	.273		-.184	8.52	6.86	14.99	.52	1.13	1.63	.168	52.8
	31 A	37,480	1.64	.12 N	231.0	1612.14	-.155	-.093	-.108		-.085	.080	.015	.370	-.517		.239	10.56	10.55	23.84	.74	1.43	1.98	.155	47.3
	33 A	43,200	1.64	5.02 N	231.6	1621.38	-.137	-.070	.086		-.044	-.057	-.0055	.168	-.160		.149	8.86	5.45	14.99	.43	1.02	1.25	.163	59.0
	20 B	37,400	1.65	.10 N	232.6	1954.17	-.229	-.153	-.136		.125	-.189	-.035	.538	-.706		--	11.58	11.95	25.89	.83	1.66	2.09	.159	47.7
	36 B	37,400	1.66	.25 S	231.0	2006.26	-.243	-.136	.176		-.114	-.159	-.077	-.370	-.555		--	13.28	8.26	32.70	.97	1.81	5.50	.160	49.4
	6 X-2	43,520	1.67	9.86 N	258.0	2021.21	-.179	-.086	.122		-.044	-.082	-.025	-.202	-.216		--	8.86	5.27	23.16	.57	1.43	1.79	.165	--

Best Available Copy

Table II (Continued)

SONIC BOOM INDUCED ACCELERATION AND STRAIN RESPONSES OF TEST STRUCTURE NO. 1 FOR A RANGE OF F-104 FLIGHT CONDITIONS

Date	Mission No.	Altitude msl ft	Mach No.	Lateral Dist. Naut. mi.	Mag. Hdg. deg.	Boom Time	Peak Amplitude														ΔPI lb/ft²		Cruciform		Vert. Wave Angle deg.
							Accelerometer Channels g's											Strain Gage μ in./in.					ΔPo Avg. lb/ft²	Δt Avg. sec.	
							101	102	103	104	105	106	107	109	110	111	112	210	211	212	207	208			
6-1-66	11	35,400	1.7	--	--		-.170	.108	.101		-.066	-.057	--	--	--	--	Channel 112 interchanged with Channel 111	7.63	6.00	-6.61	.38	.81	1.19	.087	--
6-13-66	26 A	21,200	1.4	.09 S	232.5	1712.35	-.192	.121	--		.071	-.110	-.015	.213	--	-.159		9.88	8.23	9.18	.45	.83	1.87	.071	50.8
	26 B	29,640	1.6	.64 S	--	1713.45	--	--	--		--	--	--	--	-	--		--	--	--	--	--	--	--	--
6-14-66	36 A	--	--	--	--	1608.0	-.155	-.156	-.120		.093	.091	.018	.452	.397	-.306		6.81	10.28	-12.11	.54	.97	2.08	.072	--
	36 B	29,920	1.51	.10 S	238.0	1610.50	-.145	-.081	-.110		-.067	-.087	.013	.193	.621	-.251		9.54	7.61	-13.93	.47	.72	1.56	.079	46.6
	38 A	--	--	--	--	1745.00	-.198	.125	-.120		.094	-.156	.032	.138	.222	-.302		11.58	7.40	11.51	.44	.84	2.02	.071	--
	38 B	29,700	1.32	0	232.6	1745.45	-.118	.070	-.083		-.041	-.015	.017	--	--	--		8.86	4.52	10.29	.44	.66	1.52	.079	19.1
	37 A	29,700	1.49	0	231.2	1757.10	-.162	.106	-.093		-.055	-.079	.033	.264	.225	-.306		9.54	5.76	-9.69	.38	.78	1.39	.079	18.7
	37 B	21,000	1.39	.02 S	211.0	175[illegible].40	-.211	.171	-.119		--	-.188	.035	.581	.406	-.383		11.58	10.28	11.51	.49	1.21	2.77	.075	53.2
6-15-66	1X A	14,000	1.21	.47 S	236.0	1614.50	-.278	.210	.207	-.0271	.183	.171	-.052	-.617	--	-.557		16.17	15.84	15.14	.59	1.26	3.75	.079	62.1
	1X B	28,140	1.20	.13 S	233.0	1616.40	-.108	.079	-.073	-.0108	-.054	-.089	-.039	-.206	-.306	.192		-7.27	5.96	8.48	.40	.53	1.51	.079	18.1
	2X A	29,700	1.32	.66 S	237.0	1621.80	.194	-.111	-.123	-.0076	-.078	.071	.0097	-.270	.294	.250		-7.60	6.58	10.90	.50	.82	1.74	.092	63.5
	2X B	14,000	1.20	.22 S	233.0	1622.10	--	-.216	.264	.0210	.157	-.151	-.043	.505	--	.615		22.15	18.51	18.77	.69	1.56	1.36	.079	62.0
	3X A	29,100	1.38	.17 S	231.0	1638.25	-.092	.065	-.059	-.0098	-.024	.081	-.012	.206	.259	.192		-5.95	3.91	-6.06	.32	.47	1.31	.075	51.5
	3X B	14,200	1.15	.18 S	225.0	1639.55	-.223	.135	.120	-.0260	-.054	-.154	-.031	.421	--	.801		13.01	9.67	13.93	.57	1.03	2.25	.077	63.1
	4X A	14,000	1.28	.18 S	235.0	1647.15	-.278	-.159	.159	.0173	.202	.170	-.060	.603	--	.557		15.12	13.78	12.72	.55	1.17	3.36	.067	55.0
	4X B	29,680	1.62	.11 S	233.5	1648.20	-.190	-.151	-.132	-.0098	-.085	-.080	-.019	-.802	--	-.375		14.12	9.05	14.53	.48	.82	2.58	.077	45.6
6-16-66	27 A	29,800	1.65	.10 S	230.3	1556.25	-.117	.113	.118	-.0151	-.096	-.115	-.024	.356	--	-.134		8.17	8.23	-9.69	.34	.61	1.51	.075	13.1
	27 B	20,540	1.80	.26 S	228.5	1557.30	-.156	-.092	.100	-.0154	.105	.113	-.029	.288	-.345	.134		-7.83	9.46	-10.90	.40	.76	1.73	.073	51.1
	58	29,700	1.63	.23 E	341.0	1801.25	-.107	.124	-.173	-.0166	-.045	-.075	.0055	-.591	--	.139		-4.43	-5.35	-18.17	.38	.73	1.78	.071	41.8
6-22-66	20 B	20,820	1.38	.16 S	233.0	1613.43	-.233	.166	-.158	In House #2	.197	-.241	-.053	.563	-.903		--	11.86	13.15	-18.48	.58	1.25	2.60	.078	50.1
	19 B	29,500	1.42	.20 S	213.5	1630.05	.181	.180	.104		-.121	.100	.071	.252	-.433		-.201	10.26	-7.17	18.01	.48	.71	1.87	.088	52.8
	30 B	29,720	1.37	.16 S	237.5	1740.38	.056	.037	-.013		.038	-.013	.0092	.133	.160		-.107	-5.77	3.11	-10.90	.38	.60	.97	.092	62.0
	31 B	29,400*	1.39	--	232.8	1757.06	.119	.080	.082		-.068	-.056	.015	.296	.320		.209	-7.05	-4.83	12.80	.38	.65	1.14	.091	--
	21 B	20,880	1.36	.23 S	231.3	1811.26	.167	.136	-.115		-.159	-.158	-.059	.533	-.696		.242	9.62	10.21	-16.11	.46	.99	2.10	.078	55.0
	35 B	21,040	1.28	.25 S	225.3	1822.47	-.201	.153	.133		-.117	-.115	-.028	.341	-.564		.235	-9.62	6.57	-11.22	.43	.92	2.41	.082	59.5
	25 A	21,900	1.39	.21 S	233.0	1836.39	-.191	.180	-.104		-.163	-.137	.015	.489	-.527		--	9.30	7.44	-11.37	.43	.86	1.47	.075	54.1
	23 A	29,720	1.51	.34 S	237.0	1850.21	.153	.096	-.079		-.045	-.065	-.020	-.193	-.263		-.151	-7.69	4.84	-10.90	.53	.71	1.43	.083	--
6-23-66	17 D	41,000	1.80	.46 S	227.5	1548.00	-.162	.103	.100		-.063	-.059	-.017	.302	-.339		-.232	10.22	7.03	-11.30	.45	.79	1.88	.076	19.3
	22 A	29,200	1.80	0	232.0	1559.59	-.151	.088	.090		-.066	-.087	-.012	.235	-.395		.188	-8.17	-6.98	-9.69	.15	.75	1.61	.082	51.1
	31 B	21,240	1.39	0	232.0	1612.21	-.172	.098	.101		-.077	.059	-.014	.336	-.180		-.231	10.90	8.44	-8.88	.43	.79	2.18	.076	19.6
	33 B	29,840	1.19	.10 S	229.8	1622.04	.281	.153	-.122		-.114	-.109	-.035	.554	-1.02		--	13.62	9.84	18.39	.45	.90	1.82	.084	19.7
	20 A	21,520	1.37	.19 S	233.2	1951.20	-.253	.171	.129		-.121	-.165	.016	-.154	.687		--	14.31	7.91	18.39	.48	.98	1.88	.079	55.2
	36 A	20,860	1.39	.37 S	230.2	2005.15	-.232	.179	.125		-.136	-.132	-.024	.538	-.564		--	10.90	7.56	14.99	.45	.98	2.09	.077	53.3
	7X	29,440	1.55	.29 S	257.6	2018.18	-.111	-.103	.125		.074	.083	.014	-.252	.339		--	7.57	5.63	33.70	.59	.98	2.03	.081	--

* Alt: Mach No. at 12 Naut. mi. E.

Table II (Continued)

SONIC BOOM INDUCED ACCELERATION AND STRAIN RESPONSES OF TEST STRUCTURE NO. 1 FOR A RANGE OF XB-70 FLIGHT CONDITIONS

Date	Mission No.	Altitude msl ft.	Mach No.	Lateral Dist. Naut. mi.	Mag. Hdg. deg.	Boom Time Z	Peak Amplitude															Δp_1 lb/ft^2		Δp_0 Avg. lb/ft^2	Δt Avg. sec.	Vert. Wave Angle deg.
							Accelerometer Channels g's											Strain Gage μ, in./in.							
							101	102	103	104	105	106	107	109	110	111	112	210	211	212	207	208			
6-4-66	13	32,920	1.81	2.5	243.0	1728.00	-.256	-.119	.200		-.127	.174		--	--	--		15.26	11.58	-9.25	1.33	2.75	2.52	.250	42.8
6-8-66	22	72,000	2.83	4.10 N	262.0	1726.00	-.129	.094	.101		.072	-.038	.013	.137	-.362	-.193		7.97	4.78	15.75	1.05	1.30	1.64	.3175	--
6-8-66	1	31,850	1.38	5.02 S	246.0	1519.00	.159	-.049	-.127		.038	.034	-.014	-.128	-.102	.199		11.54	5.11	-14.71	.99	1.83	2.27	.233	81.8

Table II (Continued)

Date	Mission No.	Altitude msl ft.	EPR	Velocity Kts.	Maximum Peak Amplitude													Noise Levels, dB			
					Accelerometer Channels g's										Strain Gage —, in./in.			RMS Out-side	Peak Inside		
					101	102	103	104	105	106	107	109	110	111	210	211	212	205	201	202	203
6-6-66	39 B	10,300	1.6	310	--	--	--	Not in Use	--	--	--	--	--	--	--	--	--	--	--	--	--
	70 B	5,800	1.5	260	.001	.003	.009		.009	.007	.006	.006	.016	.012	.123	.266	0	84.8	114.6	118.1	128.6
	40 B	5,400	1.5	280	.001	.005	.007		.010	.008	.006	.006	.013	.020	.123	.266	0	84.8	114.6	118.1	111.1
	71 B	3,300	1.5	270	.009	.007	.008		.015	.032	.008	.012	.042	.025	.529	.523	0	102.9	120.6	122.5	123.7
	11 B	3,300	1.5	238	.009	.037	.008		.018	.037	.008	.011	.050	.022	.123	.372	0	101.1	121.6	120.6	117.7
	72 B	2,800	1.5	290	.009	.009	.009		.028	.048	.010	.020	.083	.016	.633	.711	0	108.9	125.5	127.6	129.1
	13 B	11,300	2.35	325	--	--	--		--	--	--	--	--	--	--	--	--	--	--	--	--
	71 B	8,300	2.35	328	.007	.005	.006		.008	.007	.007	.007	.011	.018	.123	.319	0	105.7	127.6	121.6	119.0
	41 B	8,300	2.35	330	.011	.009	.009		.051	.065	.018	.030	.165	.087	.529	2.12	.779	111.1	128.6	130.4	133.0
	75 B	3,300	2.35	213	.030	.022	.024		.295	--	.032	.135	--	--	1.06	5.95	1.09	--	139.8	140.6	113.5
	42 B	2,800	2.35	213.	.061	.049	.051		--	--	.132	--	--	--	.817	--	1.09	--	--	--	--
	73 B	2,320	2.35	213	.016	.005	.009		.032	.018	.011	.021	.083	.012	.529	1.06	.779	106.9	124.1	127.6	130.4
6-7-66	76 B	1,360	2.35	190	.009	.011	.011		.081	.071	.011	.096	.110	.117				106.9			
	15 A	3,000	2.35	193	.026	.028	.024		--	--	--	.233	.311	.171				114.8			
	77 A	3,000	2.35	190	.027	.022	.024		.143	.142	.036	.216	.317	.202				115.1			
	46 A	2,620	2.35	190	.019	.018	.022		.015	.070	.035	.185	.313	.155				116.2			
	48 B	3,000	2.35	205	.035	.031	.029		.100	.117	.028	.148	.270	.322				111.5			
	79 B	2,620	2.35	195	.059	.059	.058		.311	.239	.061	.132	.716	.477				--			
	49 E	4,300	2.35	195	.009	.010	.069		.062	.051	.021	.070	.111	.091				110.4			
	80 B	3,000	2.35	190	.044	.041	.032		.146	.099	.083	.161	.285	.236				115.6			
	50 B	8,300	2.35	200	.007	.006	.007		.014	.012	.001	.011	.026	.014				--			
	81 B	1,300	2.35	195	.013	.013	.010		.046	.040	.011	.068	.101	.081				106.2			
6-8-66	13 B	11,300	2.35	182	--	--	--		--	--	--	--	--	--	--	--	--	--	--	--	--
	75 B	8,300	2.35	168	.0093	.0015	.011		.011	.0095	.0072	.023	.030	.018	.611	.511	1.09	101.0	115.0	116.5	118.0
	12 B	2,800	1.5	160	.011	.011	.011		.033	.033	.011	.079	.120	.063	.962	2.38	1.63	108.5	120.1	120.9	121.6
	73 B	2,552	1.5	175	.021	.027	.020		.068	.081	.011	.212	.357	.166	1.28	5.11	1.63	111.6	126.1	127.7	131.2
	11 B	5,300	1.5	157	.012	.0015	.011		.0070	.0071	.0095	.013	.021	.018	.611	.511	1.09	97.7	116.5	114.9	118.0
	72 B	2,800	1.5	171	.011	.011	.0091		.026	.012	.011	.071	.120	.060	.962	1.70	1.09	107.8	120.1	119.0	123.3
	57 RA	3,300	1.5	166	.012	.011	.023		.014	.018	.0072	.033	.015	.033	.611	1.19	1.63	100.4	117.9	119.0	118.0
	80 RA	2,800	1.5	169	.026	.011	.011		.031	.010	.013	.072	.099	.058	.611	1.53	1.63	106.7	120.1	119.0	123.3
	56 RA	5,300	1.5	155	.0093	.013	.0091		.0070	.0083	.0060	.018	.021	.010	.611	.511	1.09	97.7	113.0	116.5	116.6
	87 RA	3,300	1.5	166	.0093	.034	.011		.016	.021	.0072	.011	.057	.028	.962	1.19	1.63	102.9	117.9	121.7	119.1
	55 RA	10,300	1.5	146	.0070	.0090	.0091		.012	.011	.0081	.028	.015	.025	.962	.311	1.09	92.3	113.0	111.9	119.1
	86 RA	5,300	1.5	176	.0070	.0067	.011		.0070	.0071	.0060	.013	.018	.013	.611	.681	1.63	96.9	115.0	116.5	127.1

Table II Concluded

[illegible]	[illegible]	[illegible]	[illegible]	Velocity Kts.	Maximum Peak Amplitude													Noise Levels, dB			
					Accelerometer Channels g's										Strain Gage μ, in./in.			RMS Outside	Peak Inside		
					101	102	103	104	105	106	107	108	110	111	210	211	213	205	201	202	203
[illegible]	[illegible]	[illegible]	[illegible]	171	0	[illegible]	0		.022	[illegible]	0	.030	.021	.016	.962	.321	1.56	91.1	130.8	130.5	127.1
	[illegible]	[illegible]	1.[illegible]	225	0	.0052	0		.011		0	.023	.012	0	.962	.321	1.56	91.1	130.8	126.9	131.[illegible]
	[illegible]	[illegible]	[illegible]	196	.016	.0078	.011		[illegible]	[illegible]	0	.023	.040	.016	.801	.838	1.30	92.8	132.1	130.5	131.0
	[illegible]	[illegible]	[illegible]		.0049	.0052	.015		0	.0090	0	.023	.027	.021	.801	.731	1.30	100.1	127.3	126.9	143.0
	[illegible]	[illegible]	1.[illegible]	73	.011	.013	.011		.011	.030	.014	.008	.135	.073	.801	1.20	1.30	98.8	130.8	134.9	133.4
	[illegible]	[illegible]	1.[illegible]	0	.016	.0078	.011		.015	.029	0	.030	.012	.021	.801	.838	1.56	96.3	127.3	130.5	131.0
	[illegible]	[illegible]	1.[illegible]	172	--	--	--		--	--	--	--	--	--	--	--	--	--	--	--	--
	[illegible]	[illegible]	1.[illegible]	152	.0049	.0052	.011		0	.0080	0	.023	.016	.016	.041	.629	1.01	92.8	127.3	137.8	127.1
	[illegible]	[illegible]	1.[illegible]		.002	.020	.018		.071	.120	.020	.152	.273	.162	.962	1.15	1.82	103.2	133.3	137.8	135.1
	[illegible]	[illegible]	1.[illegible]	188	.014	.011	.011		.011	.126	.013	.063	.156	.065	.962	2.31	1.82	105.2	133.3	131.9	137.0
	[illegible]	[illegible]	[illegible]	162	.016	.0078	.011		0	.014	0	.030	.027	.024	.041	.321	1.56	96.3	129.2	126.9	133.1
	[illegible]	[illegible]	2.[illegible]	115	--	--	--		--	--	--	--	--	--	--	--	--	--	--	--	--
	[illegible]	[illegible]	1.[illegible]	162	.011	.013	.011		.030	.065	.011	.063	.135	.065	.801	1.15	1.56	99.5	130.8	134.9	133.1
	[illegible]	[illegible]	2.35	172	.024	.018	.021		.201	.901	.049	.288	--	.319	1.12	8.07	1.82	117.8	112.8	111.1	117.8
	[illegible]	[illegible]	1.5	161	.021	.011	.011		.012	.065	.0051	.068	.090	.019	.041	1.89	1.56	102.8	133.3	139.0	117.0
														Ch.112				Ch.204			
[illegible]	[illegible]	[illegible]	1.5	--	--	--	--		--	--	--	--	--	--	--	--	--	--	--	--	--
	[illegible]	[illegible]	1.[illegible]	190	.0082	.0092	.0080		.014	[illegible]	.0058	.029	.053	.033	.515	.913	.931	100.9	122.7	125.3	126.3
	[illegible]	[illegible]	2.[illegible]	200	.011	.019	.011		.050	.081	.029	.090	.148	.169	.515	2.20	1.25	112.2	128.0	131.8	134.9
	[illegible]	[illegible]	2.[illegible]	195	.031	.069	.022		.171	--	.041	.221	.231	.231	1.090	5.55	1.56	119.1	136.7	140.0	111.0
	[illegible]	[illegible]	2.[illegible]	195	.021	.011	.022		.101	--	.031	.211	.289	.202	.872	[illegible]	1.71	119.7	135.8	139.9	112.1
	[illegible]	[illegible]	[illegible]	180	.0070	[illegible]	[illegible]		--	[illegible]	[illegible]	[illegible]	.152	.020	0	0	.931	91.3	119.2	121.8	118.1
	[illegible]	[illegible]	--	200	.012	[illegible]	.017		.016	[illegible]	[illegible]	[illegible]	.0095	[illegible]	0	.911	.911	107.3	124.0	126.3	152.3
	[illegible]	[illegible]	[illegible]	175	.0084	.016	.011		.21	.014	[illegible]	[illegible]	.075	.018	[illegible]	1.15	1.090	106.9	129.2	127.2	129.2
	[illegible]	[illegible]	2.[illegible]	165	.019	.010	.001		.012	.017	[illegible]	[illegible]	.091	.091	.051	2.10	1.090	106.6	128.7	130.8	[illegible]
	[illegible] B	2,[illegible]	2.[illegible]	185	[illegible]	.031	[illegible]					--	--	--	1.90	11.30	2.19	--	116.6	117.9	119.1
	[illegible] A	2,600	2.30	195	.068	.019	.012		--	--	-	--	--	--	2.18	13.12	2.19	--	116.6	117.7	119.5
[illegible]-21-[illegible]	89 A	2,500	1.5	220	.028	.022	.027		.120	.118	.011	.158	.182	.115	.826	2.22	1.51	118.9	133.3	132.7	130.1
	58 A	2,800	[illegible]	205	.016	.012	.011		.026	.061	.0065	.075	.108	.053	.826	1.01	1.51	108.3	126.1	127.1	129.2
	[illegible] A	[illegible]	2.[illegible]	191	.015	.010	.011		.039	.082	.025	.098	.156	.106	.826	1.11	1.51	113.0	129.0	128.8	132.2
	[illegible] A	2,[illegible]	1.[illegible]	210	.015	.016	.011		.047	.051	.015	.088	.123	.065	.091	1.01	1.51	110.9	128.3	127.1	130.3
	100 A	3,000	2.35	200	.028	.020	.020		.143	--	.069	.211	--	--	.661	5.15	1.82	119.9	135.3	128.8	111.2
	68 A	8,300	2.35	175	.0047	.0078	.012		.0047	.0089	.0021	.015	.021	.011	.826	.505	1.21	97.1	121.6	119.9	129.7
	69 B	[illegible]	2.35	195	.0071	.011	.0080		.065	.085	.015	.065	.156	.109	.661	.998	1.21	113.7	121.1	128.2	129.2
	18 B	5,300	1.5	198	.0017	.0078	.0015		.0071	.0078	.0036	.020	.021	.014	.661	.505	1.21	91.0	120.0	121.5	120.2
	10 B	5,300	1.5	197	.0017	.0067	.0015		.0017	.0090	.0021	.015	.020	.013	.661	.301	1.21	95.2	120.0	121.5	120.2
	60 A	8,300	2.35	176	.0011	.0067	.0015		.0071	.016	.0030	.020	.035	.015	.661	.301	1.21	100.7	141.6	121.5	125.3
	61 A	7,300	2.35	200	.046	.013	.0015		.027	.071	.021	.055	.128	.091	.661	1.82	1.21	110.8	125.1	126.7	131.3
	102 A	2,600	2.35	175	.067	.058	--		--	--	--	--	--	--	1.32	11.10	1.82	--	115.3	--	--
	85 B	2,600	2.35	180	.079	.068	.012		--	--	--	--	--	--	1.32	10.31	1.82	--	112.4	--	115.9

Best Available Copy

Table III

Edwards Test House No. 2

IDENTIFICATION, TYPE, LOCATION AND DESCRIPTION OF THE VARIOUS VIBRATION RESPONSE AND PRESSURE TRANSDUCERS FOR WHICH DATA ARE INCLUDED

Item	Channel No.	Type	Date	Location	Description
A	301	Accelerometer	6/3 - 6/23	Center of Dining Room Floor	Mounted on Concrete Block Sensitive Axis Vertical
B	302	Accelerometer	6/3 - 6/23	Under Edge of Counter in Kitchen-Dinette Area	Mounted on Concrete Block Sensitive Axis Vertical
C	303	Accelerometer	6/3 - 6/14	Center of Bedroom No. 1 Floor	Mounted on Concrete Block Sensitive Axis Vertical
			6/15 - 6/21	On Mattress of Bed, Bedroom No. 1	Mounted on Concrete Block Sensitive Axis Vertical
			6/22 - 6/23	Center of Bedroom No. 1 Floor	Mounted on Concrete Block Sensitive Axis Vertical
D	304	Accelerometer	6/3 - 6/23	Bedroom No. 1, Center of North Wall	Mounted on Stud Sensitive Axis Horizontal
E	305	Accelerometer	6/3 - 6/23	Outside, N. Wall, N.E. Corner, 2nd Story Roof Line	Mounted on Stud Sensitive Axis Horizontal
F	306	Accelerometer	6/3 - 6/23	Outside, E. Wall, N.E. Corner, 2nd Story Roof Line	Mounted on Stud Sensitive Axis Horizontal
G	307	Accelerometer	6/3 - 6/23	Outside, N. Wall, N.E. Corner, 2nd Story Floor Line	Mounted on Stud Sensitive Axis Horizontal
H	308	Accelerometer	6/3 - 6/23	Outside, E. Wall, N.E. Corner, 2nd Story Floor Line	Mounted on Stud Sensitive Axis Horizontal
I	309	Accelerometer	6/3 - 6/23	Attic Above Center of Bedroom No. 1	Mounted on Ceiling Joist Sensitive Axis Vertical
J	310	Accelerometer	6/3 - 6/23	Attic Above Center of Bedroom No. 2	Mounted on Ceiling Joist Sensitive Axis Vertical
K	311	Accelerometer	6/3 - 6/23	Dining Room, Center of East Wall	Mounted on Stud Sensitive Axis Horizontal
L	312	Strain Gage	6/3 - 6/23	Quarter Point on Diagonal Inside of Large Garage Window	Sensitive Axis Perpendicular to Diagonal Line
M	313	Strain Gage	6/3 - 6/12	Bedroom No. 1, Window in East Wall	Center of Upper Middle Pane in Lower Sash, Sensitive Axis Vertical
			6/13 - 6/23	Large Garage Window, on 1/4 Point on Diagonal	Sensitive Axis Perpendicular to Diagonal Line
N	101	Audio Mike	6/3 - 6/23	In Archway Between Living and Dining Rooms	Shock Suspended, Diaphragm 6 In. Below Arch Center
O	102	Audio Mike	6/3 - 6/23	Over Counter in Kitchen-Dinette Area	Shock Suspended, Diaphragm 6 Ft. Above Floor
P	103	Audio Mike	6/3 - 6/23	Center of Bedroom No. 1	Shock Suspended, Diaphragm 6 Ft. Above Floor
Q	105	Full Range Mike	6/3 - 6/23	In Archway Between Living and Dining Rooms	Shock Suspended, Diaphragm 5 In. Below Arch Center
R	107	Full Range Mike	6/3 - 6/7	In Attic Above Center of Bedroom No. 1	Shock Suspended, Diaphragm up, 8 In. Above Ceiling Joist
			6/8 - 6/23	In Attic Above Center of Bedroom No. 1	Shock Suspended, Diaphragm up, 3 In. Above Ceiling Joist
S	109	Full Range Mike	6/3 - 6/7	In Center of Bedroom No. 1	Shock Suspended, Diaphragm 6 Ft. Above Floor, Pointed Down
			6/8 - 6/23	In Center of Bedroom No. 1	Shock Suspended, Diaphragm 2 In. Below Ceiling, Pointed Up
	110	Full Range	6/3 - 6/7	Outside in Cruciform Array	Reflection Board Mounted at Ground Level
			6/7 - 6/23	Outside, About 200 Ft. S. of Center of Cruciform Array	Reflection Board Mounted at Ground Level
104 106 108 111 112		Full Range Mikes	6/3 - 6/23	Outside in Cruciform Array, See Figure 3.	Reflection Board Mounted at Ground Level

Table IV

SONIC BOOM INDUCED ACCELERATION AND STRAIN RESPONSES OF TEST STRUCTURE NO. 2 FOR A RANGE OF B-58 FLIGHT CONDITIONS

Date	Mission No.	Altitude ft.	Mach No.	Lateral Dist. Naut. Mi.	Mag. Hdg. deg.	Reading Point	Peak Amplitude, Accelerometer Channels g's, 301	302	303	304	305	306	307	308	309	310	311	Strain Gage μ in./in., 312	313	ΔP₁ lb/ft², 405	407	409	ΔP₀ Avg. lb/ft²	Δt Avg. sec.	Vert. Wave Angle deg.
[illegible]	[illegible]	[illegible]	1.25	1.64 N	211.0	1	.020	--	.015		--	--	.011	--	.021	.027	.065	--	--				No Boom	--	--
						2	.020	--	-.015		--	--	.021	--	.025	.036	-.065	--	--						
						3	.025	--	.015		--	--	.025	--	.021	.036	.169	--	--						
	70	11,400	1.40	.55 N	[illegible]	1	-.070	.015	-.067	.224	[illegible]		-.051	-.061	-.127	-.205	.407			1.04	1.27	.85	2.00	0.183	48.1
						2	.078	-.085	.076		-.070	-.066	.015	.156	.142	.241	-.434	-26.1	-6.81						
						3	.076	-.	.071	-.182	.065	.055	-.059	-.135	-.144	.165	.456	38.3	--						
	[illegible]	31,100	1.48	.20 N	216.0	1	.112	-.130	-.120		-.108	-.176	.091	-.104	-.175	-.286	-.187	-42.2	12.5	1.33	1.76	.79	3.44	.156	51.2
						2	-.124	.130	.120		-.116	.165	-.218	.139	.280	.321	.836	56.5	-9.31						
						3	.137	1.0	-.117	.355	.095	.121	.	-.109	.142	-.250	-.765	-20.1	--						
	71	11,200	1.59	5.00 N	215.0	1	-.111	.085	.092	.471	.119	-.187	-.178	-.156	-.149	-.152	.575	19.2	7.04	1.33	1.08	.66	1.71	.177	52.1
						2	.121	-.115	-.118	-.361	-.206	.176	.212	.152	.106	.165	-.565	-13.3	-5.90						
						3	-.106	.095	.072	-.338	.157	-.193	.187	.156	-.106	.147	-.575	30.3	--						
	81	31,310	1.15	.17 N	216.7	1	-.101	-.120	-.080	.317	-.130	-.193	.089	-.164	-.170	-.321	.608	-37.0	11.1	1.27	1.37	.95	2.50	.152	50.4
						2	.111	.110	.012	-.296	.125	-.149	-.115	-.109	.174	.335	-.619	48.4	-9.08						
						3	-.101	-.100	.088	.376	-.135	.143	.148	-.148	-.132	-.272	.608	-19.9	--						
	72	13,120	1.55	1.85 S	241.5	1	-.081	.070	.071	.372	-.108	-.176	-.136	-.078	-.144	.129	.456	16.1	5.90	.81	1.08	.55	1.99	.171	60.1
						2	.091	-.080	-.076	.250	.135	.187	.115	.139	-.093	-.134	-.380	-15.6	-5.22						
						3	-.096	-.065	-.071	-.305	-.130	-.171	-.127	-.126	.085	.116	.467	23.2	--						
	[illegible]	32,110	1.30	.72 S	212.5	1	.121	-.090	-.101	--	.163	-.176	.123	.182	.170	.250	1.55	41.4	25.1	1.48	1.76	1.14	3.16	.193	73.0
						2	-.116	.090	.113	--	-.168	-.154	-.115	-.165	-.182	-.205	1.09	-29.9	-8.63						
						3	.116	-.070	-.113	--	-.157	-.198	-.123	-.165	.208	.250	1.18	38.3	-11.4				--		
	[illegible]	13,100	1.57	5.00 N	215.0	1	-.086	.070	.071	.313	-.070	-.066	.111	.113	-.115	-.098	.521	16.1	5.17	.87	.98	.55	1.70	.195	63.1
						2	.086	.090	-.081	-.279	.081	-.066	-.115	.111	.106	.113	-.123	-12.8	-4.54						
						3	-.061	.065	.059	-.182	-.076	-.072	.110	-.122	.102	-.089	.293	27.2	--						
	[illegible]	31,840	1.16	0	216.0	1	.162	-.130	-.118	.406	.233	-.198	-.136	-.200	-.246	-.375	.738	-39.3	14.3	1.21	1.57	.69	3.18	.156	56.7
						2	-.162	.130	.122	-.389	.233	.176	-.178	-.209	.306	.420	-.847	49.4	-7.95						
						3	.152	-.160	-.113	.372	.152	-.215	.191	-.209	.191	-.241	.956	-19.9	--						
	82	13,300	1.53	0	245.0	1	.121	.080	.080	.558	-.206	.209	-.272	.218	-.187	-.156	.706	-13.7	6.81	.87	1.08	.55	1.78	.182	--
						2	-.106	-.160	-.105	.558	.265	-.276	.276	-.204	.127	.187	-.586	22.2	-5.45						
						3	-.111	.075	.076	-.372	-.238	-.213	-.204	-.182	.140	.107	-.651	-7.0	--						
	[illegible]	[illegible]	1.43	.25 N	211.0	1	.117	-.135	-.118	.512	.241	-.160	-.170	-.226	-.267	-.381	.815	35.3	9.08	1.15	1.47	.71	3.54	.159	53.2
						2	-.127	.140	.122	-.381	-.309	-.176	.195	.230	-.212	.388	-.586	-39.8	-8.63						
						3	.157	-.120	-.105	.398	.190	-.209	-.182	-.235	.289	-.312	.977	51.5	--						
6-7-66	[illegible] A	31,500	1.18	1.09 S	241.5	1	.098	-.100	-.096	-.38	-.13	-.12	.13	-.15	.22		-.752	-36.3	11.8	1.09	1.62	.78	3.27	.163	59.1
						2	-.088	.160	.12	.31	.12	.11	-.13	.19	.19	-.23	.989	40.9	-7.34						
						3	.103	.091	-.083	.21	-.12	.11	-.13	-.18	.18	.20	-.774	34.5	--						
	[illegible] B	[illegible]	1.70	1.93 N	211.5	1	.110	-.091	.092	-.31	.081	-.055	-.097	.16	-.088	.22	.119	-14.0	6.25	.80	1.17	.52	2.01	.171	53.1
						2	-.078	.011	-.12	.30	-.065	.066	-.092	-.11	.10	.15	-.130	23.6	-4.00						
						3	.095	.011	.092	.26	-.065	-.011	.088	.11	.093	-.13	.130	16.3	--						

Table IV (Continued)

Date	Station No.	Altitude msl ft.	Mach No.	Lateral Dist. Naut. mi.	Mag. Hdg. deg.	Reading Point	Peak Amplitude													Δp_I lb/ft^2			$-p_O$ Avg. lb/ft^2	Δt Avg. sec.	Vert. Wave Angle deg.
							Accelerometer Channels g's											Strain Gage μ, in./in.							
							301	302	303	304	305	306	307	308	309	310	311	312	313	405	407	409			
6-7-66	77 B	31,600	1.51	0.10 S	244.5	1	-.083	-.080	-.075	.26	.060	.055	-.079		-.22	-.29	.494	36.3	11.3	1.03	1.68	.57	2.91	0.156	53.2
						2	.083	.080	-.092	-.34	-.11	-.055	.088	-.075	.20	.31	-.516	-.363	-7.79						
						3	.054		-.098		.054	-.055	.097	.068	-.14	.16	.559	.454	--						
	46 B	43,720	1.65	5.42 N		1	.11	.070	-.096		.065	.066	-.13	.12	-.097	.16	.441		5.56	.75	1.06	.52	1.63	.171	56.7
						2	.14	-.075	.083	-.34	-.11	-.061	.18	.093	.088	-.12	.318	-.114	-4.00						
						3	-.098	.065	-.075	.29	.081	-.061	-.18	-.13	.088	.13	.484	.163	--						
	48 A	38,700	1.31	5.23 N	245.5	1	.024	-.010	-.0083	.084	-.011	.028	.022	.063	.022	.053	.075	.908	3.34	.75	1.06	.49	No Boom		--
						2	-.024	.010	.0083	-.092	.011	-.011	-.022	-.034	.044	.066	.161	-14.5	-2.22						
						3	.024	.010	-.0083	-.092	-.011	.028	.022	.021	.044	.053	.107	13.6	--						
	79 A	31,600	1.52		244.5	1	-.073	-.070	-.063	-.29	.076	.14	.066	.18	-.13	-.18	.537	-41.5	13.3	1.18	1.96	.62	2.48	.169	53.0
						2	11	.075	.088	.19	-.087	-.11	-.053	-.14	.12	.20	.645	58.1	-8.01						
						3	.098	.075	.083	-.25	.059	-.11	.066	-.13	-.14	-.18	-.666	-28.5	--						
	49 A	43,340	1.43	4.65 N	152.5	1	.039			.19	-.065	-.039	.026	.038	-.040	.062	.290	18.2	4.45	.80	1.23	.52	1.44	.211	72.8
						2	-.034	-.025	-.075	-.20	.065	-.050	-.022	-.051	.053	.080	-.290	-17.6	-4.45						
						3	.034	-.045	.025	.17	-.054	.039	.026	.042	-.040	.081	.258	36.3	--						
	80 A	31,600	1.53	.25 N	244.5	1	-.088	-.091	.096	.27	-.11	-.094	-.11	.11	-.11	-.213	.484	32.7	12.2	1.03	1.68	.57	2.72	.156	51.6
						2	.11	.091	.092	-.34	.098	-.077	-.088	-.16	.19	.29	-.537	-37.4	-6.67						
						3	-.098	-.091	-.088	.29	-.076	.077	.097	-.14	.13	.16	.645	36.3	--						
	50 A	43,340	1.43	5.00 N	245.5	1	.039	.035	-.038	.19	.027	.028	-.088	.034	.088	.080	.301	9.99	3.34	.63	.78	.49	1.01	.196	72.8
						2	-.079	-.030	.042	-.19	.027	-.028	.088	.034	.053	.080	-.236	-10.4	3.34						
						3	.049	.040	-.033	.17	.027	.028	.075	.034	.066	.066	.290	14.5	-4.45						
	81 A	31,400	1.49	.06 S	245.0	1	.034	-.025	.029	-.16	-.043	.044	.031	-.042	.062	.102	.215	27.2	6.67	.92	1.56	.52	1.95	.150	53.6
						2	.039	.025	-.021	-.13	.049	-.055	-.035	.042	.079	.102	-.268	-36.3	-5.56						
						3	.054	.030	.021	.10	-.054	-.309	.035	.051	.071	-.089	-.161	36.3	--						
6-8-66	43 A	42,300	1.62	5.24 N	245.0	1	.13	.080	.076	-.30	.17	.16	-.062	-.040	.072	-.089	.325	11.6	6.59	.89	1.33	.60	1.70	.175	58.7
						2	.10	-.110	-.080	.23	-.20	-.20	.040	-.044	-.085	.12	-.347	-16.1	-4.36						
						3	.11	.015	.051	-.21	.098	.14	-.040	.053	.076	.080	.358	21.1	2.04						
	75 A	31,200	1.44	.23 N	244.5	1	.18	-.160	.13	.52	.18	.20	-.19	-.30	-.31	-.38	.824	27.6	13.2	1.21	1.86	.63	3.17	.156	50.0
						2	.15	.150	-.14		-.21	-.23	.17	-.29	.30	.47	1.08	-43.6	-7.63						
						3	.18	.170	-.15	.56	-.14	-.25	-.21	.26	-.27	-.39	.867	32.0	3.86						
	42 A	43,200	1.67	4.85 N	246.7	1	.14	.100	.11	.35	-.098	-.080	.20	.18	-.14	-.21	-.510	10.9	6.36	.82	--	.52	2.06	.179	57.9
						2	-.13	-.135	-.13	-.36	-.098	.075	-.19	-.15	.17	.31	.520	-13.8	-5.23						
						3	.12	.110	.11	-.37	.092	.069	-.18	.16	.10	.18	-.499	16.7	1.82						
	73 A	31,200	1.50	.10 N	245.0	1	-.096	.075	-.084	.27	-.103	-.115	-.115	-.16	-.17	-.22	.520	-37.9	11.1	1.04	--	.50	2.22	.147	53.9
						2	.096	-.095	.076	-.24	-.103	.10	.106	-.18	.17	.26	-.488	26.2	-5.67						
						3	-.076	.070	.076	.26	.087	.115	-.126	-.17	-.17	-.22	.488	-21.8	1.36						
	41 A	43,200	1.60	5.32 N	246.0	1	-.086	.060	.080	.49	.108	-.080	-.26	-.11	-.18	.18	.531	-17.2	6.59	.82	--	.50	1.92	.166	58.0
						2	.086	-.090	.092	.32	.098	.11	.21	.20	.11	-.18	.499	18.9	-3.71						
						3	-.081	.060	-.084	-.39	.108	.092	-.22	-.15	-.11	.17	-.423	-9.2	1.82						

Table IV . Continued

Date	Mission No.	Altitude msl ft.	Mach No.	Lateral Dist. Naut. mi.	Mag. Hdg. deg.	Reading Point	Peak Amplitude																		
							Accelerometer Channels g's											Strain Gage μ, in./in.		ΔP_I lb/ft²			ΔP_O Avg. lb/ft²	Δt Avg. sec.	Vert. Wave Angle deg.
							301	302	303	304	305	306	307	308	309	310	311	312	313	405	407	409			
[illegible]	22 A	31,2[illegible]	1.1[illegible]		215.0	1	-.106	.085	.11	.49	-.18	.22	-.283	-.32	-.32	.41	.880	-47.0	10.9	1.07	--	.63	2.85	0.141	49.0
						2	.111	-.120	.11	.57	-.22	-.29	.261	-.30	-.27	.10	.781	32.7	-6.32						
						3	.116	.090	.12	.49	-.20	.29	-.261	-.29	-.33	-.36	.716	-25.8	3.18						
	[illegible] F.B	37,000	1.66	5.90 N	218.5	1	-.081	.301	.059	-.86	.033	.034	.053	.088	.051	-.075	.282	11.6	6.81	.75	--	.52	1.76	.162	52.2
						2	.096	-.351	-.063	.21	-.043	.031	.053	-.079	-.051	.062	-.314	13.8	-3.27						
						3	-.076	.301	-.059	-.22	.038	-.046	.053	-.082	-.042	.053	.293	17.4	--						
	[illegible] E.B	31,380	1.16	.14 N	216.6	1	.121	-.100	-.092	.43	.098	-.14	-.199	-.21	-.27	-.35	.759	26.2	12.0	1.14	--	.63	2.63	.161	60.4
						2	-.096	.095	.092	-.38	-.12	-.19	.217	-.32	-.24	.34	-.716	-43.6	-8.72						
						3	.101	.075	.092	.41	.088	-.15	-.212	-.25	.24	-.30	.770	32.7	-2.40						
	[illegible] E.B	13,040	1.64	5.14 N	211.0	1	-.091	.080	.080	.26	.065	-.103	-.165	.14	-.085	-.12	-.390	10.9	6.81	.86	--	.60	2.09	.170	55.3
						2	.111	-.090	-.092	-.28	-.095	.103	.110	.115	.085	.16	-.434	-16.6	-4.36						
						3	.111	.070	.081	-.29	.081	-.092	-.150	.110	.076	.098	.369	18.9	-2.15						
	87 E.B	31,140	1.19	.40 N	215.1	1	.117	-.140	-.12	.30	-.070	-.11	-.124	-.18	-.21	-.32	.643	-48.2	12.7	1.07	--	.58	3.23	.148	48.9
						2	-.121	.110	.14	-.28	.076	.086	-.137	.15	.22	.37	-.694	38.5	-6.54						
						3	.127	-.110	.12	.39	.087	-.11	.115	-.18	-.20	-.33	.748	-29.8	2.72						
	55 E.B	13,200	1.61	5.16 N	211.0	1	.202	.130	-.16	.55	-.087	.080	-.221	.071	-.16	.31	.737	13.8	11.3	.82	--	.63	2.17	.169	58.4
						2	.177	-.170	.16	.47	-.087	-.092	.212	.12	.19	-.26	.737	-11.5	-3.19						
						3	.202	.150	.14	.44	.108	.103	-.212	-.079	.13	.30	.845	20.3	3.63						
	86 E.B	31,360	1.19	0	229.0	1	-.106	.090	-.101	.60	.27	-.21	.270	-.33	.11	-.35	1.12	26.2	10.2	1.07	--	.75	2.70	.141	45.9
						2	.101	-.095	.105	-.40	-.15	.24	.274	.26	-.38	-.35	.716	-19.3	-6.98						
						3	.111	-.090	-.118	.57	-.14	.19	.300	-.34	.11	.50	-.900	31.2	5.90						
6-9-66	[illegible] SRB	31,0[illegible]	1.50	.25 N	216.2	1	.20	-.152	.14	.54	-.17	.24	-.22	-.27	-.32	.62	.886	-53.3	5.89	1.21	1.06	.81	4.00	.153	51.1
						2	-.16	.127	.15	.64	.15	-.20	-.22	-.25	.36	-.12	-1.02	47.2	-4.31						
						3	.16	-.147	-.17	-.60	-.13	-.22	-.22	-.27	-.31	.41	1.09	-31.4	10.5						
	55 SRB	3[illegible],720	1.69	5.17 N	211.5	1	-.13	.054	.076	.17	-.092	.18	.051	.052	-.061	-.082	.256	12.3	1.31	.90	.61	.41	1.60	.140	55.5
						2	.079	-.061	-.061	-.20	.19	-.19	-.061	.083	.076	.13	-.245	-20.1	-1.36						
						3	.061	.014	-.011	.14	-.20	-.14	.068	-.13	-.051	.080	.192	21.8	1.31						
	87 SRB	31,000	1.53	.08 S	241.0	1	-.13	-.127	-.11	-.37	.12	-.12	-.13	-.20	.33	-.30	.640	-52.8	6.95	1.28	1.00	.67	3.44	.146	49.2
						2	.16	.103	.11	.43	-.13	.11	.15	-.22	-.29	.13	-.800	13.6	6.98						
						3	-.13	-.103	-.11	-.36	.12	-.094	-.15	-.16	-.27	.38	.896	-29.8	3.92						
	56 SRB	13,300	1.72	1.70 N	242.6	1	-.11	.083	.11	.27	-.087	.20	-.12	.093	-.13	.30	-.501	13.1	4.14	.93	.66	.44	2.77	.161	51.0
						2	.14	-.122	-.13	-.34	.14	-.19	.15	.098	.12	-.16	.418	-20.6	-2.72						
						3	.12	.098	.084	.27	-.17	-.14	.093	-.11	-.12	.18	.533	-18.9	2.62						
	80 SRB	31,000	1.53	.06 N	245.2	1	-.091	.061	.059	.36	-.11	-.094	-.18	-.29	-.25	-.27	.610	26.9	4.80	1.25	.89	.59	2.95	.110	48.0
						2	.098	-.093	.067	-.29	-.12	-.094	.17	.21	.27	.33	.533	-46.5	5.23						
						3	.11	-.069	-.081	.25	.11	.10	.20	-.24	.28	.33	-.619	-27.0	4.36						
	57 SRB	13,160	1.70	5.23 N	214.0	1	-.10	.078	.097	.24	.10	-.17	-.11	.096	-.102	-.13	.363	11.6	3.19	.90	.66	.41	1.94	.150	51.3
						2	.13	-.098	-.10	-.29	-.17	.21	.10	-.11	.102	.23	-.440	-21.2	-1.82						
						3	-.11	.093	-.077	-.21	.18	.11	-.11	-.087	-.085	-.13	.395	21.1	2.62						

Table IV (Continued)

Date	Mission No.	Altitude msl ft.	Mach No.	Lateral [illegible] Naut. mi.	Mag. Hdg. deg.	Reading Point	Peak Amplitude													$-p_I$ lb ft			Δp_0 Avg. lb ft^2	Δt Avg. sec.	Vert. Wave Angle deg.
							Accelerometer Channels g's											Strain Gage μ, in. in.							
							301	302	303	304	305	306	307	308	309	310	311	312	313	405	407	409			
6-9-66	41 SA	42,920	1.52	4.37 N	240.0	1	-.081	.059	.084	-.37	.15	.19	-.14	.074	-.097	-.13	.405	11.6	1.96	.93	.70	.46	2.28	0.180	60.4
						2	.009	-.069	-.085	.25	-.12	-.18	.12	-.087	.11	.15	-.416	-20.1	-1.59						
						3	-.064	.049	.050	-.25	-.15	-.16	-.11	-.13	-.097	.089	-.331	24.7	2.18						
	73 SA	31,720	1.50	.49 S	243.4	1	.13	-.12	-.11	.32	-.14	-.24	.20	-.26	.31	-.24	.672	-49.9	5.45	1.31	.98	.67	3.03	.155	54.4
						2	-.12	.108	.11	.38	-.19	.21	-.18	-.25	-.25	.38	-.661	40.0	5.07						
						3	.11	-.113	-.14	-.32	.20	-.27	.17	-.28	.25	.23	.779	-26.4	3.71						
	42 SA	43,060	1.52	4.80 N	241.2	1	.17	.088	.12	.57	-.24	-.24	-.24	.35	-.19	-.18	.736	14.5	5.89	.93	.76	.61	2.25	.176	63.6
						2	.16	-.118	-.14	--	-.23	.20	-.18	-.33	-.14	.23	-.875	-18.9	-3.86						
						3	-.18	.088	.088	.48	.23	-.21	-.20	.33	.19	-.17	-.726	21.8	5.43						
	75 SA	32,080	1.56	0	246.5	1	.17	-.122	.14	-.31	-.14	.15	-.17	-.17	.31	-.23	-.811	28.9	5.89	1.25	.89	.87	3.80	.149	48.4
						2	.15	.112	-.14	.44	-.11	-.13	-.13	-.18	.28	.31	.896	-44.2	9.59						
						3	.15	-.142	-.13	-.34	-.10	.14	-.13	-.18	-.28	-.28	-.726	34.9	5.69						
	13 SA	43,000	1.65	4.62 N	243.5	1	.12	.069	.092	.32	.10	-.083	-.18	.27	-.12	-.16	.512	12.3	3.49	.93	.46	.44	2.84	.157	51.6
						2	-.11	-.103	-.11	.30	.11	-.12	.19	.21	.14	.24	-.459	-19.5	-2.27						
						3	.11	.069	-.081	-.35	-.13	.086	-.23	-.21	-.10	-.19	.384	13.8	2.18						
	42 SA	43,300	1.70	4.92 N	264.5	1	.11	-.088	.084	-.29	.057	-.10	.089	-.070	-.060	.14	-.405	10.2	-2.27	.69	.44			.165	
						2	-.11	.059	-.050	.24	-.12	.17	-.092	.074	.089	-.13	-.405	-17.8	2.15						
						3	-.11	-.064	.084	.22	.14	.11	.058	-.061	-.059	.098	.427	16.7	-2.81						
	46 SA	42,900	1.65	1.71 N	246.0	1	-.059	.069	.051	.30	-.065	-.046	.15	.15	.11	.12	.437	19.5							
						2	.059	-.075	-.069	.25	.065	-.072	.14	.15	.10	.17	-.416	23.2	-2.04						
						3	-.074	.059	-.065	-.31	-.087	.075	-.14	.13	-.089	-.11	-.363	-10.3	2.15						
	72 SA	31,320	1.53	.63 N	248.5	1	-.074	.039	-.061	-.18	.11	-.077	.051	-.066	.12	-.13	-.459	-15.9		.18					
						2	.069	-.073	-.057	.18	-.087	.14	-.053	.12	.12	.14	.437	30.5	4.80						
						3	.054	-.089	-.061	-.25	-.057	.10	-.057	-.10	-.11	-.113	-.299	-20.1	7.41						
6-13-66	18 A	37,740	1.64	.09 S	231.0	1	.12	.094	.11	.32	.18	-.14	-.17	-.21	-.20	-.22	.616	19.9	12.8	.99	1.46	2.67	2.82	.160	42.2
						2	-.11	-.11	-.11	-.35	-.16	.15	-.19	.20	.27	.35	-.649	-43.0	-32.0						
						3	-.11	-.094	.11	-.28	.16	.15	.15	.23	-.22	-.26	.649	27.6	19.2						
	18 B	49,800	1.66	.36 S	234.0	1	.093	.084	.084	.25	-.070	.098	-.086	-.10	.21	.28	.418	16.7	-27.9	.85	1.46	2.16	2.07	.196	45.7
						2	-.098	-.089	-.084	-.27	.096	-.082	.077	-.092	-.17	-.19	-.462	-31.4	15.4						
						3	.083	.079	-.080	-.25	.079	-.071	-.086	-.088	.16	.20	.539	24.4	-15.0						
	21 A	37,840	1.69	.21 S	230.0	1	-.10	.11	.12	.39	.141	.17	-.20	-.23	-.23	-.25	.682	19.2	13.5	.93	1.60	2.45	2.86	.146	44.0
						2	.13	-.12	.11	-.39	.164	-.20	.21	-.23	.31	.42	-.704	-44.9	-27.2						
						3	-.12	.094	-.11	-.33	-.130	.15	.24	0.24	-.27	-.30	.649	23.7	16.7						
	21 B	49,160	1.72	.35 S	231.3	1	.088	.070	.084	.25	.073	.086	-.13	-.15	.21	.29	.440	15.4	10.3	.82	1.33	2.03	1.88	.195	42.4
						2	-.081	-.084	-.076	-.28	.073	-.093	-.11	-.15	-.18	-.18	-.462	-29.5	-24.5						
						3	.078	.074	-.080	.25	.096	-.082	.16	.13	.16	.22	.440	23.7	16.0						
	29 A	49,300	1.67	.03 N	232.8	1	.088	.065	.084	.23	.079	.075	-.095	-.11	.15	-.16	.429	14.7	10.3	.99	1.33		1.87	.185	46.6
						2	-.091	-.077	-.097	-.25	-.081	-.082	.120	-.13	-.14	.23	-.385	-25.6	-23.2						
						3	.075	.070	-.084	-.27	.096	.086	-.115	-.12	.13	.19	.429	25.0	16.7						

Table IV Continued,

Date	Mission No.	Altitude msl ft.	Mach No.	Lateral Dist. Naut. mi.	Mag. Hdg. deg.	Reading Point	Peak Amplitude													Δp_I lb/ft^2			Δp_0 Avg. lb/ft^2	Δt Avg. sec.	Vert. Wave Angle deg.
							Accelerometer Channels g's											Strain Gage µ in./in.							
							301	302	303	304	305	306	307	308	309	310	311	312	313	105	407	409			
6-13-66	[illegible]	[illegible]	1.67	0.11 S	232.0	1	.13		.114	.28	-.060	.071	-.098	-.13	.21	-.19	.195	19.2	12.8	1.13	1.60	1.78	3.12	.156	45.6
						2	.12		-.114	-.34	-.081	-.088	-.13	-.10	-.19	.28	-.583	-43.0	-28.6						
						3	-.12		-.143	-.27	.068	.075	-.090	-.10	.17	-.23	.627	21.8	16.0						
	32 A	19,820	1.61	.52 N	235.0	1		.070	.081	.22	.085	-.12	-.12	.087	.17	-.16	.451	-14.1	9.62	.78	1.26	1.91	1.95	.182	47.3
						2	-.081	-.071	-.080	-.21	.073	.13	.11	-.10	-.14	.23	.462	27.6	-22.5						
						3	.073	.064	.023	-.22	-.087	.11	.11	.078	.16	.18	.429	-19.2	12.2						
	32 B	38,000	1.67	0	233.0	1	.10	.089	.073	.25	.090	-.11	-.15	-.13	-.18	-.21	.605	16.7	10.9	.85	1.46	2.61	2.30	.149	43.4
						2	-.096	-.099	.101	-.32	-.076		.11	.11	.22		.581	-35.1	-13.8						
						3	.083		-		.079	-.593	-.13	-.16		-.22	-.561	18.0	12.2						
6-20-66	18 A	11,300	1.55	2.20 N	232.0	1	-.131	-.163	.025		.130	-.126	-.191	-.157	-.148	-.204	.531	-25.6	9.54	1.14	1.95	2.15	2.67	.179	51.8
						2	.151	.122	-.024	-.330	-.114	.149	-.178	.179	.153	.257	-.499	20.5	-21.8						
						3	.131	-.153	-.023	-.408	-.119	-.144	-.191	-.192	-.169	-.301	-.542	-14.1	13.6						
	79 A	32,100	1.45	1.90 S	232.0	1	.075	-.081	.017	-.395	-.108	-.264	-.178	-.219	-.186	.332	-.867	-48.1	-35.1	1.00	2.08	2.20	2.46	.153	54.1
						2	-.090	.076	.017	.295	-.103	.126	.178	.153	.292	.257	.802	28.2	19.8						
						3	.090	-.071	-.024	-.295	-.018	-.184	-.157	.211	.195	-.213	-.737	-26.9	-19.1						
	53 A	42,700	1.39	5.00 N	232.0	1	-.080	-.092	.012	-.235	-.038	.016	-.031	-.031	.068	-.089	-.325	-16.7	-14.3	.79	1.47	1.64	1.47	.175	53.7
						2	.085	.066	-.013	.200	-.043	-.040	.030	.039	-.059	.093	.271	15.4	6.81						
						3	-.085	-.066	-.010	-.191	-.043	.057	-.034	-.035	.059	-.089	-.304	-10.3	-9.54						
	84 A	31,220	1.43	0	235.6	1	-.110	.092	.019	.391	-.087	-.287	-.119	-.179	.267	-.245	-.618	-53.9	-35.4	1.07	2.34	2.61	2.58	.144	19.4
						2	.110	-.122	-.523	-.391	-.108	.138	.136	-.166	-.241	.315	.672	25.6	20.4						
						3	.095	.092	.024	.356	-.092	-.132	.093	.162	.263	.315	.596	-32.1	-17.7						
	51 A	13,000	1.57	4.87 N	230.1	1	.095	-.092	.016	.226	-.076	.086	.038	.048	-.080	.151	.282	-15.4	6.13	.78	1.39	1.53	1.47	.164	55.1
						2	-.101	.076	.012	-.322	.054	-.060	-.042	-.066	.102	-.115	-.369	13.5	-12.3						
						3	.101	.076	-.014	.243	-.070	-.669	-.059	.018	-.068	-.111	.314	-8.98	8.86						
	59 B	43,360	1.41	5.00 N	233.2	1	.161	.143	.025	-.482	.108	-.075	.080	-.122	.131	.253	.781	12.8	-21.8	1.21	2.21	2.15	2.31	.218	68.7
						2	-.151	.117	-.023	.578	-.092	.063	-.072	-.141	.148	-.160	.737	-21.8	10.9						
						3	.156	-.143	.019	.491	-.103	-.080	-.076	-.076	-.161	.231	.759	18.6	-9.54						
	98 B	31,310	1.50	0	233.0	1	.131	-.153	-.025	1.18	.108	-2.87	-.165	-.227	-.297	-.408	.943	23.7	42.2	1.25	2.51	2.69	3.04	.154	50.5
						2	-.121	.122	.027	-.400	-.103	.161	.195	-.236	.372	.505	-.889	-53.2	21.8						
						3	.121	-.127	.023	.400	-.152	-.155	-.186	-.201	-.339	.319	.911	32.1	-21.8						
	90 B	31,800	1.55	.17 S	230.5	1	-.111	.097	.020	.405	-.103	-.287	.216	-.219	.330	-.315	.737	-53.9	-34.5	1.07	2.34	2.61	2.80	.145	52.2
						2	.121	-.122	-.023	-.304	-.119	.247	-.178	.188	-.246	.430	-.781	29.5	17.0						
						3	.116	.081	.021	-.404	-.108	-.155	.212	-.214	-.263	.310	.759	-25.6	-21.8						
	85 A	32,320	1.45	4.35 N	231.4	1	--	--	--	--	--	--	--	--	--	--	--	--	--	1.00	2.01	2.25	2.39	.143	60.1
						2	--	--	--	--	--	--	--	--	--	--	--	--	--						
						3	--	--	--	--	--	--	--	--	--	--	--	--	--						
	93 B	32,140	1.55	.17 S	231.4	1	-.141	.102	.026	.400	.173	-.276	-.148	.153	.309	-.248	.813	23.1	-38.2	1.00	2.25	2.56	2.90	.141	52.2
						2	.141	-.143	.026	-.456	.152	.310	-.169	-.175	-.288	.328	-.867	-55.1	16.4						
						3	.136	.122	.024	.426	.168	.247	-.114	.157	.225	.288	.997	28.2	-17.7						

Table IV (Continued)

Date	Mission No.	Altitude msl ft.	Mach No.	Lateral Dist. Naut. mi.	Mag. Hdg. deg.	Reading Point	Peak Amplitude													ΔPI lb/ft²			−PO Avg. lb/ft²	−t Avg. sec.	Vert. Wave Angle deg.
							Accelerometer Channels g's											Strain Gage μ, in./in.							
							301	302	303	304	305	306	307	308	309	310	311	312	313	405	407	409			
6-21-66	89 B	31,760	1.46	.12 N	232.0	1	-.12	.11	.025	.49	-.16	-.26	-.19	.20	-.19	.43	.835	-53.1	-32.7	1.16	1.97	2.71	2.81	.151	49.2
						2	.14	-.15	-.025	-.48	.14	.31	.23	.23	.30	-.28	-.759	27.9	17.7						
						3	.12	-.12	.082	-.43	.13	.23	.20	.20	-.25	.27	.791	-31.3	-17.7						
	58 B	43,600	1.67	5.12 N	232.6	1	.13	.090	.020	.34	.081	-.063	.053	-.12	-.12	-.14	.423	9.54	-12.3	.82	1.15	1.59	1.95	.175	55.3
						2	-.12	-.12	-.017	-.41	.076	.080	-.071	-.078	.14	.22	.390	-16.3	8.86						
						3	-.12	.095	.016	.38	.076	.097	-.057	-.10	-.11	.14	.390	17.7	-7.49						
	99 B	31,700	1.47	.17 N	233.0	1	-.14	.12	.026	.51	.11	-.12	.12	.21	.28	.42	.802	-57.2	16.3	1.25	1.86	2.63	3.22	.148	57.0
						2	.16	-.15	-.026	-.45	.10	-.11	.11	-.15	-.31	-.39	.824	27.2	-35.4						
						3	.13	-.13	-.027	.45	-.098	-.13	.11		-.28	.33	.813	-28.6	-19.8						
	66 B	39,840	1.59	5.00 N	233.0	1	-.071	.055	.011	.17	.038	-.031	-.027	-.052	-.061	.12	.239	-16.3	5.45	.68	1.01	1.43	1.22	.167	59.0
						2	.066	-.060	.010	-.21	-.038	.029	-.035	.11	.081	-.093	-.217	10.2	-10.9						
						3	-.081	.055	.012	-.16	-.038	-.029	.027	-.087	-.059	.084	-.228	-7.49	8.15						
	100 B	31,760	1.46	.11 S	231.8	1	-.10	.085	.021	.27	.065	-.068	-.053	.10	.17	-.25	.520	-51.8	-32.0	1.02	1.64	2.51	3.03	.146	49.2
						2	.096	-.11	.029	-.34	-.065	-.10	.084	-.10	.16	.25	-.531	27.9	15.0						
						3	.081	.080	.025	-.27	-.065	-.080	.057	.10	-.14	.22	.585	-27.9	-20.1						
	68 B	41,080	1.62	1.83 N	232.0	1	.096	.675	.016	.32	-.12	.074	-.071	-.078	-.10	.18	.390	7.49	5.13	.65	.99	1.35	1.51	.167	54.5
						2	-.096	-.095	.013	.29	.11	-.086	.088	.11	.11	-.12	.336	-14.3	-10.2						
						3	.096	.080	-.014	-.30	-.13	-.074	-.081	-.083	.081	.12	.317	12.9	9.51						
	69 B	39,140	1.59	5.00 N	232.8	1	-.096	.065	.020	.25	-.065	-.051	-.049	-.056	.089	-.093	.131	-21.1	6.81	.85	1.12	1.97	1.65	.186	72.0
						2	.11	-.095	-.021	-.43	.087	.057	-.044	.061	-.093	.15	-.317	11.3	-16.3						
						3	-.091	.060	.013	.38	.10	.068	-.044	-.056	-.11	-.10	.317	-12.3	9.54						
	18 A	43,110	1.60	5.00 N	231.6	1	-.081	.070	.017	.24	-.065	-.068	-.053	.052	.072	-.098	.358	-19.8	-14.3	.91	1.29	1.83	1.51	.177	62.8
						2	.11	-.080	-.014	-.39	-.054	.057	-.049	-.071	.089	.11	-.369	12.9	7.49						
						3	.091	.070	.014	.24	.060	-.063	-.049	.074	-.072	-.080	-.336	11.6	-8.18						
	10 A	43,810	1.65	5.40 N	235.0	1	.14	.090	.020	-.43	.051	-.074	.049	.078	.093	-.12	.390	-17.7	6.81	.79	1.21	1.65	1.88	.171	57.1
						2	-.11	-.12	.018	.40	.087	.13	-.049	-.061	-.085	.16	-.390	12.9	-12.9						
						3	.13	.095	-.017	-.34	.087		-.053	-.056	-.085	-.14	.131	-12.3	7.49						
	60 B	43,910	1.61	5.16 N	233.2	1	.12	.075	.018	-.38	.065	.051	.040	-.043	-.072	-.11	-.379	-15.0	5.45	.65	1.01	1.39	1.73	.165	58.9
						2	-.12	-.10	.011	.38	.065	.097	.053	-.039	.089	.11	.358	11.6	-9.54						
						3	.12	.085	.016	-.31	.081	-.051	.040	.013	.076	-.12	-.379	-9.51	8.18						
	61 B	43,260	1.62	1.76 N	232.5	1	-.091	.055	.019	-.32	.12	.15	-.075	.11	.072	-.071	-.401	-21.1	6.81	.91	1.48	2.01	2.49	.181	59.0
						2	.096	-.090	.014	.31	-.098	.086	-.088	-.14	-.064	.11	.293	19.1	-15.7						
						3	.081	.060	-.019	-.32	.15	-.086	-.075	.12	-.081	-.084	-.336	-10.9	12.3						
	101 B	31,700	1.50	0	232.8	1	-.11	.080	--	.30	-.076	.22	-.088	.10	.19	-.20	.520	-50.4	14.3	1.13	1.81	2.63	2.67	.148	52.2
						2	.14	-.11	.030	-.31	.070	-.29	-.10	.087	.18	.23	-.542	25.9	-26.6						
						3	.13	.075	.022	.25	.076	.21	-.093	-.096	-.18	.19	.672	-25.2	-13.6						
	85 A	31,700	1.50	.22 N	233.7	1	-.12	.090	.025	-.30	.065	.063	.084	.083	.19	.35	.520	19.1	13.6	1.08	1.59	1.69	2.81	.146	50.9
						2	.13	-.12	.031	.29	-.076	.091	.088	-.087	.17	.35	-.661	-42.2	-26.6						
						3	.11	.10	.022	.30	.076	-.091	-.097	-.083	-.19	-.27	.661	18.4	-14.3						

Table IV (Continued)

[illegible]	[illegible] No.	Altitude [illegible] ft.	[illegible]	Lateral Dist. Naut. mi.	Mag. Hdg. deg.	Reading Point	Peak Amplitude													ΔP1 lb/ft²			ΔP0 Avg lb/ft²	Δt Avg. sec.	Vert. Wave Angle deg.
							Accelerometer Channels g's											Strain Gage μ in./in.							
							301	302	303	304	305	306	307	308	309	310	311	312	313	405	407	409			
6-22-66	28 A	37,000	1.63	.18 N	231.5	1	.13	-.12	-.10	.57	-.12	-.16	.39	-.36	-.20	-.31	.213	-96.7	-38.3	.96	1.78	2.47	2.66	.162	50.5
						2	.13	.13	.11	-.38	.11	.15	-.35	.24	.30	.31	-.278	24.0	17.3						
						3	.13	-.12	-.12	.11	-.13	.18	-.37	-.28	-.20	-.28	.278	-61.3	-18.0						
	[illegible] A	37,200	1.11	.11 N	233.5	1	-.011	.075	.092	.22	-.054	.016	.011	-.052	-.093	-.15	.121	-81.7	-25.6	.96	1.48	1.64	2.06	.154	47.7
						2	.071	-.075	.071	-.21	-.013	.050	-.011	.063	.127	.22	-.113	19.6	11.5						
						3	.066	.085	-.075	-.19	.051	-.063	.018	-.048	.093	-.18	.134	-40.9	-12.8						
	6 A	13,500	1.60	1.31 S	259.0	1	.13	.085	-.108	.25	.065	.098	.079	.091	.23	.32	-.325	-91.3	-30.8	.99	1.33	1.25	3.41	.167	50.9
						2	-.11	-.100	.104	.24	.065	-.080	.083	-.10	-.22	-.22	.347	22.9	12.8						
						3	-.13	.085	-.100	.25	.076	.086	.075	-.096	.18	-.23	.217	-57.2	-19.2						
	30 A	37,100	1.65	.20 S	229.8	1	-.081	-.070	.071	.18	-.051	.063	.092	-.087	.089	.13	-.182	-87.2	-28.9	1.10	1.53	1.58	2.04	.163	47.5
						2	.076	.080	.075	-.17	.019	-.075	-.075	-.078	-.127	-.13	.139	19.6	15.4						
						3	.091	-.080	.012	-.25	-.051	.063	.079	.078	.081	-.13	-.191	-54.5	-15.4						
	44 B	13,100	1.61	1.00 N	230.0	1	-.061	.055	.067	.25	-.065	-.052	.066	.065	.085	.15	.117	5.45	5.13	.66	.97	1.36	1.48	.169	56.2
						2	.076	-.070	-.058	.26	.060	.016	-.072	.065	.076	-.11	-.121	-35.4	-11.5						
						3	.071	.055	.054	-.26	-.076	-.057	.061	-.078	.085	.10	-.104	7.63	7.69						
	21 A	13,300	1.60	5.06 N	233.0	1	.066	-.075	.016	-.21	.017	.016	.018	-.052	.068	.089	-.117	7.09	-11.5	.72	1.16	1.60	1.44	--	--
						2	.081	.060	.050	-.22	.013	.057	.053	.052	-.059	-.071	.087	-36.8	6.41						
						3	.066	.060	.050	.21	.013	.040	.018	-.043	-.076	.062	-.087	13.1	-8.34						
	35 A	13,100	1.60	.92 S	225.3	1	.076	.055	.050	-.11	.081	-.075	.026	.035	.055	.098	-.069	5.45	-11.5	.61	.90	1.21	1.18	.165	--
						2	-.066	-.060	.042	.11	-.087	.13	-.026	.018	.042	-.075	.069	-32.7	5.77						
						3	.076	.060	.042	-.15	.12	.103	.035	-.043	.051	.098	-.087	9.81	-5.13						
	25 B	13,220	1.59	1.89 N	233.0	1	-.10	.075	.083	.55	.11	.103	-.14	.26	-.18	-.18	.208	7.63	5.13	.77	.99	.97	1.42	.179	56.4
						2	.13	-.100	.083	.39	.13	.103	.27	-.21	.18	.18	-.171	-27.2	-14.1						
						3	.10	.100	.11	-.41	.11	-.103	-.21	-.19	-.13	.22	-.174	15.3	6.41						
	23 B	37,110	1.63	.50 N	232.5	1	-.10	.095	.10	.21	-.013	-.016	.011	-.056	-.17	-.16	-.217	-70.8	-23.1	.93	1.40	1.99	2.37	.157	48.0
						2	.12	-.100	-.083	-.21	.013	-.016	-.011	.018	.17	.23	.226	18.0	12.8						
						3	-.10	.080	-.083	.19	.019	-.057	-.011	-.061	.102	-.23	-.156	-38.1	-14.1						
6-23-66	17 A	37,600	1.61	.39 N	231.5	1	-.093	-.12	.11	.32	-.12	.19	.39	.15	-.11	.31	.199	-163.5	-33.1	1.07	1.47	1.34	2.40	.162	46.1
						2	.098	.11	-.10	-.31	.12	.15	-.25	.27	.17	-.23	.651	24.5	20.5						
						3	-.098	-.11	.097	-.23	-.13	-.16	-.26	-.34	-.19	-.22	.499	-92.6	14.1						
	22 B	13,360	1.67	4.15 N	229.2	1	.13	-.12	.11	.36	-.070	-.055	-.060	.087	-.14	.23	.412	-43.6	6.41	.66	1.04	1.36	1.63	.168	52.8
						2	-.12	.12	-.12	-.36	-.065	.061	.073	-.087	.14	-.19	-.317	12.0	-13.1						
						3	.14	-.10	.10	.29	-.070	-.055	-.077	-.091	-.10	.18	.401	-43.6	8.98						
	31 A	37,180	1.61	.12 N	231.0	1	-.078	.091	.085	.27	.070	.12	.073	-.074	-.15	-.16	.455	14.2	10.9	.85	1.23	1.83	1.98	.155	47.3
						2	.093	-.10	-.085	-.29	-.076	-.10	-.073	.069	.18	.28	-.134	-130.8	-23.2						
						3	-.083	.096	.081	.21	.087	.099	.077	.069	-.16	-.18	.455	-18.0	-14.5						
	33 A	13,200	1.61	5.02 N	231.6	1	.098	.080	.085	.19	.092	.099	-.081		.081	.14	.325	-57.2	-11.6	.66	.89	1.31	1.25	.163	59.0
						2	-.083	-.086	-.077	-.31	.10	.12	.081	.12	.060	-.099	-. 82	10.4	7.05						
						3	.093	.070	.061	-.25	.076	-.083	-.085	.10	.068	-.099	-.314	-43.6	-7.99						
	20 B	37,400	1.65	.10 N	232.6	1	.14	-.11	.11	.11	.087	-.10	.15	-.13	-.20	-.22	.531	15.3	-26.2	.93	1.42	2.01	2.09	.159	47.7
						2	-.14	.11	-.097	-.10	-.10	.099	-.12	.11	.24	.13	-.564	-139.0	12.8						
						3	.12	.11	-.11	-.36	.087	-.10	-.11	-.14	-.18	-.24	.683	18.0	-16.7						
	36 B	37,100	1.66	.25 S	231.0	1	.21	-.16	.17	.55	-.15	.32	.23	-.22	-.25	-.31	-.976	-234.3	15.4	.96	1.70	2.42	5.50	.160	49.4
						2	-.18	.16	.15	-.51	.14	-.37	-.23	.24	.32	.43	1.26	21.8	-34.9						
						3	.19	-.15	-.17	.43	.20	.31	.17	.21	-.27	-.39	.889	-100.9	18.0						
	6X-2	13,520	1.67	1.86 N	158.0	1	-.11	-.080	.085	-.38	-.054	-.033	-.664	.083	-.071	-.11	-.520	-111.7	10.3	.88	1.21	1.17	1.79	.768	--
						2	-.13	.675	-.097	.34	-.070	-.039	.055	-.083	.094	.16	.564	19.6	-20.3						
						3	-.13	.080	.097	-.30	.054	-.038	.060	-.096	-.073	-.14	.499	-57.2	13.5						

Table IV (Continued)

SONIC BOOM INDUCED ACCELERATION AND STRAIN RESPONSES OF TEST STRUCTURE NO. 2 FOR A RANGE OF F-104 FLIGHT CONDITIONS

Date	Mission No.	Altitude msl ft.	Mach No.	Lateral Dist. Naut. Mi.	Mag. Hdg. deg.	Reading Point	Peak Amplitude													ΔP_1 lb/ft^2			ΔP_0 Avg. lb/ft^2	Δt Avg. sec.	Vert. Wave Angle deg.
							Accelerometer Channels g's											Strain Gage μ, in./in.							
							301	302	303	304	305	306	307	308	309	310	311	312	313	405	407	409			
6-1-66	14	25,600	1.7	--	--	1	-.071	[illegible]	-.088	.130	.010	.010	-.049	-.039	-.085	.173	.281	10.2	1.77	.47	.62	.31	1.19	.087	--
						2	.097	[illegible]	.117	.147	-.034	.052	.049	-.044	.110	-.137	.292	-13.6	-1.09						
						3	.066	[illegible]	-.101	.135	-.010	-.010	.049	-.052	.085	.146	.361	- 7.49	--						
6-13-66	26 A	21,200	1.1	.08 N	232.5	1	.073	-.084	-.13	.28	.090	-.13	-.13	.16	.20	.28	-.616	8.98	-9.51	.71	.67	.95	1.87	.071	50.8
						2	-.086	.089	-.13	.28	-.076	-.10	-.15	-.14	-.18	-.21	.701	-13.5	7.69						
						3	.075	-.11	.15	-.29	.079	-.12	.14	.17	.21	-.21	.627	7.69	-8.86						
	26 B	29,660	1.6	.61 S	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
6-11-66	26 A	--	--	--	--	1	--	--	.025	.072	.027	.034	.021	.021	.060	.067	--	--	--	.69	.64	1.00	2.08	.072	--
						2	--	--	.025	-.053	.027	-.034	.026	-.017	-.062	-.017	--	--	--						
						3	--	--	.021	.055	-.027	.034	.021	.017	.085	.051	--	--	--						
	26 B	29,920	1.51	.10 S	238.0	1	.079	-.080	-.11	-.18	.055	.045	.051	-.061	.15	.21	-.390	10.3	7.49	2.00	.67	.36	1.56	.079	46.6
						2	.074	.060	.093	-.20	-.065	-.067	.068	.063	-.12	.23	.444	-18.6	-10.3						
						3	.061	-.080	-.085	.22	.055	.045	-.060	-.061	.18	-.19	.433	- 8.98	8.86						
	38 A	--	--	--	--	1	.099	-.10	-.17	.35	.155	-.15	-.18	.23	.22	.32	-.617	8.98	- 9.69	2.07	.67		2.02	.071	--
						2	-.13	.11	.16	-.31	.153	.19	.16	-.24	-.20	-.31	-.661	-16.7	8.17						
						3	.12	-.135	-.15	.41	-.180	.18	.18	.23	.23	.28	.812	- 6.11	-8.18						
	38 B	29,700	1.52	0	232.6	1	-.059	-.060	.080	-.17	.055	.067	.038	-.030	.12	.21	-.379	8.98	-9.69	1.74	.71	-.36	1.52	.079	19.4
						2	.071	.065	-.085	-.18	-.065	.056	-.013	.012	-.087	-.12	.122	-17.3	9.51						
						3	-.071	-.065	.063	.17	.060	-.051	-.013	-.065	.12	.15	.317	- 9.62	-7.87						
	37 A	29,700	1.19	0	231.2	1	-.059	-.075	.088	.22	.065	-.073	.077	.092	.15	.23	.422	8.98	-7.87	1.65	.64	.36	1.39	.079	48.7
						2	.089	.070	-.094	-.21	-.087	.11	-.081	-.096	.17	-.16	.531	-14.7	6.81						
						3	.084	-.090	.109	-.27	.087	-.067	.094	.10	-.13	.19	.487	- 7.05	-8.48						
	37 B	21,080	1.39	.02 S	231.0	1	.089	-.125	-.21	.43	.126	-.24	.24	-.20	-.27	.38	-.823	10.3	-9.08	2.26	.75	.40	2.77	.075	53.2
						2	-.084	.105	.195	.16	.175	.26	.19	.22	.32	-.33	.845	-15.4	8.86						
						3	.094	-.13	-.18	-.39	-.126	-.17	.21	.21	-.32	.38	-.867	- 8.31	-7.87						
6-15-66	1X-A	11,080	1.21	.17 N	236.0	1	-.13	-.15	.037	--	.116	.11	.15	.20	-.22	.12	.832	15.0	9.51	1.26	1.13	1.55	3.75	.079	62.1
						2	.11	.13	.025	--	.134	-.13	-.16	-.17	.21	-.11	-1.13	-27.6	-16.7						
						3	.13	-.14	.029	--	.107	.11	.17	-.18	-.21	.31	1.26	--	12.9						
	1X-B	28,140	1.5	.13 N	233.0	1	-.051	.050	--	.18	.095	-.080	-.089	.083	.11	.25	-.381	8.86	6.13	.50	.65	.95	1.51	.079	18.1
						2	.071	-.067	--	-.20	.095	.068	.081	.10	.12	-.17	.491	-14.1	-7.69						
						3	.071	.060	--	.18	-.054	-.097	.085	.087	.11	.16	.373	--	8.17						
6-15-66	2X A			.66 N	251.0	1	.094	-.072	--	.33	.112	-.094	.081	-.074	.097	.18	-.514	-20.5	-11.5	.70	.87	.87	1.74	.092	63.5
						2	.096	.070	--	.30	-.102	.15	-.11	.078	-.085	-.17	-.533	14.3	8.86						
						3	-.10	.060	--	-.36	.129	.14	-.11	-.091	-.10	.16	.619	-19.2	-12.8						
	2X B	14,080	1.20	.22 N	233.0	1	-.17	-.20	.033	--	.123	-.097	-.16	-.17	.26	.50	--	17.0	10.2	1.26	1.26	1.86	1.36	.079	62.0
						2	.23	.17	--	--	.107	.14	.16	.15	-.30	-.36	--	-30.1	-19.2				--		
						3	-.19	-.13	--	--	-.097	-.11	.16	.17	.28	.31	--	13.6	11.6						
	3X A	29,100	1.58	.17 N	234.0	1	.046	.050	--	.14	.079	.097	.11	.083	.097	.11	.373	8.17	--	.46	.52	.75	1.31	.075	51.5
						2	.046	-.011	--	-.16	.090	-.18	-.13	.083	.11	-.14	.331	-10.3	-6.41						
						3	-.046	.060	--	.16	.101	.12	.14	-.087	.080	.15	-.288	7.49	6.81						

Table IV Continued,

Date	[illegible] No.	Altitude -1 ft.	Mach No.	Lateral Dist. Naut. Mi.	Mag. Hdg. deg.	Reading Point	Peak Amplitude Accelerometer Channels g's											Strain Gage μ in./in.		P1 lb/ft²			Po Avg. lb/ft²	t Avg. sec.	Vert. Wave Angle deg.
							301	302	303	304	305	306	307	308	309	310	311	312	313	105	107	109			
6-15-66	[illegible] B	11,200	1.15	.18 N	235.0	1	-.096	-.12	--	.36	-.097	-.10	.17	.12	.20	-.23	-.875	11.3	9.51	.91	.95	1.63	2.25	.077	63.5
						2	.11	.099	--	.50	-.081	.097	-.11	.11	-.17	.26	.853	-25.0	-11.7						
						3	.10	-.087	--	.19	-.066	-.091	-.11	-.16	.21	-.27	.717	--	--						
	18 A	11,[illegible]	1.28	.18 N	235.0	1	.19	.099	.029	.51	.150	.21	.30	.27	.36	.52	.917	15.0	10.2	.95	1.01	1.59	3.36	.067	55.0
						2	-.11	-.13	-.021	--	.202	-.27	-.26	-.27	-.11	-.13	-1.15	-21.8	-15.1						
						3	.15	-.13	--	--	.208	-.23	.25	.21	.16	.51	.896	--	--						
	18 B	29,850	1.62	.11 S	233.5	1	.11	.099	--	.28	.112	.080	-.085	.13	.25	.10	.701	12.9	8.17	.85	.78	1.03	2.56	.077	15.6
						2	-.091	-.098	--	-.33	.073	-.10	-.10	-.12	-.23	-.30	.811	-21.8	-11.1						
						3	.12	.099	--	.31	-.075	.097	.10	-.16	.22	-.31	.779	--	10.2						
6-16-66	27 A	29,300	1.65	.10 S	230.3	1	.051	-.071	.020	.20	.051	-.093	.11	-.091	-.11	.28	-.116	7.69	-6.06	.62	.55	.81	1.51	.075	13.1
						2	-.098	.079	-.020	-.21	-.051	.11	.12	.17	.18	.22	.512	-12.2	6.81						
						3	.069	-.10	.020	.26	.065	-.087	.11	.18	-.18	-.22	.127	5.13	-5.15						
	27 [illegible]	20,510	1.10	.26 S	228.5	1	.061	-.099	.022	.21	-.087	-.12	.13	.13	.18	.30	-.511	7.69	5.15	.65	.72	1.13	1.73	.073	51.1
						2	-.073	.065	-.022	-.21	.092	.13	-.11	.15	-.16	-.21	.701	-13.5	-7.27						
						3	.073	-.11	-.022	.27	.076	-.13	.12	-.13	.16	-.22	.555	-7.69	6.81						
	5X	29,700	1.65	.25 E	311.0	1	.061	-.060	.022	-.18	-.019	.037	-.11	-.10	.26	-.20	-.309	9.62	7.19	.67	.76	.69	1.78	.071	11.8
						2	.069	.060	-.039	.19	.076	.057	.066	-.12	-.28	.20	.137	-20.5	-8.18						
						3	-.061	-.070	.020	-.19	-.051	-.082	-.011	-.11	-.22	.19	-.331	7.69	6.81						
6-22-66	28 B	20,820	1.35	.16 S	233.0	1	.11	-.13	-.18	.61	.16	-.28	.36	.31	.31	.50	.331	12.0	-13.5	.93	.82	1.52	2.60	.078	50.1
						2	-.11	.11	.18	-.56	.15	.33	.31	-.36	-.38	-.39	.351	-19.1	8.98						
						3	.11	-.13	.11	.56	-.16	-.29	.10	.31	.35	.11	.317	-27.2	-10.3						
	19 B	29,500	1.12	.20 S	233.5	1	.086	-.080	.13	.29	.087	.13	.18	.16	.20	.32	.260	8.72	-12.8	.66	.71	1.09	1.87	.088	52.8
						2	.076	.075	-.12	.10	-.10	-.11	.21	.20	-.187	-.35	-.213	-13.6	7.69						
						3	.081	.075	.12	-.11	-.087	.17	-.18	-.17	.271	.11	.256	-25.9	-11.5						
	30 B	29,720	1.39	.16 S	232.5	1	.030	.030	.033	-.13	.033	.010	.035	-.052	.051	-.089	-.069	7.09	-7.70	.52	.51	.62	.99	.092	62.0
						2	-.030	-.030	.038	-.13	-.038	.010	-.035	-.013	.068	.089	.071	-27.2	5.13						
						3	.010	.030	-.033	-.15	-.033	-.010	.035	-.052	.017	-.071	.078	7.63	-7.69						
	31 A	29,600?	1.39		232.8	1	-.051	-.055	.083	-.23	.051	.016	-.021	-.061	-.093	.12	-.113	-35.1	5.13	.49	.56	.92	1.14	.091	--
						2	.056	.050	-.083	.21	-.051	-.075	-.011	.061	.10	-.13	.156	8.72	-11.5						
						3	-.071	.055	.092	-.31	-.051	-.037	-.053	-.063	.102	.13	-.117	8.18	9.62						
	21 B	20,860	1.36	.23 S	231.3	1	.091	-.080	-.096	.19	-.11	.15	.23	.30	-.36	.39	.325	9.81	6.11	.63	.67	1.05	2.10	.078	55.0
						2	-.091	.090	.10	.11	-.13	-.33	-.21	-.28	-.44	-.11	.360	-32.7	-7.69						
						3	.066	-.090	.083	.51	-.11	.11	.26	.28	.31	-.17	.391	10.4	7.69						
	35 B	21,060	1.28	.25 N	225.3	1	.071	-.100	.17	-.12	-.11	-.11	.15	.20	.16	.27	.173	9.27	-8.98	.77	.71	1.09	2.41	.082	59.5
						2	-.071	.105	-.17	.65	.13	.15	-.17	.17	.20	-.21	-.321	-31.1	-8.31						
						3	.071	-.100	.16	-.56	-.17	-.11	.11	-.18	-.16	.30	.325	-19.1	7.69						
	25 A	21,900	1.39	.21 N	233.0	1	-.071	-.090	.092	.25	.065	.069	.070	.069	.15	.31	-.213	8.72	-10.3	.69	.69	.78	1.17	.075	51.4
						2	-.091	.100	-.12	-.26	-.076	-.092	-.061	.069	-.18	-.22	.239	-31.3	6.11						
						3	.076	-.095	.13	.23	-.070	-.080	.061	.071	.17	.28	.191	7.63	-11.5						
	23 A	29,720	1.51	.31 N	237.0	1	.056	.035	-.050	.22	-.035	.057	-.053	-.061	.11	.18	.152	8.72	-11.5	.61	.71	1.05	1.43	.083	--
						2	.061	-.060	.016	-.21	-.019	-.057	-.011	-.056	.17	.22	-.139	-35.4	7.69						
						3	-.051	.070	-.012	.19	.080	.063	.011	.013	.16	-.15	.156	-21.8	-12.8						

Table IV (Continued)

Date	Mission No.	Altitude msl ft.	Mach No.	Lateral Dist. Naut. mi.	Mag. Hdg. deg.	Reading Point	Peak Amplitude													-Pi lb ft²			-Po Avg. lb ft²	t Avg. sec.	Vert. Wave Angle deg.
							Accelerometer Channels g's											Strain Gage μ in./in.							
							301	302	303	304	305	306	307	308	309	310	311	312	313	105	107	109			
6-23-66	17 B	21,600	1.10	.16 S	227.5	1	.068	-.091	-.10	-.30	.054	-.088	-.017	.056	.11	.19	.510	8.72	5.77	.71	.61	1.07	1.58	.076	[illegible]
						2	-.083	.080	.10	-.29	-.060	.12	-.017	-.065	-.16	-.16	-.520	-70.8	-12.3						
						3	.073	-.086	.10	.30	-.065	-.088	-.017	-.078	.16	-.16	.512	-16.3	-13.1						
	22 A	29,260	1.10	0	232.0	1	-.068	-.080	-.11	.33	.051	-.11	-.10	-.091	.16	.21	.531	9.27	-11.6	.61	.64	1.03	1.61	.082	[illegible]
						2	.078	.075	.13	-.26	-.051	.083	.12	.087	-.15	-.22	-.166	-70.8	9.62						
						3	-.083	-.070	-.11	.23	-.087	-.083	.098	-.11	.15	.26	.510	8.72	-10.2						
	31 B	21,260	1.35	0	232.0	1	.088	-.10	.12	-.33	-.087	.11	.29	.12	.19	.31	-.585	8.72	-13.1	.71	.59	1.15	2.18	.077	[illegible]
						2	-.11	.080	-.15	-.10	.076	.13	.27	-.16	-.21	-.23	.607	-70.8	7.69						
						3	.098	-.10	.15	.32	-.081	-.11	-.29	-.13	.18	.25	-.607	-10.9	-12.3						
	33 B	29,810	1.19	[illegible]	229.8	1	.11	.091	-.11	.12	.065	.072	-.077	-.071	.20	.33	-.629	9.81	-12.3	.71	.62	1.17	1.82	.081	19.7
						2	-.10	-.11	.18	-.31	-.070	-.10	-.073	.10	-.17	-.29	.629	-79.0	9.62						
						3	.083	.10	-.11	-.27	.070	-.10	-.081	-.096	.26	.11	.651	8.18	10.3						
	20 A	21,520	1.37	.19 N	233.2	1	-.098	-.12	-.18	-.10	.081	.12	-.21	.21	-.25	.33	-.716	9.81	-15.3	.77	.81	1.36	1.88	.079	55.2
						2	.13	.091	.21	-.18	.11	.10	.21	.19	.26	-.32	.856	-76.3	-11.6						
						3	-.11	-.11	-.17	.10	.087	-.12	-.21	-.21	.32	.33	.813	9.81	10.5						
	36 A	20,860	1.39	.37 S	230.2	1	.093	-.11	-.15	.13	-.11	-.15	.18	.16	.27	.11	.781	8.72	7.05	.71	.62	.99	2.09	.079	33.3
						2	-.11	.091	.17	.53	-.12	-.18	-.17	.16	-.23	.32	-.835	-62.7	-10.9						
						3	.11	-.13	-.15	-.11	-.12	-.17	.17	-.16	-.33	-.36	1.15	6.00	-11.6						
	7 X	29,610	1.55	.20 S	257.6	1	-.078	-.060	.073	-.13	-.051	-.061	-.013	.061	.13	.15	-.112	10.1	-18.9	.77	.72	.86	2.03	.081	--
						2	.083	.050	-.081	-.11	.051	.061	-.038	.065	-.090	-.091	.101	-122.6	11.5						
						3	.078	.050	.093	.18	.060	-.055	-.038	-.069	.12	.10	.561	11.1	13.5						

* Att: Mach No. at 12 Naut. mi. E

Table IV (Continued)

SONIC BOOM INDUCED ACCELERATION AND STRAIN RESPONSES OF TEST STRUCTURE NO. 2 FOR A RANGE OF XB-70 FLIGHT CONDITIONS.

Date	Flight Test No.	Altitude msl ft.	Mach No.	Lateral Dist. Naut. mi	Mag. Hdg. deg.	Reading Point	Peak Amplitude													ΔP_1 lb/ft^2			ΔP_0 Avg. lb/ft^2	Δt Avg. sec.	Vert. Wave Angle deg.
							Accelerometer Channels g's											Strain Gage ε, in./in.							
							301	302	303	304	305	306	307	308	309	310	311	312	313	405	407	409			
6-1-66	13			2.5 N		1		.115	.146		.104		-.168	.149	.195	.337	.481	23.2	10.2	1.16	1.87	0.86	2.39	.250	42.5
						2		-.156	-.143		-.090		.212	-.197		-.266	--	-31.3	--						
						3		-.143			.102	-.111	-.155	-.140	.161	.199	.537	27.9	--						
6-6-66	22	72,000	2.83	4.10 N		1	-.051	.090	.071	.182			-.115	-.091	.123	-.170	.271	12.2	5.22	1.00	1.05	1.11	1.63	.315	--
						2	.096	.095	-.076	-.203				.070	-.111	.228	.304	-15.6	--						
						3	-.071	.085	.076	-.148				-.074	.131	-.183	.271	--	--						
6-8-66	1	21,850	1.38	5.02 S	246.0	1	.142	-.100	.080	.309	-.051	.063	.019	.066	.068	-.075	-.542	16.0	9.31	1.25	1.95	.91	2.21	.233	61.8
						2	-.159	.090	-.084	.368	.087	-.080	-.053	-.052	-.093	.080	.477	-25.2	6.32						
						3	.152	-.065	-.084	.296	-.098	.080	-.053	.018	-.085	-.089	-.607	29.1	--						

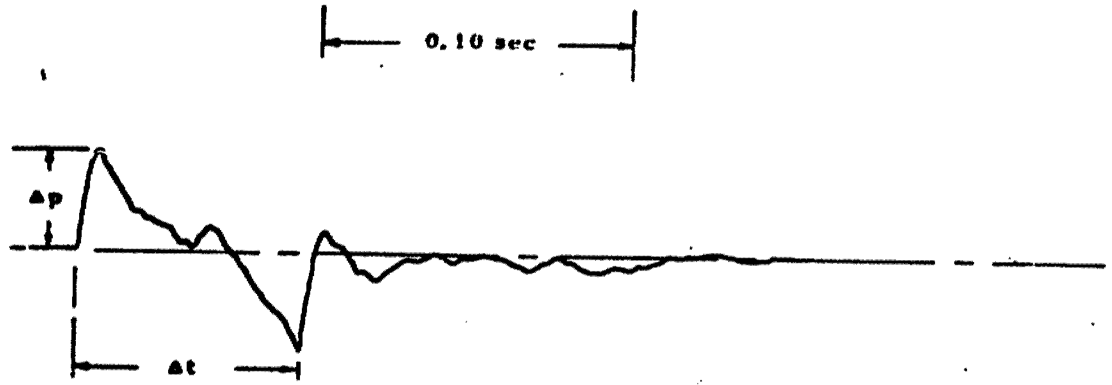
Table IV (Continued)

ENGINE NOISE INDUCED ACCELERATION AND STRAIN RESPONSES OF TEST STRUCTURE NO. 2 FOR A RANGE OF KC-135 FLIGHT CONDITIONS

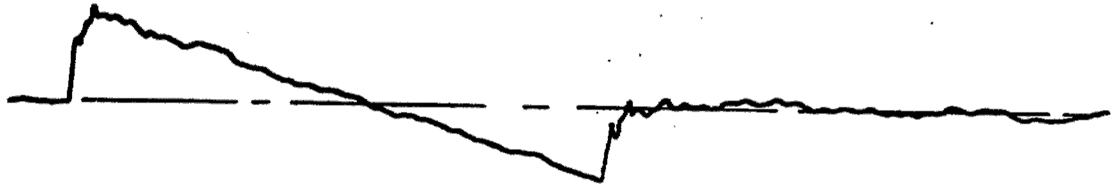
Date	Mission No.	Altitude msl ft.	EPR	Velocity Kts.	Maximum Peak Amplitude													Noise Levels, dB			
					Accelerometer Channels g's											Strain Gage ε, in./in.		RMS Out-side	Peak Inside		
					301	302	303	304	305	306	307	308	309	310	311	312	313	205	401	402	403
6-6-66	39B	10,300	1.6	310	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	70B	5,100	1.5	260	--	--	--	.11	--	--	--	.013	--	.013	--	--	--	84.8	123.6	122.0	123.5
	40B	5,400	1.5	280	--	--	--	.013	.016	.011	.019	.013	.013	.016	.027	--	.57	81.8	123.6	124.9	121.9
	71B	3,500	1.5	290	--	--	--	.036	.022	.017	.030	.026	.017	.022	.019	--	.45	102.9	127.1	127.1	127.1
	11B	3,300	1.5	238	--	--	--	.051	.027	.022	.031	.039	.017	.022	.043	--	.80	101.1	127.1	128.0	127.9
	72B	2,800	1.5	290	--	--	--	.085	.011	.011	.059	.054	.032	.042	.11	--	.80	108.9	128.0	128.9	127.9
	43B	11,300	2.35	325	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	71B	8,300	2.35	328	--	--	--	.025	.019	.014	.025	.017	.021	.018	.043	--	.80	105.7	126.1	123.6	126.0
	41B	8,300	2.35	330	--	--	--	.12	.057	.055	.081	.100	.053	.071	.13	--	.90	111.1	131.0	132.1	133.0
	75B	3,300	2.35	213	--	--	--	--	--	--	--	--	--	--	--	--	--	--	111.5	115.2	148.1
	42B	2,800	2.35	213	--	--	--	--	--	--	--	--	--	--	--	--	--	--	149.6	147.9	151.1
	73B	2,520	2.35	213	--	--	--	.070	.016	.030	[illegible]	.054	.030	.060	.076	--	.80	106.9	128.9	128.9	127.9
6-7-66	76B	4,360	2.35	190	.007	--	.008	.20	.054	.10	.092	.18	.075	.012	.16	1.65	1.11	106.9	--	--	--
	45A	3,000	2.35	195	.015	.018	.017	.12	.15	.21	[illegible]	.39	.11	.29	[illegible]	1.65	1.11	111.8	--	--	--
	77A	3,000	2.35	190	.022	.030	.021	.41	.15	[illegible]	[illegible]	.31	.15	[illegible]	.37	[illegible]	2.00	115.1	--	--	--
	16A	2,620	2.35	190	.015	.050	.021	.50	.19	.14	[illegible]	.22	.13	.20	.22	1.65	1.40	116.2	--	--	--
	18B	3,000	2.35	205	.015	.025	.017	.45	.16	.20	.020	.37	.077	.21	.31	--	1.33	111.8	--	--	--
	79B	2,620	2.35	195	.039	--	.011	--	--	--	--	--	--	--	--	--	3.11	--	--	--	--
	19B	1,300	2.35	195	.024	--	.013	.12	.054	.058	[illegible]	.15	.066	.060	.19	--	1.11	110.1	--	--	--
	80B	3,000	2.35	190	.029	.038	.033	.11	.20	.16	.24	.37	.18	.19	.10	--	1.56	115.6	--	--	--
	50B	8,300	2.35	200	.020	--	.002	.013	.003	.017	.001	.025	.004	.013	.005	--	.67	--	--	--	--
	81B	1,300	2.35	195	.007	--	.008	.12	.019	.066	.12	.11	.012	.11	.007	--	1.00	106.2	--	--	--
6-8-66	13B	11,300	2.35	182	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	75B	8,300	2.35	168	--	--	--	.013	--	--	--	.013	--	.018	--	--	--	101.0	122.1	121.9	122.2
	12B	2,800	1.5	160	--	--	--	.10	.013	.031	.10	.088	.051	.073	.098	--	.67	108.5	133.2	131.5	131.0
	73B	2,552	1.5	175	.020	.023	.019	.19	.10	.11	.19	.25	.11	.16	.26	--	1.33	111.6	138.8	137.2	139.2
	11B	5,300	1.5	157	--	--	--	.015	--	--	--	.013	--	.063	--	--	--	97.7	122.1	124.9	121.6
	72B	2,800	1.5	171	--	--	--	.068	.019	.010	.077	.071	.017	.058	.098	--	.89	107.8	131.1	130.2	132.2
	57RA	3,300	1.5	166	--	--	--	.051	.019	.023	.075	.033	.017	.027	.054	--	.69	100.4	129.0	130.9	128.4
	80RA	2,800	1.5	169	--	--	--	.078	.033	.010	.080	.077	.059	.066	.098	--	.89	106.7	130.4	130.2	131.6
	56RA	5,300	1.5	155	--	--	--	--	--	--	--	--	--	--	--	--	--	97.7	122.1	124.9	119.6
	81RA	3,300	1.5	166	--	--	--	.038	.019	.017	.035	.035	.025	.031	.054	--	.56	102.9	126.2	126.0	126.7
	53RA	10,300	1.5	146	--	--	--	--	--	--	.018	--	.013	--	.033	--	.44	92.5	123.7	121.9	123.2
	86RA	5,300	1.5	176	--	--	--	.013	.014	.023	.018	.010	.013	.009	.027	--	--	96.9	122.1	123.5	121.6

Table IV Concluded

Date	Mission No.	Altitude msl ft.	LPR	Velocity Kts.	Maximum Peak Amplitude													Noise Levels, dB			
					Accelerometer Channels g's											Strain Gage ∊, in./in.		RMS Out-side	Peak Inside		
					301	302	303	304	305	306	307	308	309	310	311	312	313	205	401	402	403
[illegible]	80A	5,300	1.5	171	--	--	--	.068	.025	.026	.021	.017	.017	.022	--	--	.41	91.1	--	125.1	--
	57A	10,300	1.5	225	--	--	--	.027	.028	--	.012	.013	.021	.013	.032	--	.65	91.1	--	123.8	--
	87A	3,300	1.5	190	--	--	--	.040	.028	.023	.030	.039	.030	.031	.053	--	.65	92.8	121.8	126.3	--
	56A	5,300	1.5	173	--	--	--	.017	.017	--	.013	.017	.013	.013	.032	--	.87	100.1	120.2	123.8	--
	80A	2,800	1.5	173	.001	.010	.013	.085	.028	.040	.047	.083	.038	.076	.085	--	.65	98.8	127.8	128.2	96.2
	57A	3,300	1.5	170	.011	--	.050	.042	.034	.017	.061	.022	.064	.027	.096	--	.87	96.3	120.2	127.3	--
	72	2,300	1.5	172	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	115B	5,300	1.5	152	--	--	--	.021	.017	.017	.013	.017	.013	.013	.032	--	.65	92.8	118.3	126.3	--
	735B	2,550	1.5	178	.015	.021	.017	.18	.073	.092	.11	.14	.076	.13	.21	--	1.31	103.2	130.9	130.5	92.6
	125B	2,800	1.5	158	.015	.020	.017	.097	.051	.046	.072	.087	.059	.067	.12	--	.76	105.2	127.8	130.5	92.6
	755B	8,300	2.35	162	--	--	--	.013	.011	--	.013	.013	.013	.013	.021	--	.41	96.3	120.2	123.8	--
	135B	11,300	2.35	135	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	125B	2,800	1.5	162	.015	--	.029	.085	.045	.032	.055	.044	.017	.015	.12	--	.87	99.5	127.1	129.8	--
	165B	3,300	2.35	172	.020	.054	.025	.19	.25	.22	.29	.48	.19	.28	.53	--	2.18	117.8	138.3	145.5	105.2
	725B	2,800	1.5	161	--	.015	.017	.085	.051	.016	.068	.066	.038	.051	.096	--	.65	102.8	126.3	128.2	96.2
6-20-66	18B	5,280	1.[illegible]	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	79B	3,300	1.[illegible]	190	--	--	--	.035	.033	.017	.017	.017	.025	.018	.051	--	--	122.2	127.2	125.1	102.1
	53B	4,300	2.35	200	--	.015	.002	.14	.070	.029	.11	.11	.068	.075	.14	--	--	131.0	130.3	127.2	104.5
	81B	3,000	2.30	195	.020	.031	.001	.39	.21	.21	.33	.34	.26	.24	.41	--	--	139.2	140.1	143.3	110.6
	51B	3,000	2.3	195	--	.036	.005	.13	.26	.21	.31	.37	.20	.28	.15	1.92	--	137.8	141.2	142.6	110.6
	59A	12,000	2.35	180	--	--	--	.017	.011	.011	.013	.013	.017	.013	--	--	--	115.6	123.7	125.1	--
	98A	6,000	2.35	200	--	--	--	.022	.033	.023	.059	.039	.038	.018	.087	--	--	121.0	127.2	126.2	100.5
	60A	6,000	2.35	175	--	--	--	.061	.038	.031	.055	.070	.012	.019	.087	--	--	121.0	129.7	129.7	100.5
	90A	6,000	2.35	175	--	--	--	.035	.038	.029	.047	.044	.051	.035	.013	--	--	129.8	129.7	131.6	100.5
	85B	2,000	2.30	185	.030	.071	.009	--	--	--	--	--	--	--	.71	2.56	2.73	--	150.0	151.7	118.5
	93A	2,600	2.30	195	.040	.056	.010	--	--	--	--	--	--	--	--	2.56	1.36	--	151.7	151.3	119.8
6-21-66	89A	2,500	1.5	220	.010	.023	.031	.17	.15	.18	.25	.59	.15	.18	.32	--	1.36	117.0	139.3	129.1	108.0
	58A	2,800	1.5	205	.010	--	.002	--	.051	.080	.086	.056	.036	.040	.081	7.19	1.02	110.9	132.3	129.1	102.0
	99A	4,300	2.35	191	.008	--	.002	.15	.081	.063	.12	.12	.081	.080	.16	--	1.36	114.6	131.7	129.8	104.5
	66A	2,800	1.5	210	.015	.015	.002	.11	.013	.051	.088	.091	.053	.066	.14	--	1.36	111.5	131.1	132.3	102.0
	100A	3,000	2.35	200	.023	.025	.005	.47	.22	.20	.31	.19	.22	.24	.58	--	1.70	121.0	141.7	138.6	108.0
	68A	8,300	2.35	175	.008	--	.002	--	.008	--	.009	.013	.009	.013	.022	--	1.36	103.0	123.8	--	--
	69A	1,300	2.35	195	--	.010	--	.12	.051	.016	.071	.10	.030	.075	.019	--	--	112.5	129.1	126.3	102.0
	48B	5,300	1.5	198	--	--	--	.021	.008	.011	.011	.013	.011	.009	.022	--	1.02	99.4	123.8	125.1	--
	40B	5,300	1.5	197	--	--	--	--	.011	--	.011	.013	.009	--	.022	--	1.36	103.0	123.8	123.8	--
	60A	8,300	2.35	176	--	--	--	.032	.016	.014	.020	.022	.015	.022	.033	--	--	101.1	123.8	123.8	--
	61A	4,300	2.35	200	--	--	--	.11	.054	.051	.071	.11	.032	.058	.076	--	--	112.5	132.8	131.7	101.5
	101A	2,600	2.35	175	.013	.055	.010	--	--	--	--	--	--	--	--	2.73	2.38	--	151.0	150.4	119.1
	35B	2,600	2.35	180	.018	.050	.009	--	--	--	--	--	--	--	.87	2.73	1.02	128.5	149.1	147.2	117.3



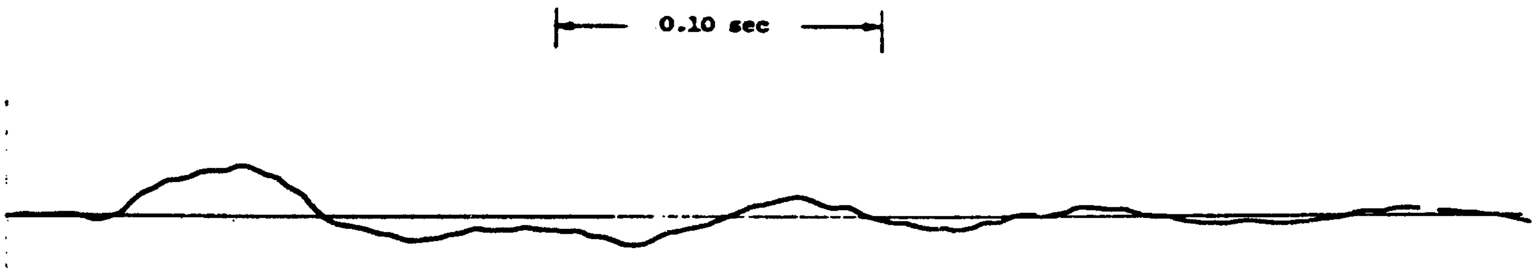
(a) F-104



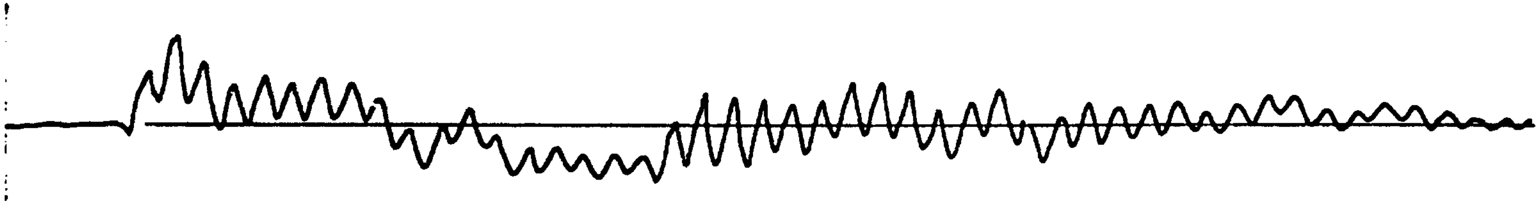
(b) B-58

(c) XB-70

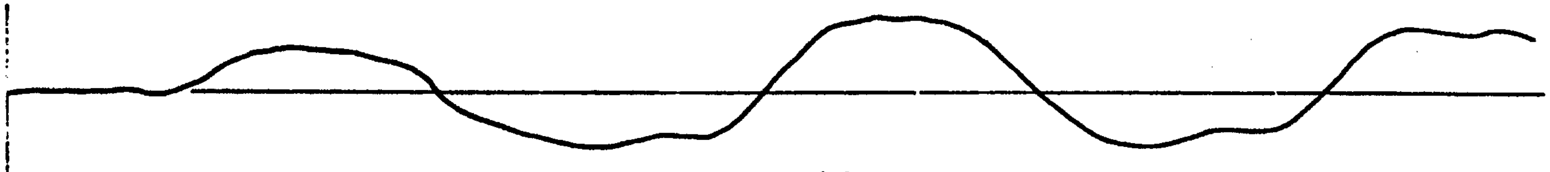
FIG. 1 TRACINGS OF SONIC BOOM SIGNATURES RECORDED DURING FLIGHTS OF THE THREE DIFFERENT AIRCRAFT FOR WHICH STRUCTURAL RESPONSE DATA WERE OBTAINED (Δp and Δt values are listed for each data flight in LWP 286.)



(a) Sliding door glass (Channel 210)



(b) Small window pane (Channel 211)



(c) Garage - plate glass window (Channel 212)

FIG. 2 TRACINGS OF RECORDS OF B-58 (Mission 80 RB) SONIC BOOM INDUCED STRAIN RESPONSES FOR THREE WINDOWS OF HOUSE NO. 1. (Strain amplitudes for each flight are listed in LWP 288.)

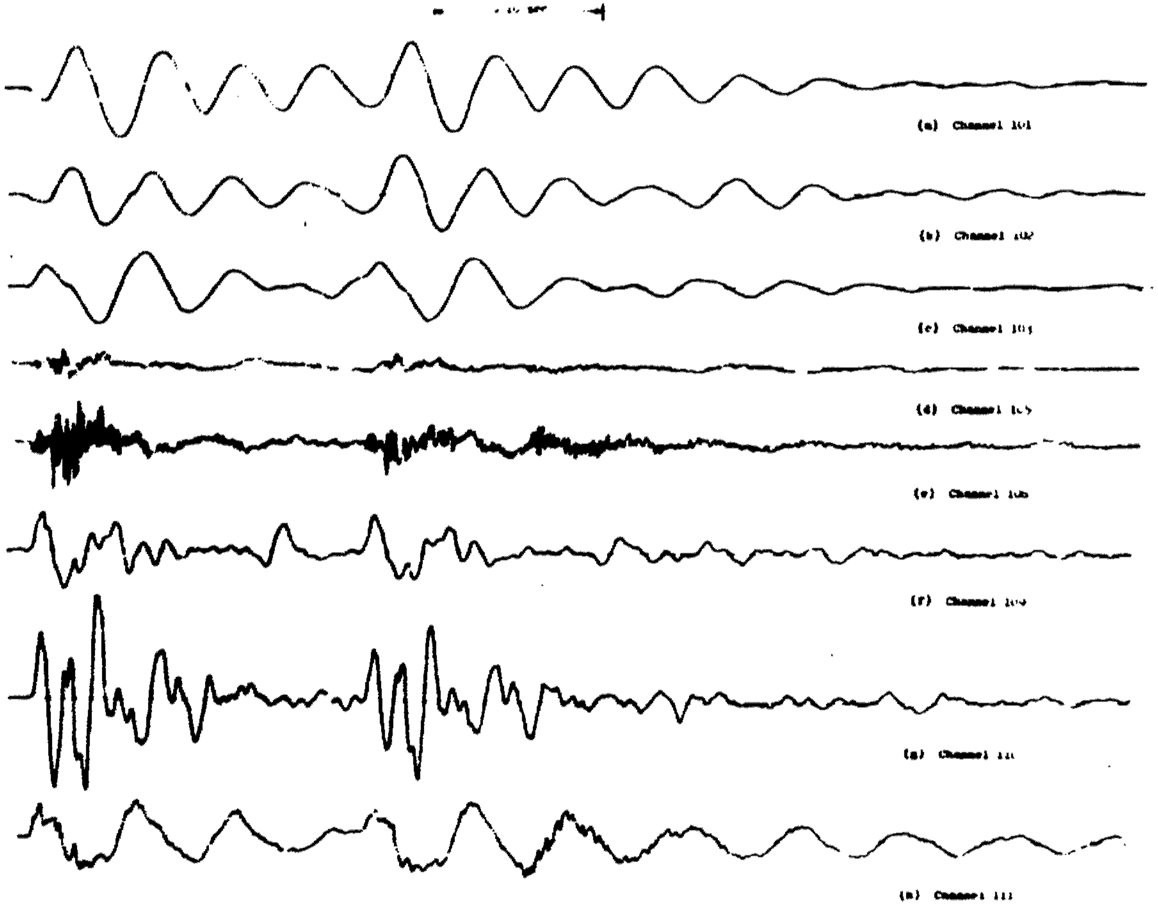
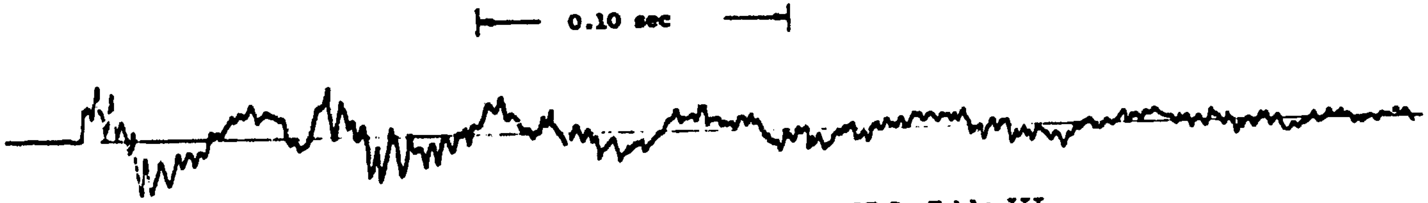
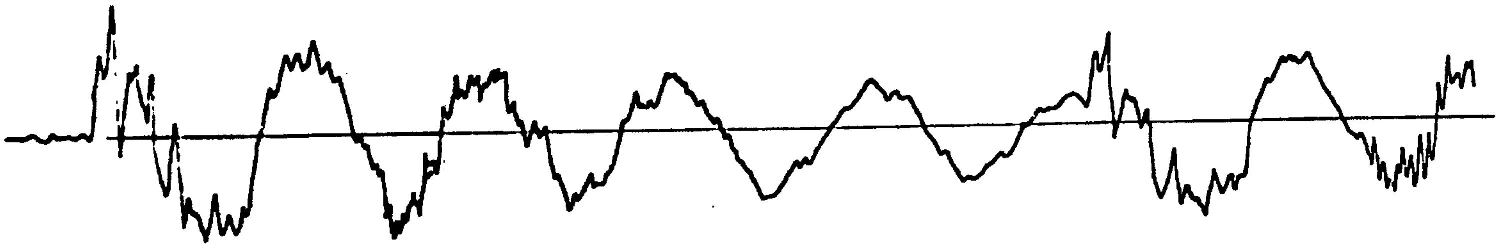


FIG. 3 TRACINGS OF RECORDS OF B-58 SONIC BOOM INDUCED ACCELERATION RESPONSES FOR EIGHT TRANSDUCER LOCATIONS AS DEFINED IN TABLE I FOR MISSION 18-B (Acceleration amplitudes are listed in LWP 288.)



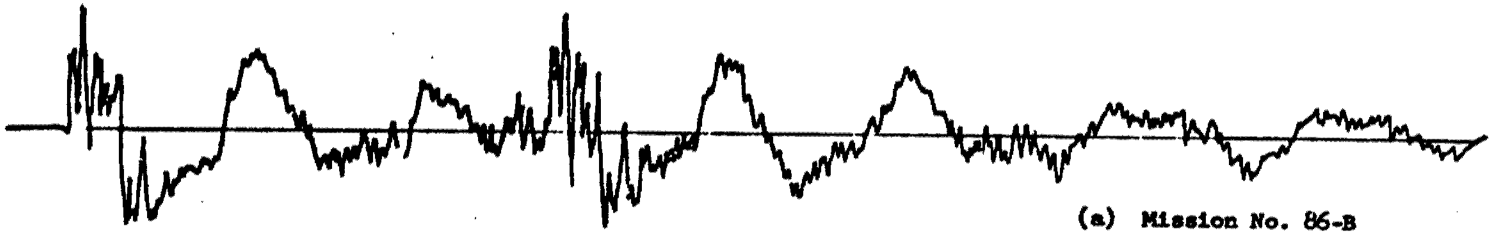
(a) F-104, Mission No. 37-B Table III

(b) B-58, Mission No. 73-A Table II

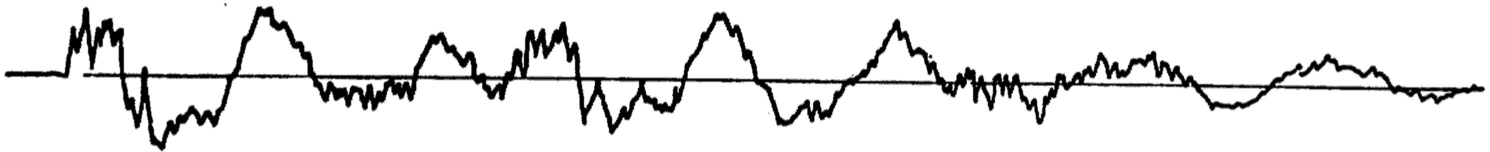


(c) B-70, Flight No. 22 Table IV

FIG. 4 TRACINGS OF TIME HISTORIES OF ACCELERATION RESPONSES OF THE BEDROOM EAST WALL (Channel 111) DUE TO EXCITATION FROM SONIC BOOMS FROM THREE AIRCRAFT

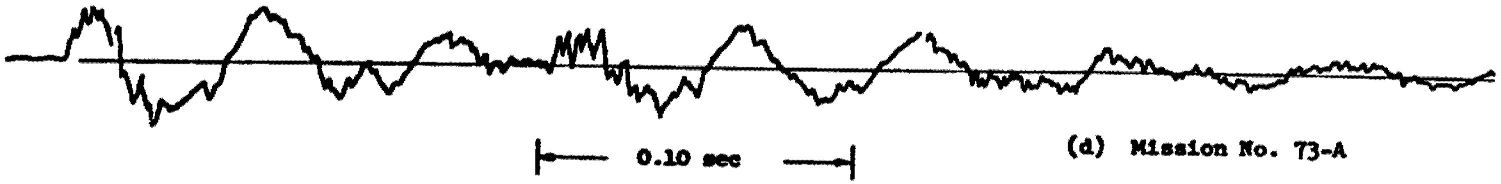


(a) Mission No. 86-B



(b) Mission No. 87-B

(c) Mission No. 80-B



(d) Mission No. 73-A

FIG. 5 TIME HISTORY TRACES OF ACCELERATION RESPONSES OF THE BEDROOM EAST WALL (Channel 111) DUE TO EXCITATION FROM THE B-58 SONIC BOOMS OVERHEAD FOR SEVERAL DIFFERENT MISSIONS

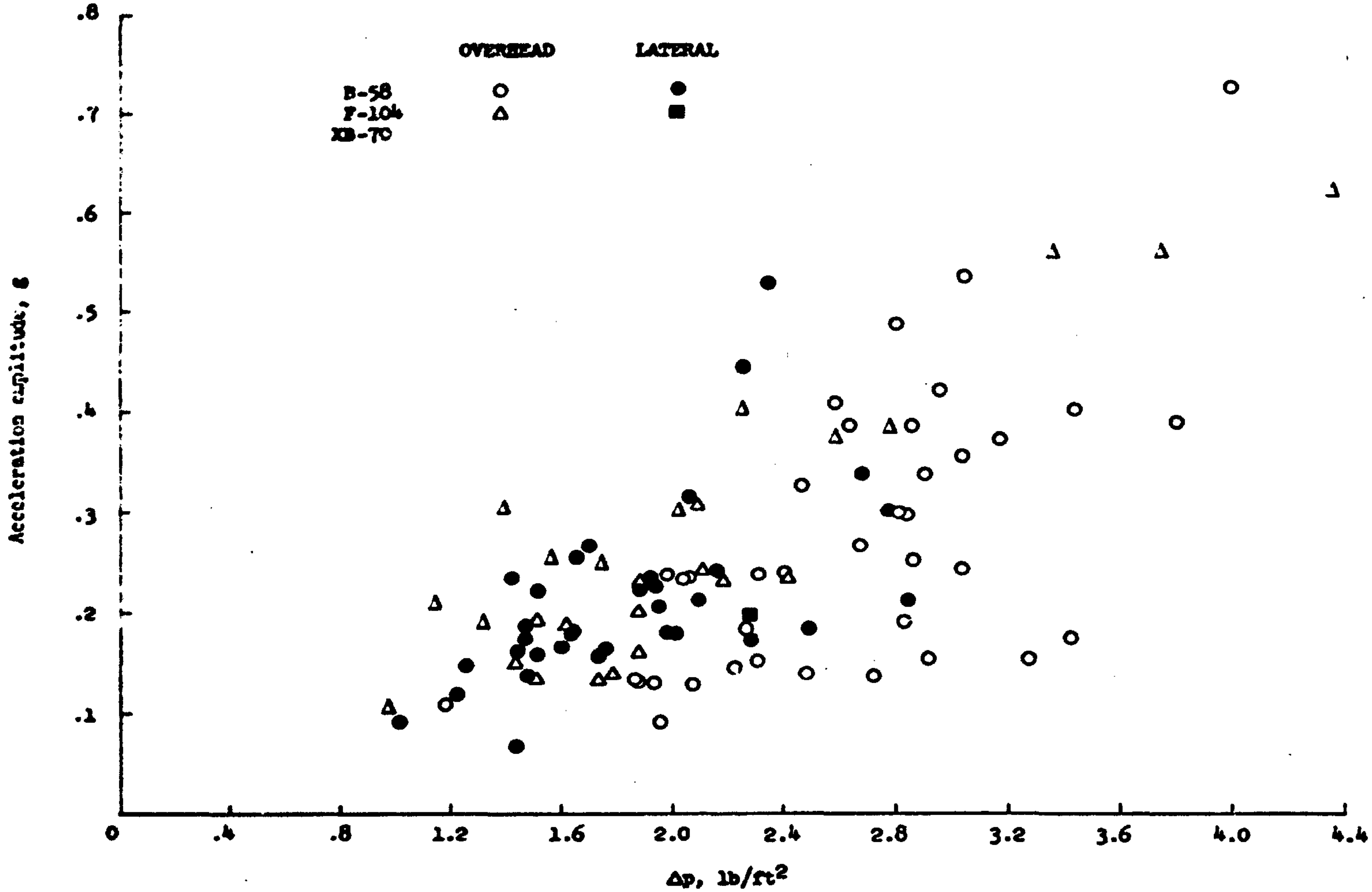
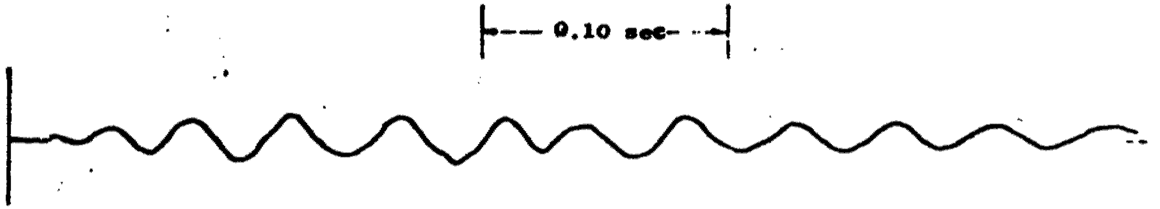
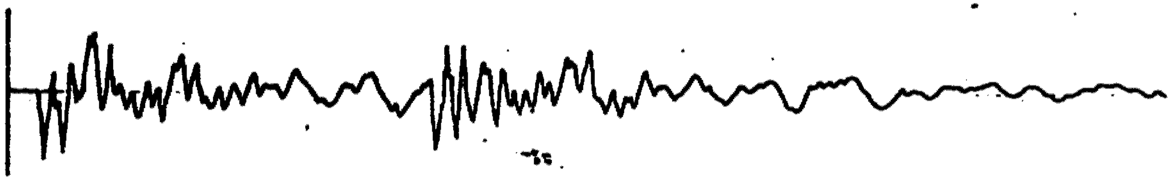


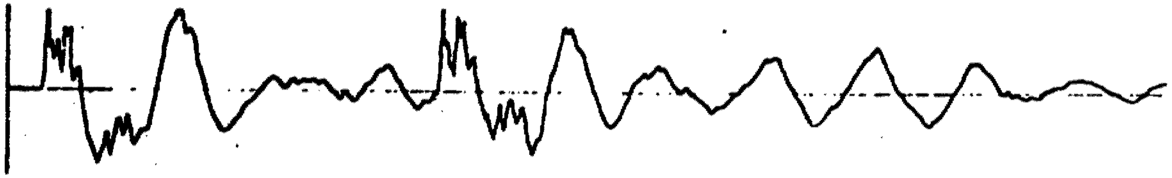
FIG. 6 PEAK ACCELERATION AMPLITUDE OF BEDROOM EAST WALL AS FUNCTION OF SONIC BOOM OVERPRESSURES FROM THREE DIFFERENT AIRCRAFT AND FOR TWO DIFFERENT FLIGHT TRACK POSITIONS. Data are for Channel 111 as listed in LWP 288.)



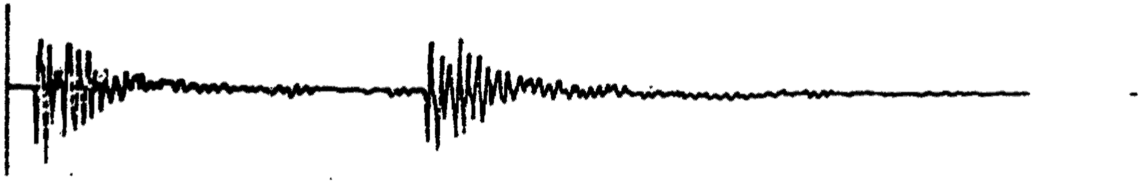
(a) Channel 303



(b) Channel 309

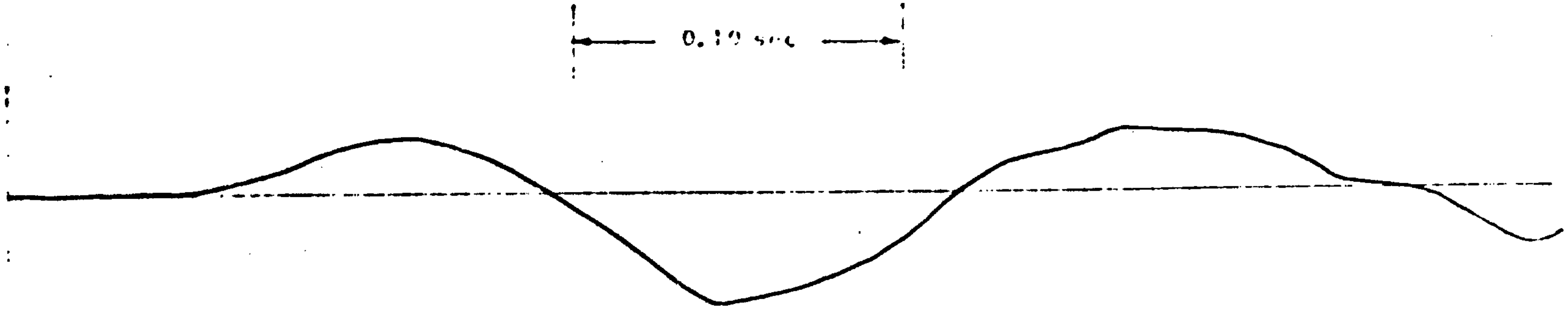


(c) Channel 311

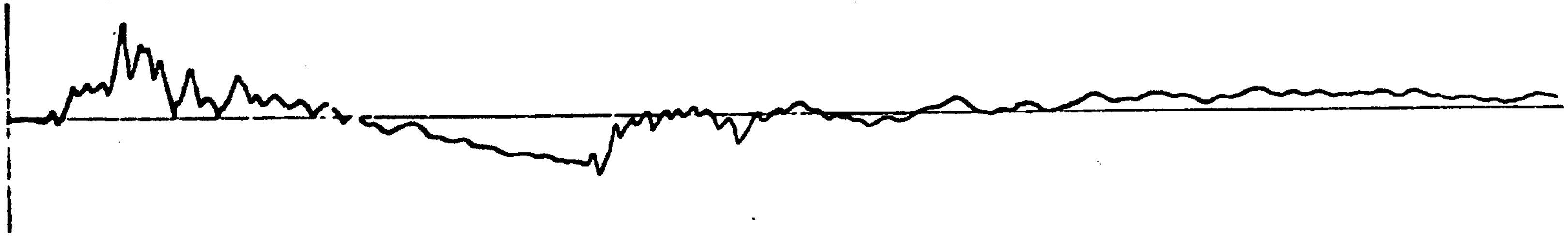


(d) Channel 308

FIG. 7 TRACINGS OF RECORDS OF B-58 SONIC-BOOM INDUCED ACCELERATION RESPONSES FOR FOUR TRANSDUCER LOCATIONS AS DEFINED IN TABLE I FOR MISSION NO. 80 RB
(Acceleration amplitudes are listed for each data flight in LWP 259.)

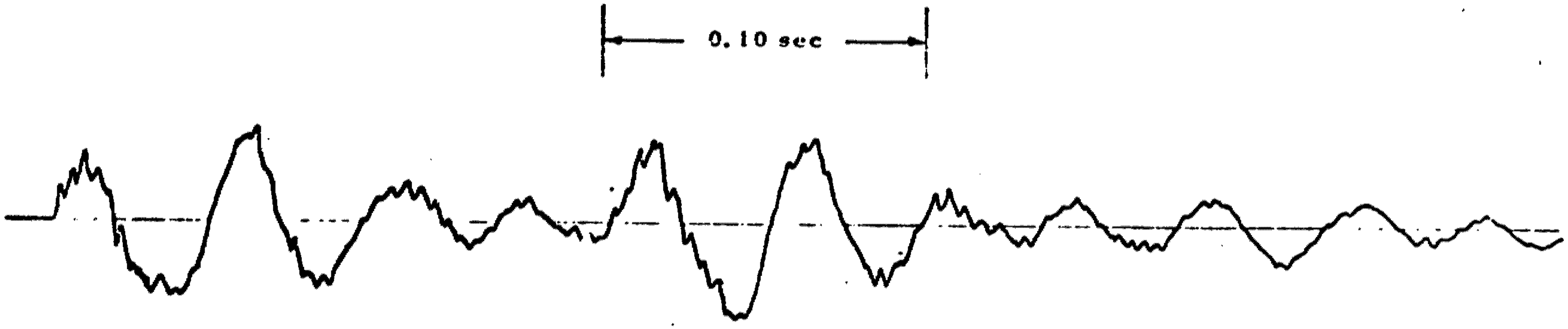


(a) Plate glass window (7' x 12')

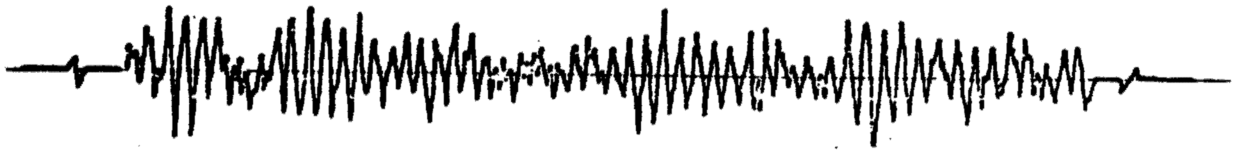


(b) Window pane (10" x 12")

FIG. 8 TRACINGS OF RECORDS OF B-58 (Mission No. 80 RB) SONIC-BOOM INDUCED STRAIN RESPONSES FOR TWO WINDOWS OF DIFFERENT SIZES. (Strain amplitudes for each data flight are listed in LWP 229.)

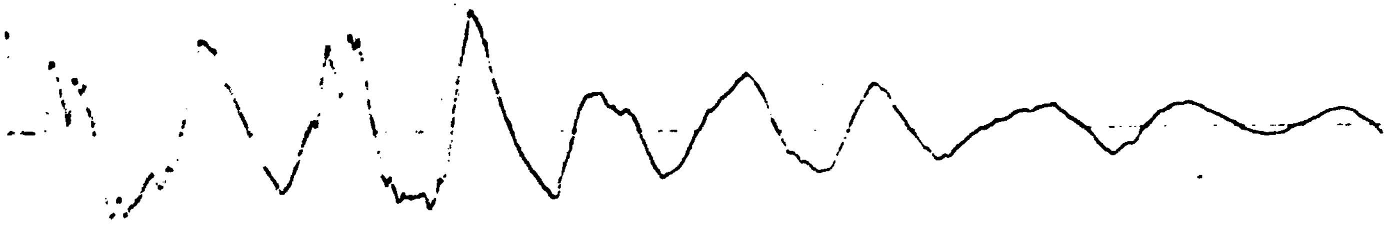


(a) B-58 sonic boom

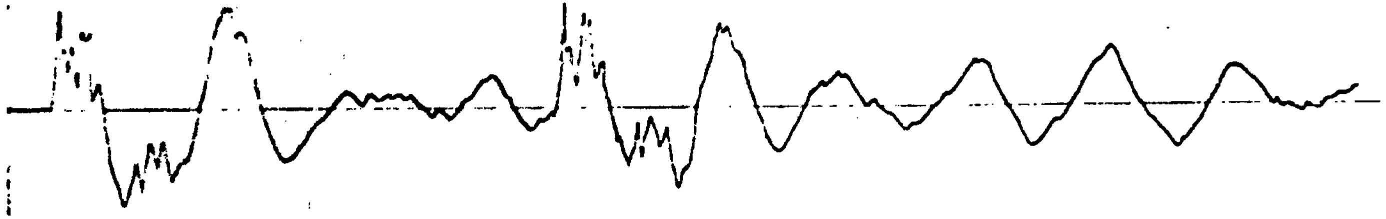


(b) KC-135 engine noise

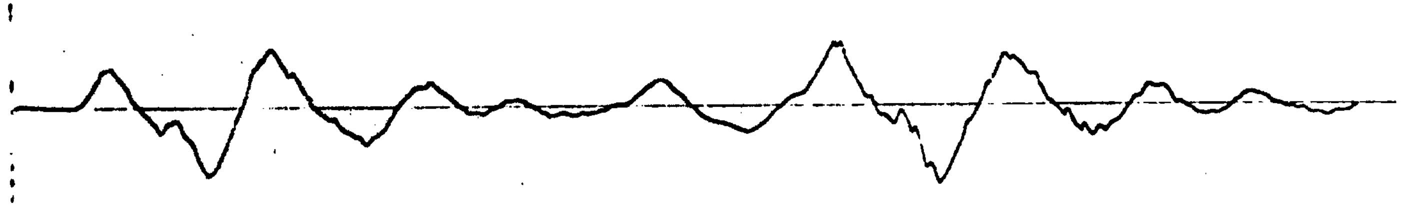
FIG. 9 COMPARISON OF TRACINGS OF RECORDS OF ACCELERATION RESPONSES INDUCED BY A SONIC BOOM AND BY ENGINE NOISE. Data are for Mission Numbers 75 A and 75 E.



(a) F-104, Mission No. 14 Table VIII



(b) B-58, Mission No. 80 R.R., Table VII



(c) XB-70, Flight No. 1, Table IX

FIG. 10 TRACINGS OF TIME HISTORIES OF ACCELERATION RESPONSES OF THE DINING ROOM EAST WALL (Channel 311) DUE TO EXCITATION BY SONIC BOOMS FROM THREE DIFFERENT AIRCRAFT

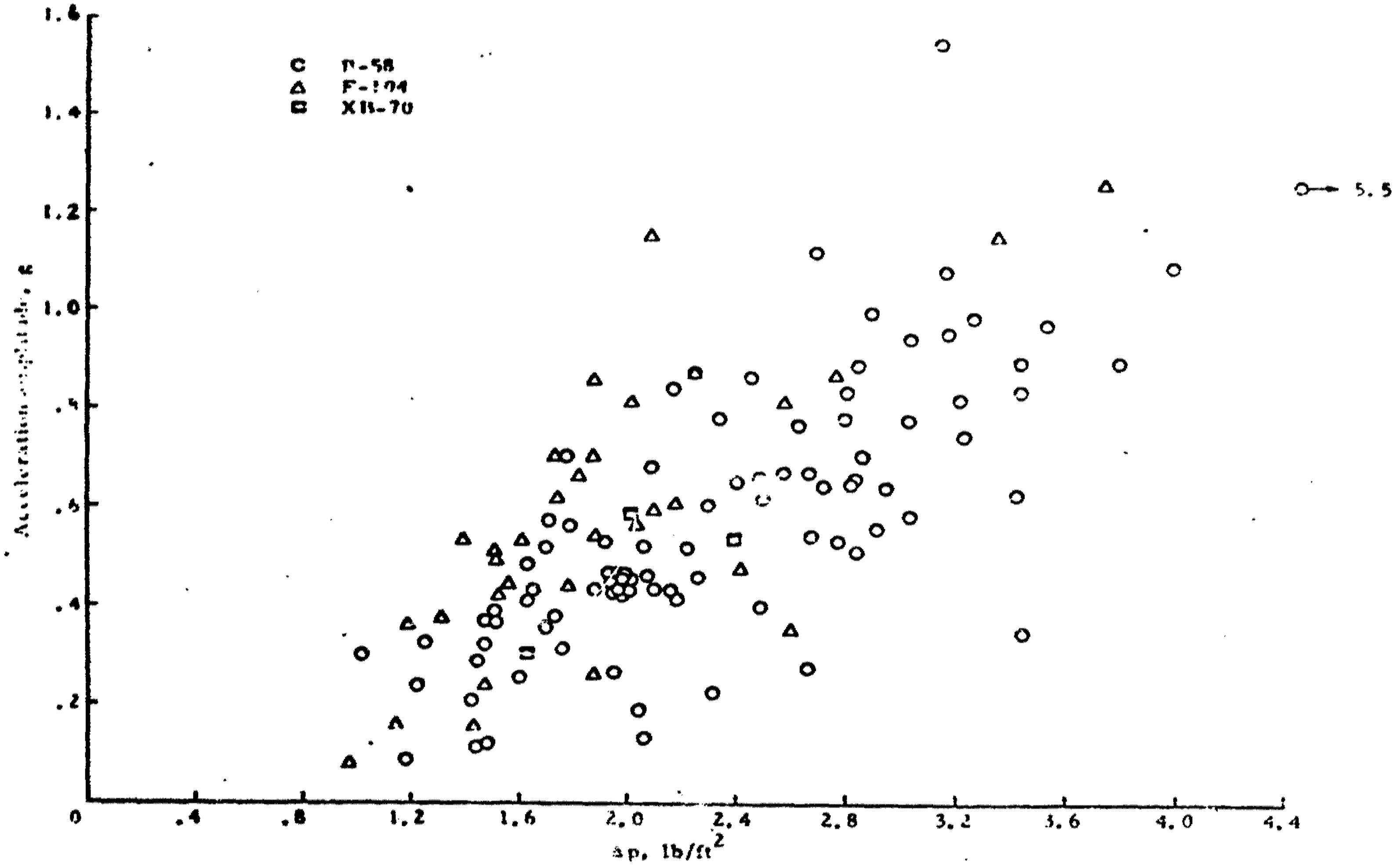


FIG. 11 PEAK ACCELERATION AMPLITUDES OF THE DINING ROOM EAST WALL AS A FUNCTION OF SONIC BOOM OVERPRESSURES FROM THREE DIFFERENT AIRCRAFT. Data are from Channel 311 as listed in LWP 288.

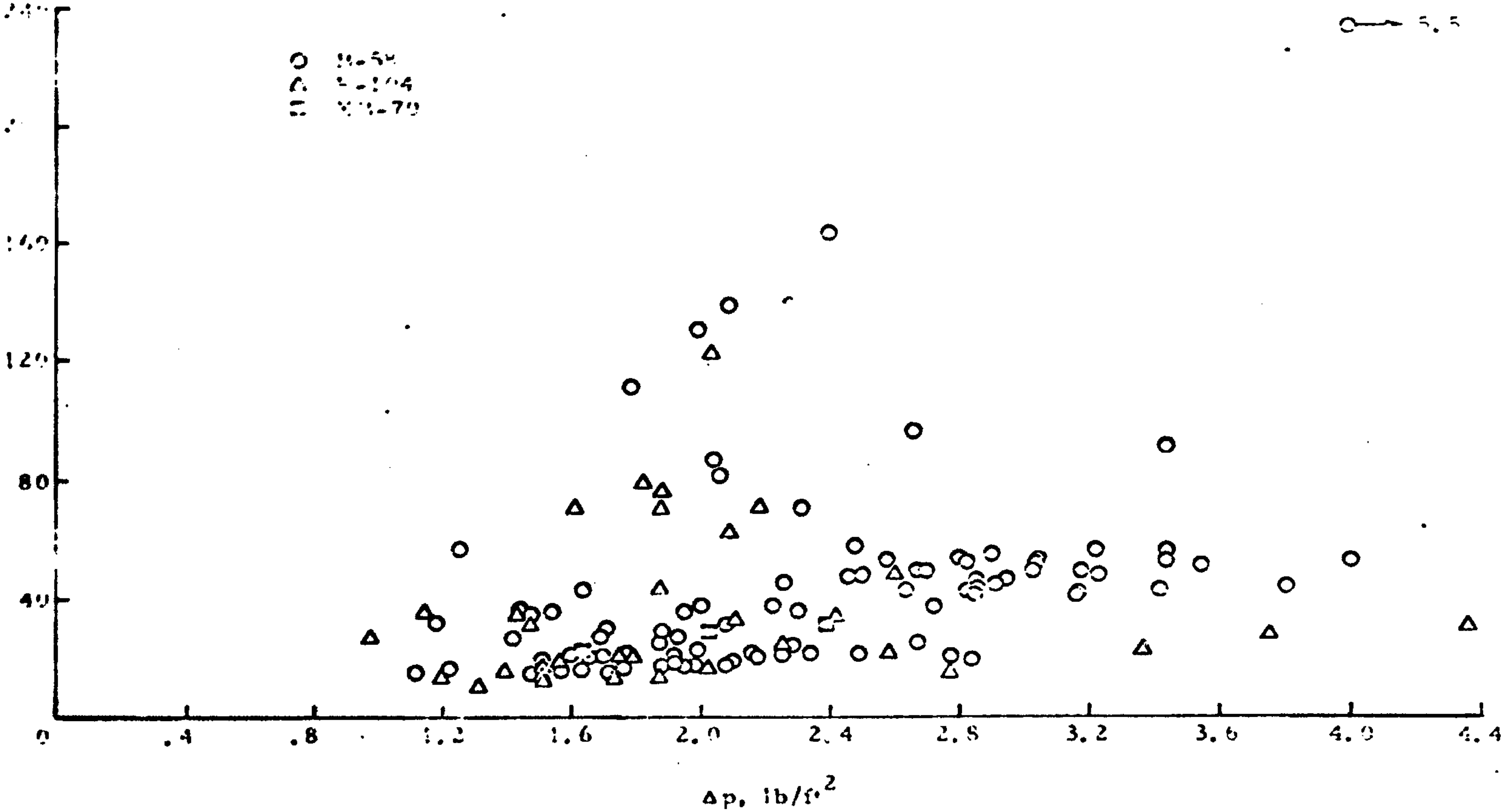


FIG. 12 PEAK STRAIN AMPLITUDES OF A LARGE PLATE GLASS WINDOW AS A FUNCTION OF SONIC BOOM OVERPRESSURES FROM THREE DIFFERENT AIRCRAFT. Data are from Channel 312 as listed in LWP 259.)

Annex H

20 September 1966

RESPONSE OF FARM ANIMALS TO SONIC BOOMS

(Studies at Edwards Air Force Base, June 6 - June 30, 1966)

The conduct of supersonic overflights at the Edwards Air Force Base during June 1966, provided an opportunity to conduct preliminary investigations of the effects of sonic boom on typical farm animal behavior and performance in order to aid in the determination of which types of farm animals would require more detailed observation in future sonic boom experiments.

I DESCRIPTION OF PROCEDURES

Ten animal installations were selected for observations of animal behavior under sonic boom conditions. They included 1 race horse breeding farm, 2 beef feeder lots, 2 turkey ranches, 2 chicken ranches, 1 sheep ranch, 1 commercial dairy, and 1 pheasant farm. Numbers of animals observed approximated 10,000 beef cattle; 125,000 turkeys; 35,000 chicken broilers; 100 horses; 150 sheep; 320 dairy cattle; and 50,000 pheasants. The horse farm and one beef feeder lot were about 13 miles from the center of the flight corridor, the large turkey ranch was at the end of the corridor within the turning radius of the planes, and the others were adjacent to the corridor 3-5 miles from its center.

Fourteen part-time observers (senior high school students); 2 alternates, one camera technician, and one supervisor (high school science teacher) were employed to make the necessary observations as the booms occurred. Booms were scheduled at varying intervals during the morning hours, Monday through Friday of each week. Observers were stationed to watch specified groups of animals and noted behavior patterns of the animals just prior to, at, and immediately following each boom, or disturbance caused by low-flying aircraft used in noise tests. They recorded their observations on charts prepared for that purpose.

In addition, 3 electronically timed 16 mm movie cameras were used to get time-lapse pictures of groups of animals at the animal installations. Some continuous footage was obtained during booms at poultry installations where the birds normally moved around too rapidly for 10 second time-lapse photography. The Edwards Air Force Base Information Office and Motion Picture Division also obtained still pictures and sound, color, film of some aspects of the program for use in public relations and in a documentary of the total program.

II RESULTS AND DISCUSSION

The results of animal observations during the Edwards Air Force Base tests are recorded in Tables 1-4, attached.

Table 1 indicates the daily frequency of total changes in activity. In studying this table one observes a somewhat higher percentage of change in beef cattle at farm No. 1 than at beef farm No. 10, yet farm 10 was much closer to the flight track than farm No. 1. This must be attributed to observer differences. At all farms there was an apparent decrease in activity from June 7 to June 23, which might be attributed to adaptation. However, it is believed that this was most likely due to observer adaptation and animal adaptation to the presence of observers.

Table 2 is a summary by species and by farms, of large animals, and includes the few abnormal behavioral changes observed. As will be described later, these changes are well within the range of normal activity of a group of animals. The few abnormal changes observed reflect a subjective definition of "abnormal behavior," since the abnormal changes in horse behavior consisted of some jumping up and galloping around the paddock, those in dairy cattle were bellowing, and those in beef cattle were evidenced by increased activity.

Table 3 indicates that among poultry there was more evidence of fright and or pandemonium, especially during the early stages of the program. The reactions consisted of occasional flying, running, crowding, and cowering. The severest reactions occurred as a result of low-level subsonic flights, where noise (and possibly aircraft shadow) was the disturbing factor. Only one case of an effect on production has been suggested. That is in the pheasant breeding flock where the owners have filed a claim with the U.S. Air Force stating that there had been a severe drop in egg production. Whether this is due to the boom program or heavy molting or a high temperature spell to which the flock was exposed has yet to be determined. No significant changes in turkey egg production, milk production, or feed consumption were apparent in this limited study.

Table 4 shows that dairy milking reactions were little affected by sonic booms. Only 19 of 104 booms produced even a mild reaction, evidenced by a temporary cessation of eating, raising of heads, or slight startle effects in a few of those being milked. Milk production was not affected during the test period, as evidenced by bulk dipstick readings and daily milk weights for the herd.

With so few abnormal changes evident in the Edwards Air Force Base test results, it was deemed advisable to conduct some control observations on normal changes in animals' behavior. Therefore, a series of tests were conducted at the Agricultural Research Center, Beltsville, Maryland, utilizing groups of beef cattle, dairy cattle, and sheep. These groups were observed by 2 individuals per group, working independently, from 9-11:30 A.M., on three consecutive days. Behavior was recorded as follows: animals were classified as to whether they were eating, drinking, resting (lying down), or loafing (ambulatory). At thirty-second intervals they were reclassified until six classifications were completed. At one-half hour intervals the procedure was repeated, giving a total of six classification periods between 9 and 11:30. Normal behavioral data were analyzed for percent change to compare with changes observed during the Edwards Air Force Base tests.

From these data we were able to observe differences among classifiers, among days, and among the time periods of a day. Each of these effects was evaluated statistically. With respect to the Edwards Air Force Base data, the pertinent figures are simply the percentages of normal changes for each of the species. These control percentages were 7.44 for beef cattle, and 16.06 for sheep. Given these figures and assuming we would have found the same percentage changes due to normal activity among animals at the test farms at Edwards Air Force Base, it can be concluded that the booms had very little effect on the larger species of farm animals.

III CONCLUSIONS

1. The observed behavior reactions of animals to the sonic booms were minimal except for the avian species. Also, the reactions were more pronounced to noise from low-flying subsonic aircraft than to booms. Furthermore, the reactions were of similar magnitude and nature to those resulting from flying paper, the presence of strange persons, or other moving objects. For these reasons, a strong relationship between observed behavior reactions and possible herd or flock production depression is very unlikely.

2. Although no significant changes were noted in production, these tests were not adequate to produce any conclusive evidence on this aspect of sonic boom effects. The number of farms available was insufficient for evaluating production effects and the location of those available was not suitable for proper evaluation.

3. It is also to be noted that the area around Edwards Air Force Base has been exposed to about 4-8 sonic booms per day for the past several years. Therefore, some of the farm animals may have become considerably "adapted" to sonic booms prior to these tests.

Table I

CHANGES IN BEHAVIOR DURING BOOM EXPOSURES--EDWARDS AIR FORCE BASE TESTS, JUNE 6-23, 1966

(Source: U.S. Department of Agriculture Animal Husbandry Research Division, Beltsville, Md.)

Date	Number of Booms	Total Observed	Total Changed	Percent Changed
Beef - Farm No. 1				
June 7	5	150	15	10.0
13	11	330	62	18.7
14	4	120	15	12.5
15	8	240	30	12.5
17	1	30	17	56.6
20	12	360	22	6.1
21	6	180	6	3.3
22	9	270	18	6.6
23	9	270	12	4.4
Totals	65	1950	197	10.1
Beef - Farm No. 10				
June 6	13	130	13	10.0
8	5	50	8	16.0
9	13	130	6	4.6
13	10	100	2	2.0
14	2	20	1	5.0
15	9	90	0	0.0
16	3	30	0	0.0
17	2	20	0	0.0
20	11	110	0	0.0
21	13	130	1	0.7
22	12	120	1	0.8
23	10	100	0	0.0
Totals	103	1030	32	3.1

Table 1 (Continued)

Date	Number of Booms	Total Observed	Total Changed	Percent Changed
Dairy - Outside				
June 7	7	560	4	0.7
9	12	960	80	8.3
13	10	600	37	6.1
14	10	500	13	2.6
20	12	780	19	2.4
21	14	1050	9	0.8
22	14	910	34	3.7
23	8	672	8	1.1
Totals	87	6032	204	3.3
Sheep				
June 6	13	260	37	14.2
7	7	350	24	6.8
9	12	360	0	0.0
13	10	200	5	2.5
14	3	60	2	3.3
15	8	160	0	0.0
17	2	40	0	0.0
20	10	300	6	2.0
21	11	330	0	0.0
22	14	420	0	0.0
23	9	270	2	0.7
Totals	99	2750	76	2.7
Horses				
June 6	4	25	8	32.0
7	4	29	8	27.5
9	14	256	22	8.5
13	9	225	12	5.3
14	6	50	0	0.0
15	6	56	0	0.0
17	1	21	0	0.0
20	10	131	4	3.0
21	12	120	0	0.0
22	10	180	0	0.0
23	9	100	0	0.0
Totals	85	1193	54	4.5

Table 2

PERCENTAGE CHANGES IN ANIMAL BEHAVIOR DURING BOOM EXPOSURES--EDWARDS AIR FORCE BASE TESTS, JUNE 6-23, 1966

(Source: U.S. Department of Agriculture, Animal Husbandry Research Division, Beltsville, Md.)

	Changed	Returned / Changed	Changed to Normal / Changed	Changed to Abnormal / Changed	Abnormal / Total	Observations	Total Changed	Total Number of Booms
				By Species				
Beef	7.68	24.89	73.79	1.31(3)	0.10	2980	229	168
Dairy	3.38	28.92	70.58	0.49(1)	0.01	6032	204	87
Sheep	2.76	0.00	100.00	0.00	0.00	2750	76	99
Horses	4.52	59.25	33.33	7.40(4)	0.33	1193	51	85
				By Farm				
Beef - 1	10.10	25.38	73.09	1.52	0.15	1950	197	65
Beef - 10	3.10	21.87	78.12	0.00	0.00	1030	32	103
Horses	4.52	59.25	33.33	7.40	0.33	1193	51	85
Sheep	2.76	0.00	100.00	0.00	0.00	2750	76	99
Dairy	3.38	28.92	70.58	0.49	0.01	6032	204	87

Table 3

POULTRY BEHAVIOR CHANGES UNDER BOOM EXPOSURES--EDWARDS AIR FORCE BASE TESTS, JUNE 6-23, 1966

(Source: Department of Agriculture,
Animal Husbandry Research Division, Beltsville, Md.)

	Number Booms	Average Effect	$0^{(a)}$	$1^{(b)}$	$2^{(c)}$	$3^{(d)}$
Species:						
Broilers	197	1.02	23	158	6	10
Young turkeys	195	0.31	100	91	3	1
Adult turkeys	198	0.52	95	103	0	0
Young pheasants	85	0.81	16	69	0	0
Adult pheasants	125	0.96	7	117	0	1
By farm:						
Jones turkeys	187	0.53	90	96	0	1
K-M turkeys	206	0.50	105	98	3	0
Del Mar broilers	106	0.95	9	93	4	0
Ringo broilers	91	1.09	14	65	2	10
Pheasants	210	0.90	23	186	0	1

(a) Number of booms producing no reaction.
(b) Number of booms producing a mild reaction.
(c) Number of booms producing a crowding reaction.
(d) Number of booms producing pandemonium.

Table 4

DAIRY MILKING REACTIONS UNDER BOOM EXPOSURES--EDWARDS AIR FORCE BASE TESTS, JUNE 6-23, 1966

(Source: U.S. Department of Agriculture,
Animal Husbandry Research Division, Beltsville, Md.)

Date	Number of Booms	$0^{(a)}$	$1^{(b)}$	$2^{(c)}$	Average Effect
June 6	12	6	6	0	
7	10	10	0	0	
9	12	6	6	0	
13	7	6	1	0	
14	14	13	1	0	
15	1	1	0	0	
20	12	10	2	0	
21	12	11	1	0	
22	13	13	0	0	
23	11	9	2	0	
Totals	104	85	19	0	0.18

(a) Number of booms producing no reaction.
(b) Number of booms producing a mild reaction.
(c) Number of booms producing a severe reaction.

THE SONIC BOOM

by Harry W. Carlson and
F. Edward McLean

There's still no way to silence it,
but a recent series of experiments suggest
that it can be reduced to a lower level
by modifying the shape of the airplane

IN BRIEF: *The intensity of the boom produced by a supersonic airplane depends on a great many factors, some of which can be controlled and some of which can't. Of those that can be controlled, the most challenging to technology is the design of the airplane itself. Recent studies suggest that, aside from the gains that can be achieved by reducing the airplane's drag (and that's where most of the boom energy comes from in the first place), there are ways to reduce the boom by modifying the shape of the airplane. This applies particularly to large airplanes the size of the proposed supersonic transport. When an airplane gets that large, the pressure signature of the boom is closely related to the detailed shape of the airplane, and small changes in the shape may yield large changes in boom.—C.J.L.*

■ If you are one of that decreasing minority who have not as yet heard the sonic boom from a supersonic airplane, we may give some indication of the experience by likening it to the surprise of hearing a clap of thunder from a cloudless sky. Like that sound, the onset of a boom is very sudden and it lasts only a fraction of a second. To the unwary, it can be a startling experience.

In this article, we will not attempt to predict how man will react to that new noise, but will focus instead on the noise itself, how it is generated, what affects its magnitude, and what, if anything, can be done about it. In connection with this last point, we want particularly to discuss some recent developments in the theory of sonic booms and some wind-tunnel work of ours, both of which seem to support the idea that the sonic-boom problem as it relates to the supersonic transport may not be as severe as was once thought.

From subtle beginnings

The popular conception of the boom is that sound waves, which cannot get out of the way of an airplane traveling at supersonic speed, pile up and produce a shock wave that is transmitted to the ground as a boom. While this description is accurate as far as it goes, for our purposes here, we will have to be a little more rigorous about where the sound comes from and how it travels.

Usually, it is the pressure fluctuations produced by an airplane's engine that carry the news of its presence to our ears. There is a more subtle disturbance, but we are not generally aware of it. This is the pressure fluctuation produced by the airplane (or any other moving body) as it displaces the air around it. For subsonic flight speed, these pressure variations are generally too weak and too slowly varying to be detected by the ear.

Because pressure fluctuations can move through the air only at a velocity fixed by the laws of nature, they are obliged to behave in a different manner when their source is moving faster than they can. When an airplane is traveling faster than the speed of sound, the slight displacement pressure fluctuations that radiate away from the airplane cannot radiate forward because the airplane is traveling faster than the pressure fluctuation can move. Consequently, a sharp pressure pulse forms in front of the airplane and is swept behind it to form a conical surface in which the pressure (and temperature) are locally higher than in the surrounding air. When a point on this surface passes over an observer on the ground, there is a rapid increase in pressure, which he perceives as a boom.

Bullets and bull whips

A moment ago we likened the sonic boom to the sound of thunder. Having now described it as a noise due to air displacement when a body travels faster than the speed of sound, it becomes evident that the similarity between the boom and thunder is more than mere coincidence. The discharge produced in electrical storms certainly travels faster than the speed of sound, and the heat energy released displaces the air in a manner similar to a supersonic airplane. The thunder of the resultant shock waves is a phenomenon closely related to aircraft sonic booms. The sharp crack of a bull whip has also been attributed to a sonic boom made by the tip exceeding the speed of sound. And those of us who have been unfortunate enough to have been placed in the vicinity of passing bullets will perhaps always remember their characteristic sharp report. This too is a sonic boom. Even if it is not very reassuring, it is quite true that there is no need to worry about the bullet you hear since, like the supersonic airplane, the one you hear has already passed by.

The first airplane-produced sonic booms were noted shortly after the conclusion of

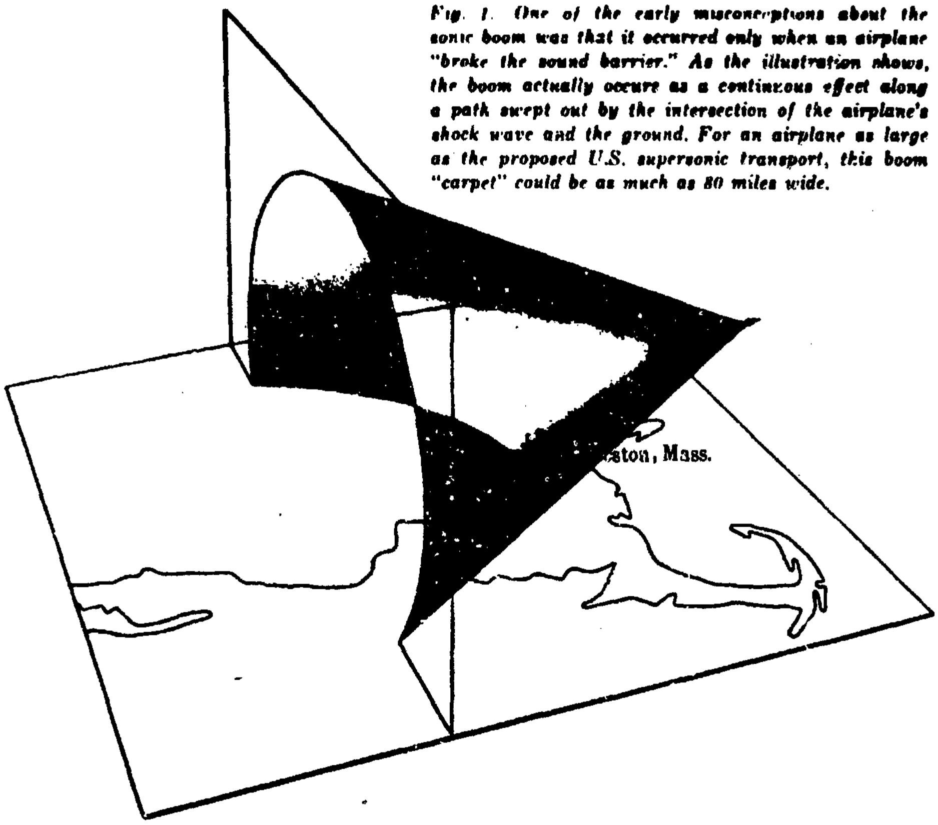
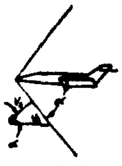


Fig. 1. One of the early misconceptions about the sonic boom was that it occurred only when an airplane "broke the sound barrier." As the illustration shows, the boom actually occurs as a continuous effect along a path swept out by the intersection of the airplane's shock wave and the ground. For an airplane as large as the proposed U.S. supersonic transport, this boom "carpet" could be as much as 80 miles wide.

World War II when advanced fighters achieved supersonic speeds in dives. At first, sonic booms were considered a novelty and were often produced intentionally as entertainment during air shows. Later demonstrations with more powerful aircraft capable of level supersonic flight for short periods of time revealed the potential destructive character of the boom. In a well publicized incident at the Ottawa Air Terminal in 1959, a U.S. Air Force fighter in a demonstration fly-by made a climbing turn during a low-level pass over the not-quite-completed terminal building and the resulting boom broke windows, distorted curtain walls and produced other damage which, however superficial, added up to a repair bill of $300,000 and considerably delayed the completion date of the new terminal building.

Many misconceptions

At the time of the earliest boom incidents there was little general understanding of the nature of the phenomenon and there were many misconceptions. According to the then-popular belief, a sonic boom occurred only when an airplane "broke the sound barrier." It was not widely known at that time that breaking the sound barrier was only the beginning and that the boom would occur continuously along the path under the airplane and for many miles on either side. Even those of us who had some understanding of supersonic aerodynamics were at a loss to explain the boom phenomenon in detail. There was, for example, no knowledge of how the intensity of the boom depended on the size of the airplane, its weight, or configuration, or how the boom was affected by atmospheric conditions. And perhaps most important of all, no one knew how to attenuate the boom even to a limited degree. In the past fifteen years, we have begun to grasp some of the most important features of these questions.



$\sin\alpha = \frac{V_s}{V_a} = \frac{1}{M}$

V_s = Speed of sound

V_a = Speed of plane

As we have indicated, shock waves produced by a supersonic airplane do not propagate through the atmosphere in the same way as sound waves. The shock that forms at the nose of the airplane must obviously begin moving forward at the same speed as the airplane since it must stay in front of it. But as it moves forward, it also moves away from the airplane at an angle, like the water waves that move away from the bow of a ship. As it moves away from the airplane, the propagation velocity measured normal to the shock front slows down and approaches a value just slightly greater than the speed of sound. At the same time, however, its velocity in the direction parallel to the path of the airplane must remain equal to the speed of the airplane. As a result, the waves assume a cone-shaped shock front that streams back from the front of the airplane. If we define the Mach number as the ratio of the airplane's speed to the local speed of sound, a little geometry will show (see margin) that the sine of the half angle at the apex

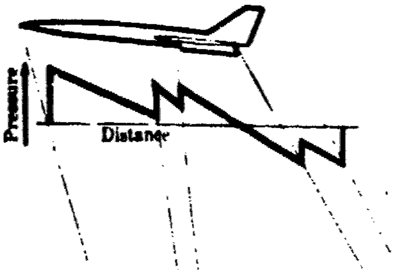


Fig. 2. A closer look at the shock wave that trails from a supersonic airplane reveals that it is not just a single shock, but a collection of shocks, one from each of the protuberances on the airplane. Close to the airplane—in the so-called "near field"—this collection of shocks forms a jagged, saw-toothed pressure pattern whose shape is representative of the shape of the airplane.

of the cone is equal to the reciprocal of the airplane's Mach number. So when the airplane is traveling only slightly faster than the speed of sound, the shock front is little more than a plane surface perpendicular to the line of flight, but at higher Mach numbers this plane surface is transformed into a narrower and narrower cone streaming behind the airplane.

The airplane leaves its signature

The disturbance from a supersonic airplane involves more than just a single shock wave from the nose of the airplane. Instead, there are many separate waves, and, in general, each discontinuity in the shape of the airplane produces its own shock wave. So in addition to the wave that originates at the nose, there will be a wave that originates at the wing-fuselage juncture, another at the engines, another at the tail surfaces, etc. Plotting pressure along the length of the fuselage reveals a complicated signature of positive and negative pressure pulses that correspond to each of the shock waves. This is the so-called "near-field" signature.

At greater distances from the airplane, the separate shock waves interact with each other and eventually coalesce into just two waves, a bow shock and a tail shock. The airplane's pressure signature then takes the form of an abrupt pressure rise followed by a linear decline in pressure to a value below ambient and a subsequent recompression to atmospheric pressure. This "*N* wave" is the usual form for the ground-level signature of a supersonic airplane at cruising altitude and it is this pressure signature that is responsible for the boom.

The peak of the positive portion of the *N* wave, defined as the "overpressure," varies from somewhat less than 1 lb/ft^2 to not much more than 4 lb/ft^2 for normal operations of supersonic airplanes. On the other hand, pressures of over 100 lb/ft^2 have been recorded for daring, low-level passes of fighter airplanes.

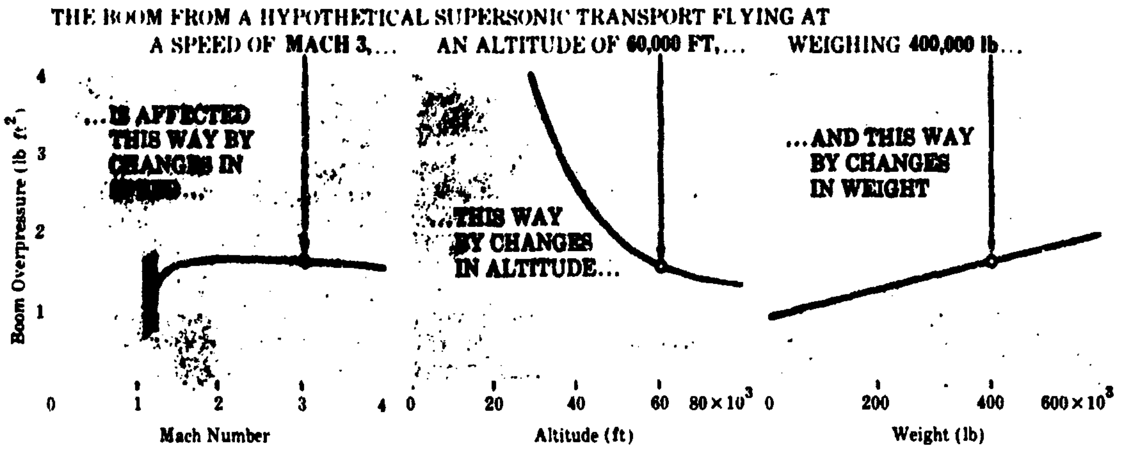
Another feature of the shock waves from an airplane is that the distance between the bow shock and the tail shock increases as they move away from the airplane. This is because the pressure at the bow shock is above ambient while the pressure at the tail shock is below ambient, and the difference in environment causes them to move away from each other. Depending on the airplane, the speed, and the altitude, the length of the *N* wave at the ground will vary from a few hundred feet to perhaps as much as ¼ mile. The corresponding time interval between bow shock and tail shock as they move over the ground may be as small as 0.05 sec or as large as 0.4 sec. The observer will normally hear two booms as the pressure pulses pass over him, but the ear may not be able to resolve the separate shocks when they are very close together.

A great many variables

All the variables that have been found to affect the magnitude of the boom—and there are a great many—can be divided roughly into three categories. There are those that depend on how the airplane is flown, there are those that depend on the atmospheric conditions, and there are those that depend on the design of the airplane itself. It is this last category—the design of the airplane—that has been of most interest to us and it is this aspect of the problem we would like to discuss in some detail. But first, let us look briefly at the other two categories, starting first with the factors that depend on the way the airplane is flown.

It probably comes as no surprise that a shock wave dissipates energy and grows weaker as it propagates away from the source, just as with any other sound. The difference in the case of the shock wave is that it diminishes with the ¾ power of distance whereas normal sound waves diminish much more rapidly than that. But there is an added feature when the shock comes from an airplane: the intensity of the shock depends on the density of

Fig. 3. At some distance away from the airplane, the individual shocks merge to form just two shocks. The resulting N-wave pressure pattern, with its abrupt pressure rises at leading and trailing edges is heard as a boom (or two booms) as it passes over an observer on the ground. It is the magnitude of the pressure rise that determines the intensity of the boom.



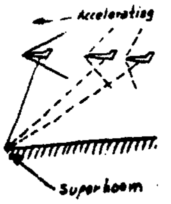
the atmosphere and the density of the atmosphere at 50,000 ft is much less than at ground level. For purposes of calculation, it is usually sufficient to assume a definable mean atmospheric density somewhere between that at the airplane and that at ground level.

The critical point

The result of all of this is that the boom decreases quite rapidly with increase in altitude, and, in fact, altitude is the factor that has the greatest influence on ground overpressure. In view of this, it would be desirable to fly the airplane so that it climbs at subsonic speeds and does not make the transition to supersonic speeds until it reaches cruising altitude, but unfortunately this is not a practical way to fly a supersonic airplane. The airplane must make the transition while climbing, and as a result it is this portion of the flight profile that is most critical from the standpoint of sonic boom.

The boom increases with the Mach number at the rate of $\Delta p \propto (M^2-1)^{1/8}$, which is to say that it increases slowly beyond about Mach 1.2. But that's not the whole story. For any given altitude, as the speed increases, the angle of attack needed to maintain any given amount of lift decreases, an effect which tends to decrease the boom (for reasons we will describe later on). The net effect is that the speed of the airplane once it is supersonic makes very little difference and that, generally, the boom decreases somewhat with increasing Mach number rather than increasing as might have been expected.

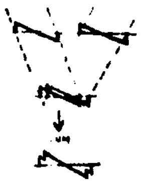
Speed changes also affect the size of the boom. As the airplane accelerates, the shock wave inclines back at an increasing angle, steadily changing the direction in which the wave propagates. It frequently happens that waves from a number of points along the flight path will all meet at one point on the ground with the effect that this point will be subjected to a number of simultaneous shocks. Such a magnified shock is known as a "superboom." Superbooms have been measured in which the amplitude was over twice that expected for normal steady flight. Radial acceleration in sharp turns, pullouts and other maneuvers can also produce superbooms.



Putting all these effects together we can see that the pilot must fly his plane as high as possible and should avoid violent maneuvers since most of them increase the intensity of the boom. For the supersonic transport, the limitations on maneuvers should not materially affect the operation of the airplane; for the comfort of the passengers, it is essential that the pilot avoid violent maneuvers anyway.

The effect of environment

In the second category of effects—the influence of atmosphere and other environmental factors—the most important effect is the intensification of the boom by reflection. When the *N* wave strikes the ground, or any other surface, it is of course reflected back just like any other wave. The pressure pulse from the reflected wave adds to the pressure pulse from the incident wave in the areas where the two coexist, and as we move closer to the point of reflection on the ground, the two waves become more nearly coincident. The timing is such that at ear level the two waves are very nearly superimposed and the observer hears what amounts to a double-sized boom. The strength of the reflection depends on the reflecting surface, but amplification factors of 1.9 are usually observed for cleared, level ground, while factors very close to 2.0 are generally measured for hard concrete or asphalt surfaces.



The fact that atmospheric density decreases with altitude not only causes a reduction in shock intensity, it also affects the way the shock propagates. As the shock moves from the less dense atmosphere to the more dense higher temperature atmosphere, its speed increases and the shock front bends forward. If the air-

Fig. 4. The sonic booms made in a wind tunnel by small models like these are an effective way of studying how the shape of an airplane influences the intensity of the boom. The models must be small because there is only a limited space in the tunnel for the characteristic N wave to form.

plane is moving only slightly faster than the speed of sound, this refraction effect may cause the front to become perpendicular to the ground. If you work out the geometry (see margin) you will see that when this happens the shock never reaches the ground; instead, it begins to travel parallel to the ground before it gets there. However, airplanes cannot fly economically at speeds where this occurs (around Mach 1.2), and so the effect is of little significance in suppressing sonic boom.

Refraction does, however, have a significant effect in reducing the lateral spread of the boom, because it causes the portion of the shock cone that spread to the side of the airplane to be bent also. Although it is a little difficult to draw (and even more difficult to describe) the shock front that extends toward the ground from the side of the airplane misses the ground beyond a certain distance. Hence, the footprint of the boom on the ground is not the intersection of a plane and a cone with the parabola extending off to infinity as might be expected, but is a parabola of finite limit (see Fig. 1). In tests with small supersonic aircraft, the boom has been found to extend 20 miles or so on either side of the airplane; for a supersonic transport, the path might be as much as 80 miles wide!

In addition to these large-scale atmospheric variations that affect the way the boom propagates, there also are important small-scale variations (turbulence, wind, and clouds). These non-uniformities in the atmosphere act like a lens to focus the boom, resulting in higher than normal pressure at some locations and compensatingly lower pressure at others.

The design effects

Aside from trying to guess how people will react to the boom, determining how airplane design affects the size of the boom has been the most difficult part of the sonic-boom problem. Plainly, it is out of the question to build and test full-scale airplanes of various configurations; not only is it expensive and time-consuming, but such test procedures preclude the possibility of studying interesting but impractical configurations in the hope of discovering design principles. In the beginning even the theoretical approach was difficult because the theory we were working with at the time did not give an adequate description of the phenomena. In fact, the most widely used theory of the early 1950's did not even predict the existence of a sharp, boom-producing pressure increase at the shock front. The present theory is much improved, and with it we have developed a rather complete understanding of how the boom is affected by design factors.

Here at Langley, we have supplemented this theoretical understanding with experimental studies of sonic booms produced by models in a wind tunnel. Although this technique is not widely practiced (there are only two or three other laboratories pursuing this approach), these wind-tunnel experiments have proven to be a valuable confirmation of the theory and in some instances have revealed effects with important consequences for reducing the boom.

Working with models in wind tunnels has its difficulties too, however. The model must be small to simulate relatively large distances in the narrow test section of a tunnel that is, say, 4 ft across. And if small changes in configuration are going to mean anything, the model must also be made to very close tolerances. We have used models varying from ¼ in. to 4 in. in length, some of which have taken a skilled modelmaker several months to build.

But perhaps the most difficult part of the wind-tunnel experiments is making accurate measurements of extremely small pressure differences. To plot the detailed pressure pulses in a small N wave requires a sensitive gage capable of measuring pressure differences as small as 1/200,000 of normal atmospheric pressure—and the variations in the ambient tunnel pressure are many times greater than that. We employ a differential pressure gage that measures the pressure in the shock and compares it to the ambient pressure in the tunnel. This gage is extremely sensitive, so sensitive that on one very cold winter day we noticed that it was recording the pressure change that re-

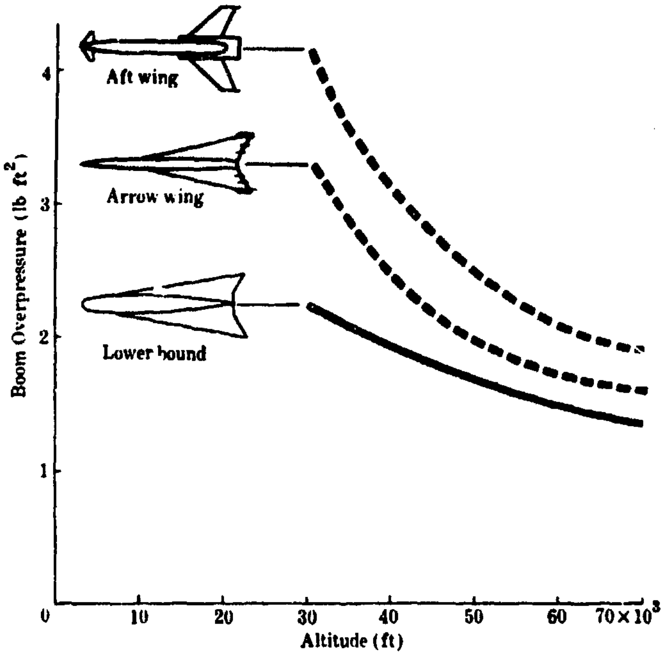


Fig. 5. Sonic boom is affected not only by speed, weight, and altitude, but also by the shape of the airplane. Here are three airplane shapes at various altitudes with the N-wave overpressures associated with each shape. The "lower bound" shape is calculated to produce a minimum boom, but unfortunately it has a very high drag and is unsuitable for an airplane. In each case, the curves are for a 230-ft airplane weighing 400,000 lb and flying at Mach 1.4.

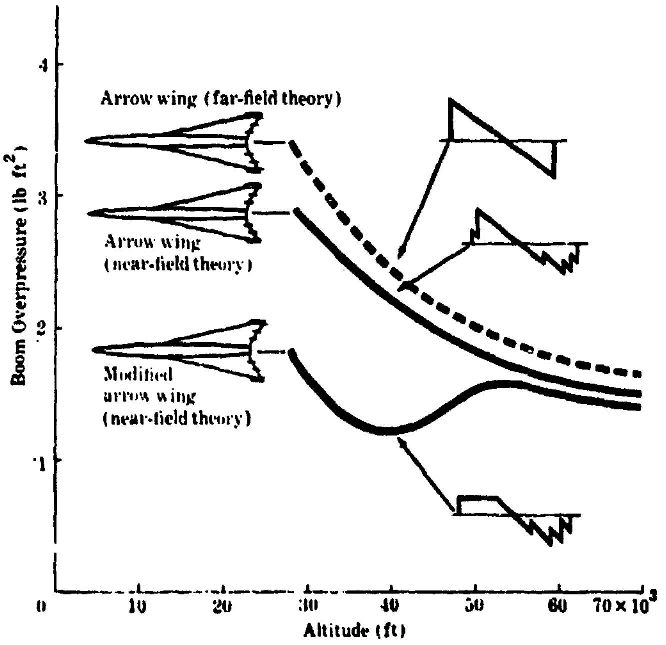


Fig. 6. Recent wind-tunnel tests suggest that the theory on which the curves of Fig. 5 are based may not be valid when the airplane is as long as the proposed U.S. supersonic transport. The curves at right show the overpressures predicted by this refined theory, taking as an example the arrow wing of Fig. 5. With the longer airplane, the individual shock waves of the near field may never quite coalesce into an N wave and the overpressure will therefore be slightly reduced (middle curve). But more important, the validity of the near-field theory offers the opportunity to make substantial reductions in overpressure by slightly fattening (in this case) the forward portion of the airplane's fuselage (lower curve).

sulted from the temperature change in the laboratory whenever an outside door was opened. We found we could prevent these fluctuations by wrapping insulation around the tubing leading to the gage. Or by locking the door.

Minimum drag, minimum boom

One of the first things the theory told us about the boom was that it is directly proportional to the ratio of maximum body diameter to airplane length. Now this is a fortunate thing, for the drag due to air displacement (the so-called "wave drag") is dependent on the square of this ratio; whatever reduces the wave drag also tends to reduce the boom. If we examine this a little more closely, however, we see that this is not just a lucky break; plainly, the energy lost in wave drag is the same energy that eventually shows up in the boom. But this may be oversimplifying the boom-drag relationship a bit too much. Later on we will discuss some exceptions to this nice simple rule.

The boom is also related to the lift, and this time the relationship is unfavorable. When the lift (or airplane weight) increases, so does the boom. As supersonic airplanes are called upon to carry more and more payload (passengers, baggage, and freight) airplane weight increases rapidly and the problems of the boom-conscious designer are compounded.

To understand why the lift affects the boom, it is perhaps sufficient to appreciate that lift is generated by displacing air, and this displaced air behaves the same as the air displaced by the volume of the airplane; as it increases, so does the boom. But it is not merely the weight of the airplane that causes this lift-displaced air to increase; the air displacement is also affected by the way the lift is generated. If the airplane's angle of attack is decreased while the lifting force is held constant (by increasing airplane speed, for example) the boom decreases because less air is displaced at the lower angle of attack.

This lift effect, however, behaves somewhat differently than the volume effect. Whereas the volume effect acts to increase the pressure all around the airplane, lift increases the pressure only below the airplane. The lift effect decreases the pressure above the airplane and has no influence off to the side.

Theory predicts that the lowest overpressure for an *N* wave produced by an airplane of a given length, weight, and speed will be achieved by a blunt-nosed vehicle (see Fig. 5). Curiously, this vehicle has too much drag to be regarded as a practical airplane shape. The explanation for the apparent contradiction between this and our previous statement that low-drag shapes produce low boom is that the blunt-nosed shape produces shocks in the near field that are much stronger than for slender shapes, but these strong shocks decrease more rapidly with distance. Therefore, much of the momentum loss of the air—and the drag to which it is related—is confined to the near field.

It is interesting to note that for airplanes as big and as fast as the proposed supersonic transport, this minimum-boom shape produces overpressures only slightly less than the design maximums of 2 lb/ft^2 in climb and 1:5 lb/ft^2 in cruise. More practical shapes will probably be able to approach to within about 0.5 lb/ft^2 of this lower bound. Of course, lower overpressures are possible for airplanes that are lighter (less than 400,000 lb) or longer (more than 230 ft) than this proposed supersonic transport configuration. But keep in mind that larger airplanes create larger booms, and there is a historical trend toward larger airplanes.

A fortunate development

Some recent experiments of ours indicate it may be possible to reduce the sonic boom from a supersonic transport more than was previously expected. In all of the efforts of the past, we have been attempting to reduce the peak pressure of the *N* wave, but recent analytic studies and wind-tunnel tests indicate that a large airplane like the supersonic transport may not be far enough away from the ground for an *N* wave to form—particularly at that critical altitude where the airplane is accelerating from subsonic to supersonic speed. Instead, the saw-toothed near-field signature will extend all the way to the ground. This effect has since been confirmed in tests of large aircraft such as the B-70 supersonic bomber.

This is a fortunate development for two reasons. First, the actual ground overpressures will be slightly less for jagged near-field signature than for an *N*-shaped far-field signature. And second, and more important, the existence of a near-field signature offers the opportunity to tailor the signature to some more desirable shape by modifying the shape of the airplane.

In modifying the shape of the signature, it is not possible to reduce in any large degree the area within the curve since this represents, in effect, the energy of the boom. But within this limit, there are many shapes that may be more desirable than an *N* wave. The positive triangle of the *N* wave could have a flat top, for example, or it could be converted to a shape that is nearly a rectangle. In either case, the peak pressure would be greatly reduced. Another possibility is to somehow change the abrupt increase in pressure at the front of the *N* wave to a more gradual increase. It is, after all, the rate of change of pressure that is responsible for the sonic-boom. The absolute change in pressure is only a few pounds per square foot, or about the same pressure change as descending two floors in an elevator. Only the rapid onset of the pressure change makes the boom an objectionable noise.

A flat-topped curve

Very subtle changes in the shape of the airplane can often make large changes in the pressure signature. For example, Fig. 6 shows a possible transport configuration with a sharply swept back arrow wing. Our calculations and wind-tunnel tests indicate that in its unmodified form (where it has a more-or-less cylindrical fuselage) it would produce a boom overpressure of about 2.2 lb/ft^2 during the critical transonic phase at an altitude of 40,000 ft. By increasing the diameter of the fuselage slightly in the area near the leading edge of the wing, the near-field signature approximates a flat-topped curve and the overpressure drops to about 1.3 lb/ft^2. The modification makes only a very small change in the shape of the airplane and has little or no detrimental influence on other aspects of the airplane's performance. It should be pointed out, however, that this might not be true for a similar near-field modification applied to some other airplane.

Now that we have discovered the beneficial

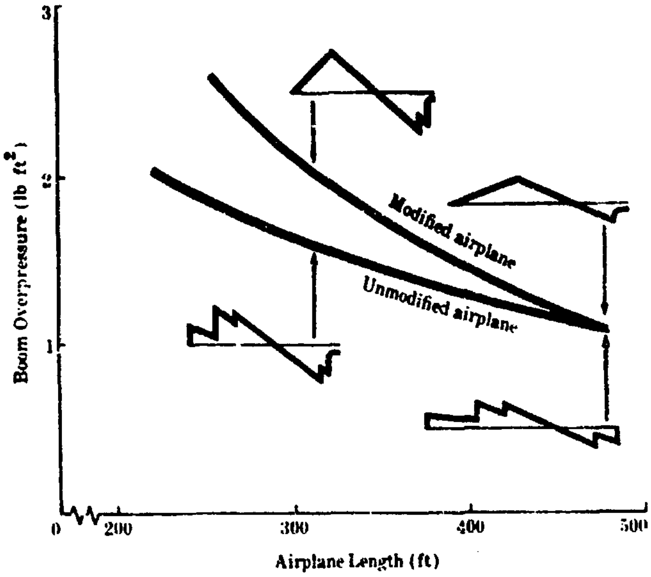


Fig. 7. Theory predicts that when the near-field pressure pattern extends all the way to the ground, the effect of the boom can be greatly reduced by reducing the rate of pressure rise, since it is the rate of pressure rise and not the magnitude that causes the boom in the first place. These curves show, however, that the airplane modification that reduces the rate also increases the magnitude, except for airplanes at least 500 ft long. At this length, which is much too long for a practical airplane, the pressure pattern becomes nearly a sine wave. As before, the figures are for a 400,000 lb airplane flying at Mach 1.4 and an altitude of 40,000 ft.

effects of a near-field signature that extends to the ground, there may be some things we can do to make the near-field signature extend to the ground even at higher altitudes and speeds. By adjusting the size and position of the individual shocks we can delay the point at which they coalesce into an *N* wave, perhaps to the point where the near-field signature extends to the ground even at cruising altitude. Certainly, this would be possible if it were practical to stretch the airplane out to any given length. In fact, it has been observed that if a supersonic airplane could be made long enough and slender enough, and with the proper area distribution, ground signatures approaching a sine wave with a very gentle pressure onset could be achieved. However, the airplane lengths required (more than 400 ft) are far in excess of those now considered practical (the British-French SST will be about 185 ft long, the U.S. SST about 270 ft).

No clear-cut decisions

The irony in all this effort to reduce the boom is that there is still no clear notion of just how much it ought to be reduced.

In an effort to resolve this question, the Federal Aviation Agency (with support from USAF and NASA) conducted a six-month series of sonic boom tests over Oklahoma City during 1964. During the tests, the city was subjected to frequent booms of the intensity levels expected for supersonic transports. Unfortunately, these tests produced no generally accepted, clear-cut decisions as to the ultimate acceptability of routine SST operations. Two-thirds of the phone calls and letters, and most of the formal complaints, referred to property damage. However, FAA inspections revealed little or no damage at these pressure levels which could unquestionably be attributed to sonic booms. During another series of tests at White Sands Missile Range, little or no damage to buildings was noticeable at overpressures less than about 5 lb/ft^2. But these figures may not apply to larger airplanes having signatures with a longer time duration and greater energy content.

In less than eight years, a U.S. supersonic transport may be flying passengers across the country in about two hours. A British-French SST will be operational before then. Our experience indicates that estimates of nominal overpressures for these airplanes in steady level flight may now be made with a good deal of confidence. As far as is possible, consistent with other features which affect the airplane performance and economics, sonic boom has influenced the design of the Boeing and Lockheed entries in the national design competition. These airplanes are expected to produce ground overpressures of about 1.5 lb/ft^2 for cruising altitudes in the range of 60,000 to 70,000 ft. Overpressures during the transonic portion of the flight, which takes place at lower altitudes, are expected to be somewhat higher—2 lb/ft^2 or more.

We feel that with the present understanding of the phenomenon, airplane design for sonic-boom reduction will be an even more important consideration for future generations of supersonic transports, particularly if the trend toward longer airplanes continues. We foresee no possibility that the boom can be eliminated entirely. The limitations on airplane design are too restricted for that. But within these limitations there are some promising possibilities.

Other aspects of the sonic-boom problem are discussed in the To Dig Deeper section.

UNCLASSIFIED
Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author)
Stanford Research Institute
Menlo Park, California

2a. REPORT SECURITY CLASSIFICATION
UNCLASSIFIED

2b. GROUP

3. REPORT TITLE
SONIC BOOM EXPERIMENTS AT EDWARDS AIR FORCE BASE

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)
Interim Report

5. AUTHOR(S) (First name, middle initial, last name)
Stanford Research Institute and various Government Agencies and Contractors

6. REPORT DATE

7a. TOTAL NO. OF PAGES
546

7b. NO. OF REFS
46

8a. CONTRACT OR GRANT NO.
AF 49(638)-1758

b. PROJECT NO.
SRI ETU-6065

c.

d.

9a. ORIGINATOR'S REPORT NUMBER(S)
Interim Report, Project ETU-6065

9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)
None

10. DISTRIBUTION STATEMENT
Qualified requesters may obtain copies of this report from DDC.

11. SUPPLEMENTARY NOTES

12. SPONSORING MILITARY ACTIVITY
Air Force Office of Scientific Research
Office of Aerospace Research
United States Air Force

13. ABSTRACT

A series of tests were conducted at Edwards Air Force Base in June 1966 and October 1966 to January 1967 in which human subjects (located indoors and outdoors), special test structures, and animals were exposed to booms from F-104, F-106, B-58, SR-71, and XB-70 supersonic aircraft, and the noise from KC-135 and WC-135B subsonic aircraft.

Physical measurements were made of the sonic boom signatures, subsonic aircraft noise, and the response of structures to the booms and noise. Psychological measurements were made of the subjective acceptability to several hundred subjects of the booms and subsonic aircraft noise.

Details of the test plan and procedures, and the results of the data analyzed to date are presented.

DD FORM 1 NOV 65 1473

UNCLASSIFIED
Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Sonic Booms:						
Physical Measures						
Propagation						
Weather Effects						
Effects on People						
Seismic Response						
Energy Spectra						
Response of Structures						
Damage to Structures						
Effects on Animals						
Comparison with Noise						