Report on Human Response to the Sonic Boom

DETAILS

21 pages | 8.5 x 11 | PAPERBACK
ISBN 978-0-309-30438-2 | DOI 10.17226/18775

AUTHORS

Subcommittee on Human Response; Committee on SST-Sonic Boom; National Research Council

Committee on SST-Sonic Boom

Subcommittee on Human Response

Report on Human Response to the Sonic Boom

June 1968

Subcommittee on Human Response

Members

Professor Raymond A. Bauer
CHAIRMAN
Graduate School of Business
Administration
Harvard University
Boston, Massachusetts

Professor William D. Neff
VICE CHAIRMAN
Center for Neural Sciences
Department of Psychology
Indiana University
Bloomington, Indiana

Dr. Henry David
Executive Secretary
Division of Behavioral Sciences
National Academy of Sciences
Washington, D. C.

Dr. Irwin Pollack
Mental Health Research Institute
University of Michigan
Ann Arbor, Michigan

Dr. Howard Raiffa
Graduate School of Business
Administration
Harvard University
Boston, Massachusetts

Dr. Peter Rossi
Department of Social Relations
John Hopkins University
Baltimore, Maryland

Staff

John P. Taylor
Executive Secretary
Committee on SST-Sonic Boom
National Academy of Sciences
Washington, D. C.

NATIONAL ACADEMY OF SCIENCES
NATIONAL RESEARCH COUNCIL
2101 CONSTITUTION AVENUE, N.W., WASHINGTON, D. C. 20418

COMMITTEE ON SST-SONIC BOOM

June 7, 1968

Dr. John R. Dunning, Chairman
Committee on SST-Sonic Boom
National Academy of Sciences
2101 Constitution Avenue, N. W.
Washington, D. C. 20418

Dear Dr. Dunning:

In accordance with your directive, the Subcommittee on Human Response has reviewed available information on the current status of matters relating to individual, group and community response to sonic booms preparatory to deciding what further human response research should be conducted.

In brief, the results of our review of sonic boom research on individuals and groups, whether under laboratory or field conditions and whether performed here or abroad, indicate that:

1. Field studies of responses to supersonic overflights, limited though each study has been, report generally consistent findings on levels of public response and complaint to currently available supersonic aircraft.

2. No damage to hearing is expected even for booms of 100 psf, many times above any level anticipated from the current version of the commercial supersonic transport even under extreme superboom conditions.

3. No direct physiological damage is expected even for booms of 100 psf. Indirect physiological responses, however, can result from the startle produced by sonic booms of even moderate proportions. These are

difficult to predict because persons differ in their response both as to kind and degree.

While physiological studies to date indicate little cause for concern, a review of field studies of the psychological impact of the sonic boom shows a growing consensus that is discouraging for the use of the current version of the commercial supersonic transport (SST) over populated areas at speeds at which it will be generating a sonic boom. However, the Subcommittee wishes to express cautious optimism in its belief that in the future it may be possible to design and build a commercial SST that will, when flying supersonically, generate a boom of acceptable characteristics. How soon and the methods by which a design team can achieve this goal we do not know, but we have confidence that American ingenuity can resolve the technical problems involved in due course. To this end the Subcommittee has listed the human response research it considers necessary to provide the aircraft designer with essential sonic boom design criteria.

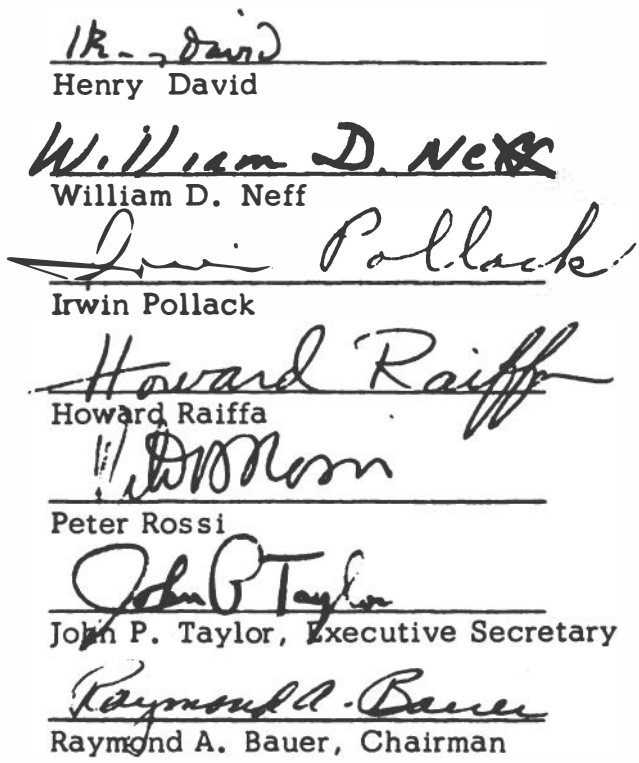
To clarify a point which has caused recent general concern, I would like to take this opportunity to point out that there is little likelihood that residents of our major metropolitan centers will hear a sonic boom generated by the currently proposed version of the commercial supersonic transport arriving at or departing from commercial airports, such as those serving intercontinental flights in the vicinity of our large metropolitan centers. Performance calculations for the current version of the commercial SST indicate that the aircraft will require approximately 100 miles after takeoff to accelerate to, or, on preparing to land, to decelerate from speeds at which a sonic boom can be generated. The exact distance will depend on the interaction of a number of factors such as payload, fuel load, climb and letdown procedures, variations in the weather, etc.

Sincerely,

Raymond A. Bauer

Raymond A. Bauer
Chairman
Human Response Subcommittee

Subcommittee on Human Response



Henry David

William D. Neff

Irwin Pollack

Howard Raiffa

Peter Rossi

John P. Taylor, Executive Secretary

Raymond A. Bauer, Chairman

June 1968

I. INTRODUCTION

When the NAS-NRC Committee on SST-Sonic Boom was formed at the request of President Johnson during the summer of 1964, one of the tasks it undertook was to estimate the probable human response to the commercial supersonic transport (SST) which was then being contemplated. The decision to proceed with a prototype, and the award of contracts to produce that prototype have since been made. In the meantime, a number of sonic boom research efforts involving human response have been completed, both in the United States and Europe. The most recent major study was the one conducted at Edwards Air Force Base, California in 1966-1967.*

As a result of such research, the concern of the Committee on SST-Sonic Boom in mid-1968 is considerably different from what it was over three years ago. What seems called for at this juncture is an intensive long-range analysis based on varied measures of individual, group and community response to different levels of sonic boom overpressure and an intensive and continuing exploration of all technical possibilities for designing a commercial SST that will produce a lower level of boom which the public will find generally acceptable. Since field tests and laboratory research have not yet defined this level of overpressure, future research efforts should be concentrated in that direction.

The Subcommittee on Human Response has focused its efforts on a better understanding of human response to the boom. Other facets of a proposed national program of research on the sonic boom such as structural response, factors concerned with the generation and propagation of the boom, meteorological effects on the sonic boom as it is transmitted through the atmosphere, and the possibility of future technological breakthroughs are covered by other Subcommittees of the parent Committee. The brief list of Subcommittee recommendations of proposed human response research.

II. RECOMMENDATIONS

The research recommended below is urgently needed irrespective of whether the current design of the supersonic transport flies

---

*Sonic Boom Experiments at Edwards Air Force Base, Interim Report, July 28, 1967, prepared by Stanford Research Institute, Contract AF 49(638)-1758.

over populated areas. Even if, as we assume, the present generation of SSTs will be restricted essentially to routes over water, this research is required to provide basic criteria necessary to the design of a future commercial SST which will be able to fly over populated areas at frequent intervals without undue annoyance to the residents of such areas. Key elements in the proposed research program include:

1. Development of a framework of analysis and of tools of measurement for an effective study, in depth, of the advantages and disadvantages of overland SST flights.

2. Continued laboratory studies of the properties of the sonic boom most important to an understanding of such human reactions as annoyance and startle.

3. Renovation of existing facilities where necessary and construction of specialized new facilities for better simulation of sonic boom to involve additional qualified investigators who seek to make specific laboratory studies of human response to the sonic boom.

4. Studies of human response to the sonic boom during sleep.

5. Continued studies, both of individuals and of organized communities, to overflights at different sonic boom levels, to be conducted if and when military overflight programs provide the opportunities for such studies.

6. Development of organizational arrangement and methodological work needed to support the research proposed above.

III. WORK OF THE SUBCOMMITTEE

The Subcommittee on Human Response has undertaken to examine the research activities of the past ten years relating to the response of individuals, communities, and organized groups to sonic booms produced by military aircraft flying supersonically. Pertinent documents from government, industry, and universities, both domestic and European, were reviewed, including the recently conducted Edwards Air Force Base program. Some preliminary data that became available as a result of operational suitability testing

of new Air Force supersonic aircraft were also examined. Several Subcommittee meetings were held to examine intensively the problems of studying individual, group, and organized community response of sonic boom effects. The purpose was to assess the current state of such activities and to recommend further research.

Central to human response studies made up to this time has been a tacit concept of a threshold of "acceptability" or "tolerability." Although there is currently no consensus as to the definition or even the appropriateness of such a concept, a diligent attempt should be made to think through what is meant by the concepts of "acceptability" or "tolerability."

In view of all the difficulties of measuring the phenomena involved, future work should involve measurements of a variety of response criteria, at both the individual and the community level, where military overflight programs provide the possibilities for doing such work. It would seem that the most appropriate approach, if it can be implemented, would be to measure the full range of social costs which might be incurred to offset the foreseeable benefits of the SST.

As the idea of a threshold of annoyance above which reactions are "inacceptable" or "intolerable" and below which they are "tolerable" or "acceptable" now seems inappropriate, the threshold may be better thought of as a boundary condition not to be exceeded routinely by commercial SST flights over populated areas. The establishment of such a boundary condition is considered to be of fundamental importance; therefore, a study of the balance of costs and benefits involved should be accomplished prior to its establishment. Despite the problems of determining fully acceptable measures of all such costs and benefits which could assist in the narrowing of the controlling boundary conditions, it is imperative to keep in mind the fact that this is the appropriate framework within which to think of the problem.

Community reactions cannot yet be predicted with certainty. We can only speak in terms of the probability of effective organized reaction. This will increase as the annoyance of the individuals in the community increases; the effective expression may depend on some dramatic trigger incident or the emergence of a vocal leader of public opinion. However, studies leading to the establishment of the suggested boundary condition will provide useful guidance not now available. In fact, the value of the boundary condition will depend on the extent to which we can approximate this ideal.

The costs to be considered must be thought of both in terms of the response of individuals who may be disturbed or annoyed, and in

terms of the problems created for the orderly and economical management of that portion of the society that is involved. Thus, one can imagine two hypothetical alternative "intolerable" conditions. At one extreme a population might accept SST booms quite passively, while suffering extensive annoyance and disturbance as individuals. At the other extreme, a population might, as individuals, suffer relatively little annoyance and disturbance, yet generate such a level of complaint behavior and of community reaction as to make the situation politically very difficult. Either one of these circumstances could prove "intolerable" in some meaningful sense.

While the management of problems of society is strongly dependent on the level of individual discomfiture, past experience with similar phenomena indicates that the two are not identical and that they vary to some extent independently of each other. Certainly the early history of urban renewal has revealed conditions under which individuals can suffer greatly without mounting any sizeable protest. On the other hand, there are controversial issues which have created a considerable amount of public disturbance but appear to have involved little or no actual costs to the ostensibly aggrieved individuals.

One of the tasks of continuing research on human response to the sonic boom will be to identify and understand more fully the complete range of responses, both of individuals and of organized communities to varying levels and frequencies of sonic booms.

Some portions of the research of the sort to be proposed may appear to be costly if any considerable amount is done. Relatively speaking, and in terms of its potential usefulness in making sound management decisions affecting the future flight of the SST over populated areas, much of the proposed research on human response can be considered to be among the least expensive of all the major facets of research connected with the development and operation of the SST.

In terms of field work for example, the very small cost of human response studies relative to the cost of flying supersonic aircraft in overflight tests, makes clear the need to be ready to gather a maximum of appropriate human response data should appropriate opportunities arise in connection with scheduled supersonic military training flights over populated areas.

From our present perspective all of the research and other activities recommended below appear relevant and necessary. Money spent wisely in this manner may well save large sums of money that

otherwise would have to be spent elsewhere at a later stage on SST development programs.

IV. RESEARCH REQUIRED

This statement of research required is based upon: 1) the existing state of our knowledge resulting from past research and current work underway, and 2) the changed nature of the task with which the Committee has been confronted as outlined above. A detailed statement of our present state of knowledge, with an outline of the merits and demerits of past and existing knowledge would be needlessly redundant. Such information is readily available in the public domain.* The Subcommittee's evaluation of this information is conveyed either explicitly or implicitly in the following statement of work to be done.

Psychoacoustic

Determination of Annoying Acoustical Aspects of the Boom. Study of the effective stimulus parameters of impulsive sounds as they relate to annoyance should be continued. Some of the relations among individual stimulus variables are known; e.g., duration, peak pressure, wavefront, and so on. But, perhaps some other dimension such as spectral energy density or rise time relates more simply, directly and significantly to annoyance. If such new relations can be established they should aid greatly in the formulation of guidelines for design of future SSTs that may produce booms of a more benign nature.

Simulation. Construction of several additional simulation facilities devoted specifically to human response studies is badly needed. These much needed facilities should be able to simulate faithfully both the low and high frequency features of the sonic boom. New as well as now-existing simulation facilities should be made available to qualified investigators and should incorporate design features that will permit easy change and modification. Understanding human response to the sonic boom is sufficiently important to warrant high priority for the maximum use of simulation facilities. For facilities in government laboratories, if in-house laboratory manpower is insufficient, contractor personnel should be sought to supplement the efforts of permanent personnel. Suitable simulation facilities could be

*Many of the reports on past sonic boom research are available either from the National Aeronautics and Space Administration, Department of Transportation or Department of Commerce Clearinghouse for Federal Scientific and Technical Information.

of considerable importance in determining long-term effects on sleep and irritability of repeated exposure to sonic booms of differing overpressures, shape and frequency over a long period of time.

Relationship of Impulse Vibration to Annoyance. Studies of subjective reaction to impulse type vibrations should be undertaken. It is important to create a valid psychological scale of annoyance to brief vibrating stimuli and to determine the interrelation between vibration and acoustic stimuli. Several psychophysical methods, especially magnitude estimation procedures, should be utilized to cross-validate the obtained scale.

Magnitude Estimation. The psychophysical methods of matching and category scaling used in past research on the sonic boom should be expanded to include the method of magnitude estimation. The latter method provides more flexibility and more information than matching and is less dependent on context than is category scaling. Magnitude estimation should be applied to the criterion of annoyance as well as to responses like acceptability, loudness and noisiness. The first of these applications should permit an additional validation of results obtained in the past. The second would lead, hopefully, to a better understanding of the psychological components of acceptability or nonacceptability. The method should be applied both in the laboratory and in the field. Analytical laboratory studies could provide information on how loudness, annoyance, and other psychological correlates depend on the various physical parameters of the sonic boom. Field studies should aim at the sociological responses to sonic booms of different overpressures and shapes under various environmental conditions. Not all variants of the method of magnitude estimation appear equally well-suited for the evaluation of psychological responses to the sonic boom. It is therefore recommended that future studies make ample use of experienced consultants.

Effect of Sonic Booms on Behavior

It is important to know more about the response of an individual to the sonic boom as a function of his ongoing activities such as skilled motor performance, conversation, daily routine, sleep at night, sleep during the day, or recovery in a hospital. These relations should be studied independently for infants, children and adults of all ages.

Sleep. Since interruption of sleep is particularly annoying and detrimental to a considerable degree to everyone and particularly to middle-aged and older persons who have difficulty in sleeping, this area of ongoing activity has been singled out for detailed recommendations.

Investigation of the effects of sonic boom on sleep and efficiency should be continued and extended. Even though SST nighttime overflights of the current version of the SST over populated areas may never be considered seriously, there are large numbers of people, including night workers, invalids, hospitalized patients and the elderly who sleep during daylight hours. Among the many questions not yet fully studied, the following are particularly relevant in this field as a background for management decisions:

1. What are intensity levels of booms below which behavioral waking is unlikely?

2. Does behavioral waking adapt to repeated boom stimuli? Does it adapt differently to changes in overpressure level or to variations in rise time?

3. Do repeated booms cause changes in the depth of sleep as judged by the electroencephalogram (EEG)? Does the simulated subject develop a chronic deficit of important stages of sleep? What is the level of boom overpressure and initial rise time at which sleep is usually not disturbed.

4. Do repeated brief awakenings of normal subjects cause behavioral changes, psychological distress or excessive fatigue?

5. What levels of simulated sonic boom aggravate existing sleep disorders? Might there be a significant subgroup in the population in whom any audible booms would cause severe loss of sleep?

Social Psychological

Studies of the distribution of individual responses should be conducted in such a way as to enhance our understanding of social psychological responses, to permit prediction of the responses of larger populations than those so far studied under boom exposure, and to identify special subgroups in the population whose responses may in some way be unusual. Studies in this category should generally be surveys of the sort conducted in Oklahoma City. Such studies may be possible in the near future only if military supersonic training overflight schedules provide circumstances in which large numbers of

individuals would be exposed frequently to sonic booms, and then, only if plans are made in advance so that people exposed may be questioned and their responses noted.

Future surveys should continue to explore the relations of personal characteristics and personal circumstances to responses to sonic booms. Survey subgroups could include those who: think SSTs are inevitable, are associated with the aircraft industry, habitually question political authority, have a special sensitivity to noise and have a history of frequent complaints. Such knowledge is important as a basis for anticipating the probable responses of other segments of the population who may share these characteristics in varying degrees. More specifically, if the distribution of relevant personal characteristics and background circumstances were to be determined for the U.S. population via methods now available for rapidly conducting a national sampling survey, we could make a better prediction of the response of the total population -- considered as an aggregate of individuals -- than we could on the basis of even a fairly large number of separate community studies.

Community studies can provide two kinds of knowledge, an understanding of the response of individual communities as such, and the consequences of individual responses in those communities. The latter knowledge will make it possible for us to extrapolate to other populations of individuals. This extrapolation can be made by ascertaining the distribution, in such populations, of the backgrounds and characteristics that have been demonstrated to be correlated with response to booms.

Studies of the distribution of responses should include a wide variety of more specific criteria beyond mere expressions of annoyance and/or tolerability; e.g., overt complaints, loss of sleep, interference with work, disturbance of other activities and so on.

The extension of the criteria to be considered should be to some extent coincidental with the investigation of special subgroups of the population. Certain subgroups attract attention because of the prior expectation that they may be especially vulnerable on one or another criterion -- startle, sleep disturbance, work interruption, and so on. Previous work such as that done in Oklahoma City has included the investigation of some special groups, though the findings have not been as fully reported as the findings for the population in general. Previous work also indicates that research on such groups may be especially difficult. Added efforts should be made to extend our knowledge of the effects that sonic booms have on special groups.

Before planning further research we must consolidate our present understanding of the reaction of subgroups such as hospital populations, daytime sleepers, infants, old people, persons engaged in delicate and vital work (e.g., surgeons), students in classrooms, and so on. The concern for special groups should be extended, as has already been proposed, to a consideration of such populations as persons on ships at sea and in small pleasure craft, both to assess their reaction and to estimate the numbers of persons involved under different conditions.

The goals of research on the distribution of responses to the sonic boom should be to predict the probable responses on several criteria, not only of the general population, but also of subgroups, especially those that might be presumed to bear an unusual burden of the costs of supersonic overflights. Such research should test also the effects of different patterns of exposure to booms; e.g., frequency versus intensity, and such specific questions as whether persons exposed to booms become more or less tolerant of them over the course of time, whether booms in a noisy community are the "straw that breaks the camel's back" or are merely one of many minor irritants.

Community response studies are required because a community is a structured system whose response does not relate in a simple way to the responses of members that comprise the community. The individual character of a given community may suppress or may amplify the responses of its individual members on a given issue. In one case, failure to understand the inhibiting effects of the circumstances of a given community may lead to an unfortunate under-estimation of the costs borne by its members; in the other case, one might under-estimate the problems generated by community reactions or the reactions of organized groups that are disproportionate to what one would have predicted on the basis of a knowledge of the distribution of individual responses in the community.

To study community response alone is to incur the risk of a faulty estimation of the personal costs involved. To study individual response alone is to risk a false estimation of the disturbance to the system. Each must be studied in its own right.

By and large, we may assume that an estimation of the personal costs to be borne by the population will be determined mainly by survey type studies that establish the distribution of individual responses. Some estimation of the added costs and difficulties of handling the problems of society will be achieved to the extent that such surveys enable one to predict the number and vigor of complaints that may be made. Community reaction studies bear more directly on the costs and

the difficulties of management that might be anticipated by estimating the number of communities that might make an official representation to their Congressional representatives, or the number that might apply for an injunction to stop overflights of the commercial SST and so on.

Our knowledge of the factors influencing community responses lags far behind our understanding of individual responses -- no matter how deficient one may conceive the latter to be.

If we contemplate the full range of situations with which we may be confronted, a national program of research on human response to the sonic boom should include consideration of the costs that might accrue via community reactions as distinct from individual reactions to different levels of the boom. Costs from adverse community reactions might be of greater magnitude than the costs to individuals. There have, in fact, been situations studied in the past in which organized action seems to have been disproprotionate to individual costs. The ultimate objective that one might foresee is that a knowledge of community characteristics associated with response to sonic booms may make it possible, by assaying the distribution of such community characteristics in a sample of American communities that may be overflown by the SST, to assess the incidence and nature of community reactions as a whole.

Problems of measurement are posed by the sonic boom issue. These problems place demands that are beyond the present state of the art. Implicit is the concept of "utility" which welfare economists have put forth as a yardstick by which monetary and nonmonetary costs and benefits can be compared. Such an ultimate yardstick is far from realization but there is every reason to believe that usable approximations can be obtained in specific situations.

There are, however, many opportunities for measurement which are most valuable yet fall far short of the ultimate attainment of a measure of common utility for all costs and benefits. For example, the Edwards Air Force Base experiment has increased our ability to translate the acceptability of sonic booms into equivalent levels of perceived noise for noise of jet airplanes and has given us new insight into probable public response to presently contemplated SSTs. There are similar problems of measurement in the broad range of issues involved in noise abatement and noise control of all kinds.

Interested agencies of the Government ought to contemplate the possibility of supporting studies of measurement and comparison as they bear on the overall noise problem. The funding of research on reactions

to noise other than sonic booms will lead to results in terms of developing new methods that can also be applied to the study of human response to sonic booms.

Certain reviews of literature can be helpful to those sponsoring or conducting research. Topics to be reviewed include: human reactions to jet noises and to noises in general; protest movements associated with noise and other types of environmental pollution; and studies of community conflict. These literature reviews should enable us to design better research in the future and to interpret more adequately the data from past and present sonic boom research.

V. METHODOLOGICAL AND ORGANIZATIONAL SUPPORT

In order to accomplish the recommended sonic boom research, certain methodological and organizational support activities become a critical part of the program. Several of these essential activities follow.

Standby research plans should be prepared. Opportunities for many types of research, especially social psychological studies of individual, group, and community reactions are likely to occur as the result of some unusual circumstance, such as special types of military overflight. Past experience indicates that such opportunities force researchers to design their research hurriedly.

Such research for which limited time has been available for detailed planning in the past has been carried out to date by highly competent persons and highly competent organizations; yet, we have no idea what innovations and improvements might be effected if an additional first rate group of researchers were given a fair amount of time to review past, present, and possible future research special event designs, and to prepare one or more plans for research on such problems as opportunities for such research present themselves.

Standby research facilities should also be set up to take advantage of special opportunities that arise with brief forewarning. Existing research organizations, at small additional cost, can be prepared to commit professional personnel on short notice with research instruments already designed, and with plans to organize field personnel as needed. A senior manager can be appointed to authorize such action within some specified time period.

What is required is the designation of some appropriate research agency for the organization of such a facility, authorization of reason-

able funds, establishment of criteria for such special research action, and provision for an immediate authorizing action when needed.

Coordination of the work of this Committee has been established with the other Committees and groups in the National Academy of Sciences and National Academy of Engineering who are interested in problems of response to aircraft noise. This close coordination should be continued where problems of these groups are closely interrelated. Similar close working relationships have been established and should be continued with the Department of Transportation's Interagency Aircraft Noise Abatement program organization, and so on.

Coordination of Government agencies interested in aircraft noise problems with such international agencies as the French Anglo-Saxon United States Supersonic Transport Committee (FAUSST) and Organization for Economic Cooperation and Development (OECD) should be continued and expanded where necessary.

Maintenance and interpretation of existing knowledge from research on human response to sonic booms and related phenomena should be done on a constant up-dated fashion so that senior government managers who have to make important policy judgments, and, researchers who have to plan and design future research will have ready access to the current state of the art. Such an effort should include the reexamination of old data in the light of newly developed techniques, the preparation of summaries of pertinent work, and the maintenance of these summaries in reasonably current status. An appropriate agency in the Government should be selected for such work and its existence widely publicized, particularly in the scientific and technical journals, so that its accumulation of sonic boom information can be made widely available.

VI. CONCLUSION

As previously stated, the sooner the various facets of human response to the sonic boom are understood and the level of boom which will be widely acceptable to the general public is determined, the sooner the engineering team responsible for aircraft design and development can come up with a commercial SST which will be able to fly over even heavily populated areas with a minimum of disturbance. It is believed that the above outlined research program, if carried out with vigor and imagination, will be a major contributor to establishing the proposed design goal. The technological challenge will then be one for American ingenuity and engineering skill to resolve.