

EPA FIVE-YEAR NOISE EFFECTS RESEARCH PLAN

DRAFT

NOVEMBER 19, 1979

SUMMARY: HEALTH CONSEQUENCES OF CHRONICALLY NOISE-DISTURBED SLEEP
EPA GRANT TO: STANFORD UNIVERSITY

I. Objectives

The objectives of the proposed work are: (1) to determine by a number of simultaneous physiological and other measures in the field, the effects of noise on sleep and subsequent daytime functioning, and (2) to test for recuperation or improvement in these parameters as a result of quiet, undisturbed sleep in the laboratory.

Phase I will monitor cardiovascular measures, respiration, temperature, and physical activity, over a 24-hour period, by use of an ambulatory monitor which will be worn throughout Phase I.

For the first few days, these parameters will be monitored during regular work on the job. The last two days, subjects will report to the laboratory, where daytime measures will include the Multiple Sleep Latency Test (MSLT) (an objective measure of sleepiness), the Stanford Sleepiness Scale and a Mood Scale. Performance tests will also be conducted. Nighttime measures, all taken in the home, will include standard sleep monitoring, and three acoustic monitors, the data to be transmitted by telephone.

In Phase II, subjects will sleep in a quiet laboratory, where sleep measures will be the same as those in Phase I. Phase II again monitors subjects around-the-clock using the ambulatory microprocessor. Subjects will go to work as usual for several days, and then report to the laboratory for MSLTs and other tests on succeeding days.

Subjects will be males between 40 and 50 years old who sleep with bed partners (who will also be instrumented for limited nighttime monitoring), and whose jobs expose them to relatively low levels of noise. Ten subjects will be chosen from a high-impact neighborhood exposed to aircraft noise. Ten controls will be matched on a number of relevant parameters, but will live in a quiet neighborhood (the controls may not participate in Phase II).

II. Relationship of this Project to Program's Mission

This study is an integral step in the development of criteria for health effects due to chronic sleep disturbance by noise, as detailed in the EPA Five-Year Noise Effects Research Plan (Initiative II: Health Consequences of Noise-Disturbed Sleep). The study involves cardiovascular and respiratory measures monitored on a 24-hour basis in the field and laboratory and will thus also contribute to the nonauditory noise effects program as well.

The following protocol is subject to change in consultation with EPA.

SUMMARIZED PROTOCOL FOR STUDY OF HEALTH CONSEQUENCES OF NOISE-DISTURBED SLEEP

PHASE I

ONE WEEK BEFORE NIGHT ONE - START SLEEP/WAKE DIARY

TWO DAYS BEFORE NIGHT ONE - START AMBULATORY MONITOR

NIGHT ONE -

TEST SUBJECT - TELEPHONIC SLEEP RECORDING

- ACOUSTIC RECORDING

- PHYSIOLOGICAL RECORDINGS FROM AMBULATORY MONITOR

BED PARTNER - OVERNIGHT AMBULATORY MONITOR

- ACOUSTIC RECORDING

DAYS TWO AND THREE:

- GO TO WORK AS-USUAL WITH AMBULATORY MONITOR.

NIGHTS TWO AND THREE:

- AS FOR NIGHT ONE

DAY FOUR:

- SUBJECT TRAVELS TO SLEEP LABORATORY AND UNDERGOES MULTIPLE SLEEP LATENCY TESTS (MSLT) AND PERFORMANCE TESTS

NIGHT FOUR:

- AS FOR NIGHT ONE.

DAY FIVE:

- AS FOR DAY FOUR

PHASE II

This phase of the project will involve the test subjects but may not involve the control subjects. The procedures will be the same as for PHASE ONE except that:

The nocturnal recordings will take place in the sleep recording laboratory and will occur in a normal (low noise) environment.

The nocturnal recordings will run for five successive nights. Subjects will work as usual during the first three days, and as before, attend the laboratory for multiple sleep latency tests during the last two days of the procedure.

THE EPA FIVE-YEAR NOISE EFFECTS
RESEARCH PLAN

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DO NOT QUOTE OR CITE

November 19, 1979

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1. INTRODUCTION

1.1 Legislative and Programmatic Requirements for Research

The Environmental Protection Agency (EPA) has the responsibility to protect people from excessive noise that may jeopardize their health and welfare. The Noise Control Act of 1972, as amended by the Quiet Communities Act of 1978, recognizes that specific information concerning the effects of noise on people is critically needed in order that EPA may efficiently carry out its mission to coordinate activities in noise control, to authorize the establishment of Federal noise emission standards for products distributed in commerce, and to provide information to the public reflecting the hazardous effects of noise, and noise levels associated with such effects.

To that end, the Act (as amended) requires EPA to:

"Conduct or finance research...including but not limited to - investigation of the psychological and physiological effects of noise...and determination of dose-response relationships suitable for use in decision making, with special emphasis on the non-auditory effects of noise." (Sect. 14. (6)).

These requirements represent a substantial expansion of noise-effects research responsibilities from those originally set forth in the Noise Control Act of 1972. Subsequently EPA is required to develop a health effects research strategy delineating (a) EPA's research objectives over a five-year period (Fiscal Years 1981-1985), (b) the relative priorities among various categories of research activities, and (c) a schedule or timetable of research activities to attain these research objectives.

In addition to the specific legislative requirements cited above, research with respect to the effects of noise on public health is required to support the various components of the EPA noise control program. On that account, a health effects research strategy must be responsive to the health-related needs inherent in the EPA noise program strategy. Elements of concern to the health effects research strategy include: the development and enforcement of noise emission regulations, the provision of technical assistance to State and local noise control efforts, the dissemination of information to the public on the health effects of noise, research and demonstration of advanced noise control technology, and the coordination of noise control activities and health effects research among Federal agencies.

The quantification of the health-related effects of noise is necessary in the development of all noise related legislation at the Federal, State and local governmental levels, since the purpose of such legislation is to protect public health. Citizens and public officials alike need to be adequately informed as to the health consequences of noise exposure in order to make rational, efficient, and cost-effective social decisions to secure a healthy environment. Research is fundamental to: 1) establishing information on the incidence and severity of health-related effects such as hearing loss, nonauditory physiologic effects, and sleep disturbance; 2) developing human response criteria to quantify the effects and health consequences of noise; and 3) ascertaining a cause-effect relationship due to specific source environments.

Other Federal agencies such as the Department of Transportation, the Department of Defense, and the National Aeronautics and Space Administration presently support their noise control activities with research programs which investigate both the direct and indirect health effects caused by exposures to different types of noise sources or noise containing specific acoustical characteristics. In many instances, the human response criteria developed by one agency are incorporated into those standards and policies of another agency. Ultimately there should be one set of health-related criteria used by all agencies. Agencies would then develop noise-related policy under their respective authorities using these criteria based upon specific health implications as well as social, legal, and economic considerations. However, the foundation of noise-related policy must rest on an understanding of basic health effects.

EPA has had extensive experience in monitoring and coordinating the noise effects research of all Federal agencies over the past few years. In 1977, EPA reconvened a panel of representatives from Federal agencies which conduct noise research to review the status of all Federal research activities with respect to the health effects of noise, and to recommend areas where further research was needed. The Panel found that over 19 agencies, or major organizations within agencies, conducted health effects research at a total funding level of approximately six million dollars annually.* EPA conducted relatively little of this research (\$190K

* Federal Noise Research in Noise Effects, (EPA Report 550/9-79-102) February 1978.

to \$349K in Fiscal Years 1975-1977). (Updated research project and funding summaries from all Federal agencies during the Fiscal Years 1978 to 1980 are now being collected.) While each agency's noise-related research might adequately support its own limited mission and goal, the Panel found that taken in its totality, the overall pattern of research on noise effects contained numerous gaps in the health effects data base and limitations in existing human response criteria. Although some health effects criteria were already being applied, other potentially severe health consequences of environmental and occupational noise exposures were not being adequately addressed. The Panel report recommended that steps be taken to fill these gaps. To that end, EPA and other Federal agencies have initiated several research projects (described in Chapters 4-12). The Panel report has also been instrumental in the design of the present health effects research strategy* and the specification of numerous research priorities.

1.2 Goals of the EPA Research Program

The overall goal of an EPA research program is stated below.

This goal is based on: 1) the fundamental importance of health effects information in support of noise control legislation and policies;
2) knowledge of the status of existing health and welfare criteria and data.

Overall goal: To improve the noise related health and welfare data base, refine existing criteria, and develop quantified dose-response criteria where they are lacking.

* This strategy will be referred to as the Research Plan.

Only through the development of quantified dose-response criteria can a thorough understanding of the health implications of noise be obtained and health benefits be properly ascribed to all noise control actions, whether taken on Federal, State or local levels.

The overall EPA research program goal has been broken down into a number of specific objectives for various identified categories of noise-effects research. The research categories used are similar to those cited in the previously discussed EPA Panel Report. Further, EPA Research Initiatives have been proposed in the present strategy to meet these specific objectives. Each Initiative will be expressed in one or more research projects, evolving in a time-phased manner, to answer major research questions in a defined area. In determining the content of the Research Initiatives, EPA will consider the specific programmatic applications of any research finding to particular noise control activities undertaken by either EPA, other Federal agencies, State and local communities, or the private sector.

EPA has a responsibility to make the latest research results available to both the general public and to State and local noise control officials in order to collectively meet our nation's noise control needs. For example, the public is more likely to make informed decisions regarding the purchase of quieter consumer products or even the selection of a location to live when they have more detailed information on the adverse health effects of noise. Citizens need more information to make decisions regarding their own personal noise exposures. Public officials need more information to set into motion the necessary programs to improve the quality of the noise environment. State and local officials need better health criteria to

support and justify their noise regulations and policies. They must have the necessary health-related information to determine what degree of noise control is needed and should be considered in the many routine administrative actions that touch each of our lives every day such as: building codes; comprehensive land use planning; traffic management; municipal purchasing decisions; zoning variances; enforcement of laws; vehicle inspections.

Accordingly, the following categories of noise effects research have been specified. There are seven major categories of noise-related health effects which either presently serve as the foundation for existing criteria or have the potential for being incorporated into specific noise effects criteria provided that the necessary research is undertaken and dose-response relationships established. These categories of research are presented with their accompanying research objectives. *They are not presented in any order of priority.*

1. Nonauditory Physiological Effects--to determine and quantify the nonauditory effects on bodily systems and on general health, with special emphasis on hypertension and other cardiovascular effects.
2. Noise-Induced Hearing Loss--to determine the extent of the problem, causative factors, and associated effects.
3. Individual and Community Response--to determine and quantify subjective reactions of individuals and communities to different environments and sources, investigating mediating factors.
4. Sleep Disurbance--to determine and quantify effects of noise on sleep, and its implications for general health and performance.
5. Communication Interference--to determine and quantify the effects of noise on communications and its developmental, social and other implications.

6. Behavioral, Social and Performance--to determine and quantify the effects of noise on social behavior, mental health, and human performance.
7. Wildlife--to determine and quantify the effects of noise on wildlife and domestic animals.

It should be pointed out that these are long-term objectives. Some information is available as a first step in meeting a few of these objectives. Accordingly, the specific Research Initiatives which EPA is now proposing to meet the identified objectives in each category will focus on the most important gaps and deficiencies in our understanding.

There are two additional areas of noise related research that have not been identified: exposure characterization and vibration. The objective of exposure characterization is to determine patterns of noise exposure, typical noise doses attributable to different sources and/or environments, and the health-related consequences of these exposures. Since this objective is common to all health-related categories (but not addressed within the five-year time frame), it has not been listed separately, although it will be discussed briefly in Chapter 11.

Vibration associated with noise is also a significant source of annoyance and discomfort. As discussed in the Panel report referred to earlier, the relative contributions of noise and vibration need to be assessed in order to derive criteria for the combined exposure conditions. However, vibration effects have not been listed separately within this Research Plan, but instead are contained as an intrinsic consideration within each of the seven categories of noise effects research. It should also be mentioned that there is some ongoing Federally sponsored, health-

related research concerning the effects of vibration, most notably by the U.S. Air Force, the U.S. Army, and the National Aeronautics and Space Administration.

It should be noted that the EPA Five-Year Research Plan does not constitute a full Federal program of needed research. While the proposed Research Initiatives and respective funding levels address most of the highest priorities, they do not represent a comprehensive research program. Such an effort would require a combined Federal approach of much greater magnitude.

1.3 Reader's Guide to the Research Plan

The body of this Research Plan consists of a set of plans--one for each category of noise effects research.

The following chapter explains how priorities were set for the EPA Noise Effects Research Plan.

Chapter 3 presents an introduction to the specific Research Plan for each category, and defines concepts such as "Research Initiative" and "Research Continuum" which are common to all of the Plans.

The specific Research Plans for each category of noise effects including exposure characterization, are presented in Chapters 4 through 11. Each chapter contains an overview of the current status of research and health effects information, a selected set of proposed Research Initiatives, and the proposed timing, funding, and coordination of the Initiatives. Additional Initiatives that will not be undertaken by EPA are also identified.

Chapter 12 provides aggregate and summary data on the entire Plan and how it relates to the core Five-Year EPA Noise Program Plan.

2. OVERALL PRIORITIES FOR EPA NOISE EFFECTS RESEARCH PLAN

This Plan outlines a viable operational research program for EPA to pursue in the noise effects research area for a five-year time frame, commencing in Fiscal Year 1981. The first requirement of the Plan is to establish priorities for the eight categories of research previously identified. Although each category and its respective research objective is felt to be important in its own right, relative priorities must be established due to the reality of limitations in resources and time. Thus, each category was evaluated on a scale from high priority to low priority, signifying where emphasis needs to be placed. Each category has been assigned one of five priority levels, from "A" (highest priority) to "E" (lowest priority). This prioritization was based on a rating and trade-off among five evaluation factors:

- o Severity of the particular health problem, as perceived by EPA, based on such available data as the number of Americans affected, and potential severity of the insult (potential magnitude of health effects)
- o Program needs of EPA's national noise abatement program for specific research results within specific time frames
- o Scientific recommendations of experts concerning the degree to which additional research is urgently needed
- o Scientific feasibility of carrying out the needed research within reasonable time, with reasonable resources
- o Appropriateness of EPA activity, in the context of whether an organization outside EPA--usually another Federal agency--is already performing the needed research

In performing the evaluation of overall priorities among categories, each of these five factors was evaluated (as high, medium or low) and then weighted. For example, if EPA research in a specific category was evaluated to be "high" in appropriateness, it meant that the needed research was not being conducted elsewhere and would not be accomplished without the commitment of EPA resources. However, not all factors were considered equally important. The most important considerations were the severity of the health problem and the degree to which the proposed research would meet EPA program needs. These were weighted accordingly.

2.1 Overall Results of Priority Analysis

Based on these evaluation factors, the overall priorities of the noise Research Plan are given below, with short explanations of the ratings. It should be noted that although a category may be rated as low or medium in priority, pending EPA or State and local actions may require that a certain Initiative be investigated. This will be explained in more depth when the operational Research Plans are presented for each category in Chapters 4 through 11.

<u>Importance</u>	<u>Level of Emphasis Rating</u>	<u>Category</u>
Highest priority	A	Nonauditory Physiologic Effects
	B	(1) Sleep Disturbance (2) Individual and Community Response
	C	(1) Noise-Induced Hearing Loss (2) Behavioral, Social, and Performance Effects
	D	Communication Interference
Lowest priority	E	Effects of Noise on Wildlife and Other Animals



2.2 Level of Emphasis A (Highest Level)

2.2.1 Nonauditory Physiologic Effects*

This research area is the highest priority because it has the greatest potential health implications and no other Federal agencies are adequately researching this category.

Severity.--The potential health problem posed by nonauditory physiologic effects is very great. Noise, like other physical stressors, is capable of producing a variety of physiologic stress responses in the body. Stress has been linked to a number of chronic diseases prevalent in our society. Although there are scattered findings associating noise with a number of health problems, the best-documented relationship is the one between noise and elevated blood pressure and related cardiovascular problems. Heart disease ranks as the number one cause of death in America. Hypertension--the most likely specific effect of noise--is a demonstrated risk factor in the development of heart disorders, stroke and kidney disease. It is conservatively estimated that from 23 to 27 million Americans suffer from hypertension. For a very large proportion of these cases (90 percent), the causes are not known; yet hypertension contributes to 250,000 deaths annually in the United States. If, as some evidence suggests, there is a cause-effect relationship between noise and hypertension, the health implications of such a relationship would be widespread and serious. In addition to cardiovascular effects, other nonauditory physiologic effects of noise may be equally serious.

* This category covers physiologic effects other than the physiologic effects of noise on the ear.

That is why it is urgent to find out as soon as possible the extent to which such relationships exist.

Program Needs.--EPA's need for better information in this category is very great because all of EPA's noise abatement program activities are based on the need to protect the public health and welfare. To the extent that EPA's criteria presently in use (annoyance, hearing loss, activity interference) do not take into consideration some of the most serious effects such as the potential for cardiovascular disorders, they are deficient. While it is unlikely that the first five years of nonauditory physiological research will yield the kind of quantified criteria which the EPA program requires, it might verify the extent to which the noise/physiologic health relationship exists, and thus change both the direction and importance of the EPA noise abatement program.

Scientific Recommendations.--Health scientists from all over the world have recommended that more attention be given to nonauditory physiologic effects of noise. These recommendations are based upon the findings of research to date. The Third International Congress on Noise as a Public Health Problem (Freiburg, West Germany, 1978) pointed out the necessity for giving priority to this research. Since the previous International Congress in 1973, at least 123 reports of related research studies have been published in the international literature, dealing not only with the heart and circulatory system, but also with effects on vision, fetal development, biochemical constituents of the bodily system, the digestive system, the muscular system, and the nervous system.

A committee (CHABA Working Group 81) of the National Academy of Sciences has recently recommended that investigation of the relationship between noise and medically significant physiological responses be accelerated, with cardiovascular measures as the initial focus.

Moreover, a recent Workshop of Cardiovascular Experts at the Massachusetts Institute of Technology underscored the plausibility of the linkage between noise and cardiovascular problems, and urged that a high priority be placed on research in this area, including epidemiological research.

Scientific Feasibility.--There are some definite methodological difficulties involved in conducting research on the nonauditory physiologic effects of noise.

Understanding the ways in which noise can change the body's dynamic physiologic systems requires a serious and in-depth program of research. A coordinated program of animal, human clinical, and epidemiological research is essential. Conducting valid research in this area requires the blending of advanced acoustic measurement with sophisticated and detailed monitoring of physiological indicators in both acute and chronic exposure situations. For the most part, the techniques are currently available; the problem is bringing them to bear on the study of noise effects. The essential development of quantifiable dose-response criteria depends on the careful and logical accumulation of causal data. It is optimistic to think that any single study or set of studies will yield the type of data that EPA needs. Although the problems standing in the way of good research in this category appear

formidable, the challenge is not different from that faced in most areas of biomedical research.

Appropriateness.--It is unlikely that the required research will be performed without EPA action. Based on a review of research being conducted or sponsored by Federal agencies, no relevant research efforts are currently being sponsored by other agencies, except for a joint EPA study with the National Institute of Environmental Health Sciences, currently in progress. Therefore, an active EPA initiative in the nonauditory physiologic effects category, particularly in research concerning the cardiovascular system, will not be duplicative of other efforts. It appears that EPA must take the lead in this category of research, at least in the initial years of study.

2.3 Level of Emphasis B

2.3.1 Sleep Disturbance

Severity.--Millions of Americans live in areas where the potential for nightly sleep disturbance by noise is high. Such residential sleep interference is one of the primary contributors to irritation and annoyance by neighborhood noise.

Some subjective effects of sleep disturbance that have been reported are fatigue, irritability and poor work performance. Often, a greater susceptibility to illness has been attributed to a poor night's sleep. Nevertheless, none of these suspected effects has been fully explored or measured.

Chronic sleep disturbance is a potentially severe health problem, yet little is known about the long-term effects of sleep disturbance on health, the national incidence of sleep disturbance by noise, and its effects on subsequent task performance and safety implications on the job, in traffic and in other settings.

Program Needs.--EPA currently uses two criteria (awakening, and sleep disturbance or changes from deeper to lighter sleep) to quantify the benefits of noise control actions. These benefits are then weighed against costs. Although adequate for Federal regulatory purposes, the present criteria have several limitations that affect their generalizability to different noise sources, to typical sleeping conditions in the home, and to various population subgroups (the elderly, the ill, and others). Thus, there is a pressing need for an EPA research effort in light of both the limitations in applicable research findings, and EPA programmatic needs to relate better the impact of sleep disturbance (including health and performance effects) to nightly noise levels that potentially interfere with sleep.

Scientific Recommendations.--In 1978 the Federal Noise Effects Research Panel recommended that considerably greater funding be applied in the sleep category, noting that funding levels had dropped since the Panel's 1975 report and that certain recommended research had received no attention. The Panel recommended that attention focus on chronic sleep interruption by noise, and on the effect of sleep interruptions on special populations such as the ill and the aged.

Similarly, experts at the 1978 International Congress on Noise as a Public Health Problem emphasized the need for noise effects researchers to determine the effects of acoustic and nonacoustic variables on sleep quality, while encouraging general sleep researchers to continue to study the effects of sleep quality on general health.

Scientific Feasibility.--As in the nonauditory physiological effects category, there are a few methodological difficulties to be overcome. One of the primary methodological problems confronting scientists is the difficulty of transferring research activity from laboratory to residential settings. Nevertheless, in-the-home techniques have been pioneered in this country and similar techniques are currently in use in Europe.

Appropriateness.-- The relative lack of other applicable research makes EPA action necessary. Over the last five years only limited sleep research has been performed by other Federal agencies and these research studies have principally focused on aircraft noise.

2.3.2 Individual and Community Response

Severity.--It is estimated that well over 100 million Americans are exposed to noise that is perceived to be unwanted, unnecessary, objectionable, and disturbing. Noise levels that are known to cause annoyance and interference with everyday activities emanate from common sources including road traffic, aircraft, construction activity, and household products to name but a few. Thus noise in our communities today is pervasive and intrusive.

Annoyance that occurs as a result of exposure to noise is a complex psycho-social reaction. Although annoyance has as its basis the unpleasantness associated with noise and the disruption of ongoing activities, the response may ultimately lead to complaints or produce strong group reactions against certain noise sources. This type of annoyance response has not yet been experimentally identified with adverse physiologic reactions. Instead it is related to subjective feelings of irritation, being upset, and a general lack of well being.

Nevertheless, increasing evidence of a possible association between excessive noise and stress-related health problems, such as hypertension and digestive changes, may link the annoyance or irritation that we commonly feel toward noise to the undesirable health effects that may occur. Although this link has as yet not been scientifically or experimentally established, it is not unreasonable to view our annoyance reactions as a biological protective mechanism - a warning or symptom of unwanted health effects. For instance, recent community noise surveys are starting to reveal a relationship between those persons who are highly annoyed by noise, and who feel that noise may be adversely affecting their health and welfare.

Program Needs.--The category of individual and community response is most important in that individuals' subjective (annoyance) reactions to noise have in fact been the primary impetus for the establishment of Federal, State and local noise control programs throughout the United States. Moreover, quantitative information that is available with respect to community response has formed the basis for noise emission

regulations, policy, and guidance promulgated at the Federal governmental level. Community noise criteria, in the form of the percentage of people expected to be highly annoyed at specific noise levels, are the primary human response criteria used in noise control policy and legislation. These criteria have predominately been developed in a number of studies of traffic and aircraft noise in an attempt to better ascertain general community or group response to noise. Although adequate for Federal regulatory purposes, the generalizability of these criteria to specific sources of noise such as construction activity and railroad noise has been questioned. As the number of different noise sources that must be considered by Federal, State and local noise programs increase, it is anticipated that more specific criteria applicable to specific sources or noise settings will be needed.

Moreover, studies completed to date have not accounted for many of the acoustic and nonacoustic factors that shape our response to noise. Severe programmatic limitations exist in understanding the influence upon individual and community reactions of certain acoustic attributes typical of many noise sources found in the community. These attributes include perceived tonal components, impulsiveness, fluctuation in level, intrusiveness over background noise, and so forth. Methods do not exist that properly account for the expected increase in adverse community reactions that typically result from these factors. Moreover, the large individual differences that typically occur in annoyance responses have not been accounted for. The result has been a rather pragmatic approach to the matter of assessing community and individual

response to noise. There exists no noise annoyance calculation procedure that deals satisfactorily with the many acoustic and nonacoustic variables that influence our subjective responses to sound and, accordingly, our perspectives on the quality of our life.

Cost effective noise abatement decisions and actions are highly dependent upon the refinement of existing criteria pertaining to individual and community response, both in environments dominated by specific noise sources, and in environments with diverse noise attributes.

Scientific Recommendations.--There exists a general consensus within the scientific community on the need for further research and the direction it should take. Scientific recommendations, including those made at the 1978 International Congress on Noise, as well as those in the forthcoming World Health Organization document on environmental noise criteria, point out that while aggregate community response to noise can be reliably predicted, more work investigating the mediating factors is needed to help account for the great individual variation in response. Further, the stress-related components of response also require more investigation. In addition, as communities experience changes in their noise environment, longitudinal studies should be conducted to assess adaptation and societal changes in public reaction to noise.

Scientific Feasibility.--Research in this category has a high expectancy of achieving useful results because it is based on very successful, well-established techniques (attitudinal survey methodologies and psychoacoustic test procedures) that are commonly used to study

subjective human reactions to noise. Improved subjective and acoustic measurement methodologies are now available.

Appropriateness.--Although other Federal agencies are active to some extent in parts of this research area, the research gaps left are sufficiently critical to require EPA activity. Recent Federal efforts, primarily by the National Aeronautics and Space Administration, the National Bureau of Standards, and the Air Force, have been significant, but have focused on relatively narrow study areas, mainly aircraft noise. Information needs specific to EPA's program requirements have not been fulfilled by these other research efforts.

2.4 Level of Emphasis C

2.4.1 Noise-Induced Hearing Loss

Although much additional research in noise-induced hearing loss (NIHL) is needed, feasible, and related to EPA program needs, EPA is placing only medium emphasis on its role, largely because of the in-depth research programs already being undertaken by other Federal agencies.

Severity.--Noise-induced hearing loss is the most widespread occupational health problem in the United States, and there is evidence that additional noise exposure from environmental sources exacerbates the problem. Of the estimated 20 to 25 million people in the United States exposed to levels of noise sufficient to cause irreversible damage to their hearing, 15 million are estimated to be workers exposed to noise on the job. Impulse noise is a particularly severe problem

in the occupational setting which has not been adequately addressed. It is estimated that over 2.7 million workers are exposed to impulse noise and are not covered adequately by present damage risk criteria. It is particularly important to consider the problem of workers whose workplace exposures are augmented by off-the-job exposures. Other potentially hazardous exposures occur in transit, in using appliances and power tools at home, and in common recreational activities. Preliminary information also suggests that people in comparatively low noise work environments such as office workers and homemakers are exposed to 24 hour noise exposure levels which may place some of them at higher risk to hearing damage.

It is estimated that as many as 19 million Americans suffer from a handicapping hearing loss. Persons suffering from noise-induced hearing loss often report other health disturbances as well. They are also frequently the victims of tinnitus (ringing in the ears), lowered auditory discomfort thresholds and other annoying side effects. Impaired hearing can be socially debilitating. Persons with NIHL often speak of difficulty in understanding communication, withdrawal from social contacts, embarrassment, frustration and isolation. Noise-induced hearing loss greatly affects the lives of millions of individuals. It is a difficult problem since the process is gradual and insidious and may not be apparent until a considerable amount of hearing is lost.

Program Needs.--Although scientifically acceptable damage risk criteria exist, EPA requires better defined hearing loss criteria to support its regulatory and Federal coordination programs for

environmental noise sources. The probability that a person will develop a noise-induced hearing loss depends on the individual's total exposure from all noises at work, home, and in the community. A determination of those sources and each source's contribution to an individual's risk of hearing loss will provide added direction to governmental regulatory programs and development of appropriate actions.

Scientific Recommendations.--There is a widespread consensus on the need for further research on the key segments of the NIHL research category, as characterized by conclusions reached at the 1978 International Congress on Noise, a recent NIH workshop on noise research, the Federal Noise Effects Panel Report, and the forthcoming World Health Organization (WHO) report. As recommended by these groups, future research should concentrate on some of the less well defined aspects of the problem such as the question of hearing loss caused by specific environmental sources, the effects of intermittent and impulsive noise, and the question of determining risk to susceptible populations such as children. These areas have in the past received a low level of funding and need to be addressed at the present time.

Scientific Feasibility.--The feasibility of ongoing and planned NIHL research is generally high. It is solidly based on research performed over the last 30 years. The development of new sophisticated personal monitoring instrumentation, clinical methodologies and microscopic assessment techniques makes research possible now that could not have been undertaken several years ago.

However, in the future, certain avenues of research will be limited. For one, workers should not be exposed to high noise levels which may jeopardize their hearing. Effective enforcement and compliance with Federal workplace noise provisions will make it difficult to identify workers for hearing loss field studies. If workers exposed to high levels of noise were found, it would be irresponsible not to take necessary actions to provide them with adequate hearing protection. Secondly, many research institutions are finding it difficult to obtain approval for human subject research under high noise exposure conditions.

Appropriateness.--Over the last five years, seven different Federal agencies have devoted considerable resources to numerous NIHL studies. Approximately 20 studies related to aspects of NIHL of particular interest to EPA have been funded at a cost of over \$1 million per year. Due to the continuing interest of other agencies in funding NIHL research, EPA will assume a very limited but focused research role in areas not presently being adequately covered.

2.4.2 Behavioral, Social and Performance Effects

The category of behavioral, social, and performance effects of noise is an extremely broad category, whose effects are often subtle, complex, and indirect, and usually mediated by nonacoustic factors.

Severity.--Although the scientific literature contains many potentially important findings, not enough information exists at this time to allow proper consideration of the severity of noise effects. Enough is known, however, to identify those areas that are most important

Good! and most in need of research. There are some definite indications of anti-social and aggressive behavior resulting at least indirectly from noise, performance decrements due to noise, learning disabilities attributed to, or aggravated by noise, and stress-related psychological responses that may be due in part to noise. Some very important questions exist concerning the way in which individuals adapt to and cope with noise, and how the performance, productivity and social and personal adjustment of adults as well as children may be impaired by noise.

Information is particularly needed on how noise affects the development of language and cognitive skills in children. Some of the most pervasive effects of noise fall within this category. These are important questions because they pertain to how noise ^{may} ~~interferes~~ ^g with personal, mental and social functioning and ^{may make} ~~makes~~ the accomplishment of important goals more difficult.

Program Needs.--The adverse behavioral, social and performance effects of noise are clearly relevant to EPA program requirements. At present, EPA has no criteria for any of the effects that noise may have on behavior and/or performance. To the extent that further research enables effects to be quantified in the form of criteria, they can and must be included in assessments made in support of regulatory programs and State and local activities. For example, definitive information concerning how noise affects the acquisition of language and other cognitive skills may necessitate that special consideration be given to noise around schools and residential environments, and to the modification of existing communication interference criteria. Information on behavioral

and social problems associated with noise exposure would have a direct application to regulatory actions and State and local noise program activities. This category of effects may be especially important where levels of exposure are only moderately high or where contextual factors characteristic of the exposure situation appear important.

Scientific Recommendations.--Recent international scientific congresses on noise have emphasized both the potential significance and the extreme complexity of these problems. One of the general areas that has been identified for future research is in the determination of the sociological effects of noise in relation to the quality of life. Other gaps in the scientific literature have been identified and a more realistic posture has been taken toward the level of sophistication required to attack these multivariate research questions.

Scientific Feasibility.--The complexity and subtleness of noise effects in this category necessitate the use of sophisticated and elaborate research designs and detailed, multivariate techniques for data analysis. The fact that noise seldom occurs alone in natural settings requires that an effort be made to ensure that research outcomes are attributable to noise. In spite of these difficulties, a number of behavioral science and sociological methodologies are available for carrying out a program of research and systematic replication which could be expected to yield results of use to EPA noise abatement activities.

Appropriateness.--Due to the relative lack of activity elsewhere, EPA will need to take the lead if this important area is to be investigated to any significant degree. Even the ongoing task

performance research is not directly applicable to the environments of concern to EPA. The relatively small amount of ongoing research on the effects of noise on children is exploratory in nature and will be used by EPA in planning more focused research in this important area.

2.5 Level of Emphasis D

2.5.1 Communication Interference

Severity.--In terms of severity of the problem, everyday experience shows that almost all Americans are exposed to noise at levels sufficient to interfere severely with their activities at home (including conversations and listening to TV, radio, or recorded music), in transit, and at their workplace. Interference with speech communication is more than an annoyance. It represents a reduction in efficiency, and in some circumstances a real threat to safety resulting from messages being missed or not understood.

Program Needs.--Investigation of communication interference is highly relevant to EPA noise program needs because much of the existing regulatory program is based on well quantified criteria for speech interference. While these criteria are adequate for Federal regulatory purposes, they may need refinement to ensure their suitability in non-steady state background noise conditions and for listeners other than normal hearing, native adults.

Scientific Recommendations.--There is consensus on the directions for continued research including: extension of the generalizability of research based on communication systems; increased emphasis on quality of communication; requirements for communication in fluctuating noise situations; and the speech communication requirements of special groups such as the very young and hearing-impaired listeners.

Scientific Feasibility.--As one of the older and better established disciplines, communication interference is well suited for further study with the well developed methodologies available.

Appropriateness.--The relatively large amount of Federal activity already underway may minimize the need for EPA emphasis, with a few exceptions. EPA's interest in conducting additional work is limited to rather well-defined topical areas not presently being adequately covered. These include development of refined criteria for the effects on special groups such as children, special effects in teaching and learning activities, and secondary effects of disrupted communication on safety and task performance.

2.6 Level of Emphasis E

2.6.1 Effects of Noise on Wildlife and Other Animals

Severity.--The severity of noise effects in the animal kingdom is unknown at this time. It is known that for many species there is behavioral habituation to the use of noise as a deterrent (e.g., to keep birds from farm crops). More shy species, however, may

respond to noise by retreating from the site of human activities, reducing territorial coverage and, possibly, population size. It is doubtful that this can be considered a noise effect, and is more likely a response to human land use.

There are certain known effects of noise on domestic animals such as livestock and fowl. These effects include undesirable changes in color and quality of meat, and effects on hatching of eggs.

The potentially serious effects of noise as a masker on species which rely on aural communication for safety from predators are not known. Nor do we know the effects of environmental noise on any endangered species.

Program Needs.--Many State and local governments look to EPA for information on wildlife noise effects largely for purposes of Environmental Impact Statements and proposed highway and airport projects. A large number of inquiries are received in this area. In EPA's regulatory program, knowledge of effects of noise on animals would help to quantify the benefits of noise control, particularly for recreational and off-road vehicles.

Scientific Recommendations.--The Ninth International Congress on Acoustics (in 1977) held a special symposium on questions of noise effects on animals, stressing the importance of understanding how noise may affect the ecosystem. This symposium prompted a session at the Third International Congress on Noise as a Public Health Problem (1978). At both meetings, results of a few studies were reported, but concern was expressed that very little is known at present, and no conclusions could be drawn.

Scientific Feasibility.--Full study of this problem would require an enormous research effort. Whereas in studying domestic animals, experimental controls and measurement techniques are relatively simple, studying animal responses in the wild is more difficult, particularly because it is desirable to do long-term studies of noise effects. Telemetric techniques are available and feasible for some species, but more investigation will be necessary.

Appropriateness.--While EPA has some statutory authority in this area, other agencies have more clear-cut missions related to environmental effects on wildlife and domestic animals and have sponsored some research on noise effects. Given their respective missions, it is more appropriate for this work to be conducted by agencies other than EPA. EPA's proper role may be seen as promoting and coordinating this research.

3. EPA'S RESEARCH PLAN IN DETAIL (INTRODUCTION)

3.1 Definition of Long-Range Objectives

Developing a comprehensive Research Plan requires as an initial step the defining of long-term objectives for each of the categories of health effects research. These objectives have been defined as broadly as possible in Chapter 2 in the light of EPA's research and program mandate, so that if they were fulfilled, the national noise abatement program would have an adequate "health and welfare" information base. This information base is needed to support future activities that will effectively and efficiently minimize adverse noise in our environment at the lowest cost possible and with the least disruption to our lives. Obviously, as general targets to be aimed at, these long-term objectives will be used for purposes of reference.

3.2 Definition of Short-Term Objectives and Base Year

The specific Plan presented here covers the time period from Fiscal Years 1981 to 1985. EPA's short-term research objectives are those which have been selected for initial action within this period. The short-term objectives, therefore, represent a set of limited but important milestones in pursuit of the identified long-term objectives.

Note also that base year research activities, for the purpose of this Plan, are those occurring in the pre-Plan year, Fiscal Year 1980.

3.3 Definition of Research Initiatives

Corresponding to each short-term objective in the Plan are one or more Research Initiatives. Each Research Initiative is conceived as a particular line of inquiry in pursuit of a specific, identified objective. Research Initiatives will be time-phased, both because of resource constraints and because of the intent that outputs of some Initiatives will act as prerequisites necessary to initiate others. Further, a given Research Initiative should not be thought of as a "project" or "program." In many cases a given Research Initiative will consist of a number of components which are frequently supported by one or more projects in a time-phased manner. A list of identified Research Initiatives within each research category is contained in Table 3-1.

3.4 Concept of Evolution in Research

Underlying the approach taken by EPA is the fact that the research categories for which long-term objectives have been set differ from each other in at least one important respect: the maturity of research activity in the category. For long-established categories, information is organized around well-defined and generally accepted concepts and methodologies. Furthermore, there is a group of recognized specialists pursuing more advanced questions such as the refinement of criteria or the investigation of the specific health risk to special populations. Other categories, which only recently have begun to be recognized, are still developing conceptually, and frequently need to involve specialists from unrelated fields organized in a cross-disciplinary, biomedical research effort. In this case the problem

TABLE 3-1
IDENTIFIED RESEARCH INITIATIVES

NONAUDITORY PHYSIOLOGIC EFFECTS	<ul style="list-style-type: none"> I. Animal Experimental Studies on the Relationship Between Noise, Elevated Blood Pressure and Other Cardiovascular Effects II. Epidemiologic Studies on the Relationships Between Long-Term Noise Exposure and Adverse Cardiovascular Effects III. Human Clinical Studies of Cardiovascular and Neuroendocrine Responses to Noise IV. Nonauditory Physiologic Effects Other Than Cardiovascular Effects
SLEEP DISTURBANCE	<ul style="list-style-type: none"> I. Relationship between field and laboratory data on sleep disturbance by noise II. Health consequences of noise-disturbed sleep III. Acoustic parameters related to sleep disturbance IV. Susceptibility of sensitive populations to sleep disturbance by noise V. Adaptation to sleep disturbance by noise
COMMUNITY AND INDIVIDUAL RESPONSE	<ul style="list-style-type: none"> I. Determination of the magnitude of community and individual response attributable to <u>specific sources of noise</u>. II. Determination of the relationship between <u>specific acoustic attributes</u> and the magnitude of individual/group response to noise.
NOISE- INDUCED HEARING LOSS	<ul style="list-style-type: none"> I. Determination of the incidence of NIHL in the United States and contribution of sociocusis (nonoccupational NIHL) presbycusis (aging), and occupational hearing loss. II. Establishment of parameters of individual sensitivity to NIHL. III. Refine criteria for low-level noise exposure.
BEHAVIORAL, SOCIAL AND PERFORMANCE EFFECTS	<ul style="list-style-type: none"> I. Effects of Noise on Cognitive and Social Development II. Behavioral and Social Adjustment to Noise

may not be well enough defined, the results are less consistent, the methodological problems are greater, and the probability of failure is higher than for research in the more established categories. For any of the categories of research presented in Chapters 4-11, a logical and scientifically developmental sequence of research activity can be suggested. This sequence is typically followed in the development of quantified dose-response relationships, the determination of health-effects risk, and ultimately, the development of refined human response criteria. These are steps in an empirical research process. This sequence is shown in Table 3-2. Thus, certain types of research are the building blocks on which progress in the more advanced topics depends. The kinds of results that can reasonably be expected from new research depend in part on where the research category falls on this research developmental continuum.

In some areas of research where the health effect is critical, research may be undertaken out of sequence. The attempt to develop criteria in the shortest possible time often results in wasteful research, large funding expenditures, many unanswered questions, and continued debate over the implications of the results. In introducing the Research Plan for each objective, therefore, an attempt will be made to place the current status of research in that category somewhere on this developmental continuum. For example, while research in the noise-induced hearing loss and communication interference categories are relatively highly developed specialities, research in the nonauditory physiologic effects category belongs at the other end of the spectrum. That is, research proposed in the category of noise induced hearing loss will lead

TABLE 3-2
RESEARCH CONTINUUM IN THE DEVELOPMENT AND REFINEMENT OF
HEALTH EFFECTS CRITERIA

1. Demonstrate the existence of an association
2. Demonstrate a basic cause-effect relationship directly attributable to noise
3. Investigate underlying mechanisms and physiologic bases of the effect
4. Improve the cause-effect relationship through the investigation of intervening factors
 - A. Acoustic factors
 - B. Nonacoustic factors
5. Establish dose-response relationships, determine risk, and develop quantified human response criteria
6. Refine criteria based upon susceptible populations and special considerations

to the refinement of criteria, whereas research being proposed in the category of nonauditory physiologic effects will attempt first to demonstrate a basic cause-effect relationship directly related to noise exposure.

In the Research Continuum Table included in each chapter of this Plan, the status of research in each category is evaluated as either "Adequate", "Marginal" or "Inadequate". These labels denote adequacy with respect to reaching the ultimate objective of fully refined criteria for each noise effect category. However, these labels do not reflect a judgment of adequacy for Federal regulatory purposes.

3.5 Contents of the Research Plan for Each Category

The total Research Plan consists of a separate Plan for each of the eight research categories. A number of Research Initiatives are proposed in each category. Each Plan will consist of the items shown in Table 3-3.

3.6 Establishing Fiscal Year Funding Levels

Overall EPA extramural funding for the Plan is projected to increase from \$1.2 million in Fiscal Year 1981 to \$3.0 million in Fiscal Year 1985. The total EPA noise effects research budget is projected to be \$10 million over the five-year period. These levels were established

TABLE 3-3

ITEMS INCLUDED IN THE PLAN FOR EACH RESEARCH CATEGORY

1. Rationale for Selecting Specific Research Initiatives--For funding over the Five Year Period.
 - o What is Known.--Status of research in the category.
 - o What is Not Known.--Research that needs to be conducted to fill in important deficiencies in data and improve understanding of specific health effects.
 - o EPA Priorities.--Research requirements of EPA due to specific noise control program needs.
 - o Current Research Activities.--Ongoing research projects of EPA and other Federal agencies.*
 - o Position on the Research Continuum.--Status of research in relation to the development of refined health effects criteria.
 - o List of Planned EPA Research Initiatives for the Five Year Period.--Identification of specific lines of inquiry in pursuit of category objectives.
2. Detailed Descriptions of the Research Initiatives.--Each description includes:
 - o Description and Basic Considerations
 - o Relation to Ongoing Non-EPA Research.--Federal and private.
 - o Expected Results.--How the results will be used upon completion of the Initiative.
3. Timing and Funding of the Research Initiatives.--Chart.
4. Monitoring and Coordination.--For example, advisory groups that will be established to evaluate progress of research and provide inputs.
5. Research Initiatives That Will Not Be Undertaken by EPA.--Because of limitations in funding, important Research Initiatives will not be undertaken by EPA, although other agencies may wish to pursue them.

[* Requests were made in early September to other agencies for this information. Some responses have not yet been received, and therefore were not included in the present Plan. When this information is obtained it will be incorporated into the appropriate discussions.]

by using the first year funding of \$1.2 million,* which was established as a base under the Federal Zero Base Budgeting process. Funding levels for successive years were then established by applying an annual growth rate factor which would be reasonable when judged by two criteria:

- o Slow enough to ensure effective program management based on present staff levels
- o Fast enough to achieve the results required by the EPA national noise control program without undue delay.

By trading off these criteria, it was determined that an optimum annual growth rate was approximately 25 percent. The following amounts are the proposed EPA extramural funding levels for research per year.

<u>Fiscal Year</u>	<u>EPA funding levels in Plan</u> (millions of dollars)
1981	1.2
1982	1.5
1983	1.9
1984	2.4
1985	3.0

3.7 Assumptions

3.7.1 Co-Funding by Other Agencies

Co-funding of certain EPA Research Initiatives by other Federal agencies is a distinct possibility in research categories where the agencies have mutual interests. Such co-funding is highly desirable

* This figure does not include \$200K set aside for general programmatic support.

because it would allow more results to be obtained within the Five-Year Plan period.

However, only in the category of nonauditory physiologic effects is co-support being assumed in the planning and design of the specific EPA Research Initiatives. The assistance of other agencies is needed due to the urgency in which this information is needed, the high costs of the required biomedical research and the requirement that the research be pursued in a broad-based, multidisciplinary manner. Furthermore, co-support is being assumed based upon the relevancy of the planned cardiovascular research to research presently being supported by the National Institutes of Health (NIH). EPA foresees a shift in the lead role to NIH by Fiscal Year 1986, after the initial thrust in cardiovascular research is completed and detailed results are available. Only with co-support during the next five years can EPA conduct the necessary animal, human clinical and epidemiologic research to determine the extent to which a basic causal relationship exists.

3.7.2 Nature and Direction of Research Findings

The Research Initiatives suggested for study within this Plan are proposed with the aim of deriving findings that will lead toward criteria development within each of the research categories. However, there exist no guarantees on the results of the specific studies that will be undertaken. Biomedical research is by nature a continual learning process. Each step of investigation at times necessitates re-definition

of new directions and replication of previous studies. Depending on research results, it may be necessary to restudy or replicate some areas of research, and abandon others.

4. RESEARCH PLAN FOR
NONAUDITORY PHYSIOLOGIC EFFECTS

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4. RESEARCH PLAN FOR NONAUDITORY PHYSIOLOGIC EFFECTS

4.1 Rationale for Selecting Specific Research Initiatives Over the Five-Year Period

The long-term objective of nonauditory physiologic effects research is to determine the physiologic effects of noise on bodily systems and on general health, with special emphasis on hypertension and other cardiovascular effects.

4.1.1 What is Known

Studies have shown that noise acts as a biologic stressor. Nonauditory physiologic stress reactions, such as transient changes in blood pressure, heart rate and respiration, alterations in hormonal levels and gastrointestinal motility, and measurable changes in skin resistance and muscle potentials have been documented for noise exposures typical in level to those encountered in the human environment. The hormonal changes and other effects produced in animals and humans to noise appear to be similar to those elicited by other stressors.

Laboratory research with rodents has yielded a variety of both transient and enduring morphologic, hormonal and metabolic responses to noise. The generalizability of the results of these studies is severely restricted due to the proclivity for convulsive behavior ("audiogenic seizures") among rodents and to the fact that the auditory sensitivities of rodents differ considerably from those of humans.

There is evidence that the fetus can be affected by noise stimuli, either directly or through changes induced in the system of the mother. Only a very small amount of animal and human work has been done in this area, but there are some preliminary data suggesting stress-related adverse effects on biochemical activity, birth defects, and birth weights.

The consequences of long-term noise exposure on general health status have been examined in several correlational field studies. Overall, these studies have provided a complex and mixed pattern of results. There are data indicating that chronic noise exposure is associated with a number of common health problems and complaints. Not atypical of field research, many of these studies are subject to criticism on methodological grounds. The major problem in this type of research is determining whether noise per se is the cause of these problems.

By far, the most systematic body of research exists on the relationship between long-term noise exposure and hypertension and other cardiovascular problems. Approximately 40 cross-sectional, retrospective epidemiologic studies have been conducted, mostly in Eastern European countries. Research in at least 11 different nations and in at least 18 different industries indicate increased cardiovascular morbidity as a function of long-term noise exposure. Hypertension appears to be the most prevalent concomitant of noise exposure in these studies. Although it is difficult, for a number of reasons, to adequately evaluate these studies, the apparent magnitude and consistency of these findings cannot be ignored.

In addition, two recent studies, one in the United States and one in Germany, have reported elevated blood pressure among children living and/or attending school in high noise areas. These studies are particularly noteworthy in determining the significance of environmental factors in the development of hypertension.

Recent laboratory research in this country, using an appropriate animal model, the Rhesus monkey, has shown that as little as several months exposure to environmental noise levels can produce significant and sustained elevations in blood pressure of approximately 30 percent. Furthermore, even a month after the noise was turned off, the animals' blood pressures did not return to pre-exposure levels, suggesting that recovery, if it occurs, will take some time. This type of controlled investigation, where noise is the only stressor present, parallels past epidemiologic research, and suggests the importance and the promise of study in this area of noise effects research.

4.1.2 What is Not Known

Although it is known that noise acts as a stressor, it is not known with certainty whether prolonged exposure results in cumulative pathology. Whereas the organism is often capable of adapting to noise at the conscious, behavioral level, there appear to be physiologic costs attached to this adaptation. What is the overall medical significance of these costs? Precise cause-effect relationships need to be drawn between noise and medically significant physiologic responses such as

blood pressure, and between noise and the so-called stress diseases or diseases of adaptation.

Information is lacking on the mechanisms underlying noise related changes and the extent to which noise operates in a similar fashion to other better understood stressors.

Quantitative data are virtually nonexistent concerning the role played by the various physical parameters of noise, its level, frequency spectrum, temporal pattern, and duration. The extent to which nonacoustic factors, or the context in which the noise occurs, mediate the stress effects of noise is not known and must also be specified. This is the type of information necessary to develop quantitative criteria in support of noise control activities.

Attention must be given to identifying those segments of the population that might be particularly susceptible to these effects, for example, children and the elderly. Individual differences must be investigated. Information pertaining to the extent to which chronic noise exposures might exacerbate pre-existing health problems such as hypertension is not available.

4.1.3 EPA Priorities

The most urgent EPA goal is to verify as soon as possible the extent to which a cause-effect relationship exists between noise and stress-related diseases such as cardiovascular disease, on the grounds that the scope of the potential public health problem is great. Noise is probably the most pervasive pollutant in the occupational and

non-occupational environment. In recognition of the potential health problem, the Quiet Communities Act requests that special emphasis be placed on conducting research on the nonauditory physiologic effects of noise.

Statistical associations have been demonstrated between noise and cardiovascular problems, but their ultimate significance awaits further, more sophisticated research aimed at establishing causality. A combination of animal, human clinical and epidemiological research is required. Information must be obtained on the role of various acoustic and nonacoustic variables, and on the susceptibility of various sub-populations to noise-related cardiovascular effects. This type of information is required in order to develop quantitative dose-response criteria. Only limited attention will be given to in-depth examination of basic mechanisms. Although a fairly extensive and costly program of research is required, the costs of ignorance are potentially very great.

Good

EPA recognizes that little is known about any of the possible nonauditory physiologic effects of noise, and that the health consequences are potentially great for all of these effects. EPA has, however, decided to concentrate primarily on cardiovascular effects research (since not all areas can be researched in depth simultaneously) for the following reasons:

- (1) It is the best documented;
- (2) It is the most feasible scientifically;
- (3) It is linked to a serious and widespread health problem.

4.1.4 Current Research Activities

EPA has already had more than three years experience sponsoring nonauditory physiologic research. The major EPA effort is an investigation of the relationship of noise to sustained elevations in blood pressure. This study is being conducted at the University of Miami and is funded by EPA with co-support from the National Institute of Environmental Health Sciences (NIEHS). EPA is also sponsoring an epidemiologic feasibility study to be completed in Fiscal Year 1980. This study will help lay the foundation for subsequent research. It will provide an objective assessment of the foreign epidemiological literature, the analysis of key sets of foreign epidemiological data, and an evaluation of various epidemiologic approaches.

Beginning in Fiscal Year 1980, EPA will be obtaining descriptive data from the National Health and Nutrition Examination Surveys on the relationship between health status and indices related to noise exposure (see Chapter 7 for the corresponding Initiative).

Other Federal agencies appear to have little additional related research planned or in progress. The only exceptions are the following studies.

- o In the cardiovascular effects category, a study sponsored by the Veterans Administration is examining the effects of stress-producing, unpredictable noise bursts on groups of "coronary-prone" or "non-coronary-prone" men. The study will ultimately look at potential cardiopathology as a result of noise-induced stress.

- o An ongoing NIH/NIEHS project is looking at several physiologic effects of noise such as teratogenic, hormonal and cardiovascular effects.
- o A study by the National Institute of Child Health and Human Development is examining the effects of high noise levels caused by aircraft noise on the physical growth and development of children.
- o A study supported by the National Science Foundation and NIEHS includes an investigation of the blood pressures of children living near a large airport.

4.1.5 Position on the Research Continuum

As can be seen in Table 4-1, the present status of research in the nonauditory physiologic effects category must be considered almost wholly inadequate for the development of human risk criteria. It is only in the cardiovascular effects area that a reasonable amount of associative data exists.

TABLE 4-1

POSITION ON THE RESEARCH CONTINUUM - NONAUDITORY PHYSIOLOGIC EFFECTS

<u>Research Continuum</u>	<u>Current State of Knowledge</u>		
	<u>Adequate</u>	<u>Marginal</u>	<u>Inadequate</u>
1. Demonstrate existence of an association		X*	
2. Demonstrate basic cause-effect relationship			
A. Animals			X**
B. Humans			X*
3. Investigate physiologic mechanisms			X**
4. Investigate intervening factors. Improve causal effect relationship			
A. Acoustic			X
B. Nonacoustic			X
5. Quantify dose-response relationship			X
6. Refinement and special populations			X

* Foreign epidemiological research suggests a statistical association between noise and hypertension and other cardiovascular problems. Some experimental primate research also shows adverse effects on the blood pressure.

** EPA/NIEHS is supporting ongoing research which involves the examination of physiologic dynamics and causal mechanisms.

4.1.6 List of Research Initiatives Selected for the Five-Year Period

After reviewing the status of nonauditory physiologic effects research, EPA program needs and priorities, and the planned research activities of other Federal agencies, the following Research Initiatives for EPA funding have been selected for the next five years. They are not listed in order of priority.

- I. Animal Experimental Studies on the Relationship Between Noise, Elevated Blood Pressure and Other Cardiovascular Effects
- II. Epidemiologic Studies on the Relationships Between Long-Term Noise Exposure and Adverse Cardiovascular Effects
- III. Human Clinical Studies of Cardiovascular and Neuro-endocrine Responses to Noise
- IV. Nonauditory Physiologic Effects Other Than Cardiovascular Effects

The assumption was made in selecting these Initiatives that there will be co-support from other Federal agencies, increasing from small scale funding initially to significant amounts at the end of five years.

The timely execution of these Initiatives with an adequate level of support will require assistance in the form of co-support from other Federal agencies. The type of research proposed herein is multidisciplinary in nature, requiring expertise in a number of biomedical and bioacoustical areas. The participation of more than one agency will insure more effective research design, monitoring and review, and will provide research outcomes with programmatic relevance to more than one

agency. Biomedical research is very expensive to conduct, and EPA recognizes that, where feasible, costs should be shared in order to avoid duplication and superficiality. As pointed out previously, the potential costs of ignorance in this area are great. *A concerted program of research is required in order to make significant progress during the five-year period covered by this Plan.*

In the text that follows, Research Initiatives will be proposed which assume co-support by other agencies at a level of 25 percent in Fiscal Year 1982, climbing steadily to 43 percent in Fiscal Year 1985. Table 4-2 contains the estimated levels of co-support over the five-year period. Major components of these Initiatives will be described which contain funding levels and time periods based on this co-funding scenario. *The components which would not be funded, underfunded or delayed in the absence of co-support are marked by an asterisk (*) in the text. After each Initiative is discussed, a summary is provided of the negative impact which would occur if co-support was not forthcoming.* Figure 4-2 at the end of the chapter contains a summary of the total nonauditory physiologic effects research program both with and without co-support.

TABLE 4-2

ESTIMATED LEVELS OF CO-SUPPORT
FROM OTHER AGENCIES IN THE NONAUDITORY
PHYSIOLOGIC EFFECTS RESEARCH CATEGORY

	<u>FISCAL YEAR</u>				
	<u>1981</u>	<u>1982</u>	<u>1983</u>	<u>1984</u>	<u>1984</u>
EPA Funding*	570	795	900	1000	1300
Other Agency Funding*	0	270	500	650	1000
Percent Co-Support	-	25%	35%	39%	43%

* Funding in thousands of dollars.

4.2 Detailed Descriptions of the Research Initiatives

I. Animal Experimental Studies on the Relationship Between Noise, Elevated Blood Pressure and Other Cardiovascular System Effects.

Description and Basic Considerations.--The purposes of this Initiative are to: assess under controlled conditions the causal relationship between noise exposure and selected medically significant physiologic responses, particularly blood pressure; investigate the associated pathophysiology; and begin to develop quantitative dose-response relationships for selected effects.

The primate is the animal of choice. Animal research with an appropriate model will permit: detailed specification of acoustic parameters, sophisticated and continuous monitoring of physiologic activity, control of extraneous variables, and investigation of underlying mechanisms. There will be three components under this Initiative.

Component I. Systematic Replications and Methodologic Refinements.

Through 1980, the purpose of the University of Miami project has been to assess the feasibility of chronic exposure work using primates, and to determine whether such exposures to environmental levels produce sustained alterations in blood pressure and heart rate. Having accomplished these goals, this project will be expanded to provide necessary replications of the rather dramatic findings of the study, and to begin to examine the cardiovascular dynamics involved, and associated biochemical changes.

Other animal research will be initiated in 1981 aimed at:

- (a) Providing independent and systematic replications of the University of Miami findings,
- (b) Determining the most suitable experimental paradigms (e.g., shorter duration designs, nonchair restrained animals),
- (c) Examining the suitability of other primate species.

Funding for Component I.--Fiscal Years 1981 and 1982:

\$290K/year.

Expected Results.--By the end of Component I, EPA should have compiled a substantial body of animal data showing a relationship between noise exposure and alterations in blood pressure and other cardiovascular parameters. The physiological and biochemical mechanisms and processes involved in these effects will be better understood. Finally, EPA will have developed sophisticated and streamlined experimental paradigms using the most appropriate, available primate species.

*Component II. Investigations of Acoustic and Nonacoustic Factors.

In the second Component of animal experimental studies, it will be appropriate to begin to focus on the development of quantitative dose-response criteria using animal models. Very detailed work will be

done on the relationship between various acoustic parameters and cardiovascular effects. Examples of parameters to be studied include noise level, frequency content, duration and temporal pattern (e.g., intermittency).

This research will also examine the extent to which the effects are mediated by various nonacoustic factors. Interest here is with the context in which the noise occurs. Using well established conditioning and scheduling techniques, it is possible to manipulate important contextual variables, such as the "aversiveness" and "controllability" of the noise.

Funding.--Fiscal Years 1983-1987: \$200K (1983), \$200K (1984), and \$250K (1985).

Expected Results.--These parametric studies will begin to provide the type of information necessary to derive tentative dose-response relationships appropriate to the animal models, providing information on how much noise and what kind of noise is associated with how much effect. Information will also be obtained on the extent to which nonacoustic factors influence the relationship.

*Component III. Investigations of Differences in Susceptibility.

In the third Component of animal experimental studies, attention will be directed to attempting to determine individual differences in susceptibility to the cardiovascular effects of noise. Work will proceed using various kinds of animals: animals bred for

hypertension; animals whose systems have been compromised through surgical intervention, the infusion of hormones, or through pharmacological means; animals displaying other cardiovascular risk factors; animals preconditioned to be hyperreactive to noise and other stressors; and older animals, young animals and infants.

Funding.--Fiscal Years 1983-1988: \$100K/year.

Expected Results.--This research will attempt to determine whether there are certain factors which predispose or place the organism at greater risk for cardiovascular effects, and whether noise exacerbates pre-existing health conditions.

Without needed co-support, \$100K less would be available in Fiscal Years 1983 through 1985 for supporting animal experimental work. This represents a significant decrease (approximately 30 percent) in the funding of this Initiative. This decrease would necessitate prolonging the required work beyond the dates specified, or even not supporting any research on individual differences in susceptibility during the Five-Year Plan period.

II. Epidemiologic Studies on the Relationship Between
Long-Term Noise Exposure and Adverse Cardiovascular
Effects

Description and Basic Considerations. -- The purposes of these studies are: to provide valid epidemiologic data on the relationship of long-term noise exposure and adverse cardiovascular effects, particularly hypertension; to determine the extent to which a causal relationship exists between noise and cardiovascular effects; and to obtain data useful in deriving criteria for the cardiovascular effects of noise. There will be three components within this Initiative.

Component I. Retrospective Analysis.

The logical first step will be to demonstrate the existence of an association by providing a more systematic and careful replication of the existing epidemiologic findings. Taking advantage of a target of opportunity, the attempt will be made to retrospectively analyze the data from existing cardiovascular data bases.

Funding.--Fiscal Years 1981 and 1982: \$100K/year.

Expected Results.--Systematic replication of Eastern European research will have been done.

*Component II. Prospective Analysis.

Phase I - Small Scale Prospective Study

A relatively small, well-controlled prospective study will be initiated in 1982. It is anticipated that the study will be conducted in a work setting and involve some type of intervention scenario. An attempt will be made to find groups equivalent with respect to all the important variables affecting the outcome measures except noise. Detailed noise measurements will be made of the current environment and these will have to be repeated on a regular basis throughout the study. Dosimeters will be used to determine individual noise exposures. As a minimum, the project will include unbiased multiple measures of blood pressure, electrocardiograms (perhaps some type of continuous monitoring), assessment of hormonal responses to noise, standard blood chemistry, and chest x-rays. Emphasis will be placed on those individuals at high risk. Detailed medical histories and noise exposure histories will be obtained as well as symptom checklists and demographic, socioeconomic, behavioral and physiologic indicators. The data collection will span a period of approximately 3 years.

Funding.--Fiscal Years 1982-1984: \$400K (1982), \$500K (1983), \$600K (1984).

Expected Results.--The prospective study will provide a test of the causal relationship between noise and cardiovascular problems.

Phase II - Addition of Noise to Ongoing NIH Cardiovascular Research

The prospective study will be useful in determining the extent to which a causal relationship exists between noise and hypertension and other cardiovascular problems. If promising results are obtained, an attempt will be made to include actual noise exposure as a factor in ongoing and/or planned large-scale NIH longitudinal cardiovascular research. It is only through such research that the contribution of noise relative to other risk factors can be assessed in a sample large enough for generalization. Such an effort would contribute greatly to the development of valid dose-response criteria.

Funding.--Fiscal Years 1985-?: \$500K/year.

Expected Results.--The addition of noise to large-scale NIH research will provide a sample large enough for generalization.

*Component III. Investigation of Special Sub-Populations.

Phase I - Blood Pressure in Children

Tentative data concerning elevations in blood pressure and a fairly extensive literature on cognitive development suggest that children may constitute a population susceptible to the nonauditory effects of noise. In the biomedical research community there is also concern about the prevalence of essential hypertension in children and the predictive value of childhood blood pressure labilities and elevations. A basic question concerns the relative contributions of genetic and

environmental factors to the development of blood pressure elevations in children. In 1983, an initial investigation will be undertaken to examine the role of noise in one of several ways: 1) through an expansion of the Fels Research Institute longitudinal hearing loss study, 2) by adding noise to one of the several ongoing childhood blood pressure studies sponsored by NIH, or 3) by including blood pressure as a component in planned research on the effects of noise on cognitive and language development and school performance.

Funding.--Fiscal Years 1983-1985: \$150K (1983), \$150K (1984), \$150K (1985).

Expected Results.--This research will begin to determine whether young children are particularly susceptible to the cardiovascular effects of noise.

Without co-support, the completion of the Phase I - Small Scale Prospective Investigation would be delayed until 1985, thus preventing the Phase II - NIH Add On from beginning during the five-year period of the Plan. Absence of co-support would necessitate funding of the Phase I study through four years instead of three. Without co-support, the Blood Pressure in Children component will be delayed two years and would not be completed in 1985.

III. Human Clinical Studies of Cardiovascular and Neuroendocrine Responses to Noise

Description and Basic Considerations.--The purposes of this Initiative are to provide controlled examination of the relationship of noise exposure to medically significant nonauditory physiologic effects in humans, and to provide data on individual differences in susceptibility and the exacerbating effects of noise. Although it is difficult to do chronic exposure research with human subjects, there are important questions which can be addressed through human field and laboratory studies. One of the advantages of this approach is that it permits a combining of nonauditory physiologic effects research with research in sleep, behavioral and performance effects.

The program will involve a series of multi-day and/or multi-session experiments directed at examining cardiovascular and neuroendocrine response to noise. The time course of response, recovery, and adaptation will be examined using both phasic and tonic response measures.¹ Two components are planned under this Initiative.

*Component I. Investigations of Acoustic and Nonacoustic Factors.

Systematic attention will be given to the role of acoustic factors like level, frequency spectrum, and temporal pattern. Investigations will be carried out to assess the role of important

¹ The terms phasic and tonic, respectively, are used here to refer to measures which are rapidly changing versus those which are relatively enduring and long-lasting.

nonacoustic or contextual factors like controllability, aversiveness (annoyance level), meaning/familiarity, contingencies, and task load.

Funding.--Fiscal Years 1981 to 1985: \$100K (1981), \$150K (1982), \$150K (1983), \$150K (1984) and \$200K (1985).

*Component II. Investigations of Differences in Susceptibility.

Experiments will be conducted using several relevant sub-populations of subjects such as normotensives, hypertensives, Type A coronary prone personalities, and the chronically noise exposed. These studies will be carried out using either residential or mobile laboratories.

Funding.--Fiscal Years 1981 to 1985: \$80K (1981), \$125K (1982), \$150K (1983), \$150K (1984), \$150K (1985).

Relation to Ongoing Non-EPA Studies.--The NIH and VA studies mentioned in Section 4.1.4 are scheduled to end in the relatively near future. Thus their results could contribute to the design of the planned EPA research under this Initiative.

Expected Results.--

1. Provide data on the time course of response, rate of recovery, and adaptation of physiological responses to noise.
2. Assess individual differences in these responses.

3. Assess the role of various acoustic and nonacoustic factors in influencing these responses.
4. Provide human data to complement and verify the findings obtained in the primate research.

Lack of co-support would amount to a reduction of over 35 percent in the support for human clinical research during the Fiscal Years 1983 through 1985. This work, which will provide the necessary complement to the animal and epidemiologic data, would be delayed well beyond the projected 1985 completion date.

IV. * Nonauditory Physiologic Effects Initiatives Other Than Cardiovascular Effects

Description and Basic Considerations.--The purposes of this Initiative are: to evaluate the state of knowledge with respect to the nonauditory physiologic effects of noise other than cardiovascular effects; to establish research priorities among those areas on the basis of health impact and feasibility; and to outline research plans in each of these categories.

Under current funding level estimates, no nonauditory physiological effects Initiatives other than those pertaining to cardiovascular effects will be possible in Fiscal Years 1981 and 1982. With the needed co-support from other agencies, work will be started in 1983 under this important Initiative.

The program as outlined would begin with a series of literature reviews, symposia, and research planning activities. Based on the results of these appraisals, research into these areas will begin in 1984 and expand greatly in 1985. Although it is not possible to discuss specific research components in detail, the following are possibilities:

- o Descriptive and correlational field studies of the relationship of noise to health symptoms, complaints and behaviors.
- o Determine whether living and/or working in high noise environments is associated with: (1) difficult

pregnancies, (2) births with complications, (3) low birth weights, (4) birth defects, (5) and other reproductive/sexual dysfunctions.

- o Investigations of the effects of noise on the physical growth, development and general health of children. (Evidence suggests that children may be a susceptible population with respect to noise effects).
- o Since noise seldom occurs by itself, laboratory and field studies are needed on the interaction of noise with other stressors and environmental hazards.

Funding.--Fiscal Years 1983-1985: \$100K (1983), \$300K (1984), and \$950K (1985).

Expected Results.--

By 1985, EPA will have determined those nonauditory physiologic effects other than the cardiovascular that are considered to be most important in terms of health consequences. Detailed research plans will have been developed in these areas and comprehensive research programs will be underway in the most important areas.

Without co-support, very little research would be initiated during the five-year period concerning other nonauditory physiologic effects. The appraisal would be delayed and funding levels for research reduced drastically from almost \$1 million in 1985 to \$300K.

4.3 Time and Funding of Research Initiatives

See Figure 4-2.

4.4 Monitoring and Coordination

Liaison will be maintained through the Federal Interagency Health Effects Advisory Group with the other agencies interested in physiologic research. The foreign literature will be closely monitored.

4.5 Research Initiatives that Will Not Be Undertaken by EPA

EPA is planning to initiate limited work in all of the Research Initiatives it believes are important in the cardiovascular area. The extent to which this can be adequately accomplished depends on co-support by other Federal agencies.

EPA believes that the type of multi-faceted program needed to study these effects will be underway by 1983. However, all the information needed for dose-response criteria will not be obtained by 1985, but EPA should be in a good position from which to decide the direction and extent of additional research. With a sizable effort in the cardiovascular area, very little attention will be given to the other nonauditory physiologic effects prior to 1984. Consequently,

there are many important topics that will not receive adequate attention;
yet they may have severe health consequences.

RESEARCH INITIATIVES	Fiscal year funding*				
	1981	1982	1983	1984	1985
I. Animal experimental studies:					
o Systematic replications and methodological refinements	\$290K ----- \$290K	\$290K ----- \$290K			
o Investigations of acoustic and nonacoustic factors			\$100K ----- \$200K	\$100K ----- \$200K	\$150K ----- \$250K
o Investigations of differences in susceptibility			\$100K ----- \$100K	\$100K ----- \$100K	\$100K ----- \$100K
II. Epidemiologic studies:					
o Retrospective analysis	\$100K ----- \$100K	\$100K ----- \$100K			
o Prospective analysis					
Phase I - Small scale prospective study		\$130K ----- \$400K	\$500K ----- \$550K	\$500K ----- \$600K	\$400K ----- 0
Phase II - NIH Add-on					\$500K ----- \$150K
o Investigations of special sub-populations - Blood pressure in children			\$150K ----- \$150K	\$150K ----- \$150K	\$150K ----- \$150K
* Funding Key: no co-support ----- co-support					
	1981	1982	1983	1984	1985

FIGURE 4-1. TIMING AND EPA FUNDING FOR NONAUDITORY PHYSIOLOGIC EFFECTS

RESEARCH INITIATIVES	Fiscal year funding				
	1981	1982	1983	1984	1985
III. Human clinical studies:					
o Investigations of acoustic and nonacoustic factors	\$100K \$100K	\$150K \$150K	\$100K \$150K	\$100K \$150K	\$100K \$200K
o Investigations of differences in susceptibility	\$80K \$80K	\$125K \$125K	\$100K \$150K	\$100K \$150K	\$100K \$150K
IV. Other nonauditory physiologic effects:					
o Scientific appraisals			\$100K	\$100K	
o Selected studies				\$300K	\$300K
TOTALS	\$ 570K \$ 570K	\$ 795K \$1065K	\$ 900K \$1400K	\$1000K \$1650K	\$1300K \$2300K
	1981	1982	1983	1984	1985

FIGURE 4-1. TIMING AND EPA FUNDING FOR NONAUDITORY PHYSIOLOGIC EFFECTS (cont.)

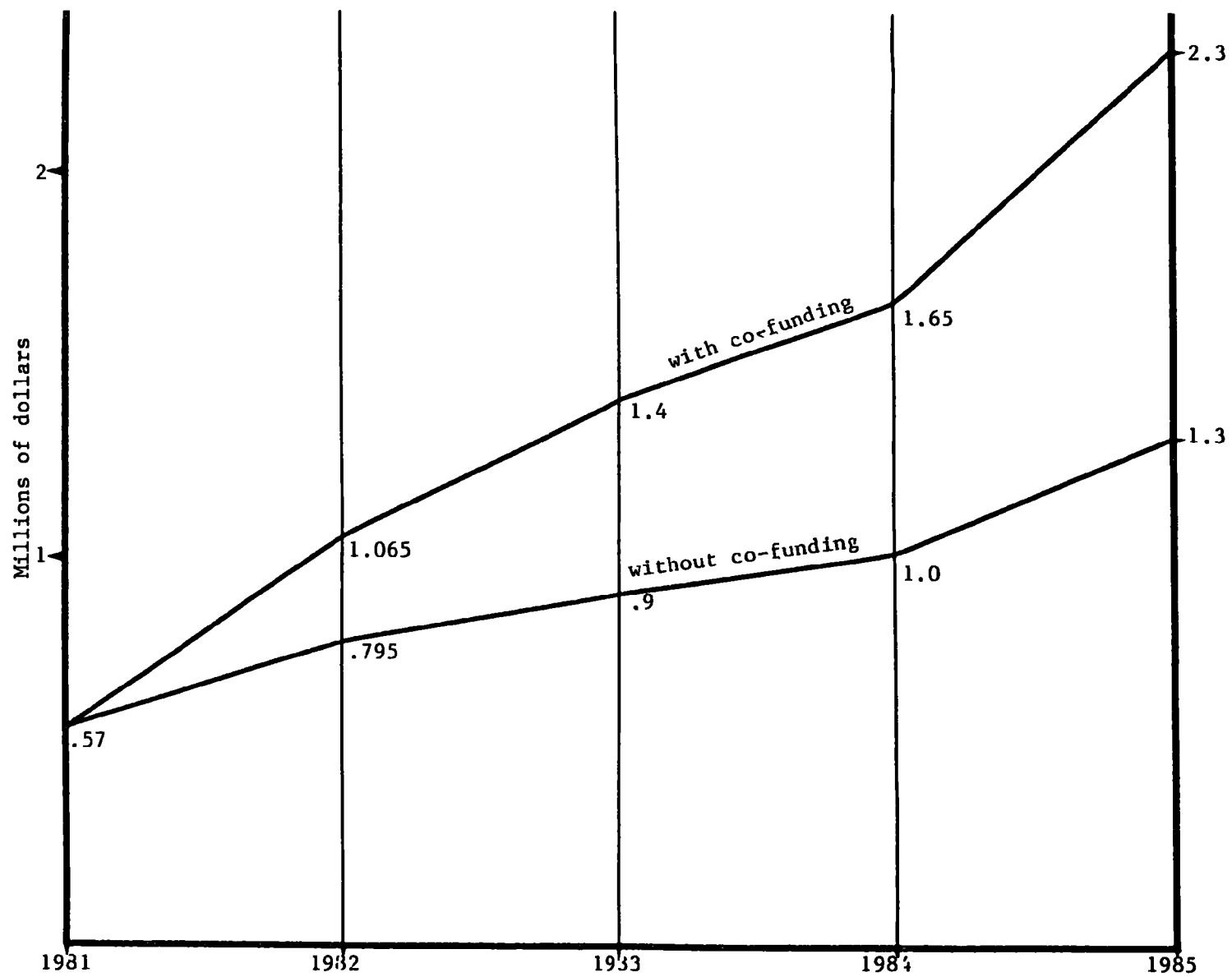


FIGURE 4-2 FUNDING FOR NONAUDITORY PHYSIOLOGIC RESEARCH, WITH AND WITHOUT CO-SUPPORT

5. RESEARCH PLAN FOR
SLEEP DISTURBANCE

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5. RESEARCH PLAN FOR SLEEP DISTURBANCE

The long-term EPA objective for research on sleep disturbance is to determine and quantify effects of noise on sleep, and its implications for general health and performance.

5.1 Rationale for Selecting Specific Research Initiatives

5.1.1 What is Known

About the Effects of Noise on Sleep Itself.--Everyone has experienced disturbances of sleep attributable to noise. The most obvious forms of disturbance are prolonging of the time initially needed to fall asleep, awakening once asleep, and interference with returning to sleep once awakened. Noise may also affect sleep in less apparent ways, that is by inducing shifts from deeper to lighter sleep stages, as measured electrophysiologically.* In the aggregate, repeated noise intrusions during sleep may influence the total time spent in sleep states of different depths.

People vary greatly from one another in their susceptibility to sleep disturbance by noise exposure. Individuals also vary in susceptibility from time to time and from situation to situation. The degree of familiarity with a noise is clearly a major determinant of

* The stages of sleep are measured by electroencephalograms (EEG). The EEG is a visual picture of brain wave patterns that have meaning and organization.

sleep disturbance, especially awakening. Other factors, such as the meaningfulness of noise intrusions, their abruptness of onset, and their expectedness, duration, and intrusiveness seem to influence the likelihood of sleep disturbance. Also, the subject's age, sex, and state of health are known to play a role. For example, susceptibility to sleep disturbance increases with age from childhood through old age.

A general relationship between increasing noise exposure levels and increasing likelihood of sleep disturbance is nonetheless well established. Based on empirical evidence, preliminary criteria have been established for the likelihood of noise disrupting sleep (causing a change in sleep stage) and for awakening induced by noise.

About the Effects of Sleep Disturbance on Health and Performance.—As is the case with other forms of physiological response, interpretation of the health effects of noise exposure on sleep is difficult; presently there is no unequivocal evidence that common forms of sleep disturbance are hazardous to health. However there are indications in the research literature that the quantity of sleep is less important than its quality as measured by the organization of sleep depth stages. Sleep quality as so defined has been found in some of the research to affect certain subjective, physiological and performance measures. This is important in studying noise effects because awakening per se seems to habituate while effects on sleep quality do not. While the results here are tenuous, in clinical practice, the medical community has long recognized the requirement for sleep and peaceful rest for recuperation from illness.

People clearly feel a loss of well-being from sleep deprivation. The major subjective consequences of noise-induced sleep disturbance that have been reported are fatigue, irritability, drowsiness, difficulty in work performance, and a diminishing in overall feeling of well-being. According to EPA's Urban Noise Survey, of those persons who said they had been bothered by noise in their neighborhoods, 60 percent cited sleep disturbance as one of the most common and annoying aspects of the problem. More serious health consequences may be associated with chronic sleep disturbance.

5.1.1 What is Not Known

About the Effects of Noise on Sleep Itself.--While forming an adequate basis for Federal regulatory purposes, a major difficulty with available information about noise-induced sleep interference is that much of it is derived from laboratory rather than field study. It is possible that some of the effects of noise on sleep demonstrated under laboratory conditions may be different in familiar residential settings. Thus, it is not known how much of present understanding is artifactual in nature.

Absence of information about the degree to which noise degrades sleep quality is also a major impediment to assessment of the effects of noise exposure on sleep. Since it is known that people vary greatly in sleep patterns from time to time and from individual to individual, it is not at all clear that sleep disturbance produced by noise exposure has serious consequences. Whether habituation or adaptation to noise takes place during sleep is also a controversial

matter. Studies suggest that habituation can occur on the behavioral awakening level without occurring on the physiological level of sleep depth.

It is not known how noises of different acoustic characteristics affect sleep. Criteria developed on the basis of one noise source may have limited validity when applied to another. It has been suggested that response patterns of people exposed to traffic noise are different from responses found due to noise from other sources. Further, the degree of influence of nonacoustic factors (such as age and state of health) is not known *completely*.

About the Effects of Sleep Disturbance on Health and Performance.—There is virtually no information on the seriousness of chronic deprivation of rather small amounts of sleep per night, nor of the shift of sleep from one electrophysiologically measured state to another. Similarly, people awoken for a number of reasons during the night, not all of which are noise-related. Further, it is not known whether additional awakenings and/or changes in sleep depth due to noise are of any consequence from a health standpoint. Research on the health and performance consequences of sleep disturbance is only just beginning. A number of potential measures of health and performance have not yet been systematically explored or applied to sleep questions. Consequently, the ultimate seriousness of chronic sleep disturbance due to noise has yet to be determined.

5.1.3 EPA Priorities

A major research need is the determination of the effects of acoustic and nonacoustic variables on sleep quality. Also, meaningful response measures of sleep disturbance to aid in conducting research should be developed. More information is needed about sleep patterns in residential rather than laboratory settings, and about the incidence of chronic sleep disturbance in the United States, especially as it is attributable to different noise sources. EPA also needs to determine the degree to which habituation and/or sensitization to noise exposure occurs. If people adapt to noise disturbance of sleep, the biological costs of the adaptation need to be defined and quantified, both in the short- and long-term.

It is necessary to define sleep quality both physiologically and behaviorally. Further, it is important to study physiological correlates of sleep disturbance, and to examine any implications of chronic noise-induced sleep disturbance on general health and performance. It is also necessary to identify any population subgroups that may be especially susceptible to noise-induced sleep disturbance and to determine the consequences of such disturbance.

5.1.4 Current Research Activities

There is only limited Federal work to date on these particular topics. EPA has not sponsored any research to date. Over the last five years expenditures by other Federal agencies for sleep-related noise studies have totaled only a little over \$350,000, and have covered only some of the

subtopics of sleep research of interest to EPA.

- o NASA presently has a study on the effects of aircraft noise on sleep, scheduled to end soon.

- o The Navy has an on going program of sleep research which may be of some assistance to EPA in planning the sleep research program.

- o The Public Health Service is planning a program of research related to sleep and sleeping pill usage, but details which may be important to EPA's mission have not been specified as yet.

- o There may be a useful data base available from a set of studies sponsored by the European Economic Commission (EEC), now in their third of four years of study. The four "in-home" studies from the UK, Netherlands, France and West Germany are investigating the effects of noise disturbance of sleep on general health and performance.

5.1.5 Position on the Research Continuum

As can be seen in Table 5-1, preliminary criteria have been established based on how noise disturbs sleep itself. However, health and performance effects of noise-disturbed sleep are among the least understood effects of noise, owing to the inability to define the functional value of sleep, among other factors.

5.1.6 List of Planned EPA Research Initiatives for the Five-Year Period

After reviewing the status of noise-induced sleep disturbance research, EPA program needs and priorities, and the planned research

TABLE 5-1
POSITION ON THE RESEARCH CONTINUUM - SLEEP DISTURBANCE

<u>Research Continuum</u>	<u>Current State of Knowledge</u>		
	<u>Adequate</u>	<u>Marginal</u>	<u>Inadequate</u>
1. Demonstrate existence of an association	y ¹	x ²	
2. Demonstrate basic cause-effect relationship			
A. Animals	y		x
B. Humans	y		x
3. Investigate physiologic mechanisms		y	x
4. Investigate intervening factors. Improve cause-effect relationship			
A. Acoustic		y	x
B. Nonacoustic			y, x
5. Quantify dose-response relationship		y	x
6. Refinement and special populations		y	x

¹The rating "y" refers to the status of research on the short-term effects of noise on sleep itself.

²The rating "x" refers to the status of research on the health and performance consequence of sleep disturbance.

activities of other Federal agencies, the following Research Initiatives for EPA funding have been selected for the next five years. They are not listed in order of priority.

- I. Relationship between field and laboratory data on sleep disturbance by noise
- II. Health consequences of noise-disturbed sleep
- III. Acoustic parameters related to sleep disturbance
- IV. Susceptibility of sensitive populations to sleep disturbance by noise
- V. Adaptation to sleep disturbance by noise

Their selection, and the selection of their funding levels, are based on the assumption that there will be no co-support from other agencies in the sleep category because of differing agency missions. The likelihood exists however, that EPA may be able to derive some benefit from studies planned by other agencies.

5.2 Detailed Descriptions of the Research Initiatives

I. Relationship Between Field and Laboratory Data on Sleep Disturbance by Noise

Description and Basic Considerations.--Present criteria proposed to assess sleep quality (sleep disturbance, or shifts in sleep depth, and awakening) are based on the sleep of subjects measured under laboratory study conditions; there is a need to relate sleep as measured in the laboratory to sleep at home. Further, reports of subjective

sleep quality as reported by people sleeping at home have never been fully validated or related to objective sleep measures. This Initiative, therefore, is designed to meet short-term programmatic objectives by improving the criteria now used, that is, by comparing the influence of noise upon sleep in both the laboratory and the home. This information will also be used in other Research Initiatives dealing with the longer-term health and performance impact of noise-disturbed sleep. This research will be conducted during Fiscal Years 1981 and 1982 at a cost of \$100K per year.

Expected Results.—Correction factors or new criteria are expected which, when applied to laboratory data, may be used to predict the magnitude of noise-related sleep disturbance in the home environment. Additional information will be needed to relate subjective sleep quality evaluations to objective sleep measures.

II. Health Consequences of Noise-Disturbed Sleep

Description and Basic Considerations.—This Initiative is designed to objectively define and quantify the impact of noise-disturbed sleep on general health and performance. It will consist of two related components.

Primate Studies:

Under controlled conditions, the first component will use animals (primates) to study the biochemical and electrophysiological parameters related to sleep disturbance, health and performance. The initial years of primate studies (Fiscal Year 1981: \$100K; Fiscal Year

1982: \$150K) will explore physiological parameters and protocols best suited to related human research.

Human Studies:

The second component, human studies, will be conducted for the most part in parallel with the animal work and will be based on the results of the initial primate work. These studies will investigate parameters such as drug consumption, absenteeism, medical records, biochemical and performance measures. Research in this component will begin in Fiscal Year 1983, interrelating through Fiscal Year 1985 with the primate research.

Funding for the Health Consequences Initiative (both human and animal) is projected at \$250K in 1983, \$350K in 1984, and \$450K in 1985. Approximately \$200K of the funding in 1985 will be assigned to studying how the primate data can be generalized and applied to humans.

Relation to Ongoing Non-EPA Research.—In designing the Health Consequences Initiative it was assumed that the series of studies being sponsored by Commission of the European Communities (CEC) will provide useful information on which to base EPA research. EPA will be in continuing communication with the CEC investigators.

Expected Results.—

1. An objective preliminary definition and measurement of the value of sleep for health and performance, and the ability to measure the deficits due to sleep disturbance by noise.

2. A quantified relationship between noise-disturbed sleep and consumption of drugs such as tranquilizers, sleeping pills, and stimulants.

3. Quantified relationships between noise-disturbed sleep and other health and performance measures to be specified in the course of the research (after pilot work) will probably not be forthcoming within the five-year period because of extreme complexity and large gaps existing in our understanding of sleep.

4. Validation of laboratory-home correction factor derived from Initiative I.

III. Acoustic Parameters Related to Sleep Disturbance

Description and Basic Considerations.--The basic thrust of this Initiative will assess how different types of noise (as from different noise sources) differentially affect sleep. Existing criteria are based mainly on responses to aircraft overflights. Their specific application to sources such as trucks, buses, automobiles, rapid transit vehicles, railyards, construction equipment, household appliances, garden and shop tools should be studied. Studies will specifically investigate the effects of rise time, frequency spectra, duration, vibration concomitant with noise, impulsiveness, intermittency, and intrusiveness over background levels.

This Initiative is to begin in Fiscal Year 1982, and it will continue through Fiscal Year 1985 at funding levels of \$60K (1982), \$150K (1983) \$150K (1984) and \$50K (1985).

Relation to Ongoing Non-EPA Research.--NASA is investigating similar types of questions for aircraft noise.

Expected Results.--A family of sleep disturbance criteria for different noise characteristics and sources is expected.

The information will allow quantification of benefits of noise control action, and also contribute to the Health Consequences Initiative (II). The correction factor developed from Initiative II, assessing differences between home and laboratory studies, will be applied.

IV. Susceptibility of Sensitive Populations to Sleep Disturbance by Noise

Description and Basic Considerations.--Existing studies and criteria are based mainly on the sleep of young, healthy male students. Susceptibility to sleep disturbance is known to vary with age and other factors (e.g., the elderly are highly susceptible to sleep disturbance). No special criteria exist for these groups at this time. This Initiative would quantify sleep disturbance for special populations such as the elderly, middle-aged people, children, the ill, and the growing number of night-workers (day-sleepers).

This Initiative is scheduled for Fiscal Years 1984 and 1985 and beyond, and is anticipated to extend at least through Fiscal Year 1987. Budgeting will be \$100K/year for Fiscal Years 1984 and 1985.

Relation to Ongoing Non-EPA Research.--NIH's study on sleep and sleeping pill usage may be considered to address a "special population," i.e., persons who perceive themselves as having difficulty sleeping and who are regular users of drugs. Potential applicability of this work is presently unknown.

Expected Results.--The objective is a family of sleep disturbance criteria (by noise) for people of different ages, states of health,

occupations, and lifestyles.

V. Adaptation to Sleep Disturbance by Noise

Description and Basic Considerations.—Using both short-term (behavioral and electroencephalographic) as well as other measures (biochemical, health and performance) derived from previous Initiatives, studies will determine degrees of adaptation, habituation and/or sensitization to noise disturbance over time (in terms of years of chronic exposure).

Studies are planned to be conducted in Fiscal Years 1985 and 1986, funded at \$150K per year.

Expected Results.—Objectives are revised criteria for sleep disturbance and awakening, and preliminary criteria for the long-term effects of noise-disturbed sleep on general health and performance.

5.3 Timing and EPA Funding for the Research Initiative.

See Figure 5-1, on the following page.

5.4 Monitoring and Coordination

EPA staff will maintain liaison with other agencies and groups involved in the sleep area. Additional liaison and coordination is anticipated to take place through the National Academy of Sciences.

RESEARCH INITIATIVES		Fiscal year funding				
		1981	1982	1983	1984	1985
I.	Relationship between field and laboratory data on sleep disturbance by noise.	\$100K	\$100K			
II.	Health consequences of noise-disturbed sleep					
	o Primate studies	\$100K	\$150K			
	o Human studies and continuation of primate			\$250K	\$350K	\$250K
	o Application of primate findings to humans					\$200K
III.	Acoustic parameters related to sleep		\$50K	\$150K	\$150K	\$50K
IV.	Susceptibility of sensitive populations to sleep disturbance by noise				\$100K	\$100K
V.	Adaptation to sleep disturbance by noise					\$150K
TOTALS		\$200K	\$300K	\$400K	\$600K	\$750K
		1981	1982	1983	1984	1985

FIGURE 5-1. TIMING AND EPA FUNDING FOR SLEEP-DISTURBANCE

5.5 Research Initiatives That Will Not Be Undertaken by EPA

The identified funding levels will not permit the type of comprehensive investigation necessary to meet the full objectives of the described Initiatives. In addition, work under some Initiatives which would otherwise be completed in a year or two, is being prolonged over a number of years or being delayed to later years to meet the funding requirements.

6. RESEARCH PLAN FOR
INDIVIDUAL AND COMMUNITY RESPONSE

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6. RESEARCH PLAN FOR INDIVIDUAL AND COMMUNITY RESPONSE

The long-term EPA objective for research in this category is to determine and quantify subjective reactions of individuals and communities to different noise environments and sources, and to investigate mediating factors.

For purposes of brevity, this category will be referred to as "community response" in this chapter.

6.1 Rationale for Selecting Specific Research Initiatives

6.1.1 What is Known

Information is available about individual and community response to commonly occurring forms of noise exposure. The major physical determinants of both individual and community annoyance due to noise are understood in fair depth. For example, most of the variability in individual judgments of annoyance associated with noise can be accounted for under laboratory conditions by a number of objective physical measurement procedures.

Psychoacoustic research in the last two decades has refined the long-known relationship between the frequency sensitivity of human hearing and annoyance judgments. Scales of varying complexity, some directly readable from simple instrumentation, others requiring complex computations, are commonly used to predict the annoyance of a great many noise sources. The combined effects of pure tones and duration of

sounds, among other factors, are known to influence annoyance reactions to noise, but research has not yielded the anticipated applications to the community environment.

General relationships of overall community response to noise (the central tendency of large numbers or groups of individuals) have been derived and accepted scientifically, and are more precisely known than are the responses of individuals (that is, individual variations are generally "averaged out" in commonly used community response measures).

It is also known, however, that nonacoustic factors, such as attitudes toward noise sources, or the particular activities disturbed, can affect both individual and community reactions to sound. Thus, although many determinants of individual and community annoyance are well understood on a global level, this general knowledge will not yet support precise situation-specific predictions of individual or community response to noise exposure.

The prevalence of annoyance due to noise exposure throughout American society is known in considerable detail. It is known, for example, that annoyance due to noise exposure is not only restricted to neighborhoods near airports, highways, and other major noise sources, but that exposure to levels typical of many urban environments also produces widespread annoyance. Noises associated with automotive sources (e.g., street traffic noise) are the most universal sources of annoying noise exposure in urban America.

Cumulative measures of total outdoor noise levels (for example, L_{dn} , the Day-Night Sound Level) have been shown to provide a

useful reflection of community reaction, at least at higher exposure levels. Thus, the proportion of a community highly annoyed by noise exposure can be reliably predicted from objective measures of noise levels. Demographic factors such as age, sex, and socioeconomic status do not appreciably affect the accuracy of such calculations.

6.1.2 What is Not Known

Quantitative information is still lacking on the influences of a number of factors that may affect individual and community response to noise exposure. On an individual basis, considerable uncertainty remains about the annoyance of specific noise intrusions superimposed on the ambient noise environment. Other unsettled issues concern the annoyance associated with exposure to unusual and unsteady sounds. These include sounds that may vary in level over time, sounds of very short duration, and sounds that occur infrequently, intermittently, or unpredictably. The precise influence of audible pure tones in the noise, and the presence of impulsiveness is open to question. It is also unclear how the immediate annoyance of noise intrusions is affected by the nature of an individual's ongoing activities at the time of the noise intrusion. The manner in which people integrate or cumulate annoyance or other adverse reactions over time is not at all understood.

On the community level, the effects of noise exposures at different times of the day and seasons of the year are not fully resolved, nor are the effects of temporary (as opposed to long term) exposure,

or numbers of discrete noise events. Although existing criteria are judged adequate for Federal regulatory purposes, a controversy exists as to differences in annoyance response that may be attributable to specific yet different sources of noise such as construction noise, recreational noise, household noise, and so forth, as well as reactions that occur in special noise environments such as in transit vehicles or work places. Annoyance by warning signals is as yet unexplored.

The influence of accompanying nonacoustic variables such as people's preconceived attitudes toward or associations with particular sources of noise are not understood. The questions of annoyance and stress upon special population groups such as children, the elderly, and the ill, as well as the variability in annoyance response between individuals, have not been addressed.

In addition, little is known about annoyance response to low levels of noise (below $L_{dn}=55$ dB). The variability of individual annoyance judgments on low level noise cannot yet be accounted for on the basis of physical (acoustical) parameters of the noise. Yet there are environmental settings such as parks, and residential, recreational and wilderness areas, where such annoyance certainly exists.

6.1.3 EPA Priorities

EPA program priorities require that research attention be focused on individual and community response to a variety of special sources of noise exposure, including construction, railroads, household and consumer products, mass transit, noise sources in outdoor recreational

areas, blast noise, and certain forms of air and ground transportation. For example, more specific criteria for construction sites will be needed to support planned EPA construction noise programs, as well as to support State and local noise control programs in their efforts to control construction noise.

Determining the relationship between specific attributes of noise and the magnitude of individual or community response will require further research attention by EPA for the same programmatic reasons. The specific noise attributes that need to be addressed are noise with pronounced tonality, fluctuating levels, and impulsive components; vibration concomitant with noise; noise of varying duration, time of occurrence, and number of discrete occurrences; and noise of varying intrusiveness.

The influence of a number of nonacoustic factors on individual and community response also requires more careful study. These include contextual factors such as the purpose of noise emissions (e.g., warning signals), the perceived ability to control the noise emission exposure, and certain attitudes toward the sources of noise exposure. The response of certain, identifiable special groups within the population also deserves study.

6.1.4 Current Research Activities

EPA has undertaken two base year activities dealing with community response to noise: (1) A study of community reactions and attitudes towards construction noise, and (2) an examination of response to noise that intrudes into the environment over relatively short periods of time.

The first study, "Construction Site Noise Attitudinal Survey," is being conducted in cooperation with the U.S. Army Construction Engineering Research Laboratory. Community response data will be acquired around construction sites in order to establish the relationship between construction noise and degree of impact on the community.

The other study is "Annoyance by Intrusive Sounds." The base-year activity will consist of a psychoacoustic laboratory investigation to determine the influence of the subjects' degree of involvement in various foreground tasks on their indicated annoyance by intrusive type sounds. This is a necessary step before the development of a quantitative intrusiveness-type annoyance scale.

An additional study will soon be undertaken assessing human response to the repetitive-type impulse noise associated with engine brake noise.

Over \$1 million has been spent by other Federal agencies in the area of individual and community response to noise over the last three to six years. Of the three agencies primarily active in this category, NASA leads the way, with over eight projects and more than \$600K devoted to such studies. However, these activities concern mainly aircraft noise. Some of the specific Federal research activities in the base-year include the following:

- o NASA study of the validity of the 10 dB night-time weighting penalty applied to aircraft noise;
- o NBS (National Bureau of Standards) investigation of the human response to time-varying traffic noise;
- o An Air Force study assessing the impact of their aircraft noise activities.

6.1.5 Position on the Research Continuum

As indicated in Table 6-1, preliminary criteria exist for quantifying the relationship between general community annoyance response and higher level noise exposures. However, little is known about the effect of lower level exposures, intervening factors, and effects on special populations.

6.1.6 List of Planned EPA Research Initiatives for the 5-Year Period

After reviewing the status of community and individual response research, EPA program needs and priorities, and the planned activities of other Federal agencies, the following major Research Initiatives have been selected for EPA funding over the next five years.

- I. Determination of the magnitude of community and individual response attributable to specific sources of noise.
- II. Determination of the relationship between specific acoustic attributes and the magnitude of individual/group response to noise.

The assumptions made selecting these Initiatives are as follows:

1. Specific components within the Initiatives can only be identified for Fiscal Years 1981-82. Since each Initiative and its components undertaken during the five-year period have a direct programmatic application, only during the first two years of this Plan can specific components be identified based on defined program needs in the Fiscal Year 1984-85 time frame. Research results derived from the latter three years of the five-year period, however, will feed into programs beyond the Fiscal Year 1985 time frame. Therefore, only broad,

TABLE 6-1
POSITION ON THE RESEARCH CONTINUUM - INDIVIDUAL AND COMMUNITY RESPONSE

<u>Research Continuum</u>	<u>Current State of Knowledge</u>		
	<u>Adequate</u>	<u>Marginal</u>	<u>Inadequate</u>
1. Demonstrate existence of an association	x		
2. Demonstrate basic cause-effect relationship		x	
3. Investigate response mechanisms			x
4. Investigate intervening factors. Improve cause-effect relationship			
A. Acoustic		x*	
B. Nonacoustic			x
5. Quantify dose response relationship		x*	
6. Refinement and special populations			x

*Although rated as marginal, the only parameter that has been substantially quantified and is fully usable for noise assessment purposes is that of perceived amplitude or intensity (level).

general Initiatives are entered into Fiscal Years 1983-85, with the intent of narrowing the Initiatives into specific components as defined program needs become apparent.

2. Because of the emphasis placed on the nonauditory physiologic effects research, only low-level funding for individual and community response is anticipated during this five-year period. However, it is expected that other Federal agencies, and investigators in other countries and in the private sector, will conduct some research in this effects category. Although EPA will have only limited influence on the precise direction of this research, it is anticipated that many of the experimental findings will be usable by EPA. As new program needs are defined in the next few years, funding levels in this category will be reevaluated.

3. No component within any Initiative will be completed within this five-year time frame. Thus, results may not yield quantitative relationships suitable for all conceivable applications.

4. The level of funding suggested will allow study of only one or two components within any Initiative at a time.

6.2 Detailed Description of the Research Initiatives

I. Determination of the magnitude of community and individual response attributable to specific sources of noise.

Description and basic Considerations.--This Initiative consists of two components: a construction noise component to be started immediately, and other components to be started later.

Construction Noise.--The construction noise component undertaken in Fiscal Year 1981 is a carryover from the previous year (Fiscal Year 1980). The purpose of this research element is to acquire community response data around construction sites in order to establish the relationship between construction noise and the degree of impact upon the people exposed. Special emphasis will be placed on the varying longitudinal aspects of the exposure and on the impact on two particular populations: residential and workday. The program will include the development of a survey questionnaire and noise measurement protocol; a site selection and respondent sampling plan; and the implementation and analysis of a comprehensive attitudinal survey and noise measurement programs. Total funding will be \$300K between Fiscal Year 1980 through 1983. Funding will be on the order of \$65K in Fiscal Year 1980, \$100K in Fiscal Year 1981, \$100K in Fiscal Year 1982, and \$35K in Fiscal Year 1983.

Other components.--These will consist of topics most important to EPA program needs beginning in Fiscal Year 1983. One or more of the following are the most likely candidates:

a. Railroad and rail facility noise: formulate criteria directly pertaining to this type of noise, including yard as well as main line activities.

b. Household and consumer products/interior noise: formulate quantitative criteria pertaining to these special types of noises and/or situations of exposure.

c. Mass transit noise: formulate criteria directly pertaining to this type of noise, including community as well as passenger subjective response.

d. Recreational areas/off-road vehicles: formulate criteria pertaining to this special type of noise exposure.

e. Aviation noise: refine currently available criteria for application to special situations.

f. Ground transportation noise: refine currently available criteria for application to special situations.

g. Blast noise: formulate quantitative criteria pertaining to human subjective response to this special type of noise.

At least two of the components listed above will be studied from Fiscal Years 1983 through 1985 (depending on program requirements defined at that time) at a total cost of \$590K. Funding will be \$150K in Fiscal Year 1983, \$190K in Fiscal Year 1984, and \$250K in Fiscal Year 1985.

Expected Results.--

1. The program will initially yield dose-response type criteria (annoyance and/or other subjective evaluative attributes) pertaining to construction noise by Fiscal Year 1983. These criteria will not have general application to all aspects of the construction noise problem, but will yield criteria directly applicable to construction noise for which no criteria already exist. Information from this research will feed into the EPA construction site/equipment noise control programs anticipated beyond the Fiscal Year 1984 time frame. Also, the research

results will feed into State and local noise control programs where interest in controlling construction noise has been expressed.

2. Based upon the selection of one or more additional research components under this Initiative, this research will yield additional dose-response criteria with respect to other sources of noise, although these criteria will be somewhat limited for many applications.

II. Determination of the relationship between specific acoustic attributes and the magnitude of individual/group response.

Description and Basic Considerations.—This Initiative consists of three components.

In the first component, undertaken in Fiscal Year 1981, human subjective response to intrusive noise will be studied, continuing work started in the base year (Fiscal Year 1980). Formulation of a descriptor or metric that pertains to noise that intrudes into the environment for discrete periods of time (whether minutes, hours, days, or seasons) has been identified as a high programmatic need within EPA. Cumulative predictive methods are not entirely adequate in a descriptive sense to account for this type of noise. This program will, in the initial years, consist of a series of laboratory psychoacoustic studies aimed at scaling the magnitude of subjective response to various degrees of "intrusiveness" or detectability of noise over a background. Funding levels are at \$65K in Fiscal Year 1980, \$125K in Fiscal Year 1981, and \$100K in Fiscal Year 1982.

A second component consists of a small program undertaken to investigate the annoyance and detectability of warning signals within construction settings. This program will consist of a laboratory psychoacoustic study examining signal detectability of warning devices or signals over a series of background noises typical of construction site activity. Funding will be at a level of \$55K in Fiscal Year 1981.

Other components to start in Fiscal Year 1982 will be selected later on the basis of EPA's latest assessment of its program requirements. Only a few components can be chosen. Candidates include:

a. Intrusiveness of low-level noise: further work is needed to develop criteria pertaining to low-level noise (a problem noted in many areas where background noise is already low), or to refine work completed up to this point (as described above in the first component).

b. Tonality: a descriptor or adjustment method is needed to ascertain adverse subjective response of people to noise which contains perceptible tones.

c. Duration: a descriptor or adjustment method is needed to assess the influence of duration on human subjective response.

d. Impulsiveness: a descriptor or adjustment method is needed to ascertain the adverse subjective response of people to noise which is characterized by impulsiveness.

e. Fluctuating noise: a descriptor or adjustment method is needed to ascertain adverse subjective response of people to noise that fluctuates in character over time.

f. Interaction of vibration and noise: determine the contribution to subjective human response caused by vibration concomitant with noise.

g. Multiple events: the manner in which people perceive and integrate multiple events over time as reflected in their subjective response.

h. Diurnal penalties: the adjustment method currently in use needs to be further verified with regard to magnitude of response as a function of time of day.

Research studies investigating selected components will be funded at a level of \$60K in Fiscal Year 1982, \$150K in Fiscal Year 1983, \$200K in Fiscal Year 1984, and \$50K in Fiscal Year 1985.

Expected Results.--

1. The program on intrusive noise will yield criteria based on laboratory psychoacoustic studies that will be usable for limited application in the Fiscal Year 1984 time frame. Criteria will relate objectively measured intrusiveness of noise to anticipated annoyance reactions. EPA will evaluate the need to proceed with additional work for Fiscal Year 1984 and beyond in this area, depending upon adequacy of the research findings up to that time and EPA priorities reevaluated at that time.

2. Results from the program pertaining to detectability of warning signals on construction sites will yield information for use within EPA programs in the Fiscal Year 1982 time frame and beyond.

3. Depending upon the selection of one or more additional research components under this Initiative, research will yield additional, but preliminary, adjustment methods or descriptors with respect to the specific acoustic attributes, discussed above, that may influence the exact individual and community response to noise. The information derived from this research will be useful as a basis for regulatory and certification measurement procedures, as well as a focus for the development of noise control techniques.

6.3 Timing and EPA Funding of Research Initiatives.

See Figure 6-1.

6.4 Monitoring and Coordination

This set of Research Initiatives will require careful coordination, since specific components are closely tied to producing results in accordance with the core EPA Five-Year Noise Plan. A second type of coordination of particular importance to this category is close liaison with researchers in other agencies and institutions, since EPA is also relying on the large amount of work going on elsewhere. Coordination will be maintained with the American National Standards Institute's (ANSI) committees on community noise and auditory magnitude, as well as the Federal Interagency Noise Effects Research Panel.

FIGURE 6-1. TIMING AND EPA FUNDING FOR COMMUNITY RESPONSE

6.5 Research Initiatives that will not be Undertaken by EPA.

The identified funding levels will not permit the type of comprehensive investigation necessary to meet the full objectives of the described Initiatives. In addition, work under some of the Initiatives is being delayed under the funding constraints.

The following Initiatives will not be undertaken by EPA due to limited resources available:

- o Identification and quantification of nonacoustic determinants of community and individual response to noise.

This Initiative will not be undertaken during the five-year period, because (a) it is more important to acquire information on the acoustic determinants initially since they will have the most direct programmatic applications, and (b) it is not experimentally desirable to proceed to examine the nonacoustic parameters unless the variation typically encountered in measuring human response to noise is minimized to the greatest extent possible by proper quantification of the acoustic factors.

Components within this Initiative include:

- a. Influence of contextual factors and attitudes on response to noise.
- b. Identification of nonverbal reactions to noise.
- c. Determination of reactions to warning signals or other noises with high meaningfulness.

o Determination of susceptible population subgroups.

Criteria for source specific environments and acoustic/
nonacoustic attributes are needed prior to the refinement of these
criteria to account for especially sensitive or susceptible populations.

7. RESEARCH PLAN FOR
NOISE-INDUCED HEARING LOSS

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7. RESEARCH PLAN FOR NOISE-INDUCED HEARING LOSS

The long-term objective for research in this category is to determine the extent of the problem, causative factors, and associated effects.

7.1 Rationale for Selecting Specific Research Initiatives Over the Five-Year Period

7.1.1 What is Known

The prevalence of hearing loss among workers in industry has been recognized since the start of the industrial revolution. Within the last three decades a number of hearing loss studies in industry have shown a direct relationship between hearing loss and the intensity and duration of noise exposure. As the intensity and duration of noise exposure increases, a greater proportion of the sensory cells within the inner ear will be damaged and eventually destroyed. This will result in a permanent, irreversible loss in hearing sensitivity.

Noise-induced hearing loss (NIHL) increases most rapidly over the first 10-15 years of noise exposure in the higher frequencies. Noise-induced hearing loss has been observed for daily noise levels as low as 75 dB after 10 years of exposure. Because the loss in hearing is so gradual, most people do not recognize the reduction in their hearing sensitivity until it is too late. Hearing loss often causes a complete change in a person's social and work life. The hearing process is

fundamental to the perception and understanding of speech, and persons with noise-induced hearing loss have great difficulty understanding speech when there is some noise in the background.

Industrial hearing loss studies have provided a set of quantitative damage risk criteria. Risk refers to the probability that a certain percentage of a noise exposed population will suffer NIHL in excess of a specified value. Specific noise limits have been proposed for the purpose of protecting workers' hearing levels based on these criteria. However, there is a great deal of individual variation in susceptibility to hearing loss. Industrial studies have shown a wide variation in hearing levels for worker populations of the same age and with the same occupational noise exposure. Animal experiments as well have shown substantial variations in the hearing damage of animals of the same species after comparable exposures. There is also some evidence that young animals incur more auditory damage than predicted for older animals. This finding has relevance to the issue of children and NIHL.

Some hearing surveys in the population have shown demographic differences in the hearing levels of different races, sexes, cultures and social groups. Certain people in remote areas of the world, who have not been exposed to the din of noise in our mechanized society, have much better hearing in comparison to urban populations of corresponding ages. The only factor that is known to increase the likelihood of a hearing loss besides aging and disease is increased exposure to environmental noise. For example, listening to amplified music, shooting guns, and motorcycle riding are a few of the common recreational noise exposures

known to contribute to hearing loss. The auditory effects of environmental noise exposures in transit, recreation and in the household have not been studied in enough detail to determine their consequences on hearing.

7.1.2 What is Not Known

Although generally adequate for Federal regulatory purposes, there remain a number of unanswered questions concerning the effects of noise on hearing. Most of the data concerning the long-term auditory hazards of noise come from studies of continuous steady state occupational noise exposure. There is a lack of definitive information on the effects of shorter term intermittent noise exposures which may be less harmful to hearing. Most of the knowledge concerning impulse noise comes from studies of the effects of gunfire noise, yet millions of Americans are exposed to impulse/impact noise on the job. Existing criteria may not fully account for time varying noise exposures. Neither do these criteria account for what may well be additive effects of concurrent impulse noise and steady state noise exposure.

Much of the present occupational hearing loss data base is contaminated by nonoccupational noise exposures in the military, transportation, hobbies and recreational activities. Furthermore, there is a marked deficiency in our knowledge of the incidence of NIHL in the United States outside of the workplace. Very little is known about the contribution of certain environmental noise source exposures and

patterns of exposure on the population's hearing sensitivity. These lower level nonoccupational noise exposures must be considered when investigating the effect of occupational noise.

Although significant efforts are being made to improve our understanding of the relationship between noise exposure and hearing loss in industry, little is known about the effects of varying degrees of hearing impairment on the social and economic functioning of the affected individuals. Criteria for hearing handicap have been developed indirectly from speech discrimination tests which do not simulate life-like conditions. The relationship between hearing sensitivity and social functioning must be more adequately researched. Likewise, very little is known about the secondary auditory effects of NIHL such as tinnitus (ringing in the ear), changes in loudness, and discomfort, which are highly annoying to hearing impaired persons and seem to accompany most hearing losses due to noise.

Important

Susceptibility to noise-induced hearing loss varies considerably among individuals. Little is known about the causative factors underlying these differences in susceptibility. Little is known about the susceptibility of children to NIHL. Furthermore, current monitoring methods do not allow for the identification of persons susceptible to NIHL. It is often assumed that Temporary Threshold Shift (TTS) is correlated with susceptibility to NIHL, yet this has not been proven in humans.

Good!

Properly planned studies are needed to address the interactions of noise with other stressors. There is little information describing whether poor health status, specific disease states, ototoxic

drugs, or chemical agents increase predisposition to or enhance noise induced hearing loss. Further, if a high level noise exposure is voluntary and less aversive to the individual, there is little information on whether the net effect on hearing sensitivity is different.

7.1.3 EPA Priorities

In the EPA document published in 1977, "Towards a National Noise Strategy," EPA identified the important goal of taking all practical steps necessary to ^[or reduce to an acceptable amount] ~~eliminate~~ hearing loss as a consequence of exposure in the workplace and the general environment. This program goal will require more detailed information on hearing loss caused by nonoccupational noise. Thus, the following EPA priorities have been established.

EPA will focus on environmental exposures causing temporary and permanent defects in the auditory acuity of adults and children. Research is needed to assess the consequences of high level non-occupational noise source exposures on the public and to determine the contribution of specific exposures to the public's hearing status.

Major emphasis will be placed on investigating the auditory effects of noise on children. Hearing is considered by many to be the most critical sense in childhood because of language development and its implications for overall cognitive development and learning.

EPA will also place high priority on studying the interrelationships between NIHL and other general health conditions of the public. Certain health conditions may interact with noise to produce reduced hearing sensitivity.

7.1.4 Current Research Activities

The current and planned research activities of other Federal agencies have influenced the EPA decision for a limited but very focused role in the category of NIHL research. Over the past few years, other Federal agencies have spent over \$3 million per year in related research under this category. These agencies have indicated their intent to continue at least the present level of effort in the future. In the areas of impulse noise, intermittent noise, the social impact of hearing loss and individual susceptibility research, funding levels are expected to rise.

In order to better understand the responsibilities and particular interests of other agencies in researching the category of NIHL, a brief overview of the Research Initiatives anticipated to be undertaken by other agencies is as follows:

Underlying Physiologic Mechanisms of NIHL

Physiologic and biomedical research will continue to be principally supported by the National Institute of Health (NIH) at funding levels of approximately \$1 million per year. Other agencies such as the Department of Defense (DOD) will conduct research at a much lower funding level.

Refinement of Criteria for Intermittent Noise and Impulse Noise

The National Institute for Occupational Safety and Health (NIOSH) and the U.S. Army have assumed lead responsibilities in filling

the research gaps related to non-steady state noise and developing revised criteria for impulse and intermittent noise. Both animal and field research will be sponsored.

Establishment of Parameters of Individual Susceptibility

NIOSH research plans specify the study of the interactive effects of noise with lead and other potentially ototoxic agents.

NIH and the U.S. Navy are planning to undertake research to enable the identification of individuals susceptible to NIHL and to determine causative factors underlying this enhanced susceptibility.

Determination of Social and Economic Impact of NIHL

The Department of Labor is presently studying the technical appropriateness of different hearing impairment criteria used in workers' compensation laws for NIHL.

A related EPA research project in Fiscal Year 1980 will attempt to develop a methodological research design for quantifying the social and economic consequences of hearing loss with the aim of eventually developing a more accurate index of hearing handicaps.

7.1.5 Position in the Research Continuum

As depicted in Table 7-1, NIHL research is relatively well advanced compared to some of the other health effects of noise. From years of research, a systematic relationship has been developed between steady-state noise exposure levels, the duration of exposure, and the resulting hearing loss. The statistical predictiveness of this relationship provides a good basis for Federal occupational noise legislation. However,

TABLE 7-1

POSITION ON THE RESEARCH CONTINUUM - NIHL

<u>Research Continuum</u>	<u>Current State of Knowledge</u>		
	<u>Adequate</u>	<u>Marginal</u>	<u>Inadequate</u>
1. Demonstrate existence of an association	x		
2. Demonstrate basic cause-effect relationship			
A. Animals	x		
B. Humans	x		
3. Investigate physiologic mechanisms		x	
4. Investigate intervening factors. Improve cause-effect relationship			
A. Acoustic		x	
B. Nonacoustic			x
5. Quantify dose-response relationship		x	
6. Refinement and special populations			x

research has not yet accounted for wide individual variations in susceptibility to NIHL, the effect of noise with varying temporal patterns, nonacoustic intervening factors, and the severity of NIHL.

7.1.6 List of Planned EPA Research Initiatives for the Five-Year Plan Period

After reviewing the status of NIHL research, EPA program needs and priorities, and the planned research activities of other Federal agencies, the following Research Initiatives for EPA funding have been selected for the next five years. They are not listed in order of priority.

- I. Determine the incidence of NIHL in the United States and contribution of sociocusis (nonoccupational NIHL) presbycusis (aging), and occupational hearing loss.
- II. Establish parameters of individual sensitivity to NIHL.
- III. Refine criteria for low-level noise exposure.

These EPA Research Initiatives are chosen based on the following assumptions:

1. That other Federal agencies will continue to play the most active role in NIHL research. Although EPA will have only limited influence on the direction of this research, it is anticipated that many of the findings will be useful to EPA.
2. The planned research studies of other agencies will be conducted with adequate funding levels until completion.

7.2 Detailed Descriptions of the Research Initiatives

I. Determine the incidence of NIHL in the United States and contribution of sociocosis (environmental exposure), presbycusis (aging), and occupational exposures.

Description and Basic Considerations.—The objective of this Research Initiative is to isolate NIHL from other hearing loss etiologies and estimate the magnitude of the problem caused by different noise source environments. In the past it has been difficult to separate the hearing loss caused by age, societal factors and industry, and to predict the hazards of noise in different environments. This research will assist in describing the extent and severity of hearing loss due to different patterns of noise source exposures.

The principal data for this initiative will be provided by the National Center for Health Statistics (NCHS) of the Public Health Service in their periodic health surveys. Specifically, EPA will use the results from past, current and planned National Health and Nutrition Examination Surveys (HANES) in the areas of hearing-related problems, demographic information, and indices related to noise exposure. The HANES survey is periodically conducted to obtain national estimates of the health status of the population.

EPA will incur only data analysis costs. Funding of \$50K per year between Fiscal Years 1981 and 1985 will be necessary. Cardiovascular and other health status information will be included in the analysis supportive of data requirements in other research categories. Some co-support funding is anticipated from the National Institute of Neurological and Communicative Disorders and Stroke (NINCDS).

Expected Results.—The resulting analyses will attempt to (1) describe hearing-related problems caused by recreational, transportation and residential noise; (2) determine the incidence of NIHL in the United States; and (3) develop separate sets of curves for presbycusis, sociocusis and NIHL. The results of this analysis will then be available for use in source specific assessment programs planned for Fiscal Years 1982, 1983 and 1984.

All of the resulting information will be useful to Federal agencies and State and local governments in support of regulatory, labeling, and consumer information programs.

II. Establish Parameters of Individual Sensitivity to NIHL.

II-A. Relationship between physiologic disease and hearing loss.

This research will attempt to isolate relevant biologic variables and physiologic problems which are correlated with auditory difficulties. Certain health conditions will be analyzed to determine whether they predispose an individual to NIHL. At the present time, the HANES survey results will provide the focus for this investigation. More in-depth research plans are contingent upon the results of the HANES data analysis and the results of research planned by NIH and the U.S. Navy. No additional funding is being planned above what is required for Research Initiative I.

Expected Results.—Descriptive analyses will be provided which show whether there are any associations between certain health conditions, diseases and hearing loss.

II-B. Susceptibility of special populations -- children.

While environmental noise may adversely affect people of all ages, children may require special consideration and safeguards. Research with animal models indicates that younger organisms are more susceptible to NIHL than are adults. Children may also be exposed to different sources of noise not currently recognized as affecting hearing.

For the past four years, EPA in cooperation with the Air Force has funded a longitudinal study at Fels Research Institute of the Wright State Medical school to analyze age-related changes in the auditory thresholds of children, and to relate changes in auditory sensitivity to environmental noise exposures and developmental and physiologic variables. This information is essential in order to determine whether additional controls are necessary to reduce the noise exposure of children.

This research study will continue to be funded by EPA at a level of approximately \$50K per year over the next five years. A comparable level of co-support will be added by NINCDS to expand the subject population to include a large sample of urban and minority children.

Expected Results.--Periodic results are awaited describing:

1. changes in the hearing sensitivity of both children and teenagers related to specific environmental factors;
2. the consequences of a hearing loss in childhood with respect to communicative and educational problems;
3. whether auditory patterns and noise exposures during childhood may be correlated with hearing acuity later in life.

II-C. Determine source exposures causing TTS and assess debilitating consequences.

There are many hazardous noise environments outside of the workplace which can cause temporary reductions in auditory sensitivity, commonly called TTS (Temporary Threshold Shifts). The results of TTS experiments have been used in the past to predict permanent reductions in hearing for persons with long-term occupational noise exposure. However, TTS itself may warrant special consideration where the reduction in sensitivity interferes with ongoing activities. Specifically, the activities of children will be investigated where the repeated occurrence of TTS may have deleterious effects on education, communication and performance. Field and laboratory TTS studies with children will be conducted. The Research Initiative will assess whether there is a need to control source exposures on the basis of TTS. The planned Research Initiative will be a continuation of research started in Fiscal Year 1980. The funding level will be approximately \$50K.

Expected Results.—The results will be incorporated into the EPA regulatory program, State and local noise control programs, and public information materials for parents, the PTA and other organizations. Results include:

1. the identification of hazardous noise conditions particular to the activities of children (e.g. riding school buses, listening to music on stereo headsets);
2. determination of the amount of TTS caused by these common activities of children;
3. assessment of the related consequences on education, communication, and performance.

III. Refine Criteria for Low-Level Noise Exposures.

Existing criteria are extrapolated downward from the higher level noise exposures in industry to determine the related auditory risk at lower level noise exposures. Recent studies have revealed that children, homemakers and many segments of the public are exposed to noise levels in environmental settings capable of causing permanent reductions in auditory sensitivity. There is an urgent need to more accurately estimate the lower limit of steady state and fluctuating noise levels capable of causing permanent hearing loss and incorporate these into comprehensive damage risk criteria.

The HANES data analyses will determine specific environmental noise source exposure patterns associated with reduced hearing sensitivity. The research effort planned under this Initiative will isolate and quantify these specific source exposures in a selected population and determine the contribution of these source exposure patterns on an individual's hearing sensitivity. Hearing tests will be conducted in conjunction with dosimetry measurements and a questionnaire program. Research is to start in Fiscal Year 1982 and continue through Fiscal Year 1984 at \$50K/year.

Expected Results.--The magnitude of the auditory problems associated with specific environmental source exposures will be determined. This information will assist in the development of refined hearing loss criteria.

7.3 Timing and Funding of the Research Initiatives.

See Figure 7-1.

7.4 Monitoring and Coordination

Performance of these Initiatives will be coordinated with the Interagency Regulatory Liaison Group (IRLG). The IRLG has established a subgroup on noise, which among other things is concerned with the total body burden of noise and the interaction of workplace noise with off-the-job noise exposures.

Liaison will also be maintained with the other Federal agencies sponsoring NIHL research through the Federal Interagency Noise Effects Research Panel as well as the ANSI committees on hearing conservation criteria and impulse noise.

7.5 Research Initiatives That Will Not Be Undertaken by EPA

The following research initiatives are expected to be undertaken by other agencies, and are therefore not considered for the EPA Plan:

- o Underlying physiologic mechanisms of NIHL
- o Refinement of criteria for intermittent noise and impulse noise
- o Determination of social, economic, and other impacts of NIHL.

Substantial increases in funding will be needed under this (last) Initiative by other agencies. Research initiated by EPA

RESEARCH INITIATIVES		Fiscal year funding				
		1981	1982	1983	1984	1985
I.	Determine the incidence of NIHL in the U.S., and contribution of sociocusis, presbycusis, and occupational exposures.	\$50K	\$50K	\$50K	\$50K	\$50K
II.	Establish parameters of individual sensitivity to NIHL.					
	o Relationship between physiologic disease and hearing loss. (included in I)					
	o Susceptibility of special populations - children (Fels - Continuation from 1976).	\$50K	\$50K	\$50K	\$50K	\$50K
	o Determine source exposures causing TTS and asses debilitating consequences. (Begun in FY 80.)	\$50K				
III.	Refine criteria for low-level noise exposures.		\$50K	\$50K	\$50K	
TOTALS		\$150K	\$150K	\$150K	\$150K	\$100K
		1981	1982	1983	1984	1985

FIGURE 7-1. TIMING AND EPA FUNDING FOR NOISE-INDUCED HEARING LOSS (NIHL)

and the Department of Labor in Fiscal Years 1979 and 1980 should provide focus as to what is needed and the ramifications of the work. Workers compensation costs for NIHL are predicted to increase to approximately \$1 billion over the next 10 years, yet little is still known about the adequacy of current criteria in terms of the real social and economic impacts. Increased research above what is presently being planned is mandatory. The real cost to the nation of NIHL remains unknown.

- o Establishment of Parameters of Individual Susceptibility

This Research Initiative will be partially undertaken by EPA. It is listed both in the EPA Plan as Initiative II and in the list of Initiatives being undertaken by NIH and the Navy (in Section 7.1.4).

8. RESEARCH PLAN FOR

BEHAVIORAL, SOCIAL AND

PERFORMANCE EFFECTS

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8. RESEARCH PLAN FOR BEHAVIORAL, SOCIAL AND PERFORMANCE EFFECTS

The long-term objective of research under this category is to determine the effects of noise on social behavior, mental health and human performance.

8.1 Rationale For Selecting Specific Research Initiatives

8.1.1 What is Known

The behavioral, social and performance effects category is a very broad category encompassing most aspects of personal and social adjustment and performance. These effects are often complex, subtle and indirect, and the result of complex interactions with nonacoustic variables.

By a wide margin, the greatest amount of scientific attention has been devoted to relatively short-term laboratory investigations (typically exposures of one hour or less) of the performance of mental and motor tasks under noise. Unfortunately, findings to date have been quite ambiguous and controversial. Although no direct, simple statements are possible, some rather general conclusions can be drawn.

It is probably safe to conclude that few performance decrements occur under steady state noise when the level is below 80 to 90 dB. A number of studies have shown that exposure to unpredictable or aperiodic intermittent noise may result in more pronounced performance effects, even at levels considerably below 80 to 90 dB. Changes in the prevailing noise level may also have an adverse effect on performance.

Tasks that require simple, repetitive operations are usually unaffected and sometimes even improved by the presence of noise. On the other hand, most performance decrements have been found on complex tasks that require continuous activity, prolonged attention, or the accomplishment of two or more simultaneous tasks. Noise has often been found to reduce the accuracy rather than the overall rate of performance.

Research has shown that motivational and personality variables can influence the effects that noise will have on performance. A fairly recent series of studies demonstrated that although performance may be unaffected during noise exposure, impairments may occur after the noise stops. It has also been demonstrated that providing the individual with the perception of control over the noise resulted in the elimination of these effects. These findings suggest the importance of contextual and other nonacoustic variables in influencing performance under noise.

A small amount of laboratory research suggests that noise may have an adverse effect on certain aspects of social behavior. There has been work on the relationship between noise and social conformity, aggression, verbal disinhibition, and altruistic (helping) behavior.

There is a growing body of evidence which shows that noise adversely affects the learning and cognitive development of children. Studies have shown that auditory discrimination and reading achievement are adversely affected in children attending school or residing in high noise environments. These studies represent some of the few attempts to assess long-term performance effects.

There have been a few other scattered attempts to assess the long-term effects of noise in field settings. There is some evidence of decreased productivity and increased absenteeism and accidents among workers exposed to high noise levels on the job. Some correlational research has also been performed on the relationship between noise exposure and mental hospital admissions, showing increased admission rates in high noise environments. Social survey work has revealed positive associations between the noise levels and various symptoms of psychological stress and negative affective states.

8.1.2 What Is Not Known

Thus far, no direct cause-effect relationships have been derived that quantitatively express the effects of noise on performance or other kinds of behavior.

A major stumbling block to progress is that there are few, if any, direct effects of noise on performance. Under most circumstances, it is not practicable to predict effects by relying only on information concerning the physical parameters of the noise. Although we have acquired some knowledge of the connection between noise and performance, the exact relationship is quite complex and often dependent upon many elusive nonacoustical parameters such as the demands of the task, intervening factors of the performance situation, and the presence of intrinsic personality variables. Identification, description and quantification of the many non-physical parameters is clearly required before a concern

with performance as disrupted by noise will become a critical factor in influencing the nature, direction and stringency of noise control programs.

Precise data are needed on the effects of noise on the cognitive and social development of children. Noise does appear to interfere with the acquisition of important language and reading skills.

It is not known with any certainty, the extent to which noise may adversely affect work performance and social behavior in real world situations. If people are forced to cope with noise, the question is what, if any, are the costs incurred as a result of the extra effort required to cope with noise? Are there affects which occur after the noise is no longer present? Research is needed to determine whether existing laboratory findings are generalizable to natural settings.

Information is lacking on the relationship between noise and social and mental pathology. Methodologically sound studies in this area are needed. Very little is known about individual differences in sensitivity to noise. Research is needed to help explain the observed large variability in individual sensitivity to noise.

8.1.3 EPA Priorities

As pointed out previously, there is ample support for the contention that behavioral effects of noise are of direct concern to EPA, in view of EPA's responsibility of guarding public health and welfare. The potential adverse behavioral effects of noise are great and include not only unnecessary disruption of productivity but also accidents on the job, absenteeism, effects on learning, social behavior,

and increased social problems like crime. Quantified dose-response relationships between noise and adverse behavioral, social and performance effects are now completely lacking. However, there are promising avenues along which future research should be directed in support of EPA's requirements.

Taking into consideration current funding estimates, relatively little research can be adequately carried out in this health effects category over the five-year period. Based on programmatic needs and other factors, emphasis will be placed on investigating the effects of noise on children and studies of behavioral and social adjustment to long-term noise exposure.

8.1.4 Current Research Activities

At the present time, EPA is not sponsoring any research in the behavioral category. The amount of related activity by other Federal agencies has also been less than adequate. Only seven studies have been undertaken by other agencies in the last few years, at a cost of approximately \$500K. According to the information gathered to date in the update of the Panel Report, overall funding levels may have declined in this category of research. Moreover, with few exceptions, much of the ongoing research does not seem to be directly applicable to everyday environmental noise problems.

Some of the specific research activities include the following:

- o Studies by the Department of Defense (DOD) assessing the performance effects of noise (and other environmental stressors) in military situations. Some of the findings of these studies may be applicable to EPA questions concerning the interaction of noise and other stressors in affecting performance.
- o A small study by the National Institute of Mental Health (NIMH) investigating personal adjustment to urban noise.
- o Performance effects research by the National Science Foundation (NSF) investigating the relationship between noise control in the workplace and productivity.
- o Research by the National Science Foundation (NSF) on the effects of environmental noise on children's attentional strategies and generalized expectations concerning controls.
- o A study sponsored by the State of California on achievement test scores of elementary school children in schools near freeways.

8.1.5 Position on the Research Continuum

From Table 8-1, it is clear that compared to some of the other health effects research categories, research in many facets of the behavioral category is still in the exploratory phase. With the exception of laboratory studies of task performance, suspected effects have been identified, but not sufficiently investigated.

8.1.6 List of Planned EPA Research Initiatives for the Five-Year Period

- I. Effects of Noise on Cognitive and Social Development
- II. Behavioral and Social Adjustment to Noise

These initiatives, together with their proposed funding levels, have been chosen based on the following assumptions:

- 1. Due to the relatively low level of emphasis placed on this category, only limited funding will be available during the five-year Plan period.
- 2. Because Research Initiatives in higher priority categories must be started as soon as possible, limited EPA resources make it necessary to defer research startups in this category until Fiscal Year 1983.

8.2 Detailed Descriptions of the Research Initiatives

I. Effects of Noise on Cognitive and Social Development

Description and Basic Considerations.--A relatively small but growing literature exists showing that environmental noise is

TABLE 8-1

POSITION ON THE RESEARCH CONTINUUM - BEHAVIORAL, SOCIAL, AND PERFORMANCE EFFECTS

<u>Research Continuum</u>	<u>Current State of Knowledge</u>		
	<u>Adequate</u>	<u>Marginal</u>	<u>Inadequate</u>
1. Demonstrate existence of an association		X*	
2. Demonstrate basic cause-effect relationship			
3. Investigate physiologic mechanisms			X
4. Investigate intervening factors. Improve cause-effect relationship			
A. Acoustic			X
B. Nonacoustic			X**
5. Quantify dose-response relationship			X
6. Refinement and special populations			X***

* Task performance studies only

** Much research in this area has established that nonacoustic factors have a strong influence in most aspects of this category.

*** Generally inadequate, but research indicates that noise does interfere with the acquisition of important language and reading skills in children.

associated with impaired speech discrimination or understanding, reading achievement, problem solving, and task performance in children. This research has involved infants through young adolescents, and has dealt with noise in both home and school environments. Other research exists which indicates that certain groups of special children may be even more sensitive to noise than normal children.

The aim of this Initiative is to determine the extent to which living or attending school in high noise areas has adverse effects on cognitive and social development.

A. In the first phase, an appraisal of the existing data will be carried out, using not only noise studies per se, but other relevant studies as well. A fairly extensive literature base reveals the importance of early environmental stimulation on the development of both animals and humans. Other research has dealt with the concepts of selective attention and distraction in children, particularly with respect to learning and performance in educational settings.

The first phase will be undertaken in Fiscal Year 1983 at a cost of \$60K.

B. In the second phase, a lab and/or field study will be conducted, incorporating the following factors in its design.

- o Socioeconomic characteristics (age, race, sex)
- o School performance (in-class performance, homework performance, standardized tests.)
- o Social behavior (in home; at school)
- o Acquisition of speech and language
- o Performance of selected tasks (psychomotor, cognitive).

The second phase will be funded at a level of \$150K in Fiscal Year 1984 and \$100K in Fiscal Year 1985.

Expected Results.--The results of the first-year appraisal will be used to develop the protocol of the study. The study will yield some of the information necessary for deriving quantitative dose-response criteria including speech communication criteria for children.

II. Behavioral and Social Adjustment to Noise

Description and Basic Considerations.--Many of the behavioral effects of noise are complex, subtle and indirect. Although it is widely accepted that noise has disruptive effects, little is known about how people adapt to and cope with noise in their environment. Research under this Initiative will try to assess and quantify some of the major adverse effects of noise on social and personal adjustment.

The emphasis will be on methodologically sound studies of long-term adaptation to noise. Attempts will be made to assess the social and behavioral costs of adaptation and, where warranted, to assess the generalizability of laboratory findings to naturally occurring situations.

In the first phase, the literature will be reviewed and evaluated to 1) determine which areas of behavioral and social adjustment offer the most promise in providing criteria and 2) the specific research questions that need to be addressed. Research studies will then be designed and implemented under the second phase of this Initiative.

The appraisal of literature will be conducted in 1983 at a level of funding of \$55K. Research studies will be conducted in Fiscal Years 1984 and 1985 at funding levels of \$110K and \$250K, respectively.

Expected Results.--Results of the literature appraisal will be used to decide which topics should be selected, and in designing the specifics of the research studies planned for the following years (Fiscal Years 1984-6). Only preliminary results may be expected from the research before Fiscal Year 1986.

8.3 Timing and Funding of Research Initiatives

See Figure 8-1.

8.4 Monitoring and Coordination

During the appraisal work, liaison will be maintained with scientific groups to provide important inputs for the research design of the planned studies. Workshops for this purpose are also being considered.

Coordination will be maintained with such agencies as DOD, NSF and NIMH and through the Noise Effects Advisory Group.

8.5 Research Initiatives That Will Not Be Undertaken by EPA

The scientific appraisals currently planned will place EPA in a position to move into studying two major topics under these two Initiatives. Other topics will be identified, but due to limited resources will not be started. It is too early to list these topics.

RESEARCH INITIATIVES	Fiscal year funding				
	1981	1982	1983	1984	1985
I. Effects of noise on cognitive and social development.			\$60K	\$150K	\$100K
II. Behavioral and social adjustment to noise.			\$55K	\$110K	\$250K
TOTALS			\$115K	\$260K	\$350K
	1981	1982	1983	1984	1985

FIGURE 8-1. TIMING AND EPA FUNDING FOR BEHAVIORAL, SOCIAL AND PERFORMANCE RESEARCH

Other major Initiatives will not be addressed at all. These include:

- o The relationship of noise to mental pathology (virtually no attention under this Plan)
- o The role of acoustic and nonacoustic factors on task performance
- o Individual differences in sensitivity to noise
- o Interaction of noise with other stressors in the performance situation

9. RESEARCH PLAN FOR
COMMUNICATION INTERFERENCE

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9. RESEARCH PLAN FOR COMMUNICATION INTERFERENCE

The long-term EPA objective for research on Communication Interference is to determine and quantify the effects of noise on communication and its developmental, social and other implications.

The reader should note that the contents of this chapter and the following chapters differ from the others thus far, in that Research Initiatives are proposed but none are expected to be funded by EPA due to higher priorities and resource constraints.

9.1 Rationale for Selecting Specific Research Initiatives

9.1.1 What is Known

The ease with which normal-hearing adults can communicate with each other face-to-face, or understand speech over communication systems such as telephones, intercoms, radios, and the like, is governed primarily by the amount of background noise present in the environment. Although individuals can compensate to some degree for the interference created by masking noise by raising their voices, or by listening more carefully, such compensation is often tiring and unpleasant, and in extreme background noise conditions, ineffective.

Most research on the adequacy of speech communication was initially conducted in the context of evaluation of military communication systems. More recently, this body of knowledge has been applied to

the slightly different problem of determining the effects of environmental noise on face-to-face communication. The fundamental tools used for assessing the acceptability of speech communication are procedures for estimating speech intelligibility on the basis of assumed background noise spectra and speech levels. A number of efforts have been made to equate percentages of words and sentences correctly understood within fixed contexts to typical speech and noise characteristics. Thus, EPA has developed and published in the "Levels Document"* general purpose criteria relating levels of continuous noise to percentage of sentence intelligibility at specific distances under normal, face-to-face speaking conditions. One set of criteria exists for indoor speech interference and one for outdoor speech interference. These criteria are judged to be adequate for most Federal regulatory purposes. In addition, criteria exist for intelligibility where the speaker has exerted greater vocal effort to overcome perceived background noise, for cases where the communications are perceived by the speaker as "vital" or "not vital."

9.1.2 What is Not Known

Although the major acoustic determinants of speech interference are well known, the assessment of the quality of face-to-face verbal communication is not yet a routine matter. This is so because nonacoustic circumstances of the communication situation have not yet been reduced to a manageable set of standard conditions. For example,

* Information on Levels of Environmental Noise Requisite to Protect Public Health and Welfare with an Adequate Margin of Safety, U.S. EPA 550/9-74-004, March 1974.

it is not yet known at what distances people actually choose or attempt to communicate indoors, outdoors, and in other special environments (schools, transportation vehicles, public meeting places, group gatherings, etc.).

Similarly, the degree to which other non-standard conditions affect speech intelligibility (such as non-native or inexperienced, or very young, old, or hearing-impaired speakers or listeners) are not yet usefully quantified. By the same token, it is not yet known how unusual background noise conditions (such as intermittent high level or time varying noise) affect satisfaction with speech communication.

Additional gaps exist in our knowledge of the indirect effects of communications interference. These include: effects on education, safety and the quality of everyday social interactions. There are numerous anecdotal reports of noise interference in the classroom. Likewise, there are reports of safety hazards in a number of different traffic and industrial situations due to the masking of emergency signals. None of these more indirect effects of communications interference by noise has been quantified.

9.1.3 EPA Priorities

To continue to support the EPA mission of protecting the public health and welfare from the adverse effects of environmental noise, research must now focus on refined criteria which will be helpful in assessing the effects of noise on special subpopulations, the effects of special noise patterns on the population, and the indirect effects of noise on safety, productivity and performance.

From EPA's point of view, therefore, the most useful specific directions for work refining criteria are to:

- o Establish criteria for special groups (elderly, children, hearing-impaired, people with English as a second language)
- o Establish criteria (families of dose-response curves) for:
 - relaxed vocal effort indoors
 - relaxed vocal effort outdoors
 - relaxed vocal effort inside transportation vehicles
- o Establish better criteria for time-varying noise.

In addition, EPA needs to understand better the indirect adverse effects of disruption of speech by noise. These include the question of safety, extreme annoyance, disturbance of normal activities such as domestic life or learning, and effects on social interaction. Of particular interest, and already addressed by a Research Initiative in the behavioral, social and performance effects Plan, is the determination of the effects of noise on teaching and learning activities. Thus it can be seen that understanding of communication interference is a necessary aspect of work in some of the other research categories.

9.1.4 Current Research Activities

EPA is presently providing indirect support in this area through the Fels longitudinal study. The speech discrimination abilities of children are being investigated under different noise conditions. Other Federal agencies are much more directly active in this category. According to the information gathered to date in the update of the Panel

Report, over \$1 million has been spent by other agencies on at least nine projects over the last few years. Three agencies are significantly involved in investigating the effects of noise on the speech perception of special groups of people. Their specific research activities include the following:

- o The National Institute of Neurological and Communicative Disorders and Stroke (NINCDS) has sponsored the bulk of the research. Their research includes studies of speech perception problems of children and the hearing-impaired.
- o The Veterans Administration is investigating the acoustic needs of aphasics (persons with neurologically damaged language functions).
- o The National Institute of Environmental Health Sciences (NIEHS) has sponsored studies of the effects of time-varying noise on communication interference of people with special hearing problems.
- o In addition, branches of the Department of Defense are continually undertaking research studies in assessing and redesigning speech communication systems for maximum communication effectiveness and the least interference by noise.

9.1.5 Position on the Research Continuum

General criteria have been achieved, and work is now proceeding on refined criteria and factors related to special populations (See Table 9-1).

9.1.6 List of Selected EPA Research Initiatives

There are no EPA Research Initiatives slated for funding in this five-year Plan period. However, EPA has developed a set of Research Initiatives which are important from the EPA standpoint. Those are described in Section 9.5 of this Plan.

Moreover, part of a needed Initiative will be carried out under the Plan for behavioral, social and performance effects. Under Initiative I, as part of the study of effects of noise on learning, preliminary work on developing speech criteria for children will be conducted.

9.2 Detailed Descriptions of the Research Initiatives

(Not applicable, See Section 9.5).

9.3 Timing and Funding of the Research Initiatives

(Not applicable).

9.4 Monitoring and Coordination

Although EPA will not need to coordinate with outside groups with respect to EPA projects, it will be necessary to stay abreast

TABLE 9-1

POSITION ON THE RESEARCH CONTINUUM - COMMUNICATION INTERFERENCE

<u>Research Continuum</u>	<u>Current State of Knowledge</u>		
	<u>Adequate</u>	<u>Marginal</u>	<u>Inadequate</u>
1. Demonstrate existence of an association	X		
2. Demonstrate basic cause-effect relationship	X		
3. Investigate physiologic mechanisms		NA	
4. Investigate intervening factors. Improve cause-effect relationship			
A. Acoustic (impulse, intermittent)		X	
B. Nonacoustic (situational factors),			X
5. Quantify dose response relationship	X*		
5. Refinement and special populations			X

* Adequate for normal-hearing adults only under ideal listening contexts.

of progress made by other research agencies so that work useful to the EPA mission may be acquired in a timely fashion. Of particular relevance in this regard is work being conducted by NINCDs and NIEHS. In addition there will be continuing active participation in ANSI committees dealing with speech intelligibility.

9.5 Research Initiatives That Will Not Be Undertaken by EPA

The following Initiatives will not be undertaken by EPA due to limited resources available:

o Relaxed Conversation in Different Environments

Under this Initiative are included criteria for relaxed conversation indoors, outdoors, and inside transportation sources (cars, trains, buses, etc.).

o Speech Intelligibility for Special Groups

Special dose-response criteria are needed for the elderly, children, and the hearing-impaired (both listeners and speakers) and for dialects and speech as spoken by non-native speakers.

o Effect of Time-Varying Noise on Speech Intelligibility

The effects of time-varying noise of various types (e.g., passbys, overflights, periodic sources) need to be studied in laboratory conditions to develop appropriate criteria.

- o Communications Interference Effects in High-Noise Work
and Traffic Environments

The objective of this Initiative is the eventual quantification of risk from accidents caused by failure to hear warning signals, of loss of productivity, and decrements in performance where auditory communication is required. As such, the contents of this Initiative are similar to and partly covered by the Initiatives to be pursued under the behavioral, social, and performance effects research Plan.

10. RESEARCH PLAN FOR EFFECTS OF
NOISE ON WILDLIFE AND OTHER ANIMALS

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10. RESEARCH PLAN FOR EFFECTS OF NOISE ON WILDLIFE AND OTHER ANIMALS

The long-term EPA objective for noise effects research in this category is to determine and quantify the effects of noise on wildlife and domestic animals.

10.1 Rationale for Selecting Research Initiatives

10.1.1 What is Known

Research on effects of noise on laboratory animals is fairly plentiful. While its purpose is usually to apply findings to human beings, it also serves to focus attention on the range of potential noise effects on domestic animals and wildlife. The applicability of the existing laboratory research is limited, however, by at least two factors: (1) the extreme noise levels or other unnatural exposure characteristics presented in many of the experiments, and (2) the use of species which, for the most part, are different from the wild animals of interest. Considering these limitations, laboratory research has demonstrated the following potential effects of noise: noise-induced hearing loss; nonauditory physiologic effects; important behavioral changes; masking of auditory signals.

A number of studies have demonstrated some adverse, and a few beneficial, noise effects in domestic animals, such as cattle, sheep, pigs and fowl. Largely, these studies employ experimental and unnatural noise conditions, rather than typical noise environments for

these animals, such as highway and aircraft noise. Effects observed include adverse color changes in meat, other metabolic changes in sheep and lamb, reduced egg hatching due to decreased broodiness in hens, and startle and alarm responses in all species studied.

Very little is known about effects of noise on wildlife. Only a handful of studies exist, and these are largely anecdotal or based on captive wild animals. Many wild animals, fish and birds are startled by noise, but the response appears to habituate in a number of species. Attempts to use noise to repel species considered pests have failed for this reason. Where flight from noise does occur, it is unknown whether there are any adverse consequences. Adverse physiologic effects either have been noted or suggested in a number of species, including caribou and deer. These were noted under artificial conditions, however, and any effects in the wild are unknown.

An area of potential concern is masking effects of noise. Noise interferes with the hearing of desired signals for animals just as for humans. While this masking is known to occur, we can only suggest possible effects on auditory behaviors such as when evading predators; locating mates, young and prey; defining territory; and avoiding harm from falling trees and other hazards.

10.1.2 What is Not Known

With regard to domestic animals, existing information on noise effects on growth, metabolism, reproductive, physiological and behavioral activity needs to be expanded and refined. Special emphasis

should be placed on quantifying effects in everyday noise exposure situations for these animals. At present, the impact of different noise sources such as highways and airports cannot be estimated.

Effects on physiologic functioning, hearing, communications and behavior are all unknown, although many potential effects have been hypothesized. A prerequisite for much of the needed research is to measure the hearing thresholds of the species of concern, because animals often have auditory sensitivities greatly different from humans. Thresholds of audibility across frequencies are known for some species, but unknown for others.

10.1.3 EPA Priorities

The highest EPA noise program priority in this research category is the identification and quantification of effects of noise on susceptible animal populations. At this time, these are judged to be:

- o Endangered species;
- o Animals heavily reliant on audition for survival, for which continuous masking noise in the habitat could have grave effects (such as fish, marine mammals and birds);
- o Animals which are important to humans for food, such as livestock, fowl, fish and other marine animals.

It is important for research to focus on effects in natural or typical settings because confined animals will show different effects.

It is also important to study everyday noise levels due to exposures from typical mechanical noise sources or products (as opposed to waterfalls and other natural sources).

10.1.4 Current Research Activities

EPA is not proposing to conduct any research activities in this category within the five-year time frame. It also appears that no research is presently being sponsored by other Federal agencies such as the Department of Agriculture and the National Park Service.

10.1.5 Position on the Research Continuum

Overall, existing knowledge is not adequate for an appraisal of noise effects on wildlife and other animals. (See Table 10-1).

10.1.6 List of Selected EPA Research Initiatives

Due to higher priorities and limitations in resources, EPA will not be funding any Initiatives in this category within the Five-Year Plan period. A set of Initiatives has been developed, however, and is listed in Section 10.5. It is hoped that these may be pursued by other agencies.

10.2 Detailed Descriptions of the Research Initiatives

(Not applicable. See Section 10.5).

TABLE 10-1

POSITION ON THE RESEARCH CONTINUUM -- WILDLIFE EFFECTS

<u>Research Continuum</u>	<u>Current State of Knowledge</u>		
	<u>Adequate</u>	<u>Marginal</u>	<u>Inadequate</u>
1. Demonstrate existence of an association		X	
2. Demonstrate basic cause-effect relationship			X
3. Investigate physiologic mechanisms			X
4. Investigate intervening factors. Improve cause-effect relationship			
A. Acoustic			X
B. Nonacoustic			X
5. Quantify dose-response relationship			X
6. Refinement and special populations			X

10.3 Timing and Funding of the Research Initiatives

(Not applicable.)

10.4 Monitoring and Coordination

Although EPA has no plan to undertake research within the next five years, it is essential to learn from ongoing studies being conducted elsewhere. This information is very relevant to EPA program activities.

10.5 Research Initiatives That Will Not Be Undertaken by EPA

These Initiatives will produce results relevant to EPA programmatic activities. (Note that there is considerable potential overlap among Initiatives.) It is hoped that some of them will be undertaken elsewhere during the Five-Year Plan period.

o Noise Impact on Endangered Species

The objective of this Initiative is to produce criteria where adverse effects are found to occur in threatened species. Studies should focus on long-term effects found in natural habitats where noise made by humans may occur.

o Impact of Masking Noise on Susceptible Species

This Initiative comprises studies on species heavily reliant on audition for activities such as locating offspring, mates, prey and/or predators, defining territories, and other activities related

to survival. These studies should focus on long-term effects in natural habitats, using typical man-made noise sources.

- o Impact of Noise on Species Prominent in the Production of Food for Humans

This Initiative addresses the impact of noise exposure on livestock, domestic fowl, fish and other marine animals. Of particular importance are stress effects in farm animals. Typical noise sources for each species should be investigated.

11. RESEARCH PLAN FOR

EXPOSURE CHARACTERIZATION

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11. RESEARCH PLAN FOR EXPOSURE CHARACTERIZATION

The long-term EPA objective for research in this category is to determine patterns of noise exposure, typical noise doses attributable to different sources and/or environments, and health-related consequences of these exposures.

11.1 Rationale for Selecting Specific Research Initiatives

11.1.1 What is Known

Current knowledge of the noise exposure of the American population is composed primarily of source and situation information. Information about source levels is quite comprehensive. Typical levels produced by virtually all types of high-level noise sources and a great many moderate- to low-level noise sources have been measured, tabulated, analyzed, and compiled many times. Standards for measuring many noise sources have been proposed and/or adopted. Some of these standard procedures deal with technical details of physical aspects of measurement, while others deal with means of calculating complex indices and contours of various sorts. Computerized models of noise levels produced by simultaneous operation of multiple noise sources engaged in specific activities have also been devised. Information about noise levels encountered in different environments, although less comprehensive than information about sources per se, is nonetheless quite extensive. Noise levels of many indoor and outdoor spaces have also been repeatedly

measured. Some limited studies have been undertaken assessing exposures of workers, military personnel, homemakers and children over 24-hour and longer periods. For the most part, these studies have shown rather high individual exposures over these periods.

11.1.2 What is Not Known

Many studies have been undertaken which have increased our knowledge of source and situation contributions to the undesirable effects of noise. However, these studies so far have not provided us with critically needed information concerning how people interact with their total noise exposure environments and the implications of this interaction with respect to the health-related consequences of noise exposure. The emphasis is on knowing the levels and patterns of noise actually received by people as they move from environment to environment. With this information, noise doses can be better related to health effects, such as hearing loss that depend on a 24-hour dose and not just on the exposure at work.

For example, knowledge about individual exposure patterns is quite fragmentary. It is not yet known, for example, whether groups of people engaged in similar occupations share similar individual exposure patterns outside of work; whether certain subgroups of the population are more heavily exposed to noise than would be suggested by their occupations; whether recreational and other forms of voluntary noise exposure contributes substantially to the total daily noise dose; and so forth. One reason this issue is so important is that certain population

subgroups may be more susceptible to noise effects due to their total noise dose, both inside and outside work.

Results of a few preliminary dosimetric studies are not yet readily interpretable, due to a number of technical problems and small sample sizes. A major uncertainty in exposure characterization is the careful determination of the relationships between source and situation oriented measures of noise levels and measures of personal exposure. Most importantly, the critical relationships between personal noise exposure patterns, and the incidence and magnitude of the harmful effects of noise, have yet to be derived.

11.1.3 EPA Priorities

There are many reasons to undertake a national program to assess individual or personal noise exposure. A primary need is to obtain information which will enable EPA to determine the kind and extent of the principal known effects of noise on health and welfare due to all of the varying noise exposure patterns typical of different personal lifestyles. Such information will also aid in determining the relative importance of typical environmental noise situations experienced day to day. Furthermore, it will help to develop and validate predictive models to assess the contribution of specific sources of situations to the total noise problem. Information to be obtained must include site specific monitoring, identification of lifestyles, personal noise monitoring and exposure time-histories, and recognition of human response patterns.

To that end, EPA program priorities require that both individual dosimetric and site specific studies be conducted to quantify the sources and situations responsible for major contributions to total at-ear noise exposures. It is also recommended that such studies concern themselves with differences in exposure patterns for different segments of the population, and that exposure patterns in turn be associated with patterns of activity such as sleeping. Additional study is desirable ultimately to associate noise effects information from all the other research categories with patterns of personal at-ear exposures. This will help to establish the incidence and severity of different noise-related effects on the U.S. population.

11.1.4 Current Research Activities

EPA has undertaken a relatively small-scale base year effort of site-specific community noise monitoring. Specifically, this activity will attempt to define national ambient noise levels over time within an array of environments, and to identify specific noise source contributions to those noise environments.

Additionally, EPA is completing in the base year a study of typical daily activity patterns of the United States population, as well as various population subgroups identified on the basis of a number of occupational and demographic characteristics. The objective of this study is to relate particular lifestyles or patterns of human activity to noise exposure and/or dosimetry information to be gathered in the future.

In the Fels longitudinal study being jointly sponsored by EPA and the Air Force, measurements are being taken of the specific noise exposures of children and the major source contributants to their total daily noise exposures. Individual noise exposures will be measured in a serial manner to determine changing noise exposure patterns as a function of age and sex. The measured exposures will then be related to the childrens' hearing abilities in an effort to determine the resulting auditory effect caused by noise.

Other Federal agencies have little additional related research in progress or planned. The only exception is the Air Force and Navy who are assessing personal monitoring methods using dosimeters, and measuring military noise exposures and exposure patterns.

11.1.5 Position on the Research Continuum

Not directly applicable. Only limited exposure information has been related to the various effects of noise.

11.1.6 List of Planned EPA Research Initiatives for the 5-Year Period

There are no direct EPA Research Initiatives slated for funding in this five-year Plan period. Some limited work will be indirectly conducted by EPA under Initiative I in the NIHL Research Plan. Data from national health surveys of the Public Health Service will be used to relate the hearing status of the public to certain demographic indicators and indirect indices of exposure. However, EPA has developed a set of Initiatives which are important. They are described in Section 11.5 of this Plan.

11.2 Detailed Description of the Research Initiatives

(Not Applicable.)

11.3 Timing and EPA Funding of Research Initiatives

(Not Applicable.)

11.4 Monitoring and Coordination

EPA will closely participate with the IRLG subgroup on noise, in assessing the total body burden of noise and the interacting effect of workplace noise with off-the-job exposures. This group will try to come up with suitable methods and models to assess the cumulative noise doses of workers and the differential effects of noise sources on hearing. Close coordination will also be maintained with DOD in their noise exposure assessments.

11.5 Research Initiatives That Will Not Be Undertaken By EPA

The following Research Initiatives will not be undertaken during the five-year period due to relatively low priority and the necessity of obtaining basic human response and health effects information before relating to patterns of exposure.

- o Determine where and when primary exposures occur, and sources of exposure.
- o Determine total exposure patterns of different people, and relate to time/activity profiles.
- o Relate health effects of noise with different patterns of exposure (total and interactive effects).

CHAPTER 12

SUMMARY AND INTEGRATION

The purpose of this chapter is to pull together information on the proposed Research Initiatives year by year, so that for any year, the total array of research activities, research milestones and research decision points can be identified, compared, and discussed across all of the health effects categories. This overview (as presented in Sections 12.1, 12.2* and 12.3*) will then set the stage for interrelating the proposed Health Effects Research Plan with the core EPA Noise Control Program Plan throughout the five-year period. The interrelation between the two Plans will be discussed in Section 12.4.* Although the Research Plan is presented independently, it is an integral and inseparable part of the EPA Program Plan. The Research Plan provides for the development and refinement of necessary health effects criteria to support noise control activities over the Five-Year Plan period and even beyond, when some of the results of planned research activities started during the 1981-1985 Fiscal Year period are expected. A projection of research needs for the following five years, beyond the present Plan, is presented in Section 12.5.*

*These sections will be included in the next cycle of revisions to the Plan.

12.1 Integrated Research Initiatives by Fiscal Year

Figure 12-1 displays the aggregate funding levels for each research category per year, from Fiscal Year 1981 through 1985. Approximately \$10 million of health effects research related to noise will be undertaken by EPA over the duration of the Plan.

As shown, the largest share of the research funding will go to nonauditory physiologic effects research, specifically the effects of noise on the cardiovascular system. Funding in this category will comprise approximately 46 percent of the EPA noise effects research budget over this period ranging from approximately \$570K in 1981 to \$1.3 million in 1985.

These funding levels are dependent upon co-support from other agencies to conduct the necessary work within the Five-Year Plan period. The assumed level of co-support by other agencies will increase the effective size of the nonauditory research budget by 34 percent in Fiscal Year 1982 and by 77 percent in Fiscal Year 1985. Thus by 1985, the total research budget in the category will climb to \$2.3 million, with 43 percent of the funding coming from other agencies.

The necessity for funding at this level is based on the potentially great health implications of such effects, the small amount of research that has been undertaken in this country thus far, and the high cost of biomedical research. These funds will support Research Initiatives to assess medically significant physiologic responses due to noise in experimental animal and human clinical studies, the first

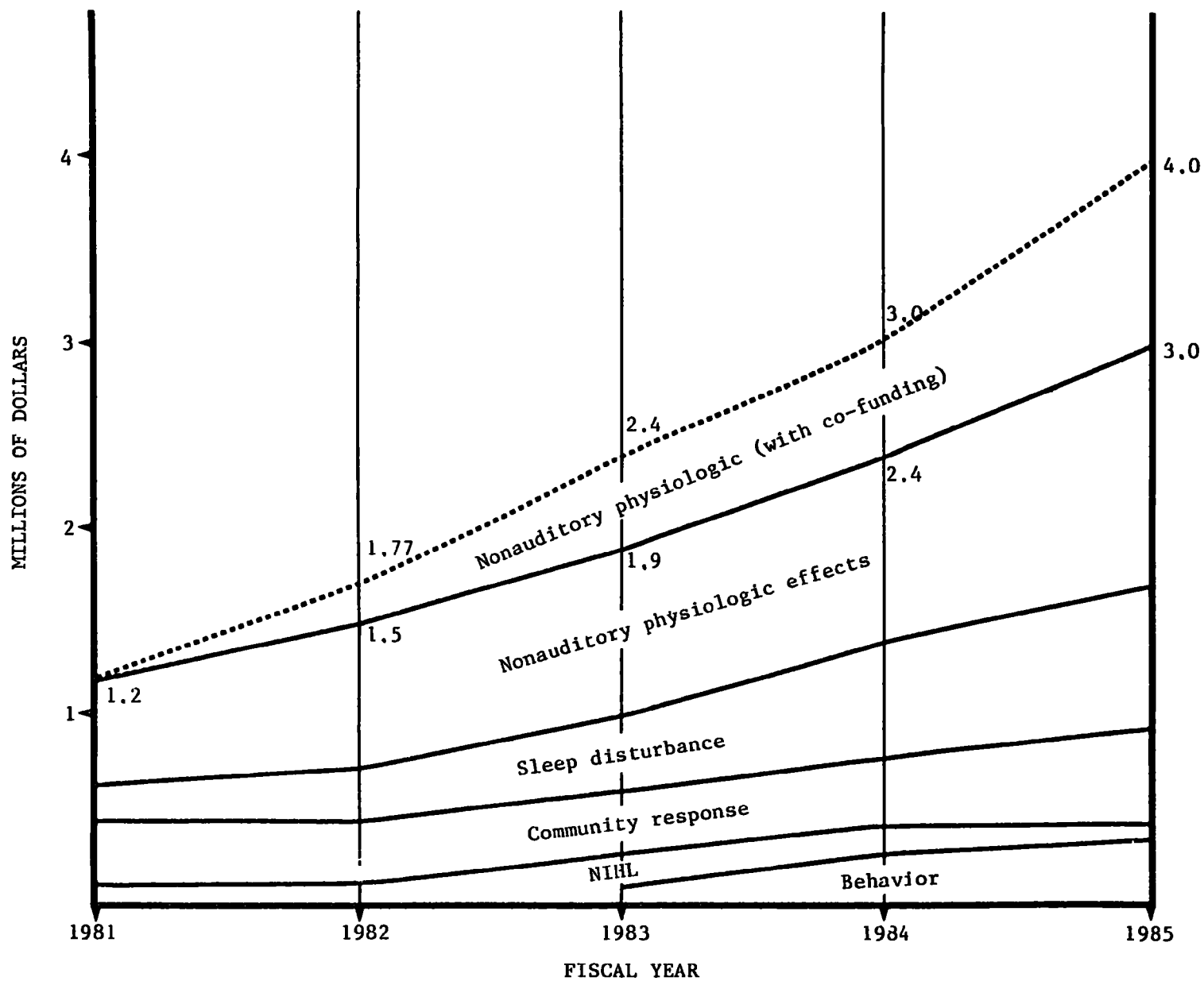


FIGURE 12-1. AGGREGATE FUNDING FOR ALL CATEGORIES BY FISCAL YEAR

U.S. prospective epidemiological study in this area, and basic investigations of physiologic effects other than on the cardiovascular system.

Table 12-1 lists the specific Research Initiatives proposed to be undertaken by EPA each year across all categories. Detailed descriptions of these Initiatives are provided in Chapters 4 to 8.

Turning to research categories other than the nonauditory physiologic category, the following budgetary trends and features can be seen in the research budgets over the Five-Year Plan period.

Funding in support of sleep disturbance research will require approximately 23 percent of the research budget over the five-year period and, therefore, will be the second highest funded research category. Over 50 percent of the proposed research in this category will address the long-term health consequences of noise.

Funding in the area of community and individual response will constitute approximately 17 percent of the total EPA noise effects research budget over the next five years. Social surveys and psychoacoustic studies will be conducted in response to EPA needs for more detailed human response criteria for special noise sources and acoustical parameters.

In terms of noise-induced hearing loss research, the proposed EPA research effort will maintain a limited but focused profile due to the continuing research efforts of other agencies. Funding will comprise approximately 7 percent of the total EPA research budget and will not be higher than \$150K in any year. Research will focus narrowly

on the incidence of NIHL, with emphasis on the contribution of non-occupational noise environments.

Funding in support of behavioral, social and performance effects will not start until Fiscal Year 1983, due to the resource requirements for funding research in other health effects categories. Overall, only 7 percent of the total research budget (the same amount as for NIHL research) will be put towards research in this category, which will feature the clarification of the adverse role noise plays in the learning process of children.

Research in the categories of communication interference, wildlife, and exposure characterization will not be directly funded by EPA over the Five-Year Plan period due to resource constraints and higher priorities.

It is hoped that other agencies can undertake research efforts in these areas, which are applicable to general EPA objectives as defined in Chapter 2. Accordingly, Research Initiatives have been identified in these latter categories for the consideration of the other agencies.

FY 81: 1.2 Million

**EPA Funding of Each
Research Initiative**

NONAUDITORY PHYSIOLOGIC EFFECTS

Animal Experimental Studies	
o Replications and Refinements	\$290K
Epidemiologic Studies	
o Retrospective Analysis	\$100K
Human Clinical Studies	
o Acoustic/nonacoustic Factors	\$100K
o Susceptibility Differences	<u>\$80K</u>
	(\$570K)

COMMUNITY RESPONSE

Specific Sources of Noise:	\$100K
o Construction	
Specific Acoustical Attributes:	\$180K
o Intrusiveness and warning signals	<u></u>
	(\$280K)

SLEEP DISTURBANCE

Relationship between field and laboratory data on sleep disturbance by noise	\$100K
Health Consequences of noise-disturbed sleep	<u>\$100K</u>
	(\$200K)

NOISE-INDUCED HEARING

Parameters of Individual Sensitivity	
o Susceptibility of Special Populations - Children. (Fels)	\$ 50K
o Determination of Source Exposures Causing TTS and Assessment of Debilitating Consequences.	\$ 50K
Incidence of NIHL in the U.S. and Contribution of Sociocusis, Presbycusis, and Occupational Exposures.	<u>\$ 50K</u>
	(\$150K)

\$1.2 Million

TABLE 12-1 FUNDING OF PLAN BY FISCAL YEAR

<u>FY 82: \$1.5 million</u>	<u>EPA Funding of Each Research Initiative</u>	<u>Total Funding of Nonauditory Physiologic Research Initiatives with Co-Funding*</u>
NONAUDITORY PHYSIOLOGIC EFFECTS		
Animal Experimental Studies		
o Replication and refinement	\$290K	\$290K
Epidemiologic Studies		
o Retrospective Analysis	\$100K	\$100K
o Prospective Analyses (Phase I)	\$130K	\$400K
Human Clinical Studies		
o Acoustic/Nonacoustic Factors	\$150K	\$150K
o Susceptibility Differences	<u>\$125K</u>	<u>\$125K</u>
	(\$795K)	(\$1065K)
COMMUNITY RESPONSE		
Specific Sources of Noise:	\$100K	
o Construction		
Specific Acoustical Attributes:		
o Intrusiveness	\$100K	
o Other Topics	<u>\$ 60K</u>	
	(\$260K)	
SLEEP DISTURBANCE		
Relationship between field and laboratory data on sleep disturbance by noise	\$100K	
Health Consequences of Noise- disturbed Sleep	\$150K	
Acoustic Parameters Related to Sleep	<u>\$ 50K</u>	
	(\$300K)	
NOISE-INDUCED HEARING LOSS		
Parameters of Individual Sensitivity: Susceptibility of Special Populations - Children. (Fels)	\$ 50K	
Incidence of NIHL in the U.S. and Contribution of Sociocusis, Presbycusis, and Occupational Exposures.	\$ 50K	
Refinement of Criteria for Low-level Noise Exposures.	\$ 50K	
	<u>(\$150K)</u>	
	\$1.5 million	

* It is assumed that approximately \$270K will be provided by other agencies. This amounts to approximately 34 percent of EPA's Nonauditory Physiologic Effects Research Funding of \$795K, or 25 percent of the combined funding.

TABLE 12-1 FUNDING OF PLAN BY FISCAL YEAR (cont'd)

FY 83: \$1.9 Million

**EPA Funding of
Each Research
Initiative**

**Total Funding of
Nonauditory Physiologic
Research Initiatives
with Co-Funding***

NONAUDITORY PHYSIOLOGIC EFFECTS

Animal Experimental Studies		
o Acoustic/Nonacoustic Factors	\$100K	\$200K
o Susceptibility Differences	\$100K	\$100K
Epidemiologic Studies		
o Prospective Analyses (Phase I)	\$500K	\$550K
o Special Sub-populations-- Children	--	\$150K
Human Clinical Studies		
o Acoustic/Nonacoustic Factors	\$100K	\$150K
o Susceptibility Differences	\$100K	\$150K
Other Nonauditory Effects		
o Appraisals	--	<u>\$100K</u>
	(\$900K)	(\$1400)

COMMUNITY RESPONSE

Specific Sources of Noise:	
o Construction	\$ 35K
o Other Topics	\$150K
Specific Acoustic Parameters	<u>\$150K</u>
o Other Topics	
	(\$335K)

SLEEP DISTURBANCE

Health Consequences of Noise- disturbed Sleep	\$250K
Acoustic Parameters Related to Sleep	<u>\$150K</u>
	(\$400K)

NOISE-INDUCED HEARING LOSS

Parameters of Individual Sensitivity: Susceptibility of special populations - children. (Fels)	\$ 50K
Incidence of NIHL in the U.S. and Contribution of Sociocusis, Presbycusis, and Occupational Exposures.	\$ 50K
Refine criteria for low-level noise exposures.	\$ 50K
	<u> </u>
	(\$150K)

BEHAVIOR, SOCIAL AND PERFORMANCE

Cognitive and Social Development: Noise and School Performance Study	\$ 60K
Behavior/Social Adjustment to Noise	\$ 55K
	<u> </u>
	<u>(\$115K)</u>

\$1.9 Million

* It is assumed that approximately \$500K will be provided by other agencies. This amounts to approximately 56 percent of EPA's Nonauditory Physiologic Effects Research Funding of \$900K, or 35 percent of the combined funding.

TABLE 12-1 FUNDING OF PLAN BY FISCAL YEAR (cont'd)

FY 84: \$2.4 Million

**EPA Funding of
Each Research
Initiative**

**Total Funding of
Nonauditory Physiologic
Research Initiatives
with Co-Funding***

NONAUDITORY PHYSIOLOGIC EFFECTS

Animal Experimental Studies		
o Acoustic/Nonacoustic Factors	\$100K	\$200K
o Susceptibility Differences	\$100K	\$100K
Epidemiologic Studies		
o Prospective Analyses	\$500K	\$600K
o Special Subpopulations— Children	--	\$150K
Human Clinical Studies		
o Acoustic/Nonacoustic Studies	\$100K	\$150K
o Susceptibility Differences	\$100K	\$150K
Other Nonauditory Effects		
o Appraisal. Selected Studies	<u>\$100K</u>	<u>\$300K</u>
	(\$1000K)	(\$1650K)

COMMUNITY RESPONSE

Specific Sources of Noise	\$190K
Specific Acoustic Attributes	<u>\$200K</u>
o Other Topics	
	(\$390K)

SLEEP DISTURBANCE

Health Consequences of Noise-Disturbed Sleep	\$350K
Acoustic Parameters Related to Sleep	\$150K
Susceptibility of Sensitive Populations to Sleep Disturbance by Noise	<u>\$100K</u>
	(\$600K)

NOISE-INDUCED HEARING LOSS

Parameters of Individual Sensitivity: Susceptibility of Special Populations - Children. (Fels)	\$ 50K
Incidence of NIHL in the U.S. and Contribution of Sociocusis, Presbycusis, and Occupational Exposures.	\$ 50K
Refinement of Criteria for Low-level Noise Exposures.	<u>\$ 50K</u>
	(\$150K)

BEHAVIOR, SOCIAL AND PERFORMANCE

Cognitive and Social Development: Noise and School Performance Study	\$150K
Behavior/Social Adjustment to Noise	<u>\$110K</u>
	<u>(\$260K)</u>

2.4 million

* It is assumed that approximately \$650K will be provided by other agencies.
This amounts to 65 percent of EPA's Nonauditory Physiologic Effects Research
Funding of \$1000K, or 39 percent of the combined funding.

TABLE 12-1 FUNDING OF PLAN BY FISCAL YEAR (cont'd)

FY 85: \$3.0 Million

EPA Funding of
Each Research
Initiative

Total Funding of
Nonauditory Physiologic
Research Initiatives
with Co-Funding*

NONAUDITORY PHYSIOLOGIC EFFECTS

Animal Experimental Studies		
o Acoustic/Nonacoustic Factors	\$100K	\$250K
o Susceptibility Differences	\$150K	\$100K
Epidemiologic Studies		
o Prospective Analyses (Phase I)	\$400K	—
o Prospective Analyses (Phase II)	—	\$500K
o Special Subpopulations— Children	\$150K	\$150K
Human Clinical Studies		
o Acoustic/Nonacoustic Studies	\$100K	\$200K
o Susceptibility Differences	\$100K	\$150K
Other Nonauditory Effects		
o Selected Studies	<u>\$300K</u>	<u>\$950K</u>
	(\$1300K)	(\$2300K)

COMMUNITY RESPONSE

Specific Sources of Noise	\$250K
Specific Acoustic Attributes	<u>\$250K</u>
o Other Topics	(\$500K)

SLEEP DISTURBANCE

Health Consequences of Noise-Disturbed Sleep	\$450K
Susceptibility of Sensitive Populations to Sleep Disturbance by Noise	\$100K
Adaptation to Sleep Disturbance by Noise	\$150K
Acoustical Parameters Related to Sleep	<u>\$ 50K</u>
	(\$750K)

NOISE-INDUCED HEARING LOSS

Parameters of Individual Sensitivity: Susceptibility of Special Populations - Children. (Fels)	\$ 50K
Incidence of NIHL in the U.S. and Contribution of Sociocusis, Presbycusis, and Occupational Exposures	\$ 50K
	<u>(\$100K)</u>

BEHAVIOR, SOCIAL AND PERFORMANCE

Behavior/Social Adjustment to Noise	\$250K
Cognitive and Social Development: Noise and School Performance	<u>\$100K</u>
	\$350K
	\$3.0 Million

* It is assumed that approximately \$1000K will be provided by other agencies. This amounts to approximately 76 percent of EPA's Nonauditory Physiologic Effects Research Funding of \$1300K, or 43 percent of the combined funding.

TABLE 12-1 FUNDING OF PLAN BY FISCAL YEAR (cont'd)