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FEDERAL RESEARCH, DEVELOPMENT AND DEMONSTRATION PROGRAMS

IN

SURFACE TRANSPORTATION NOISE

PREPARED BY

THE FEDERAL INTERAGENCY
SURFACE TRANSPORTATION
NOISE RESEARCH PANEL

FEBRUARY 1978

OFFICE OF NOISE ABATEMENT & CONTROL
U.S. ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

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Transportation Noise Research Panel

February 1978

U.S. Environmental Protection Agency
Office of Noise Abatement and Control
Washington, D.C. 20460

PREFACE

One of the purposes of the Noise Control Act of 1972 was to establish a means for effective coordination of Federal research, development, and demonstration activities for noise control. As part of this coordination role, the Act directs the Administrator of EPA to compile and publish, from time to time, a report on the status and progress of Federal research and noise control programs and to assess the contributions of these programs to the Federal Government's overall efforts to control noise.

In partial fulfillment of its responsibility, EPA established four interagency ad hoc research panels in early 1974 in the areas of aviation, surface transportation, machinery and construction, and noise effects. Reports were issued by the panels in the March-June 1975 time period. The reports summarized the ongoing or planned noise research, development and demonstration (RD&D) programs within the various agencies of the Federal Government through FY 75.

During 1976, the four panels were reestablished for the purpose of updating and extending the program and fiscal data base through FY 78. The primary objectives of the panels were broadened to include assessment of the RD&D programs in light of each agency's mandates, goals, and objectives as well as the overall goals of the Federal Government to control noise.

The Surface Transportation Noise Research Panel included representatives of the Department of Transportation (DOT); the Department of Defense (DOD); the Environmental Protection Agency (EPA); the Department of Commerce, National Bureau of Standards (DOC/NBS); the Department of Housing and Urban Development (HUD); and the Department of Energy (DOE). With the exception of HUD and DOE, these agencies sponsor and/or conduct the majority of surface transportation noise research development, and demonstration activities in the Federal Government. In addition, the Department of Agriculture, U. S. Forest Service (USDA/USFS), and the Department of Justice (DOJ) provided the panel with pertinent noise research information. Mr. W. Harry Close of DOT, the lead department within the Federal Government for surface transportation noise RD&D, was chairman of the panel; EPA served as the secretariat.

The information, assessments, and recommendations are the consensus of the panel members and are not necessarily the official views of each of the Federal agencies.

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1.0 INTRODUCTION

The United States Government is involved in research, development, and demonstration (RD&D) activities related to surface transportation noise abatement and control through a number of its agencies and departments. These agency programs have varying goals and objectives according to their individual agency charters, statutory authorities, and other priorities.

Section 4 of the Noise Control Act of 1972

> "...authorizes and directs that Federal agencies shall, to the fullest extent consistent with their authority under Federal laws administered by them, carry out the programs within their control in such a manner as to further the policy ... to promote an environment for all Americans free from noise that jeopardizes their health or welfare."

The Act further requires the Administrator of EPA to

> "...coordinate the programs of all Federal agencies relating to noise research and noise control and "On the basis of regular consultation with appropriate Federal agencies ... shall compile and publish, from time to time, a report on the status and progress of Federal activities relating to noise research and noise control. This report shall describe ... and assess the contributions of those programs to the Federal Government's overall efforts to control noise."

1.1 BACKGROUND

In partial fulfillment of its responsibility for coordinating Federal noise research, the Environmental Protection Agency has reconvened the Interagency Surface Transportation Noise Research Panel. After its original establishment in 1974, that panel produced the first report summarizing ongoing and planned noise research, development, and demonstration programs within the various agencies and departments of the Federal Government through FY 75. In addition to brief descriptions and fiscal data for the agencies' programs, references of reports and publications resulting from the Federal RD&D activities were included. The data through FY 73 were firm. FY 74 resource allocations

were best estimates in many cases. FY 75 funding resources were estimates and project descriptions were incomplete. This report is a continuation of the first report. FY 75 programs are reexamined. FY 74 funding is identified for those projects underway in FY 74 and continuing into the time frame of this report (FY 75-78).

1.2 PURPOSE AND SCOPE

When the reestablished panel met to charter its course of action as a consultative body, they significantly broadened the panel's objectives—in addition to updating the status and progress of ongoing Federal surface transportation noise research activities—to include (1) identification of each agency's statutory mandates, goals, and objectives; (2) assessment of each agency's noise program in light of these mandates; (3) assessment of the contributions of each agency's noise RD&D program to the Federal Government's overall effort to control noise; and (4) recommendation of future Federal Government research programs in the area of surface transportation noise abatement and control. It is hoped that by involving many Federal agencies in the preparation of such a report, in addition to fulfilling the mandate of the Act to provide information to the public, a vehicle will be provided to inform and increase the dialogue among Federal agency officials concerning the relationship of noise research programs. In this regard, these published reports contribute to the coordination of Federal research activities.

The research programs undertaken by each agency during the FY 75-78 period are at the end of this report in appendices B through H. Appendix A contains a summary of the funds expended by the agencies and an Index of Surface Transportation Noise Projects. The Index is grouped into six categories as follows:

- Highway Vehicles
- Off-Highway and Recreational Vehicles
- Rail Vehicles
- Surface Vehicle Components
- Measurement and Enforcement
- Acoustic Properties.

This report is directed toward noise research, development and demonstration programs; however, a significant portion of the EPA effort is for regulatory noise control programs. Appendix I provides brief descriptions of EPA regulatory projects.

2.0 SUMMARY

This report is a compilation of the research, development, and demonstration (RD&D) activities of Federal agencies and departments in the area of surface transportation noise from FY 75-78. It also contains assessments of these activities and recommendations for future areas of work.

Federal agencies and departments with surface transportation noise RD&D programs during this time period are as follows:

- Department of Transportation (DOT)
- Environmental Protection Agency (EPA)
- Department of Defense (DOD)
- Department of Agriculture (USDA)
- Department of Justice (DOJ)
- Department of Housing and Urban Development (HUD)
- Department of Energy (DOE)
- Department of Commerce (DOC).

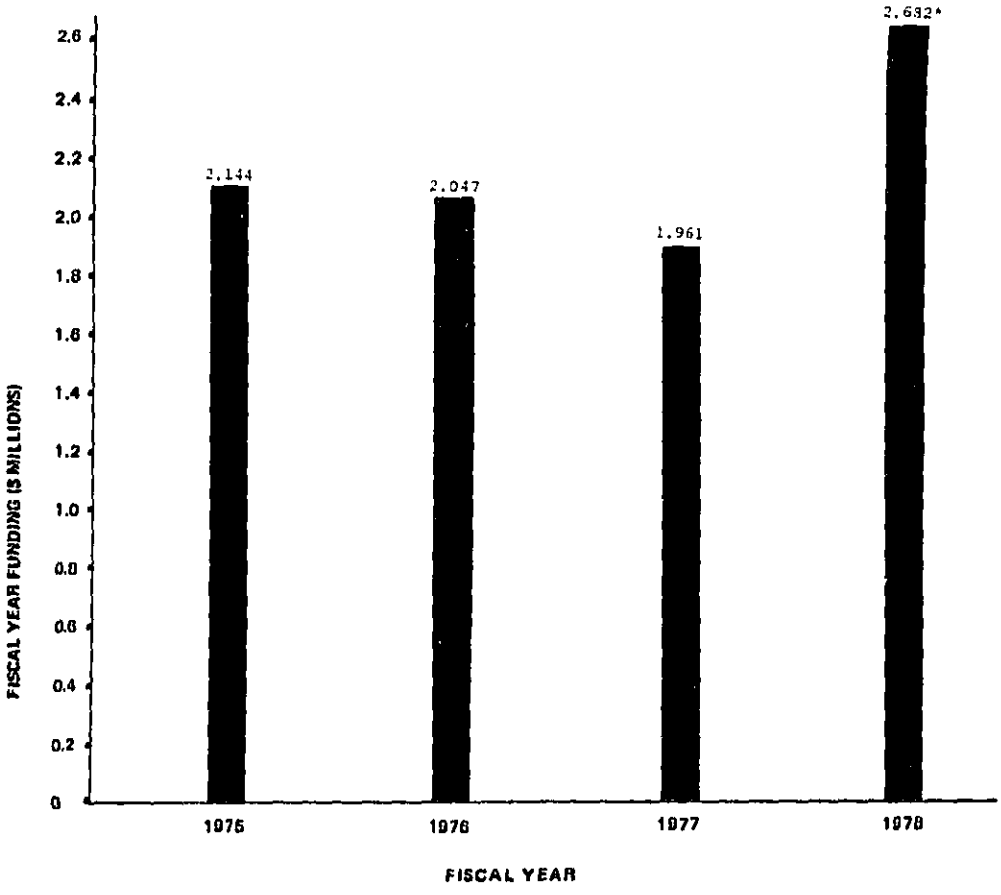
The various RD&D activities undertaken by these agencies and departments are implemented under their various mandates as well as in accordance with the intent of the Congress as expressed in Section 2(b) of the Noise Control Act of 1972:

> ". . . it is the policy of the United States to promote an environment for all Americans free from noise that jeopardizes their health or welfare . . ."

The extent of the activity on surface transportation noise RD&D as indicated by the levels of funding is shown in Figure 2-1 and Figure 2-2. Figure 2-1 shows the total combined levels of noise RD&D funding of all Federal agencies and departments from FY 75 through FY 78. Figure 2-2 shows the level of funding for each individual Federal agency and department during this time period.

The three most active participants in terms of funding surface transportation noise RD&D are DOT, EPA, and the Department of the Army. The DOT effort is significantly larger than that of other Federal agencies and departments.

Note - Funding levels are exclusive of sponsoring agency's internal expenditures except for DOD, USDA and DOC



* Funding data are incomplete.

FIGURE 2-1
TOTAL FEDERAL FISCAL YEAR FUNDING
FOR SURFACE TRANSPORTATION NOISE RD&D

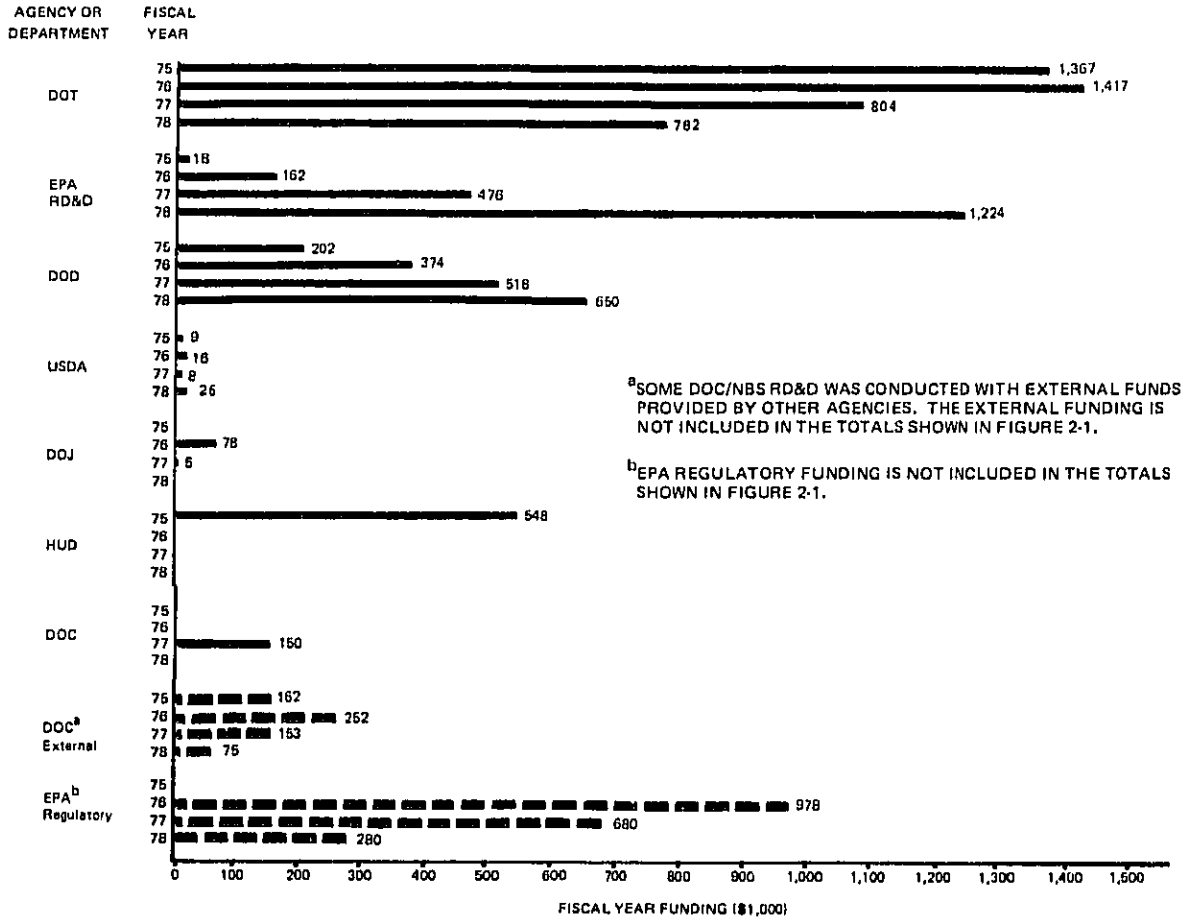


FIGURE 2-2
FISCAL YEAR FUNDING FOR EACH FEDERAL AGENCY AND DEPARTMENT FOR SURFACE TRANSPORTATION NOISE RD&D

Within DOT, the Office of the Secretary of Transportation, the Federal Highway Administration, the Federal Railroad Administration, and the Urban Mass Transportation Administration are engaged in surface transportation noise RD&D. DOT has undertaken considerable expenditures in the areas of highway vehicles, rail, surface vehicle components, and measurement and enforcement. DOT has, for example, undertaken major RD&D noise programs on medium and heavy trucks and related truck components such as mufflers, tires, and engines; on guided mass transit systems such as urban rail rapid transit systems; on railroad systems; and on highway noise prediction, measurement, and mitigation.

EPA's activities are conducted principally to support the regulatory process, but also to advance the state-of-the-art of noise control technology, and to demonstrate the existing state-of-the-art. EPA has, for example, undertaken technology and measurement methodology studies to support the regulatory process for medium and heavy trucks and related truck components, buses, motorcycles, tires, light vehicles, snowmobiles, motor boats, and guided mass transit. Research and demonstration have been conducted on such items as medium and heavy trucks and engines. Demonstration programs have involved noise mitigation methods for highways and transit malls.

DOD's surface transportation RD&D noise programs principally support their combat and tactical support and training mission requirements, but also support their community, environmental, and occupational protection needs. The RD&D program efforts are undertaken to increase survivability through reduced detection, to protect the hearing of personnel, to improve speech communication, and to reduce the environmental impact of their base operations on the civilian public.

The U.S. Forest Service (USFS) is the organization within USDA concerned about the effect of surface vehicle noise on the environment. The USFS efforts in surface transportation noise RD&D are small compared to those of DOT, EPA, DOD, and DOC. These efforts for the most part contribute to the development of noise measurement methodologies for recreational vehicles and identifying hearing hazards. Although few funds have been expended on noise control, the USFS has tried to influence manufacturers to develop quiet recreational equipment.

During the period FY 75-77, the DOJ engaged in one surface transportation noise RD&D activity in the area of warning signals for emergency vehicles.

HUD's efforts relating to surface transportation noise RD&D are associated with developing policies and techniques for compatible land use and building construction practices to attenuate urban noise.

DOE's surface transportation noise program is ancillary to their primary mission of energy RD&D. Noise efforts are undertaken when needs are identified in DOE's technology development programs.

DOC's National Bureau of Standards (NBS) performs RD&D efforts in surface transportation noise to support the programs of other Federal agencies and departments. NBS activities principally involved development of measurement methodologies as well as measuring equipment. NBS has provided technical assistance to DOT, EPA, and DOJ in the area of surface transportation noise. NBS has been involved in studies dealing with medium and heavy trucks, railroads, tires, and sirens.

Many interagency and interdepartment cooperative efforts were undertaken during the FY 75-78 time period. DOT and DOC, for example, provided assistance to EPA during development of the 1976 medium and heavy-truck regulation. NBS supported EPA's truck regulation efforts in the area of noise measurement and methodology. DOJ supported an evaluation of emergency vehicle warning sirens carried out by NBS. Besides collaborating with other Federal activities for regulatory actions, EPA has been cooperating on demonstration programs. These programs are undertaken to encourage development and implementation of improved noise mitigation measures. Cooperating with UMTA, EPA will demonstrate noise abatement measures on a transit mall in New York City. In conjunction with FHWA, EPA will demonstrate noise abatement measures on a New York State highway.

3.0 ASSESSMENT

3.1 BASIS FOR ASSESSMENT

The majority of Federal agencies currently involved in research, development, and demonstration (RD&D) activities related to surface transportation vehicle noise abatement and control had active programs directed toward satisfaction of the individual agency's statutory mandates, operational authorities, goals, and objectives prior to the passage of the Noise Control Act of 1972. For the most part, these programs have continued along the same lines since passage of the Act.

The Congress was cognizant of these responsibilities and authorities as evidenced by the explicit wording in various sections of the Act. For example, Sections 4(a) and 14 of the Act state:

> "The Congress authorizes and directs that Federal agencies shall, to the fullest extent consistent with their authority under Federal laws administered by them, carry out the programs within their control in such a manner as to further the policy...to promote an environment for all Americans free from noise that jeopardizes their health and welfare..."

The Act authorizes the Administrator (of EPA) to conduct and/or carry out research, technical assistance, and public information"...to complement, as necessary, the noise-research programs of other Federal agencies..."

For these reasons, any assessment of Federal programs must be carried out on two levels, namely:

- Assessment of RD&D programs in light of each agency's mandates, goals, and objectives
- Assessment of the contributions of each agency's noise programs to the Federal Government's overall effort to control noise.

In general, the Federal agencies have utilized their RD&D funds to carry out those programs necessary to meet the mandates of their individual agencies. The programs in the past have resulted in significant advances in the development and demonstration of noise control technology applicable

to surface vehicles. Each agency establishes its priorities and applies its existing funding and manpower to its most significant problem areas. The noise from surface transportation vehicles affects operator/passengers of the vehicle, passengers waiting at pick-up locations (in the case of buses, transit vehicles, etc.), other pedestrians, motorists, and persons living or working along the routes used by such vehicles. These problems exist to some extent in all areas of concern to this panel whether it be highway vehicles such as trucks, buses and cars; or off-highway vehicles such as off-road motorcycles, snowmobiles, boats, trains, or mass transit systems.

With regard to environmental, or community noise exposure, EPA estimates close to half the Nation's population, 103 million Americans, experience noise levels that may interfere periodically with normal activities such as speech communication, sleep, relaxation, and privacy.[1] Of these estimated 103 million Americans, urban traffic noise is the primary noise problem for 97.5 million.[2] EPA estimates that 13.5 million Americans have noise exposures ($L_{eq(8)}^{*} \geq 75$ decibels) that are considered to be hazardous to hearing as a result of riding in transportation or recreational vehicles[3] Most people, of course, are exposed to many sources in addition to surface vehicles, including machinery, construction equipment, and aviation noise sources, and noises generated by the multitude of people activities. In general, the Federal agencies and departments listed in this report are concerned with both operator/passenger, and environmental noise, but a particular agency may focus most of its attention on one or the other area. Through proper budgeting, planning, and coordination, most needs can be addressed by joint and/or complementary programs.

The noise RD&D efforts of the Federal Government provide technological answers, which can and do solve noise problems. However, there are many cases where research is not fully implemented. To understand why problems still exist in spite of technological solutions, it is necessary to understand the steps in effecting technological change. The process of technological change is comprised of three stages:

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* L_{eq}, equivalent sound level, is the average A-weighted energy level of sound over a given period of time. The period of time is shown in parentheses; in this case, it is 8 hours.

† A list of numbered references may be found at the end of this section.

- RD&D which provides the knowledge basis for technological change.

- Production in which new knowledge and its resources are incorporated in goods, productive processes, or services; and

- Market use, whereby the fruits of production enter the market place and provide social and economic benefits.

This report deals only with the first stage, RD&D.

Any break within these three stages stops the process of technological change. If the technology to solve a noise problem does not exist, then there is no first stage and no basis for technological change to take place. However, having the noise technology available does not, in itself, ensure technological change. There are many problems which can arise to forestall efforts to implement known noise technology. A principal problem is economics. The ratio of cost versus benefit is a vital trade-off parameter.

The following assessments have been prepared collectively by members of the Interagency Surface Vehicle Noise RD&D Panel. These assessments are the consensus of the panel members and are not necessarily the official views of the Federal agencies.

3.2 AGENCY ASSESSMENTS

3.2.1 Department of Transportation

The Department of Transportation plays a variety of roles in the field of surface transportation noise control. It is a regulator; it is the administrator of large trust funds which finance the building of roads and mass transit systems; it is the developer of new transportation systems; it is a research organization seeking technology to improve the effective discharge of its various responsibilities; it is the enforcement agency for the interstate motor carrier and railroad noise standards promulgated by EPA; and it is, by law, a technical consultant to EPA.

Each element of the Department, Office of the Secretary, the Federal Highway Administration, the Urban Mass Transportation Administration, and the Federal Railroad Administration, integrates noise control within its policy, program criteria, and project requirements. The Office of the Secretary provides technical and policy assistance to all elements of the department as appropriate; including the administration of the Transportation Systems Center in Cambridge, Massachusetts, where much of the Department's research is performed or managed. This diffusion of responsibilities throughout the Department places responsibility where new technology is most likely to be implemented but presents some difficulties to those interested solely in noise control.

Office of the Secretary

The DOT/Office of the Secretary, Office of Noise Abatement*, provides centralized Department level leadership and direction in the development of programs for the abatement of environmental noise caused by transportation systems. This office also provides policy guidance to, and coordination among, the operating administrations and their individual noise abatement programs to ensure the timely development of effective Department policies and programs for the abatement of noise generated by all modes of transportation. This office is also responsible for liaison and coordination between DOT and other Federal agencies in the consideration of the technical aspects of the environmental impact of transportation systems and facilities.

* DOT's Office of Noise Abatement was disestablished in December 1977.

Although both staff and funding of the Office of Noise Abatement have been decreasing in recent years, the accomplishments of the program remain significant and include the following:

- Demonstrated in actual revenue service practical design techniques for reducing noise levels of heavy trucks by as much as 15 decibels* at 50 feet
- Demonstrated practical modifications to existing trucks and buses (retrofit) for reducing noise levels to comply with Federal interstate motor carrier noise emission standards
- Developed practical procedures for enforcing compliance with Federal interstate motor and rail carrier noise emission standards
- Provided technical and economic assistance in support of new truck and interstate motor carrier noise emission standards promulgated by EPA
- Provided technical and economic bases for potential regulatory efforts by California and/or EPA regarding automobile and truck noise (the dominant high speed highway noise source)
- Demonstrated practical noise reduction techniques for railroad retarder facilities, identified major locomotive noise sources, and hence, potential for application of noise control modifications for railroad locomotives
- Added to the data base of transportation related noise and continued to upgrade computer prediction methods to provide valid, reliable information on which to base transportation noise-related decisions.

The funding restraints have hindered research efforts across the board; however, two areas are particularly impacted: development of necessary data to design quieter tires and definition of the site and environment effects on sound propagation.

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* A-weighted levels are used throughout this report unless otherwise noted.

Federal Highway Administration

As administrator of the Highway Trust Fund, a major goal of the Federal Highway Administration is the reduction of community exposure to traffic noise and vibration. In direct response to the legislative requirements of the Federal Aid Highway Acts, FHWA noise research programs are directed toward the development of highway noise and vibration impact criteria, prediction methodologies, and abatement measures.

The FHWA noise research program has had a significant level of activity since 1975. The program is beginning to have an influence on the highway noise problem as information resulting from the research programs is brought to the field and implemented. Some of the accomplishments and significant programs to date include:

- Developed a simple non-computer oriented method for predicting sound levels of freely flowing traffic as a design tool for the highway engineer

- Identified and evaluated the variables associated with current design and/or construction practice for wall-type barriers and developed a highway barrier design manual to disseminate this information to the highway designer and state agencies

- To complement the highway barrier design manual, a program is underway within the National Cooperative Highway Research Program(NCHRP) to define the influence of factors not included in barrier design methods; e.g., cross-section shape and surface characteristics. The importance of this and the barrier design manual is emphasized when the high costs associated with highway barrier construction ($100 to $200 per foot) are considered.

FHWA maximizes the results of its research work through its organizational structure. The Office of Engineering, utilizing the results of research programs, provides technical assistance to the state highway administrations in resolving noise problems. The Demonstration Projects Division undertakes programs to demonstrate the availability of technology. The Implementation Division has the responsibility for disseminating the research results.

Many of the highway noise problems that need to be addressed, e.g., noise propagation in cities, noise in tunnels, effects of environment and site on sound propagation, etc., are complex and require sustained efforts and substantial funding. Ongoing research programs, in general, can be characterized as being limited in scope and/or underfunded. Additional funding would allow for more comprehensive approaches to the problems and would provide more immediate solutions. However, major increases in funding will require attendant increases in manpower. Such additional in-house capability would allow for more timely response to technical/policy needs. In general, contracting out does not provide for timely response to critical issues of this type.

The current program is gaining momentum, and steps are being taken to improve long range planning, to improve the means for anticipating policy needs, and to identify the research necessary to support such policy.

With the enactment of the Noise Control Act of 1972, DOT became the agency to assure compliance with the Interstate Motor Carrier Noise Standards which were to be established by EPA. Even though the number of Bureau of Motor Carrier Safety (BMCS) enforcement officers is limited, enforcement experience has shown positive results. Initial enforcement efforts found 6.7 percent of the vehicles tested in 1974-75 to be out of compliance, while more recent data show only 2.8 percent of the 15,000 vehicles tested in 1976 to be out of compliance. These same inspectors also enforce the BMCS promulgated in-cab noise standards.

Federal Railroad Administration

The Federal Railroad Administration is the enforcement agency for the railroad noise emission standards promulgated by EPA. The final railroad noise emission compliance regulations were published in the Federal Register on August 23, 1977. Until the Noise Control Act of 1972, noise was not a major consideration within FRA programs.

Current and planned programs in the noise area are directed toward identifying and reducing the noise from rolling stock, maintenance-of-way equipment, and railroad yards and toward the development of practical measurement methodologies for use in enforcing the Federal Interstate Railroad Noise Emission Standards. Additional programs deal with workplace noise—either in locomotive cabs and/or cabooses and layover sleeping quarters.

Because noise is not a high priority within FRA, funding and manpower limitations and conflicts in priorities have forced the time frames of these programs to be extended. Furthermore, large scale noise abatement demonstration programs are not envisioned.

Urban Mass Transportation Administration

Noise is just one of a myriad of considerations in the majority of UMTA's programs. One notable exception is the Urban Rail Noise Abatement Program. This program is successful in addressing both current technology and long-term development of innovative methods for control of urban rail noise. The major accomplishments of this program to date include:

- Development of a basic understanding of wheel-rail noise generation, resulting in identification of innovative noise control techniques
- Determination of current noise levels and estimated costs to achieve reduced levels for each U.S. urban rail rapid transit system
- Performance of in-service evaluative tests of currently available treatments for reducing wheel-rail noise at the source
- Development of an analytic framework to evaluate noise reduction options for elevated transit structures
- Dissemination, through reports and workshops, of information for prediction and control of urban rail noise
- Establishment of uniform noise specifications for the purchase of new transit buses.

Existing noise control methods are being evaluated in-service, resulting in the identification of problems as well as benefits associated with these techniques. The fundamental research into the cause of wheel-rail noise has led to the identification of new, potentially effective methods for the control of the major noise source on urban rail systems.

Analytical models have been developed that are capable of predicting the effects of structural changes and noise control treatments on the noise radiated from elevated transit structures. These models together with field data will now be used to develop noise control recommendations for elevated structures existing in U.S. transit systems.

Noise assessment of the U.S. transit systems provides UMTA with a basis for forming long range plans on urban rail noise reduction as well as for evaluating noise-related capital grant requests from the transit properties. This assessment also provides EPA with an important part of the data necessary for the evaluation of guided mass transit system noise.

Future emphasis of the program is aimed at (1) evaluating new, potentially more effective methods of noise control, first on a test track and then on an operating property and (2) integrating available noise control data and methods into an easily usable and accessible format.

In the transit bus area, noise considerations need to be given a higher priority than in the past. Since UMTA provides capital grants covering approximately 80 percent of all transit coach purchases (and up to 50 percent of maintenance and operating costs) and must approve the proposed specifications for such coaches; UMTA has established "83dB(A)"* for Advanced Design Bus purchases (effective now) and "80dB(A)" for Transbus purchases (effective 1979) under their capital grant authority. Thus, significant advances are to be made in the reduction of noise from transit vehicles as a result of the UMTA program. In general, the UMTA programs are adequately funded, but are understaffed.

3.2.2 Environmental Protection Agency

The primary noise research and control efforts undertaken at EPA have been directed for the most part in support of regulatory actions. EPA's noise RD&D activities are conducted at EPA's Office of Noise Abatement and Control (ONAC) and are undertaken to complement the noise research programs of other Federal agencies as well as to support regulatory activities at EPA/ONAC.

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* At 50 feet to the side of the bus center line per SAE J366b procedures.

Regulatory

Surface transportation vehicles already identified as major noise sources by EPA as of February 1977, for which initial technology assessments have been completed, include medium- and heavy-duty trucks, motorcycles (street, off-road, and mopeds), and buses. Additional technology assessment efforts are underway for medium- and heavy-duty trucks to determine the feasibility of better noise control for these vehicles in the 1985 time frame. Surface transportation vehicles under investigation to determine if they represent major noise sources and for which technology assessments are currently underway include the following: automobiles, light trucks, tires, guided mass transit, motorboats, and snowmobiles. Additionally, EPA has assessed noise control technology applicable to in-use noise reduction for interstate rail and motor carrier vehicular operation. Studies are underway at this time in both the rail and motor carrier area to update and expand the best available technology application assessments for both of these in-use vehicle categories. The Agency is also pursuing various approaches to product noise emission labeling under Section 8 authority of the Noise Control Act. In the surface transportation area, the product category of exhaust system/muffler is being studied as a potential candidate for labeling. The technology related work is concentrated on development of suitable measurement methodologies for defining the products' acoustical performance and the assessment of what constitutes best available technology.

Some of the EPA's principal regulatory accomplishments to date for transportation vehicles have been through the establishment of a series of uniform Federal noise control standards setting specific vehicle operational requirements and have resulted in surface transportation vehicles of quieter design. Standards promulgated to date include:

- Railroad Noise Emission Standards. EPA promulgated on December 31, 1975, regulations setting specific maximum in-use standards applicable to locomotives and railcars operated by interstate rail carriers. The Department of Transportation, through the FRA, is responsible for the enforcement of this regulation.

- Motor Carrier Noise Emission Standard. On October 29, 1974, EPA promulgated regulations setting specific maximum in-use noise standards applicable to vehicles over 10,000 pounds Gross Vehicle Weight Rating (GVWR) operated by interstate motor carriers. EPA estimates that this regulation will lessen the noise impact for approximately 10 million people. The regulation also requires vehicle exhaust systems not to be defective and bans the use of noisy tires on vehicles subject to the regulation. The Department of Transportation's Bureau of Motor Carrier Safety (BMCS) is responsible for enforcement of this regulation.

- Medium and Heavy Truck Noise Emission Standards. On April 13, 1976, the Agency published noise regulations for medium and heavy trucks. EPA estimates that these regulations will reduce the urban traffic noise impact for 97 million people.

- Bus Noise Emission Standards. On September 12, 1977, EPA published the proposed standards for buses establishing noise control levels for the interior and exterior of newly manufactured buses over 10,000 pounds GVWR.

- Light Vehicle Test Procedure. EPA has developed a light vehicle urban noise test procedure representative of the way light vehicles are operated in the low speed urban traffic situation. The procedure provides a more realistic measure of the light vehicle noise contribution to the environment compared with the existing SAE J986 and ISO 362 test procedures.

Noise RD&D

In the past ONAC has elected not to request research funds but to depend on existing resources and research commitments in other agencies. With the de-emphasis that is taking place in other agencies in noise RD&D, there is a greater need for EPA to provide the needed research support.

In 1976 the initial noise research and demonstration program related to surface transportation noise was undertaken. This study involved engine enclosures for noise

control. Since FY 77 EPA has initiated demonstration programs for the mitigation of noise in transit malls, on recreational land, and along highways. EPA has also initiated a Quiet Truck Technology Demonstration Program as an extension of the earlier DOT program. Research programs to advance the state-of-the-art in noise control of tires and internal combustion engines, including demonstrating the developed noise reduction techniques applicable to these components, has also been initiated. Since the engine program will advance the state-of-the-art of noise control for internal combustion engines common to machinery and construction equipment as well as surface vehicles, accomplishments will result in significant benefits in both of these areas.

Noise technology RD&D efforts are needed for a wide range of products in the surface transportation area to reduce excessive noise levels. Standards are limited by and based upon available technology. The lack of demonstrated technology is a constraint in establishing the necessary national source control standards. There are several areas where EPA has identified future needs for technology demonstration which could appropriately be initiated at this time to provide some assurance that advance technologies would be available to meet future needs:

- Noise control technology demonstration program for 70 to 72 dB transit buses in order to meet the future needs of major urban bus transit authorities.

- Initiate new technology demonstration programs to identify what can be done to reduce noise from light vehicle configurations and still meet fuel economy goals. Current projections for the mid-1980 period are that fuel economy requirements will cause and increase in the total population of higher noise diesel and four cylinder gasoline powered automobiles.

- Provide RD&D support for noise control to ensure advanced design energy efficient tires continue to be quiet at the same time that their rolling resistance is being decreased.

- Development of an accurate simulation or parametric test procedure for exhaust systems applicable to a bench test would provide a number of benefits to the muffler manufacturing industry, marketers, and the public.

3.2.3 Department of Defense

Only the Department of the Army has identified surface transportation research programs underway or planned within DOD. The Army recognizes the importance of noise related to: detection avoidance in combat; possible risk of hearing loss of military personnel; speech communication and related mission requirements; and the impact of peace time military operations on the surrounding communities. It must be recognized, however, that combat capability, reliability, and maintainability are the prime requisites for Army vehicles and that noise control cannot be given an equal priority in design.

Survivability of man and machine under combat conditions is paramount and dictates certain requirements in terms of vehicle design, mission performance, and cost that are quite different from those which respond solely to the national goals for health and welfare as expressed by EPA. There are no standards or generalized goals for noise where survivability is concerned. The Noise Control Act of 1972 specifically excludes vehicles which are designed for combat use; hence, Federal noise emission standards do not apply to such vehicles. Beyond survivability, the Army has documented requirements which are contained in Military Standard MIL STD 1474A, Noise Limits for Army Materiel. The coverage, with regard to risk to hearing, conforms to the Surgeon General's office medical document TB MED 251, Noise and Conservation of Hearing. The military standard also contains suggested limits for vehicle exterior noise. The military standard is employed for design and conformance purposes where suitable.

Since 1965, the Army has pursued a program to characterize the noise emission of the existing fleet of military vehicles, to investigate noise reduction techniques, and to develop noise reduction kits suitable for installation in the field or during production as funding was available and priorities dictated.

Prior year's efforts on noise reduction in the Army fleet of vehicles has emphasized survivability of man and vehicle for optimum mission performance, reduced exposure to hearing-hazardous noise, and improved environmental conditions. The work has been performed on both tracked and wheeled vehicles. Some of the accomplishments and significant programs to date include:

- Tracked combat vehicles generate interior and exterior noise that is higher than that of any other Army vehicle type. The effort to reduce tracked vehicle noise has concentrated on the armored personnel carrier class of vehicles. Interior and exterior sources of noise have been identified. A major finding from these efforts is that noise reduction may be possible. The studies have shown that softer compliance between idler wheels and the track, lowering of sprocket wheel stiffness, and reductions of road wheel noise provid the potential for noise reductions.

- Preliminary results of a study to reduce fueling hydraulic system noise of the M559 GOER fuel servicing truck shows that a field modification can reduce exterior noise emissions by approximately 6 dB and can reduce operator noise levels by approximately 20 dB.

- A computer program has been developed that predicts the distances for vehicle inaudibility. It utilizes variables such as noise levels, hearing threshold, terrain, atmospheric variables, vegetation effects and barriers.

- Noise reduction kits, suitable for field implementation have been developed for a number of vehicles: M 35 vehicles series (2½ ton class), 520 GOER cargo and fuel servicing trucks, M561/ M792 GAMA Goat (1¼ ton) cargo/ambulance, and M746/ M747 heavy equipment transporter.

- New vehicles that incorporated noise reduction measures were developed (XM963 and XM939 cargo trucks).

Because of the military requirements, retrofit of surface vehicles now in the field for reduced noise is a difficult and costly process. Concept vehicles, now on the drawing board, can and will benefit by past and current noise control research, development, and demonstration. Continued attention to noise control on a fleet-wide basis, rather than on an as-required basis—especially in the design, development, and specification of new vehicles—is encouraged. Army vehicles purchased commercially, however, are built to meet current Federal regulations.

The Army takes advantage of noise control technology resulting from other Federal Government programs; however, noise abatement techniques applicable to military vehicles are, in general, so specialized as to have little carry-over to non-DOD industry. For similar reasons, there is little chance for duplication of effort.

3.2.4 Department of Agriculture

The U.S. Forest Service (USFS) has as one of its objectives the protection and improvement of the quality of the environment of land under its management. Current work in the surface transportation noise area is focused on off-road vehicles and their noise impact on the sylvan environment. The priority given off-road vehicle noise research within the USFS has been very low, and available funding has been limited.

Even though funding levels and manpower allocations have not been very large, through active participation on Society of Automotive Engineers (SAE) standards committees, USFS personnel have been able to participate actively in the development of measurement procedures for such vehicles as motorcycles and snowmobiles which are of direct interest in forest areas. Emphasis is also being placed on the development of prediction models for evaluating the impact of vehicles and machines utilized within the forest on the users of outdoor recreation areas. However, current understanding of sound propagation through a forest environment coupled with a lack of acceptability criteria for the sylvan environment limits the usefulness of such models.

Current regulatory efforts for on-highway vehicles will not contribute to a reduction of off-road vehicle noise; therefore, the USFS needs to expand their efforts to address adequately the problems at hand. As more and more people utilize our nation's limited forest lands, sound land management and environmental impact assessment takes on added significance.

3.2.5 Department of Justice

The Law Enforcement Assistance Administration (LEAA) of the Department of Justice (DOJ) is, in general, not involved in surface transportation noise RD&D. The one exception is in the area of emergency vehicle warning signals. This work conducted by NBS under the sponsorship

of DOJ, in conjunction with a complementary program sponsored by DOT, has provided information on the characteristics and effectiveness of emergency vehicle warning signals and has pointed out the necessity for training operators of emergency vehicles not to rely on their sirens totally for recognition—and, thus, accident avoidance—in emergency situations. It is not anticipated that DOJ/LEAA would have any future programs in the surface transportation noise area.

3.2.6 Department of Housing and Urban Development

The activities of the Department of Housing and Urban Development (HUD) in environmental research and planning pertain directly to the overall national goal of "a decent home and a suitable living environment for every American family."[3] Noise abatement activities focus on achieving a suitable auditory environment in and around our homes through land use and construction practices that will ameliorate noise impact on people. These activities include the development of policies, criteria, standards and environmental assessment guidelines and procedures, and coordination with the Council of Environmental Quality and other Federal agencies.

Specific accomplishments include:

- Development and promulgation of a noise abatement and control policy that encourages land use patterns compatible with uncontrollable noise sources through withholding HUD support for new construction on sites having unacceptable noise exposures

- Noise assessment guidelines and a noise measurements system for use by a staff not specifically trained in acoustics has been developed to assist in the implementation of departmental policy. The development of the noise measurement system was a joint program with NBS.

HUD's noise abatement and control policy has been successful in discouraging new residential development with Federal assistance in areas with unacceptably high noise levels. HUD programs, however, involve only a portion of the national housing market and some new residential construction may still take place in unacceptably noisy locations. HUD frequently depends upon state and local agencies for specific acoustic data. Coordination with these agencies must be given a high priority to ensure that specific community objectives are met.

HUD's efforts in noise abatement and control research have been severely reduced; yet additional research is needed in the areas of land use and building construction practices—areas of concern that are HUD's responsibility. These are especially important with the increased emphasis on revitalization and rehabilitation of our cities and the increased emphasis on the use of mass transit. Construction and rehabilitation practices that provide noise attenuation without increasing energy consumption, play an important role in achieving a suitable auditory environment.

3.2.7 Department of Energy

The primary objective of the Department of Energy (DOE) is to develop energy-efficient systems. DOE has a mandate to support environmental and safety research (including noise research) related to the development of energy technology; however, since noise reduction is not a primary responsibility, the priorities assigned to the prime objectives place a limitation on the noise related effort.

Various Federal agencies have utilized the capabilities of DOE's Bartlesville Energy Research Center for the conduct of noise research on engines.

While national concerns for reductions in energy utilization are real, the technology being developed for the future must consider the noise implications of alternative energy systems and their applications. Future technology should result in products that are no noisier and hopefully quieter than those currently existing.

3.2.8 Department of Commerce

The National Bureau of Standards does not directly fund any surface transportation noise research. However, they do conduct research on surface transportation noise through agreements with other Federal agencies and non-governmental organizations. This support role is in keeping with legislation which directs NBS to provide an advisory service to the Federal government on scientific and technical matters, and with the Noise Control Act of 1972 which encourages cooperation between NBS and EPA in the development of improved methods for measuring and monitoring noise. The limitation criteria in regard to undertaking such support are that NBS should not compete with the private sector but should only provide support in those areas where it has unique expertise and/or responsibility, or in those matters where an unbiased third party opinion is required.

The technical data resulting from such measurement programs, especially those dealing with truck and tire noise, have contributed to the total data bases which were utilized—in conjunction with other technological, economic, and political data—to develop the BMCS in-cab truck noise regulation and the EPA interstate motor carrier noise emission regulation. Other areas in which NBS has made significant contributions are:

- Assistance to DOT in the establishment of an extensive truck tire noise data base
- Assistance to EPA in the evaluation and development of a measurement methodology for the medium- and heavy-duty truck regulation
- Assistance to DOJ in the design and development of directional sirens for use on emergency vehicles.

Measurement accuracy and instrumentation performance are continuing needs to support noise control research and regulatory actions. However, the accuracy and precision required of a given measurement must be tempered by practicality.

NBS does not have the ultimate responsibility for improving the noise climate in either the workplace or the environment. Therefore, they must work closely with those agencies having the ultimate responsibility to ensure that

the measurements are accurate and precise for the purpose at hand. The restraints of field measurements must be considered, and it must be recognized that people cannot, in general, discern a 2-dB change in level. Precise measurements are useless unless there is an end environmental/ workplace benefit that is cost effective. At the same time, it must be recognized that once a regulation is in effect, failing to meet the regulated level by any amount, due to inadequate measurement procedures or instrumentation limitations, has serious consequences to the affected industry and to the public.

There are a number of items which need urgent attention. These include development of acoustic instrumentation performance requirements which are not adequately covered by existing domestic and international standards; quantification of the meteorological and site effects on the generation, radiation, and propagation of sound; and assessment of the resultant instrumentation and meteorological effects on the accuracy and precision of surface vehicle noise measurements. NBS, as the nation's measurement laboratory, is uniquely suited to perform the basic research necessary to investigate these items. In order to adequately serve the transportation noise community and the public, NBS should significantly increase its effort in these areas using in-house funding.

3.3 GENERAL ASSESSMENT

Despite the fact that surface transportation represents one of the most pervasive noise sources throughout the nation, the Federal noise research effort in this area continues to be relatively small.

There has been a steady decline in the total level of Federal surface transportation noise RD&D funding from FY 74* through FY 77. The estimated FY 78 funding, however, restores the dollar level to approximately that of FY 74; but inflation reduces its value. This restoration is only a result of a significant increase by EPA with an estimated funding of 1.2 million dollars in FY 78. Most notable is the continuing decline in the level of surface transportation noise RD&D funding by DOT, the lead Federal agency responsible for surface transportation activities.

The noise RD&D efforts of both industry and the Federal Government can provide technological answers to solve both present and future problems. However, the demonstration of this technology may not have evolved to the point where it has been practically shown to provide the degree of noise reduction which is necessary. Also, attempts to demonstrate feasibility may never have been made. There currently appears to be an insufficient number of noise abatement technology demonstration programs. Federal efforts to develop and demonstrate noise control technology for future noise abatement actions should be increased significantly.

There are many reasons why the Federal Government should have a greater involvement in noise research and development. While the major responsibility for developing the needed technology should rest with industry, investment by the Federal Government is necessary in some cases to help bring new technology into the market-place or to stimulate industry developments. This Federal initiative is appropriate when:

- The market is not responsive to the demands (needs) of society
- A directed effort is needed to meet a national objective
- Development costs exceed the financial capability of any one manufacturer

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* See Table A-1 in Appendix A.

- Feasible noise-reducing technology exists for enforcement of regulations.

Two specific benefits of Federal research sponsorship are:

- The results of Federally funded RD&D programs are equally available to all manufacturers whereas results of industry RD&D are generally proprietary and, even if implemented, would not provide a broad base of application

- The potential for technology transfer to other products.

Without its own research the Federal Government has limited basis for judgment regarding industrial claims as to the extent that noise control measures are feasible in a particular area. Without involvement in noise research and especially involvement in the development and demonstration of new noise technology, the Federal Government becomes particularly vulnerable when promulgation and enforcement of regulations become an issue. For example, a present Occupational Safety and Health Review Commission (OSHRC) ruling against the Occupational Safety and Health Administration (OSHA) reversed earlier assertions that OSHA could write "technology-forcing" regulations; i.e., the Secretary of Labor could require improvements in existing technologies or the development of new technology in order to meet OSHA regulations. The recent ruling substantially nullified these principals and now requires that, in order for enforcement, feasible noise-reducing technology must exist. Though this ruling was in the area of industrial machinery, the implications exist that the demonstration of noise control technology in all areas including surface vehicles is imperative to reducing noise levels.

Another reason for Federal involvement is that a myriad of noise sources remains to be addressed. It will be necessary to initiate noise research in new areas in addition to continuing research in areas where some accomplishments have already been made; but, in order to reduce noise levels of surface vehicles to levels that will meet future noise goals, more research is needed. In fact, all vehicular traffic noise sources will require further noise reduction to meet goals for the year 2000. All studies of future noise impact indicate that just maintaining present noise levels of surface vehicles would result in increased noise levels to the community due to increased traffic flow.

3.4 ADEQUACY OF FUNDING

In 1974 the requirements of the Noise Control Act of 1972 began to have an impact on the budget cycle of Federal agencies. The charge to EPA/ONAC by the Act was interpreted by the other agencies as a lessening of the charges to their agencies. The end result of this misinterpretation was a change in priorities among the other Federal agencies in the area of noise RD&D in the belief that EPA/ONAC could solve all noise problems. This slackening interest in noise was coupled with a steady decrease in the available funds. In addition, other priorities have occurred which have resulted in changes of emphasis such as:

- The National Science Foundation, which was one of the earliest proponents of noise RD&D has significantly reduced its emphasis in this area.
- The Department of Housing and Urban Development has significantly reduced its efforts in the area of noise control research.
- The recent reorganization of the Secretary's Office in the Department of Transportation disestablished the Office of Noise Abatement which provided effective centralized coordinating functions for all of the operating administrations of DOT.

3.5 FUTURE RD&D NEEDS

Research programs for surface transportation noise RD&D should be planned and shaped to fill existing voids. There must be a balance between exploratory research and the demonstration of noise control technology. In order to encourage general acceptance of the findings of noise research, it must be demonstrated that the noise control methodologies are both technologically and economically feasible. Demonstration programs should go beyond the laboratory demonstration stage and should prove practicality under actual use conditions including production type processes.

In the past, the benefits of demonstrated noise control have been significant and their value has greatly exceeded the investment of both funding and manpower. Perhaps one of the more publicized noise demonstration programs is the highly successful "Quiet Truck Demonstration Program" of DOT. Much momentum has been gained by the success of the program; however, on the basis of existing funding levels, this momentum cannot be translated into successful demonstration programs for other vehicles. Demonstration programs are much needed for other types of trucks and surface vehicles such as buses, automobiles, rapid rail, light rail, and elevated train structures. There is also a need for demonstration programs in related areas such as highway noise mitigation procedures, including roadway design, barriers, land use planning, and highway and building construction practices. The hardware to quiet many surface vehicles and highways has been developed. Without the demonstration of this hardware many factors such as cost of implementation, production penalties, and degree of quieting available remain unknown.

Another area where there should be more Federal involvement is in the transfer and dissemination of developed noise RD&D to industry. One effective means of ensuring the transfer of noise RD&D is through purchase specification. UMTA, for example, has the capital grant authority to write purchase specifications for transit vehicles. Using this authority, UMTA will influence the design and procurement of virtually all transit vehicles and effect significant advances in the reduction of noise from these vehicles.

Accomplishments of noise RD&D should also be disseminated through participation in noise conferences, symposia, and publication in trade and acoustic journals. Specific areas of research which are anticipatory of future noise

problems include the need for quieter buses for compatibility with urban noise requirements along major mass transit routes; quieting of energy efficient vehicles, particularly automobiles and light trucks powered by four cylinder or diesel engines; more insight into tire noise generation mechanisms by the development and validation of a tire/road interaction noise model; compatability between noise and energy considerations such as quieting of tires which have energy efficient configurations; and measurement methodologies for bench testing the acoustic performance of components such as exhaust systems.

To facilitate the measurement of noise emissions, especially as it relates to roadside noise enforcement for both highway and rail, significant experimental investigation is needed on the effects of ground surface (topography) and meteorological effects on sound propagation.

Noise RD&D efforts of the Federal Government have just begun to address the many problems which exist. Much research is still needed to achieve lower noise levels of already quieted vehicles, and to find less expensive, more practical abatement techniques as well as to address those vehicles which have not yet been quieted.

3.6 INTERAGENCY COOPERATION

In order for the Federal agencies involved in surface transportation noise RD&D to meet effectively national objectives for noise abatement, continued cooperation is essential. EPA/ONAC will continue to take a lead role in coordinating the activities of all Federal agencies for surface transportation noise RD&D primarily because of its role in the promulgation of regulations. The technological accomplishments of the other Federal agencies are most important in forming the bases for regulatory legislation. EPA/ONAC must collaborate with all agencies: (1) to gain knowledge on noise control techniques as well as measurement methodologies and (2) to disseminate information to other agencies for their use in either setting priorities for research, setting policy for land use planning, or enforcement of regulations. DOC/NBS should play a major role in determining measurement accuracies of different methodologies. As a result of the disestablishment of the Office of Noise Abatement, DOT has lost its coordinator for noise. It is hoped that coordination between Federal agencies will continue despite the loss of the DOT centralized coordinating element (Office of Noise Abatement). Examples of the type of interagency cooperation that have occurred with noise mitigation demonstration projects are: a joint UMTA and EPA program on a transit mall in New York City, FHWA and EPA cooperation on a New York State highway; and a cooperative program by USFS and EPA on recreational land use in public forests.

ASSESSMENT REFERENCES

1. Toward a National Strategy for Noise Control, GPO No. 1977-720-117/1999, U. S. Environmental Protection Agency, April 1977

2. Noise in America, Draft Report No. 3318, Bolt, Beranek and Newman, Inc., June 1976

3. Housing Act of 1949, P.L. 171 St. 413, 42 U.S.C. 1441

4.0 AGENCY PROGRAMS

Noise research programs conducted or sponsored by each Agency, while contributing to the national objectives of noise reduction in general, are primarily focused on the specific Agency's needs for complying with its legislative mandates. The noise RD&D activities are directly related to their civilian or military constituency needs.

This section of the report discusses the overall noise program objectives of each Agency with respect to their noise control mandates.

4.1 DEPARTMENT OF TRANSPORTATION

The Department of Transportation plays a variety of roles in the field of surface transportation noise control. It is an independent regulator; it is the administrator of large trust funds which finance road building and urban mass transit grants; it is the developer of new transportation systems; it is a research organization seeking technology to improve the effective discharge of its various responsibilities; it is the enforcement agency for the interstate motor carrier and railroad noise standards promulgated by EPA; and, it is by law a technical consultant to EPA. These various Departmental responsibilities are presently carried out by the Federal Highway Administration, the Federal Railroad Administration, the Urban Mass Transportation Administration, and the Office of the Secretary of Transportation.

The diffusion of responsibilities throughout the Department presents some difficulties to those interested solely in noise control; however, one must consider that the Department of Transportation was created by the Department of Transportation Act of 1966, Public Law 89-670, October 15, 1966, in the interest of the general welfare, economic growth, and national stability to develop:

> "...national transportation policies and programs conducive to the provision of fast, safe, efficient, and convenient transportation at the lowest cost consistent therewith and with other national objectives (such as noise control) including efficient utilization and conservation of the nation's resources..."

To accomplish these basic mission goals and other specific Congressional mandates, each element of the Department is expected to integrate noise control within its policy, program criteria, and project requirements. The Office of the Secretary provides technical and policy assistance, as appropriate to the administrations within DOT, including the administration of the Transportation Systems Center in Cambridge, Massachusetts, where much of the Department's research is performed or managed.

4.1.1 Office of the Secretary/Office of Noise Abatement[1]

The Office of Noise Abatement (ONA) was established in response to the Department of Transportation Act of 1966 (P.L. 89-670, October 15, 1966), Section 4(a) which authorized and directed the Secretary to "...undertake research and development relating to transportation, including noise abatement...". The mission of this Office is to provide Department level leadership and direction in the development of programs for the abatement of environmental noise caused by transportation systems and to provide policy guidance to, and coordination among, the operating administrations and their individual noise abatement programs to ensure the timely development of effective Department policies and programs for the abatement of noise generated by all modes of transportation. This office is also responsible for liaison and coordination between DOT and other Federal agencies in the consideration of the technical aspects of the environmental impact of transportation systems and facilities.

Heavy-Duty Truck and Bus Noise

Although the research activities of the Office of Noise Abatement cover the broad spectrum of surface transportation noise, major emphasis had been on the control of highway noise, especially the control of heavy-duty truck and bus noises, which have been identified as the major highway noise sources. In February 1972, the DOT issued a request for a proposal to industry to undertake a program to demonstrate the lowest practical noise levels that could be engineered into heavy-duty trucks.

As part of the Quiet Truck RD&D Program, Freightliner Corporation, International Harvester Company and White Motor Company were awarded contracts to identify individual noise sources (exclusive of tire noise), to develop efficient means for reducing these noises to the lowest level consistent with reasonable operational constraints, and to demonstrate and evaluate in line-haul service for a 1-year period. The findings were thoroughly documented in the open literature.[1-16†] Table 4-1 illustrates the initial, intermediate (or unenclosed engine) configuration and final

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1 DOT's Office of Noise Abatement was disestablished in December, 1977.

† All references appear at the end of the section.

TABLE 4-1. INITIAL, UNENCLOSED, AND ENCLOSED ENGINE CONFIGURATION (A-Weighted Sound Levels-dB)*

BASELINE	FREIGHTLINER CUMMINS NTC 350	INTERNATIONAL DDA 8V-71N 65	WHITE MOTORS†† CUMMINS NTC 270CT
Initial, Total Vehicle Noise Level	88	88	86
Unmuffled Exhaust Noise Level	93	104	92
Installed Exhaust Noise Level	82	83	76
Installed Engine Noise Level	84	78	77
Installed Cooling System Noise Level	83	86	83
PROTOTYPE			
Unenclosed Engine Total Vehicle Noise Level	not available	79	79
Exhaust Noise Level	not available	73	68
Engine Noise Level	not available	75	75
Cooling System Noise Level	not available	70	76
Enclosed Engine Total Vehicle Noise Level	72†	77	76
Exhaust Noise Level	71	73	68
Engine Noise Level	69	73	
Cooling System Noise Level	68	68	74.5

* Measured 50 feet to side per SAE J366b test procedures.

† Final configuration not subjected to noise source diagnostic tests--subsources listed related to 75dB configuration.

†† Due to site differences 2dB should be added to these results for comparability with other data.

enclosed engine configuration noise levels for the total vehicle and the major noise sources of each of the three truck types.

The fleet evaluation program showed that the noise abatement components generally performed well and serviceability was good. No unusual maintenance problems or complaints were observed in the program. Driver reaction was favorable.

Based on the initial results of the Quiet Truck program and previous evaluation of a wide range of commercially available exhaust mufflers and intake silencers, DOT/ONA sponsored (Cambridge Collaborative) the development of a noise control handbook (DOT-TSC-74-5) for diesel powered vehicles. The purpose of the handbook was to assist the truck fleet operator and the independent truck owner/operator in understanding and diagnosing noise problems and in selecting retrofitable components to lower truck exterior and interior noise levels. The handbook includes procedures for identifying and evaluating major truck noise sources, considerations for selection of acoustic materials, procedures for minimizing exhaust, intake, and cooling fan noise, and methods for the minimization of in-cab noise levels. The handbook's appendices give standard noise measurement procedures, muffler and intake filter selection data, cooling system design considerations, and a list of known manufacturers of acoustic materials.

In addition to the development of noise abatement technology for future vehicles, retrofit packages have been demonstrated for some twenty trucks and buses which could be used today to lower the noise of existing vehicles. In FY 74, cost sharing contracts were obtained with five heavy-duty truck and bus manufacturers. The intent of these contracts was to determine optimum intake, exhaust, and fan designs applicable to existing and present production vehicles and to inform vehicle owners, through service bulletins, of the expected noise reduction and vehicle operational effects of those recommended components. The contractors completed this work during FY 75 and submitted final reports on their programs. A symposium on this program, together with the FY 74 work performed by the Stemco Manufacturing Company and Donaldson Company on truck intake and exhaust noise reduction was held at the DOT Transportation Systems Center (TSC) on June 26, 1975. The results are shown in Table 4-2.

TABLE 4-2. RESULTS OF TRUCK/BUS RETROFIT PROGRAM

(a) General Motors, Truck and Coach Division, Report No. DOT-TSC-OST-75-51.

VEHICLE	ENGINE	A-WEIGHTED SOUND LEVEL INITIAL/FINAL PER SAE J366b, dB
DH 9502 (Cab Over)	Detroit Diesel 8V-71	94/87
JN 9500 (Conventional)	Cummins NAC-250	87/83
JI 9500 (Conventional)	Detroit Diesel 6-71	84/82
T8H5305 (Transit Bus)	Detroit Diesel 8V-71	86/82

(b) PACCAR, Inc., Report No. DOT-TSC-OST-76-21

Peterbilt 352A86	Detroit Diesel 8V-71T	89/85
Kenworth K-123	Cummins NTC-350	91/87

(c) Rohr Industries, Report No. DOT-TSC-OST-76-5

Flexible (Transit Coach)	Detroit Diesel 6V-71	83/77

(d) International Harvester Co., Report No. DOT-TSC-OST-76-14, I-II

COF 4070A (Cab Over)	Cummins NHC-250	87/83
2000D (Conventional)	Detroit Diesel 6-71N65	87/83

(e) McDonnell-Douglas, Report No. DOT-TSC-OST-76-3, I-II

White Motor Corp. 9564TDV	Cummins V-903	90/86

Neither tire noise nor inherent engine noise were addressed in the Quiet Truck Demonstration Program. Engine noise was reduced on the quiet trucks through the use of enclosures which added unwanted extra weight to the vehicles.

Tire Noise

The importance of tire noise as a contributor to total vehicle noise was appreciated by DOT/ONA, as evidenced by the initiation of tire noise research efforts in 1969 through an interagency agreement with NBS.

The initial catalog of maximum A-weighted sound levels for typical bias-ply rib and cross-bar truck tires was expanded to include one-third octave and narrow band spectral data and directionality data in the form of octave band and equal A-weighted sound level contours. These data provide additional information for understanding tire noise generation mechanisms and serve as input data for the prediction of noise levels in communities near present and proposed highways.[17]

Pavement surface was identified as a major factor which influences tire-road interaction noise. Although this dependence has been noted, the lack of an appropriate method for characterizing the pavement texture in a quantitative manner had hindered the understanding of the effect of surface texture on the generation of tire noise.

In cooperation with the Society of Automotive Engineers (SAE) Truck Noise Subcommittee, DOT/NBS participated in a series of truck tire noise tests on various surfaces at the Automative Proving Grounds, Inc., Pecos, Texas[18] and DOT-NBS conducted an extensive tire noise versus surface texture study on the special skid surfaces at the Texas Transportation Institute (TTI), Bryan, Texas[19] in order to place bounds on the extent of the pavement surface effect. In addition to noise measurements, surface profile measurements[20] were also made (for the TTI surfaces) and an attempt--only partially successful--was made to correlate pavement surface texture with tire noise. Up to a certain macrotexture scale the generated noise appears to be tire dependent, while above this value the pavement macrotexture appears to be the controlling factor.

Utilizing the extensive Wallops Island truck tire noise data base, DOT/NBS developed an empirical model to allow the prediction of in-service noise levels on the

basis of SAE J57 type tests.[21-22] This full scale model validation program was conducted at the U.S. Army Proving Ground, Yuma, Arizona. The usefulness and expected accuracy of the predictive model are shown through a comparison of the predicted and measured maximum A-weighted sound levels for a variety of truck/tire combinations.

In order to be able to compare the parametric trends between truck tires (for which extensive data exist) and automobile tires (for which limited data exist), a pilot measurement program was conducted in conjunction with a review of the open literature.[23] Load and wear effects were found to be less important for automobile tire noise, while pavement surface was found to be more important. All automobile tires generate approximately the same noise level regardless of carcass type/tread design which was not the case for truck tires.

The truck tire noise data base was further expanded to provide data on the noise levels of radial tires and the effect of load and/or inflation pressure and tire size on tire noise levels.

NBS conducted noise measurements on the radial tires utilized by the Highway Safety Research Institute (HSRI) of the University of Michigan in the tire traction study. Measurements were made at the Dana Test Track, Ottawa Lake, Michigan. Radial rib tires were found to be slightly quieter than comparable bias-ply rib tires.

The available data on the effects of tire size and load and/or inflation pressure on tire noise levels were not sufficient to determine how they should be addressed in any measurement procedure. Utilizing tires loaned by manufacturers and American Trucking Associations (ATA) member fleets, measurements were made by NBS at Yuma. The variation in sound level with tire size (for both automobile and truck tires) was approximately 1dB. Thus, it appears that compliance testing utilizing a single tire size should be feasible. For tire loads greater than 70-75 percent of the maximum rated loads, smaller variations of the measured sound levels were observed when constant inflation pressure was maintained than when the inflation pressure was adjusted to either Tire and Rim Association (T&RA) recommendations or to maintain constant tire deflections. Reports on these two studies are in preparation; however, the results have been summarized.[24]

DOT has just completed a two-year cooperative study with ATA, Consolidated Freightways, Firestone, Goodyear, Michelin, and NBS to generate data from fleet service which can be used to compare both the wear rates and noise levels of bias-ply rib, bias-ply cross-bar, and radial rib tires. Work on the final report was initiated during the first quarter of FY 78.

These tire noise efforts have quantified the important physical parameters which affect the noise generation characteristics of tires, have developed an extensive data base which led to standardized tire noise testing procedures, and have investigated the regulatory implications. However, the matter of specific tire noise generation mechanisms would remain unanswered unless more specific research was successfully conducted. Accordingly, in 1972 DOT awarded a grant to North Carolina State University to undertake an experimental and theoretical study of tire noise generation mechanisms.

The emphasis of the program has been on tire vibration as opposed to air pumping or other turbulent aerodynamic phenomena. The investigation has pointed out the difficulties associated with an experimental program to measure tire vibration/noise and has led to some rather sophisticated data collection and analysis schemes.

The results of the program to date have been documented in a series of technical reports/papers.[25-31] Continued experimental evaluation of energy propagation mechanisms in the time structure is planned. Specific goals include (1) assessment of the importance of the sidewall and tread regions of the tire through evaluation of tread-sidewall transfer functions, (2) definition of vibration noise source size through coherence analyses, (3) investigation of tire wave motion, and (4) prediction of the base line sound produced by the tire tread and sidewall based on experimental and theoretical considerations.

In order to fully evaluate the technical and economic implications of tire noise regulations, non-noise items such as tire traction, power consumption, and life cycle costs need to be assessed.

The body of data currently available concerning truck tire traction is limited; however, since tradeoffs between vehicle safety and tire noise reduction are difficult if not impossible to justify, there exists a need to critically evaluate the statement that "tires with good traction make more noise."

To satisfy this need, a tire traction test program was initiated by DOT in FY 76. A contract was written with HSRI for the conduct of a comprehensive set of longitudinal and lateral force measurements on both dry and wet pavement for a sample of six popular truck tires of radial construction. The specialized HSRI laboratory and mobile dynamometers represent the only such hardware that can be utilized to develop traction data of high statistical quality.

The data obtained in this study directly complement a similar set of measurements on a sample of bias-ply truck tires conducted by HSRI under sponsorship of the Motor Vehicle Manufacturers Association (MVMA).

Data analysis shows that for both wet and dry conditions, tires exhibiting improved traction performance are generally those whose tread patterns yield lower noise output. Regarding both lateral and longitudinal traction properties, the common usage of cross-bar tires on rear driving axles (with rib tires on the steering axle) results in a typically disadvantageous arrangement from an on-highway vehicle control point of view, i.e., braking and cornering maneuvers.[32-33]

It is well documented that radial rib tires are appreciably quieter than bias-ply cross-bar tires and slightly quieter than bias-ply rib tires. In addition, radial tires provide a high potential for lower tire power consumption which has important implications on fuel economy.

To date, only limited data have been generated and published in the open literature which evaluate the true potential of radial tires applied to trucks and buses specifically to achieve improved fuel economy.

To overcome problems associated with measuring rolling resistance during road tests with actual trucks (i.e., it is difficult to separate the tire losses from the aerodynamic and drive-line losses), DOT contracted with Calspan to utilize their Tire Research Facility (TIRF) which is a laboratory flat road test machine which completely defines and measures the forces and moments transmitted between the roadway and the tire over a wide range of operating conditions.

The objective of the program is the provision of power loss data of truck tires as a function of tire design (bias-ply, radial), tread design (rib, cross-bar), state

of tread wear and tire operational parameters (load, inflation pressure), speed, road surface (flat belt versus drum), tire temperature, slip angle, torque and trip length.

The data[34-35] indicate approximately 50 percent lower rolling resistance for radial tires. For actual in-service operations, the power loss would be approximately 25 percent less for radial tires than for bias-ply tires.

Since any noise regulation for pneumatic tires would have to be technologically and economically feasible, the life cycle costs associated with tires of various carcass construction/tread design need to be documented. Few cost data are presently available to serve as a base against which tire noise reduction benefits can be judged; therefore, DOT has contracted with Wyle Laboratories to quantify the costs associated both with current tire use practices and with revisions to these use practices which may be necessary to comply with future noise regulations.

Typical tire use practice for both local and long haul service will be depicted, including tire and wheel purchasing, maintenance, and inventory; vehicle running gear maintenance, vehicle mileage, fuel usage, etc. Significant variables in tire economics such as vehicle configuration and power, regional roadway and/or terrain, maintenance practices, recapping practices, etc., will be determined. Cross-bar replacement strategies will be postulated and the tire use and variable factor scenarios will be extrapolated to California and the nation to obtain an aggregate cost picture of the present and regulated future. The contract was awarded in the first quarter of FY 77 with completion scheduled for the second quarter of FY 78.

The findings of the DOT tire noise research programs will serve as the basis for a report on tire noise regulatory implications which will provide supporting information for California tire noise regulations. Such regulations will be written by the California Highway Patrol in accordance with Sections 27502 and 27503 of the California Motor Vehicle Code which specifically call for the regulations to be based upon DOT research results and recommendations.

To complement and supplement the DOT report to the State of California, a contract was written with the Society of Automotive Engineers to organize and conduct an open forum symposium to address current and pertinent information regarding technical, economic, regulatory, and

social aspects of motor vehicle tire noise. The proceedings of such a meeting would serve as a vehicle for further dissemination of the information brought forward.

The technical program of this symposium was organized by an ad-hoc panel whose members represented tire and vehicle manufacturers, truck fleet operators and government. This symposium--SAE Highway Tire Noise Symposium--was held November 10-12, 1976, in San Francisco, California. The proceedings were published in May 1977. The symposium served as a unique opportunity for all parties to pool their professional thoughts, data and engineering recommendations to ensure that the best information is available to the public servants charged with the responsibility to develop economically and technically reasonable tire noise regulations.

On the basis of work under this program as well as related programs in the traction, rolling resistance, and economics areas, additional papers have been generated which discuss the technical and economic considerations and their implications on possible future tire noise regulatory developments.[36-38]

Diesel Engine Noise

Initial diesel engine noise abatement work carried out as part of an interagency agreement with the Bartlesville Energy Research Center has produced a variety of information on the performance and air emissions of similar diesel engines with specific attention paid to effects of noise reduction components. Bartlesville personnel also participated in program planning for future diesel engine noise research.

The next major thrust in this area was initiated when the Calspan Corporation was awarded a three year contract dealing with the abatement of truck diesel engine noise. Abatement work is being performed on four popular in-service heavy-duty truck engines (GM, Cummins, Mack, Caterpillar). The work is structured in two phases. The first phase concentrates on noise reduction that can be achieved by surface modification and replacement or relocation of attachments connected externally to three of the engines. The second phase will continue with Phase I type of work on a Caterpillar engine and will concentrate on the reduction of noise and vibration by modification to head and functioning mechanisms and components internal to the engine and attached engine operating components.

To date, Calspan efforts have accomplished the following: (1) procurement of engines and a truck, (2) design, construction, and qualification of a unique engine noise evaluation facility, (3) development and implementation of test procedure instrumentation for engine noise, vibration, and performance measurements, (4) development of data reduction and analysis software for measurement interpretation, (5) comparison of various noise source ranking techniques, (6) measurement of engine damping characteristics as a design aid for noise abatement treatments, and (7) performance and acoustic testing on a Detroit Diesel (8V71TT) engine, a Cummins (Formula 290) engine, and a Mack (676) engine.

TSC has contracted with the Automotive Engineering Advisory Group of the Institute of Sound and Vibration (ISVR) to provide engineering and design data to assist TSC in guiding and evaluating the engine noise reduction programs. In addition, engineering data will be provided to assist TSC in solving related technical problems involving engine design improvements. Data will be provided on a task item basis as required. As examples: ISVR has produced two reports on automobile and truck diesel engines. One report, A Comprehensive Review of Diesel Combustion Models for NOX and Smoke Emissions, presents a state-of-the-art review on modeling of combustion for emissions and smoke which includes recommendations for test programs on selected engines leading to a practical usable model for the prediction of emissions, smoke, and noise related to particular combustion systems. Another report, Rate of Heat Release in Diesel Engines,[39] presents a review of heat release modeling which includes a description of the combustion model developed at ISVR specifically for noise control purposes. These two reports will be published during the first quarter of FY 78.

The results of these truck noise reduction programs provided technical and economic assistance in support of new truck and interstate motor carrier noise emission standards promulgated by EPA. The regulations are based upon known means of design and maintenance which represent best current practice and consider cost of compliance; however, even if all trucks were in compliance with these regulations, thousands of Americans would still be exposed to levels of truck-generated noise in excess of the criteria for acceptable community noise.

Future Truck Noise Research

The DOT is exploring more effective and less costly means to reduce truck noise. To develop the needed additional information which will make possible informed decisions regarding the levels and timing of future truck noise regulations and aid motor carrier and manufacturer design choices which will minimize the cost of compliance with present and/or future truck noise regulations, DOT is cooperating with the United Parcel Service (UPS)--at no cost to the government--in demonstrating the feasibility of integrating low noise requirements into the purchase specifications for new trucks.

Measurement and Enforcement Programs

Sections 17 and 18 of the Noise Control Act of 1972 charge the Secretary of Transportation to promulgate and enforce regulations to ensure compliance with noise standards promulgated by EPA for interstate railroads and motor carriers, respectively.

To support DOT in their responsibilities for highway noise reduction enforcement, TSC performed field noise measurements to define the requirements for acceptable interstate motor carrier noise enforcement sites along highways. The measurement program to categorize the highway sites was conducted by TSC at Fort Wayne, Indiana, during the period July 8-20, 1974. Data recorded at eight microphone locations at each of ten different measurement sites were reduced, tabulated, and analyzed. A civil engineering firm was obtained to conduct a detailed topographical survey of each of the measured sites. A technical report entitled An Investigation of Site Effects on Roadside Measurement of Truck Noise (DOT-TSC-OST-76-6) was published in January 1977.

As a complementary approach to this problem a contract was awarded to Cambridge Collaborative, Inc. in April 1975 for the construction of detailed acoustic models of two designated highway sites, the conduct of acoustic measurements utilizing these scale models, and the comparison of scale model noise propogation with field measurement data previously obtained by TSC at sites in the Fort Wayne, Indiana, area.

The objective of this study was to investigate the possibility of using scale models to determine the effects of site topography near roadways on the propagation of

noise from trucks. A final report will be published during the second quarter of FY 78. A general finding was that representation of a vehicle as a point source, because of strong interference patterns, is not workable in modeling but that a distributed source (several point sources) correlates reasonably well with field measurement data.

An additional contract with the Calspan Corporation involves tests and evaluation of vehicle and engine noise levels against operating performance of typical high speed automobile engines. The Ricardo and Company Engineers Ltd. is a major subcontractor for this work.

The Ricardo Company will test a Saab 99E with a fuel injected engine of 2.0 liters displacement and a design rating of 110 hp at 5500 RPM and a Peugeot 504D with a prechamber type diesel engine of 2.1 liters displacement and a design rating of 65 hp at 4500 RPM.

Following the testing of these two vehicles a series of vehicles with a variety of power-to-weight ratios will be evaluated to define the span of noise produced by accelerating vehicles.

The contractor will integrate all engine and vehicle test results regarding noise, fuel economy, and emissions and make projections and recommendations for optimized vehicle/power plant configurations. A final technical report on this program is scheduled for the third quarter of FY 78.

Roadside Noise Barriers

In addition to vehicle noise abatement and enforcement activities, the Office of Noise Abatement also has programs on roadside barrier effectiveness, highway noise prediction, and optimization of audible warning devices.

To more accurately predict and assess the performance of barriers as a method of wayside noise reduction, a series of controlled experiments were conducted under conditions of heavy (line source) traffic. A temporary 1000 foot plywood barrier was constructed along I-93 in Andover, Massachusetts, for testing purposes. The TSC Noise Measurement and Assessment Laboratory made baseline noise measurements at the site prior to and following construction of the barrier. Measurements were made for barrier heights of 4, 8, 12, and 16 feet and with the barrier surface in both a reflective (unpainted plywood) and an absorptive (acoustic fiberglass board) condition.

The results show that the insertion loss of the barrier (reduction in noise level at a point alongside the roadway due to installation of the barrier) cannot be accurately predicted by use of existing design charts which do not take into account ground absorption effects. However, existing design charts can be used with reasonable accuracy to predict noise levels behind a barrier as long as the level at a reference point above the barrier is known or can be predicted accurately. It may be possible to postulate corrections to take into account the effect of the ground and revise the current design charts accordingly. Reports on the findings will be issued in the second quarter of FY 78.

Highway Noise Prediction

TSC is involved in an extensive field measurement, reduction, and analysis program to evaluate the three existing highway noise prediction programs against field data and, where needed, to develop a revised noise prediction scheme. The TSC work includes making the three existing programs--TSC model, Michigan 117 model, and Revised Design Guide model--operational at TSC and utilizing a computer graphics system to present various output plots to aid in the analysis of results. Extensive field measurements were made in North Carolina, Florida, Minnesota, and Washington by state personnel initially trained by TSC. Data reduction was accomplished at TSC.

These data were used as the basis for evaluating the predictive models and for revision (minor) of the TSC model. This effort was initiated in FY 76 and a final report is scheduled for publication during the second quarter of FY 78.

Optimization of Audible Warning Devices

In 1974 a contract was awarded to the SAE to conduct a test program on the effectiveness of existing audible warning signals for emergency vehicles and to determine ways to minimize community annoyance. The SAE panel monitoring this effort selected Bolt, Beranek and Newman Inc. (BBN) to conduct the test program.

The experiments involved analyses of real life situations. The results[40] showed that any reliance by emergency vehicle operators on present audible warning devices is not justified. To be loud enough to warn in all ordinary circumstances, the sound level of audible warning devices

would have to be increased greatly--producing intolerable community noise.

Present audible warning devices can, however, be improved in terms of more uniform horizontal radiation and higher frequency sounds to increase their detectability. Equally important is emergency vehicle driver training to inform all drivers about the short detection distances commonly encountered.

ONA Accomplishments

Although both staff and funding of ONA have been decreasing in recent years, the accomplishments of the program remain significant and include the following:

- Demonstrated in actual revenue service the practical design techniques for reducing noise levels of heavy trucks by as much as 15 decibels at 50 feet.
- Demonstrated practical modifications to existing trucks and buses for reducing noise levels to comply with Federal interstate motor carrier noise emission standards.
- Developed practical procedures for enforcing compliance with Federal interstate motor and rail carrier noise emission standards.
- Provided technical and economic assistance in support of new truck standards and interstate motor carrier noise emission standards promulgated by EPA.
- Provided technical and economic bases for potential regulatory efforts by California and/or EPA regarding automobile and truck tire noise (the dominant high speed highway noise source).
- Demonstrated practical noise reduction techniques for railroad hump yard facilities, identified major locomotive noise sources, and hence potential for application of noise control modifications, for railroad locomotives.
- Added to the field measurements of transportation related noise and continued to upgrade computer

prediction methods to provide valid, reliable information on which to base transportation noise-related decisions.

The funding restraints have hindered research efforts accross the board; however, two areas are particularly impacted: development of necessary data to design quieter tires and definition of the site and environment effects on sound propagation.

Although much data, insight, and understanding have been acquired in the tire noise and related areas (traction, cost, rolling resistance, etc.) the information needed to design quieter tires is not now available. The development and validation of a tire/road interaction noise model is a critical need. Such research must not lose sight of the fact that the roadway and the tire are both vitally important--and at the moment more is known about the tire part of the equation.

Other areas that warrant significant experimental investigation are ground surface effects (topography) and meteorological effects on sound propagation--especially as they relate to roadside noise enforcement (both highway and railroad).

4.1.2 Office of the Secretary/Office of Environmental Affairs

The Office of Environmental Affairs (OEA) is sponsoring the development of a series of notebooks, or guidance manuals, designed to assist in the conduct of social, economic, and environmental impact assessments. Two of these notebook series are applicable to surface transportation noise sources, namely, highways and urban mass transit systems.

Federal policies and procedures regarding such impact assessment have evolved rapidly over the past few years as a result of the National Environmental Policy Act (NEPA) of 1969 (P.L. 91-190, January 1, 1970), Section 102(2)(C) which authorizes and directs:

> "all agencies of the Federal Government...(to) include in every recommendation or report on proposals for legislation and other major Federal actions significantly affecting the quality of the human environment, a detailed statement...on

(i) The environmental impact of the proposed action,
(ii) any adverse environmental effects which cannot be avoided should the proposal be implemented,
(iii) alternatives to the proposed action,
(iv) the relationship between local short-term use of man's environment and the maintenance and enhancement of long-term productivity, and
(v) any irreversible and irretrievable commitments of resources which would be involved in the proposed action should it be implemented."

Section 102(2)(A) of the Act further requires:

> "...a systematic, interdisciplinary approach which will insure the integrated use of the natural and social sciences and the environmental design arts in planning and in decision-making which may have an impact on man's environment."

The notebook series provides a ready means of access to the extensive technical literature, describes techniques for conducting social, economic and environmental impact analyses, and serves as a means of facilitating and improving the quality of the environmental assessment process and organizing the findings in a readily usable form.

The initial notebook series[41] (prepared by Skidmore, Owings and Merrill consists of a six-volume technical resource manual, primarily for use by State Highway Departments and Federal Highway Administration field offices who are responsible for conducting transportation planning and environmental impact assessment studies.

The notebook series is an attempt to better integrate the transportation planning process (which involves establishing the need for proposed highway and other transportation improvements, and identifying feasible alterations including modal, locations, and design options) and the environmental impact assessment process (which involves the identification, measurement, and evaluation of impacts associated with various transportation alternatives).

A study for mass transit projects similar to the one discussed above for highways was awarded in the first quarter of FY 78, with an estimated 12-month completion date.

The information contained in these notebooks will be of use to other Federal, State, and local agencies and private individuals who review and evaluate or otherwise participate in the planning and selection of highway and urban mass transit projects.

Another study sponsored by OEA, A Comprehensive Policy to Ameliorate Adverse Effects of Transportation Facilities,[42] analyzes ways to reduce adverse effects to persons and property adjacent to transportation facilities. Urban Systems Research and Engineering, Inc. addressed potential policy and legislative initiatives for such adverse impacts as noise and property value loss that detract from the overall positive benefits of airport, highway, and mass transportation facilities.

Initiatives outlined and analyzed in the report include acquisition of affected land or of development rights in such land outside transportation rights-of-way; construction of sound barriers; soundproofing of public and private structures; short-term loans to financially affected municipalities and small businesses; and cash compensation to homeowners suffering property value loss.

The report also discusses public acquisition of adjacent land which may increase in value as a result of the transportation investment so that the public may recapture some of the financial benefits of its investment. This study was jointly funded by the OEA, UMTA, FHWA, and FAA.

4.1.3 Federal Highway Administration/Offices of Environmental Policy, Research, and Implementation

Research programs for identifying highway noise and vibration criteria, for developing highway noise and vibration impact prediction methodologies, and for development of abatement and mitigation measures are currently underway within the Federal Highway Administration (FHWA).

It should be noted that FHWA programs fall into either of two categories: (1) the Federally Coordinated Program (FCP), or (2) the Highway Planning and Research Program (HP&R).

The legislative mandates for the FCP program derive initially from the Federal-Aid Highway Act of 1954 (P.L. 83-350, May 6, 1954), Section 10(a) which authorizes and directs the Secretary:

> "...in his discretion to engage in research on all phases of highway construction, reconstruction, modernization, development, design, maintenance, safety..."

Subsequent legislation provided specific mandates in the noise area. For example, the Federal-Aid Highway Act of 1970 (P.L. 91-605, December 31, 1970), Section 136(c) authorizes and directs the Secretary to:

> "...include in the highway research program...studies to identify and measure, quantitatively and qualitatively, those factors which relate to economic, social, environmental and other impacts of highway projects."

Section 136(b) of this Act further authorizes and directs the Secretary to:

> "Not later than July 1, 1972...promulgate guidelines designed to assure that possible adverse economic, social and environmental effects relating to any proposed project on any Federal-aid system have been fully considered in developing such project, and that the final decisions on the project are made in the best overall public interest, taking into consideration the need for fast, safe and efficient transportation...and the costs of eliminating such adverse effects and the following: ...air, noise and water pollution... Such guidelines shall apply to all proposed projects...approved by the Secretary after the issuance of such guidelines."

The Federal-Aid Highway Act of 1973 (P.L. 93-87, August 13, 1973), Section 114 authorizes and directs the Secretary to:

> "...not approve plans and specifications for any Federal-aid system for which location approval has not yet been secured unless he determines that such plans and specifications include adequate measures to implement the appropriate noise level standards... may approve any project on a Federal-aid system to which noise-level standards are made applicable...

> Such project may include, but is not limited to, the acquisition of additional rights-of-way, the construction of physical barriers and landscaping. Sums apportioned for the Federal-aid system...shall be available to finance the Federal share of such project."

In response to these legislative guidelines, FHWA developed and issued guidelines for the analysis of traffic noise impacts and abatement measures--Procedures for Abatement of Highway Traffic Noise and Construction Noise (Federal-Aid Highway Program Manual FHPM 7-7-3). This latest issuance represents a consolidation and update of PPM 90-2 and FHPM 7-7-3-1.

The guidelines outline the necessary steps in the preparation of noise study reports for FHWA concurrence, namely, (1) identification of existing noise levels and activities or land uses which may be affected by noise from the highway, (2) prediction of traffic noise using an FHWA approved traffic noise prediction method, (3) comparison of predicted noise levels for each alternative with the existing and design noise levels, and (4) where there is an impact identified, calculation of alternative noise abatement measures for reducing or eliminating the noise impact; e.g., barriers, insulation of buildings, acquisition of property, etc.

The following research programs are intended to provide valid, reliable information on which to base and/or support policy decisions and to expand the theoretical and empirical data base for the identification, prediction, and mitigation of highway traffic noise impacts.

IDENTIFICATION OF TRAFFIC NOISE AND VIBRATION CRITERIA

Determination of Impact From Vibrations Related to Highway Use

A significant number of complaints and much of the litigation pertaining to environmental vibrations stem from highway operations. Such highway-induced vibrations have been cited as causing both human psychological discomfort and structural damage. FHWA contracted with Science Applications, Inc. to define the nature and extent of the highway vibration problem by improving the existing understanding of vibration excitation, propagation, and effects.

Since the human threshold of vibration perception is very low, considerable human discomfort can occur without actual damage to structures. It is thought that a significant cause of the anxiety and annoyance associated with vibration may be due to a fear of structural fatigue or failure. The final report, which is presently in preparation, will collate and assess the physical as well as behavioral and legal literature on vibrations from highways, construction, blasting, etc., and develop guidelines to preclude or control environmental vibrations devoting special attention to situations resulting in complaints or litigation.

DEVELOPMENT OF TRAFFIC NOISE AND VIBRATION IMPACT PREDICTION METHODOLOGIES

Manual Method for Prediction of Equivalent Sound Levels for Highway Noise
(In-House)

FHWA is preparing a manual for use by the states for predicting the equivalent sound levels generated by freely flowing traffic.

Highway Noise Propagation

In-house FHWA personnel in cooperation with personnel from the Pennsylvania State University (under contract to FHWA) are examining the physical phenomenon of propagation of highway noise over finite impedance ground planes through the evaluation of mathematical treatments of wave propagation over absorbing ground planes. The objective of the study is the development of a propagation model based on the rigorous mathematical solution of the boundary value problem.

Improvement of Highway Noise Prediction Procedures

FHWA has written a contract with Science Application, Inc. to identify and correct sources of prediction error and/or inefficiencies associated with the TSC predictive model for highway noise and to develop a user's manual for the revised procedures.

Application of Acoustical Scale Modeling Techniques to Traffic Noise Propagation at Urban Freeway Sites

Existing highway noise predictive models are applicable to freely flowing traffic on roadways in non-urban areas. It is doubtful that current modeling

techniques can handle, with an acceptable degree of accuracy, noise impacted areas adjacent to urban and suburban freeways where prominent structures exist between the highway and the noise sensitive areas. Since it is desirable to develop a procedure for predicting noise impacts in these situations, FHWA has contracted with Bolt Beranek and Newman (BBN) for a 2-year study to develop a noise prediction procedure for urban and suburban freeway sites using a combination of the reference site approach and site scale modeling techniques. As such, the project involves selecting actual highway sites, modeling them in the laboratory, and comparing the noise measurements at the site to those obtained under controlled laboratory conditions.

DEVELOPMENT OF ABATEMENT AND MITIGATION MEASURES

Highway Barrier Design: Acoustic Attenuation Surfaces and Materials

In FY 74, a contract was let by FHWA with BBN to explore the ramifications of using sound absorbing material on existing highway noise barriers and within tunnels. The scope of the study was expanded to include barrier design considerations. The results of the study formed the basis for a series of handbooks relating to noise barrier design.[43-47]

The Noise Barrier Design Handbook, a tool for the highway designer, provides a means of defining the geometric configuration of a barrier to produce a desired noise reduction and also provides a design evaluation and selection procedure in which specific barriers are detailed and then evaluated in terms of cost and acoustical and non-acoustical characteristics (i.e., durability, ease of maintenance, safety, aesthetics, and community acceptance).

The other four reports serve as technical backup for the Noise Barrier Design Handbook. The Noise Barrier Catalogue documents the physical parameters, costs, acoustical performance, and public reaction for 50 noise barriers built along U.S. highways. The Catalogue of Sound Absorbing Treatments for Highway Structures documents the acoustic characteristics of standard sound absorbing materials, as well as novel materials, suitable for use on highway walls and within tunnels. Noise Barrier Attenuation: Theory and Field Experience presents a literature review of the theory of noise attenuation provided by barriers and the various predictive methodologies for highway

noise barriers which have been developed from the theory. A field measurement program compared measured values of barrier attenuation with analytical predictions. Barrier types studied include concrete, masonry, and wooden walls, and berms of various shapes. For both walled highways and tunnels, the noise impact of multiple reflections can be significantly reduced by application of sound absorptive material to the highway walls. In A Study of Multiple Sound Reflections in Walled Highways and Tunnels, a series of design charts are presented for use in estimating the impact of multiple reflections and the benefits attainable from use of absorptive materials.

Vegetative Noise Barriers

FHWA through the U.S. Forest Service has funded a study at the Pennsylvania State University to assess the potential effectiveness of narrow forest barriers in terms of insertion loss relative to highway noise and to formulate the research plan for a larger scale study of vegetative and forest noise barriers.

Insulation of Buildings Against Highway Noise

FHWA contracted with Wyle Laboratories for the preparation of a manual[48] presenting procedures for selecting effective noise insulation and ventilation modifications that can be made to residential buildings to minimize highway noise impacts. The feasibility of applying these design procedures will be evaluated as part of the Experimental Projects program -- Feasibility of Soundproofing Private Dwellings.

Aesthetics of Noise Barriers

The greatest impetus behind the noise barriers which have been constructed to date have been complaints and requests from residents, citizen groups, and local governments. To be acceptable to the communities, the barriers, in addition to effectively attenuating the highway noise, should be aesthetically pleasing. To highlight this important facet of the barrier design process, FHWA contracted with the Organization for Environmental Growth, Inc. to develop a manual for use by highway engineers, landscape architects, and others involved with the design of barriers. This manual is presently in printing.

Highway Noise Barrier Selection, Design, and Construction Experiences

Techniques and practices in highway noise barrier design and construction are still evolving. Research is underway to refine highway noise prediction methods on which barrier design is based and to develop a procedure to assist in optimizing barrier design and material selection.

Several states have had considerable experience with highway noise barrier design and construction and others have limited experience. In the aggregate, this experience constitutes a body of knowledge which can provide guidance for highway engineers in selecting, designing, and constructing noise barriers.

Personnel from FHWA Region 10 cataloged the items to be considered in the process of designing noise barriers. Implementation Package 76-B, Highway Noise Barrier Selection, Design and Construction Experiences, documents actual experience, such as cost, selection process, site, barrier materials, height, length, etc., where information is available. Where factual information based on experience is not available, considerations have been discussed in general terms.

Feasibility of Soundproofing Private Dwellings

Utilizing highway construction funds, FHWA is planning to conduct an experimental project at the state level to demonstrate the feasibility of applying sound proofing to private dwellings as an abatement measure for highway traffic noise. Various soundproofing techniques, such as double-glazed windows, total environmental conditioning so that windows can be permanently closed, careful attention to sealing acoustic leaks, etc., will be evaluated as to their practicality as a retrofit technique, to their effectiveness in insulating against traffic noise and to the costs involved. The results will be documented in a summary report.

Study of Economic Costs of Alternative Measures to Mitigate Highway Noise Impacts

FHWA contracted with New York, Minnesota, Texas, and Washington to develop a data base on the costs of alternative measures (to noise barriers) to attenuate highway noise propagation into the community. At four to six sites

within each state, the costs and benefits of such alternatives as (1) razing the dwellings adjacent to the highway, (2) buying the houses and reselling the land for other than residential purposes, (3) soundproofing the houses, etc., were evaluated. FHWA is presently utilizing this information as the basis for an assessment of the nationwide costs of alternative methods of mitigating highway traffic noise propagation into the community.

Interstate Motor Carrier Noise Emission Compliance

FHWA, Bureau of Motor Carrier Safety (BMCS), is also the agency charged with ensuring compliance with the Federal Interstate Motor Carrier Noise Emission Standards. To provide necessary guidance and training material for use by Federal, State, and local motor carrier noise enforcement personnel, a contract was written with Michigan Acoustical Consultants to develop a guidebook outlining BMCS guidelines for the measurement of motor carrier noise emissions. The guidebook[49] is now available for distribution.

Two additional programs were also aimed at state needs. During FY 77, FHWA (region 15) initiated a contract with Dames and Moore for the development of a manual to present the state-of-the-art of noise measurements related to highways and their effect on the environment. The goal of the manual is the promotion of uniformity among highway noise measurements. Material will include, but not be limited to, noise emission levels for vehicles, insertion loss/attenuation of barriers, evaluation procedures for noise prediction models, etc.

In order to develop information demonstrating the benefits of future motor vehicle noise emission level reductions to the Federal Highway Program, FHWA wrote a contract with BBN (1) to perform a cost effectiveness analysis of vehicle source control versus alternative highway noise mitigation measures, (2) to demonstrate to state and local governments the advantages of quieting motor vehicles, and (3) to evaluate the effect, if any, of reduced exhaust heights (for trucks). A final report entitled Evaluation of Benefits to the Federal Highway Program Provided by the Regulation of Vehicle Noise Emissions, BBN Report 3467, was received in December 1976.

FHWA is currently formulating a long range research plan. One tool utilized in the development of this plan was the sponsorship of a workshop. A small group of

knowledgeable individuals were brought together to assess the state-of-the-art in highway noise and vibration, to identify and prioritize long term research needs, and to organize these research needs into manageable research projects.

The ongoing FHWA research programs are making substantial contributions toward identifying highway noise criteria and developing prediction methodologies and abatement and mitigation strategies in support of the primary goal of FHWA in the noise area—the reduction of community noise impact from traffic noise.

However, many of the problem areas are quite complex—problems which demand substantial funding and long time frames for solution. In general, ongoing research programs aimed at solving these problems can be characterized as either underfunded and/or limited in scope. Additional funding and manpower would allow for such problems to be addressed in a more comprehensive manner.

Additional in-house capability in noise would allow for more timely response to technical/policy needs. In general, contracting out does not provide for timely response. A more innovative approach to procurement/contractural matters would also help.

Present programs are, in general, supportive of existing policy. Steps taken to improve long range planning, e.g., highway noise research strategies workshop, should provide an improved means for anticipating policy needs and identifying the research necessary to support such policy.

Specially designated funding supports a number of overall management and coordination activities that encompass the entire Federally Coordinated Program. One such activity is continued support to the National Academy of Sciences' Transportation Research Board (TRB) for its role in advising and counseling FHWA through expert advisory committees, research correlation service, definition of research areas, and information dissemination through the Highway Research Information Service.

NCHRP PROJECTS IN THE SURFACE TRANSPORTATION NOISE AREA

The National Cooperative Highway Research Program (NCHRP) results from a tripartite contract between the American Association of State Highway and Transportation

Officials (AASHTO), the FHWA, and TRB. Research activities are selected by a special committee of AASHTO and administered by the TRB in conjunction with and having approval of the State highway officials.

Under this program, 4½ percent of Federal-aid highway planning and research (HP&R) funds are pooled by the States on a voluntary basis to fund research activity structured to respond quickly to the needs of State highway departments. Because the FHWA is technically responsible for Federal-aid funds used in NCHRP programs, it reviews contractor selection and program content. However, program selection and composition remain the prerogative of AASHTO and the participating State highway agencies.

NCHRP - Highway Noise Model Project

Bolt Beranek and Newman, under contract to the Transportation Research Board, National Cooperative Highway Research Program, developed a design guide which provides the highway engineer or designer with the tools necessary to predict, evaluate and minimize traffic generated noise in the surrounding community. The developed procedures are based on the theoretical, experimental, and practical results developed under NCHRP Project 3-7 as well as on other highway noise studies undertaken in the past 10 years, especially the NCHRP 117 model (computerization performed by the Michigan State Highway Department) and the DOT-Transportation System Center model. The design guide and its supporting technical backup have been published as NCHRP Report 173, Highway Noise - Generation and Control and NCHRP Report 174, Highway Noise - A Design Guide for Prediction and Control.[50-51]

NCHRP - Investigation of Selected Noise Barrier Acoustical Parameters

The use of noise barriers is becoming an increasingly important abatement measure along new and existing highways where noise has become a matter of greater public concern. Procedures currently used to analyze such barriers and to predict their effectiveness have some limitations. The basic objectives of this project are to complete an analysis of certain highway noise barrier parameters in addition to those examined in recent studies. The additional factors include:

- Barrier cross-sectional shape (mounds, wedges, multiple-edge barriers, etc.)

- Barrier surface characteristics (surface impedance of covering, etc.)

- Barrier influence on ground cover effect (the influence of a noise barrier on the net ground effect on noise propagation).

The study includes the analysis of the significance of the above parameters to the overall performance of noise barriers in terms of the sensitivity of barrier effectiveness to each of the study parameters.

Since current procedures for calculating barrier effectiveness are based on the thin-wall barrier assumption, the effects of the factors defined above will be related to the thin-wall barrier case for convenience in the application of the research project results. The project is scheduled for completion during the second quarter of FY 78.

The theoretical, experimental, and practical results developed under NCHRP Project 3-7, as well as other highway noise studies undertaken over the past 10 years, form the basis for the tools (predictive models) presently utilized by highway engineers and/or designers to predict, evaluate and minimize traffic generated noise levels in the surrounding community.

It is anticipated that data resulting from the noise barrier study will serve as the basis for refining the procedures for predicting barrier effectiveness, thus, improving the cost/effectiveness of barrier designs.

HP&R PROGRAM

In addition to projects funded under the FCP Program, surface transportation noise research projects are funded through the HP&R Program. Section 151 of the Federal-Aid Highway Act of 1972 (P.L. 93-87, August 13, 1973) authorizes Highway Planning and Research Funds:

> "Not to exceed 1½ percentum of the sums apportioned for each fiscal year beginning with fiscal year 1974 ...shall be available for expenditure upon request of the State highway department, with the approval of the Secretary...for research and development, necessary in connection with the planning, design, construction, and maintenance of highways..."

The HP&R funds are available for solution of specific State and local research needs. The FHWA assists in coordinating this research but does not use Federal aid funds to control or unduly influence State or local research programs. Therefore, the HP&R programs are listed but are not assessed.

Alabama

To improve their capability for the accurate measurement and prediction of highway noise, the State of Alabama developed and implemented the following analytic and experimental tools: (1) an automated traffic noise data acquisition system and associated user's manual and (2) a computer program for the prediction of traffic noise based on the methodology of NCHRP Reports 117 and 144 and associated user's manual. The adequacy of the instrumentation system and experimental procedures was verified by carrying out field measurements at a number of highway sites. The results of this study are documented in a three volume report.[52-54]

California

The State of California attempted to develop better methods for the evaluation, prediction, and control of traffic noise in areas adjacent to highways. They investigated the effect of highway design factors and terrain variables including natural or man-made obstructions, reflecting surfaces, grades, etc. Criteria were developed for desirable separation distances between the nearest travelled roadway lane and noise sensitive areas such as schools, hospitals, and residences.[55]

Connecticut

An evaluation was made by the State of Connecticut of an experimental noise reduction earth berm constructed alongside I-84 in West Hartford, Connecticut. The noise reduction effectiveness of the barrier was measured, opinions on the effectiveness of the barrier were surveyed among nearby residents, and the measured and predicted noise reductions were compared.

Kentucky

The State of Kentucky has initiated a field study to quantify highway noise propagation parameters, i.e., traffic, environmental, and geometric factors, in relation to improving the highway noise prediction models.

New Jersey

The State of New Jersey is conducting an investigation of truck noise levels in order to empirically correct the TSC Highway Noise Prediction Model by accurately classifying truck noise emission levels.

Noise measurements have been made by the State of New Jersey to obtain initial data and to monitor noise sensitive areas in the State. Such measurements form the basis for the investigation, development, and implementation of noise abatement alternatives.[56]

The State of New Jersey is performing an evaluation of traffic noise barrier design methods. They plan to develop and implement a method to evaluate existing noise barrier design methods utilizing noise measurements before and after barrier construction.

Virginia

A field study of highway noise barriers is presently being carried out by the State of Virginia. They are utilizing current prediction procedures to evaluate barrier performance in conjunction with before and after barrier construction measurements which will provide the basis for an assessment of the effectiveness of predictive computer programs in the design of noise barriers.

Washington

A series of four reports[57-60] have resulted from a barrier study by the State of Washington. The study, conducted by the Applied Physics Laboratory, University of Washington, included laboratory modeling and full scale noise studies to investigate barrier attenuation of automobile and truck noise at selected locations.

A field study is underway in the State of Washington to quantify the highway noise propagation losses over various types of ground covers considering the influence of wind speed and direction.

Oklahoma

The Oklahoma Department of Highways has received funding for a 3-year study to validate the noise prediction models currently utilized by the department. Of special concern is the effect of average daily traffic on the model. The program research program will develop procedures for measuring noise using digital sound recording equipment. Noise data will be correlated with the noise prediction models currently in use and any new or modified predictive models made available to the states by the FHWA during the time frame of the project.

Even though these programs are directed to specific State or local needs, the results are applicable, in general, to similar problems on a nationwide basis.

4.1.4 Federal Railroad Administration/Office of Research and Development

Within the Federal Railroad Administration (FRA), railroad noise abatement research is carried out by the Office of Research and Development (OR&D) in support of the following legislative mandates:

1. The Federal Railroad Safety Act of 1970 (P.L. 91-458, October 16, 1970), Sections 101 and 202 authorizes the Secretary:

> "...to promote safety in all areas of railroad operations...to reduce deaths and injuries (including hearing loss) to persons...to conduct, as necessary, research, development, testing, evaluation, and training for all areas of railroad safety..."

2. The Noise Control Act of 1972 (P.L. 92-574, October 27, 1972), Sections 17(a)(1) and 17(a)(4) authorizes:

> "Within nine months after the enactment of this Act, the Administrator (of EPA) shall publish proposed noise emission regulations for surface carriers engaged in

interstate commerce by railroad...after consultation with the Secretary of Transportation to permit the development and application of the requisite technology, giving appropriate consideration to the cost of compliance."

In 1973, the Office of Noise Abatement, in cooperation with TSC, FRA, and AAR, developed a comprehensive railroad noise abatement research plan for identifying and reducing the noise from locomotives, rolling stock, maintenance-of-way equipment and railroad yards---especially retarders--- and for the development of practical measurement methodologies for use in enforcing the Federal Interstate Railroad Noise Emission Standards.

These programs discussed below were initiated according to this plan; however, funding limitations and conflicting priorities have forced the time frame of the program to be stretched out. Furthermore, a large scale noise abatement demonstration program, such as a "quiet locomotive program," is not envisioned at this time due to a lack of sufficient funding to support such an undertaking.

Locomotive and Rail Car Exterior Noise

As part of its responsibilities under the Noise Control Act, the DOT Office of Noise Abatement requested the support of FRA/OR&D, TSC, and the Association of American Railroads (AAR) in developing a comprehensive research program on railroad noise.

The initial cooperative effort was directed toward identifying the overall and individual component noise levels from a typical line-haul diesel-electric locomotive (General Motors EMD/SD 40-2). The noise study was conducted under a contract by BBN under the technical guidance of TSC, in cooperation with the AAR and the Burlington Northern Railroad, St. Paul, Minnesota.

BBN conducted moving and stationary measurements at St. Paul during the first quarter of FY 76. Exhaust, engine cooling fans, and the traction motor cooling system were found to be the major contributors to overall locomotive noise. A final report, An Assessment of Railroad Locomotive Noise (DOT-TSC-057-76-4, DOT-TSC-FRA-76-2), was published in the first quarter of FY 77. An additional program of this type will be conducted in FY 78 utilizing a General Electric locomotive.

Retarder Noise

Another significant source of noise in the railroad environment is the hump track in classification yards, where retarders are used to control the speed of free-rolling cars during the classification process. When the retarders are applied to the car wheels in a clamping fashion, they create a loud squeal audible some distance from the yard. Besides disturbing nearby communities, the noise associated with retarder operation creates an unsafe environment for railroad personnel in the vicinity. A cooperative effort between DOT(TSC) and the Burlington Northern Railroad was undertaken during the spring and summer of 1975 to collect, assess, and disseminate information on the noise environment associated with the operation of retarders and also to provide information on the effectiveness of noise barriers as a means to reduce retarder noise both in the yard and in surrounding communities.

Data were obtained during a parametric analysis program conducted at the North Town freight classification yard of the Burlington Northern Railroad in Fridley, Minnesota. TSC, utilizing its mobile noise laboratory and its associated instrumentation, made the noise measurements, obtained baseline data, and analyzed the noise environment (under controlled test conditions) for (1) a retarder without a noise barrier and (2) the identical retarder shielded by a variable height (4, 8, 10 and 12 feet) noise barrier. A final report indicating the positive effect of barriers to reduce lateral sound propagation from classification yard retarders and the further improvement to be gained by use of absorptive surfaces on the barriers is scheduled to be completed during the second quarter of FY 78.

Building on the results of these initial programs, continued research on locomotive and rail car exterior noise emissions is planned. This research will further investigate specific sources of noise and will address the need for additional data to support compliance regulations associated with the Federal Railroad Noise Emission Standards.

FY 77 funded tasks sponsored jointly by FRA/OR&D and DOT/ONA in cooperation with the AAR include:

- A survey of the types of load cells presently available in terms of design, location, and estimated noise levels will be conducted. An attempt will be made to develop a methodology to relate, where possible, locomotive noise levels

measured at typical load cell sites to those measured at sites in strict conformance with the requirements of the EPA promulgated standard.

- The feasibility of developing and demonstrating simplified noise measurement procedures, e.g., unloaded, stationary tests, that correlate with measurements made in strict accordance with the EPA standard.

FY 78 initiatives include the following:

- A series of wayside noise measurements of high speed train pass-bys to determine if the current 93 dB peak pass-by standard will restrict rail speed in the future and in turn limit the ability of railroads to compete with highway trucking operations.

- A new series of noise measurements in freight yards and terminals to provide data needed to support FRA positions with regard to imminent railroad facilities standards to be promulgated by EPA and the preparation of subsequent enforcement regulations.

Locomotive In-Cab Noise

In addition to locomotive and rail car exterior noise, a locomotive in-cab noise survey has been initiated within FRA/OR&D by the Office of Rail Safety Research in cooperation with the AAR. Technical contract support is being provided under interagency agreement by NBS. The objective of the program is (1) to determine, by means of a representative sample of locomotives in operational settings, the extent of crew exposure to noise; (2) to identify simplified test procedures and measurement methodologies that can be used in an environment to determine whether or not an individual locomotive is capable of generating excessively high noise levels; and (3) to identify measurement techniques whereby component sources of noise within the locomotive cab can be identified so that, if a noise problem exists on a given locomotive, the least expensive and most effective corrective actions can be taken.

The program effort is currently underway and is in its preliminary stages. The program is expected to continue through May 1978.

4.1.5 Urban Mass Transportation Administration/Office of Technology Development and Deployment

Research, development, and demonstration programs within the Urban Mass Transportation Administration (UMTA) are carried out by the Office of Technology Development and Deployment. Section 6 of the Urban Mass Transportation Act of 1964 (P.L. 88-365, July 9, 1964) authorizes the Secretary:

> "...to undertake research, development and demonstration projects in all phases of urban mass transportation (including the development, testing, and demonstration of new facilities, equipment, techniques, and methods)..."

In addition to R&D authority, Section 3(a) of the Act provides UMTA with the authority

> "...to make grants or loans...to assist States and local public bodies and agencies thereof in financing the acquisition, construction, reconstruction, and improvement of facilities and equipment for use...in mass transportation service in urban areas..."

Purchase Specifications

Utilizing this authority, UMTA provides capital grants covering about 80 percent of all transit coach purchases. In FY 74, it was proposed to closely examine the test procedures and specifications for community and passenger noise levels associated with transit buses.

The Mitre Corporation was funded in FY 75 but the purchase specifications portion was not carried out. Instead, Mitre studied current transit bus models to determine specific improvements that can be accomplished through a modification program. Three improvement kits, consisting of new or modified components to lower exterior bus noise were recommended[61]: treatment of the radiator fan, insulation of the engine compartment, and the addition of an effective air intake silencer. The proposed kits were not prototype tested.

Mitre also proposed a new noise measurement procedure for diesel transit buses. The procedure, based on SAE J366, called for maximum noise mode measurements at a distance of 50 feet with microphones at 4 and 39.4 foot elevations.[62] It is interesting to note that for the data presented, the maximum sound level was always measured at the normal 4-foot high microphone. Procedures for making interior measurements at various positions within the bus were also proposed.

Since UMTA must approve proposed specifications for mass transportation equipment to be purchased pursuant to grants made under the amended Urban Mass Transportation Act of 1964, an attempt---the Transbus Program---was made to establish the basis for essentially uniform specifications.

The UMTA Transbus research and development program, undertaken with the participation of bus operators and suppliers (General Motors Truck and Coach; Rohr, Inc.; and AM General Corporation) has produced a number of design and performance improvements has been incorporated into the specifications for ordering full size transit buses (see Transbus Procurement Requirements, Department of Transportation, Urban Mass Transportation Administration, Washington, D.C., April 1976).

Several issues have now emerged concerning the extent to which UMTA should encourage or mandate performance or other requirements for transit buses purchased with Federal assistance.

Personal and Group Rapid Transit Systems

Other systems development and exploratory efforts in the area of personal and group rapid transit systems (PRT's and GRT's) also include noise related activities as a part of the advanced work necessary to determine the applicability of such systems for future urban transportation needs. Some of the findings of these systems study contracts may be pertinent to more conventional tracked rapid transit vehicles and to future design specifications for systems implementation. Estimates as to the specific cost of the noise related portions of these contracts are not provided since the segregation of noise from other design and evaluation tasks cannot be readily performed. In the area of rail rapid transit a concerted effort was mounted in FY 74 to address the problems of noise in the community and the noise environment of riders and customers waiting in stations. Grants were provided the New York Polytechnic Institute and the University of Illinois to study the New York City Transit Authority (NYCTA) and Chicago Transit Authority (CTA) properties, respectively. Boeing Vertol was awarded a contract to conduct similar studies for the rapid transit systems of Cleveland, Philadelphia, and San Francisco. The studies followed the approach developed by TSC during its study of Massachusetts Bay Transportation Authority (MBTA) lines.

Wheel/Rail and Elevated Structure Noise

At the same time, contracts were written for the conduct of basic research on the noise and vibration resulting from wheel/rail interaction and from operation on elevated structures.

A contract was written with BBN in FY 74 for the development of wheel/rail noise and vibration control technology. A two-volume report[63-64] presents analytical models of the impedance, radiation efficiency, directivity of wheels and rails, and analytical formulas for the prediction of wheel/rail noise. The predictions are compared with both laboratory and field measurements. New devices for the control of wheel/rail noise were suggested and old techniques were evaluated. Testing techniques were suggested for evaluating wheel/rail noise control measures.

Also in FY 74, a contract was written with Cambridge Collaborative for the development of track and elevated structure noise and vibration control technology. A theoretical model was developed for the prediction of noise radiated by elevated structures on rail transit lines. The validity of the predictive model was shown through comparison with a field study of three different types of elevated structures on the Massachusetts Bay Transportation Authority (MBTA).

Also developed was a theoretical model for the prediction of vibration reduction by use of floating slab tracks in subway tunnels. Comparative field data were taken in New York City. The results of this study are documented in a series of three reports.[65-67] The efforts previously discussed have concentrated on careful mapping of the rail rapid transit noise environment, establishing analytical relationships between this environment and physical characteristics of the systems. The eventual objectives are to reduce vehicle internal noise, as well as wayside noise within stations and throughout the community. Since these objectives must be met in a realistic and cost-effective manner, a transit property was selected to serve as a test bed for a study of the most promising currently available techniques for abating wheel/rail noise at its source. The Southeastern Pennsylvania Transportation Authority (SEPTA) was selected as the transit property on which to implement rail grinding, wheel truing, resilient wheels, and wheel damping as the four techniques which would abate the noise at its source, the wheel/rail interface. While these four techniques are employed on a very limited basis, careful

records are being kept on the actual cost of installing, maintaining and utilizing the appropriate hardware. Noise measurements are taken while these abatement techniques are being utilized, and the results compared with normal trains under comparable conditions. Thus, measures of cost and effectiveness are obtained concurrently. This in-service test and evaluation program replaced the 250K in the test program described in the previous (FY 73-75) Federal surface vehicle noise transportation report.

Noise Assessment of the New York City Rail Transit System

This project is a continuation on UMTA University Grant initiated in FY 74. Three efforts are being undertaken:

- Reviewing and upgrading of the cost estimates for noise reduction obtained in the previous NYCTA noise assessment work
- Field measurements to monitor "degradation" (in terms of noise) of specific car models
- Analysis of car maintenance records to determine useful life and costs of car improvements.

Elevated Structure Noise Control

Previous UMTA funded research in this area (FY 74) has resulted in analytical tools for predicting noise from elevated rail transit structures. These tools will now be used to interpret and extend the results of field tests of noise abatement on elevated structures in order to develop a Noise Control Design Guide for Elevated Structures. Specific recommendations will be given for reducing noise from the noisiest types of U.S. elevated rail structures.

Handbook of Urban Rail Noise and Vibration Control

During FY 76-77, DOT/TSC wrote a summary of the available technology for prediction and control of rail system noise. This document will form the basis of a Handbook of Urban Rail Noise and Vibration Control to be initiated in FY 78.

Systems Specification

In addition to the research and demonstration program activities, progressive systems specifications are being

drawn up for new transit systems under Federal support. Examples include the Bay Area Rapid Transit District, the Washington Metro System, the Baltimore Transit System, and the Metropolitan Atlanta Rapid Transit System. Such specifications developed by the system consultants and approved by DOT exhibit incremental noise improvements with time. Estimates of the costs of such specifications cannot be provided; however, the noise reduction contributions will be significant.

Other programs such as the State-of-the-Art Car and the development of a screech loop at the Transportation Test Center will add to the body of information permitting continuous improvement in rapid transit noise control.

The results of basic research and development of rail/wheel interaction noise and noise resulting from operation of vehicles on elevated structures will be applied to an operating transit system as part of a full scale field evaluation program. Over the next 5 years, once the technology has been developed and demonstrated, some incentive will be necessary to ensure rapid commercial application of the technology. UMTA, under its capital grants authority, could provide such an incentive, for example, through the development of vehicle purchase specifications containing noise requirements which would promote the application of state-of-the-art technology. To date such authority has not been fully utilized.

Noise is just one of a myriad of considerations in the majority of UMTA programs. Noise considerations need to be given a higher priority than they have in the past and UMTA must utilize their capital grants program authority fully if significant advances are to be made in the reduction of noise from transit vehicles.

4.1.6 DOT Concluding Statement

These programs in the area of surface transportation noise (identified as a major source of noise in Section 6(a)(1) of the Noise Control Act of 1972 (P.L. 92-574, October 27, 1972)) are consistent with Section 4(a) of the Noise Control Act which

> "...authorizes and directs that Federal agencies shall, to the fullest extent consistent with their authority under Federal laws administered by them, carry out the programs within their control in such a manner as to further the policy...to promote an environment for

all Americans free from noise that jeopardizes their health or welfare."

DOT RD&D programs in surface transportation noise are briefly described in Appendix B.

4.2 ENVIRONMENTAL PROTECTION AGENCY

The Environmental Protection Agency (EPA) was established in the executive branch of the Federal Government as an independent agency pursuant to Reorganization Plan No. 3 of 1970. It was created to facilitate coordinated and effective governmental action relative to protection of the environment. EPA endeavors to abate and control pollution systematically by integration of a variety of research, monitoring, standard-setting, and enforcement activities.

EPA derives its noise control authority primarily from the Noise Control Act of 1972 (P.L. 92-574, October 1972), which states that its purpose is

> "...to establish a means for effective coordination of Federal research and 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 respecting the noise emission and noise reduction characteristics of such products..."

EPA's responsibilities relative to noise emission regulatory authority include:

- Identification of major noise sources; noise criteria and control technology (Section 5)
- Noise emission standards for products distributed in commerce (Section 6)
- Noise emission labeling (Section 8)
- Interstate rail carrier noise emission standards (Section 17)
- Interstate motor carrier noise emission standards (Section 18).

Regulatory activities include evaluation of the state-of-the-art of product noise abatement technology, costs, and development of noise measurement methodologies. These activities do not advance technology but instead provide an assessment. Since these activities are essential to EPA in the promulgation of regulations both in the setting of noise emission levels and the determination of noise measurement procedures, they are tabulated separately in the report (Appendix I) and are not included in the noise RD&D funding totals (Appendix A).

Section 14 of the Noise Control Act defines EPA's primary responsibilities relative to noise abatement and control research programs and authorizes the Administrator of EPA to complement as necessary the noise research efforts of other Federal agencies by conducting and financing research on the effects, measurement, and control of noise.

The Office of Noise Abatement and Control (ONAC) of EPA is responsible for all noise-related research within the Agency. This Office was established under the authority of the Clean Air Amendments of 1970 (P.L. 91-604, December 31, 1970), which amended Title IV, "Noise Pollution," Section 402(a), of the Clean Air Act (P.L. 88-206, 77 Stat. 392).

Technology Assessment Programs. Surface vehicles identified as major noise sources by EPA as of February 1977, for which technology assessments have been completed, include the following:

- Medium and heavy trucks
- Motorcycles (street, off-road, mopeds)
- Buses.

Surface vehicles (and related components) under investigation to determine if they represent major noise sources and for which technology assessments are to be undertaken or are underway include the following:

- Automobiles
- Light trucks
- Tires
- Guided mass transit
- Special-purpose recreational vehicles
- Snowmobiles
- Motorboats

In the area of technology assessment, EPA has undertaken efforts to support the process of publishing a regulation as well as to evaluate the performance of a regulation. EPA has undertaken to evaluate the degradation of those noise control devices incorporated to meet 1976 new truck regulations and to determine technology requirements necessary to reduce truck noise levels below the January 1, 1982, standard.

Research Programs. Traditional noise-related RD&D activities in which ONAC participates involve advancement of the state-of-the-art of surface vehicle and product noise control and demonstration of technical adequacy of

newly developed noise control measures. Of these a significant portion of EPA's efforts have been concerned with highway vehicle noise, principally medium and heavy trucks.

EPA will continue the efforts initiated by DOT's Office of Noise Abatement in the Quiet Truck program by further developing noise abatement measures for medium and heavy trucks and by demonstrating these measures. The results of this effort will support work to develop the medium and heavy truck noise emission levels for 1985. Complementary to this effort is a research program to evaluate close-fitting engine noise prediction models and prediction of highway noise through the year 2000.

Starting in FY 77, EPA initiated a major RD&D program to identify, develop, and demonstrate noise abatement measures applicable to the internal combustion engine. In addition to advancing the state-of-the-art of the internal combustion engine, this program will attempt to investigate and modify the basic engine processes and components. Results may support future regulatory actions covering a variety of vehicles, as well as other products.

EPA has a number of general surface transportation noise RD&D programs dealing with areas other than highway vehicles. With respect to highway traffic noise, EPA has undertaken cooperative programs with the Federal Highway Administration and the Urban Mass Transportation Administration to investigate and demonstrate noise mitigation measures for highways and transit malls. Another program, being conducted with the Forest Service, is investigating recreational vehicle noise.

EPA RD&D and regulatory programs in surface transportation noise are briefly described in Appendices C and I, respectively.

4.3 DEPARTMENT OF DEFENSE

The Department of Defense is the successor agency to the National Military Establishment created by the National Security Act of 1947 (61 Stat. 495). It was established as an executive department of the Federal Government by the National Security Act Amendments of 1949, with the Secretary of Defense as its chief administrator (63 Stat. 578; 5 U.S.C. 101). The Act identified the Army, Navy, and Air Force organizations as military departments within the Department of Defense.

Surface transportation noise RD&D efforts are conducted to support mission needs such as survivability of man and equipment, protecting the hearing of military personnel, and reducing the acoustical impact of peace-time military operations on the surrounding communities.

Environmental quality matters are coordinated through the Office of the Secretary of Defense. Each of the military departments is responsible to the Secretary for individual environmental programs, including noise abatement and control.

Only the Department of the Army has identified surface transportation research programs underway or planned within DOD. Other pertinent noise reduction programs are being sponsored by DOD, particularly by the Navy on watercraft. However, details of these programs and funding levels were not available.

Within the Department of the Army, the organization charged with surface vehicle noise RD&D responsibilities is the U.S. Army Materiel Development and Readiness Command (DARCOM).

Within DARCOM, the Tank-Automotive Research and Development Command (TARADCOM) has the responsibility for conducting surface transportation noise RD&D programs. The Test and Evaluation Command (TECOM) and the Human Engineering Laboratory (HEL) are two additional commands engaged in surface vehicle RD&D work.

TARADCOM is assigned primary management responsibility for tactical surface vehicles; combat and assault vehicles; carriers, including scout and reconnaissance vehicles; and special-purpose vehicles. Technical and materiel support responsibilities include self-propelled artillery and rapid-fire weapon vehicles and Gun Air Defense Systems.

TARADCOM's mission, in part, is to perform and manage research, design, and development for all assigned materiel items and systems. TARADCOM also provides interchange of technical information between TARADCOM, industry, DOD agencies, and interested contractors. The primary objectives of TARADCOM's Tank-Automotive equipment noise reduction and control program include ensuring survivability and mission performance. A secondary goal is conformance to MIL-STD-1474A, which establishes noise limits for detection, hearing protection, and environmental acceptance for all Army materiel where suitable.

Vehicles and equipment designed for combat use are not included in the requirements of the Noise Control Act of 1972 and subsequent EPA regulations. However, certain military design vehicles that may travel public highways may be subject to current and proposed EPA regulations with respect to exterior noise. The TARADCOM vehicle noise program is thus concerned with reducing noise levels of the existing fleet.

TARADCOM's RD&D activities involve surveying the noise emissions of existing military vehicles, investigating noise reduction techniques, developing noise reduction kits suitable for installation in the field or during production, and assistance to vehicle offices in design for minimum noise in new equipment. Proposed unfunded programs include continued investigation of current efforts and further efforts involving new vehicles.

Current vehicle component noise programs address noise reduction of engines, exhaust systems, track, and power train components. In the future, TARADCOM expects to contribute to the development of new vehicles and investigate cooling fans, mufflers, improved vibration-isolating mountings, and current hydraulic systems. TARADCOM also has an ongoing effort to study vehicle detectability.

TECOM provides test and evaluation support, facilities, and services to DOD, DARCOM, private industry, and other Government agencies. TECOM programs evaluate vehicle noise and the effectiveness of noise reduction modifications with respect to interior, exterior, and impulse conditions.

HEL is a separate activity, reporting directly to the Deputy Commanding for Materiel Acquisition, DARCOM. The mission of the Laboratory is to conduct basic and applied research in human factors engineering and to provide direct design support to all materiel development programs sponsored by DARCOM.

HEL is conducting a major RD&D program to reduce interior noise levels on tracked armored personnel carriers. Initial areas of investigation in this program have centered on track and suspension system components. HEL was the leading Army activity in the development of MIL-STD-1474 (MI), Noise Limits for Army Materiel. The use of this noise specification in all appropriate Army materiel development programs will result in obtaining lower noise materiel as well as significant reduction in the $50 to $60 million annual expenditure in hearing loss compensation paid by the Veteran's Administration to future military veterans.

DOD RD&D projects for surface transportation noise are briefly described in Appendix D.

4.4 DEPARTMENT OF AGRICULTURE

The U.S. Department of Agriculture (USDA) was created by an act of Congress May 15, 1862 (12 Stat. 387; 5 U.S.C. 511, 514, 516). The Department was enlarged and made the eighth executive department in the Federal Government in 1889.

The USDA is directed by law to acquire and disseminate information on agricultural subjects. To accomplish this purpose, the Department also functions in the areas of research, conservation, and regulation over matters pertinent to agriculture. The organization within the USDA primarily concerned with surface vehicle noise RD&D is the U.S. Forest Service.

The Forest Service was created by the act of February 1, 1905 (33 Stat. 628; 16 U.S.C. 472), which transferred the Federal forest reserves and the responsibility for their management from the Department of the Interior to the Department of Agriculture. The Forest Service has Federal responsibility for national leadership in forestry. Toward this purpose, its objectives and policies include protection and improvement of the quality of air, water, soil, and the natural beauty of lands under their management.

Forest Service research programs are conducted under the authority of the McSweeney-McNary Act of May 22, 1928 (45 Stat. 699; U.S.C. 518-581i), as amended and supplemented.

Surface transportation noise RD&D programs have involved primarily off-road and recreational vehicles and the impact of related noise emissions on the sylvan environment. Noise measurement methodologies have been developed for snowmobiles, motorcycles, four-wheel-drive jeeps and other ground-borne off-road vehicles. The effects of off-road vehicle noise on the operator and users of outdoor recreation areas have been investigated. A methodology has been developed for predicting the environmental impact of off-road and recreational noise. The results of these efforts have been applied to forest transportation system planning, including location of logging roads, trails, campgrounds, and highways. Research has also been conducted on the propagation of off-road vehicle and highway noise over terrain and through vegetation.

RD&D programs on snowmobiles were directed primarily toward the characterization of noise emissions and the identification of available noise control technology. The Motorcycle Industry Council has published a test standard for motorcycle noise measurement. The Forest Service has cooperated with the Motorcycle Industry Council in developing this standard.

Additionally, through their interest in reducing snowmobile noise, the Forest Service has been able to influence the snowmobile industry to voluntarily reduce noise levels.

USDA RD&D programs in surface transportation noise are briefly described in Appendix E.

4.5 DEPARTMENT OF JUSTICE

The Department of Justice (DOJ) was established by the act of June 22, 1870 (16 Stat. 162; 28 U.S.C. 501, 503). The chief purposes of the Department of Justice are to enforce the Federal laws, furnish legal counsel in Federal cases, and construe the laws under which other departments act. Within DOJ the Law Enforcement Assistance Administration (LEAA) was created by the Omnibus Crime Control and Safe Streets Act (P.L. 90-351, June 1968). Under the provisions set forth in section 402(b)(1) of this act, LEAA is authorized to perform research which includes:

> "...the development of new or improved approaches, techniques, systems, equipment, and devices to improve and strengthen law enforcement and criminal justice."

Only one program was reported by LEAA relative to surface transportation noise RD&D. This program was sponsored by the National Institute of Law Enforcement and Criminal Justice, the research arm of LEAA, and was performed by interagency agreement with NBS. This program was concerned with determining the characteristics and effectiveness of directional emergency vehicle warning systems with variable beam width. This is reported in Appendix F.

4.6 DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT

The Department of Housing and Urban Development (HUD) was established by the Department of Housing and Urban Development Act, effective November 9, 1965 (79 Stat. 667; 42 U.S.C. 3531-3537). Its overall purpose is to assist in providing for rational development of the nation's communities and metropolitan areas.

Enhancement of environmental quality and environmental planning activities are conducted by HUD in implementation of the National Environmental Policy Act (NEPA) of 1969, which requires that environmental impacts resulting from Federal actions be assessed and considered as decision making factors of equal import with economic, technical, and other considerations of national policy.

The Housing and Community Development Act of 1974 (P.L. 93-383; 42 U.S.C. 5301), Title I, Community Development, provides further authority for HUD's activities in improving neighborhood and community environments. The objective of this act is the achievement of a national housing goal of a decent home and a suitable living environment (including acoustical environment) for every American family.

The Department's activities in the area of environmental quality and environmental planning include development and implementation of HUD environmental policies and procedures, development of environmental assessment criteria, and coordination with other Federal departments and agencies and with the Council on Environmental Quality (CEQ). Other environmental functions encompass development of strategies for the amelioration of environmental problems such as noise pollution. Emphasis is placed on environmental and land use planning and environmental management practices. In the area of research, HUD is concerned with developing policies and techniques for land use and building construction practices. Current surface transportation noise RD&D programs at HUD involve architectural acoustics. HUD is systematically evaluating noise abatement policies and guidelines in reducing the impact in residential communities. A second program is aimed at developing techniques and procedures for site design and construction practice. The procedures are expected to be used as guidelines by HUD personnel and others responsible for community development.

HUD programs in surface transportation noise are briefly described in Appendix G.

4.7 DEPARTMENT OF ENERGY

The Department of Energy Organization Act of August 1, 1977 (P.L.-95-91:91 Stat. 565) combined all Federal energy agencies, including the Energy Research and Development Administration (ERDA), into the Department of Energy (DOE). Section 102 of the Act identifies DOE's responsibilities to include:

> "...incorporation of national environmental goals in the formulation and implementation of energy programs, and to advance the goals of restoring, protecting, and enhancing environmental quality, and assuring public health and safety."

DOE's primary objective is the development of energy-efficient systems. It has a mandate to support environmental and safety research (including noise research) related to the development of energy technology; because noise is not a primary responsibility, the priorities assigned to the prime objectives provide a limitation on the direct noise research.

RD&D carried out by the Transportation Energy Conservation Division (TEC) in the Office of Conservation and Solar Application will have positive impacts on urban traffic noise. Long term R&D efforts in the turbine and Stirling engine programs have incorporated vehicle drive-by and interior noise into the design standards; both vehicles are expected to have lower noise impact than internal combustion engine vehicles. Vehicles using these engines could be on the road in the late 1980's.

The electric and hybrid vehicle program promises positive impacts on urban traffic noise levels. Electric vehicles generate considerably less exterior noise than heat engine vehicles; in fact, their quiet operation could require an audible device to assist pedestrians who use vehicle noise as a warning of the vehicle's approach. The introduction of electric vehicles into urban areas could lower urban traffic noise levels beginning in the late 1980's or early 1990's.

Various Federal agencies have utilized the capabilities and facilities of DOE's Bartlesville Energy Research Center for the conduct of noise research on engines. No noise related programs have been conducted or are planned for the FY 75-78 period.

Surface vehicle energy programs planned for the time period beyond FY 78 that may require noise control efforts include:

- Noise control for chopper equipped controllers utilized in the Electric Vehicle Systems and Batteries Program
- Noise considerations for hybrid powered vehicles during on-off engine operation and idling at higher than normal engine speed
- Noise emissions from a continuously variable transmission
- Federal noise regulations applicable to gas turbine and Stirling cycle engines in medium and heavy trucks.

The approach used to identify potential environmental problems (including noise) that may result from the commercialization of a technology is specified in the Environmental Development Plan (EDP) for TEC, FY 78. In addition to identifying potential noise or other environmental problems, the EDP also schedules the necessary R&D required to resolve the issue. The guidelines defining the EDP recognize that some of the identified environmental problems may best be resolved by outside Federal agencies rather than by the DOE technology program. Therefore, early consideration is given to determine which Federal agency is most appropriate to conduct the required environmental RD&D in a timely and competent manner. The potential for interagency research is also examined.

4.8 DEPARTMENT OF COMMERCE

The Department of Commerce was designated by the act of March 4, 1913 (37 Stat. 736; 15 U.S.C. 1501). The mission of the Department of Commerce is to foster, serve, and promote the nation's economic development and technological advancement. This is carried out through activities that encourage and assist States and local organizations and private industry.

The Department of Commerce is composed of the Office of the Secretary and several operating units. Of these, only the National Bureau of Standards reported surface vehicle noise abatement activities.

NBS Statutory Authority

The National Bureau of Standards (NBS) was established by Public Law 56-177, "Organic Act of 1901," March 3, 1901, and as amended by Public Law 81-619, July 22, 1950. NBS was originally part of the Treasury Department and was subsequently transferred to the Department of Commerce. This act as amended authorized the Secretary of Commerce to undertake the following functions:

> "The custody, maintenance, and development of the national standards of measurement, and the provision of means and methods for making measurements consistent with those standards, including the comparison of standards used in scientific investigations, engineering, manufacturing, commerce, and educational institutions with the standards adopted or recognized by the Government"
>
> "The determination of physical constants and properties of materials when such data are of great importance to scientific or manufacturing interests and are not to be obtained of sufficient accuracy elsewhere"
>
> "The development of methods for testing materials, mechanisms, and structures, and the testing of materials, supplies, and equipment including items purchased for use by Government departments and independent establishments"
>
> "Cooperation with other governmental agencies and with private organizations in the establishment of standard practices, incorporated in codes and specifications"

"Advisory service to Government agencies on scientific and technical problems"

"Invention and development of devices to serve special needs of the Government"

NBS is also specifically mentioned in two other acts: the Noise Control Act of 1972 (P.L. 92-574) and the Consumer Product Safety Act (P.L. 92-573).

Under the Noise Control Act the EPA Administrator is authorized to:

"...conduct research, and finance research by contract with any person, on the effects, measurement and control of noise, including but not limited to...development of improved methods and standards for measurement and monitoring of noise, in cooperation with the National Bureau of Standards, Department of Commerce..."

The Consumer Product Safety Act directs that:

"The (Consumer Product Safety) Commission shall, to the maximum extent practicable, utilize the resources and facilities of the National Bureau of Standards, on a reimbursable basis, to perform research and analyses related to risks of injury associated with consumer products (including fire and flammability risks), to develop test methods to conduct studies and investigations, and to provide technical advice and assistance in connection with the functions of the Commission."

NBS Program Approach

At the present time, NBS does not directly fund any surface transportation noise research. However, NBS does conduct research on measurement procedures required for the measurement of noise emissions, which is related to and supportive of these interagency programs.

The objective of NBS work on measurements of noise emission from stationary and moving sources is to quantify the measurement uncertainties associated with existing test methods and to conduct research to enable improved measurement technology.

NBS surface transportation noise research performed under reimbursable interagency agreements emphasizes the determination of the adequacy of present standards for the measurement of noise emissions. This determination consists primarily of critical reviews of the sources of measurement error and the conduct of experimental measurements using existing NBS facilities and present measurement procedures. These studies are intended to (1) indicate the magnitude of measurement imprecision and systematically address the requirements for improvements in the existing standards, and (2) provide the scientific and technical basis for improvements to those standards.

NBS Surface Transportation Programs

Several of the programs, which NBS has conducted, provided important information that was subsequently used to formulate Federal noise abatement regulations. Data obtained in a program conducted for DOT dealing with the measurement of interior and exterior truck noise were used by EPA in developing the Interstate Motor Carrier and Medium and the Heavy Truck Noise Emission Regulations.

The in-cab operator noise level data were used by the Bureau of Motor Carrier Safety (BMCS) of DOT in establishing the vehicle interior noise level standard contained in the Federal Motor Carrier Safety Regulations. The stationary test procedure developed in this same program was later adopted by EPA in developing the Interstate Motor Carrier Noise Emission Standard and by BMCS in the subsequent regulation for checking compliance with the EPA standard.

The data obtained in the tire noise research program have been widely used and referenced in other studies on high speed truck noise and community noise resulting from highway operations. In the development of the recently promulgated Medium and Heavy Truck Noise Regulations, the NBS truck tire noise data were used by EPA as the basis for their decision not to include a high speed test in this standard. This decision was based on the fact that at high speeds, i.e., above 50 to 60 km/hr, tire noise is equivalent to or dominant over other truck noise sources and therefore, high speed truck noise reduction can be accomplished only by treating both engine and tire noise sources together. Additionally, EPA included a section in the Interstate Motor Carrier Noise Emission Standard forbidding the use of tires composed primarily of cavities in the tread, unless the motor carrier operator can demonstrate that the

vehicle is in compliance with the noise emission standard. This ruling was based in part on NBS tire noise data which showed that tires with a tread pattern composed primarily of pockets not vented to the tire shoulder were significantly louder than other types of truck tires.

Current projects being conducted by NBS include the study of in-cab locomotive noise, the investigation of microphone windscreen performance, the measurement of test site acoustic properties, and the evaluation of various temporal sampling schemes.

The in-cab locomotive noise study is sponsored by the DOT Federal Railroad Administration in cooperation with the Association of American Railroads. The objectives of this program are (1) to determine, by means of a representative sample of locomotives in operational settings, the extent of crew exposure to noise; (2) to identify simplified test procedures and measurement methodologies that can be used in an environment to determine whether or not an individual locomotive is capable of generating excessively high noise levels; and (3) to identify measurement techniques whereby component sources of noise within the locomotive cab can be identified.

Under an interagency agreement with EPA, NBS is conducting a project to determine the characteristics of microphone windscreen performance when used as part of a sound measurement system. This study is designed to investigate wind-induced noise and acoustic insertion loss at wind speeds up to 14 m/sec. for a variety of windscreen sizes, materials, porosities and configurations.

NBS programs in surface transportation are briefly described in Appendix H.

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APPENDIX A

AGENCY FUNDING TOTALS AND INDEX TO PROJECTS

TABLE A-1
Summary of Surface Transportation Noise RD&D Funding by Agency and Department

	FISCAL YEAR FUNDING ($1000)				
	1974	1975	1976[a]	1977[b]	1978[b]
AGENCY					
• DEPARTMENT OF TRANSPORTATION	2267	1367	1417	804	782
– OFFICE OF NOISE ABATEMENT	877	625	593	28	–
– OFFICE OF ENVIRONMENTAL AFFAIRS	440	–	–	100	–
– FEDERAL HIGHWAY ADMINISTRATION	264	341	699	501	126
– FEDERAL RAILROAD ADMINISTRATION	49	–	17	175	106
– URBAN MASS TRANSPORTATION ADMINISTRATION	637	401	108	–	550
• ENVIRONMENTAL PROTECTION AGENCY					
– RD & D PROGRAMS	–	18	162	476	1224
– REGULATORY PROGRAMS	178[cd]	–	978[c]	680[c]	280[c]
• DEPARTMENT OF DEFENSE/ARMY	412[d]	202	374	518	650
• DEPARTMENT OF AGRICULTURE	73[d]	9	16	8	26
• DEPARTMENT OF JUSTICE	–	–	78	5	–
• DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT	–	548	–	–	–
• DEPARTMENT OF COMMERCE					
– DOC SPONSORED	–	–	–	150	–
– OTHER AGENCY SPONSORED	110[de]	162[e]	252[e]	153[e]	75[e]
TOTAL	2752[f]	2144	2047	1961	2682

[a]INCLUDES TRANSITION QUARTER FROM JULY 1 THROUGH SEPTEMBER 30.
[b]ESTIMATED
[c]EPA REGULATORY FUNDING IS NOT INCLUDED IN THE TOTAL.
[d]INCLUDES FUNDING FOR PROGRAMS COMPLETED IN FY 74 (NOT COVERED IN THIS REPORT)
[e]DOC/NBS FUNDING PROVIDED BY OTHER AGENCIES IS NOT INCLUDED IN THE TOTAL.
[f]DOES NOT INCLUDE FY 74 FUNDING BY THE NATIONAL SCIENCE FOUNDATION

INDEX OF SURFACE TRANSPORTATION NOISE PROJECTS

APPENDIX B

DEPARTMENT OF TRANSPORTATION
RD&D PROGRAMS

APPENDIX B

DEPARTMENT OF TRANSPORTATION

The fiscal year funding for 1976 includes the transition quarter (July 1, 1976 to September 30, 1976). Funding figures for 1977 and 1978 are estimates or represent incomplete new data.

OFFICE OF NOISE ABATEMENT

Quiet Truck Program

The goal of this program was to demonstrate the lowest practical noise levels that could be engineered into heavy-duty trucks. Individual noise sources were identified (exclusive of tire noise), and efficient means for reducing these noises to the lowest level consistent with reasonable operational constraints were developed, demonstrated and evaluated inline haul service for a one year period and the findings were thoroughly documented.

Sponsor: DOT/Office of Noise Abatement
Investigator: Freightliner Corp.; International Harvester Co.; and White Motor Co.

Fiscal Year Funding ($1,000):	1974	1975	1976	1977	1978
		183*			

Noise Control Handbook For Diesel Powered Vehicles

A handbook was prepared in May 1974 to assist the truck fleet operator and the independent truck owner/operator in understanding and diagnosing noise problems and in selecting retrofittable components to lower exterior and interior noise levels. It included procedures for identifying and evaluating major truck noise sources, considerations for selection of acoustic materials, procedures for minimizing exhaust, intake and cooling fan noise, and methods for

* Total DOT funding, spanning three years, was 1.3 million dollars. Industry contribution is not included.

the minimization of in-cab noise levels. Standard noise measurement procedures, muffler and intake filter selection data cooling system design considerations and a list of known manufacturers of acoustic materials were also given.

The handbook is report No. DOT-TSC-74-5 with an NTIS accession No. PB-236-382/8WT.

Sponsor: DOT/Office of Noise Abatement
Investigator: Cambridge Collaborative

Fiscal Year Funding ($1,000):	1974	1975	1976	1977	1978
	*				

Diesel Powered Highway Vehicle Noise Reduction (Truck/Bus Retrofit)

In FY 74, cost sharing contracts with five heavy-duty truck and bus manufacturers were initiated to determine optimum intake, exhaust, and fan designs applicable to existing and present production vehicles. Contract provisions provide for service Lulletins to inform vehicle owners, of the expected noise reduction and vehicle operational effects of those recommended designs. The contractors completed this work during FY 75 and submitted final reports on their programs. A symposium of this program, together with the FY 74 work performed by the Stemco Manufacturing Company and Donaldson Company on truck intake and exhaust noise reduction was held at the DOT Transportation Systems Center (TSC) on June 26, 1975.

Sponsor: DOT/Office of Noise Abatement
Investigator: General Motors/PACCAR/International Harvestor Co./Rohr Industries/ McDonnell-Douglas Co.

Fiscal Year Funding ($1,000):	1974	1975	1976	1977	1978
	†	44			

* $25K prior to FY 74

† Funding from previous year funding. Total DOT funding for this project was $494K.

Engine Noise Support

This program represented the initial diesel engine noise abatement work and was carried out under an interagency agreement with the Bartlesville Energy Research Center. The program produced information on the performance and air emissions of similar diesel engines with specific attention paid to noise reduction components. Bartlesville personnel also participated in program planning for future diesel engine noise research.

Sponsor: DOT/Office of Noise Abatement
Investigator: DOI/Bureau of Mines

Fiscal Year Funding ($1,000):	1974	1975	1976	1977	1978
	40*				

Diesel Engine Noise Reduction

This noise abatement work was performed on four popular in-service heavy duty truck engines (GM, Cummins, Mack, and Caterpillar). The work was structured in two phases. The first phase concentrated on noise reduction that could be achieved by surface modification and replacement or relocation of attachments connected externally to three of the engines. The second phase continued with first phase work on a Caterpillar engine and concentrated on the reduction of noise and vibration by modifications to head and functioning mechanisms, and to components internal to the engine and internal to attached engine operating components.

Efforts have accomplished the following: (1) procurement of engines and a truck, (2) design, construction, and qualification of a unique engine noise evaluation facility, (3) development and implementation of test procedure and instrumentation for engine noise, vibration, and performance measurements, (4) development of data reduction and analysis software for measurement interpretation, (5) comparison of various noise source ranking techniques, (6) measurement of engine damping characteristics as a design aid for noise abatement treatments, and (7) performance and acoustic testing on a Detroit Diesel 8V71TT engine, a Cummins Formula 290 engine, and a Mack 676 engine.

* Total DOT Funding for this project was $120K.

Sponsor: DOT/Office of Noise Abatement (TSC)
Investigator: Calspan Corporation

Fiscal Year Funding ($1,000):	1974	1975	1976	1977	1978
	245	253	131		

Engine Noise Reduction

This project, carried out by the Automotive Engineering Advisory Group of the Institute of Sound and Vibration Research (ISVR), will provide engineering and design data to assist TSC in guiding and evaluating engine noise reduction programs. In addition, engineering data will be provided to assist TSC in solving related technical problems involving engine design improvements. ISVR has produced two reports (November 1976) on lightweight automobile diesel engines. One report concerned modeling for emission tests, and the second was a review of heat release modeling and included a description of the combustion model developed at ISVR specifically for noise control purposes.

Sponsor: DOT/Office of Noise Abatement
Investigator: Institute of Sound Vibration Research

Fiscal Year Funding ($1000):	1974	1975	1976	1977	1978
		25	41		

Lightweight Vehicle/Engine Noise

This project involves tests and evaluation of typical high speed automobile engines. A series of vehicles with a variety of power-to-weight ratios will be evaluated to define the span of vehicle noise produced by accelerating vehicles.

The contractor will analyze and project all engine and vehicle test data into integrated vehicle results regarding noise, fuel economy, and emissions will make projections and recommendations for optimized vehicle/power plant configurations. A final technical report on this program is scheduled for third quarter FY 78.

Sponsor: DOT/Office of Noise Abatement
Investigator: Calspan Corporation/Ricardo and Company Engineers Ltd.

Fiscal Year Funding ($1000):	1974	1975	1976	1977	1978
			97		

Truck Noise Reduction Research

This study is an extension of the DOT Quiet Truck Program with truck manufacturers, and involves the procurement and service evaluation of up to six new trucks built to specification to demonstrate the feasibility of integrating low noise requirements into the functional requirements of trucks.

This program is being carried out in cooperation with the United Parcel Service (UPS) at no cost to the government.

Investigator: United Parcel Service

Fiscal Year Funding ($1000):	1974	1975	1976	1977	1978
				*	*

Tire Noise Study

Utilizing the extensive tire noise data base accumulated during 1970 and 1971, the DOT Office of Noise Abatement continued its interagency agreement with the National Bureau of Standards and expanded the study through additional data collection and/or analysis.

Accomplishments to date for typical bias-ply rib and cross-bar truck tires include: (1) a catalog of maximum A-weighted sound levels; (2) a catalog of one-thid octave and narrow band spectral data; (3) directionality data in the form of octave band and equal A-weighted sound level contours.

The influence of pavement surface has been investigated and includes: (1) tire noise versus surface texture; (2) surface profile measurements; (3) correlation of pavement surface texture with tire noise (a partially successful attempt).

* No cost to government

There has been several other accomplishments: (1) development of an empirical model to predict in-service base noise levels for truck tires on the basis of SAE J57 type tests; (2) a comparison of parametric trends between truck and automobile tires; (3) acquisition of noise data on truck radial tires; (4) determining the effect of load and/or inflation pressure on noise levels; (5) determining the effect of tire size on noise levels; (6) completion of noise measurements on radial tires utilized by HSRI; (7) comparing wear rates with noise levels.

Sponsor: DOT/Office of Noise Abatement
Investigator: National Bureau of Standards

Fiscal Year Funding ($1000):	1974	1975	1976	1977	1978
	120	162	119*		

Tire Noise Basic Research

This experimental and theoretical study has resulted in a description of tire surface vibration; definition of location, small size and high intensity of the acoustic source; prediction of sound pressure and sound power levels from mathematical models and experimental measurements. A comprehensive summary report is in preparation. It is anticipated that publication will occur during the third quarter of FY 78.

Sponsor: DOT/Office of Noise Abatement
Investigator: North Carolina State University

Fiscal Year Funding ($1000):	1974	1975	1976	1977	1978
	150†				

Tire Noise State-of-the-Art

This project was an effort to organize and conduct an open forum symposium to address the current and pertinent information regarding the technical, economic, regulatory, and social aspects of motor vehicle tire noise. The proceedings of this meeting serve as a vehicle for futher dissemination of the information brought forward.

* Total DOT funding for this program was $960K.

† Total DOT funding for this program was $269K.

Sponsor: DOT/Office of Noise Abatement
Investigator: Society of Automotive Engineers/In-house

Fiscal Year Funding ($1000):	1974	1975	1976	1977	1978
	*	*	6	*	

Power Consumption of Truck Tires

It is well documented that radial rib tires are appreciably quieter than bias-ply cross-bar tires and slightly quieter than bias-ply rib tires. In addition, radial tires provide a high potential for lower tire power consumption. This has important implications on fuel economy.

The objective of the program was to develop power loss data on truck tires as a function of tire design (bias-ply radial), tread design (rib, cross-bar), state of tread wear and tire operational parameters (load, inflation pressure, speed), road surface (flat belt versus drum), tire temperature, slip angle, torque and trip length.

The data indicate 50 percent lower rolling resistance for radial tires.

Sponsor: DOT/Office of Noise Abatement
Investigator: Calspan Corp.

Fiscal Year Funding ($1000):	1974	1975	1976	1977	1978
			60		

Traction Properties of Radial Tires for Heavy Trucks

The body of data currently available concerning truck tire traction is limited; however, since tradeoffs between vehicle safety and tire noise reduction are difficult (if not impossible) to justify, there exists a need to critically evaluate the statement that "tires with good traction make more noise."

To satisfy this need, a tire traction test program was initiated by DOT in FY 76. This study will perform a comprehensive

* In-house

set of longitudinal and lateral force measurements on both dry and wet pavement for a sample of six popular truck tires of radial construction.

Results show that for both wet and dry conditions tires exhibiting improved traction performance are generally those whose tread patterns yield lower noise output. Regarding both lateral and longitudinal traction properties, the common usage of cross-bar tires on rear driving axles (with rib tires on the steering axle) results in a typically disadvantageous arrangement from an on-highway vehicle control point of view, i.e., braking and cornering maneuvers.

Sponsor: DOT/Office of Noise Abatement
Investigator: Highway Safety Research Institute of the University of Michigan

Fiscal Year Funding ($1000):	1974	1975	1976	1977	1978
			46		

Life Cycle Costs of Quiet Truck Tires

The life cycle costs associated with tires of various carcass construction/tread design need to be documented so that the optimal trade-off between noise and economical liabilities can be assessed as a basis for future tire noise regulations. The purpose of this task is to quantify the costs associated both with current tire use practices and with revisions to these use practices which may be necessary to comply with such regulations.

Typical tire use practice for both local and long haul service will be depicted, including tire and wheel purchasing, maintenance, and inventory; vehicle running gear maintenance, vehicle mileage, fuel usage, etc. Significant variables in tire economics such as vehicle configuration and power, regional roadway and/or terrain, maintenance practices, recapping practices, etc., will be determined. Cross-bar replacement strategies will be postulated and the tire use and variable factor scenarios will be extrapolated to California and the nation to obtain an aggregate cost picture of the present and regulated future.

The contract was awarded in the first quarter of FY 77 with completion scheduled for the second quarter of FY 78.

Sponsor: DOT/Office of Noise Abatement
Investigator: Wyle Laboratories

Fiscal Year Funding ($1000):	1974	1975	1976	1977	1978
			54		

Model Studies of Truck Noise Measurement Sites

This contract was for the construction of detailed acoustic models of two designated highway sites, the conduct of acoustic measurements utilizing these scale models, and the comparison of scale model noise propagation with field measurement data previously obtained by TSC at sites in the Fort Wayne, Indiana, area. The objective was to investigate the possibility of using scale models to determine the effects of site topography near roadways on the propagation of noise from trucks. Two general findings were that a vehicle as a point source cannot be modeled because of strong interference patterns and that a distributed source (several point sources) correlates reasonably well with field measurement data.

Sponsor: DOT/Office of Noise Abatement
Investigator: Cambridge Collaborative

Fiscal Year Funding ($1000):	1974	1975	1967	1977	1978
			25		

Roadside Noise Enforcement Sites

To support DOT in their responsibilities for highway noise reduction enforcement, TSC performed field noise measurements to define the requirements for acceptable interstate motor carrier noise enforcement sites along highways. The measurement program to categorize the highway sites was conducted by TSC at Fort Wayne, Indiana, during the period July 8-20, 1974. Data recorded at eight microphone locations at each of ten different measurement sites were reduced, tabulated and analyzed. A civil engineering firm was obtained to conduct a detailed topographical survey of each of the measured sites.

Sponsor: DOT/Office of Noise Abatement
Investigator: Transportation Systems Center

Fiscal Year Funding ($1,000)	1974	1975	1976	1977	1978
		*	*	*	*

Environmental Noise Test Variables

Although existing voluntary standards have achieved considerable uniformity, significant variations remain between noise measurements made at different sites or on different times on the same site. These differences are in part attributable to differences in the environment, including site and meteorological influences. An understanding of the magnitude and extent of these effects will provide a basis for better site selection criteria and possible redefinition, or elimination, of existing tolerance factors, and will ensure more uniform enforcement by DOT of the EPA Interstate Motor Carrier and Interstate Rail Carrier Noise Emission Regulations.

To satisfy the need for experimental work, DOT is sponsoring a portion of an Environmental Variables Study in cooperation with the Motor Vehicle Manufacturers Association (MVMA) and the Engine Manufacturers Association (EMA). The exporimental program will measure the acoustic, vehicle, and environmental data for a variety of vehicle and environmental conditions. These data will be used to determine the systematic and nonsystematic dependence of observed truck drive-by and stationary noise on the environmental effects present during the measurement. The experiment is designed to permit separation of generation/radiation and propagation effects. During the fourteen months from September 1976 to November 1977, NBS mounted a substantial effort to conduct the experimental program. However, a wide range of technical difficulties relating to the complexity of the program forced termination before achievement of the stated goals.

Sponsor: DOT/Office of Noise Abatement
Investigator: National Bureau of Standards

Fiscal Year Funding ($1000):	1974	1975	1976	1977	1978
				28†	

* In-house funds

† Does not include DOC funding of $150K in FY 77, and MVMA and EMA funding of $10K in FY 76 and $60K in FY 77

Highway Noise Prediction

This task involves an extensive field measurement, data reduction and analysis program to evaluate the three existing highway noise prediction programs against field data and, where needed, to develop a revised noise prediction scheme. The work includes making the three existing programs-TSC model, Michigan 117 model and Revised Design Guide model-operational at TSC and utilizing a computer graphics system to present various output plots to aid in the analysis of results.

These data were used as the basis for evaluating the predictive models and for revision (minor) of the TSC model. This effort was initiated in FY 76 and the final report is now being printed.

Sponsor: DOT/Office of Noise Abatement
Investigator: Transportation Systems Center

Fiscal Year Funding ($1000):	1974	1975	1976	1977	1978
	*	*	*	*	*

Roadside Barrier Effectiveness

To more accurately predict and assess the performance of barriers as a method of wayside noise reduction, a series of controlled experiments were conducted under conditions of heavy (line source) traffic. A temporary 1000-foot plywood barrier was constructed for this purpose along I-93 in Andover, Massachusetts. The TSC Noise Measurement and Assessment Laboratory made baseline noise measurements at the site prior to and following construction of the barrier. Measurements were made for barrier heights of 4, 8, 12 and 16 feet and with the barrier surface in both a reflective (unpainted plywood) and an absorptive (acoustic fiberglass board) condition.

These tests show that the insertion loss of the barrier cannot be accurately predicted by use of existing design charts which do not take into account ground absorption effects. However, existing design charts can be used with reasonable accuracy to predict noise levels behind a barrier as long as the level at a reference

* In-house funds

point above the barrier is known or can be predicted accurately. It may be possible to postulate corrections to take into account the effect of the ground and revise the current design charts accordingly.

Sponsor: DOT/Office of Noise Abatement
Investigator: Cambridge Collaborative and DOT/Transportation Systems Center

Fiscal Year Funding ($1000):	1974	1975	1976	1977	1978
	40	47	39		

Optimization of Audible Warning Devices

Under this program, tests were conducted to determine the effectiveness of existing audible warning signals for emergency vehicles and to determine if ways exist to minimize community annoyance. Final report has been published.

Sponsor: DOT/Office of Noise Abatement
Investigator: Society of Automotive Engineers and Bolt, Beranek, and Newman

Fiscal Year Funding ($1000):	1974	1975	1976	1977	1978
	99				

Railroad Retarder Noise Abatement

A cooperative effort was undertaken between DOT (TSC) and the Burlington Northern Railroad to collect, assess, and disseminate information regarding the character of the noise environment associated with the operation of active retarders in railroad classification (hump) yards, and also, to present in useful form information on the use of noise barriers to reduce retarder noise both in the yard and in surrounding communities. Data were obtained during a parametric analysis program conducted at the Northtown freight classification yard of the Burlington Northern Railroad in Fridley, Minnesota. TSC made the noise measurements, obtained baseline data, and analyzed the noise environment under controlled test conditions for: (1) a retarder without a noise barrier and (2) the identical retarder shielded by a variable geometry noise barrier.

The final report indicates the positive effect of barriers to reduce lateral sound propagation from classification yard retarders and the further improvement to be gained by use of absorptive surfaces on the barriers.

Sponsor: DOT/Office of Noise Abatement
Investigator: Burlington Northern, Inc. and Transportation Systems Center

Fiscal Year Funding ($1000):	1974	1975	1976	1977	1978
		69	*	*	

OFFICE OF ENVIRONMENTAL AFFAIRS

A Comprehensive Policy to Ameliorate Adverse Effects of Transportation Facilities

This project analyzed ways to reduce adverse effects to persons and property adjacent to transportation facilities. It addressed potential policy and legislative initiatives for such adverse impacts as noise and property value loss that detract from the overall positive benefits of airport, highway and mass transportation facilities.

Sponsor: DOT/Office of Environmental Affairs; DOT/Office of the Secretary; DOT/Urban Mass Transportation Administration; DOT/Federal Highway Administration; and DOT/Federal Aviation Administration.

Investigator: Urban Systems Research and Engineering, Inc.

Fiscal Year Funding ($1000):	1974	1975	1976	1977	1978
		130			

Environmental Assessment Notebook Series: Highways

An Environmental Assessment Notebook Series will be designed as a technical resource manual for those who are responsible for conducting transportation planning and environmental impact assessment studies. The Notebook Series is an attempt to better integrate the transportation planning process and the environmental impact assessment process.

* In-house funds

It describes techniques for conducting social, economic, and physical impact analyses as a means of facilitating and improving the quality of the environmental assessment process and organizing the findings in a readily usable form.

Sponsor: DOT/Office of Environmental Affairs
Investigator: Skidmore, Owings and Merrill, Inc.

Fiscal Year Funding ($1000):	1974	1975	1976	1977	1978
	310				

Environmental Assessment Notebook Series: Mass Transit

An Environmental Assessment Notebook Series will be designed as a technical resource manual for those who are responsible for conducting transportation planning and environmental impact assessment studies. The Notebook Series is an attempt to better integrate the transportation planning process and the environmental impact assessment process.

It describes techniques for conducting social, economic, and physical impact analyses as a means of facilitating and improving the quality of the environmental assessment process and organizing the finds in a readily usable form.

The study will be initiated early in FY 78, with an estimated 12-month completion date.

Sponsor: DOT/Office of Environmental Affairs
Investigator: Not cited

Fiscal Year Funding ($1000):	1974	1975	1976	1977	1978
				100	

FEDERAL HIGHWAY ADMINISTRATION

Noise Standards and Procedures

Section 114 of the Federal-Aid Highway Act of 1973 (Public Law No. 93-87) authorized FHWA to develop and promulgate procedures which would permit state highway agencies to use apportioned Federal Highway funds for abatement of traffic noise from existing highways. Interim regulations providing guidelines for the

submission and approval of noise abatement projects on previously constructed highways were promulgated on February 13, 1974, and published February 22, 1974 (39 FR 6696). These regulations were promulgated in final form on May 14, 1976 as a Federal-Aid Highway Program Manual (FHPM).

Sponsor: DOT/Federal Highway Administration
Investigator: In-house

Fiscal Year Funding ($1000):	1974	1975	1976	1977	1978
	*	*			

Highway Barrier Design: Acoustic Attenuation Surfaces and Materials

The original objective of this study was to explore the ramifications of using sound absorbing material on existing highway noise barriers and within tunnels. The scope of the study was expanded to include barrier design considerations. The study has been completed, and the results have formed the basis for a series of handbooks relating to noise barrier design.

Sponsor: DOT/Federal Highway Administration
Investigator: Bolt, Beranek and Newman

Fiscal Year Funding ($1000):	1974	1975	1976	1977	1978
	15	100	97		

Determination of Impact from Vibrations Related to Highway Use

Highway-induced vibrations have been cited as causing both human psychological discomfort and structural damage. The objective of this study was to define the nature and extent of the highway vibration problem by improving the existing understanding of vibration excitation, propagation and effects.

The final report collates and assesses the physical as well as behavioral and legal literature on vibrations from highways, construction, blasting, etc., and develops guidelines to preclude or control environmental vibrations devoting special attention to highway vibration situations resulting in complaints or litigation.

* In-house funds

Sponsor: DOT/Federal Highway Administration
Investigator: Science Applications, Inc.

Fiscal Year Funding ($1000):	1974	1975	1976	1977	1978
		76	109		

Study of Economic Costs of Alternative Measures to Mitigate Highway Noise Impacts

This program is to develop a data base on the costs of alternative measures (to noise barriers) to attenuate highway noise propagation into the community. At 4 to 6 sites within each state, the costs and benefits of such alternatives as (1) razing the dwelling adjacent to the highway, (2) buying the houses and reselling the land for other than residential purposes, (3) soundproofing the houses, etc., were evaluated. FHWA is presently utilizing this information as the basis for an assessment of the nationwide costs of alternative methods of mitigating highway traffic noise propagation into the community.

Sponsor: DOT/Federal Highway Administration
Investigator: State of New York, State of Minnesota, State of Texas, State of Washington, and In-house

Fiscal Year Funding ($1000):	1974	1975	1976	1977	1978
		60	3	*	

Evaluation of Benefits of Source Reduction to Federal Highway Program

This contract was written (1) to perform a cost effectiveness analysis of vehicle source control versus alternative highway noise mitigation measures, (2) to demonstrate to state and local governments the advantages of quieting motor vehicles and (3) to evaluate the effect, if any, of reduced exhaust heights (for trucks).

Sponsor: DOT/Federal Highway Administration
Investigator: Bolt, Beranek and Newman, Inc.

Fiscal Year Funding ($1000):	1974	1975	1976	1977	1978
			13		

* In-house funds

Manual Method for Prediction of Equivalent Sound Levels for Highway Noise

This is a task to prepare a manual for use by the states for predicting the equivalent sound levels generated by freely flowing traffic.

Sponsor: DOT/Federal Highway Administration
Investigator: In-house

Fiscal Year Funding ($1000):	1974	1975	1976	1977	1978
			*	*	

Highway Noise Propagation

This project involves examining the physical phenomenon of propagation of highway noise over finite impedance ground planes through the evaluation of mathematical treatments of wave propagation over absorbing ground planes. The objective of the study is the development of a propagation model based on the rigorous mathematical solution of the boundary value problem.

Sponsor: DOT/Federal Highway Administration
Investigator: Pennsylvania State University and In-house

Fiscal Year Funding ($1000):	1974	1975	1976	1977	1978
			10		

Improvement of Highway Noise Prediction Procedures

This program will identify and correct sources of prediction error and/or inefficiencies associated with the TSC predictive model for highway noise and develop a user's manual for the revised procedures.

Sponsor: DOT/Federal Highway Administration
Investigator: Science Applications, Inc.

Fiscal Year Funding ($1000):	1974	1975	1976	1977	1978
			4	6	

* In-house funds

Application of Acoustical Scale Modeling Techniques to Traffic Noise Propagation at Urban Freeway Sites

Existing highway noise predictive models are applicable to freely flowing traffic on roadways in nonurban areas. It is doubtful that current modeling techniques can handle, with an acceptable degree of accuracy, noise impacted areas adjacent to urban and suburban freeways where prominent structures exist between the highway and the noise sensitive areas. This contract was awarded to develop a procedure more adaptable for noise prediction in the above situations using a combination of the reference site approach and site scale modeling techniques. The project involves selecting actual highway sites, modeling them in the laboratory, and comparing the noise measurements at the site to those obtained under controlled laboratory conditions.

Sponsor: DOT/Federal Highway Adminstration
Investigator: Bolt, Beranek and Newman

Fiscal Year Funding ($1000):	1974	1975	1976	1977	1978
			70	105	

Insulation of Buildings Against Highway Noise

A manual was prepared identifying procedures for selecting effective noise insulation and ventilation modifications for residential buildings to minimize highway noise impacts. The feasibility of applying these design procedures was evaluated as part of the Experimental Projects program, Feasibility of Soundproofing Private Dwellings.

Sponsor: DOT/Federal Highway Administration
Investigator: Wyle Laboratories

Fiscal Year Funding ($1000):	1974	1975	1976	1977	1978
			20		

Aesthetics of Noise Barriers

To be acceptable to the communities, highway noise barriers, in addition to effectively attenuating the highway noise, should be aesthetically pleasing. To highlight this important facet of the barrier design process FHWA has developed a manual for use by highway engineers, landscape architects, and others involved with the design of barriers.

Sponsor: DOT/Federal Highway Administration
Investigator: Organization for Environmental Growth, Inc.

Fiscal Year Funding ($1000):	1974	1975	1976	1977	1978
			80		

Highway Noise Barrier Selection, Design and Contruction Experiences

Techniques and practices in highway noise barrier design and construction are still evolving. Research is underway to refine highway noise prediction methods on which barrier design is based and to develop a procedure to assist in optimizing barrer design and material selection.

Several states have had considerable experience with highway noise barrier design and construction; and others have limited experience which, in the aggregate, constitutes a body of knowledge which can provide guidance for highway engineers in selecting, designing, and constructing noise barriers.

Personnel from FHWA Region 10 cataloged the items that have been and need to be considered in the process of designing noise barriers. Implementation Package 76-B, Highway Noise Barrier Selection, Design and Construction Experiences, documents actual experience such as cost, selection process, site, barrier materials, height, length, etc., which have been reported where information is available. Where factual information based on experience is not available, considerations have been discussed in general terms.

Sponsor: DOT/Federal Highway Administration
Investigator: In-house

Fiscal Year Funding ($1000):	1974	1975	1976	1977	1978
		*	*		

BMCS Guidelines for the Measurement of Motor Carrier Noise Emissions

Michigan Acoustical Consultants developed a guidebook for use by Federal, State and local motor carrier noise enforcement personnel. The bases for the guidebook are the Interstate Motor Carrier Noise Emission Compliance Regulations promulgated by BMCS.

* In-house funds

Sponsor: DOT/Federal Highway Administration
Investigator: Michigan Acoustical Consultants

Fiscal Year Funding ($1000):	1974	1975	1976	1977	1978
			13		

Vegetative Noise Barriers

This study will assess the potential effectiveness of narrow forest barriers in terms of insertion loss relative to highway noise and formulate the research plan for a larger scale study of vegetative and forest noise barriers.

Sponsor: DOT/Federal Highway Administrative
Investigator: Pennsylvania State University

Fiscal Year Funding ($1000):	1974	1975	1976	1977	1978
				10	

Highway Noise and Vibration Research Strategies

A workshop coordinated by Florida Atlantic University was held May 1977 to assist FHWA in identifying the future research needs in highway noise and vibration and in formulating a long range research plan. The workshop resulted in the determination and assessment of the state-of-the-art in highway noise and vibration, identification and prioritization of long term research needs, and the organization of these research needs into manageable research projects.

Sponsor: DOT/Federal Highway Administration
Investigator: Florida Atlantic University/In-house

Fiscal Year Funding ($1000):	1974	1975	1976	1977	1978
				19	

Feasibility of Soundproofing Private Dwellings

Utilizing highway construction funds, FHWA is planning to conduct an experimental project at the state level to demonstrate the feasibility of applying soundproofing to private dwellings as an abatement measure for highway traffic noise. Various soundproofing techniques, such as double-glazed windows, total environmental

conditioning so that windows can be permanently closed, careful attention to sealing acoustic leaks, etc., will be evaluated as to their practicality as a retrofit technique, and as to their effectiveness in insulating against traffic noise and the costs involved. The results will be documented in a summary report.

Sponsor: DOT/Federal Highway Adminstration
Investigator: Not selected

Fiscal Year Funding ($1000):	1974	1975	1976	1977	1978
				*	*

Noise Measurements Related to Highways

During FY 77, FHWA initiated a contract for the development of a manual for use by the states which will present the state-of-the-art of noise measurements related to highways and their effects on the environment. The goal of the manual is the promotion of uniformity among highway noise measurements. Material will include, but not be limited to, noise emission levels for vehicles, insertion loss/attenuation of barriers, evaluation procedures for noise prediction models, etc.

Sponsor: DOT/Federal Highway Administration
Investigator: Dames and Moore

Fiscal Year Funding ($1000):	1974	1975	1976	1977	1978
				20	

NCHRP—Highway Noise Model Project

A design guide was developed under this program which provides the highway engineer or designer with the tools necessary to predict, evaluate and minimize traffic-generated noise in the theoretical, experimental, and practical results developed under other highway noise studies undertaken in the past ten years especially the Michigan 117 model and the DOT/TSC model. The design guide and its supporting technical backup NCHRP Report 173, Highway Noise—Generation and Control and NCHRP Report 174, Highway Noise—A Design Guide for Prediction and Control.

* Funds will come from Highway Construction Funds (experimental project).

Sponsor: DOT/Federal Highway Administration
Investigator: Bolt, Beranek and Newman

Fiscal Year Funding ($1000):	1974	1975	1976	1977	1978
	180				

NCHRP Investigation of Selected Noise Barrier Acoustical Parameters

Procedures currently used to analyze highway noise barriers and to predict their effectiveness have some limitations. The basic objectives of this project are to complete an analysis of certain highway noise barrier parameters in addition to those examined in recent studies.

The additional factors include: (1) barrier cross-sectional shape (mounds, wedges, multiple-edge barriers, etc.); (2) barrier surface characteristics (surface impedance of covering, etc.); (3) barrier influence on ground cover effect (the influence of a noise barrier on the net ground effect on noise propagation).

The study includes the analysis of the significance of these parameters to the overall performance of noise barriers in terms of the sensitivity of barrier effectiveness to each of the study parameters.

Since current procedures for calculating barrier effectiveness are based on the thin-wall barrier assumption, the effects of the factors defined above will be related to the thin-wall barrier case of convenience in the application of the research project results. The project is schedule for completion during the second quarter of FY 78.

Sponsor: DOT/Federal Highway Administration
Investigator: Pennsylvania State University

Fiscal Year Funding ($1000):	1974	1975	1976	1977	1978
				75	

Traffic Noise Prediction and Measurement

To improve their capability for the accurate measurement and prediction of highway noise, the State of Alabama developed and implemented the following analytic and experimental tools: (1) an automated traffic noise data acquisition system and associated

user's manual and (2) a computer program for the prediction of traffic noise based on the methodology of NCHRP Reports 117 and 144 and associated user's manual. The adequacy of the instrumentation system and experimental procedures was verified by carrying out field measurements at a number of highway sites.

Sponsor: DOT/Federal Highway Administration
Investigator: State of Alabama

Fiscal Year Funding ($1000):	1974	1975	1976	1977	1978
	3	21	58		

Traffic Noise Near Highways: Design and Environmental Variables

The State of California attempted to develop better methods for the evaluation, prediction, and control of traffic noise in areas adjacent to highways. They investigated the effect of highway design factors and terrain variables including natural or man-made obstructions, reflecting surfaces, grades, etc. Criteria were developed for desirable separation distances between the nearest travelled roadway lane and noise sensitive areas such as schools, hospitals, and residences.

Sponsor: DOT/Federal Highway Administration
Investigator: State of California

Fiscal Year Funding ($1000):	1974	1975	1976	1977	1978
	12	4	1		

Evaluation of Earth Berm Noise Barriers

An evaluation was made of an experimental noise reduction earth berm constructed alongside I-84 in West Hartford, Connecticut. The noise reduction effectiveness of the barrier was measured, opinions on the effectiveness of the barrier were surveyed among nearby residents, and the measured and predicted noise reduction were compared.

Sponsor: DOT/Federal Highway Administration
Investigator: State of Connecticut

Fiscal Year Funding ($1000):	1974	1975	1976	1977	1978
	2	8			

Propagation of Traffic Noise

The State of Kentucky has initiated a field study to quantify highway noise propagation parameters, i.e., traffic, environmental and geometric factors, in relation to improving the highway noise prediction models.

Sponsor: DOT/Federal Highway Administration
Investigator: State of Kentucky

Fiscal Year Funding ($1000):	1974	1975	1976	1977	1978
			10		

Determination of Truck Noise Levels

The State of New Jersey is conducting an investigation of truck noise levels in order to empirically correct the TSC Highway Noise Prediction Model by accurately classifying truck noise emission levels.

Sponsor: DOT/Federal Highway Administration
Investigator: State of New Jersey

Fiscal Year Funding ($1000):	1974	1975	1976	1977	1978
				79	46

Community Noise Measurements

Noise measurements were made by the State of New Jersey to obtain initial data and to monitor noise sensitive areas in the State. The measurements formed the basis for the investigation, development, and implementation of noise abatement altenatives.

Sponsor: DOT/Federal Highway Administration
Investigator: State of New Jersey

Fiscal Year Funding ($1000):	1974	1975	1976	1977	1978
	52	17	48		

Evaluation of Barrier Design Methods

The State of New Jersey is performing an evaluation of traffic noise barrier design methods in order to develop and implement

a method of evaluating existing noise barrier design methods utilizing noise measurements before and after barrier construction.

Sponsor: DOT/Federal Highway Administration
Investigator: State of New Jersey

Fiscal Year Funding ($1000):	1974	1975	1976	1977	1978
			23	67	47

Noise Measurements

The Oklahoma Department of Highways has received funding for three-year, $136K study to validate the noise prediction models currently utilized by the department. Of special concern is the effect of average daily traffic and truck traffic on the model. The research program will develop procedures for measuring noise using digital sound recording equipment. Noise data will be collected and correlated with the noise prediction models that are currently being used and any new or modified predictive models made available to the states by the FHWA during the time frame of the project.

Sponsor: DOT/Federal Highway Administration
Investigator: State of Oklahoma

Fiscal Year Funding ($1000):	1974	1975	1976	1977	1978
				54	33

Effectiveness of Barrier Design Computer Programs

A field study of highway noise barriers is presently being carried out by the State of Virginia. They are utilizing current prediction procedures to evaluate barrier performance in conjunction with before and after barrier construction measurements which will provide the basis for an assessment of the effectiveness of predictive computer programs in the design of noise barriers.

Sponsor: DOT/Federal Highway Administration
Investigator: State of Virginia

Fiscal Year Funding ($1000):	1974	1975	1976	1977	1978
			30	18	

Acoustic Barrier Research

A series of four reports have resulted from a barrier study by the State of Washington. The study, conducted by the Applied Physics Laboratory, University of Washington, included laboratory modeling and full scale noise studies to investigate barrier attenuation of automobile and truck noise at selected locations.

Sponsor: DOT/Federal Highway Administration
Investigator: State of Washington

Fiscal Year Funding ($1000):	1974	1975	1976	1977	1978
		55	15		

Ground Cover and Wind Effects on Sound Propagation

A field study is underway in the State of Washington to quantify the highway noise propagation losses over various types of ground covers considering the influence of wind speed and direction.

Sponsor: DOT/Federal Highway Administration
Investigator: State of Washington

Fiscal Year Funding ($1000):	1974	1975	1976	1977	1978
			95	48	

FEDERAL RAILROAD ADMINISTRATION

Locomotive Noise Source Assessment

The Transportation Systems Center (TSC) in behalf of the Federal Railroad Administration (FRA) and the DOT Office of Noise Abatement (ONA) and in cooperation with the Association of American Railroads (AAR), initiated a project to assess the overall and individual component noise levels from a typical diesel-electric linehaul locomotive. Data show exhaust, engine cooling fans, and the traction motor cooling system to be the major contributors to overall locomotive noise.

Under a second contract, the data base collected in the above discussed study is being used to develop simplified noise source diagnostic procedures and simplified overall noise level testing procedures to facilitate the field assessment of locomotive noise.

An additional contract to be initiated in FY 78 will address the sources of noise from a locomotive of a different manufacturer.

Sponsor: DOT/Federal Railroad Administration
Investigator: Bolt, Beranek and Newman, Inc.

Fiscal Year Funding ($1000):	1974	1975	1976	1977	1978
	49		17		61

Locomotive and Rail Car Exterior Noise Emissions

This research program will build upon previous efforts of the locomotive noise sources assessment program and will further investigate specific sources of noise and address the need for additional data to support standards associated with the December 1975 Federal Railraod Noise Emission Regulation.

Specific requirements to be addressed include: (1) compliance certification of stationary locomotives, (2) the effect of load cell noise as a contaminant in stationary locomotive tests, (3) the difficulty in determining individual locomotive noise contributions in moving consists, and (4) identification of individual rail car noise contributions in a moving train.

FY 77 Funded tasks include:

(1) A survey of load cells will be conducted to evaluate their design, location and estimated noise level. Methodology will be developed to relate locomotive noise levels measured at typical load cell sites to those measured at sites in strict conformance with the requirements of the 1975 noise emission regulation.

(2) The feasibility of developing and demonstrating simplified noise measurement procedures, e.g., unloaded, stationary tests, that correlate with measurements made in strict accordance with the 1975 regulation.

The contract was awarded in the first quarter of FY 78.

Sponsor: Federal Railroad Administration
Investigator: Bolt, Beranek and Newman

Fiscal Year ($1000):	1974	1975	1976	1977	1978
				72	

In-Cab Locomotive Noise Survey

The program is being conducted by the Office of Rail Safety Research in cooperation with the AAR. Technical contract support is being provided under interagency agreement by the Department of Commerce, National Bureau of Standards. The objective of the program is threefold: (1) to determine, by means of representative sample of locomotives in operational settings, the extent of crew exposure to noise; (2) to identify simplified test procedures and measurement methodologies that can be used in an operational environment to determine whether or not an individual locomotive is capable of generating excessively high noise levels; and (3) to identify measurement techniques whereby component sources of noise within the locomotive cab can be identified.

This program effort is currently underway and is expected to continue through May 1978.

Sponsor: DOT/Federal Railroad Administration
Investigator: National Bureau of Standards

Fiscal Year Funding ($1000):	1974	1975	1976	1977	1978
				103	45

URBAN MASS TRANSPORTATION ADMINISTRATION

New York City Transit System Study

This project was funded under the UMTA University grant program to study the problems of noise in the community and the noise environment of riders and customers waiting in stations. The grant was extended in FY 76 (see description under "Noise Assessment of the New York City Rail Transit System").

Sponsor: DOT/Urban Mass Transportation Administration
Investigator: Polytechnic Institute of New York

Fiscal Year Funding ($1000):	1974	1975	1976	1977	1978
	120				

Chicago Transit Authority Study

This project was to study the problems of noise in the community and the noise environment of riders and customers waiting in stations. The report will be published in FY 78.

Sponsor: DOT/Urban Mass Transportation Administration (University grant program)
Investigator: University of Illinois

Fiscal Year Funding ($1000):	1974	1975	1976	1977	1978
	66				

Cleveland, Philadelphia, and San Francisco Transit System Studies

This project was to study the problems of noise in the community and the noise environment of riders and customers waiting in stations. The report will be published in FY 78.

Sponsor: DOT/Urban Mass Transportation Administration
Investigator: Boeing-Vertol

Fiscal Year Funding ($1000):	1974	1975	1976	1977	1978
	120				

Wheel/Rail Noise and Vibration Study

This project was to develop wheel/rail noise and vibration control technology. A two volume report presents analytical models of impedance, response, radiation efficiency, directivity of wheels and rails, and analytical formulas for the prediction of wheel/rail noise.

Sponsor: DOT/Urban Mass Transportation Authority
Investigator: Bolt, Beranek, and Newman

Fiscal Year Funding ($1000):	1974	1975	1976	1977	1978
	184				

Track and Elevated Structure Noise and Vibration

A theoretical model was developed for the prediction of noise radiated by elevated structures on rail transit lines. The validity of the predictive model was shown through comparison with a field

study of three different types of elevated structures on the Massachusetts Bay Transportation Authority. Also developed was a theoretical model for the prediction of vibration reduction by use of floating slab tracks in subway tunnels. The results of this study are documented in a series of three reports.

Sponsor: DOT/Urban Mass Transportation Administration
Investigator: Cambridge Collaborative

Fiscal Year Funding ($1000):	1974	1975	1976	1977	1978
	147				

In-Service Noise Abatement: Test and Evaluation

The Southeastern Pennsylvania Transportation Authority (SEPTA) was selected to serve as a test bed for a study of the most promising currently available techniques for abating rail/wheel noise at its source. These techniques include rail grinding, wheel truing, and using resilient wheels and wheel damping.

While these four techniques are employed on a very limited basis, careful records are being kept on the actual cost of installing, maintaining, and utilizing the appropriate hardware. Noise measurements are taken while these abatement techniques are being utilized, and the results compared with normal trains under comparable conditions. These measures of cost and effectiveness are obtained concurrently.

Sponsor: DOT/Urban Mass Transportation Administration
Investigator: DeLeuw Cather; and Wilson, Ihrig & Associates

Fiscal Year Funding ($1000):	1974	1975	1976	1977	1978
		379	46	*	50

New Systems Specifications: Capital Grants

In addition to the research and demonstration program activities, very important improvements and advancements are being made as a result of progressive systems specifications being drawn for

* Funding includes noise considerations which are not separately identified.

new transit systems which are being developed with massive Federal support. Such specifications exhibit incremental noise improvements with time. Estimates of the costs of such specifications cannot be provided; however, the noise reduction contributions of such system specification will be significant.

Sponsor: DOT/Urban Mass Transportation Administration
Investigator: Not cited

Fiscal Year Funding ($1000):	1974	1975	1976	1977	1978
	*	*	*	*	*

State-of-the-Art Car

Programs such as the State-of-the-Art Car and the development of a screech loop at the Pueblo High Speed Test Center will add to the body of information permitting continuous improvement in rapid transit noise control.

Sponsor: DOT/Urban Mass Transportation Administration
Investigator: Boeing-Vertol/Transportation Systems Center

Fiscal Year Funding ($1000):	1974	1975	1976	1977	1978
	†	†	†	†	†

Screech Loop Pueblo Facility

Programs such as the State-of-the-Art Car and the development of a screech loop at the Pueblo High Speed Test Center will add to the body of information permitting continuous improvement in rapid transit noise control.

Sponsor: DOT/Urban Mass Transportation Administration
Investigator: Transportation Systems Center

Fiscal Year Funding ($1000):	1974	1975	1976	1977	1978
	††	††	††	††	††

* Not dedicated primarily to surface transportation noise
† Funding includes noise considerations which are not separately identified
†† In-house funds

Noise Assessment of the New York City Rail Transit System

This project is a continuation of an UMTA University Grant initiated in FY 74. Three efforts are being undertaken:

- Reviewing and up-grading of the cost estimates for noise reduction in the previous NYCTA noise assessment work.
- Field measurements to monitor "degradation" (in terms of noise) of specific car models.
- Analysis of car maintenance records to determine useful life and costs of car improvements.

Sponsor: DOT/Urban Mass Transportation Administration (University Grants Program)
Investigator: Polytechnic Institute of New York

Fiscal Year Funding ($1000):	1974	1975	1976	1977	1978
			62		

Advanced Automated Systems

This task involves systems development and exploratory efforts in the area of personal and group rapid transit systems (PRT's and GRT's) and also includes noise related activities as a part of the advanced work necessary to determine applicability of such systems for future transportation needs.

Sponsor: DOT/Urban Mass Transportation Administration
Investigator: Not cited

Fiscal Year Funding ($1000):	1974	1975	1976	1977	1978
	*	*	*	*	*

Elevated Structure Noise Control

Previous UMTA funded research in this area (FY 74) has resulted in analytical tools for predicting noise from elevated rail transit structures. These tools will now be used to interpret and extend

* Not dedicated primarily to surface transportation noise

the results of field tests of noise abatement on elevated structures in order to develop a "Noise Control Design Guide for Elevated Structures". Specific recommendations will be given for reducing noise from the noisiest types of U.S. elevated rail structures.

Sponsor: DOT/Urban Mass Transportation Administration
Investigator: To be determined

Fiscal Year Funding ($1000):	1974	1975	1976	1977	1978
					*

Handbook of Urban Rail Noise and Vibration Control

During FY 76-77, DOT/TSC wrote a summary of the available technology for prediction and control of rail system noise. This document will form the basis of a Handbook of Urban Rail Noise and Vibration Control. Work on this handbook will be initiated in FY 78.

Sponsor: DOT/Urban Mass Transportation Administration
Investigator: To be determined

Fiscal Year Funding ($1000):	1974	1975	1976	1977	1978
					150

Transbus Program

The UMTA Transbus research and development program, undertaken with the participation of bus operators and suppliers (General Motors Truck and Coach; Rohr, Inc.; and AM General Corporation) has developed a number of design and performance improvements for incorporation into the specifications for ordering full size transit buses.

Sponsor: DOT/Urban Mass Transportation Administration
Investigator: Rohr Industries, General Motors Truck, and Coach and AM General Corp.

Fiscal Year Funding ($1000):	1974	1975	1976	1977	1978
	†	†	†	†	†

* Funds allocated; amount not disclosable because of contract procurement procedures.

† Funding includes noise considerations which are not separately identified.

Purchase Specifications, Transit Coaches

The Mitre Corporation examined current transit bus models to determine specific improvements that can be accomplished through a modification program. Three improvement kits, consisting of new or modified components to lower exterior bus noise were recommended: treatment of the radiator fan, insulation of the engine compartment, and the addition of an effective air intake silencer. The proposed kits were not prototype tested.

Mitre proposed a new noise measurement procedure for diesel transit buses, based on SAE J366. Procedures for making interior measurements at various positions within the bus were also proposed.

Sponsor: DOT/Urban Mass Transportation Administration
Investigator: Mitre Corp.

Fiscal Year Funding ($1000):	1974	1975	1976	1977	1978
		22			

Development of a Noise Control Design Guide for Urban Rail Transit Elevated Stuctures

This study will assess and utilize existing models of elevated structure noise propogation, inventory U.S. urban rail transit elevated structures, and review existing noise control case studies and case history data. Field and laboratory testing will be conducted to determine engineering and cost effectiveness of noise control measures. From this work a design guide for noise abatement in existing elevated structures will be prepared.

Sponsor: DOT/UMTA
Investigator: Not selected

Fiscal Year Funding ($1000):	1974	1975	1976	1977	1978
					350

APPENDIX C

ENVIRONMENTAL PROTECTION AGENCY
RD&D PROGRAMS

APPENDIX C

ENVIRONMENTAL PROTECTION AGENCY

Funding for 1976 includes the transition quarter (July 1, 1976 to September 30, 1976). Figures cited for 1977 and 1978 represent estimates or new data.

Truck Noise Identification and Control Through Enclosure

This project is an extension of the noise control research work done by the DOT in support of the DOT Quiet Truck Program. This is an effort on the part of EPA to advance technology and to demonstrate the existence of technology for reducing truck noise levels below the 80 dBA limit set for January 1, 1982, in the medium and heavy truck regulation. The study involves two principal areas: experimental and analytical methods of identifying truck noise sources, and the development and construction of a closefitting enclosure for engine noise reduction. This program is still in progress.

Sponsor: EPA/Office of Noise Abatement and Control
Investigator: Purdue University

Fiscal Year Funding ($1000):	1975	1976	1977	1978
		155		25

Quiet Truck Demonstration

This effort is a continuation of the noise control research work done by DOT from FY 72 through FY 74. This program will have three activity areas. The first two involve continuing efforts to develop noise abatement measures of light, medium, and heavy trucks and the demonstration of their effectiveness. The third is to demonstrate compatibility of noise control measures with operational service requirements. New trucks will be procured and modified to incorporate identified noise reduction components. All variables surrounding truck performance will be evaluated. This program will provide an input to the total technology assessment which is planned in support of the regulatory process.

Sponsor: EPA/Office of Noise Abatement and Control
Investigator: Elements 1&2 - Applied Hydroacoustics
Element 3 - Not Selected

Fiscal Year Funding ($1000):	1975	1976	1977	1978
				750

Transit Mall Noise Mitigation Demonstration

This study will develop methods for abating noise at transit malls, and demonstrate the effectiveness of these methods at the future Broadway Plaza Mall in New York City. Part of this study will include literature review, evaluation of existing transit malls, and identification and demonstration of advanced noise reduction techniques. This research is a cooperative effort between UMTA of the DOT and the EPA. Project will start in FY 78. UMTA will serve as project manager.

Sponsor: EPA/Office of Noise Abatement and Control, DOT/UMTA
Investigator: New York City

Fiscal Year Funding ($1000):	1975	1976	1977	1978
			40*	

Internal Combustion Engine†

This program will advance noise control state-of-the-art and demonstrate noise reduction techniques applicable to internal combustion engines (gas turbines are excluded). Included are diesel, gasoline, and rotary engines. Engines powering such products as small industrial compressors, automobiles, trucks, marine vessels, locomotives, lawn mowers, chain saws, and tractors are to be considered. Only existing engine concepts will be utilized. The work will focus on methods of adjusting or modifying structure, combustion process, and mechanical design of power producing parts.

Sponsor: EPA/Office of Noise Abatement and Control
Investigator: Calspan and Cambridge Collaborative

Fiscal Year Funding ($1000):	1975	1976	1977	1978
			319	244

* Contribution from other Federal agencies not finalized.

† The internal combustion engine program contributes to both the surface transportation and machinery and construction areas. This program is shown in this report and in the machinery and construction noise report with proportionate funding. Total FY 77 and 78 funding levels are $425K and $325K, respectively. Total planned funding for the program is 2.25 million dollars.

Automatic Identification of Noise Sources

This program will develop a surface transportation noise source identifier for use with community noise monitoring systems. The basis for this program will be a technique using cross-correlation to distinguish noise emissions from from motorcycles, trucks, buses, and automobiles. In addition, alternative identification techniques will be examined.

Sponsor: EPA/Office of Noise Abatement and Control
Investigator: US Army/CERL

Fiscal Year Funding ($1000):	1975	1976	1977	1978
			10	

Highway Noise Impact Through Year 2000

This study provided the information base for developing future strategy and future research needs with respect to vehicular traffic noise. Trucks and cars at high speeds, power trains (engine, transmission), and tires were some of the variables investigated.

Sponsor: EPA/Office of Noise Abatement and Control
Investigator: Wyle Laboratories

Fiscal Year Funding ($1000):	1975	1976	1977	1978
			22	

Comparison of Highway Noise Prediction Models

This study reviews and compares the existing highway noise prediction methodologies of the National Cooperative Highway Research Program (NCHRP), Transportation Systems Center (TSC) of DOT, and Wyle Research Laboratories. The three models often predict different values for identical situations. Simplified methods for estimating the differences among the predictive models are identified. Conclusions on the validity of these models are

drawn. In addition based on this analysis a highway noise impact review manual was published in May 1977.

Sponsor: EPA/Office of Noise Abatement and Control
Investigator: Wyle Research Laboratories

Fiscal Year Funding ($1000):	1975	1976	1977	1978
			25	

Recreational Land Use Noise Reduction Demonstration at a Public Forest

This study is to develop for recreational land use areas noise assessment techniques, noise criteria, and noise abatement measures, e.g. operational reductions and land management. The abatement procedures developed are to be demonstrated at selected forest land recreational sites. This study is a cooperative program between the Department of Agriculture and the EPA.

Sponsor: EPA/Office of Noise Abatement and Control, USDA/Forest Service
Investigator: Department of Agriculture/Forest Service

Fiscal Year Funding ($1000):	1975	1976	1977	1978
			50*	35*

Evaluate Change in Sensitivity of Microphone Systems as a Function of Temperature and Humidity

This study evaluated three pressure transducers: the condenser and electret microphones and the hydrophone. Areas investigated were:

- the effects of temperature on sensitivity
- the effects of humidity on the condenser and electret microphones
- the significance of temperature and himidity effects on the computation of L_{eq}.

* EPA contribution only.

Sponsor: EPA/Office of Noise Abatement and Control
Investigator: Department of Commerce/National Bureau of Standards

Fiscal Year Funding ($1000):	1975	1976	1977	1978
	18			

Acoustic Classification of Highway Vehicles

This study investigated the possiblility of using the Cross Correlation Classifier System developed by ENSCO for the Army to classify highway vehicles (cars, trucks, buses, and motorcycles) by their noise signatures. This study was a preliminary effort toward developing an inexpensive highway noise monitor.

This study results indicated that the Cross-Correlation Classifier System was inapplicable for classifying the various nonmilitary highway vehicles. The signature variations within any specific civilian class makes isolation of a single vehicle class extremely difficult.

Sponsor: EPA/Office of Noise Abatement and Control
Investigator: ENSCO, Inc.

Fiscal Year Funding ($1000):	1975	1976	1977	1978
		7		

Characteristics of Microphone Windscreen Performance

Characteristics of microphone windscreen performance when used as part of a sound measurement system will be investigated. The study will consider wind noise as a function of wind speed; and wind screen size, material, and porosity.

Sponsor: EPA/Office of Noise Abatement and Control
Investigator: Department of Commerce/National Bureau of Standards

Fiscal Year Funding ($1000):	1975	1976	1977	1978
			10	

Highway Noise Mitigation Demonstration

The purpose of this study is to demonstrate highway noise control technology. The study will be conducted in four phases:

identification of sites suitable for demonstrating noise mitigation measures, determination of available mitigation alternatives, demonstration, and evaluation and dissemination of information on results. Various mitigation measures such as barriers, and land use management are to be considered. The major interest is in the demonstration of barrier effectiveness. This effort is to be a cooperative program between the FHWA of DOT and the EPA.

Sponsor: EPA/Office of Noise Abatement and Control, DOT/Federal Highway Administration

Investigator: New York State

Fiscal Year Funding ($1000):	1975	1976	1977	1978
				20*

Tire Noise Reduction

The objective of this program is to provide a technology and cost demonstration of quiet tires for light medium and heavy duty highway vehicles. The first phase of this program scheduled for FY 78, will study and address unresolved technological issues such as:

(A) By class of tire, which of the potential sources of noise (tread air pumping, tread vibration, carcass vibration, rim and wheel vibration, aerodynamics, etc.) dominates or significantly contributes to the overall tire noise level?

(B) Are there reliable methods of identifying and measuring the relative contribution of noise from each source?

(C) Are there reliable methods of predicting or estimating the relative contribution of noise from each source?

(D) If there are methods of predicting the noise, are these methods based upon a relationship between tire noise and tire materials and designs in such a manner as to provide insight as to what design changes will lead to reduced noise?

(E) Can changes in other operational parameters (wear, ride, handling, traction, etc) to be quantitatively predicted for proposed changes in designs to reduce noise?

* EPA funding only, FHWA funding has not been finalized.

The results will advance the state-of-the-art in noise control engineering as applied to tires of various classes. The second phase of this program will demonstrate the technology and costs associated with quiet tires.

Sponsor: EPA/Office and Noise Abatement and Control
Investigator: Not selected

Fiscal Year Funding ($1000)	1975	1976	1977	1978
				150*

* The estimated total funding from FY 78 thru FY 81 is $675K.

APPENDIX D

DEPARTMENT OF DEFENSE
RD&D PROGRAMS

APPENDIX D

DEPARTMENT OF DEFENSE

The fiscal year funding for 1976 includes the transition quarter (July 1, 1976 to September 30, 1976). Funding figures for 1977 and 1978 are estimates or represent incomplete new data.

TARADCOM Analysis of Armored Reconnaissance Scout-Vehicle Contractor Program to Reduce Exhaust System Noise, Noise Reduction of the M561 (Gama Goat) and Information Dissemination

The noise reduction effort on the Scout Vehicle was initiated because of the reduced noise required in a reconnaisance vehicle. The contractor's work accomplished, mainly on the exhaust system, was closely monitored to arrive at required specification levels.

The M561 and M792 GAMA GOAT 1-1/4 ton cargo and ambulance vehicles are somewhat different type trucks in that the engine is directly behind the cab. The driver and assistant driver therefore are in close proximity to a high level noise source. A kit was designed which consisted only of sound barrier and absorption materials attached to the inside of the cab. The heavy sound barrier material attached to the cab rear surface provided sound transmission reduction between the engine and cab personnel. The noise was reduced to within three dB of the military standard limit of 85 dB and below the 90 dB limit of the Motor Carrier Safety Regulation.

The dissemination of noise information to the various vehicle offices and other Army agencies is an important phase of the noise effort. Vehicle offices are required to be aware of relatively new noise requirements and limits from initial to final phases of procurement, production and test. Certain mission operational condition such as "Silent Watch" have differing or no documented noise requirements and each case is studied and noise levels developed as needed. Noise requirements and limits for vehicles are delineated in the Army's MIL-SID 1474A "Noise Limits for Army Materiel," March, 1975; TB-MED 251 "Noise and Conservation of Hearing (Army), March 1972; The Noise Control Act of 1972; and EPA, DOT/FHWA regulations imposed on the commercial vehicle manufacturer.

Sponsor: Army/TARADCOM
Investigator: In-house

Fiscal Year Funding ($1,000):	1974	1975	1976	1977	1978
	20	60	10	60	30

Computer Correlation of Vehicle Detectability

A research effort was funded to devise a computer program which would predict the distance to inaudibility based on measured vehicle noise levels and conditions including hearing threshold, terrain, climate (wind, temperature, etc.) foliage and vegetation, barriers and other variables. These are fed into the program. The computer then prints out a predicted range to inaudibility in meters. Reports were issued in August, 1974 (DOD ref. 11) and January 1977, (DOD ref. 16).

Sponsor: Army/TARADCOM
Investigator: Bolt Beranek and Newman

Fiscal Year Funding ($1000):	1974	1975	1976	1977	1978
	30	12	30	20	

Isolation and Measurement of Component Noise Emissions of a M813 5-Ton Cargo Truck

The M813 5-ton cargo was the subject of an out-of-house research and development effort to reduce in-cab noise. This program was accomplished in two phases. In the first, sound reduction materials were installed in the cab and in the engine compartment. Noise levels were reduced but insufficiently to meet targeted limits. Further modifications to the exhaust system and coolant fan installation made a further reduction in the cab and on the exterior but not to anticipated acceptable levels. Further recommended work includes a clutch fan of the viscous type. Costs for the two step reduction are estimated at $189 and $410, respectively. A report was issued in July, 1974 (DOD ref. 13).

Sponsor: Army/TARADCOM
Investigator: Cummins Engine Co./H.L. Blachford, Inc.

Fiscal Year Funding ($1000):	1974	1975	1976	1977	1978
	40	20		40	120

Noise Reduction of Military Vehicles

This program consisted of four major tasks.

1. Survey Noise Conditions, Existing Vehicle Fleet

The first task of this program was a continuation of work to evaluate noise conditions of the present vehicle fleet. This baseline data enabled a rank ordering of vehicles for further attention with the initial noise analysis and reduction effort on combat vehicles of high density, high noise level and/or high personnel exposure to hazardous levels. Immediate attention was given to equipment in Product Improvement Program (PIP) stages. Vehicles which are subjects of Equipment Improvement Reports (EIR's), Engineering Change Proposals (ECP's) and Unsatisfactory Equipment Reports (UER's) also will be high in order for work to be performed. The task will be structured as follows:

(1) Rank order vehicles

(2) Test for baseline data

(3) Complete eight vehicle types per year (five vehicles of each type) for 3 years.

Seven vehicles have already been satisfactorily evaluated. The results of this work have been published in TACOM Technical Report No. 82628, "Procedure for Statistical Analysis of Vehicular Noise Emission Spectra for Limited Samples."

Investigator: In-house

2. Analyze and Rank Order Noise Sources on Selected Fleet Vehicles

Based on the priorities established in the above task, an experimental phase will determine major noise sources and determine noise control methodology for selected fleet vehicles.

This task will cover two vehicle type per year, one combat and one tactical type, for 5 years.

Investigator: In-house and unspecified contractor.

3. Perform Experimental Noise Reduction as Required

Once noise sources have been isolated and rank order, noise abatement techniques will be developed that will be cost beneficial as a kit installation in the field or in production as applicable.

Investigator: Not specified

4. TECOM Validation of Noise Reduction Modification Effectiveness

The vehicle with a final design product or modification will require validation testing by TECOM to determine that the vehicle meets the military standards or other performance requirements for aural detectability at a distance.

Validation data will be compared to Motor Carrier, and Medium and Heavy Truck Regulations for those vehicles likely to travel public roadways within cities and on highways.

Sponsor: Army/TARADCOM
Investigator: TARADCOM (In-house)/TECOM

Fiscal Year Funding ($1000):	1974	1975	1976	1977	1978
	30	50	120	78	200

Research in Power Train Noise

The power train is a major source of noise on many vehicles, both combat and tactical. In a parallel effort on representative candidates such as the M60 and M520 GOER cargo, the scope of work will include:

- Isolation of engine and drive train from chassis through the use of high compliance vibration reduction mountings
- Reduction of airborne noise through the use of manifolding mounted exhaust silencers and noise reducing absorption and barrier materials

- Noise reduction investigation of the drive train through use of improved gear design. NOTE: Progress has been attained on the M520 GOER cargo. The draft technical report is complete. It indicates such gear redesign is required and this constitutes a good starting point.

Sponsor: Army/TARADCOM
Investigator: In-house

Fiscal Year Funding ($1000):	1974	1975	1976	1977	1978
		30		60	60

Track and Suspension Noise Reduction Research

Due to the seriousness of the noise problem on tracked vehicles, the Army initiated three studies.

1. One study consisted of a theoretical and experimental analysis of the track and suspension system. This consisted of three phases:

   - The design of a computer program to simulate the track and suspension
   - The isolation of the noise produced by the sprocket, idler and roadwheels in order to determine the contribution of each of these sources
   - The measurement of vibration levels at the suspension system, and force-to-noise transfer functions for predicting interior noise levels.

In order to pursue the theoretical finds of this study, an experimental idler will be designed and tested to determine the actual noise reduction achievable when measuring, in isolation, the noise of a low compliance idler. In addition, the compliance and shape of the inner track will be modified to assess potential noise reduction.

Further analysis will include the determination of coupling efficiency between the suspension system and the hull, and the potential noise reduction achievable by structural changes to the hull.

Sponsor: Army/Human Engineering Laboratory
Investigator: FMC Corp,; Bolt Beranek and Newman

Fiscal Year Funding ($1000):	1974	1975	1976	1977	1978
			130	130	130

2. A second study was aimed primarily at light tracked combat vehicles with the M113A1 armored personnel carrier as a possible test rig candidate. The contribution to overall noise of sprockets, idlers, roadwheels, and track will be investigated through a one-tenth scale vehicle model developed by TARADCOM.

Sponsor: Army/TARADCOM
Investigator: In-house and unspecified contractor

Fiscal Year Funding ($1000):	1974	1975	1976	1977	1978
	30	30	30	60	40

3. A third study analyzed and described in quantitative terms the noise reducing effect of track tension variations stemming from the geometric changes in track periphery accompanying chordal action and from the sprocket driving action. The mechanical and/or structural concepts selected for controlling noise and vibration will be designed, fabricated, and tested for effectiveness.

Sponsor: Army/DARCOM
Investigator: In-house

Fiscal Year Funding ($1000):	1974	1975	1976	1977	1978
			54	40	

Provide Technical Assistance in Development of Design Concepts for New Vehicles

In addition to supporting noise measurement and redution in the present vehicle fleet, an important part of the proposed program involves the establishment of close liaison with offices engaged in development, design, and specification of new vehicles. Much can be done in the earliest stages. Advance knowledge of the type of engine, track and suspension, and/or body style permits a preliminary estimate of nose conditions. This task will:

- Provide technical guidelines to the vehicle manager in development and design of concept and new vehicles and equipment toward acceptable noise conditions
- Provide similar technical assistance to suppliers and contractors where indicated by the vehicle manager
- Support draft technical specification to support limits required by Required Operational Capability (or other document) and to delineate required tests.

Sponsor: Army/TARADCOM
Investigator: In-house

Fiscal Year Funding ($1000):	1974	1975	1976	1977	1978
				30	30

Other Component Research

Candidate components include:

- Cooling fans - newer fans include high efficiency, low rotational speed and viscous (clutch type) units and high efficiency radiators.
- Low volume, low back pressure exhaust and intake silencers (mufflers)
- Mountings with new, higher compliance values for improved vibration isolation to meet severe shock requirements, etc.
- Turret hydraulic system - important during silent watch.

Other important noise sources will be identified through coordination with vehicle user (Ft. Knox, etc.).

The work will be coordinated with appropriate TARCOM/TARADCOM offices.

Sponsor: Army/TARADCOM
Investigator: In-house

Fiscal Year Funding ($1000):	1974	1975	1976	1977	1978
					40

APPENDIX E

DEPARTMENT OF AGRICULTURE
RD&D PROGRAMS

APPENDIX E

DEPARTMENT OF AGRICULTURE

Funding for 1976 includes the transition quarter (July 1, 1976 to September 30, 1976). Figures cited for 1977 and 1978 represent estimates or new data.

Recreational Land Use Noise Reduction Demonstration at a Public Forest

This study is to develop for recreational land use areas noise assessment techniques, noise criteria, and noise abatement measures, e.g. operational reductions and land management. The abatement procedures developed are to be demonstrated at selected forest land recreational sites. This study is a cooperative program between the Department of Agriculture and the EPA.

Sponsor: EPA/Office of Noise Abatement and Control
Investigator: Department of Agriculture/Forest Service

Fiscal Year Funding ($1000):	1975	1976	1977	1978
		2	2	9*

Environmental Impacts of Off-Road Vehicle Noise

Work to predict environmental impact of off-road vehicle operations was begun in FY 75. This continued through FY 76 based on previous work which cataglogued the noise levels and spectra of motorcycles, dune buggies, four-wheel drives, and snowmobiles. This methodology is not limited to the prediction of environmental impact of off-road vehicles, but has been used in forest planning of transportation systems, including location of logging roads, trails, and campgrounds, as well as forest highways.

Sponsor: USDA/Forest Service
Investigator: In-house

Fiscal Year Funding ($1000):	1975	1976	1977	1978
	†	3		6

* Forest Service funding has not been finalized.

† Not dedicated primarily to surface transportation noise.

Measurement Methodology for All Terrain Vehicles

The measurement methodology for motorcycles is being applied to other off road vehicles including four-wheel drive jeeps. It is being adapted on a Forest-by-Forest basis throughout the Forest Service.

Sponsor: USDA/Forest Service
Investigator: In-house

Fiscal Year Funding ($1000):	1975	1976	1977	1978
	*	*		2

Measurement Methodology for Boats

In order to prepare a measurement methodology for pleasure boats a study will be initiated to develop a classification for boats and identify boating noise sources.

Sponsor: USDA/Forest Service
Investigator: In-house

Fiscal Year Funding ($1000):	1975	1976	1977	1978
				3

Measurement Methodology for Snowmobiles

Prior to 1975, an easily conducted field test for snowmobiles was developed as part of this task. In 1976, a seminar was held to disseminate this noise measurement methodology and discuss snowmobile noise control technology. Future work will include the development of predictive model to assess snowmobile noise in forested areas.

Sponsor: USDA/Forest Service
Investigator: In-house

Fiscal Year Funding ($1000):	1975	1976	1977	1978
		4		3

* Not dedicated primarily to surface transportation noise.

Measurement Methodology for Motorcycles

This is an ongoing program to assess motorcycle noise. Development of a methodology for measurement of off-road motorcycle noise has resulted in the publication of a stationary half-meter test standard for both off-road and highway motorcycles by the Motorcycle Industry Council.

Sponsor: USDA/Forest Service
Investigator: In-house

Fiscal Year Funding ($1000):	1975	1976	1977	1978
	2	*		1

Suburban Noise Control with Plant Materials and Solid Barriers

This project involves the study of traffic noise control using combination of planted trees and shrubs with solid barriers. The effectiveness of these barriers is dependent upon space available, severity of noise, barrier placement with respect to noise source, screen height, and density of foliage. The combination of plant materials and solid barriers has been found to be one of the most effective types of highway noise barriers and to provide more uniform noise reduction over a large area.

Sponsor: USDA/Forest Service
Investigator: University of Nebraska

Fiscal Year Funding ($1000):	1975	1976	1977	1978
	7	7	6	

General Propagation Studies

This project studies the effects of terrain and vegetation on the propogation of off-road vehicle noise under sylvan conditions.

Sponsor: USDA/Forest Service
Investigator: In-house

Fiscal Year Funding ($1000):	1975	1976	1977	1978
				2

* Not dedicated primarily to surface transportation noise.

APPENDIX F

DEPARTMENT OF JUSTICE
RD&D PROGRAMS

APPENDIX F

DEPARTMENT OF JUSTICE

Funding for 1976 includes the transition quarter (July 1, 1976 to September 30, 1976). Figures cited for 1977 and 1978 represent estimates or new data.

Emergency Vehicle Sirens

The goal of this program was to provide the Law Enforcement Assistance Administration with information on the characteristics and effectiveness of emergency vehicle warning systems.

The acoustic characteristics, including directional response, sound power level, field insertion loss, interior masking noise and the effect of ground reflections were determined for emergency vehicle sirens.

As a result of this work two different siren systems using four folded horn loudspeakers in a linear array were designed and constructed. These systems along with a conventional electronic siren were evaluated both in an anechoic chamber and in the field mounted on a vehicle.

Future plans include completion of the program to develop a directional siren and construction of a prototype for delivery to NBS Law Enforcement Standards Laboratory.

Sponsor: Law Enforcement Assistance Administration, National Institute of Law Enforcement and Criminal Justice
Investigator: DOC/National Bureau of Standards

Fiscal Year Funding ($1000):	1975	1976	1977	1978
		78	5	

APPENDIX G

DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT
RD&D PROGRAMS

APPENDIX G

DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT

The fiscal year funding for 1976 includes the transition quarter (July 1, 1976 to September 30, 1976). Funding figures for 1977 and 1978 are estimates or represent incomplete new data.

Evaluation of HUD Noise Abatement Policies and Guidelines

HUD noise abatement policies and guidelines are being systematically evaluated with respect to their technical adequacy, HUD operating procedures, and their impact on communities. Research on the impact of various noise sources is expected to lead to recommendations for improvement of standards and guidelines. This program is due to be completed in 1977.

Sponsor: HUD
Investigator: Bolt Beranek & Newman, Inc.

Fiscal Year Funding ($1000):	1975	1976	1977	1978
	352			

Noise Attenuation Features for Housing and Community Development

Guidelines, techniques, and procedures are being developed for minimizing the impact of environmental noise through site design and construction practice for use by HUD personnel and others responsible for community development.

Sponsor: HUD
Investigator: Wyle Laboratories

Fiscal Year Funding ($1000):	1975	1976	1977	1978
	196			

APPENDIX H

DEPARTMENT OF COMMERCE
RD&D PROGRAMS

APPENDIX H

DEPARTMENT OF COMMERCE

Funding for 1976 includes the transition quarter (July 1, 1976 to September 30, 1976). Figures cited for 1977 and 1978 represent estimates or new data. Funding provided by other agencies to DOC is shown for information only and is reported under sponsoring agency.

Environmental Noise Test Variables

Although existing voluntary standards have achieved considerable uniformity, significant variations remain between noise measurements made at different sites or at different times on the same site. These differences are in part attributable to differences in the environment, including site and meteorological influences. An understanding of the magnitude and extent of these effects will provide a basis for better site selection criteria and possible redefinition, or elimination, of existing tolerance factors, and will ensure more uniform enforcement by DOT of the EPA Interstate Motor Carrier and Interstate Rail Carrier Noise Emission Regulations.

To satisfy the need for experimental work, DOT sponsored a portion of an Environmental Variables Study in cooperation with the Motor Vehicle Manufacturers Association (MVMA). The experimental program was designed to measure the acoustic, vehicle, and environmental data for a variety of vehicle and environmental conditions. These data were then to be used to determine the systematic and nonsystematic dependence of observed truck drive-by and stationary noise on the environmental effects present during the measurement. The experiment was designed to permit separation of generation/radiation and propagation effects. During the fourteen months from September 1976 to November 1977, NBS mounted a substantial effort to conduct the experimental program. However, a wide range of technical difficulties relating to the complexity of the program forced termination before achievement of the stated goals.

Sponsor: DOT/Office of Noise Abatement, Motor Vehicle Manufacters Association, Engine Manufacturer's Association and National Bureau of Standards

Investigator: National Bureau of Standards

Fiscal Year Funding ($1000):	1975	1976	1977	1978
			150*	

* Does not include DOT funding of $28K in FY 77 or MVMA and EMA funding of $10K in FY 76 and $60K in FY 77.

In-Cab Locomotive Noise Survey

The program is being conducted under an IAG with the DOT Office of Rail Safety Research in cooperation with the AAR.

The objective of the program is threefold: (1) to determine, by means of a representative sample of locomotives in operational settings, the extent of crew exposure to noise; (2) to identify simplified test procedures and measurement methodologies that can be used in an operational environment to determine whether or not an individual locomotive is capable of generating excessively high noise levels; and (3) to identify measurement techniques whereby component sources of noise within the locomotive cab can be identified.

Sponsor: DOT/Federal Railroad Administration
Investigator: National Bureau of Standards

Fiscal Year Funding*($1000):	1975	1976	1977	1978
			103	40

Tire Noise Study

Utilizing the extensive tire noise data base accumulated during 1970 and 1971, the DOT Office of Noise Abatement continued its interagency agreement with the National Bureau of Standards and expanded the study through additional data collection and/or analysis.

Accomplishments to date for typical bias-ply rib and cross-bar truck tires include: (1) a catalog of maximum A-weighted sound levels; (2) a catalog of one-thid octave and narrow band spectral data; (3) directionality data in the form of octave band and equal A-weighted sound level contours.

* Funding levels are shown for information only.

The influence of pavement surface has been investigated and includes: (1) tire noise versus surface texture; (2) surface profile measurements; (3) correlation of pavement surface texture with tire noise (partially successful attempt).

In addition, accomplishments include: (1) an empirical model to predict in-service base noise levels for truck tires on the basis of SAE J57 type tests; (2) a comparison of parametric trends between truck and automobile tires; (3) an expansion of truck tires noise data to include radial tires; (4) the effect of load and/or inflation pressure on noise levels; (5) the effect of tire size on noise levels; (6) noise measurements on radial tires utilized by HSRI; (7) a comparison of wear rates with noise levels.

On the basis of work under this program as well as related programs in the traction, rolling resistance and economics areas, additional papers have been generated which discuss the technical and economic considerations and their implications on possible future tire noise regulatory developments.

Sponsor: DOT/Office of Noise Abatement
Investigator: National Bureau of Standards

Fiscal Year Funding*($1000):	1975	1976	1977	1978
	162	119		

Environmental Noise Measurements

Technical assistance was provided to EPA to support the development of regulations for specific noise sources. Specifically NBS has provided:

- Measurement methodology for portable air compressor noise and procedures for estimating sound power from measurements of sound pressure.
- Docket analysis for the new truck regulation.
- Evaluation of existing data bases and measurement procedures for six major noise sources: tires, buses, motorcycles, dozers and loaders, truck refrigeration units, and compactors.

*Funding levels are shown for information only.

- Measurements of the impulsive noise emission of garbage compactors, motorcycles, pavement breakers, and rock drills.
- Identification of difficulties or ambiguities in measurement by using different methodologies.
- Evaluation of alternative measurement techniques for characterization of asphalt surface acoustic properties.
- Development of procedures for measurement of noise impact from household and consumer products.

Sponsor: EPA/Office of Noise Abatement and Control
Investigator: National Bureau of Standards

Fiscal Year Funding* ($1000):	1975	1976	1977	1978
		55	35	35

Emergency Vehicle Sirens

The goal of this program was to provide the Law Enforcement Assistance Administration with information on the characteristics and effectiveness of emergency vehicle warning systems.

The acoustic characteristics, including directional response, sound power level, field insertion loss, interior masking noise and the effect of ground reflections, were determined for emergency vehicle sirens.

As a result of this work two different siren systems using four folded horn loudspeakers in a linear array were designed and constructed. These systems along with a conventional electronic siren were evaluated both in an anechoic chamber and in the field mounted on a vehicle.

Future plans include completion of the program to develop a directional siren and construction of a prototype for delivery to NBS Law Enforcement Standards Laboratory.

* The Environmental Noise Measurements program contributes to both the surface transportation and machinery and construction areas. This program is shown in this report and in the machinery and construction noise report with proportionate funding. Total FY 75 through FY 78 funding levels are $50K, $120K, $75K and $75K respectively.

Sponsor: Law Enforcement Assistance Administration, National Institute of Law Enforcement and Criminal Justice
Investigator: DOC/National Bureau of Standards

Fiscal Year Funding *($1000):	1975	1976	1977	1978
		78	5	

Characteristics of Microphone Windscreen Performance

The objective of this program is to determine the characteristics of microphone windscreen performance when used as a part of a sound measurement system. The study will investigate wind noise at various wind speeds for a 1/2-inch microphone and a variety of windscreen sizes, materials and porosities. For each of these subsets, measurements will be made of both the acoustic insertion loss and wind-induced noise. The wind effects will be simulated by mounting the microphone-windscreen system at the end of a 1.52 m rotating arm. Wind speeds up to 14 m/sec (±0.1%) will be obtained by using an electronically controlled rate table. All testing will be conducted in the NBS anechoic chamber.

Sponsor: EPA/Office of Noise Abatement and Control
Investigator: National Bureau of Standards

Fiscal Year Funding *($1000):	1975	1976	1977	1978
			10	

*Funding levels are shown for information only.

APPENDIX I

SURFACE TRANSPORTATION NOISE REGULATORY PROGRAMS

APPENDIX I

SURFACE TRANSPORTATION NOISE REGULATORY PROGRAMS

This report is concerned with research, development, and demonstration programs; however, EPA has a primary responsibility in the regulatory area. This appendix presents brief descriptions of technology assessments done in support of regulatory programs.

These programs are for the collection and verification of current equipment noise levels and engineering estimates of potential noise reduction.

Funding for 1976 includes the transition quarter (July 1, 1976 to September 30, 1976). Figures cited for 1977 and 1978 represent estimates or new data.

Continued Investigation on the 1976 Truck Regulation

The first part of this study involves determining and assessing the noise control technology required to reduce medium and heavy truck noise below the 80 dB limit set for January 1, 1982 in the medium and heavy truck regulation. The second part involves reassessing the noise measurement methodology used in the 1976 truck regulation.

Sponsor: EPA/Office of Noise Abatement and Control
Investigator: Not selected

Fiscal Year Funding ($1000):	1975	1976	1977	1978
			25	75

Light Vehicles Study

Done in support of future regulatory action, the aim of this study is to identify the technology available to reduce noise levels of light trucks and automobiles and to develop vehicle and truck noise measurement methodologies. The availability of low noise emission tires for use on trucks, buses, and automobiles was also examined.

Sponsor: EPA/Office of Noise Abatement and Control
Investigator: Not cited

SURFACE TRANSPORTATION NOISE REGULATORY PROGRAMS
(Continued)

Fiscal Year Funding ($1000):	1975	1976	1977	1978
		200	200	

Bus Technology Study

This study identified the technology available to reduce bus noise, assessed the noise level degradation that occurs during operational service, and developed a methodology for noise measurement. The study considered diesel and gasoline powerplants; and transit, intercity, school and general (airport, hotel, government) buses. The technology study was done to support bus noise regulation activities. This study was completed in August 1976.

Sponsor: EPA/Office of Noise Abatement and Control
Investigator: Booz, Allen Applied Research

Fiscal Year Funding ($1000):	1975	1976	1977	1978
		89		

Tire Noise Study

This contract requires collection of existing technical information on tires and a parametric assessment of the health and welfare benefits accruing from various regulatory options. The acquisition of this information will enable EPA/ONAC to decide whether: (1) to regulate, (2) to label, (3) to regulate and label, or (4) do nothing.

Sponsor: EPA/Office of Noise Abatement and Control
Investigator: Bolt, Beranek and Newman

Fiscal Year Funding ($1000):	1975	1976	1977	1978
			275	

Motorcycles Study

This study identified the technology available to reduce motorcycle noise, identified noise levels, and developed noise measurement methodologies. The research was undertaken as part of the effort to develop a motorcycle noise regulation.

Sponsor: EPA/Office of Noise Abatement and Control
Investigator: McDonnell-Douglas Company

SURFACE TRANSPORTATION NOISE REGULATORY PROGRAMS
(Continued)

Fiscal Year Funding ($1000):	1975	1976	1977	1978
		153		

Snowmobile Study

Done in support of future regulatory action, this study identified the technology available to reduce snowmobile noise, incorporated noise abatement measures on a snowmobile to demonstrate the existence of technology, and developed a noise measurement methodology to assess hearing hazard. A measurement methodology for enforcement was not developed.

Sponsor: EPA/Office of Noise Abatement and Control
Investigator: Cambridge Collaborative

Fiscal Year Funding ($1000):	1975	1976	1977	1978
		96	40	

Motorboat Study

This study, done in support of future regulatory action, will identify the technology available to reduce motorboat noise, emphasizing identification of noise control measures already in use. The study will also characterize motorboat noise, assess the impact of boat noise, and develop a noise measurement methodology.

Sponsor: EPA/Office of Noise Abatement and Control
Investigator: Not selected

Fiscal Year Funding ($1000):	1975	1976	1977	1978
			40	70

Special Purpose Recreational Vehicles

This study is to be done in support of future regulatory action. It will identify levels of special purpose recreational vehicles and technology available to reduce noise levels, and develop a noise measurement methodology.

Sponsor: EPA/Office of Noise Abatement and Control
Investigator: Not selected.

SURFACE TRANSPORTATION NOISE REGULATORY PROGRAMS
(Continued)

Fiscal Year Funding ($1000):	1975	1976	1977	1978
				50

Guided Mass Transit Study

This program supports future possible regulation activity. It will identify noise levels, noise control technology, and develop noise measurement methodology for guided mass transit systems. The following guided mass transit systems will be considered: light rail (trolley), heavy rail (intracity system such as BART or METRO), passenger railroad (intercity), monorail, and other guided systems.

Sponsor: EPA/Office of Noise Abatement and Control
Investigator: Cambridge Collaborative

Fiscal Year Funding ($1000):	1975	1976	1977	1978
		100	15	

Noise Labeling of Mufflers and Surface Vehicles

This study was done to support labeling regulatory action on mufflers and surface vehicles. The study identified existing noise measurement methodologies for various surface vehicles, investigated muffler attenuation, identified existing test methodologies for determining muffler attenuation, and developed test methodologies for determining muffler performance when installed on the vehicle. The following vehicles were considered: trucks, automobiles, buses, motorcycles, railroad locomotives, guided mass transit, snowmobiles, and motorboats.

Sponsor: EPA/Office of Noise Abatement and Control
Investigator: McDonnell-Douglas Company

Fiscal Year Funding ($1000):	1975	1976	1977	1978
		80		

Environmental Noise Measurements

Technical assistance was provided to EPA to support the development of regulations for specific noise sources. Specifically NBS has provided:

- Measurement methodology for portable air compressor noise and procedures for estimating sound power from measurements of sound pressure.
- Docket analysis for the new truck regulation.
- Evaluation of existing data bases and measurement procedures for six major noise sources: tires, buses, motorcycles, dozers and loaders, truck refrigeration units, and compactors.
- Measurements of the impulsive noise emission of garbage compactors, motorcycles, pavement breakers, and rock drills.
- Identification of difficulties or ambiguities in measurement by using different methodologies.
- Evaluation of alternative measurement techniques for characterization of asphalt surface acoustic properties.
- Development of procedures for measurement of noise impact from household and consumer products.

Sponsor: EPA/Office of Noise Abatement and Control
Investigator: National Bureau of Standards

Fiscal Year Funding *($1000):	1975	1976	1977	1978
		55	35	35

Motor Carrier Regulation Study

A number of areas were investigated to provide support for a possible revision to the 1974 Motor Carrier Noise Regulation. Significant areas of investigation in Phase 1 were: identification of recent information on maintenance, operation, and costs for trucks in meeting EPA's 1976 Medium and Heavy Truck Regulation; tire variables associated with truck noise; industry conformance to the 1976 truck regulation; and problems associated with industry conforming to the 1974 Motor Carrier Regulation. Phase 2 involved the identification of the degradation of noise control devices incorporated on trucks built in compliance with the 1976 truck regulation, and the increase in noise levels that occurred with this degradation.

* The Environmental Noise Measurements program contributes to both the surface transportation and machinery and construction areas. This program is shown in this report and in the machinery and construction noise report with proportionate funding. Total FY 75 through FY 78 funding levels are $50K, $120K, $75K and $75K respectively.

SURFACE TRANSPORTATION NOISE REGULATORY PROGRAMS
(Continued)

Sponsor: EPA/Office of Noise Abatement and Control
Investigator: Wyle Laboratories

Fiscal Year Funding ($1000):	1975	1976	1977	1978
		205	50	50

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