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VOLUME 2

RESEARCH PANEL REPORTS

U. S. ENVIRONMENTAL PROTECTION AGENCY
Washington, D. C. 20460

EPA 550/9-75-023

# FIRST REPORT ON STATUS AND PROGRESS OF NOISE RESEARCH AND CONTROL PROGRAMS IN THE FEDERAL GOVERNMENT

JUNE 1975

VOLUME 2

RESEARCH PANEL REPORTS

THE U. S. ENVIRONMENTAL PROTECTION AGENCY
OFFICE OF NOISE ABATEMENT AND CONTROL

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## APPENDIX D

Federal Aircraft Noise Research, Development, and Demonstration Programs: FY73–FY75, Report EPA-600/2-75-003, Prepared by Interagency Aircraft Noise Research Panel, March 1975

TABLE OF CONTENTS

Appendix

EPA-600/2-75-003
MARCH 1975

Environmental Protection Technology Series

# Federal Aircraft Noise Research, Development, and Demonstration Programs: FY 73 - FY 75

Office of Research and Development
U.S. Environmental Protection Agency
Washington, D.C. 20460

## RESEARCH REPORTING SERIES

Research reports of the Office of Research and Development, Environmental Protection Agency, have been grouped into five series. These five broad categories were established to facilitate further development and application of environmental technology. Elimination of traditional grouping was consciously planned to foster technology transfer and a maximum interface in related fields. The five series are:

1. Environmental Health Effects Research
2. Environmental Protection Technology
3. Ecological Research
4. Environmental Monitoring
5. Socioeconomic Environmental Studies

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This report has been reviewed by the Office of Research and Development. Approval does not signify that the contents necessarily reflect the views and policies of the Environmental Protection Agency, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

Report 600/2-75-003
March 1975

# FEDERAL AIRCRAFT NOISE RESEARCH, DEVELOPMENT AND DEMONSTRATION PROGRAMS: FY73 - FY75

Prepared by

The Interagency Aircraft Noise Research Panel

Task No. 21AXV
Program Element No. 1GB090

Project Office:
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Prepared for

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ABSTRACT

The Interagency Aircraft Noise Research Panel was established by the Environmental Protection Agency to aid EPA in fulfilling its responsibility for coordinating the Federal noise research activities. This report is the first prepared by the Panel and provides an inventory of current and planned Federal aircraft noise RD&D programs. The Federal agencies which sponsor aircraft noise RD&D are the National Aeronautic and Space Administration, the Department of Transportation, the Department of Defense, the National Science Foundation, and the EPA. The report is organized by technical areas with each agency's programs presented under the appropriate technical area. Emphasis is on fiscal years 1974 and 1975, but summary information on fiscal years 1973 and 1976 is also included. The Appendix contains detailed programmatic information as furnished by the Federal agencies on their aircraft related RD&D activities.

TABLE OF CONTENTS

## LIST OF TABLES

LIST OF TABLES (continued)

## 1. INTRODUCTION

Section 4(C)(1) of the Noise Control Act of 1972 requires that the Administrator of the Environmental Protection Agency coordinate research programs of all Federal agencies. To aid the Administrator in fulfilling this requirement, each agency must furnish to the Administrator such information as may be necessary to determine the nature, scope, and results of the noise research programs of the agency. A further requirement under Section 4(C)(3) is that the Administrator publish a report from time to time to describe the status and progress of Federal noise research programs and assess the contributions of these programs to the Federal Government's overall efforts to control noise.

To fulfill these provisions relating to aircraft noise research, the EPA Office of Research and Development has organized an interagency Aircraft Noise Research Panel. The responsibilities of the Panel include collecting programmatic information to develop an inventory of Federal aircraft noise research and providing the expertise to make an assessment of the adequacy of current programs to meet public health and welfare goals relative to noise as specified by the Environmental Protection Agency.

This is an interim report prepared under the cognizance of the Aircraft Noise Research Panel as a first step in carrying out a plan of action to assess aircraft noise related research, development and demonstration (RD&D). The purpose of this report is to provide an inventory of current and planned Federal aircraft noise RD&D programs, and it represents the initial data base upon which the assessment will be made.

The report is organized by technical areas with each agency's programs presented under the appropriate technical areas. Sections 1 through 9 provide an overview of objectives and funding for the programs with emphasis on fiscal years (FY) 1974 and 1975. Summary information on past funding for FY 1973 and planned obligations for FY 1976 are also included. The Appendix contains detailed programmatic information as furnished by the Federal agencies on their aircraft noise related RD&D activities.

In the future, the Aircraft Noise Research Panel will carry out the assessment phase of its responsibilities. To accomplish this objective the Panel will:

1. Review the public health and welfare goals and objectives relating to noise as developed by the Environmental Protection Agency;

2. Establish appropriate Working Groups for specific technology areas calling on the expertise available in Federal agencies engaged in aircraft RD&D;

3. Identify specific requirements and need for detailed review of Federal programs and analyze industry independent research and development programs;

4. Coordinate Working Group activity and integrate findings of the Working Groups relative to the adequacy of ongoing programs;

5. Prepare a summary report that specifies the extent to which current programs can meet the EPA public health and welfare goals and objectives relative to noise and make recommendations on what should be done where the assessment indicates that the schedule for meeting EPA goals and objectives cannot be accomplished with current programs and plans.

## 2. SUMMARY

The overall Federal activity in aircraft noise related research, development and demonstration is summarized in Table 2.1. Table 2.1 shows the technical areas under investigation, the Federal agencies with a significant program in each technical area and noise relevant funding data for fiscal years 1973 through 1976. Funding data for FY 1975 and FY 1976 are based on planned obligations.

It is noted from Table 2.1, that a significant amount of total funding in FY 73 and FY 74 is associated with studies to reduce noise of the current commercial fleet and is shown under subsonic conventional takeoff and landing (CTOL) aircraft. Several study categories related to noise of existing commercial aircraft are presented in Table 2.2. The programs included in Table 2.2 involve operational procedures for reduced noise exposure, technology development, and demonstration to support decision making on the question of retrofit of the existing commercial fleet and demonstration of advanced technology for nacelle design for application on modern wide-body transports. The status of some of the NASA and DOT/FAA activities identified in Table 2.2 were reviewed before the United States House of Representatives Subcommittee on Aeronautics and Space Technology in July 1974. The testimonies presented by NASA and DOT/FAA are included in the Appendix of this report.

The ongoing programs to provide the research and technology base necessary to design more quiet future generation aircraft are summarized in Table 2.3, page 5. Major areas of investigation are propulsion system noise, materials, and nonpropulsive noise (airframe aerodynamic noise). A parallel decrease of propulsion system noise and airframe noise is required to reduce approach noise of future aircraft below FAR-36 minus 10 dB (see References 1 and 2, Section 10, for detailed technical treatment of this point).

Programs to develop acceptably quiet commercial powered lift aircraft to reduce congestion around major cities are summarized in Table 2.4. The technical objectives of these programs are given in Section 4, and detailed program planning is included in the Appendix. A technical treatment of progress and prospects for powered lift aircraft is provided in Reference 1, Section 10.

Table 2.5 summarizes program activity and funding for rotorcraft and vertical takeoff and landing (VTOL) aircraft. These programs, conducted by NASA, have civil and military applications. Noise relevant technology development for application to supersonic cruise aircraft is given in Table 2.6. These programs are basic and deal with propulsion, aerodynamics and sonic boom.

Table 2.1 SUMMARY OF FUNDING BY TECHNICAL AREA, AGENCY, AND FISCAL YEAR

Funding in Thousands of Dollars

| Technical Area | Agency | FY 73 | FY 74 | FY 75 | FY 76 |
|---|---|---|---|---|---|
| Basic Research and Technology | NASA | 10,765 (1) | 14,149 | 13,840 | 14,269 |
| | DOT | 2,830 | 785 | 1,282 | 1,760 |
| | DOD | 1,784 | 1,752 | 793 | 1,112 |
| | Total | 15,379 | 16,686 | 15,915 | 17,141 |
| Powered Lift Aircraft Noise Technology | NASA | 4,406 (1) | 2,082 | 2,977 | 2,952 |
| | DOT | 241 | - | - | - |
| | Total | 4,647 | 2,082 | 2,977 | 2,952 |
| Rotorcraft/VTOL Noise Technology | NASA | - (2) | 1,774 | 2,284 | 2,294 |
| | DOD | 267 | 534 | 675 | 275 |
| | Total | 267 | 2,308 | 2,959 | 2,569 |
| Air Transportation Systems Studies | NASA | 255 | 428 | 248 | 227 |
| | EPA | - (4) | 404 | - | - |
| | Total | 255 | 832 | 248 | 227 |
| Supersonic Cruise Aircraft Noise Technology | NASA | 2,070 (1,3) | 2,086 | 1,490 | 1,730 |
| | DOT | 316 | 299 | 100 | - |
| | Total | 2,386 | 2,385 | 1,590 | 1,730 |
| Subsonic Conventional Takeoff and Landing Aircraft Noise Programs | NASA | 27,704 (1,6) | 25,204 | 6,017 | 2,703 |
| | DOT | 8,176 | 1,899 | 900 | - |
| | Total | 35,880 | 27,103 | 6,917 | 2,703 |
| General Aviation Noise Technology | NASA | 80 (1) | 355 | 448 | 996 |
| GRAND TOTAL | | 58,894 | 51,751 | 31,054 | 28,318 |

1. The NASA funding data included in this table for FY 73 are based on information supplied to EPA by NASA in December, 1973. The content of the breakouts by research area is not exactly the same as those for other fiscal years listed.

2. FY 73 funding included in Powered Lift Aircraft Noise Technology.

3. Some program activity included here that is listed under Basic Research and Technology for other fiscal years.

4. EPA FY 74 total includes some funds committed in FY 73.

5. See Section 11 for an explanation of acronyms, abbreviations, and definition of noise relevant program costs.

6. For FY 73, $1090K of the funds listed were for subsonic engine and nacelle technology-Quiet Engine I.

Table 2.2. FUNDING SUMMARY FOR SUBSONIC CTOL AIRCRAFT NOISE PROGRAMS

| Area | Agency | Funding Distribution, Thousands of Dollars FY 74 | FY 75 | FY 76 |
|---|---|---|---|---|
| Noise Reduction Flight Procedures Experiments | NASA | 3,600 | 1,380 | - |
| Terminal Configured Vehicle Operating Systems Experiments | NASA | 271 | 1,563 | 1,613 |
| REFAN Program | NASA | 20,803 | 2,514 | - |
| Advanced Acoustic Composite Nacelle Program | NASA | 530 | 560 | 1,090 |
| Source Noise Reduction | DOT/FAA | 1,899 | 900 | - |
| | GRAND TOTAL | 27,103 | 6,917 | 2,703 |

Table 2.3. FUNDING SUMMARY FOR BASIC RESEARCH AND TECHNOLOGY PROGRAMS

| Area | Agency | Funding Distribution, Thousands of Dollars FY 74 | FY 75 | FY 76 |
|---|---|---|---|---|
| Propulsion Noise Reduction | NASA | 13,348 | 12,194 | 12,490 |
| | DOT/ONA* | 750 | 1,232 | 1,710 |
| | DOD | 563 | 271 | 400 |
| | Total | 14,661 | 13,697 | 14,600 |
| Propulsion System Integration Nonpropulsive Noise | NASA | 801 | 1,646 | 1,779 |
| | DOD | 272 | 75 | 125 |
| | Total | 1,073 | 1,721 | 1,904 |
| Human Response** | NASA | (1,154) | (1,200) | (1,458) |
| Materials and Sound Propagation | DOT/ONA | 35 | 50 | 50 |
| | DOD | 917 | 447 | 587 |
| | Total | 952 | 497 | 637 |
| | GRAND TOTAL | 16,686 | 15,915 | 17,141 |

*DOT/FAA funding included in Table 2.2

**NASA allocations for Human Response studies are shown here for informational purposes only. These resources are accounted for in the Federal noise effects research fiscal data. (Reference 3)

Table 2.4. FUNDING SUMMARY FOR POWERED LIFT AIRCRAFT NOISE TECHNOLOGY

| Area | Agency | Funding Distribution, Thousands of Dollars FY 74 | FY 75 | FY 76 |
|---|---|---|---|---|
| Advanced Powered Lift Aircraft | NASA | 310 | 1,480 | 1,470 |
| Augmentor Wing Flight Experiment | NASA | 160 | - | - |
| Quiet Clean Short Haul Experimental Engine (QCSEE) | NASA | 167 | 840 | 825 |
| Quiet Propulsive Lift Research Aircraft | NASA | 1,310 | - | - |
| STOL Operating Systems Experiments | NASA | 135 | 657 | 657 |
| GRAND TOTAL | | 2,082 | 2,977 | 2,952 |



Table 2.5. FUNDING SUMMARY FOR ROTORCRAFT/VTOL NOISE TECHNOLOGY

| Area | Agency | Funding Distribution, Thousands of Dollars FY 74 | FY 75 | FY 76 |
|---|---|---|---|---|
| Advanced Rotorcraft Aerodynamic Technology | NASA | 920 | 1,045 | 1,040 |
| | DOD | 34 | - | - |
| | Total | 954 | 1,045 | 1,040 |
| Advanced VTOL Aircraft Aerodynamic Technology | NASA (Total) | 80 | 150 | 160 |
| Tilt Rotor Research Aircraft Program | NASA (Total) | 274 | - | - |
| Rotor Systems Research Aircraft | NASA | 500 | - | - |
| | DOD | 500 | 675 | 275 |
| | Total | 1,000 | 675 | 275 |
| Rotor Systems for RSRA | NASA (Total) | - | 465 | 470 |
| VTOL Operating Systems Experiments | NASA (Total) | - | 624 | 624 |
| GRAND TOTAL | | 2,308 | 2,959 | 2,569 |

Table 2.6. FUNDING SUMMARY FOR SUPERSONIC CRUISE AIRCRAFT NOISE TECHNOLOGY

| Area | Agency | Funding Distribution, Thousands of Dollars | | |
|---|---|---|---|---|
| | | FY 74 | FY 75 | FY 76 |
| Propulsion Technology | NASA | 1,422 | 1,233 | 1,360 |
| Aerodynamic Performance | NASA | 664 | 257 | 370 |
| Source and Operational Sonic Boom Reduction | DOT/FAA | 299 | 100 | - |
| | GRAND TOTAL | 2,385 | 1,590 | 1,730 |

A more detailed treatment of the Federal noise relevant RD&D summarized in Tables 2.1 to 2.6 is given in subsequent sections of this report. Program planning and several status reviews (July 1973) on the potential of reducing noise of the current commercial fleet are included in the Appendix.

## 3. SUBSONIC CONVENTIONAL TAKEOFF AND LANDING AIRCRAFT NOISE PROGRAMS

Noise relevant programs relating to subsonic conventional takeoff and landing aircraft technology are listed in this section. These programs have application to the existing commercial fleet and the newer wide-body aircraft designs.

### National Aeronautics and Space Administration

The status of NASA programs noted here was reviewed in testimony before the United States House of Representatives Subcommittee on Aeronautics and Space Technology in July 1974. The brief technical descriptions of programs that follow can be understood in proper context by referring directly to that testimony which is included in the Appendix.

- Noise reduction flight procedures experiments. To reduce 90 EPNdB approach noise footprint by at least 60% through scheduled airlines' demonstrations of avionic systems for noise abatement flight procedures.

- Terminal configured vehicles operating systems experiments. To identify and provide proven technology and operating techniques for advanced CTOL and RTOL aircraft for reducing approach and landing accidents, reducing weather minima, increasing air traffic controller productivity and airport and airway capacity, saving fuel by more efficient terminal area operations, and reducing noise by operational procedures during the 1976-2000 time period.

- REFAN Program. To provide the technology to obtain a 75 percent reduction in the noise footprint area of JT8D-Powered Aircraft (727, 737, and DC-9) which account for over 60 percent of domestic fleet operations.

- Advanced acoustic composite nacelle flight program. To demonstrate on a modern wide-body transport in airline operation the application of advanced interwoven acoustic absorbent and composite structural materials to an engine which will:

  - Reduce the noise footprint area of future production wide-body transport aircraft by 30 percent with no increase in aircraft weight or fuel consumption or alternately reduce aircraft weight and fuel consumption with no increase in noise.

- Together with advanced technology engines, reduce the 90 EPNdB noise footprint area of advanced technology transport aircraft to 5.2 square kilometers (2 square miles) with no increase in aircraft weight or fuel consumption resulting from the nacelle or alternately reduce aircraft weight and fuel consumption together with some noise reduction.

Table 3.1 is a summary of noise relevant funding for the subsonic conventional takeoff and landing aircraft noise program. Listed in the table are a descriptive title of the program and gross RD&D and manpower costs for FY's 1974 through 1976. The Appendix contains more detailed program descriptions on all programs.

Department of Transportation-Federal Aviation Administration

DOT/FAA has several subsonic conventional takeoff and landing aircraft noise programs under the overall program of source noise reduction. The objective of this program is to develop a noise source prediction capability for all categories of aircraft. Projects under the source noise prediction and reduction program and their objectives are:

- Core engine noise control. To provide theoretical and experimental data to assist the designers in developing future aircraft capable of conforming to lower noise levels than are now required by FAR Part 36. This program would more properly be listed in Section 4 but is presented here since it cannot be easily separated from the schedule and cost data of other programs presented in this section.

- Prediction of aircraft configuration effects. To study the feasibility of use of aircraft configuration and engine placement to reduce noise propagation to the ground plus development of prediction procedures for configurations of practical interest.

- General aviation aircraft. To survey and define the noise characteristics of all general aviation aircraft plus development of suitable noise prediction capabilities.

- Retrofit feasibility. To provide test data to assist in determining whether certain classes of turbofan propelled airplanes in the current fleet can be modified for meaningful noise reduction in a feasible manner. The results of this

Table 3.1. NAS/ NOISE RELEVANT SUBSONIC CTOL AIRCRAFT PROGRAMS
NOISE RELEVANT PROGRAM COSTS
(Thousands of Dollars)

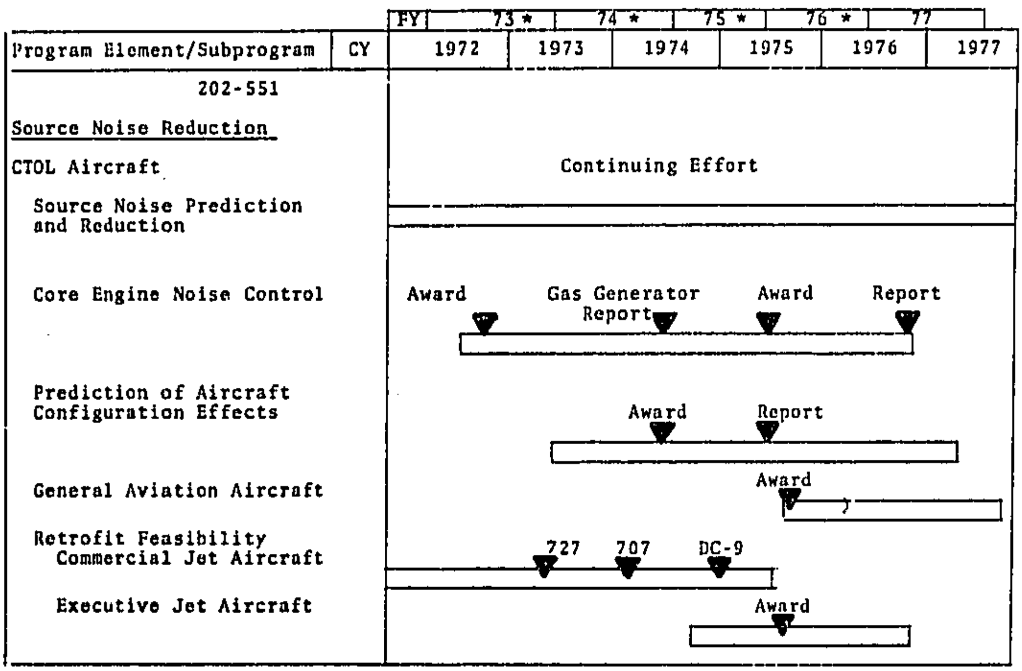
| | FY 1974 | | | FY 1975 | | | FY 1976 | | |
|---|---|---|---|---|---|---|---|---|---|
| Descriptive Title | Gross R&D | Manpower Costs | Total | Gross R&D | Manpower Costs | Total | Gross R&D | Manpower Costs | Total |
| Noise Reduction Flight Procedure Experiments | 3140 | 460 | 3600 | 1050 | 330 | 1380 | - | - | - |
| Terminal Configured Vehicle System Experiments | 214 | 57 | 271 | 1450 | 113 | 1563 | 1500 | 113 | 1613 |
| REFAN Program | 19545 | 1258 | 20803 | 1000 | 1514 | 2514 | - | - | - |
| Advanced Acoustic Composite Nacelle Program | 500 | 30 | 530 | 500 | 60 | 560 | 1000 | 90 | 1090 |
| TOTALS | 23399 | 1805 | 25204 | 4000 | 2017 | 6017 | 2500 | 203 | 2703 |

programmatic activity were reviewed before the United States House of Representatives Subcommittee on Aeronautics and Space Technology July 1974. That testimony is included in the Appendix.

Table 3.2 gives the schedule and funding for source noise reduction programs. The Appendix contains additional information on the direction and status of these projects.

12

Table 3.2. DOT/FAA AIRCRAFT NOISE ABATEMENT--SOURCE NOISE REDUCTION
Program Schedule (July 1, 1974)




*Funding allocations (100% noise relevant) are: FY 73-$8,176,000; FY 74-$1,899,000; FY 75-$900,000; FY 76-No Data.

## 4. BASIC RESEARCH AND TECHNOLOGY

Strict guidelines have not been employed in listing various agency programs under the category of Basic Research and Technology. In general, the results of programs presented in this section have a broader range of application and are more fundamentally oriented than programs listed in other sections.

### National Aeronautics and Space Administration

Descriptive titles and specific objectives for each noise relevant study being conducted by NASA are:

- Propulsion noise reduction. To provide data and a technology base for reducing aircraft propulsion noise with minimum weight, performance, and economic penalties.

- Nonpropulsive noise. To understand and minimize, by aerodynamic means, the undesirable effects of airframe noise.

- Human Response. To define and quantify those properties of aircraft noise exposure that are responsible for causing negative individual and community response to air transportation systems.

Funding data for programs included with each study category are shown in Table 4.1. The Appendix contains objective documentation for the programs listed in Table 4.1.

### Department of Transportation-Office of Noise Abatement

Studies relevant to aircraft noise reduction are sponsored by the Office of Noise Abatement within the Office for Systems Development and Technology and by the Federal Aviation Administration within DOT. While some FAA studies may be appropriately considered here, a consistent treatment of cost data requires their listing elsewhere. For this reason, only the DOT/ONA programs are considered under Basic Research and Technology.

DOT/ONA sponsors one program in aircraft noise reduction. This program is directed toward understanding, modeling, and suppressing jet noise. The studies included in the program are conducted under contract and through interagency agreement. The title, contracting organization, and funding data for each project are shown in Table 4.2. Detailed descriptions of each project are included in the Appendix.

Table 4.1 NASA NOISE RELEVANT BASIC RESEARCH AND TECHNOLOGY
NOISE RELEVANT PROGRAM COSTS
(Thousands of Dollars)

| Descriptive Title | FY 1974 Gross R&D | FY 1974 Manpower Costs | FY 1974 Total | FY 1975 Gross R&D | FY 1975 Manpower Costs | FY 1975 Total | FY 1976 Gross R&D | FY 1976 Manpower Costs | FY 1976 Total |
|---|---|---|---|---|---|---|---|---|---|
| Propulsion Noise Reduction | | | | | | | | | |
| Basic Noise Research | 2108 | 1886 | 3994 | 1300 | 2161 | 3461 | 1500 | 2200 | 3700 |
| Noise Technology and Prediction | 3073 | 6281 | 9354 | 4450 | 4283 | 8733 | 4330 | 4460 | 8790 |
| Nonpropulsive Noise | | | | | | | | | |
| Airframe Aerodynamic Noise | 408 | 393 | 801 | 900 | 746 | 1646 | 1000 | 779 | 1779 |
| Human Response[1] | | | | | | | | | |
| Acceptance of Aircraft Operations | (796) | (358) | (1154) | (842) | (358) | (1200) | (1100) | (358) | (1458) |
| GRAND TOTALS | 5589 | 8560 | 14,149 | 6650 | 7190 | 13,840 | 6830 | 7439 | 14,269 |

[1]The fiscal data for NASA's Human Response studies are accounted for in the Federal noise effects research resource allocations and shown here for informational purposes only. (Reference 3)

Table 4.2 DOT/ONA JET NOISE RESEARCH PROGRAM

| Project Title | Contracting Organization | Contract Number | Program Manager | Planned Obligations (Thousands of Dollars) FY73 | FY74 | FY75 | FY76 |
|---|---|---|---|---|---|---|---|
| Modeling Jet Noise | USC | DOT-OS-0000-2 | G.Banerian | 75 | 75 | 50 | 50 |
| Noise Reduction from Supersonic Jet Flow with Co-Axial Jets | Syracuse | DOT-OS-20094 | G.Banerian | 75 | 75 | 75 | 75 |
| Jet Combustion Noise | Cal. Tech. | DOT-OS-20197 | G.Banerian | 147 | 50 | 50 | 50 |
| Effects of Nonlinearity on Jet Noise Propulsion | UT | DOT-OS-4117 | G.Banerian | 0 | 20 | 0 | 0 |
| On the Origin of Combustion Generated Noise | NCSU | DOT-OS-40056 | G.Banerian | 0 | 25 | 30 | 30 |
| High Velocity Jet Noise Source Location and Reduction Program | GE | DOT-OS-30034 | G.Banerian | 2500 | 500 | 1000 | 1500 |
| Interagency Symposium: Transportation Noise | - | - | G.Banerian | 0 | 5 | 5 | 5 |
| Acoustic Material Research | MIT | DOT-OS-30011 | G. Banerian | 33 | 35 | 50 | 50 |
| Suppression of Multiple Pure Tones | VPI | DOT-OS-50047 | G. Banerian | 0 | 0 | 22 | 0 |
| GRAND TOTALS | | | | 2830 | 785 | 1282 | 1760 |

## Department of Defense

DOD has projects in several research categories. General areas of research are summarized below:

### Propulsion Noise Reduction

- Jet Exhaust noise programs. To develop the technology base necessary to significantly reduce aircraft propulsion system noise with minimum associated performance and weight penalties.

- Rotating machinery noise programs. To define the fundamental physical mechanisms by which combustion affects the general sound field surrounding an engine, to aid in providing design guidelines and techniques for modifying the combustion process for minimum noise levels, developing effective combustor noise suppression devices, and establishing criteria for engine design, development and control.

- Duct acoustics and suppression programs. To develop computer routines to predict the effect of duct linings on noise propagation and to optimize a given duct configuration for maximum noise reduction.

- Propeller noise programs. To formulate and computer program a comprehensive unified aerodynamic acoustic source theory and to reduce propeller noise through utilizing unique propeller designs based on noise source theory analysis.

### Structural Response Programs

Objectives of projects in this area are:

- To investigate the effects of high intensity sound on aircraft structures.

- To study the effects of high lift device noise on aircraft structures and the community environment.

- To dampen noise in helicopters.

### Sound Propagation Programs

Objectives of projects in this area are:

- To analyze the generation and propagation of multiple turbojet exhaust noise sources.

- To analyze the aerodynamic generation of noise, propagation, and detectability of unpowered aircraft.

Airflow Surface Interaction Programs

Objectives of the projects in this area are:

- To investigate the reduction of noise by liquid vaporization.
- To investigate the dynamics of vortices and shock waves in nonuniform media.
- To investigate the areas of boundary layer flows.

Table 4.3 is a compilation of the DOD funding distribution on Basic Research and Technology Programs. The Appendix contains a brief description of each project.

Table 4.3 DOD AIRCRAFT NOISE RESEARCH PROGRAMS[1]

| Descriptive Title[2] | Agency | Funding Level, Thousands of Dollars | | | |
|---|---|---|---|---|---|
| | | FY 73 | FY 74 | FY 75[3] | FY 76[3] |
| Propulsion Noise Reduction | | | | | |
| • Jet Exhausts | Air Force | 447 | 204 | 122 | 250 |
| • Rotating Machinery | Air Force Army, Navy | 297 | 288 | 75 | 85 |
| • Duct Acoustics and Suppression | Air Force Army | 10 | 45 | 65 | 65 |
| • Propeller Noise | Air Force | 26 | 26 | 9 | - |
| Structural Response Programs | Air Force | 178 | 335 | 302 | 340 |
| Sound Propagation Programs | Air Force | 580 | 582 | 145 | 247 |
| Airflow Surface Interaction | Navy | 246 | 272 | - | - |
| | Air Force | - | - | 75 | 125 |
| GRAND TOTALS | | 1,784 | 1,752 | 793 | 1,112 |

[1]All programs are 100% noise relevant.
[2]See Appendix for detailed project listing and description of projects
[3]Data on FY 75 and FY 76 are incomplete.

## 5. POWERED LIFT AIRCRAFT NOISE TECHNOLOGY

Noise technology activities associated with power-generated lift aircraft technology programs are considered in this section. Coverage is restricted to STOL/RTOL aircraft for short-haul applications to meet civil and military transport needs.

National Aeronautics and Space Administration

The major study categories related to powered lift aircraft with noise relevancy being conducted by NASA are as follows:

- Advanced powered lift aircraft aerodynamic technology. To develop the aerodynamics and systems technology needed to attain the integrated aerodynamic performance, noise, stability, control, and handling qualities characteristics required for viable powered lift in civil and military aircraft designs.

- C-8 augmentor wing flight experiment. To validate in flight the augmentor wing powered lift concept developed in laboratory programs as a practical means for providing STOL capability. To assess in flight the handling qualities of this type of aircraft. To provide a versatile representative powered lift aircraft for assessment of navigation and control systems requirements for safe terminal area operation.

- Quiet, clean, short-haul experimental engine (QCSEE). To design, build, and test experimental engines to consolidate and demonstrate the technology needed for very quiet, clean, and efficient propulsion system for economically viable and environmentally acceptable powered lift short-haul aircraft.

- Quiet propulsive lift technology (Advanced medium STOL (AMST) prototype aircraft). To obtain, through participation in the Air Force AMST prototype programs, propulsive lift flight research data on a straight-wing externally blown flap configuration at lift coefficients up to about 3.5.

- STOL operating systems experiments. To establish a technology base upon which operational STOL short-haul systems can be based with confidence in the 1978-2000 time period. To demonstrate operating systems technology, operating procedures, and guidance, navigation, and control concepts for high-density terminal area operation.

Funding data for these programs are given in Table 5.1. Specific technology goals, milestones, and technical and management approach are given in the Appendix for each NASA study category presented in Table 5.1.

## Department of Transportation-Federal Aviation Administration

The FAA participates with NASA in program activity related to powered lift aircraft technology as noted previously in Table 5.1. Additionally, the FAA conducts a program on V/STOL aircraft. A descriptive title and broad statement of objectives for this program follows:

- V/STOL aircraft - noise source reduction. To identify, evaluate, and control component noise sources inherent in V/STOL systems including studies of jet propulsion and rotary systems and noise prediction techniques.

Table 5.2 gives the FAA identification number for the V/STOL aircraft noise program, the major subprogram titles, the program schedule, and funding data as of July 1, 1974. For FY 1974 and FY 1975 contract funding is included with other programs and is therefore listed elsewhere in this report. A more detailed description of this program is given in the Appendix.

Table 5.1 NASA NOISE RELEVANT POWERED LIFT AIRCRAFT TECHNOLOGY
NOISE RELEVANT PROGRAM COSTS
(Thousands of Dollars)

| Descriptive Title | FY 1974 Gross R&D | FY 1974 Manpower Costs | FY 1974 Total | FY 1975 Gross R&D | FY 1975 Manpower Costs | FY 1975 Total | FY 1976 Gross R&D | FY 1976 Manpower Costs | FY 1976 Total |
|---|---|---|---|---|---|---|---|---|---|
| Advanced Powered Lift Aircraft Aerodynamic Technology | 140 | 170 | 310 | 900 | 580 | 1480 | 900 | 570 | 1470 |
| C-8 Augmentor Wing Flight Experiment | 100 | 60 | 160 | - | - | - | - | - | - |
| Quiet, Clean Short-Haul Experimental Engine (QCSEE) | 137 | 30 | 167 | 800 | 40 | 840 | 800 | 25 | 825 |
| Quiet Propulsive Lift Technology | 1100 | 210 | 1310 | - | - | - | - | - | - |
| STOL Operating Systems Experiments | 107 | 28 | 135 | 600 | 57 | 657 | 600 | 57 | 657 |
| TOTALS | 1584 | 498 | 2082 | 2300 | 677 | 2977 | 2300 | 652 | 2952 |

**Table 5.2. DOT/FAA PROGRAM SCHEDULE RELEVANT TO POWERED LIFT AIRCRAFT NOISE TECHNOLOGY**

| Program Element/Subprogram | Program Element Number | FY 73* / CY 1972 | FY 74 / CY 1973 | FY 75 / CY 1974 | FY 76 / CY 1975 | FY 77 / CY 1976 | CY 1977 |
|---|---|---|---|---|---|---|---|
| V/STOL Aircraft | 202-590 | Continuing Effort | | | | | |
| Source Noise Prediction and Reduction | | | | | | | |
| Jet Propulsors | | | | | | Award Report | |
| Rotary Propulsors | | | | | | Award Report | |

*Funding for FY 1973: $241,000 - 100% noise relevant.

## 6. ROTORCRAFT/VTOL NOISE TECHNOLOGY

This section considers noise relevant studies associated with technology programs for aircraft with rotor induced lift and advanced VTOL lift concepts. It deals primarily with VTOL aircraft for civil and military applications.

### National Aeronautics and Space Administration

The noise relevant rotorcraft technology programs and statements of objectives are as follows:

- Advanced rotorcraft aerodynamic technology. To determine and improve the performance, dynamic loads, noise, control, stability, vibration, and handling qualities characteristics of helicopter rotors and rotorcraft configurations in order to permit the development of rotorcraft having substantially greater mission and cost effectiveness than current (1973) operational vehicles in military and civil usage.

- Advanced VTOL aircraft aerodynamic technology. To provide the technology required to enable the development of viable military and civil aircraft having effective VTOL capability together with speed, range, operating cost, and mission/operational capabilities, approaching those of 1973 operational medium range military and civil CTOL aircraft. This requires the development of a thorough knowledge and understanding of the aerodynamic performance, noise, control, stability characteristics, and piloting qualities peculiar to VTOL system concepts.

- Tilt rotor research aircraft. To demonstrate advanced rotorcraft technology for military and civil VTOL vehicles having twice the cruise speed of the helicopter while retaining its efficient hover capability.

- Rotor systems research aircraft. To provide a unique flight test capability in 1976 for advanced rotor research on a wide variety of promising new rotor concepts. To expedite improved rotorcraft research through the use of a specially designed flight test vehicle.

- Rotor systems for rotor systems research aircraft (RSRA). To select, acquire, and evaluate on the Rotor Systems Research Aircraft (RSRA), under joint development by the Army and NASA, three practical advanced rotor systems concepts. To demonstrate through tests of these concepts in the real flight environment the integrated performance, dynamics, and acoustics technology improvements achievable.

- VTOL operating systems experiments. To establish a technology base leading to improved operational capability, improved VTOL operating efficiency, and decreased environmental impact. To support military technology requirements for assuring VTOL operational capability with a wide variety of landing sites and under reduced visibility conditions.

Table 6.1 provides a funding summary of the Rotorcraft/VTOL aircraft technology studies with noise relevance being conducted by NASA. Specific technology goals, milestones, and technical approach are included in the Appendix for each of the studies listed in Table 6.1.

Department of Defense

DOD Rotorcraft/VTOL noise technology programs and their objectives are:

- Tip vortex effects on rotary-wing aerodynamics. To significantly reduce undesirable rotor blade noise signatures and alleviate the blade-tip vortex interaction problem.

- Glare and noise reduction of helicopter rotor blades. To develop various materials and compositions capable of reducing the glint, glare, and noise from helicopter rotor blades without impairing lift or increasing weight or drag.

- Unsteady aerodynamics of blade-vortex interaction. To study the unsteady aerodynamic mechanisms responsible for helicopter noise.

- Investigation of noise generation on a hovering rotor. To define the noise field generated by a rotor.

- Analytical studies of helicopter rotor broadband noise generation. To establish a closed form solution for predicting the broadband noise intensity radiated by helicopter rotors.

- Studies in low speed flight. To investigate problems associated with low speed flight of helicopters.

- Systems studies of helicopter noise requirements. To establish a new methodology for systems analysis which includes noise criteria and to develop a new wind tunnel facility for making

Table 6.1 NASA NOISE RELEVANT ROTORCRAFT/VTOL TECHNOLOGY PROGRAMS
NOISE RELEVANT PROGRAM COSTS
(Thousands of Dollars)

| | FY 1974 | | | FY 1975 | | | FY 1976 | | |
|---|---|---|---|---|---|---|---|---|---|
| Descriptive Title | Gross R&D | Manpower Costs | Total | Gross R&D | Manpower Costs | Total | Gross R&D | Manpower Costs | Total |
| Advanced Rotorcraft Aerodynamics Technology | | | | | | | | | |
| Helicopter Aerodynamics | 265 | 180 | 445 | 205 | 95 | 300 | 200 | 100 | 300 |
| Tilt Rotor Aerodynamics | 20 | 10 | 30 | 70 | 40 | 110 | 70 | 40 | 110 |
| Civil Helicopter Tech. | 220 | 50 | 270 | 280 | 55 | 335 | 280 | 50 | 330 |
| Rotor Systems Technology | 140 | 35 | 175 | - | - | - | - | - | - |
| Rotor Acoustics and Aeroelasticity | - | - | - | 195 | 105 | 300 | 200 | 100 | 300 |
| Advanced VTOL Aircraft Aerodynamic Technology | 50 | 30 | 80 | 100 | 50 | 150 | 100 | 60 | 160 |
| Tilt Rotor Research Aircraft Program | 250 | 24 | 274 | - | - | - | - | - | - |
| Rotor Systems Research Aircraft | 500 | - | 500 | - | - | - | - | - | - |
| Rotor Systems for RSRA | - | - | - | 400 | 65 | 465 | 400 | 70 | 470 |
| VTOL Operation Systems Experiments | - | - | - | 400 | 224 | 624 | 400 | 224 | 624 |
| TOTALS | 1445 | 329 | 1774 | 1650 | 634 | 2284 | 1650 | 644 | 2294 |

useful noise measurements on V/STOL aircraft types.

- Tilt rotor research aircraft. To supplement funding of program conducted by NASA in cooperation with the Air Force.

- Rotor systems research aircraft. To supplement funding of program being conducted by NASA in cooperation with the Air Force.

Funding levels for DOD Rotorcraft Noise Technology Programs are: $267,000 for FY 1973, $534,000 for FY 1974, $675,000 for FY 1975, and $275,000 in FY 1976. The Appendix contains brief descriptions of DOD programs listed here.

## 7. SUPERSONIC CRUISE AIRCRAFT NOISE TECHNOLOGY

Programs with noise relevancy that are directed toward providing a technology base for future generation aircraft with supersonic cruise capability are presented in this section. It is noted that many of the programs listed under Section 4, Basic Research and Technology, have direct application to supersonic cruise aircraft.

### National Aeronautics and Space Administration

NASA has two programs dedicated to supersonic cruise aircraft (SCAR) technology with noise relevancy:

- SCAR propulsion technology. To establish an expanded supersonic propulsion technology base in parallel with the expansion of other supersonic disciplinary technologies which will permit the reduction of noise in takeoff and landing to levels less than the Douglas DC-10 and Lockheed 1011; reduce fuel consumption rates which can make supersonic cruise aircraft significantly more efficient; and nitric oxide emissions at high altitudes that are greatly reduced from levels possible with today's technology.

- SCAR aerodynamic performance technology. To establish an expanded supersonic aerodynamics technology base in parallel with the expansion of other supersonic disciplinary technologies which will permit improvements in L/D, reductions in sonic boom, and the translation of technical advances into integrated aircraft systems.

Table 7.1 is a funding summary for the supersonic cruise aircraft noise technology programs. Each program and noise related project is listed. More detailed program descriptions are given in the Appendix.

### Department of Transportation-Federal Aviation Administration

The FAA is conducting two programs relative to supersonic cruise aircraft noise technology. They are:

- Source sonic boom reduction. This is an effort to develop a definition of the air and ground system requirements for successful threshold mach number operation.

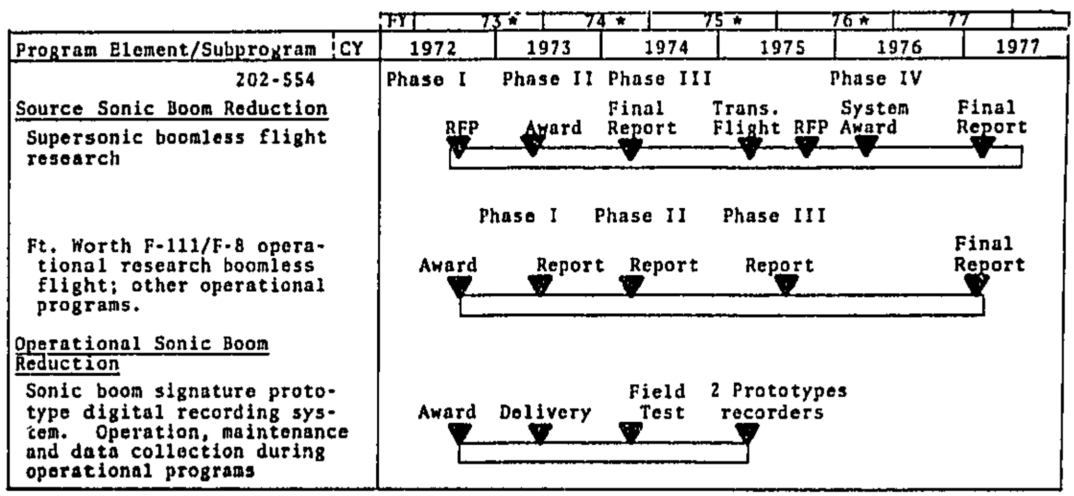
Table 7.1 NASA NOISE RELEVANT SUPERSONIC CRUISE AIRCRAFT TECHNOLOGY STUDIES
NOISE RELEVANT PROGRAM COSTS
(Thousands of Dollars)

| | FY 1974 | | | FY 1975 | | | FY 1976 | | |
|---|---|---|---|---|---|---|---|---|---|
| Descriptive Titles | Gross R&D | Manpower Costs | Total | Gross R&D | Manpower Costs | Total | Gross R&D | Manpower Costs | Total |
| Propulsion Technology | | | | | | | | | |
| Propulsion Noise Reduction Technology | 618 | 330 | 948 | 843 | 390 | 1233 | 1000 | 360 | 1360 |
| Experimental Engine Cycle Studies | 410 | 18 | 428 | - | - | - | - | - | - |
| Low Noise Engine Unique Components | 46 | - | 46 | - | - | - | - | - | - |
| Aerodynamic Performance Technology | | | | | | | | | |
| Integration Studies | 137 | 90 | 227 | - | - | - | - | - | - |
| Theory | - | 30 | 30 | - | - | - | - | - | - |
| Sonic Boom | 137 | 270 | 407 | 167 | 90 | 257 | 280 | 90 | 370 |
| TOTALS | 1348 | 738 | 2086 | 1010 | 480 | 1490 | 1280 | 450 | 1730 |

- <u>Operational sonic boom reduction</u>. This effort is to provide prototype, digital, lightweight, inexpensive sonic boom recorders and to obtain real time atmospheric data for use in long-range threshold mach number operational feasibility studies.

Table 7.2 shows the program schedule for the source sonic boom reduction and operational sonic boom reduction programs. The schedule has been updated to indicate milestones and targets as of July 1, 1974.

Table 7.2. DOT/FAA SOURCE SONIC BOOM REDUCTION, OPERATIONAL SONIC BOOM REDUCTION PROGRAM SCHEDULE (JULY 1, 1974)




*Funding allocations (100% noise relevant) are: FY 73 - $316,000; FY 74 - $299,000; FY 75 - $100,000; FY 76 - no funds scheduled

## 8. AIR TRANSPORTATION SYSTEMS STUDIES

Studies considered in this section are concerned with the interrelation of future air transportation needs, technology requirements, socioeconomic and environmental factors, and aircraft/airport interface.

National Aeronautics and Space Administration

Systems studies being conducted by NASA that have significant noise relevance are:

- Quiet propulsive lift transport technology systems studies. To identify, through aircraft definition and transportation systems studies, the problem areas, configurations and technology for emphasis in future quiet propulsive lift technology programs, including flight research.

- Short-haul transportation systems analysis. To develop a sound technological base for future decisions relating to the design, development, and operation of short-haul transportation systems; to examine the relationships between short-haul technology and short-haul economics, markets, and implementation; to identify potential viable short-haul airplane concepts and their design and performance criteria for practical short-haul transportation systems including consideration of market, economic, and environmental factors.

- Analysis of future civil air transportation systems and concepts. To identify promising aeronautical systems, determine optimum characteristics, and define technology requirements and costs associated with such systems. Studies include general aviation aircraft, CTOL, STOL, and VTOL transports, advanced subsonic transonic transport aircraft, and advanced supersonic transports.

- High transonic speed transport (HiTST) system study. To provide detailed configuration definitions of a high transonic speed transport concept with design studies to include fatigue and flutter characteristics of composite structures, low speed stability, and control of yawed wing for emergency maneuvers, and new engine technology application for reduced noise.

- Subsonic/Transonic C/RTOL transport technology systems and design studies. To make technology advances available for superior subsonic C/RTOL transport aircraft to satisfy anticipated requirements in the 1980's; to determine the feasibility of utilizing aircraft fuels other than JP fuel for subsonic cargo and passenger aircraft; to investigate new approaches to providing more economical subsonic transport of liquid and solid cargo in anticipation of the need for increased air transport of cargo.

- Subsonic/Sonic CTOL transport technology propulsion studies. To study the application of advanced technology to the improvement of future commercial transport aircraft including consideration of economic factors involving parameters such as aircraft drag, propulsion efficiency, cost, and propulsion system noise and exhaust emissions.

Table 8.1 provides a funding summary of the air transportation systems studies being conducted by NASA and discussed in the preceding paragraphs. Additional detail on objectives, approach, and milestones for each program is provided in the Appendix.

Environmental Protection Agency (EPA)

EPA sponsors studies to support its activities related to aircraft regulations. The FY 1973 and FY 1974 projects, which are most relevant, for inclusion here, are listed in Table 8.2.

Table 8.1 NASA NOISE RELEVANT AIR TRANSPORTATION SYSTEMS STUDIES NOISE RELEVANT PROGRAM COSTS (Thousands of Dollars)

| | FY 1974 | | | FY 1975 | | | FY 1976 | | |
|---|---|---|---|---|---|---|---|---|---|
| Descriptive Title | Gross R&D | Manpower Costs | Total | Gross R&D | Manpower Costs | Total | Gross R&D | Manpower Costs | Total |
| Short-Haul Transportation Systems Analysis | 150 | 30 | 180 | - | - | - | - | - | - |
| Analysis of Future Civil Transportation Systems and Concepts | 61 | 27 | 88 | 120 | 48 | 168 | 120 | 27 | 147 |
| High Transonic Speed Transport System Study | 15 | 1 | 16 | 80 | - | 80 | 80 | - | 80 |
| Subsonic/Transonic C/RTOL Transport Tech. Systems and Design Studies | 80 | 30 | 110 | - | - | - | - | - | - |
| Subsonic/Sonic Transportation Technology Propulsion Studies | 28 | 6 | 34 | - | - | - | - | - | - |
| TOTALS | 334 | 94 | 428 | 200 | 48 | 248 | 200 | 27 | 227 |

Table 8.2 EPA AIRCRAFT NOISE SYSTEMS STUDIES

| Project Title | Contracting Organization | Contract Number | Project Manager | Key Dates Start | Key Dates End | Amount, thousands of dollars |
|---|---|---|---|---|---|---|
| Aircraft/Airport Operations Noise Study | Bolt, Beranek & Newman | 68-01-1835 | J. Schettino | 4/73 | | 182 |
| Installation, Refinement and Training in Utilization of USAF-NEF | Bolt, Beranek & Newman | 68-01-2265 | D. Gray | 2/74 | 2/75 | 79 |
| Aircraft/Airport Study: Legal Analysis | George Washington University | 68-01-1834 | E. Cuadra | 4/73 | 9/73 | 110 |
| Development of Implementation Tools for Administration of Airport Noise Regulation | E. H. Robbins | 68-01-2266 | E. Cuadra | 2/74 | 4/75 | 33 |
| TOTAL for FY 73 & 74 | | | | | | 404 |

## 9. GENERAL AVIATION NOISE RELATED TECHNOLOGY

Many of the noise related programs presented in other sections of his report have application to general aviation aircraft. In particular, the NASA programs, Basic Noise Research and Noise Technology, involve studies of propeller noise reduction. DOT/FAA also conducts studies relevant to general aviation aircraft; however, these are included in Section 8 since it is difficult to isolate this activity from cost and program scheduling data.

### National Aeronautics and Space Administration

The title and statement of objective of the NASA programs dedicated specifically to general aviation aircraft are:

- General aviation aerodynamic technology. To develop and demonstrate advanced technology for general aviation use that will permit the design of future U.S. aircraft that will be safer, more productive, and clearly superior to foreign competition.

- Quiet, clean general aviation turbofan (QCGAT). To identify, extend, and demonstrate the technology applicable to small general aviation turbofans to achieve future environmental requirements with economic viability.

Table 9.1 shows the major study categories and the funding in the general aviation aerodynamic technology program. The Appendix contains an expanded discussion of this program.

Table 9.1 NASA NOISE RELEVANT GENERAL AVIATION AIRCRAFT TECHNOLOGY STUDIES
NOISE RELEVANT PROGRAM COSTS
(Thousands of Dollars)

| Descriptive Title | FY 1974 Gross R&D | FY 1974 Manpower Costs | FY 1974 Total | FY 1975 Gross R&D | FY 1975 Manpower Costs | FY 1975 Total | FY 1976 Gross R&D | FY 1976 Manpower Costs | FY 1976 Total |
|---|---|---|---|---|---|---|---|---|---|
| Aerodynamics and Crash-worthiness | 65 | 30 | 95 | - | - | - | - | - | - |
| General Aviation Technology | 200 | 60 | 260 | 250 | 198 | 448 | 370 | 90 | 460 |
| Quiet, Clean General Aviation Turbofan (QCGAT) | - | - | - | - | - | - | 400 | 136 | 536 |
| TOTALS | 265 | 90 | 355 | 250 | 198 | 448 | 770 | 226 | 996 |

## 10. REFERENCES


1. Civil Aviation Research and Development Policy Study. Report DOT TST-10-4, NASA SP-265; Supporting Papers DOT TST-10-5, NASA SP-265. March 1971.

2. Aircraft Noise Reduction Technology. A report by the National Aeronautics and Space Administration to the Environmental Protection Agency for the Aircraft/Airport Noise Study, March 30, 1973. This report gives a technical treatment of progress, status, and planned research by NASA relative to aircraft noise. (Unpublished)

3. Federal Noise Effects Research: FY73-FY75. A report prepared by the Interagency Noise Effects Research Panel, for the U.S. Environmental Protection Agency: EPA Report #600/2-75-001. March 1975. (31 pages.)

## 11. GLOSSARY OF ACRONYMS AND TERMS

AMST - Advanced Medium STOL Transport.

ARC - Ames Research Center.

C/RTOL - Conventional/Reduced Take Off and Landing.

CTOL - Conventional Take Off and Landing.

DOD - Department of Defense.

DOT - Department of Transportation.

EPNdB - Effective Perceived Noise Level in dB.

FAA - Federal Aviation Administration.

FAR-36 - Federal Aviation Rule, Part 36.

FRC - Flight Research Center.

FY - Fiscal Year.

HiTST - High Transonic Speed Transport.

JP-Fuel - Jet Petroleum Fuel

JPL - Jet Propulsion Laboratory.

L/D - Lift-Drag Ratio.

LaRC - Langley Research Center.

LeRC - Lewis Research Center.

NASA - National Aeronautics and Space Administration.

ONA - Office of Noise Abatement.

QCSEE - Quiet Clean Short-Haul Experimental Engine.

QSRA - Quiet Short-Haul Research Aircraft.

RD&D - Research, Development, and Demonstration.

RSRA - Rotor Systems Research Aircraft.

RTOL - Reduced Take Off and Landing.

RTOP - Research and Technology Operating Plan.

SAM - Sound Absorbing Material.

SCAR - Supersonic Cruise Aircraft.

STOL - Short Take Off and Landing.

USAF - United States Air Force.

V/STOL - Vertical/Short Take Off and Landing.

VTOL - Vertical Take Off and Landing.

## 12. APPENDIX - COMPENDIUM OF AIRCRAFT NOISE RELATED FEDERAL PROGRAM PLANNING AND PROJECT DESCRIPTIONS

This document contains detailed program planning information of the Federal Agencies' Aircraft noise research, development, and demonstration activities. The information and data are presented basically in the form submitted to EPA through the agencies' representatives on the Aircraft Noise Research Panel. This document can be viewed as the status of programs and plans as of July, 1974.

TABLE OF CONTENTS

# I. NASA PROGRAM DESCRIPTIONS

## 1. NASA SUBSONIC CONVENTIONAL TAKEOFF AND LANDING AIRCRAFT NOISE PROGRAMS

## NOISE REDUCTION FLIGHT PROCEDURES EXPERIMENTS
(768-80) Ongoing

### Program Objective

Reduce 90 EPNdB approach noise footprint by at least 60% through scheduled airlines' demonstrations of avionic systems for noise abatement flight procedures.

DOT considers the two-segment approach procedure to be the most promising operational noise abatement technique now under evaluation and an important part of the overall noise reduction program.

### Program Targets

NASA will demonstrate operational avionics and flight procedures that can be used to reduce airport community noise through the following steps:

- Complete six month trunk airline demonstration of two-segment approach with a B-727 in scheduled air-line service - November 1973.
- Complete six-month trunk airline demonstration of two-segment approach with a DC-8 in scheduled air-line service - October 1974.
- Demonstrate potential of other operating techniques for reducing aerodynamic and propulsion noise on approach and landing - January 1976.

### Program Approach

The NASA program for noise reduction has placed primary emphasis on the two-segment approach, which offers significant benefits.

- For reduced noise impact
- At a relatively small cost
- With the potential of early implementation

Program activities are closely coordinated with the FAA and the Joint ODT/NASA Office of Noise Abatement. They are being managed by the Ames Research Center with participation by the airline industry, airline pilots, avionic manufacturers, and air traffic controllers at several airports.

Two avionic system concepts are being evaluated. The main differences between the concepts are the techniques that will be used to establish the upper segment glide slope guidance. One concept, for aircraft not equipped with area navigation, will cost approximately $37,000 installed. The other concept, based on modification of area navigation equipment already installed in the aircraft, will cost approximately $9,000.

The program involves analysis, simulation, flight test, and in-service evaluation in two aircraft types: the B-727, and DC-8. The applicability of the procedures over the remainder of the fleet of current jet transports will be evaluated by analysis and simulations.

Over 1200 two-segment approaches have been made in the B-727 by over 120 pilots from 13 airlines at five airports. Of these, approximately 600 approaches by 58 line pilots have been made in passenger carrying service.

Preliminary results:

- Have obtained line pilot acceptance in one airline in one type aircraft:
  - Procedure has been demonstrated to be safe
  - Procedure can be interfaced with today's ATC environment
  - Avionics system provides good navigation accuracy on upper segment
  - No significant increase in pilot workload
  - Passenger comfort not affected
- Two-segment approach provides approximately 60% reduction in the 90 EPNdB approach noise footprint area for the B-727.

Research continuing into FY 75 includes the DC-8 in-service evaluation, investigations of the effects of operating procedures on aerodynamic and propulsive noise, and development of procedures that achieve maximum noise reduction.

Investigations have been conducted on a preliminary evaluation of the wake vortex behind and below jet aircraft flying a two-segment approach in order to determine if any additional hazard exists to following aircraft.

Need and Relevancy

The NASA in cooperation with the FAA and the airlines has been involved in developing and evaluating the operational procedures for noise reduction for a number of years. The landing approach studies indicated potentially large noise reductions could be achieved by three noise reduction approach techniques: the two-segment approach, the energy management of decelerating approach, and the curved ground tracts approach. Although it was found that these flight procedures are well within the performance capability of current day jet transports, they impose new requirements on the pilot duties and workload, on the pilot displays, on the guidance and navigation system, on the aircraft control system, on the ATC flow of aircraft to high density runways, and possible different wake turbulence effects. NASA decided in 1971 to embark on a substantial effort to develop suitable avionics for noise abatement procedures and to obtain sufficient experience so that they are accepted for routine operations.

In July 1973, the Administrator of the Environmental Protection Agency submitted a "Report to Congress on Aircraft/Airport Noise" in compliance with the Noise Control Act of 1972. The purpose of the report is to recommend ways in which the public health and welfare can be protected from excessive aircraft noise.

The following excerpts from this report reinforce the soundness of NASA's decision relative to the need and relevancy of procedural methods of aircraft noise reduction.

"Approximately 16 million persons are presently impacted by aviation noise in the United States, and in spite of the introduction of quieter new aircraft, the number will continue to be of major proportion until the mid-1980's unless aggressive action is taken."

"Aircraft noise around airports is presently a principal constraint on the future growth of the air transportation system."

"It is evident that there is a need to mobilize available resources and technology, including those of providing newer and quieter aircraft for the future, to deal with this problem in a coordinated time-phased fashion."

"If noise levels protective of the public health and welfare are to be achieved around the Nation's airports in the near future, it will be necessary to establish a Federal regulatory program which effectively combines Federal controls on aircraft flight procedures, technology, and noise control options available to airport operations and local jurisdictions."

"From the foregoing, it can be seen that a number of noise abatement flight procedures are available for implementation. Although by themselves, they cannot totally resolve the noise problem, they play an important part in any comprehensive plan for noise abatement."

"The two-segment approach seems to hold the most promise (of several different noise abatement approach procedures) for significant approach relief."

"The main objections to two-segment approaches come from ALPA pilots and some segments of the airline industry. They desire more testing to be certain that safety will not be degraded by the higher descent rates in the steep segment."

"EPA also concludes that two-segment approaches in IFR conditions are technically feasible after installation of equipment currently available in prototype form. Such approaches are expected to be consistent with the highest degree of safety upon completion and evaluation of the current NASA test program and certification of the equipment."

The Noise Reduction Flight Procedures Experiments program is being conducted by the NASA Office of Aeronautics and Space Technology to be responsive to the national need to protect the public health and welfare from aircraft noise.

## TERMINAL CONFIGURED VEHICLE OPERATING SYSTEMS EXPERIMENTS

(768-81) Ongoing

### Program Objective

Identify and provide proven technology and operating techniques for advanced CTOL and RTOL aircraft for reducing approach and landing accidents, reducing weather minima, increasing air traffic controller productivity and airport and airway capacity, saving fuel by more efficient terminal area operations and reducing noise by operational procedures during the 1976-2000 time period.

An expression by the U.S. scheduled airlines through the Air Transport Association on the desired direct thrust and content of the government's aviation research and development efforts proposes a research, development and applications engineering effort with three major work areas: (1) solution of environmental problems; (2) air traffic control process development and automation; and (3) aircraft and aviation support systems improvement.

Program Targets

Major targets of this program include technology readiness in the late 1970's for:

- Precision 4D flight path control by FY 1976 for
  - improved accuracy of time of arrival at runway from 18 sec. to 5 sec.
  - decreased spacing between parallel runways from 5000' to 3000'.
- Steeper, curved, and decelerating landing approach - FY 1976.
- Automatic landings in zero visibility - FY 1977.
- Reduction of the impact of aircraft on the environment in terms of aircraft noise and air pollutions FY 1976.
- Landing rates in IFR which approach VRF rates - FY 1977.
- Guidance and control capability for reduction in separation between aircraft on landing approach from 3 and 5 miles to 1 and 2 miles - FY 1976.
- Reduction in runway occupancy time from 55 sec. to 25 sec. - FY 1977.
- Avionics which interface with an advanced ATC system - FY 1978.
- Greater safety - FY 1979.
- Improved productivity by minimizing terminal area delays - FY 1979.

## Program Approach

NASA and FAA are working together on this program, under a joint agreement. The program is being managed by the Langley Research Center with most of the flight experiments being conducted from Wallops Station.

In comparison with existing transport aircraft, a terminal configured CTOL or RTOL aircraft should possess improvements in the following areas: greater flight path flexibility; less pollution and noise; improved acceleration, deceleration and lift capability; slower approach and departure speeds; closer spacing without wake vortex hazard; more accurate position, speed, and time control; less time on the runway, less sensitivity to wind and weather; greater speed flexibility; safer and better handling qualities; and reduced operating costs. To define operational systems needed to produce the above improvements and to identify areas where technology emphasis should be placed, initial attention in this program will be placed on analytical and experimental studies. Later, simulation and flight evaluation will be the primary tools in carrying out this program.

Plans for the program include research in conjunction with the Microwave Landing System (MLS), now under development by the FAA, and applying the greater accuracy and reliability of digital computer techniques to what are presently analog avionic systems. The MLS opens up many opportunities for improvement in terminal area operations because the aircraft is freed from the standard one-course ILS approach. Present aircraft instrument approach systems are not compatible with MLS.

Flight experiments using advanced displays and performing precision 4D flight paths in a uniquely equipped B-737 aircraft will commence late in FY 74. This research will continue heavily in FY 75 with particular emphasis on improving adverse weather approach and landing capability and safety through use of advanced displays and flexible, automatic digital flight control and guidance systems. Available and simulated advanced radio navigation aids will be utilized in flight tests at Wallops Station. Flight simulation and analysis work will lead and support flight tests. Feasibility demonstrations of advanced equipment will be conducted at key points during the program.

Additional details are available in the Dec. 1, 1973 Program Plan entitled, "Terminal Configured Vehicle Program."

## Need and Relevancy

The following excerpts from The National Aviation System Policy Summary, March 1973, which summarizes the FAA policies for the development of National Aviation System over the next ten years, clearly state the need and relevancy of the objectives of this program:

> "Thus, in consonance with National Transportation System goals, the broad technical goals over the next ten years can be summarized as follows:
>
> - Increase airport capacity
> - Increase airway capacity
> - Improve airway and airport safety
> - Minimize system operating costs
> - Minimize the impact of air transport on the environment"
>
> "The heart of the present air traffic problem lies at five high-density terminal locations where congestion and costly delays occur during adverse weather conditions and regularly during the peak hours. Without system improvements, the number of terminals experiencing such congestion is expected to increase to 21 by 1981."
>
> "Of all the major issues, this (the impact of environmental concerns on aviation systems development) is potentially the most important."
>
> "Long range impacts of the energy problem on aviation are still unclear, but it is quite probable it will act as a constraint on expanded aviation service."

These positions are supported by many others; for example, the DOT Air Traffic Control Advisory Committee and the Joint DOT/NASA Civil Aviation Research and Development Policy Study.

Since the problems of safety, adverse weather, noise, congestion, and fuel wastage manifest themselves most strongly in the high density terminal area, this program is concentrating on the terminal area performance characteristics of civil transport aircraft. Terminal area air traffic control is not merely a combination of procedures and hardware, but is a complex system involving people, aircraft, airports, and airport neighbors. All elements of the system must be studied in relation to each other and to their environment. The terminal area performance characteristics of aircraft are vital parameters in air traffic control.

If the long-term rate of growth of air transportation continues, airplane characteristic improvements in combination with planned FAA improvement in the ground system have the potential benefits of:

- Improvement of runway operations by 50 to 150%.

- Saving an average of 750,000 gallons of fuel per transport aircraft per year.

- Reducing the cost of delays by ½.

- Saving passenger time valued at more than $100M per year.

- Maximizing the effectiveness of the FAA Third and Fourth Generation ATC Systems.

In order to provide the system operating technology in a timely and effective manner, the TCV program will undertake to identify gaps in the current technology of operating systems (such as displays and aircraft performance requirements), and generate solutions which will permit more efficient terminal area operations. It is important that the TCV program be conducted in a time frame that is compatible with planned improvements in the National Aviation System. In order that the advanced airborne technology and systems required to interface with the future ATC system being developed under FAA leadership are available by the mid 1980's, they must be essentially demonstrated by the late 1970's. The planned schedule of TCV activities is designed to accomplish this purpose.

Safety of aircraft occupants is of fundamental importance in an air transportation system. Through a 60-plus year history of operations, accidents have provided clear and sometimes not so clear indications of hazard areas. With the advent of more reliable jet engines, en route accidents due to piston engine failure, severe weather encounters, and in-flight fires as well as takeoff accidents due to engine failure have declined as major accident prone areas, leaving the approach and landing phase accounting for more than half the fatal accidents. Offsetting higher approach and landing impact speeds as a threat is the improved structural integrity of modern aircraft and improved passenger seat retention. Control systems are more sophisticated, and navigation/communication is exceedingly complex by 1950 standards, and decision times for critical events in the landing process are short, all of which add up to more stress on the pilot's judgement and decision process. This makes an error in judgement potentially more dangerous in terms of an accident. A systems analysis will provide a rational assessment of potential accident-prone areas in flight operations.

TCV experiments will lead to reduced pilot workload by improved flight deck design, better understanding of crew inter-personal relationships, and automation. The aft flight deck of the 737 RSFS will provide a unique facility for man-vehicle (human factors) technology development.

The potential for significant reduction of approach and landing accidents is considered high.

Not only is the activity conducted under this program relevant to our efforts to ensure future airplanes capability to meet forecast traffic demand without adverse effect on safety and airport communities, it is aimed at putting the U.S. industry on a more competitive basis in world markets of manufactured aircraft and aeronautical equipment.

## REFAN PROGRAM (739-14)

### Program Objectives

Provide the technology to obtain a 75 percent reduction in the noise footprint area of JT8D-powered aircraft (727, 737 and DC-9) which account for over 60 percent of domestic fleet operations.

Furnish FAA and EPA with the technological and cost data essential for consideration of rulemaking on engine retrofits.

### Program Targets

Major targets of the Refan Program are the following:

- Complete the design of the refanned JT8D engine and acoustic nacelles for 727 and DC-9 aircraft by July 1973.
- Verify the predicted aerodynamic and acoustic performance of the refanned engine with ground engine tests starting in February 1974.
- Demonstrate the objective of 75 percent noise reduction with refanned engines and 727 aircraft nacelles by ground tests starting in February 1975.
- Demonstrate the objective of 75 percent noise reduction by actual flight tests of a DC-9 aircraft starting in February 1975.
- Final economic and performance data to FAA by June 1975.

## Program Approach

The approach to accomplishing this objective is to develop modifications for the JT8D engine that can be produced as retrofit kits, develop nacelles with acoustic treatment for the modified engines, and demonstrate the noise levels and performance levels of a DC-9 airplane in flight and a 727 propulsion system in ground tests.

The JT8D engine will be modified by replacing the existing two-stage fan with a larger diameter single-stage fan employing wide spacing between the vanes and rotor. The core engine pressure and flow will be maintained by two booster stages in front of the compressor. The fan turbine last stage rotor blade will be recambered. These changes will increase the engine thrust and lower the core jet velocity for the same cycle temperature. The lower jet velocity will result in decreased jet mixing noise. Acoustic treatment will be added to fan ducts and other acoustic devices will be considered to select an optimum engine nacelle. In the interest of minimizing the cost of the retrofit kit, no modifications will be made to any engine or airframe components unless they are necessary for or contribute directly to the substantial reduction of noise.

The program will be conducted through contracts with engine manufacturers, aircraft manufacturers and airline operators. NASA inhouse effort will be used both to manage the contracted efforts and to directly support the program through studies and tests in NASA facilities. The first phase of the program, completed in June 1973, established the refanned engine and nacelle definition through analysis, design and limited component testing. The second phase of the program, starting in July 1973, will culminate in ground tests of a 727 refanned propulsion system and flight tests of a refanned DC-9 aircraft both in February 1975.

## Need and Relevancy

The environmental impact of aircraft noise has been identified as a critical factor limiting the growth of civil aviation. Vigorous public reaction to the annoyance of aircraft operations has stifled civil air system expansion, produced costly litigations, and resulted in operational constraints which limit airport capacity and constrain aircraft procurement. Demonstration of the refan feasibility provides a basis for implementation of a refan retrofit which would reduce the noise footprint areas of the aircraft principally responsible for the high community noise exposure by 75 percent. Further, these same modifications can be introduced in the production of new 727, 737, and DC-9 aircraft to result in quieter, new aircraft.

OBJECTIVE NO. 766-78
ADVANCED ACOUSTIC COMPOSITE NACELLE
FLIGHT PROGRAM

Program Objective

Demonstrate on a modern wide-body transport in airline operation the application of advanced interwoven acoustic absorbent and composite structural materials to an engine nacelle which will:

- Reduce the noise footprint area of future production wide-body transport aircraft by 30 percent with no increase in aircraft weight or fuel consumption or alternatively reduce aircraft weight and fuel consumption with no increase in noise.

- Together with advanced technology engines, reduce the 90 EPNdB noise footprint area of advanced technology transport aircraft to 2 square miles with no increase in aircraft weight or fuel consumption resulting from the nacelle or alternatively reduce aircraft weight and fuel consumption together with some noise reduction.

Program Targets

Recent materials and structures developments at Langley Research Center on interwoven acoustic and composite materials offer the promise of considerable reduction in operating costs. This program will exploit these materials to:

- Complete nacelle concept definition studies and verify approach by January 1976.

- Complete ground tests of an advanced technology nacelle by early 1979.

- Certify an advanced nacelle for airline service on a wide-body transport by late 1979.

- Demonstrate quiet nacelle performance in routine airline service by 1982.

Program Approach

Current technology using uniform wall treatment basically attenuates the noise by the addition of acoustic absorbent materials to the structural materials. A promising advanced technology noise suppression technique embodies a reflection principle in addition to attenuation to decrease noise transmission. This is accomplished by interweaving acoustic absorbent and structural materials in a composite material form and thereby forming an acoustic structural material. By using multiple changes in wall acoustic treatment (segmented treatment), lower net transmission is achieved. The performance of the technique is striking - experimental results indicate about 15dB-reduction in sound intensity compared to the same weight of metalic material with added acoustic absorbent material. Utilization of the acoustic composite material can further eliminate the inlet and duct splitter rings which are currently used for noise suppression together with their associated drag and fuel penalties.

The project will be based on FY 1974 studies to determine areas where the application of composites with integrated acoustic material has the greatest payoff with respect to weight, cost, and noise reduction. The experimental program will be carried out in two phases. The first phase consists of preliminary design of the engine nacelle to be tested. The second phase will include the detail design, fabrication, and testing of the nacelle. The program, will: (1) evaluate various design concepts for the integration of composite materials with nacelle acoustic treatment in terms of initial cost, noise reduction, weight reduction, maintenance cost, and feasibility of application to existing propulsion systems as well as to advanced installations; (2) develop the technology associated with selected design concepts by means of analyses, ground tests, and limited flight tests and perform all analyses and tests required for commercial application; and (3) perform ground tests, and flight tests in commercial service, of production composite/acoustic nacelles to provide sufficient data on performance, maintenance requirements, and maintenance costs to establish aircraft and airline industry confidence in the application of composites to engine nacelles.

Overall direction and coordination of the Program will be accomplished by the OAST Transport Experimental Programs Office. The Langley Research Center will be designated the lead Center for the project with support by Lewis Research Center (propulsion activities). Program coordination with DOT/FAA and with the airlines will be maintained and nacelle certification will be under the direction of the FAA.

Need and Relevancy

The ICAO World Traffic Forecast for air passenger demand indicates a potential fivefold increase in air passengers by the mid 1980 period. The number of air passenger seats required is approximately double the number now available and on order. While the world fuel crisis may in time result in modification of this projected growth in demand for air transportation, the demand will certainly increase.

Market studies indicate that the bulk of this aircraft seat need will be met by new wide-body type aircraft. Current and quieted narrow-body aircraft will begin to be removed from service and the world aircraft fleet will be made up largely of wide-body aircraft certified to meet current noise regulations. Other types of aircraft such as advanced technology transports, SSTs, and STOLs will contribute to air lift capacity but to much less extent than current type wide-body aircraft.

With such a fleet mix, community noise exposure is expected to again increase during the 1980 period unless steps are taken now to provide technology which will permit noise reduction without fuel consumption penalties. The acoustic composite nacelle flight program is designed to serve that need.

a. NASA July 25, 1974 Testimony on Aircraft Noise Programs before the House Subcommittee on Aeronautics and Space Technology

RESEARCH AND TECHNOLOGY FOR AIRCRAFT NOISE ABATEMENT

Statement of

J. Lloyd Jones
Deputy Associate Administrator for Aeronautics Technology
Office of Aeronautics and Space Technology

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Before the

Subcommittee on Aeronautics and Space Technology
Committee on Science and Astronautics
House of Representatives

Mr. Chairman and members of the Subcommittee, I am pleased to have this opportunity to bring the Subcommittee up to date on NASA's activity related to the abatement of noise in the present and projected civil air transportation fleet. As you know, we consider this an important public matter and have given it considerable attention over an extended period of time.

Today I will present a brief report on the progress of our work on the refan retrofit option for civil aircraft certificated before Federal Air Regulation Part 36 came into effect; and on the result of a meeting on the Refan Program and related regulatory activity between Dr. Fletcher, Administrator of NASA, Mr. Barnum, Under Secretary of DOT, and Mr. Meister, Associate Administrator for Plans of FAA, attending for Mr. Butterfield, Administrator of FAA, and attended by Mr. Strelow, Acting Assistant Administrator for Air and Waste Management of EPA, attending for Mr. Train, Administrator of EPA. I will also report on the progress made on NASA's Two-Segment Approach Program, the coordination of aircraft noise abatement programs, and NASA programs to provide data for the reduction of noise in the near and long term.

Before discussing our programs, I would like to note that NASA is concerned primarily with the technological aspects of aircraft noise abatement. The treatment of all the complex factors (economic, social, operational, and foreign) associated with regulation are the responsibility of other branches of government, noteably DOT, FAA, EPA, and OMB.

# REFAN PROGRAM SCHEDULE

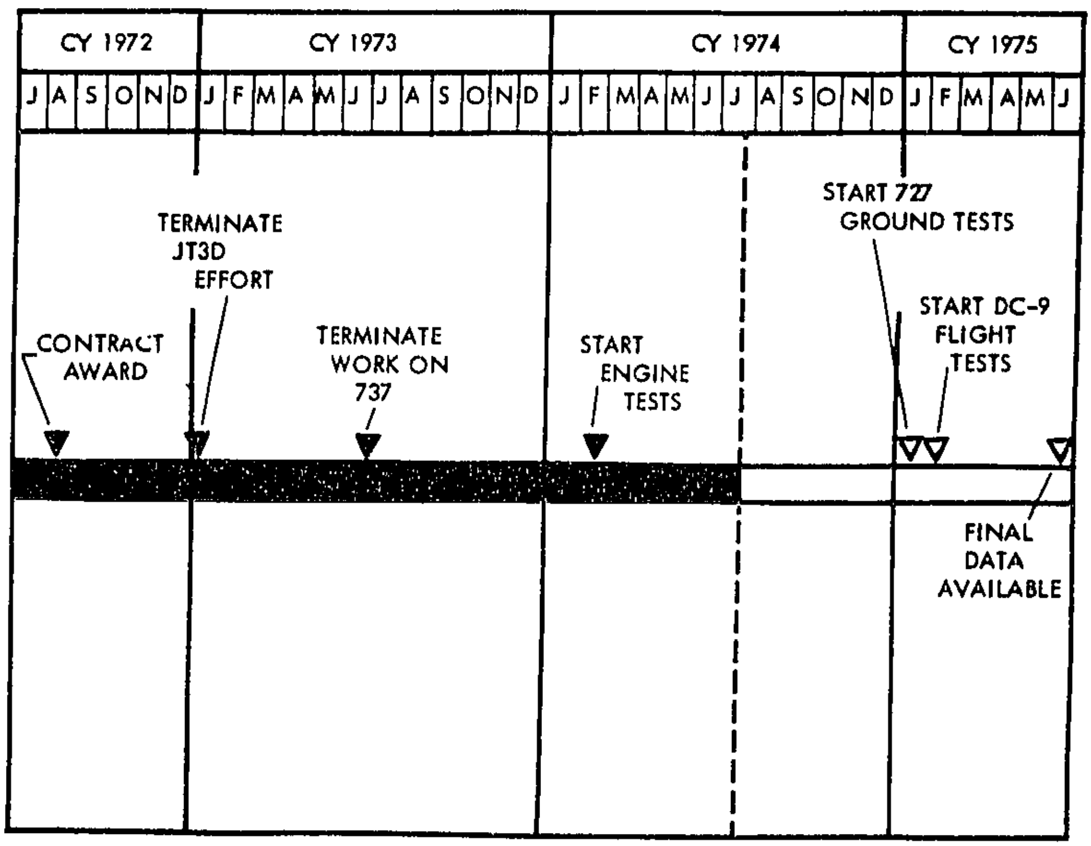



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FIGURE 1

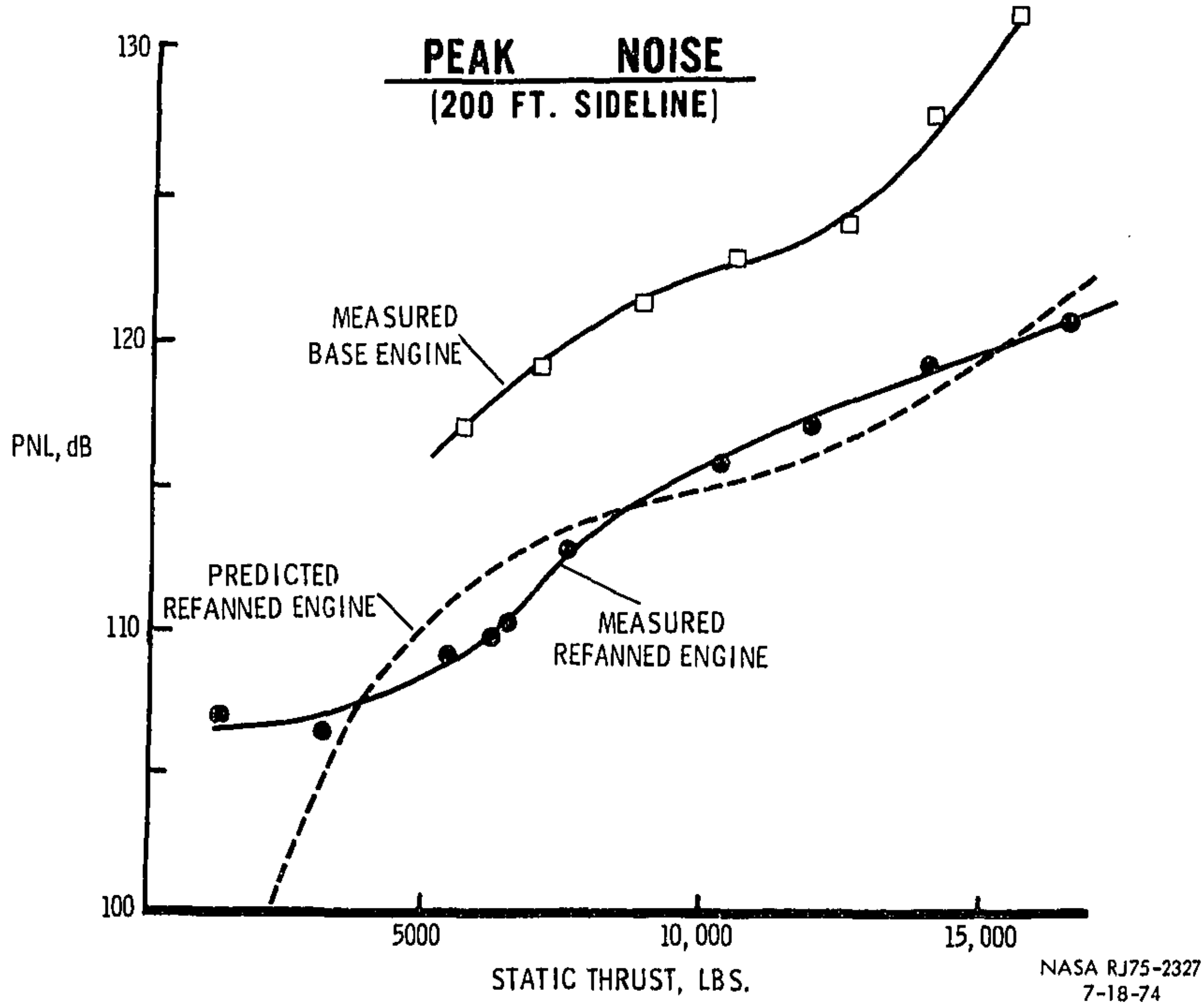

PEAK NOISE
(200 FT. SIDELINE)
130
120
110
100
PNL, dB
MEASURED
BASE ENGINE
PREDICTED
REFANNED ENGINE
MEASURED
REFANNED ENGINE
5000
10,000
15,000
STATIC THRUST, LBS.
NASA RJ75-2327
7-18-74

FIGURE 2

Thus, the comments and data we present are not the sole basis for decisions in the complex arena of noise abatement.

## REFAN RETROFIT

As you know, NASA's part of the retrofit program is to develop and assess the costs, effectiveness and technical feasibility associated with refanning the JT8D-powered fleet. This program has been described in detail to the Subcommittee in previous hearings. Figure 1 presents the program schedule discussed with the Subcommittee at its hearings in December of last year. All of the major milestones are being met. The testing of refanned JT8D engines began in February as planned. Our schedule still calls for initiation of detailed ground tests with the 727 airplane refan hardware in January of 1975, about six months from now. The DC-9 airplane refan flight tests will start a month later, in February. An updated assessment of the Phase I acoustic and performance design estimates for the 737 will be developed after the 727 and DC-9 tests. Final data will be available by June of 1975.

A substantial amount of data on the mechanical, aerodynamic and acoustic performance of the refanned engines is now in hand. Two engines have been tested extensively and testing of a third engine begins this month.

Figure 2 shows a typical result from the refanned engine acoustic tests, the peak noise level of the engine measured at the 200 foot sideline. The top curve on the figure shows the data from a standard JT8D-9 engine plotted against engine thrust. The lower solid and dashed curves are the measured and predicted noise levels for the refanned version of the engine. The measured and predicted noise levels are in good agreement.

On the basis of the engine acoustic results, new baseline aircraft data, and new analysis procedure, the airframe contractors have revised their estimates of the noise levels of the DC-9 and 727 aircraft. These estimates are still under study by the Refan Project Office at the Lewis Research Center. Although the measured overall noise of the refanned engine was as predicted, the distribution of the noise among the various engine components was not. The distribution of component noise affects the calculated aircraft noise. Further acoustic tests at Pratt and Whitney and further analysis of the acoustic data are needed to establish confidence in the aircraft noise predictions.

Specific fuel consumption (SFC) is also an important factor in assessing retrofit options. In the March 1974 Authorization Hearings we noted that preliminary measurements of SFC for retrofitted engines were higher than estimates and corrective action was being considered. Minor engine changes have been made and further tests have been conducted.

The basic predicted improvement in SFC for the uninstalled refanned engine has been achieved over most of the engine thrust range. At maximum power the increment of improvement was less than predicted by about two percent. Furthermore, the absolute level of SFC is higher than predicted. This is thought to have resulted from the fact that the SFC of the basic engine that was modified to provide the refan test engine was higher than that of a new engine. Refanning, therefore, resulted in largely achieving the predicted incremental reduction in SFC but not the absolute level expected. We do not know whether the same improvement in SFC will be realized for a new engine conversion to a refanned engine. A new engine, refanned, is being tested this month and we will soon have the answer to this question.

It should be noted that the tests to date were conducted at sea level static conditions. The translation of these test data to altitude cruise conditions is uncertain. The SFC could be high by as much as the 2 percent experienced at the maximum power conditions. Better SFC data for altitude cruise will be available some time after August as a result of wind tunnel flight simulation tests to be conducted at the Lewis Research Center.

Assuming we achieve our predicted values of SFC at all conditions, the estimated changes in block fuel due to refanning the 727 and DC-9 aircraft shown in Figure 3 should be realized. For some combinations of altitude, speed, and distance, fuel is increased as much as 3 percent and for others it is decreased as much as 1 percent. As you see, the impact of refanning on fuel usage is estimated to be small and a function of specific operating conditions. A refined analysis of specific airline operations would be required to substantiate gain or loss for a specific operator.

As we have discussed with you before, the refan technology is a higher cost technology than sound absorption material alone. The investment cost for a retrofit of the JT3D- and JT8D-powered fleets with SAM is estimated to be $667 million, in the 23 airport study of the Joint DOT/NASA Office of Noise Abatement, whereas a retrofit of the JT3D-powered aircraft with SAM and the JT8D-powered aircraft with refan is estimated to be $2.82 billion, or more than four times as much as a complete SAM retrofit. These numbers are based on assumptions of inflation rate and starting schedule for the SAM and refan retrofits that are necessarily subject to uncertainty. In 1973 dollars, the cost of a SAM JT3D and refan JT8D retrofit is $1.95 billion.

In addition to the initial investment cost there are other costs associated with a fleet retrofit that would increase the cost of the SAM JT3D/Refan JT8D retrofit program. The current estimate in the 23 airport analysis would indicate a total cost of about $5 billion. These additional costs include consideration of changes in direct

# BLOCK FUEL CHANGES FOR REFANNED AIRCRAFT

(55 - 60 PERCENT LOAD FACTOR)

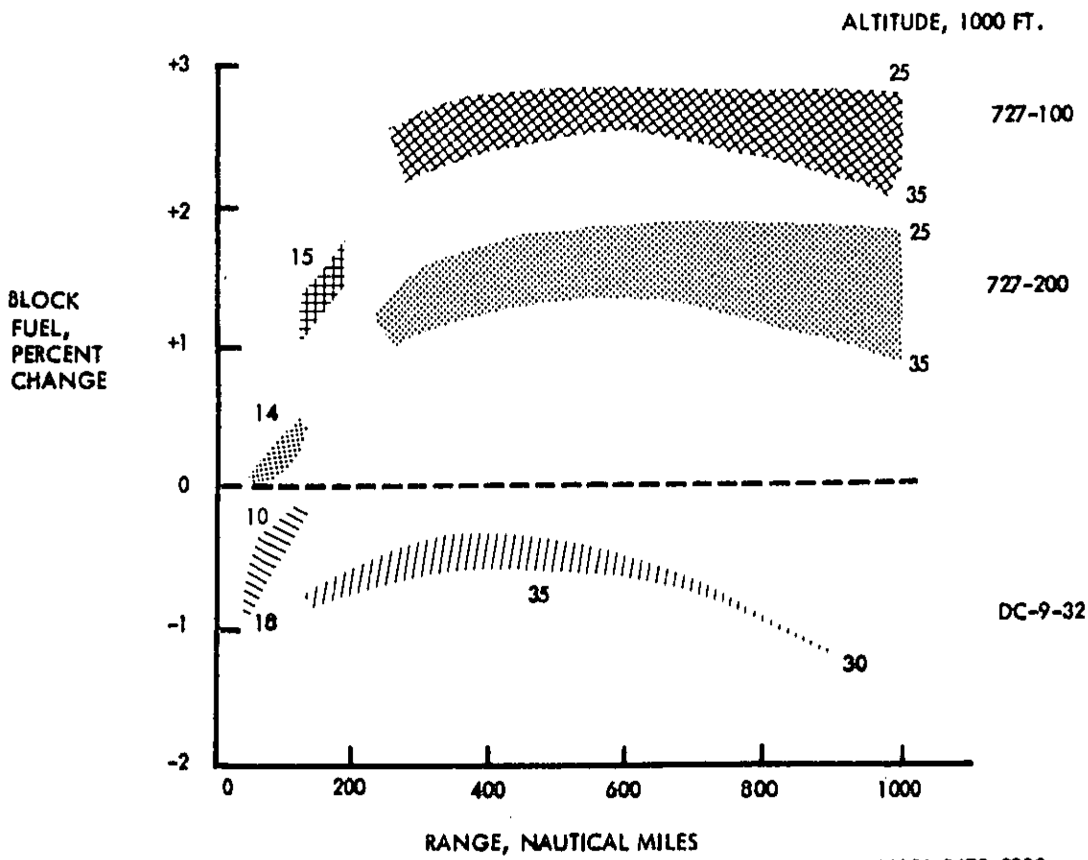



FIGURE 3

operating cost (DOC) over the projected life of the aircraft, "lost productivity" resulting from the retrofitted aircraft being unable to perform maximum range missions because of increased weight, and the aircraft being out of service during the retrofit installation.

There are sufficient uncertainties in evaluating these additional factors, excluding the assumed inflation rate and retrofit schedule, that the $5 billion cost could be over-estimated. These complex factors are currently being discussed with DOT to develop a realistic accounting procedure.

We have provided data to DOT, FAA, and EPA on all aspects of the Refan Program: acoustics, performance, and cost. As the program moves into the final stages we will continue to provide data needed to these agencies for their deliberations regarding retrofit.

## REFAN PROGRAM/REGULATORY ACTIVITY REVIEW

At our March 6, 1974 hearings before this Subcommittee, we advised you that the Under Secretary of DOT, and the Administrators of FAA and NASA were planning a series of meetings to review the progress of the Refan Program and the plans for related regulatory activity. A meeting of this group was held this past July 22. At this meeting, the Refan Program progress was reviewed as well as the results of the Joint DOT/NASA Office of Noise Abatement study of the effects of various retrofit and operational techniques for noise reduction at 23 airports. In addition, the position of DOT/FAA on regulatory action for retrofit was reviewed.

At this July 22 meeting, it was concluded by DOT/FAA that there was nothing new to warrant a change in the DOT/FAA position on the retrofit NPRM. It was concluded by NASA that the Refan Program should continue exactly as planned because of the technological advances provided by the program, the possible use of refanned engines in derivative aircraft, and the need for keeping the technological option for lower noise levels in the future.

## THE TWO-SEGMENT APPROACH PROGRAM

I will now move on to discuss our two-segment approach activity. We have described this program, supported by the FAA, in past testimony. As you know, the objective of the program is to provide a significant near-term reduction in the aircraft landing approach noise through the provision of operational avionics and flight procedures that can be used safely by airlines in both visual and instrument flight.

I will review for you briefly the program approach, the results of the 727 in-service flight program, and update you on the in-flight evaluation with the DC-8 aircraft.

The Two-Segment Approach Program, managed by our Ames Research Center, is closely coordinated with DOT, FAA, and EPA. Program guidance has been provided by a Research and Technology Advisory Ad Hoc Panel on Noise Abatement Flight Procedures. Its members came from DOT, FAA, aircraft and avionics manufacturers, airlines, and the airline pilots' association.

Figure 4 shows one version of the two-segment guidance equipment required in the airplane to permit either manual (flight director) or automatic (autopilot) two-segment approaches. This airborne equipment requires ground based distance measuring equipment (DME), co-located at the instrument landing system (ILS) glide slope transmitter.

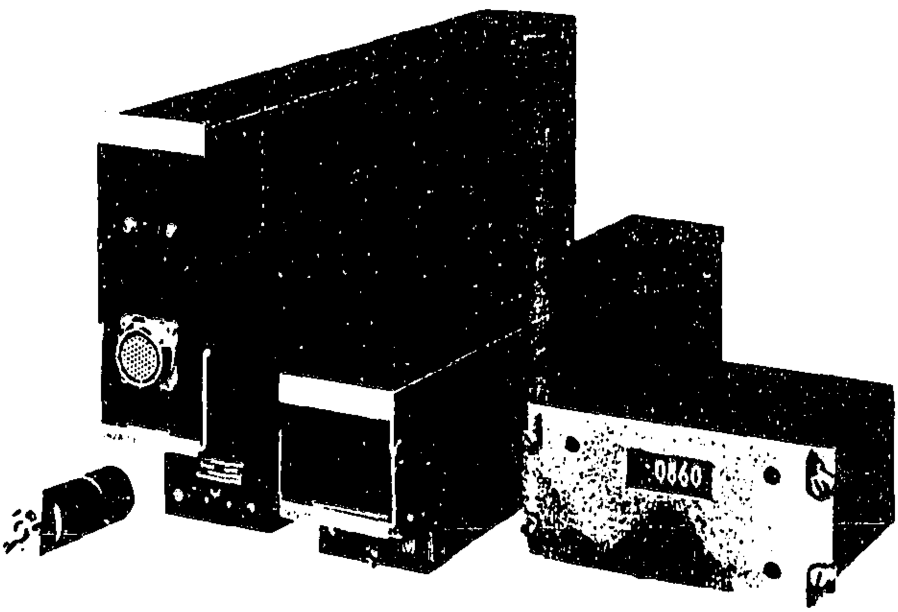
Briefly, the two-segment approach technique can be described as follows. A special airborne computer constructs a preselected upper glide slope (normally $6^{o}$) using barometric altitude and distance information from the DME. Field elevation is set-in by the pilot before the approach is initiated. On an approach, the upper glide slope is captured by the aircraft and the descent initiated. At about 1000 feet above ground level the computer programs a gradual round out. Then, the lower nominal $3^{o}$ glide slope is captured and tracked as on a conventional approach. At an altitude of about 500 feet, the airplane is stabilized on the $3^{o}$ glide slope and goes on to a normal landing.

The cost of the two-segment guidance system, illustrated in Figure 4, is approximately $40,000 per aircraft for a dual installation. To add two-segment guidance to an existing three-dimensional area navigation system, such as shown in Figure 5, would cost approximately $9,000 for a dual installation. For this system the DME need not be co-located with the ILS glide slope transmitter. The costs noted include the basic equipment, aircraft modification and installation, check-out spares and training, and as noted dual installations. Dual installations, however, may not be required.

## The 727 Two-Segment Approach Program

The 727 Two-Segment Approach Program has been completed. It had two objectives: to develop operational avionics and two-segment flight procedures for safe use with 727's in routine scheduled operations; and, to conduct a six month evaluation in revenue service. The special avionic equipment illustrated in Figure 4 was used.

# TWO-SEGMENT APPROACH SYSTEM COMPONENTS FOR NOISE ABATEMENT FLIGHT PROCEDURES PROGRAM




TWO-SEGMENT APPROACH COMPUTER

TWO-SEGMENT APPROACH SWITCHING UNIT

TWO-SEGMENT APPROACH CONTROLLER

SELECTOR SWITCH

FIGURE 4

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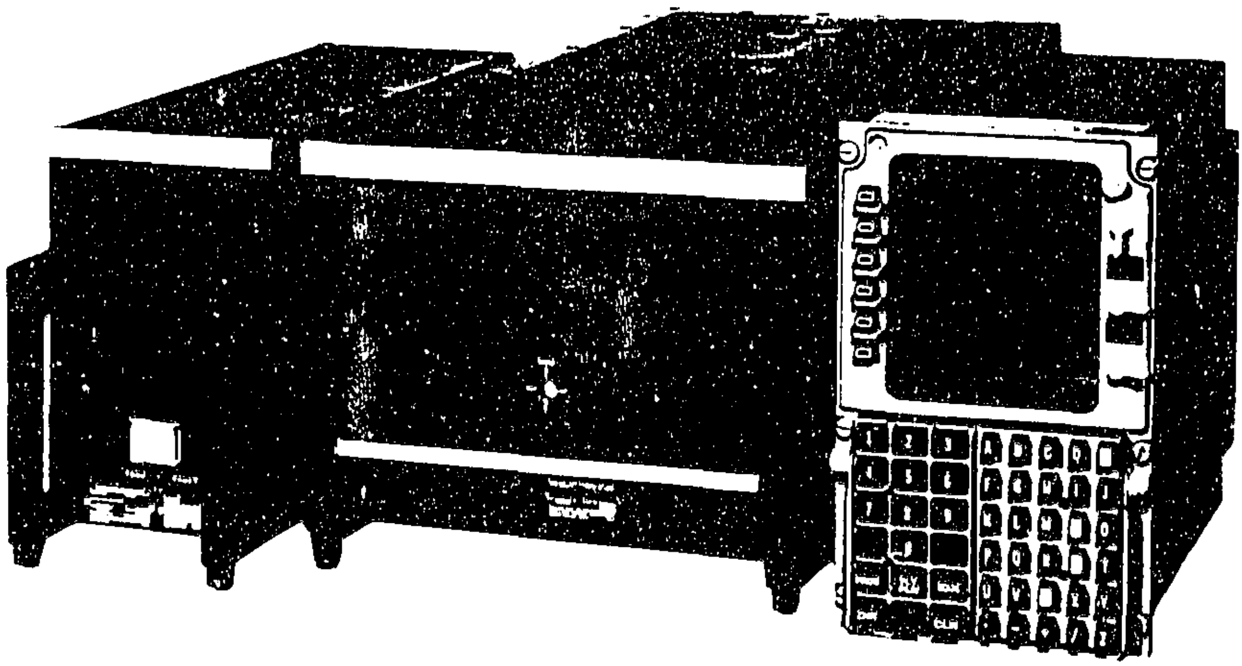
# AREA NAVIGATION SYSTEM COMPONENTS MODIFIED FOR TWO-SEGMENT NOISE ABATEMENT APPROACHES



FLIGHT DATA STORAGE UNIT
NAVIGATION COMPUTER UNIT
CONTROL DISPLAY UNIT

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FIGURE 5

Prior to actual flight tests, extensive flight simulator evaluations were conducted to assess, evaluate, and assure flight safety. Flight profile variations, operational abnormalities, and equipment malfunctions were simulated. Extensive engineering flight tests and guest pilot evaluations were conducted before initiating the in-service 727 flights by United Air Lines.

More than 600 two-segment approaches were flown, in the pre-service phase of the program, about 30 percent of them under instrument-flight weather conditions. Pilots from 12 airlines, NASA, and the FAA were involved.

The in-service evaluation commenced on the West Coast in April 1973, with two-segment approaches being made at Los Angeles, San Francisco, and Portland. The six-month evaluation was successfully completed on October 28, 1973.

Fifty-five United pilots participated, 555 two-segment approaches were flown without incident, and over 40,000 passengers were carried. The approaches were accomplished uneventfully by the flight crews and unnoticed by the passengers.

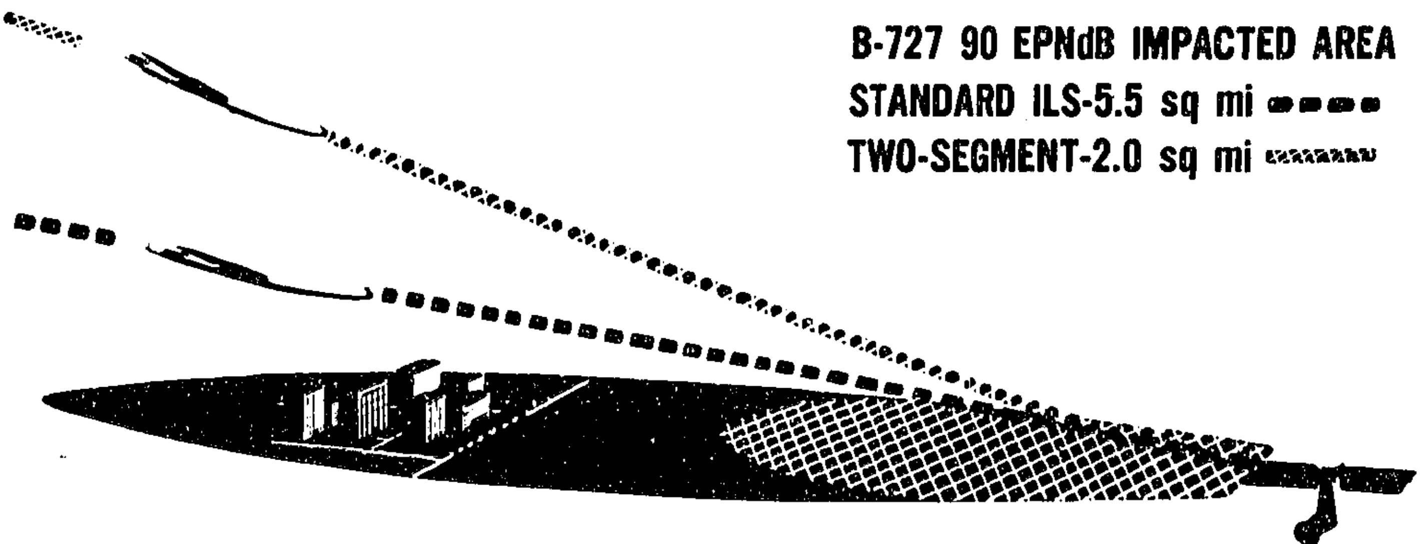
Figure 6 illustrates that the 727, using a two-segment approach, exposes 2.0 square miles of land to noise levels greater than 90 equivalent preceived noise, decibels (EPNdB), compared to 5.5 for a normal approach, a 64 percent reduction. The reduced power setting of the two-segment approach also saves a small amount of fuel, about ten gallons for a 727. An annual saving of about 50 million gallons of fuel would accrue if all U. S. carriers were making two-segment rather than conventional approaches.

## DC-8 Two-Segment Approach Program

United Air Lines is now conducting an investigation of DC-8-61 two-segment approaches for NASA. It is considered the most challenging airplane for two-segment approaches because of its low drag in the landing configuration. Our tests have confirmed that the recommended upper segment of the DC-8 two-segment approach should be $5.5^{\circ}$ rather than the $6^{\circ}$ attainable with the 727. As shown in Figure 7 the DC-8 on a $5.5^{\circ}$ two-segment approach exposes about 5.5 square miles to greater than 90 EPNdB, compared to 11.6 for a normal approach, a 53 percent reduction.

The modified area navigation system shown in Figure 5 is used to provide the two-segment approach guidance for the DC-8. This mechanization provides a low cost option for aircraft already equipped with an area navigation system.

# NOISE RELIEF FROM TWO-SEGMENT APPROACH




NOISE IMPACTED AREAS

FIGURE 6

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# TWO-SEGMENT APPROACH

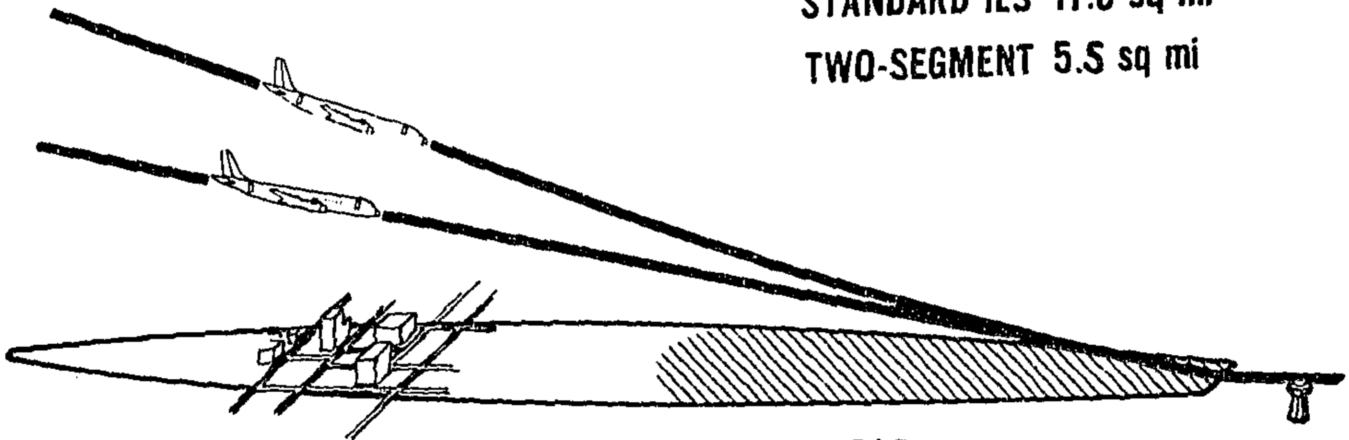


FIGURE 7

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In August, in-service evaluation of the DC-8 two-segment approach system will be initiated with line pilots. This will follow a three month engineering flight evaluation period. To date, nearly 800 DC-8 two-segment operational approaches have been made by United in the engineering flight evaluation period. Early reports indicate acceptance by the 45 (including 21 guest) pilots that participated in the program.

Applicability of the Two-Segment Approach to Other Aircraft

Analytical studies by the manufacturers have established the applicability of the two-segment approach to other aircraft in the civil jet transport fleet. Figure 8 summarizes the noise relief that would be expected. When these benefits are considered in proportion to the projected operations of the fleet for 1977, the area impacted by an approach noise level, of 90 EPNdB or greater, is estimated to be reduced by about 57 percent.

Wake Turbulence

One anticipated problem with the two-segment approach is the airplane's wake turbulence, which can cause an upset of a following airplane. With the two-segment approach, it has been postulated that a closely following aircraft might not be able to operate clear of the preceding airplane's trailing wake vortex as often as behind an airplane making a conventional straight-in approach.

Results of joint NASA/FAA flight tests have shown that the strength of the wake vortex generated on a two-segment approach is substantially the same as that generated from conventional approaches. Vortex settling characteristics also appeared to be about the same. The significance of these factors with regard to the spacing and other operating requirements for following aircraft are under study with the FAA. The FAA will use these data to help determine its position of the use of two-segment approaches for noise abatement.

Summary

In summary, as of July 1, 1974, nearly 2000 two-segment approaches have been conducted with 727 and DC-8 aircraft by about 170 pilots. Guest pilots have generally started their evaluations with an apprehensive, skeptical attitude toward the desirability, feasibility and acceptability of two-segment approaches. Typically, a guest pilot appeared to have the procedure in-hand by the third practice approach. With very few exceptions, by the end of their evaluation flights there was

# APPROACH NOISE AREA REDUCTION POTENTIAL WITH THE TWO-SEGMENT APPROACH

| AIRPLANE | REDUCTION IN 90 EPNdB IMPACTED AREA WITH TWO-SEGMENT APPROACH % | ESTIMATED OPERATIONS IN 1977 -% | FLEET-WEIGHTED REDUCTION IN 90 EPNdB IMPACTED AREA - % |
|---|---|---|---|
| B-707 | 57 | 9 | |
| B-727 | 64 | 40 | |
| B-737 | 52 | 10 | |
| B-747 | 39 | 5 | 57 |
| DC-8 | 53 | 5 | |
| DC-9 | 63 | 18 | |
| DC-10 / L-1011 | 44 | 13 | |

FIGURE 8

NASA RO74-2498
2-19-74

a nearly complete reversal of opinion, i.e., from opposed to cautious optimism and support. Acceptance of the concept by a pilot appeared to progress in proportion to the number of two-segment approaches flown.

The results of the Two-Segment Approach Program indicate that the technique is an operationally feasible and safe technique for providing a significant reduction in aircraft approach noise. A full understanding of the operational implications of wake turbulence for following aircraft remains to be developed.

## AIRCRAFT NOISE PROGRAM COORDINATION

My following comments are directed to the Subcommittee's interest in the coordination of the Government's programs related to aircraft noise reduction.

NASA is continuing to work closely with DOT, FAA and EPA, at the staff level, through working panels, and through the Joint DOT/NASA Office of Noise Abatement, to help assure that the Government has an integrated research and technology program directed toward the near and longer term reduction of aircraft noise.

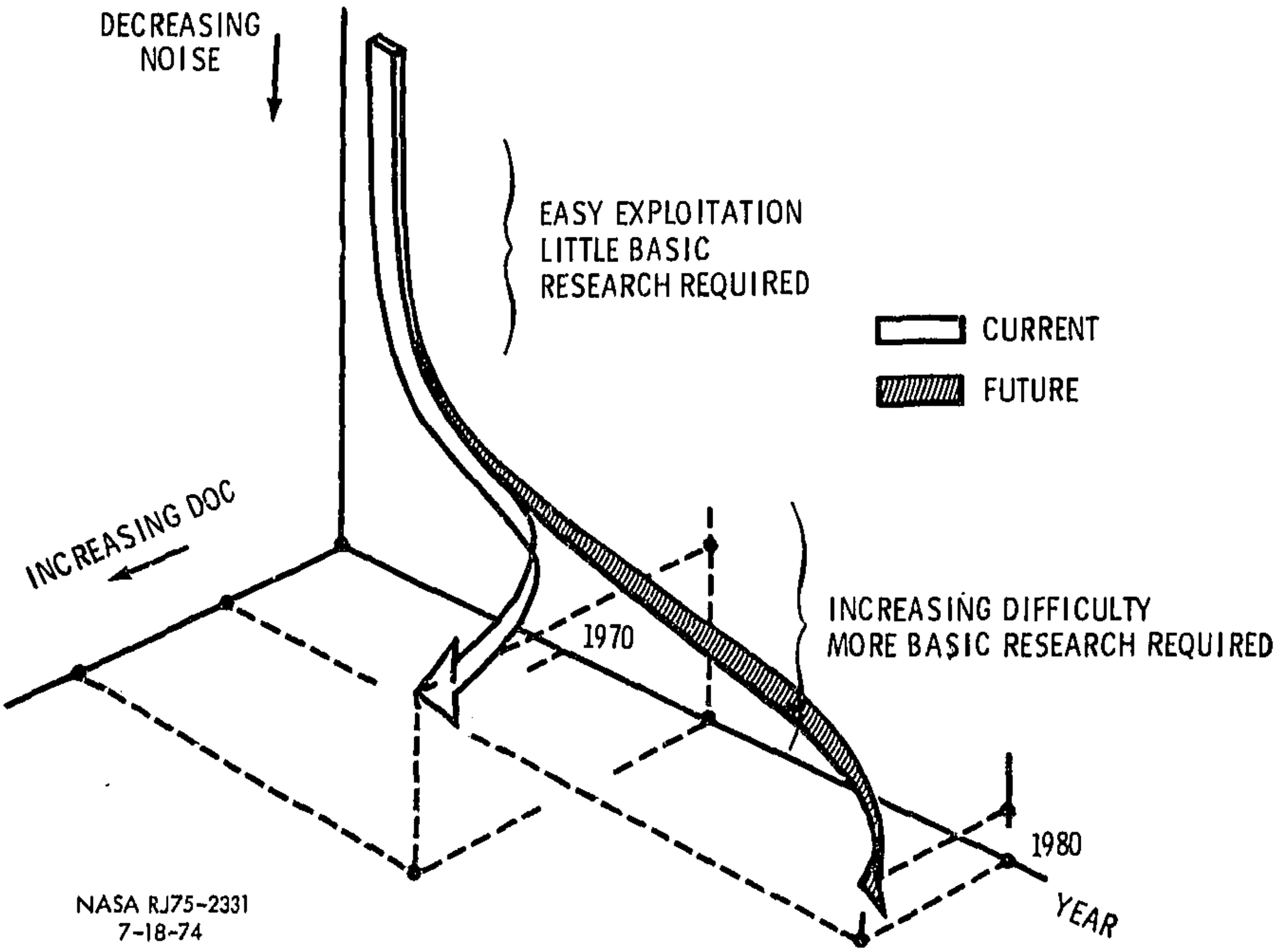
Through the Joint Office, we have provided EPA with our most recent internal program planning data and as members of their noise research and technology program coordination panels, we have met with them as late as this past month to assist in their coordination effort.

## NASA AIRCRAFT NOISE REDUCTION ACTIVITY

We believe that NASA has made and is continuing to make progress in the development of technology for the reduction of aircraft noise. This progress is being achieved through research on the understanding, control and reduction of engine, aircraft and operations related noise. We are also vitally concerned with the reaction of people and communities to air transportation noise.

The Civil Aircraft Research and Development (CARD) policy study set a general goal for the reduction of aircraft noise of 10 dB per decade. Technologically, this goal is achievable in this decade. However, the prospects of achieving this goal in the next decade are reduced by the consideration of technical and practical operating costs. This situation is illustrated in Figure 9. For near term practical air transport designs, we believe designers will be able to reduce aircraft noise to conform to FAR-36 with little increase in direct operating costs (DOC). In the longer term it is not clear that we can achieve an additional 10 dB noise reduction without a significant and possibly unacceptable increase in DOC.

# AIRCRAFT NOISE REDUCTION

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7-18-74

FIGURE 9

We feel, however, that it is important for us to continue our efforts to reduce noise and maintain operating efficiency. Our longer term programs are directed toward these objectives. To illustrate, I will review selected efforts to provide for future noise reduction, improved noise prediction, and an understanding of the impact of noise on people. These programs include: advanced acoustic composite nacelles, airframe noise reduction, propeller noise reduction, aircraft noise prediction, and human response to noise.

## Acoustic Composite Nacelles

The acoustic composite nacelle program was developed to design and demonstrate light-weight nacelles constructed of integrated structural acoustical material. As shown in Figure 10, current nacelle noise reduction technology involves lining the nacelle with non-load-carrying sound absorption material. This reduces engine noise, but weight and fuel consumption are increased. We are exploring the use of advanced acoustic composite materials which interweave sound absorbent and structural materials to form a sound absorption structure. Laboratory studies indicate that for the same nacelle weight at 15 dB reduction in sound intensity may be possible through the use of acoustic composite structural material.

Conceptual design studies of such a nacelle were initiated in FY 1974. The findings from these studies will be verified through laboratory investigations during FY 1975, and nacelle designs will be initiated in FY 1976. We plan to complete ground tests in FY 1979.

The nacelle design will be appropriate for current wide-body transports so that after completion of ground testing (including flight-qualification tests) the nacelle could be demonstrated in flight. The potential value of this type of nacelle is shown in Figure 11. An acoustic composite nacelle applied, for example, to a future production DC-10 offers the performance potential of reducing the 90 EPNdB noise footprint area by an estimated 30% without a change in airplane weight or operating cost or, for the same noise performance (footprint), the aircraft weight could be reduced by about 2700 lbs., and 1000 lbs. of fuel could be saved on a transcontinental flight.

This technology, of course, is applicable to future advanced technology transports.

# APPLICATION OF ACOUSTIC COMPOSITE STRUCTURAL MATERIAL

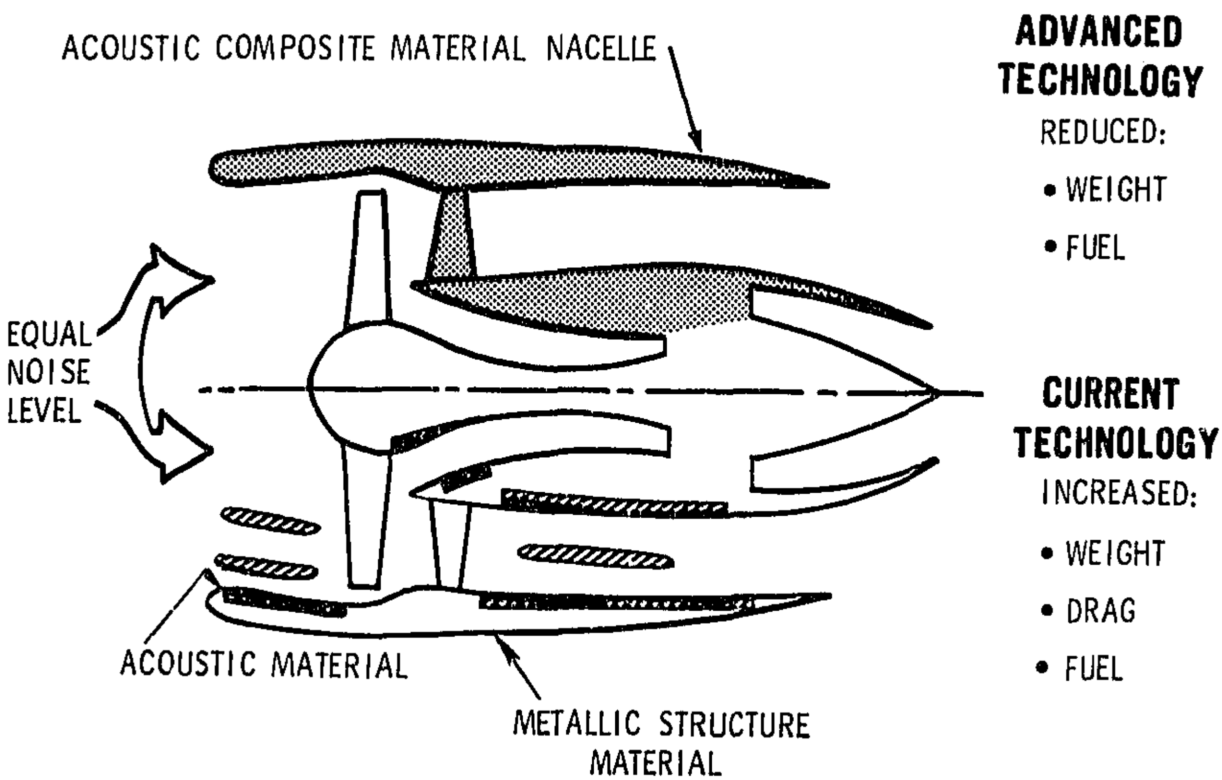


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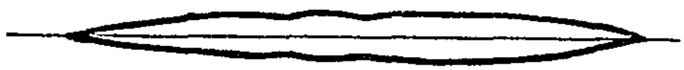
FIGURE 10

## TYPICAL ACOUSTIC COMPOSITE NACELLE BENEFITS FOR A 3 ENGINE WIDE-BODY TRANSPORT

CURRENT AIRCRAFT

**90 EPNdB NOISE FOOTPRINT**

100%



**WITH APPLICATIONS OF ACOUSTIC COMPOSITE NACELLES**

NO CHANGE IN WEIGHT AND FUEL

70%

**OR**

2700# LESS WEIGHT
1000# LESS FUEL, TYPICAL TRANSCONTINENTAL FLIGHT

100%

FIGURE 11

NASA HQ RG74-15492 (1)
(Rev. 3) 7-18-74

## Airframe Noise

A relatively new area of concern is airframe noise. Our concern stems from the fact that noise from landing gears, wings and flaps, body flow separation and tail surfaces is at levels about 8 to 10dB below the current FAR-36 requirement as illustrated in Figure 12. Because future conventional aircraft engine noise at landing may be reduced some 10 and possibly 15 EPNdB below FAR-36, airframe noise could become the factor limiting approach noise reduction.

The objectives of our airframe noise reduction program are to identify and quantify the sources of airframe noise, and to determine the principles and provide the data for minimizing this noise. A major part of the work will be accomplished through model studies of components in quiet wind tunnels and in the new Aircraft Noise Reduction Laboratory facilities at the Langley Research Center. Flight testing will continue to support development of data in this critical area. Special studies will be made to relate airframe noise measurements, made at model scale in wind tunnels, to full-scale flight test data.

Later phases of the effort will involve studies of noise generation and its control as related to advanced concepts for high lift devices, landing gears, other protuberances, and bodies and wings.

## Propeller Noise Reduction

During testimony on General Aviation in March 1974, the Subcommittee expressed interest in what NASA was doing to improve propeller design to achieve better performance and reduce noise. We are approaching propeller noise from several aspects.

Under a grant to the University of Illinois, effort is being directed toward providing practical free-propeller design criteria to optimize planform, airfoil section, twist and camber for minimum noise and maximum efficiency. The effect of the supercritical airfoil section, on both noise and efficiency, as applied to propellers, is also under study. Flight tests of these propellers will be carried out in conjunction with the Advanced Technology Light Twin (ATLIT) Program during the second and third quarter of FY 1975.

Noise reduction potential and thrust efficiency of shrouded propellers are under study. Full scale wind tunnel tests of a modified Cessna 327 incorporating an aft propeller shroud were completed this month. Reduction of the data is underway and will provide the basis for decisions on the feasibility of a subsequent flight demonstration program.

## SIGNIFICANCE OF AIRFRAME NOISE

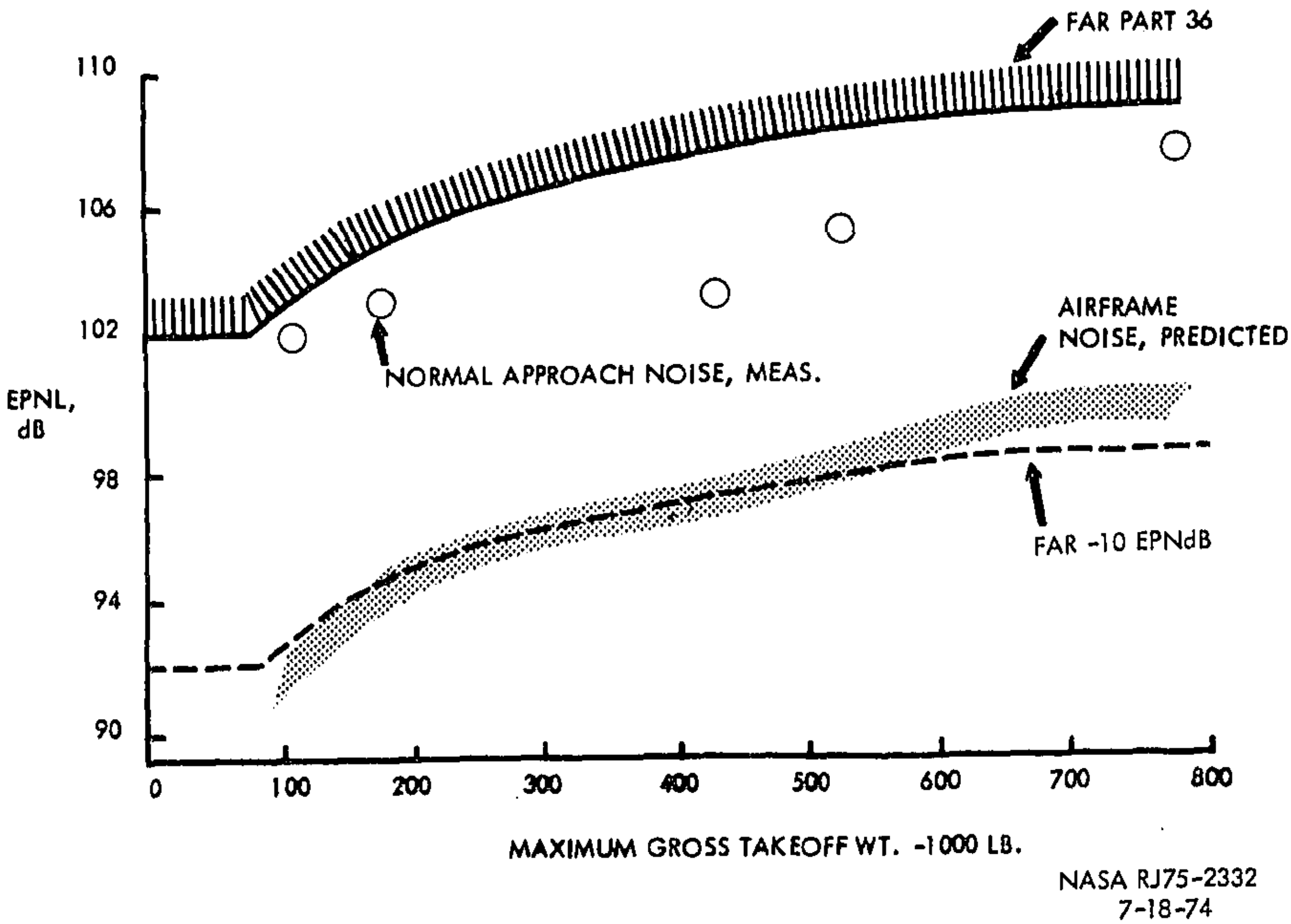



FIGURE 12

The same Cessna 327 will be modified to incorporate a Hamilton Standard "Quiet-Fan" (Q-fan) turbofan engine. Although the Q-fan is expected to be an expensive system, the noise reduction potential is great. Full scale wind tunnel tests of the modified airplane, in mid-1975, will provide a basis for further studies or flight programs.

Aircraft Noise Prediction

Our concern with the design of aircraft for minimum noise generation or to specific noise standards led to the establishment of an Aircraft Noise Prediction Office at our Langley Research Center this past year. The Office with support from other NASA centers, will develop computational techniques for accurate prediction of operating aircraft noise levels as perceived on the ground. This capability is essential for assessing the noise characteristics of aircraft: new designs, aircraft modifications, proposed noise abatement operational procedures, as well as the impact of future air transportation systems on airport communities.

The prediction capability will also provide a basis for identifying noise reduction technology goals and research needs related to aircraft components, aircraft design, and airport operations. It will assist Federal agencies in future rulemaking and regulatory activities, airport planners in airport development, and airport communities in land use planning.

Response to Aircraft Noise

The last subject I will comment upon is human response to aircraft noise. During the FY 1975 authorization hearings, reference was made to such a study completed at Columbia University. In this research program the range of noise reduction proposed for retrofits for the 727 airplane was simulated. Figure 13 summarizes the results of the investigation. An annoyance number of 4 is very annoying. A number of 0 is not annoying. A reduction of 6 EPNdB represents the level of noise reduction under the landing approach path expected for the SAM and anticipated for the refan retrofits for the 727 airplane. From these test results we conclude that under laboratory conditions significant reductions in annoyance can be realized by a 6 EPNdB noise reduction. In the Columbia study at the 1.1 mile approach point for the untreated airplane, 72 percent of the subjects were highly annoyed; for the -6 EPNdB case, 34 percent of the subjects were highly annoyed; and for the -12 EPNdB case, 16 percent were highly annoyed.

# SUBJECTS' RESPONSE TO SIMULATED AIRCRAFT OPERATIONS

COLUMBIA UNIVERSITY STUDY

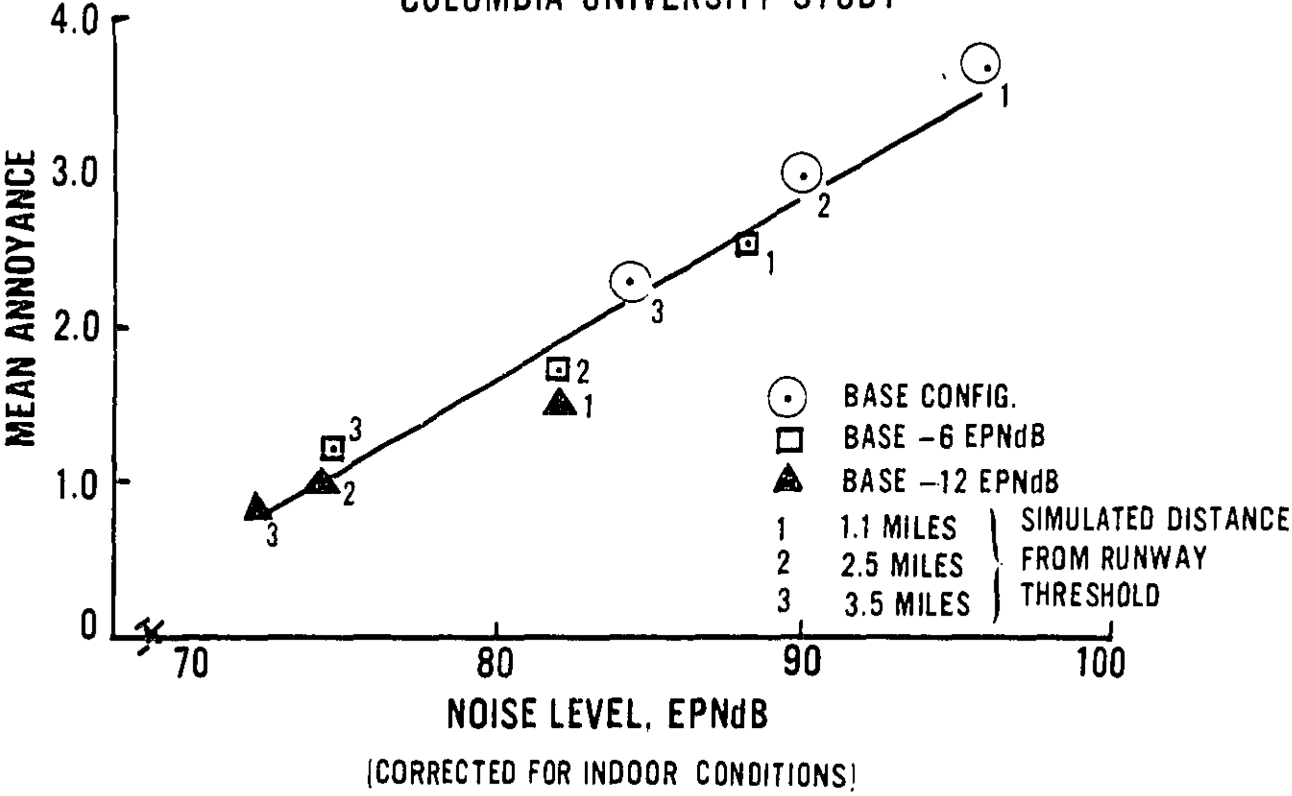



FIGURE 13

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We believe that the experimental tools developed in this program provide a useful technique for the study of the annoyance of aircraft noise.

The Columbia study initially was limited to one aircraft type and to the landing condition, but has been extended to consider several aircraft types for both landing and takeoff. The results of the extended investigation should be available early this fall. More detailed experiments are being planned for the Aircraft Noise Reduction Laboratory at Langley. These studies will complement those underway at Columbia and will assess both the effects of different mixes of aircraft and different rates of noise exposure.

Attention is also to be given to resolving the differences in the responses to aircraft noise of various population sub-groups. This information should provide a basis for the definition of more acceptable noise environments for airport communities.

## Closing

We believe that our program will provide the data base needed for near and longer term action by industry, the public, and responsible government groups to evolve toward a more compatible airport community noise environment. We will continue to work closely with the responsible government groups, DOT, FAA and EPA to help bring into practical realization the fruit of our research and technology.

2. NASA

BASIC RESEARCH
AND
TECHNOLOGY
PROGRAMS

OBJECTIVE DOCUMENTATION

Title: Propulsion Noise Reduction

Type of Specific Objective

X Discipline ___ Study ___ System and Experimental Program

Organizational Element Responsibility:

Noise and Pollution Reduction Branch - Harry W. Johnson (Act.)

Statement of Specific Objective and Targets:

Objective: To provide data and a technology base for reducing aircraft propulsion generated noise with minimum weight, performance and economic penalties. Specific targets are:

- Obtain experimental and analytical data for a more accurate understanding of noise generating mechanisms in simple jet flows which can be used to guide the technology for reducing jet noise generation. FY 1976 for subsonic jets; FY 1978 for supersonic jets.

- Reduce by 60% the currently achievable thrust loss penalty due to supersonic jet noise suppression devices to 1% per 5 EPNdB. FY 1977.

- Determine the basic effects of forward velocity on jet noise generation and propagation. FY 1977.

- Achieve 4 to 6 EPNdB reduction in fan-stage source noise (relative to Quiet Engine I fan technology levels) by means of aeroacoustic design. FY 1977.

- Improve the efficiency of acoustic suppression materials and technology to achieve, for a given dB reduction, a 50% reduction (relative to 1974 design practice) in the installation weight attributable to such suppression treatment. FY 1977.

- Demonstrate practical (high subsonic throat Mach number inlet design concepts to achieve 20 EPNdB suppression of forward radiated fan noise without increasing aft radiated noise nor introducting undesirable engine performance, stability and operating condition limitations. FY 1977.

- Determine the noise generation or suppression effects due to internal and external surfaces which guide or control jet flows, including effects of shielding and surface treatment. FY 1977.

- Determine the mechanisms responsible for noise emanating from core noise sources (combustors, struts, turbines) and establish practical techniques for controlling these noise sources to optimize acoustic designs of propulsion systems. FY 1978.

- Establish the effects of the random characteristics of the atmosphere on the propagation of aircraft noise into the airport community. FY 1977.

Approach:

Propulsion noise reduction aims at providing a technology base and data for the understanding and reduction of aircraft propulsion component and system generated noise with minimum weight, performance and economic penalties. The program at Lewis Research Center is directed at fundamental studies of turbo-machinery, jet and jet interaction. Experimental studies will continue on sonic inlets, fans, nozzles, core suppression and wing shielding including tests using Quiet Engines A and C. The program at Langley Research Center emphasizes fundamental studies of component and jet noise and the effects of atmospheric conditions of sound propagation. The aircraft Noise Reduction Laboratory, completed in early 1974, is the focal point for Langley in-house research and complementary university acoustic research activities. The programs at Ames Research Center will include wind tunnel tests to measure forward velocity effects. Aircraft static and flyover noise measurements will be made at Flight Research Center. The Jet Propulsion Laboratory conducts research on high temperature supersonic velocity jet noise and the correlation of different noise measurement instrumentation techniques now in use. Major milestones for Propulsion Noise Reduction are:

- FY 1975 - Demonstrate J-85 noise suppression using a retractable nozzle in F-106 flight tests.

- Early FY 1975 - Complete exploratory studies of noise propagation and atmospheric attenuation using an instrumental tower.

- Mid FY 1975 - Complete flight test noise measurements on supercritical propeller design.

- Early FY 1976 - Conduct wind tunnel noise tests on variable pitch Q-Fan for General Aviation Aircraft.

Need and Relevancy:

Aircraft noise is a major constraint to the growth of civil aviation, and has become a major target for environmental improvement. The NASA noise reduction program is intended to provide the technology for reducing aircraft noise ultimately to levels which communities will find acceptable, and to do so in a manner that permits aircraft operations to remain economically viable.

OBJECTIVE DOCUMENTATION

Title: Noise Footprint Prediction

Type of Specific Objective

_X_ Discipline ___Study ___System and Experimental Program

Organizational Element Responsibility:

Noise and Pollution Reduction Branch - Harry W. Johnson (Act.)

Statement of Specific Objective and Targets

Objective: To establish techniques for accurate prediction of ground noise levels of operating and future aircraft to establish total acoustic characteristics, identify parameter sensitivities, and guide research efforts. Specific targets are:

- Select and construct an interim computer program for noise contour predictions by FY 1975.

- Improve the data base capabilities of the interim program to predict noise contours (footprint areas) within $\pm$ 40 percent accuracy ($\pm$ 1.5 dB accuracy of noise contour). FY 1976.

- Establish a prediction and design capability to compute noise contours for current and proposed aircraft systems based on analytical modeling of individual component noise sources. FY 1978.

## Approach

The Noise Footprint Prediction program at Langley Research Center, with specific support by the other centers, will evolve computational techniques for accurate prediction of ground noise levels from operating aircraft to establish acoustic characteristics, identify parameter sensitivities and guide research efforts.

Major milestones of the Noise Footprint prediction research are:

- By FY 1975 - Establish interim aircraft noise prediction program.
- Mid FY 1975 - Establish basic analytical models for key technical areas in source noise prediction, noise transmission, and community impact.
- Late FY 1975 - First results from the integrated noise prediction program.

## Need and Relevancy

Demands imposed on jet aircraft by recent noise regulations have emphasized the need for an accurate noise footprint prediction capability. This capability is essential not only for evaluating the effect of proposed noise abatement procedures and aircraft modifications, but also for evaluating the impact of future aircraft systems on airport communities. The prediction capability will provide a basis for establishing noise reduction technology goals and identifying research needs in the areas of components, aircraft designs, and airport operations. In addition, the prediction program will assist other federal agencies in future rulemaking and regulatory activities, and will aid airport communities in land use planning.

OBJECTIVE DOCUMENTATION

Title: Minimization of Undesirable Aerodynamic Phenomena

Type of Specific Objective

XX Discipline ____ Study ____ System and Experimental Program

Organizational Element Responsibility

Aerodynamics & Vehicle Systems Division - Alfred Gessow

Statement of Specific Objective and Targets

Objective: To understand, and minimize by aerodynamic means, the undesirable effects of aerodynamic phenomena such as wake vortex turbulence, aircraft buffeting and airframe noise. Specific targets are:

- Determine by January 1974 one or more aerodynamic techniques which show promise of effectively eliminating the wake vortex hazard in order to provide FAA with information with which to set potential requirements for operational vortex detection and tracking systems at airports for safe spacing of aircraft during landing and takeoff.

- Demonstrate in flight by FY 1977 aerodynamic design techniques which would permit a reduction from the present 3-5 mile landing separation distance imposed on transport aircraft by the wake vortex problem to two miles.

- Determine the design principles and provide the necessary data on airframe (i.e. nonpropulsive) noise to insure that the CARD policy study goal of reducing aircraft noise by 10 dB per decade can be achieved. The technology required for the first 5 dB reduction to be in hand by FY 1977.

- Using unsteady pressure distributions measured on wing sections in wind tunnels, provide a means for predicting the intensity of the buffet phenomenon of combat aircraft throughout their maneuver range by mid FY 1975. With such predictive capability, not currently available, provide the design information necessary to extend the buffet boundary of combat aircraft by approximately 100% by FY 1977 and thus provide the potential for the development of new aircraft with greater operational capability in combat situations.

Approach

Aerodynamic factors that control the generation and magnitude of wake vortex, aerodynamic noise, and aircraft buffet phenomena will be studied to determine the means by which the detrimental effects can be reduced or eliminated.

- The airframe noise (i.e. the noise generated by an aircraft in flight with its propulsion system noise subtracted out) program effort will be concentrated on determining the source, magnitude, and method of reducing such noise for large transport aircraft in the clean and approach (i.e., flaps and landing extended) configurations. The individual noise contributions of high-lift devices, separated flow associated with the landing gear, gear-well cavity flow, and flaps will be investigated. The program will be conducted with LRC as the lead Center, aided by flight research at FRC, and supporting wind tunnel and basic research at ARC and JPL. Basic noise source measurements will be made in conventional and quiet wind tunnels and anechoic chambers with simple wings and configurations to establish the feasibility and test techniques for these types of measurements in inherently "noisy" ground facilities. Airframe noise prediction techniques will be developed using fundamental noise source principals and data correlations. Far field aerodynamic noise measurements from flight tests of jet transport aircraft will be compared with predicted noise levels and corresponding measurements from wind tunnel tests of scaled transport models for verification of the ground test techniques. Aerodynamic design concepts for minimizing airframe noise will then be defined from analytical prediction techniques, developed in ground facilities and demonstrated in flight tests.

- The wake vortex hazard alleviation program will be conducted at ARC, LRC, and FRC and will include a vigorous ground research effort with preliminary flight tests to develop promising alleviation devices, and measure detailed vortex structure. The development of promising vortex alleviation devices or concepts will require investigations planned to be conducted in contractor water channels, NASA ground facilities and in flight. The effectiveness of such aerodynamic devices or concepts as spoilers, trailing drag devices (splines), vortex generators steady and pulsed mass injection, and tailored span load distributions will be investigated. Ground facility measurements to evaluate the effectiveness of the alleviation devices include documenting the vortex-induced rolling moment imposed on trailing aircraft models, positioned at scaled distances up to about 1½ miles downstream of the generating aircraft models. In addition, hot-wire probes and LDV instrumentation will be further developed for obtaining vortex tangential and axial velocity and core growth measurements. Based on preliminary results from the on-going ground research program, aerodynamic devices or techniques which show promise of significantly reducing the wake vortex strength include deployment of spoilers and splines, and tailored span loading to achieve a triangular-like lift distribution. Plans are to intensify the ground research effort to further refine and develop those aerodynamic devices, and to verify and demonstrate the most promising devices in flight tests using existing NASA aircraft initially and to later lease a wide body jet transport for final demonstration.

- The buffet program will be conducted at ARC in the Ames transonic unitary tunnel complex and will be supported by contractor flight studies and analyses. Correlations will be made of measured and calculated buffet alleviation techniques--supercritical wings, flaps, etc.--will be studied. Locations of shock waves and flow separation will be identified, and studies of unsteady pressures and forces will be made. Predictions of aircraft structural response characteristics during buffet will be developed to assess the effects of buffet on aircraft design loads.

Major Milestones of the Minimization of Undersirable Aerodynamic Phenomena Program are:

Late FY 1974 - Select candidate vortex minimization devices or concepts for flight test evaluation.

Mid FY 1975 - Begin flight test evaluation and demonstration of promising vortex alleviation devices.

Mid FY 1975 - Identify individual airframe noise source contributions on jet transport.

Mid FY 1975 - Develop analytical prediction techniques for radiated aerodynamic noise from discrete sources.

Mid FY 1975 - Develop capability to predict buffet intensity of combat aircraft throughout maneuver envelope.

Mid FY 1976 - Initiate final flight demonstration with most effective vortex alleviation devices on wide-body jet transport.

Need and Relevancy

The persistent nature of trailing vortices generated by jet transports creates a documented safety hazard for closely following aircraft and severely curtails optimum use of our nations airports. FAA has taken action to deal with the problem by increasing approach and takeoff separation distances to 5 miles (from 3 miles) for smaller aircraft following a wide-body aircraft. This is not a satisfactory long term solution because of the greatly reduced runway utilization rate, particularly in view of the heavier jet transports and increased traffic volume projected for the future. Also, the increased separation distances cause ground holding delays prior to takeoff and in-flight holding delays prior to landing during peak traffic periods which waste precious fuel. Additionally, a major NASA/FAA goal aimed at relieving air traffic congestion involves as one facet the development and implementation of a sophisticated, accurate airport-located aircraft tracking system to allow less separation than presently employed. This will not be possible as long as the wake vortex hazard continues to define the minimum separation. The wake vortex hazard research program will attempt to reduce the present 3-5 mile separation distance to two miles.

A major CARD policy study goal concerns the reduction of aircraft noise by 10 dB per decade. Toward this goal, engine quieting efforts are achieving significant progress. However, recent measurements of jet transport aerodynamic noise during approach (engines throttled back) indicate that the noise level associated with the airframe is significant (only 10 dB below the FAR PART 36 guideline). Therefore, to realize full benefits from engine quieting efforts and to ensure that the CARD policy study goal can be achieved beyond the first step, airframe noise must be reduced below its current high level.

Buffeting and buffet induced roll instability at high angles of attack seriously restrict transonic maneuverability of military aircraft in the high subsonic speed range where aerial combat takes place. Consequently, to improve odds for victory, buffeting effects must be reduced to widen the combat envelope of military fighters.

## OBJECTIVE DOCUMENTATION

Title: Acceptance of Aircraft Operations

Type of Specific Objective

_X_ Discipline ___ Study ___ System and Experimental Program

Organizational Element Responsibility

Aeronautical Man-Vehicle Technology Division - R. P. Whitten

Statement of Specific Objective and Targets

Objective: To define and quantify those properties of aircraft noise exposure that are responsible for causing negative individual and community response to air transportation systems. Specific targets are below:

- Devise proper methodologies for laboratory and field studies of human response to aircraft operations. FY 1975.
- Determine effects of multievent noise exposure characteristics on human response to aircraft operations. FY 1976.
- Quantify the effects of background environmental noise exposure on the human response to aircraft-generated noise. FY 1977.
- Ascertain the effects of aircraft noise on man's speech production/perception. FY 1977.
- Evaluate the effects of aircraft operations on sleep, relaxation and subsequent performance of people. FY 1978.

- Study the effects of low frequency noise characteristics generated by present and future aircraft on auditory and nonauditory responses of people. FY 1979.

- Develop a model for reliable prediction of responses of people to aircraft operations that will satisfy laboratory and field conditions. FY 1980.

## Approach

Research on the psychophysiological response of humans to aircraft operations will be conducted primarily in the new Aircraft Noise Reduction Laboratory at the Langley Research Center. Sociopolitical impact analysis of new aviation technology will be conducted by the Ames Research Center.

- Develop a model that will scientifically explain the composite response of man to aircraft noise. As identified by the model, improve and/or develop those methods essential to the conduct of meaningful laboratory studies which simulate the impact of aircraft operations on the community: Verify the model and the methods developed for simulation studies by several field studies.

- Obtain data and record it in such a manner that it can be used for NASA data bank utilization, and for other federal agencies, i.e., DOT/FAA, EPA.

- Design simulation and field studies with a view towards correlation with specific characteristics of earlier studies so that proper interpretation and extrapolation of results can be made.

## Need and Relevancy

Information to provide criteria for the prediction of community acceptance of aircraft operations by people living in communities near airports is of major importance in the development of noise control technology and operational procedures for civil aviation. The physical characteristics of noise and its propagation are fairly well understood; however, scientific data permitting an understanding of the impact of aircraft operations and noise on the community are sparse. Comprehensive scientific information on the psychophysiological effects of aircraft operations and noise is needed to assure the acceptability and effectiveness of programs designed to alleviate adverse community response to the air transportation system.

Because community research is time consuming and expensive, there exists a need to simulate the real world in a laboratory environment in such a manner that the laboratory results can be directly related to the operational world. The benefit of this capability is seen in the savings of resources and the ability to synthesize operations of future aircraft systems and then evaluate the degree of acceptance by the airport communities. To achieve this degree of sophistication, further development is needed in the area of subjective testing methodology to modify existing or develop new measurement scales. Such scales must be adequate to properly evaluate responses of people during both awake and sleep and for indoor and outdoor background noise. There is a special significance of current research in this area to the programs on advanced aircraft whose low frequency noise and impulse noise characteristics are not characterized adequately by existing measures of human response.

Today there exists a climate of general public hostility towards large visible technologies. A thorough understanding of this social attitude is needed to allow for accurate economic projections of future aircraft systems prior to system development. Development of such understanding would aid in the planning process of integrating a new system into an existing system.

3. NASA

POWERED LIFT AIRCRAFT
NOISE TECHNOLOGY PROGRAMS

## OBJECTIVE DOCUMENTATION

Title: Advanced Powered-Lift Aircraft Aerodynamic Technology

Type of Specific Objective

XX Discipline ____ Study ____ System and Experimental Program

Organizational Element Responsibility

Aerodynamics & Vehicle Systems Division - John M. Klineberg

Statement of Specific Objective and Targets

Objective: To develop the aerodynamics and vehicle systems technology needed to attain the integrated aerodynamic performance, noise, stability, control, and handling qualities characteristics required for viable powered-lift civil and military aircraft designs having overall aircraft performance and flight characteristics compatible with operational approach $C_L$'s of about 4.5, 90 EPNdB noise, footprint less than 1 sq. mile, and direct operating costs not more than 10% above good CTOL transports. Specific targets are:

- Aero/Acoustic Exploratory Research - Provide, by 1975, first-order trade-off information on low-speed aerodynamic performance and noise for augmentor wing (AW) flap systems (including the use of break-up nozzles and thrust reversers) and for upper surface blowing (USB) concepts.

- Cruise Drag - Provide, by 1976, first-order trade-off information to avoid or reduce by half cruise drag penalties of upper surface blowing systems, indicated for preliminary analysis to be as great as 10% of total drag.

- Large-Scale Aero/Acoustic Verification - Verify the integrated aerodynamic noise, stability and control characteristics of representative complete powered-lift transport configurations models incorporating lobe-nozzle AW concepts by 1975 and USB concepts by 1976. Advanced systems with improved nozzles and augmented jet flap designs, will be verified by 1978.

- Handling Qualities and Control Systems - Evaluate the handling qualities requirements and promising methods of integrating vehicle aerodynamic and propulsion controls for powered-lift transports to enable precise flight path and airspeed control during low-speed terminal-area operation. Result will be the definition of tentative handling qualities design criteria and specific control system concepts by 1975. Also evaluate by 1976 a hinged plate spoiler system for improving flight path control and landing dispersion of a low wing loading nonpowered-lift STOL transport.

- Certification Criteria - Define tentative handling qualities and performance criteria necessary to serve as the basis for establishing airworthiness standards and define procedures for demonstrating compliance with standards. Targets for initial evaluation of individual system concepts are:

| | CY |
|---|---|
| Deflected slipstream | 1973 |
| Augmentor Wing | 1974 |
| Externally blown flap | 1974 |

## Approach

The powered-lift STOL/RTOL aerodynamic programs are conducted at the Ames and Langley Research Centers. Effort at Ames emphasizes large-scale wing and model performance and noise tests in the 40- x 80-foot tunnel, primarily on the augmentor-wing and upper-surface blown flap concepts; related contracted analytical and experimental studies; and ground-based motion-simulator flight dynamics investigations. Langley performance, noise and handling qualities studies are concentrated on the upper-surface blown flap, involving use of theoretical analyses, small-scale and large-scale wind tunnel models, static rigs, and ground-based simulators. The specific approaches for accomplishing each of the identified targets follow:

- Aero/Acoustic Exploratory Research - Ames, in FY 1975, will conduct diagnostic experimental small-scale tests in the 7- x 10-foot tunnel and sponsor contractual investigations of advanced AW flap concepts to develop fundamental performance, acoustic, and thrust reversal technology for first-order design trade-off analyses for systems having superior terminal area performance and noise. This will include short-element flap systems. Langley will conduct small-scale and free-flight model parametric investigations to improve performance, stability and control characteristics of USB configurations which utilize the wing for noise shielding; will investigate fundamentals of USB noise on a static rig with engine exhaust directed through USB type nozzles over flaps; and will conduct some USB performance/noise trade-off design studies. Langley will also complete a series of experimental studies to establish reliable tunnel-wall corrections for powered-lift systems being experimentally investigated at high-lift conditions, and will continue powered-lift theoretical studies to devise improved flow and performance prediction methods. Ames will complete an investigation of turbulent mixing within AW multi-element nozzles to guide improved nozzle designs.

- Cruise Drag - Langley will perform parametric small-scale wind tunnel evaluations and analyses to develop by FY 1976 an adequate understanding of how to reduce cruise penalties accruing from USB installations. Ames will complete by FY 1975 a contractual small-scale study to develop cruise augmentor technology.

- Large-Scale Aero/Acoustic Verification - On a new semispan swept wing powered-lift model, Ames in FY 1975 on the static test rig and in the 40- x 80-foot tunnel will (1) complete the initial evaluation of an Ames-designed AW concept utilizing advanced multi-element lobe nozzles, (2) initiate evaluation of a Boeing cruise augmentor concept, and (3) initiate evaluation of a hypermixing ejector flap concept. This research model will be utilized for several large-scale verification tests of dirrerent powered-lift systems over a 3-5 year period. Langley will complete the initial static and low-speed noise and performance evaluations of a large-scale USB model (modified Aerocommander) in FY 1975, using the full-scale tunnel and the lunar-landing facility (for some of the noise measurements). A large-scale swept-wing USB model will be investigated in the Ames 40- x 80-foot tunnel. These large scale investigations as a whole are required to verify the integrated aerodynamic, propulsive, acoustic and structural dynamics characteristics and to provide valid data for design proposals.

- Handling Qualities and Control Systems - Ames, in FY 1975, will conduct handling-qualities investigations of representative powered-lift STOL/RTOL transports using ground-based simulators such as the FSAA, to provide solution to problems related to flight-path control and of the transition from cruise to approach. Ames, also in a joint program with the FAA, will conduct flight evaluations of a hinged-plate spoiler system integrated into the pilot's controls to augment flight path and roll control of a DHC-6 low-wing-loading nonpowered-lift aircraft. These evaluations under STOL operational conditions will investigate certification implications.

- Certification Criteria - In a joint program with the FAA, Ames in FY 1975 will perform studies on the FSAA in-house and under contract to provide additional criteria for establishing handling-qualities and performance certification standards for future STOL/RTOL powered-lift civil transports. Tentative criteria will be developed for aircraft using several of the more promising powered-lift concepts, contributing to a generalized criteria applicable to all concepts. Consideration will also be given to the development of safe flight procedures for demonstrating compliance with the criteria.

Need and Relevancy

The Joint DOT/NASA Civil Aviation Research and Development (CARD) Policy Study stressed the urgent requirement to reduce aircraft noise, to reduce congestion at airport terminals and to evaluate efficient, quiet short-haul transportation systems as a means towards such ends. Only 10 percent of the Nation's airports can accommodate today's jet transports requiring runway lengths of 5,000 feet or longer. Aircraft with operationally usable approach $C_L$'s of about 4.5 capable of operating from 2,000 foot runways could be accommodated by 75 percent of the Nation's airports, and thereby offer tremendous congestion relief for some currently overcrowded airports. Such aircraft could also help congestion relief by operating from short new runways within existing major terminal hubs.

The achievement of this performance in aircraft having acceptable ride qualities and noise characteristics for the general riding and airport community public requires the use of efficient, quiet, powered-lift to provide useable approach lift coefficients up to 5 with noise levels not exceeding 90 EPNdB over a 1 square mile footprint. The research and technology efforts in this program are geared toward improving, evaluating and validating the aerodynamic and noise characteristics of advanced powered-lift concepts having promise of attaining the stated overall aircraft performance and noise goals as a part of the national effort to establish a high-density short-haul air transportation system.

## C-8 AUGMENTOR WING FLIGHT EXPERIMENT

(766-71) Ongoing

### Program Objective

Validate in flight the augmentor-wing powered-lift concept developed in laboratory programs as a practical means for providing short take-off and landing capability (under 2,000 foot balanced runway length) to alleviate terminal area congestion problems. Assess in flight the handling qualities of this type of aircraft. Provide a versatile representative powered-lift aircraft for assessment of navigation and control systems requirements for safe (precise control with low pilot workload) terminal area operations foreseen for this class of aircraft.

### Program Targets

- Documentation by December 1974 of augmentor-wing proof-of-concept flights to be completed by May 1974.

- STOL operational assessment by U.S. and Canadian test pilots to be completed by April 1974.

- Development by February 1975 of definitive criteria for control of flight path and airspeed, and for roll and yaw power for powered-lift transports through flight confirmation and refinement of results of analytical studies and piloted simulator experiments.

- Development by February 1975 of flight director laws and integrated controls for transition management through flight evaluation of a flight director concept system developed by analysis and simulation.

- Confirm and extend by 1977, certification criteria for powered-lift aircraft developed through piloted simulation.

- Initiate by November 1974, main body of STOL operating systems experiments (supported under separate program).

Program Approach (Abbreviated Version)

A C-8A aircraft was modified in FY 71 and 72 to incorporate a jet augmentor wing and appropriate jet engines in a joint U.S./NASA - Canadian/ Department of Industry, Trade, and Commerce program. Following contractor check-out flights, the aircraft was delivered in August 1972 to the Ames Research Center where airworthiness and proof-of-concept flights were initiated. During this phase of testing the vehicle was further modified to include a powered elevator and the STOLAND avionics systems to permit handling qualities studies at lower speeds and more realistic long-term flight experiments on STOL operating systems. Parallel studies were undertaken under contract using a variable-stability Navion aircraft to aid in planning the C-8 flight research program. The C-8 handling-qualities experiments will begin in mid 1974 following completion of the proof-of-concept tests and of pilot assessment of the STOL operational characteristics of the aircraft. The main part of the handling-qualities criteria studies will be completed by February 1975. The STOL operating systems experiments will begin in November 1974 utilizing the C-8 augmentor-wing aircraft in a program supported under a separate project. During the course of the latter experiments, the C-8 research aircraft will be used to evaluate flight director laws and certification criteria for powered-lift flight.

Additional details are available in the March 23, 1973 Project Plan entitled "C-8 Augmentor Wing Research Aircraft and Flight Experiment."

Need and Relevancy

OAST has a responsibility to develop short-haul transport technology for high density civil transportation. The C-8 augmentor-wing research vehicle is the first jet powered-lift STOL aircraft to operate. It will therefore enable early examination of low-speed flight and operational characteristics representative of future STOL/RTOL transports, which (with rotorcraft and jet VTOL aircraft) are expected to provide the U.S. with more efficient high-density short-haul systems. Information obtained from STOL handling qualities tests with the aircraft will aid in verifying the results of ongoing and planned ground-based simulator studies, and in providing the criteria to establish civil certification requirements for such aircraft. The vehicle, being equipped with the STOLAND avionics system, will also provide a unique facility for scheduled general STOL transport operating-systems experiments, to be carried out jointly with DOT in a separate program.

## QUIET, CLEAN, SHORT-HAUL EXPERIMENTAL ENGINE (QCSEE)

(738-13) Ongoing

### Program Objective

Design, build and test experimental engines to consolidate and demonstrate the technology needed for very quiet, clean and efficient propulsion systems for economically viable and environmentally acceptable powered lift short-haul air-craft. Program goals translate as follows:

- 95 EPNdB noise footprint area less than 0.5 sq. mi. (~10% of DC-10), or 500 ft. sideline = 95 EPNdB.
- Emission levels of Experimental Clean Combustor.
- Thrust to weight ratio 6 or better.
- High bypass ratio engine technology for under-the-wing and over-the-wing systems: composite, variable pitch, thrust reversing, low pressure ratio fans with gear reduction drive for low tip speed.

### Program Targets

The program objectives will be met through the following steps:

- Source selection and contract award in December, 1973.
- Design layout review - June, 1974.
- Critical Design Review - January, 1975.
- Delivery of first engine to LeRC for in-house testing in an under-the-wing configuration in August, 1977.
- Delivery of second engine to LeRC for in-house testing in an over-the-wing configuration in December, 1977.

### Program Approach

The approach is a competitive procurement, single-contractor experimental engine program managed by the Lewis Research Center. System definition/optimization studies of powered lift propulsion concepts in FY 1973 formed the hardware program basis. Two full scale engines, one for under-the-wing installation, the second for over-the-wing will be designed, fabricated, assembled, tested, and delivered to Lewis. In-house acoustic and aerodynamic performance testing in wing/flap system installations will be conducted to verify system characteristics and achievement of program goals.

## OBJECTIVE DOCUMENTATION

Title: Quiet Short-Haul Research Aircraft (QSRA)

### Type of Specific Objective

X System and Experimental Program

### Organizational Element Responsibility

Transport Experimental Programs Office - William Gardner/Jack Levine

### Statement of Specific Objective and Targets

Objective: To obtain, by means of a low-cost experimental aircraft, quiet propulsive-lift flight research data on an advanced propulsive-lift configuration at lift coefficients greater than 4.5, 90 EPNdB footprint areas smaller than one square mile, and roll control power greater than one radian per second$^2$. Specific targets are:

- Provide by the end of FY 1974 a Project Plan and Risk Assessment which will include the objectives, technical approach, schedules and cost for the effort and the risk assessment in achieving the same.

- Determine by the end of FY 1974 the airframe and engine design requirements, schedule and cost to modify an existing airplane for use as a low-cost quiet, high performance propulsive-lift research aircraft.

- Modify the design, fabricate and assemble by the end of FY 1976 an existing aircraft with an advanced propulsive-lift system and perform ground checkout and limited flight tests of the assembled aircraft by the third quarter of FY 1977.

- Define by the end of FY 1976 and conduct beginning in the third quarter of FY 1977 appropriate multi-discipline propulsive-lift flight experiments in areas of general configuration, handling qualities, noise, flight dynamics, flight control systems, information displays, propulsion system, and operating environment.

- Generate and verify by FY 1978 the integrated total vehicle and operating systems technology base from which design requirements and certification criteria can be established for practical and efficient quiet propulsive-lift civil and military short-haul transports.

Need and Relevancy

Future powered lift short-haul aircraft need quiet, clean, efficient and economical propulsion systems whose technology is not yet available. Demonstrations of component and system interactions in credible, full-scale engines and propulsion installations are needed to establish the data base to stimulate industry development with acceptable risk, and to help government establish environmental and operational requirements.

Approach

The project will include modification of an existing aircraft into an advanced quiet propulsive-lift configuration with modified existing engines to power the aircraft and the use of the aircraft in a flight research program to achieve the previously stated objective and targets.

Two parallel preliminary design study contracts were awarded on January 3, 1974 to the Lockheed Aircraft Corporation and the Boeing Company for a nine and one-half month period to determine the most effective configuration of the quiet propulsive-lift research aircraft. Each contractor will conduct preliminary design of (1) a C-8A Buffalo aircraft configured with an advanced quieted augmented jet flap (AJF) propulsive-lift system, and (2) a contractor-selected aircraft and quiet propulsive-lift concept. In support of these studies, three separate engine study contracts were awarded on January 31, 1974 to General Electric, Allison, and AVCO Lycoming for a two-month period. The engine contractors will define their engine concepts for the AJF aircraft and for the configuration alternatives being considered by the airframe study contractors.

Approximately mid-way in the design studies it is planned that a single design concept for the research aircraft will be selected by NASA. The selection will be based on results of the contractor efforts as well as on our own in-house studies and considerations will be given to the technical, schedule, and cost risks; the estimated project cost; aircraft research capability; industry interest in the approach; and other related factors. After concept selection the two design studies will complete preliminary design for the aircraft and provide detailed budgetary and schedule estimates for detail design, airframe modification, engine integration, and contractor tests. Results of these studies will be utilized as a basis for issuing an RFP to industry for the engines and for the aircraft. The engine RFP is planned for release in mid-1974 and the aircraft RFP in late 1974. Flight research will be initiated early in 1977.

The flight research program will be developed in a series of steps including the refinement of the established flight research objectives into more detailed and specific objectives, the development of detailed experiments to achieve these objectives, the preparation of a flight experiments program plan that orders and integrates the experiments, and finally, the flight research program itself. The experiments program will be developed in cooperation with other Government agencies and interested industry groups and carried out by NASA as an in-house effort.

The Ames QSRA Project Office is responsible for overall management of the aircraft modification with support by Lewis Research Center to provide modified engines for the aircraft. The QSRA Project Office is also responsible for management of the flight research program with participation by the other OAST Centers.

Major milestones of the QSRA Project are:

| | |
|---|---|
| Contract award for aircraft preliminary design studies | January 3, 1974 |
| Contract award for engine support studies | January 31, 1974 |
| Select aircraft design concept | 4th Qtr. FY 1974 |
| Contract award for engines for modified research airplane | 3rd Qtr. FY 1975 |
| Contract award for design, fabrication of hardware and modifications for research airplane | 4th Qtr. FY 1975 |
| Initiate NASA quiet propulsive-lift flight research program | 3rd Qtr. FY 1977 |

| | |
|---|---|
| Initial quiet propulsive-lift flight research results available | 4th Qtr. FY 1977 |
| Technology data base available for use in establishing design criteria and development of civil commercial aircraft | FY 1978 |

Need and Relevancy

The flight research program is necessary in order to reduce the technical risk associated with the development by industry of both civil and military propulsive-lift transports and to provide a comprehensive technical foundation on which Government regulation agencies can establish realistic criteria for certification of commercial subsonic propulsive-lift transport aircraft and for enroute and terminal area operations. A quiet propulsive-lift research airplane must be designed, built and flown in a research program in order to provide verification and demonstration of the technical base for the future design, development, fabrication and operation of reliable, quiet and economic fan-jet propulsive-lift transports. Powered lift technology is a key to community noise reduction, airport congestion relief, and improvement of civil transport and military tactical airlift.

## OBJECTIVE DOCUMENTATION

Title: AMST Prototype Aircraft (769-48)

Type of Specific Objective

X System and Experimental Program

Organizational Element Responsibility

Transport Experimental Programs Office - William Gardner/Jack Levine

Statement of Specific Objective and Targets

Objective: To obtain, through participation in the Air Force AMST prototype program, propulsive-lift flight research data on straight-wing externally blown flap configuration at lift coefficients up to about 3.5, 90 EPNdB footprint areas greater than 11 square miles, and roll control power about $\frac{1}{2}$ radian per second$^2$. Specific targets are:

- Obtain by FY 1976 flight verification of the detailed performance predicted by NASA ground based research data for USB and EBF propulsive-lift aircraft.

- Define by the end of FY 1974 and conduct on a non-interference basis with the Air Force during FY 1976 to the maximum extent possible multi-discipline flight experiments in areas of general configuration, handling qualities, flight dynamics, noise, flight control systems, information displays, propulsion system, and operating environment.

- NASA completes by FY 1978 documentation of the flight characteristics and evaluation of handling qualities and operational techniques as related to civil short-haul operations.

## Approach

NASA's direct involvement in the AMST program includes support of development of the aircraft and participation, through membership of the AMST Joint Test Team, in defining and conducting part of the AMST flight test program. Support of development of the aircraft includes scale-model tests in various wind tunnels to fill voids in available wind tunnel capabilities on the part of the Air Force contractors. Further developmental support is provided through use of the unique ARC Flight Simulator for Advanced Aircraft for assessing adequacy of stability and control levels inherent in the AMST designs, operational procedures and emergency conditions that may influence aircraft configuration and/or control systems characteristics.

The flight program will be conducted in two stages. In the first stage, NASA will accomplish cooperatively with the Air Force such technology-oriented flight research as can be undertaken without interference with the primary Air Force objectives. Recognizing the Air Force objective of the evaluation of these prototypes for tactical and logistic military applications, it is expected that during the Air Force-led flight program, the time devoted to the acquisition of data of interest both to the Air Force and NASA (i.e. basic aerodynamic performance, handling qualities and operational techniques) will be limited. In the second stage, following completion of the one-year prototype evaluation currently scheduled by the Air Force, NASA will assume the primary role and will conduct additional flight research. This second stage of the program will complete the documentation of flight characteristics and evaluation of handling qualities and operational techniques as related to civil short-haul operations. Modifications to the aircraft will be made depending upon a weighing of feasibility and cost, and benefits to the QPLT Program. It is anticipated that installation of STOLAND in one of the AMST aircraft would best facilitate the study of advanced avionics applied to short-haul operations in the terminal area. In addition to studying integration of advanced avionics with pilot display and flight control systems, STOLAND would aid in the evaluation of techniques for defining noise abatement flight patterns in the terminal area. Additional modifications may be made to the aircraft to reduce noise generated by aero-propulsion systems to permit development of criteria for noise certification.

Major milestones of the AMST Prototype Aircraft Program applicable to NASA are:

| | |
|---|---|
| Initiate Air Force-led flight evaluation of the AMST aircraft | 1st Qtr. FY 1976 |
| Initial propulsive-lift flight research results available for EBF and USB configurations | Mid FY 1976 |
| Initiate NASA-led flight research using the AMST aircraft | Mid FY 1977 |

Need and Relevancy

In considering the requirements for technology and operational data to support development of civil and military transports with the advantages of improved approach, landing, takeoff, climbout, and airport area low-speed maneuvering capabilities, the U.S. Air Force and NASA have agreed that the national needs can best be served through cooperation activity which assures a close working relationship between the Air Force and NASA in the Air Force Advanced Medium STOL prototype (AMST) program and the NASA Quiet Propulsive-Lift Technology programs.

The Air Force/NASA Memorandum of Understanding on the coordination of the Air Force and NASA propulsive-lift programs provides both for NASA participation in the Air Force flight testing of the AMST prototypes and for subsequent use of these aircraft in a NASA-led flight test program. These aircraft can be used to accomplish a part of the objectives of the flight test program planned for NASA's quiet propulsive-lift research airplane to the extent that their performance capabilities permit.

## STOL OPERATING SYSTEMS EXPERIMENTS
(768-83) Ongoing

### Program Objective

Establish a technology base upon which operational STOL short-haul systems can be based with confidence in the 1978-2000 time period.

Regarding NASA STOL technology programs, the draft Federal Plan for Short-Haul Air Transportation Improvement states that "The data from these programs are considered critical to this plan, for this data provides the basis for assessing which short-haul options are the most promising from an operational and technology point of view."

### Program Targets

In this joint DOT/NASA program, operating systems technology, operating procedures, and guidance, navigation, and control concepts for high-density terminal area operation will be demonstrated in the following steps:

- Integrated digital avionics research systems (STOLAND) available - July 1973.
- Synthesize flight paths for STOL independent of CTOL operations - September 1974.
- Initiate flight experiments to provide systems performance data

  - DHC-6 June 1974
  - Augmentor Wing C-8 - December 1974.
- Initiation of Microwave Landing System (MLS) validation flight experiments - April 1976.

Benefits which will be demonstrated include:

- Noise - 90 EPNdB footprint within airport boundary.
- Weather - Low visibility automatic landing capability.
- Guidance Accuracy - Maximum touchdown dispersions of $\pm$ 15 ft. laterally and $\pm$ 100 ft. longitudinally.
- Pilot Workload - Reduced 30% through automation and displays.

Program Approach

This joint DOT/NASA program is being conducted primarily at Ames Research Center, with supporting simulation studies being conducted at Langley Research Center and FAA's NAFEC.

An integrated digital avionics research system (STOLAND) has been provided by Ames Research Center. One simulator STOLAND system and two flight systems have been fabricated. The first flight system has successfully completed flight acceptance tests in the ARC CV-340 aircraft and is currently being installed in a DHC-6 Twin Otter. Flight experiments with this aircraft will begin in June 1974. The second flight system is being installed in the modified C-8A augmentor wing STOL research aircraft and flight acceptance tests will be performed in November 1973. Flight experiments with this aircraft will commence in December 1974.

Introduction of the Microwave Landing System (MLS), now under development by the FAA, will provide better terminal area landing guidance than is presently available. The MLS will by used by CTOL, STOL and VTOL aircraft. Consequently, one task to be accomplished in this program is to support the FAA in development of the MLS to ensure its suitability for STOL applications. Analysis, field investigations, computer simulations and flight experiments will be conducted to define realistic criteria for MLS proof-of-concept evaluation and prototype validations. The field investigations will include ground and flight tests with the programmable STOLAND avionic system. These investigations will emphasize MLS performance for terminal area navigation and approach and landing guidance for low visibility automatic operations. Flight validation of the K model prototype system will be completed in 1977.

In addition to the MLS validation, operating systems experiments will be conducted to provide information to aid in the choice of STOL terminal area guidance, navigation and control system concepts and to define operational procedures. Steep ascents and descents, tight turns and slow speed approaches and landings will be studied using analysis, simulation and flight test. The simulation and flight test experiments will be conducted using the STOLAND avionics system, the DHC-6 Twin Otter and the C-8A augmentor wing research aircraft. The navigation and landing aids to be used in the experiments are VOR, DME, TACAN and MODILS (Modular Instrument Landing System).

Improved navigation and guidance will be investigated using an innovative inertial guidance and navigation concept making full use of digital computer technology and redundancy management. This strapdown inertial reference unit (SIRU), now in the design phase, will be delivered to

ARC in September 1974 for flight acceptance tests in the CV-340. Flight experiments using a STOL vehicle equipped with both STOLAND and SIRU will begin in November 1975.

Additional details will be included in the Program Plan to be available in early 1974.

## Need and Relevancy

The Joint DOT/NASA Civil Aviation Research and Development Policy Study report identified the two most important problems plaguing civil aviation as noise and congestion. Development of a National Short-Haul Air Transportation System utilizing the capabilities of STOL aircraft has the potential of reducing the projected terminal area congestion and noise impact.

The ability of STOL aircraft to operate from runways 3000 to 9000 feet shorter than those required for CTOL aircraft and containment of the 90 EPNdB footprint within the airport boundary will allow modification or acquisition of STOL landing facilities with reduced real estate costs. Advanced navigation, guidance, and control systems will provide zero visibility landing capability and maximum touchdown dispersions of $\pm$ 15 ft. laterally and $\pm$ 100 ft. longitudinally. This will allow STOL aircraft to interface with the ATC system with minimal interference and will permit STOL vehicle operations independent of CTOL operations at existing airports. Reducing the pilot workload by 30% will increase the safety of operations.

New operating systems criteria and procedures must be established. Thus, NASA and DOT, in attempting to solve some of the potential problems associated with STOL navigation, guidance, and air trafic control, have joined forces in conducting a STOL Operating Experiments Program which is discussed in "Final Report of the Flight Experiments Committee of the Joint DOT/NASA Operating Experiments Steering Group," dated July 21, 1972.

# 4. NASA
# ROTORCRAFT/VTOL NOISE TECHNOLOGY PROGRAMS

OBJECTIVE DOCUMENTATION

Title: Advanced Rotorcraft Aerodynamic Technology

Type of Specific Objective

___ Discipline ___ Study ___ System and Experimental Program

Organizational Element Responsibility

Aerodynamics & Vehicle Systems Division - John M. Klineberg

Statement of Specific Objective and Targets

Objectives: to determine and improve the performance, dynamic loads, noise, control, stability, vibration, and handling qualities characteristics of helicopter rotors and rotorcraft configurations in order to permit the development of rotorcraft having substantially greater mission and cost effectiveness than current (1973) operational vehicles in military and civil usage. Specific targets are:

- Rotor Tip Vortices - By FY 1975, verify through full-scale experimental evaluations the projected ability of both passive and active devices, such as the ogee tip shape and mass injection concepts, to reduce blade-vortex impulsive noise about 5 EPNdB compared to conventional square tip blades for rotors of equivalent thrust level.

- Variable-Geometry Rotor - Evaluate the performance and noise characteristics of one of the current RSRA system candidates, the variable-geometry rotor concept, analytically in FY 1975 and experimentally in full-scale static tests in FY 1975-76.

- Controls and Displays for Improved Handling Qualities - Evaluate in flight the handling qualities improvements during curved decelerating approaches achievable with a 3-axis vector velocity command system by FY 1975, and a non-linear control concept by FY 1976.

- Civil Helicopter Technology Assessment - Apply in FY 1975, 1973 state-of-the-art technology on a large transport helicopter (CH-53) to provide passenger compartment acoustic/ and motion environment and assess suitability for feeder line aircraft use, and to provide civil helicopter noise certification and community acceptance criteria.

- Advanced Rotorcraft Design Studies - Define in FY 1975, to the extent possible in modest design studies incorporating estimated technology advancements, the broad design and operational characteristics of large advanced compound helicopter and tilt rotor transports which could realistically be operational by 1985.

- Controllable-Twist Rotor - Verify at full-scale in FY 1975 the ability of a controllable-twist rotor concept to reduce cyclic vibration 10 percent and improve performance 2 percent, compared to 1973 operational rotor types.

- Flight Controls and Handling Qualities for Unique Military Helicopters - Through evaluating a hierarchy of helicopter control systems by 1976, determine the minimum augmentation requirements for specific military low-level missions, and develop methods of implementation to minimize the number and complexity of hardware components. Using moving base simulation, establish by 1975 the effect of gross weight up to 250,000 pounds on handling qualities and flight-control requirements for crane helicopters.

- Design Prediction Methods - Validate existing design predictive methods and modify them where deficiencies exist to provide the required improved understanding of interrelated basic factors contributing to rotorcraft performance, noise, dynamics, and control. The subjects to be examined include: (1) main rotor/fuselage/tail rotor flow interferences and effects by FY 1975, (2) unsteady flow conditions on rotor blades and in the rotor wake by FY 1976, and (3) rotor blade and control system dynamics including feedback by FY 1977.

- Tilt-Rotor Control Systems - Develop and demonstrate by 1978 the technology for advanced control systems suitable for commerical and military operational tilt rotor vehicles.

## Approach

The NASA rotorcraft aerodynamic programs are conducted at the Ames and Langley Research Centers--in almost all cases jointly with the Army Air Mobility R&D Laboratory located at each Center. Effort at Ames emphasizes large-scale rotor model tests in the 40- x 80-foot tunnel, ground-based flight simulation studies, and analytical and design studies conducted primarily under contract. Langley in-house studies utilize such facilities as the V/STOL and full-scale tunnels for small-scale rotor model studies, the whirl tower for large- or full-scale hover performance and noise evaluations, and available rotorcraft for flight-dynamics investigations; contracted analytical and experimental studies are also supported. The specific approaches for accomplishing each of the identified targets follow:

- Rotor Tip Vortices - In the program oriented toward reduction of rotor tip vortex strength (and therefore reduction of vibration and noise) rotor tip geometric variations and mass injection will be studied. In one phase, Langley will evaluate the characteristics of full-scale ogee-tip blades on the whirl tower and in flight on the UH-1H helicopter in FY 1975, and Ames will carry out coordinated tests of the UH-1H blades in the 40- x 80-ft. tunnel. Langley will conduct flight tests to evaluate the mass-injection concept in FY 1975-76.

- Variable-Geometry Rotor - In Langley studies of the variable-geometry rotor (VGR), also designed for tip vortex strength alleviation, computer programs will be improved for the calculation of VGR performance and dynamics by FY 1975; following complete performance evaluations of a VGR scale model rotor through wind-tunnel tests in FY 1974, performance and noise tests will be made of full-scale models in FY 1975-76 on the whirl tower.

- Controls & Displays for Improved Handling Qualities - The CH-46 in-flight simulator helicopter will be utilized in FY 1975 to develop improved design and certification criteria for rotorcraft--and other VTOL aircraft--primarily in the areas of handling qualities and overall low-speed flight characteristics, such as during decelerating curved approaches. Advanced flight control systems including a 3-axis vector velocity command concept will be examined by early FY 1975 and a non-linear control concept by early FY 1976. Preparations will be completed for phasing in a CH-47 in-flight simulator (made available through the Army) having an improved research capability. The SH-3A helicopter will be used to fly pilot-controlled, simulated IFR VTOL approaches while varying the electro-optical pilot display parameters (resolution field of view, contrast, magnification factor, etc.) for reduced pilot workload and improved safety.

- Civil Helicopter Technology Assessment - The ride quality improvements achievable from current state-of-the-art design of a quieted vibration-isolated cabin in a CH-53 helicopter will be demonstrated at Langely in FY 1975. Design studies will be continued in FY 1975-77 to define and assess other advanced technology applications for improving performance, safety, economy and community acceptance of civil helicopter transports; flight evaluations of the more promising applications will be conducted in FY 1976-80.

- Advanced Rotorcraft Design Studies - Ames contracted design studies will be completed in FY 1975 to define representative tilt-rotor and advanced helicopter commericial aircraft design models for future short-haul air transportation. (The studies will enable a comparison with the characteristics of other STOL and jet VTOL concepts provided in other similar contracted studies.) Information on these design models, derived from analysis, wind tunnel tests, and simulation will be used to define their operating characteristics--e.g., noise, fuel utilization, flight path, pilot workload, and passenger acceptance--during approach and landing.

- Controllable-Twist Rotor - Ames, in FY 1975, will evaluate the dynamics and performance of a large-scale controllable-twist rotor on a new rotor test rig (RTR) to be developed for the 40- x 80-ft. tunnel. The RTR represents a major improved test capability for Ames, and will be used for a number of large-scale rotor investigations in future years.

- Flight Controls and Handling Qualities for Unique Military Helicopters - Simulation studies will be conducted at Ames of a number of low-level helicopter missions of interest to the Army. A hierarchy of control systems will be investigated during FY 1975 to establish the minimum augmentation requirements and to develop methods of implementation. Emphasis will be given to minimizing the number and complexity of the hardware components, minimizing the effects of upsets and disturbances, and on developing techniques for decoupling controls. By 1975, simulation investigations will be completed to determine the effect of gross weight up to 250,000 pounds on the handling qualities and flight control requirements for crane helicopters up to the very heavy lift class. Simulation results will be validated through use of flight results on a CH-54 helicopter obtained at Langley during FY 1974.

- Design Prediction Methods - Langley will conduct analytical and experimental studies to identify factors contributing to the aerodynamic, dynamics and noise characteristics of rotors. University grants and contracted studies will be continued through FY 1979 to define wake geometry and analytical procedures which include wake characteristics in predicting airloads, structural response, rotor control feedback, performance and noise. Langley in-house experimental studies will be made in FY 1975-77 to better define unsteady local-flow and aeroelastic parameters and rotor system dynamics. Tests will continue in FY 1975 with a highly instrumented generalized research helicopter model in the V/STOL tunnel to obtain a better quantitative understanding of main rotor/fuselage/tail rotor interference flows and effects. The effectiveness of a helicopter fan-in-fin in lieu of a tail rotor will be evaluated in the full-scale tunnel by FY 1976. A sophisticated rotor noise prediction technique will also be computerized in FY 1976. Ames will refine math modeling of tilt rotor dynamics through FY 1975; will continue contracted generalized studies of tilt rotor gust response problems and control system suppression technique through FY 1976; and will develop a method for computing tilt rotor/wing/empenage aerodynamic interference in FY 1975-76.

- Tilt Rotor Control Systems - A simulator model of a commercial tilt-rotor transport will be obtained by 1976 for use in simulation studies to define handling qualities and control system design criteria. Pertinent information will be obtained from coordinated simulation and flight studies supported under the XV-15 Tilt-Rotor Research Aircraft Program (RTOP 744-28-01).

Need and Relevancy

Rotorcraft have attained wide usage by the military (35 percent of the DOD aircraft inventory are helicopters and 85 percent of the Army inventory) for application primarily in assault, medical evacuation, aircrew rescue, aircraft retrieval and ground support missions. There is likewise a growing use of helicopters in the civil sector for industrial, ambulance and police, and short-haul transportation applications. Despite this wide rotorcraft usage, their full potential is far from realized in both military and civil sectors due to technology limitations resulting in poor cruise efficiency, inadequate speed and range capability, poor dynamics and high vibration, bothersome noise, and inadequate all-weather flight capability. These limitations seriously impact mission capability, initial and operating (including maintenance) cost, and passenger and community acceptance. The programs of this objective are aimed at effective alleviation of the technology limitations to permit the realization of rotorcraft having greater mission and cost effectiveness for both military and civil needs. An indication of the relevancy of the programs to military needs is the fact that about 90 percent of the programs are supported equally in funding and manpower by NASA and the Army.

OBJECTIVE DOCUMENTATION

Title: Advanced VTOL Aircraft Aerodynamic Technology

Type of Specific Objective

XX Discipline ____ Study ____ System and Experimental Program

Organizational Element Responsibility

Aerodynamics & Vehicle Systems Division - John M. Klineberg

Statement of Specific Objective and Targets

Objective: To provide the technology required to enable the development of viable military and civil aircraft having effective VTOL capability together with speed, range, operating cost, and mission/operational capabilities approaching those of 1973 operational medium range military and civil CTOL aircraft. This requires the development of a thorough knowledge and understanding of the aerodynamic performance, noise, control and stability characteristics, and piloting qualities peculiar to VTOL system concepts. Specific targets are:

- Ejector Wing VTOL Aerodynamics - In FY 1975, evaluate the VTOL aerodynamic performance, stability, and control of XFV-12A ejector wing configuration. Examine by FY 1976 the performance of advanced high pressure hypermixing VTOL ejector-concepts in forward flight transition engines.

Obtain by FY 1976 a preliminary evaluation of the performance of VTOL ejectors located chordwise at the root of a low aspect ratio combat aircraft type wing.

- Lift-Fan VTOL Aerodynamics - Verify in FY 1975 through large and small-scale tunnel tests that a lift-fan VTOL transport can be configured to achieve satisfactory performance, control and stability characteristics in terminal area operation.

- Lift/Cruise Thrust Vectoring - Demonstrate by FY 1975 through large-scale static tests the technology for rapid response ($\pm$ 20% thrust modulation and $\pm$ 20° thrust deflection in 0.2 sec.) lift/cruise propulsion system thrust vectoring/modulation systems whose thrust vector can be varied in a practical design from 0° (cruise thrust mode), to 90° (hover lift mode) with no more than 5% thrust loss, and to 130° for thrust reversal/braking.

- Lift/Cruise VTOL Aerodynamics - Demonstrate by FY 1976, technology for applying basic fluid mechanic phenomena to improve transition-flight interference effects on performance, stability and control of selected military VTOL combat type configurations through wind tunnel evaluations of small-scale models.

- SCS VTOL Aircraft Handling Qualities - Establish by FY 1976 through simulator investigations the envelope of acceptable approach aspects (relative headings of aircraft, ship, and wind) for satisfactory handling qualities of VTOL aircraft on Sea Control Ships under various sea states and weather conditions.

- Land-Based VTOL Aircraft Handling Qualities - Devise and demonstrate by FY 1977 an integrated control system for all flight phases of high-performance VTOL transport type aircraft. Verify through X-14 flight tests and related simulation studies, design criteria for vehicle lateral control power in hovering by FY 1975.

- VTOL Flow Interactions - Provide predictive methods adequate for design needs by FY 1978 of complex flows and their interactions (including noise effects) typically associated with VTOL aircraft having concentrated propulsion/lift system inlet and exhaust flows. As one specific example, a satisfactory analytic method for predicting vehicle induced lift accruing from lift engine propulsion installations in wing mounted pods will be sought in FY 1976.

Approach

The high performance VTOL aerodynamic programs are conducted at Ames and Langley. At Ames, the primary emphasis is on large-scale aerodynamic performance and acoustic studies, and on handling quality investigations. Langley concentrates on small-scale model investigations of aerodynamic performance, stability and control. NASA funding for the joint USN/USAF, NASA, FAA X-22 handling qualities program has been directly from Headquarters with technical monitoring by Langley. The approach toward accomplishing each identified target and the major milestones is as follows:

- Ejector-Wing VTOL Aerodynamics - Langley in FY 1975 will evaluate the VTOL aerodynamic performance, stability and control of small-scale wind-tunnel and free-flight models of XFV-12A VTOL aircraft configurations, and Ames will test the actual aircraft in the 40- x 80-ft. tunnel if provided by the Navy. Ames in FY 1975 will continue exploratory investigation of hypermixing VTOL ejectors, which will be extended in FY 1976 to advanced ejectors having pressure ratios perhaps as high as 2 to 3. Ames in FY 1975 will investigate the feasibility of VTOL ejectors located axially in the chordwise direction near the root of low aspect ratio military type aircraft configurations of VTOL performance in FY 1976.

- Lift-Fan VTOL Aerodynamics - The characteristics of a current technology lift-fan civil transport model and of a military multi-mission lift/cruise fan configuration will be determined in large-scale powered model tests on the Ames static test stand and in the 40- x 80- ft. tunnel in FY 1975. Langley in FY 1975 will complete small-scale model investigations of the performance, stability, and control of an intercenter VTOL transport model incorporating a different wing-pod-mounted lift-fan configuration, and of McDonnel Douglas VTOL transport design. On the basis of these results, Ames in FY 1976 will initiate the design of a more advanced VTOL transport type model for the 40- x 80- ft. tunnel, having substantially less required thrust/weight than current designs, to develop the integrated aerodynamic and acoustic technology.

- Lift/Cruise Thrust Vectoring - Ames in FY 1975 will complete a first series of small- and large-scale static tests of lift/cruise fan nacelles and thrust vectoring vehicle control systems aimed at developing technology for simple lightweight systems that can meet the stringent requirements for large vectoring angular ranges, fast angular and thrust modulation, high temperatures, and acceptable interactions of the exhaust flow with the aircraft, ground, and airstream.

- Lift/Cruise VTOL Aerodynamics - Langley in FY 1975 will continue wind tunnel evaluations of small-scale VTOL combat type aircraft configurations with wing and lift jet relative positions varied to optimize jet interference effects on performance, stability and control during transition flight.

- SCS VTOL Aircraft Handling Qualities - Ames will continue in FY 1975 and complete in FY 1976 a first series of simulator investigations to establish the envelope of acceptable approach parameters for satisfactory handling qualities of VTOL aircraft under manual control during take-off, approach, and landing on Sea Control Ships under severe weather conditions. Additional investigations will extend into FY 1977.

- Land-Based VTOL Aircraft Handling Qualities - Research at Ames toward demonstrating by FY 1977 an integrated flight control system for high performance VTOL transport type aircraft will include in FY 1975: (1) analytical and simulation studies of such a control system; (2) continued X-14 flight investigations to extend and refine hover control system and handling quality design criteria determined through simulation; (3) completion of simulation math models of advanced V/STOL transports to support transportation systems terminal area efficiency studies and; (4) initiation of a major simulator study on the FSAA to examine in considerable detail how best to detect and handle system failures on representative VTOL aircraft designs during critical conversion flight regimes (this effort will extend into FY 1977). Reporting of the X-22 flight evaluation of VTOL curved decelerating approaches, monitored by Langley, will be completed.

- VTOL Flow Interactions - Ames by FY 1976 will attempt to devise satisfactory theoretical methods to predict induced flows for VTOL podded configurations. Generalized studies will continue through FY 1978 at Langley on VTOL crossflow interferences, and at Ames, on the noise of VTOL exhaust jets as related to turbulent mixing.

Need and Relevancy

Efficient high-density short-haul civil transportation systems for the future have a need for quiet efficient vehicles which can operate over short to modest stage lengths competitively with other forms of transportation from small inexpensive VTOL ports which can be readily located to meet transportation demnds with a minimum impact on the community environment and with an economic advantage to both the traveling public and the communities being served. Likewise, the DOD has a requirement for future carrier-on-board delivery (COD) logistic and surveillance type VTOL aircraft which can be operated from small Sea Control Ships, as well as for VTOL combat aircraft. There is considerable commonality in the vehicle technology requirements for both the civil and military needs. The programs of this objective are oriented to provide the vehicle aerodynamic and flight dynamics technology required to develop viable vehicles for such civil and military needs.

## TILT ROTOR RESEARCH AIRCRAFT
(744-28) Ongoing

Program Objective

Demonstrate advanced rotorcraft technology for military and civil VTOL vehicles having twice the cruise speed of the helicopter while retaining its efficient hover capability.

Program Targets

Major targets of this program include the following:

- Initiate detail design - August 1973.
- Critical design review - August 1974.
- Fabricate two tilt rotor aircraft - October 1975.
- Complete ground testing - May 1976.
- Start flight research - June 1976.

- Definitize advanced flight research program - July 1977.

## Program Approach

Under a joint agreement signed November 1, 1971, NASA and the Army are sharing the funding and management of this program. A jointly staffed project office is located at the Ames Research Center.

Two contractors participated in a Phase I competitive design and analysis which was the basis for the selection of a Phase II contractor. The Bell Helicopter Company was awarded a contract on July 31, 1973, for the design, fabrication, and flight test of two Tilt Rotor Research Aircraft.

The program will be conducted on an "experimental shop" basis to emphasize cost and time savings as well as controlling the technical aspects to insure the aircraft will best meet the research objectives. Prior to first flight, a comprehensive ground test program will be conducted, including tie-down and full-scale wind tunnel tests.

Ames' flight simulators will be utilized to verify aircraft characteristics and to familiarize Army/NASA operating personnel with normal and emergency procedures. The initial flight tests will be conducted at the contractor's facility to verify flight safety and train Army/NASA flight personnel. NASA facilities will be used for proof-of-concept flight tests and definition of the advanced flight research program.

## Need and Relevancy

Helicopters have been widely accepted for both civil and military missions where efficient hover and VTOL capability are required. Their application to a wide range of civil short-haul and military tactical roles has been restricted, however, because of high dynamic blade loads and the loss of propulsion efficiency at higher forward flight speeds. Noise, vibration, high maintenance costs, and poor ride qualities have also added to the limitation of the helicopter.

For the past twenty years, the Army, Air Force, NASA, and industry have been pursuing the establishment of a tilt rotor technology base. Based on in-house studies and analyses by NASA/Army engineers, it was concluded that the tilt-rotor concept showed the greatest promise for a capability to meet the military and civil V/STOL needs anticipated in the future.

ROTOR SYSTEMS RESEARCH AIRCRAFT
(745-79) Ongoing

## Program Objective

A unique flight test capability in 1976 for advanced rotor research on a wide variety of promising new rotor concepts.

This program will expedite improved rotorcraft research through the use of a specially designed flight test vehicle. Extensive on-board instrumentation will provide better research data, and repeated use of the test vehicle will enable timely and economical completion of rotor research projects.

## Program Targets

Major targets of this program include the following:

- Initiate detail design - December 1973.
- Critical design review - December 1974.
- Fabricate two Rotor Systems Research Aircraft - September 1975.
- Initiate contractor flight test - November 1975.
- Aircraft delivery to Government - December 1976.
- Initiate NASA/Army rotor research program - January 1977.

## Program Approach

NASA and the Army are jointly funding and managing this program under an agreement signed November 1, 1971. A joint project office is located at the Langley Research Center where the rotor research program will be conducted. NASA/Army in-house and two contractor pre-design studies were used to establish the feasibility of an advanced flight research vehicle and to define its characteristics, the flight control system, and the research instrumentation systems.

An RFP was issued, proposals were evaluated, and Sikorsky Aircraft was awarded a contract for the design fabrication, and flight test of two Rotor Systems Research Aircraft.

Supporting research and technology efforts will be conducted, as required, to support the design effort and reduce the technical risk of the project. Wind tunnel tests will be conducted and the Flight Simulator at Ames Research Center will be utilized.

The "experimental shop" concept will be used to stress time and cost savings in addition to controlling the technical aspects to insure the aircraft will best meet the research objectives.

After a thorough ground test program, the contractor will conduct airworthiness flight tests, determine the aircraft characteristics and handling qualities, and check out the research instrumentation.

The NASA/Army research program will be started shortly after the aircraft are accepted by the government.

## Need and Relevancy

The expanding role of the helicopter in both civil and military applications has generated requirements which exceed the current state-of-the-art of rotary wing technology. To date, flight tests of promising advanced concepts have been conducted by modifying an existing aircraft or by building a new aircraft for each concept. This approach is time consuming, costly, and often gives less that good results.

NASA and the Army have been looking for a way to conduct adequate and timely investigations and demonstrations of advanced concepts in flight without the excessive time, cost, or data limitations of the "one at a time" approach. Both agencies have concluded that a specially designed research aircraft with adequate instrumentation is needed to test advanced rotor concepts and verify rotorcraft supporting technology. The Rotor Systems Research Aircraft is planned to fulfull this need.

ROTOR SYSTEMS FOR RSRA
(766-79) New Start

## Program Objective

Select, acquire, and evaluate on the Rotor System Research Aircraft (RSRA)--now being developed jointly by the Army and NASA--three practical advanced rotor-system concepts. Demonstrate through tests of these concepts in the real flight environment the integrated performance, dynamics and acoustics technology improvements achievable, such as increased speed (above 300 knots), with attendant lower vibration levels (by ½), noise (below 95 PNdB at 500 feet), and extended component life (by 100%), leading to community acceptance, improved ride comfort (to feederline aircraft levels), and reduced direct operating costs (by 20%). Particular objectives will depend in large part on the three rotor system concepts selected. Concepts currently considered promising include the:

- Aero-acoustic rotor for reduced external acoustic noise and increased cruise L/D
- Variable-geometry rotor for reduced external acoustic noise and rotor vibration and increased hover efficiency
- Composite structures rotor for reduced rotor system weight
- Variable diameter rotor for increased cruise speed
- Controllable twist rotor for increased cruise speed and L/D, increased hover efficiency and reduced rotor vibration

## Program Targets

The program objectives will be approached through the following steps:

- Initial selection of rotor systems by mid FY 1975.
- Begin design and fabrication of first rotor system by late FY 1975, ground tests by mid FY 1977, and flight tests by early FY 1978.

- Begin design and fabrication of second rotor system in mid FY 1976, ground tests by late FY 1977, and flight tests by mid FY 1978.

- Begin design and fabrication of third rotor system by mide FY 1977, ground tests by early FY 1979 and flight tests by late FY 1979.

Because the program involves evaluating advanced rotor concepts on a new flight test facility, strong supporting technology efforts will be conducted during FY 1975-77 to aid in establishing design criteria for the rotor systems and guiding their development to assure a successful program.

Program Approach

The technical approach will encompass four major related elements conducted cooperatively with the U.S. Army:

1. Direct Supportive Research & Technology Activities - This includes (a) evaluation of advanced technology airfoils and components which will likely be incorporated into selected advanced rotor system concepts as described in item 2; (b) scale model dynamic investigations of some of the candidate advanced rotor concepts; and (c) correlation of analytical prediction and flight data obtained as described in item 4.

2. Advanced Rotor System Concept Definition Studies & Selection - Concept definition studies will be made under contract to serve as the basis for the eventual selection of the initial three concepts for investigation on RSRA. The definition study contracts will document information on concept potential, preliminary design data, development support requirements, and cost/schedule relationships necessary for subsequent preparation of proposal requests and contract award to procure the rotor systems.

3. Advanced Rotor Systems Design & Procurement for RSRA - This includes the design, fabrication and ground test of three advanced research rotor systems in a manner to provide flight hardware consistent with the RSRA flight schedule. Priorities and sequencing of the hardware development will be based in part on concept potential, on extent of development and full-scale ground test requirements, and on timeliness.

4. Flight Evaluations Utilizing RSRA - Upon delivery of the RSRA, documentation flight tests will be made to evaluate system capabilities and provide baseline data for correlation with future test results. Thereupon, extensive flight investigations will be made of each of the three research rotor systems provided by this systems technology program. During the course of evaluating the three rotor systems per se as they become available, there will be additional flight evaluations utilizing the unique versatility and capability of the RSRA to study important broad helicopter problem areas such as: (a) control system technology including feed-back systems for gust alleviation and ride comfort, (b) rotor/airframe structural dynamic response, and (c) compound helicopter maneuver characteristics.

Need and Relevancy

The NASA and Army are jointly developing two RSRA vehicles at a cost of \$33M to provide an efficient, expanded and economic capability (1) to evaluate potentially superior, advanced technology rotor system concepts in flight; (2) to investigate rotorcraft systems and characteristics over a much greater envelope of flight conditions than achievable with currently available laboratory facilities or flight vehicles; and (3) to provide an extensive flight data base to validate many complex rotorcraft design prediction methods. Development of the RSRA vehicles is being agressively pursued to provide the expanded test capability for evaluating a number of rotor concepts at a substantial cost savings compared to the current approach of validating each advanced concept on separate "one shot" test vehicles. The RSRA project is completed upon government acceptance of the aircraft, however, and this research program is required for utilization of the valuable national test facilities to achieve the return on their investment in a cooperative effort with the U.S. Army.

The first RSRA vehicle is scheduled to be delivered to the Langley Research Center by the mid FY 1977 with its baseline rotor system, and to be ready for initial evaluation of an advanced research rotor system by late FY 1977. On the basis of R&T base technology programs to date, several rotor system concepts appear to warrant the thorough flight evaluation which RSRA will permit. However, none of the rotor systems exist in flight hardware suitable for direct use on RSRA. Although the time requirements for design, fabrication, ground test, and integration of a complete rotor system on RSRA will vary with different concepts, a minimum of about two years is anticipated. Therefore, it is imperative that concept definition studies and evaluations be initiated early in FY 1975 to select the most appropriate rotor systems for development, to establish a concept priority which will allow the most effective development of flight test hardware, and to begin the design/fabrication of the first research rotor system. The provision and evaluation of the second and third rotor systems of this program are timed for maximum effective utilization of the two RSRA vehicles for all NASA/Army flight investigations requiring the vehicles.

The development of advanced rotor systems and their evaluation of RSRA contribute directly to the NASA National Goals of providing efficient short-haul transport technology and establishing the technology for superiority in military aeronautics. The program will in addition aid greatly in focusing technology efforts carried out under the NASA Rotorcraft Research and Technology Base programs which also support the two National goals mentioned.

# 5. NASA
# SUPERSONIC CRUISE AIRCRAFT NOISE
# TECHNOLOGY PROGRAMS

OBJECTIVE DOCUMENTATION

Title: SCAR Propulsion Technology

Type of Specific Objective

___ Discipline ___ Study _X_ System and Experimental Program

Organizational Element Responsibility

Advanced Supersonic Technology/Hypersonic Research Office - W.S. Aiken, Jr.; L. Sternfield

Statement of Specific Objective and Targets

Objective: To establish an expanded supersonic propulsion technology base in parallel with the expansion of other supersonic disciplinary technologies which will permit the reduction of noise in takeoff and landing to levels less than the Douglas DC-10 and Lockheed 1011; reduce fuel consumption rates which can make supersonic cruise aircraft significantly more efficient; and nitric oxide emissions in high altitude cruise that are greatly reduced from levels possible with today's technology. Specific targets are:

- By the end of FY 1975, establish noise reduction potential of suppressors for coannular jets for application to duct-heating turbofan cycle engines.
- By FY 1977, verify the potential of $NO_x$ reductions to 90% less than current engines at supersonic cruise altitudes.
- By FY 1977, verify inlet shock stabilization valve concept operational suitability by YF-12 flight tests.
- By FY 1979, synthesize and apply an integrated propulsion control system to the YF-12.

Approach

NASA's fundamental research on supersonic propulsion system problems is conducted primarily by LeRC, with contributions from ARC in the noise area and FRC in the area of inlet control systems. Primary emphasis is placed on the development of engine components and propulsion systems which will provide high levels of propulsive efficiency with reduced levels of noise and pollutant emissions. The secondary emphasis is on the development of integrated control systems which will stabilize inlet shock waves and thus provide for improved propulsion system performance and reliability.

- Noise suppressors developed in the FAA SST Phase II Follow-on program and in-house LeRC programs will be flight tested using the Lewis F-106 and also tested in Ames 40' x 80' wind tunnel. The sources and treatment of coannular jet noise, important for applications to duct-heating turbofan engines, will be studied by Lewis leading to later engine tests. Wind tunnel techniques to be developed by ARC for the prediction of the effects of forward speed on noise characteristics will lead to testing of powered models of supersonic cruise aircraft.

- The LeRC will continue the current in-house/contractor clean combustor program which is aimed at reducing the $NO_x$ emissions at supersonic cruise speeds to levels which are only 90% of those of current subsonic aircraft. Tests of candidate combustors will be tested at flight conditions representative of those of long-range supersonic cruise aircraft and these tests will lead to the development of Low $NO_x$ combustors suitable for use in low-noise engines.

- Inlet shock stabilization valve concepts and digital integrated control techniques will be applied by the Lewis and Flight Research Centers to the YF-12 aircraft. The shock stabilization system will be tested in the Lewis 10' x 10' wind tunnel and subsequent flight tests will be conducted on a YF-12 which has been modified to include the new system.

Major milestones of the SCAR Propulsion Technology program are:

Early FY 1975 - Initiate wind-tunnel tests of inlet shock stabilization valve.

Mid FY 1975 - Initiate studies of augmentor pollution.

Early FY 1976 - Establish noise reduction potential of suppressors for coannular jets.

Need and Relevancy

The SCAR Propulsion research is for direct support of the Supersonic Cruise Aircraft Research program. This work is of primary relevance to the OAST focus on basic research on supersonic cruise aircraft.

The propulsion system is always a key technology area in the development of any advanced aircraft. In the case of supersonic cruise aircraft, additional constraints imposed by the need to reduce terminal area noise (less than new widebody civil aircraft) and terminal area and upper atmosphere pollution (ninety percent less than current engines at high altitude cruise), while retaining cruise efficiency for military aircraft and economic viability for civil aircraft, present a set of interlocking problems which must be addressed through noise suppression programs, clean combustor programs, and the initiation of research on advanced low-noise engines which permit efficient operation at both subsonic and supersonic speeds. In addition, since very precise and complex propulsion controls are required to prevent major interactions of propulsion system components as well as potentially adverse interactions with airframe control systems, research on the dynamics and control of supersonic propulsion systems must be conducted by means of wind tunnel and flight tests.

We expect that the results of this research will provide the background data which will lead to quieter, cleaner, and more efficient propulsion systems for both military and commercial supersonic airplanes.

OBJECTIVE DOCUMENTATION

Title: Supersonic Cruise Aircraft (SCAR) Aerodynamic Performance Technology

Type of Specific Objective

___ Discipline ___ Study _X_ System and Experimental Program

Organizational Element Responsibility

Advanced Supersonic Technology/Hypersonic Research Office - W.S. Aiken, Jr.; L. Sternfield

Statement of Specific Objective and Targets

Objective: To establish an expanded supersonic aerodynamics technology base in parallel with the expansion of other supersonic disciplinary technologies which will permit improvements in L/D, reductions in sonic boom, and the translation of technical advances into integrated aircraft systems. Specific targets are:

- By FY 1977, validation of low-speed high-lift aerodynamic performance theories.

- By FY 1978, verification of theoretical methods for rapid analysis of critical design loads.

- BY FY 1979, 30% increase in L/D over present state-of-the-art for aerodynamic configurations meeting all propulsion system, structure, and control system restraints.

- By FY 1981, 40% reduction in sonic boom during cruise conditions potentially applicable to far term advanced supersonic transport designs.

Approach

NASA's fundamental research on supersonic aerodynamic performance is conducted primarily by the Langley and Ames Research Centers. Primary emphasis is placed upon evolving supersonic cruise aircraft concepts which have high levels of supersonic performance, on obtaining sufficient low-speed and supersonic wind tunnel data to permit optimization of these concepts, and on the development of improved theoretical methods for use in the design and analysis of both military and commercial supersonic aircraft. The secondary emphasis is on the development of a more complete understanding of the sonic boom phenomena which are so critical to commercial overland supersonic flight.

- Integrated supersonic cruise configuration concepts which show promise of meeting the demanding requirements of future long-range supersonic cruise missions will be developed by LaRC with extensive analyses and wind tunnel tests. Both "near-term" concepts, which depend on only small improvements in the related disciplines of structures, propulsion, and flight controls to become viable supersonic cruise aircraft, and "far-term" concepts which depend on extensive technology advancements in all areas, will be considered. In addition, the ARC will give consideration to unconventional concepts which might show future promise in an advanced technology environment.

- The purpose of the theory development program is to fill the voids apparent in the recent United States SST program. Needs for improved, and more rapid, means for supersonic cruise aerodynamic design and analysis methods; more valid means for predicting critical wing and fuselage design loads; and methods for analytically assessing the low-speed, high-lift aerodynamic performance were indicated during this program. LaRC will conduct contract studies to meet the needs for better supersonic and loads methods while ARC will direct a contract study to fill the need for improved low-speed methods. The goal is to combine the improved methods into a unified design and analysis method which is applicable to most classes of supersonic aircraft.

- It is generally accepted that the future market for commercial supersonic cruise aircraft would be more than doubled if the sonic boom problem could be solved of ameliorated. The SCAR sonic boom technology will be directed towards obtaining a better understanding of sonic boom pehnomena and towards evolving configuration concepts which have low levels of sonic boom disturbance.

Major milestones of the SCAR Aerodynamic Performance research are:

Early FY 1975 - Complete Cornell University study of sonic boom phenomena.

Mid FY 1975 - Extend contracts for improved supersonic loads, and low-speed theory.

Late FY 1975 - Complete transonic tests of arrow-wing propulsion and pressure distribution model.

## Need and Relevancy

The SCAR Aerodynamic Performance research is for direct support of the Supersonic Cruise Aircraft Research program. This effort is of primary relevance to the OAST focus on basic research on supersonic cruise aircraft.

Improved aerodynamic performance in all flight regimes is critical in the development of superior military and commercial airplanes. A thirty percent increase in L/D would provide the option for an approximate thirty percent increase in range or payload capability. In the case of supersonic commercial airplanes, the additional constraint of sonic boom and the need for high levels of low-speed aerodynamic efficiency to reduce noise, seriously complicate the aerodynamic design and integration problems. In order to provide the technology for future supersonic cruise aircraft with either military or commercial missions, advanced configuration concepts must be evolved, advanced theoretical procedures for use in predicting and optimizing the aerodynamic performance must be validated, and an extensive data base must be obtained from wind tunnel tests of representative models. The SCAR Aerodynamic Performance research is directed toward these needs.

# 6. NASA AIR TRANSPORTATION SYSTEM STUDIES

## SHORT-HAUL TRANSPORTATION SYSTEMS ANALYSIS

The objective of this work is to help develop a sound technological base for future decisions relating to the design, development, and operation of short-haul transportation systems. This objective will be achieved through a related group of studies that: examine the relationships between short-haul technology and short-haul economics, markets, and implementation; identify potential viable short-haul airplane concepts and their design and performance criteria for practical short-haul transportation systems including consideration of market, economic, and environmental factors; and, perform sufficient aircraft design to provide a realistic assessment of technical problems and questions regarding their design, development and operations, and their development and operational costs. These data will be used to help define the future direction of productive technical (and system related) activity for short-haul transportation systems. This investigation will be performed in-house and under contract.

Two contracted studies (Lockheed and Douglas) to determine the operational and economic viability of turbofan powered propulsive lift aircraft for short-haul transportation have been completed. Final reports will be distributed in June. The current contracts have been extented to (a) allow Lockheed to optimally design and compare the OTW/IBF propulsive lift and mechanical flap concepts in terms of noise impact and operating economics and (b) allow Douglas to determine the impact on operating economics of the effect of combining terminal area operations with various engine cycles to minimize community noise impact for several propulsive lift and mechanical flap concepts.

## ANALYSIS OF FUTURE CIVIL AIR TRANSPORTATION SYSTEMS AND CONCEPTS

The objective of this study is to provide systems analyses of future civil air transportation systems and concepts in order to identify promising aeronautical systems, determine optimum characteristics, and define technology requirements and costs associated with such systems. Studies of general aviation aircraft, CTOL, STOL, and VTOL transports, advanced subsonic/transonic transport aircraft, and advanced supersonic transports will be conducted. Total system studies will be carried out considering all of the interactions between aircraft, airports, airways, community impact, and economics (both within the aviation industry and on a national basis). In addition, studies of a short term nature will be conducted in support of the aeronautical program planning activities of ARC and OAST.

## HIGH TRANSONIC SPEED TRANSPORT (HiTST) SYSTEM STUDY

The objective of this study is to provide detailed configuration definition of a high transonic speed transport concept. The contract system study of FY 1973 identified a promising yawed wing aircraft at the conceptural design level. The study this year will provide needed definition at a more detailed level, providing in-depth analysis in several individual new technology areas, and adding credibility to certain design concepts. Examples of such design studies would include fatigue and flutter characteristics of composite structures, low speed stability and control of yawed wing for emergency maneuvers, and new engine technology applications for reduced noise.

## SUBSONIC/TRANSONIC C/RTOL TRANSPORT TECHNOLOGY SYSTEMS AND DESIGN STUDIES

This work covers systems and design integration studies for subsonic C/RTOL long and medium-range passenger and cargo transport aircraft. The objective is three-fold. (1) Make technology advances available for superior subsonic C/RTOL transport aircraft to satisfy anticipated requirements in the 1980's. Anticipated requirements include the need to improve aircraft cruise efficiency not only for better economics but also for energy (fuel) savings; to alleviate terminal-area congestion; and to reduce aircraft noise and emissions without suffering economic penalties. (2) Determine the feasibility of utilizing aircraft fuels other than JP fuel for subsonic cargo and passenger aircraft as a potential partial solution to a projected shortage of petroleum in the 1990's and to identify aircraft-technology requirements peculiar to alternate fuels. (3) Investigate new approaches to providing more economical subsonic transport of liquid and solid cargo in anticipation of the need for a greatly increased air transport of cargo.

## SUBSONIC/SONIC CTOL TRANSPORT TECHNOLOGY PROPULSION STUDIES

NASA has initiated an effort to study the application of advanced technology to the improvement of future commercial transport aircraft. The results were resolved in terms of economic factors involving parameters such as aircraft drag, propulsion efficiency, costs, and propulsion system noise and exhause emissions. Detailed analyses has been completed through in-house and contract studies and have been documented in NASA Contractor Reports. Results indicated that the environmental constraints imposed compromises to the the optimum fixed-area turbofan cycle with resulting economic penalties. The studies also indicated areas where advanced technology would decrease the noise and emissions and improve the system economics.

Results of recent studies of unconventional cycles have indicated that to achieve low noise, variable geometry inlets in conjunction with variable-area exhaust nozzles will be needed. Also, the use of high throat Mach number inlets appear to offer significant performance and economic improvement over inlet splitter rings. Several designs, including hybrid variable geometry cowls, expanding and translating centerbody types, and translating ring-type inlets were proposed for further study.

# 7. NASA GENERAL AVIATION NOISE TECHNOLOGY PROGRAMS

OBJECTIVE DOCUMENTATION

Title: General Aviation Aerodynamic Technology

Type of Specific Objective

XX Discipline ____ Study ____ System and Experimental Program

Organizational Element Responsibility

Aerodynamics & Vehicle Systems Division - Roger L. Winblade

Statement of Specific Objective and Targets

Objective: To develop and demonstrate advanced technology for general aviation use that will permit the design of future U.S. aircraft that are safer, more productive and clearly superior to foreign competition.

The following targets have been established to provide the advanced capabilities and design techniques necessary to achieve the stated objective.

- Flight demonstration in FY 1975 of low speed airfoils with a 30% increase in $C_{L_{max}}$ maintaining the same or less cruise drag.

- Application of supercritical aerodynamic technology by all U.S. business jet manufacturers by 1975.

- Flight demonstration by FY 1976 of pilot displays and control systems to improve flight path control and landing performance with special application to

    - pilot training
    - pilots who fly infrequently
    - landing at unfamiliar airfield
    - night landings
    - emergency conditions

- Provide definitive design criteria, test, and evaluation techniques by FY 1976 for aircraft that will not spin unintentionally.

- Establish design criteria for airfoil sections and planforms optimized for low noise propellers by FY 1976.

Approach

Analytical and experimental efforts are directed toward the generation of design data for safer more productive general aviation aircraft. Simulators, wind tunnels and when appropriate, experimental aircraft will be utilized in programs addressing the problems and limitations unique to the general aviation category of aircraft. Improved safety and utility are predominate factors; however, user requirements, manufacturing and cost limitation and certificability are significant factors in development and conduct of the technology programs.

- Both analytical predictions and wind tunnel testing have been used to develop a new low speed airfoil section. The characteristics of the new airfoil show an increase of 30% in $C_{L_{max}}$ and a 50% improvement in L/D when compared to airfoils currently in use. Experimental flight verification will be accomplished through the testing of a modified aircraft incorporating new wings designed with this airfoil section. The wing design was completed in FY 1973 with fabrication by a general aviation manufacturer underway in FY 1974. Detailed flight testing in FY 1975 will provide a completed data package including analysis, wind tunnel data, application techniques and flight verification.

- Supercritical aerodynamic theory, while developed in the context of large transports and military aircraft, will be of significant advantage to business jet aircraft. Classification of supercritical data requires implementation of specific agreements under which the necessary access to data can be authorized. Such agreements, providing data, technical consultation and NASA wind tunnel validation of the resulting designs, are in effect with four U.S. business jet manufacturers. Discussions are underway with the remaining two U.S. companies concerning similar arrangements.

- Direct modulation of the L/D ratio has been shown to provide significant improvements in the precision of flight path control and reduction in touchdown dispersion when properly integrated into the pilot's task. The successful completion in FY 1974 of the direct drag control (plate spoilers) effort to demonstrate the feasibility of using spoilers on powered light aircraft is being followed by a similar effort on direct lift control in FY 1975 and FY 1976.

An aircraft modified to incorporate the slot spoiler lift modulation concept will be utilized to obtain definitive data on effectiveness and operational characteristics. Simulation and actual flight tests of an experimental "breadboard" version of a simple head-up display presenting information on angles of attack and sideslip as well as airspeed have shown a beneficial effect on the landing performance of selected pilots with considerable experience in light aircraft. Continuing flight verification of this and an improved prototype version will be performed with pilots of lesser skills and experience to demonstrate the effectiveness of the unit and application in the operational environment.

- The stall/spin problem currently is the largest single factor in general aviation fatal accidents. The program initiated at the Langley Research Center in FY 1973 to define the criteria and design techniques for spin resistant airplanes is intended to alleviate that problem. Exploratory investigations will be conducted at Langley and Ames on both aerodynamic and avionic methods for preventing stalls and spins. Wind tunnels, radio controlled models and full scale aircraft are being used to identify and document the critical aerodynamic characteristics relative to spin entry and recovery. Modernization of the tail damping power factor criteria is a primary aim of this effort, as is the development and demonstration of an economically viable radio controlled model testing technique for preflight verification of spin characteristics. A compact and easily-installed spin recovery system employing monopropellant (hydrogen peroxide) thrusters and a self contained fuel supply system is to be developed and flight tested to demonstrate the suitability of this type of system for basic spin research and possible use by manufacturers in their spin certification tests.

- Both in-house and university grant efforts are being directed toward development of modern design criteria for propellers. Operational and manufacturing compromises have resulted in propellers that currently operate well below the theoretical maximum efficiencies. During FY 1975 and 76, concentration will be on application of advanced aerodynamic theory to optimizing planforms and airfoil sections for maximum noise. Optimized blade shapes will be fabricated from both conventional materials and composites to investigate potential benefits of the newer manufacturing techniques.

Need and Relevancy

The impact of general aviation on the air transportation systems in terms of numbers of operations, flight hours, and people transported has been well documented. The projected large increases in this activity are validated by past history. With 500 million intercity travelers projected to be using general aviation by 1985, it is imperative that a vigorous technology program be directed at improving the safety of these operations.

The general aviation industry in the United States currently exports 20 to 30% of its production. This market has been maintained primarily through the technical superiority of the U.S. manufacturing. Countries in Europe, South America, and Asia, through government support, are rapidly developing their general aviation industries. Projections to the 1985 time period indicate that unless the U.S. industry can generate aircraft that are technologically superior, the emerging foreign competition will not only absorb the export market but will make significant inroads into the domestic market as well.

## SPECIFIC OBJECTIVE

Title: Quiet, Clean General Aviation Turbofan

Management Responsibility

David J. Miller/Aeronautical Propulsion Division

Specific Objective

The specific objective of this program is to identify, extend, and demonstrate the technology applicable to small general aviation turbofans to achieve future environmental requirements with economic viability.

Targets

- Perform studies to define an experimental technology demonstration program, January 1976.

| | | |
|---|---|---|
| • Contract award | February | 1976 |
| • Critical design review | June | 1976 |
| • Delivery of experimental engine for test | May | 1977 |

Need and Relevancy

The use of small aircraft has the potential to create a more widespread adverse community reaction to jet noise and pollution than do transport aircraft. This is so because minor airports used by small aircraft are apt to be located near suburban residential areas unprotected by commercial/industrial buffer zones. Jet powered general aviation aircraft sales are increasing at a faster rate than the rest of general aviation aircraft.

Existing FAR 36 noise restrictions probably can be met by new production aircraft. It is probable that these restrictions will be tightened to require reduced noise levels for the next generation of aircraft.

EPA emissions standards applicable to subsonic gas turbine engines of less than 8000 lb thrust will enforce a more stringent set of criteria for all engines manufactured after January 1, 1979. No current small turbofan or turbojet engine can meet these 1979 emission standards.

Approach

Program definition studies will be accomplished during FY 1975 as part of the R&T Base Technology program. The studies, to be performed by general aviation turbofan manufacturers will:

1. Analyze the applicability of large engine technology (noise/pollution) to general aviation turbofans.

2. Examine other factors significant in improving the applicability of small turbofans to general aviation.

A program plan will be included as part of the FY 1975 studies.

The Quiet, Clean, General Aviation Turbofan (QCGAT) program will be a contracted effort. A single contractor will be competitively selected for the experimental program. This program will include design, fabrication, assembly, and ground tests of the experimental engine. Further ground testing will be performed by NASA. Extensive use will be made of existing engine component technology and existing engine cores in order to hold down costs. Cost sharing will be explored.

There is no intention to proceed into a development program for a flight demonstrator engine.

## II. DOT AIRCRAFT NOISE PROGRAMS

### 1. DOT/FAA AIRCRAFT NOISE PROGRAMS

SOURCE NOISE REDUCTION PROGRAMS

The objective of this program is to develop a noise source prediction capability for all categories of aircraft. This program involves the investigation and determination of the parameters that cause or influence the actual generation of noise emanating from aircraft, definition of noise sources and methods of reduction plus development of guidelines for changes to the engine and aircraft configuration required to minimize noise. Aircraft noise source elements are identified as follows:

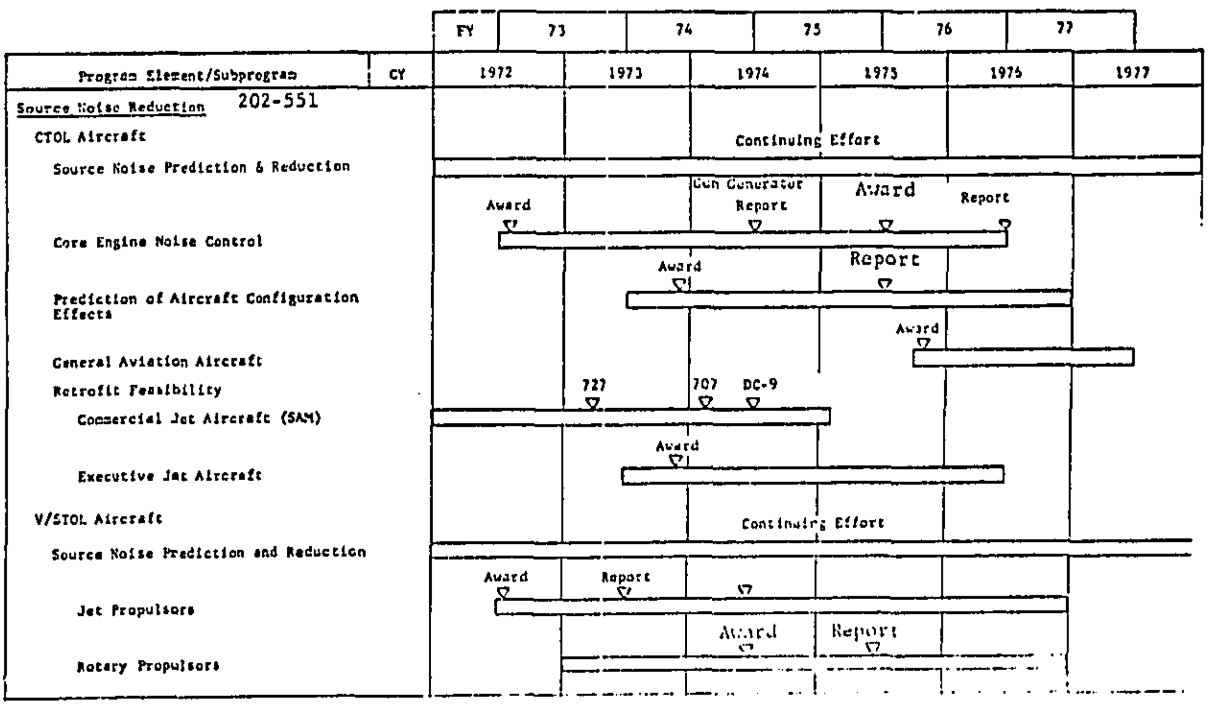
- Turbo machinery
- Jet mixing
- Combustion/case
- Propeller and rotor
- Airflow surface interaction
- Lift augmentation
- Reciprocating engine
- Duct acoustic lining
- Aircraft configuration noise shielding

Source noise reduction research and development efforts can conveniently be described according to aircraft type: CTOL (transonic, subsonic and supersonic) and V/STOL. The schedule of major activities is described below and is shown in Table 1. A continuing effort to update and add to current capabilities is planned for both CTOL and V/STOL aircraft types through both in-house and contract activities. It is important that the latest technology in noise prediction and reduction techniques be readily available so that community exposures can be accurately estimated and noise control can be implemented by technologically practicable and economically reasonable regulations.

Core Engine Noise Control

The purpose of this project is to provide theoretical and expermental data to assist the designers in developing future aircraft

Table 1
AIRCRAFT NOISE ABATEMENT -- SOURCE NOISE REDUCTION
Program Schedule -- 1972-1977



capable of conforming to lower noise levels than are now required by FAR Part 36. The effort shall be directed to identifying, evaluating, and controlling the component noise sources inherent in the core engine (the gas generator) which establishes the limit of effectiveness of the current noise control state-of-the-art.

For the purpose of this project, core engine noise is defined as the noise produced by the gas generator portion of the gas turbine engine either solely or as influenced or amplified by the fan discharge, tail pipe, and/or any other portion of the exhaust system. Core engine noise shall be assumed to radiate only in the aft engine quadrant and its sources may be generated either upstream or downstream of the tail pipe exit plane. Core engine noise shall not be assumed to contain compressor generated noise radiating from either the engine inlet or fan exhaust ducting. Core engine noise, however, may include compressor generated noise transmitted downstream through the engine flow passages or fan generated noise enhanced by interaction with the core engine noise or gas stream.

## Prediction of Aircraft Configuration Effects

The purpose of this project is to study the feasibility of use of aircraft configuration and engine placement to reduce noise propagation to the ground plus development of prediction procedures for configurations of practical interest.

## General Aviation Aircraft

This project covers a survey and definition of the noise characteristic of all general aviation aircraft plus development of suitable noise prediction capabilities.

## Retrofit Feasibility

- Current Commercial Jet Aircraft - The purpose of this project is to provide test data to assist in determining whether certain classes of turbofan propelled airplanes in the current fleet can be modified for meaningful noise reduction in a feasible manner. Feasibility relates to three key instructions contained in Public Law 90-411; that is, the noise abatement methods must be technologically practicable, economically reasonable, and appropriate for the particular type of aircraft, aircraft engine appliance, or certificate to which it will apply. The effort is directed to providing acoustical treatment, designed to conform to specified noise reduction goals. The acoustical treatment may be any hardware or mechanical device, applied either singly or in combination with the inlet and primary and secondary exhausts that will either absorb sound or otherwise effect a noise reduction at the FAR Part 36 measurement positions. Current retrofit programs for 727 aircraft will be completed in FY 1973; 707, DC-8, and DC-9 retrofit programs will be completed in FY 1974. The effort is directed to providing nacelles that are capable of being certificated. Results to date indicate that the retrofitted aircraft can comply with FAR Part 36.

- Executive Jet Aircraft - A retrofit feasibility program covering business jets is planned to follow the commercial retrofit project. The number of this type of aircraft is more than one-half that of the commercial fleet considered for retrofit and is growing rapidly. The purpose of this project is the same as given above for commercial jets. This program will draw upon knowledge gained and relate closely to the commercial jet program covered above. It is scheduled for completion in FY 1976.

## V/STOL

V/STOL aircraft have propulsive lift systems that are distinctly different from conventional aircraft. Both rotary and jet propulsion systems are being considered. It is anticipated that V/STOL aircraft (including helicopters) will supply a major segment of the short haul transportation requirements in the near future. These aircraft, which are being considered for city center airports, may cause substantial increases in noise exposure for adjacent urban areas and also for suburban areas under the cruise path.

This effort is directed to identification, evaluation and controlling component noise sources inherent in V/STOL systems. Both jet propulsion and rotary propulsion systems will be studied. Prediction techniques will be developed.

## OPERATIONAL NOISE REDUCTION PROGRAMS

The objective of this program element is the determination, investigation and measurement of significant factors which affect the transmission of noise from its source to the airport community. Elements are identified as follows:

- Aircraft Operational Procedures

• Atmospheric Parameters

Operational noise reduction is a continuing effort through both in-house and contract activities. Information developed will be used to update FAR Part 36, and in future noise rules. Projects apply to certification measurement and compliance.

The operational noise reduction program plan is presented in Table 2 and elements of the program are discussed below.

Noise Propagation Measurement and Evaluation

This program element will include studies of ground attenuation and of the importance of temperature and humidity measurements along the noise propagation path versus ground measurements only in correcting flyover noise measurements to standard conditions as currently required by FAR Part 36. This project could provide a refinement to FAR Part 36 and to improved accuracy in calculation of noise exposure areas.

Noise Measurement

This program involves development of methods and equipment for noise measurement. The project objectives are to develop noise measurement systems with capabilities suitable for certification research, studies of noise abatement operating procedures, long-range noise propagation, and community noise exposure. Certification measurement capability objectives include commercial subsonic and supersonic aircraft, general aviation including business jets, plus VTOL and STOL aircraft.

Increasing air traffic brings with it increasing complexity in airport noise patterns and as a consequence, more complete automatic and sophisticated measurements will be needed to determine the extent of the noise exposure. It would therefore be technologically advantageous to develop noise measurement systems capable of handling extensive measurement tasks, at greater accuracies, then the conventional systems.

NOISE EVALUATION AND RESPONSE

The objective of this program element is to determine the effects of noise on individuals and on the community as a whole; to develop methods required to predict the reaction of communities to noise resulting from varying numbers and types of aircraft; and to develop

Table 2
AIRCRAFT NOISE ABATEMENT -- OPERATIONAL NOISE REDUCTION, NOISE EVALUATION AND RESPONSE
Program Schedule -- 1972-1977

| Program Element/Subprogram | CY | 1972 | 1973 | 1974 | 1975 | 1976 | 1977 |
|---|---|---|---|---|---|---|---|
| | FY | 73 | 74 | 75 | 76 | 77 | |
| <u>Operational Noise Reduction</u> 202-552 | | | | Continuing Effort | | | |
| Research and Technology Base | | | | | | | |
| Noise Propagation Measurement and Evaluation | | Report | Award | Report | | | |
| Noise Measurement Systems | | | Award | Report | Design Award | Install | Operational |

and/or refine acceptable yardsticks for evaluation and rating of various levels of aircraft noise. The program schedule is included in Table 2. Elements of noise evaluation and response are identified as follows:

- Noise exposure evaluation
- Community response surveys
- Subjective noise evaluation
- Psychoacoustic studies
- Noise exposure forecasting

Research to improve the technology base in this area is a continuing effort through both in-house and contract activities.

Current and planned projects are outlined below:

Noise Exposure

- Noise Evaluation and Community Response - The purpose of this project is the development of accurate and comprehensive noise evaluation criteria suitable for application to all CTOL aircraft including business jets and also suitable for application to V/STOL aircraft.

  Psychoacoustic laboratory and field tests will be conducted on response of human beings to aircraft sounds and noise evaluation measures developed for regulatory purposes by statistical correlation of test results. Investigations will be made of the significance of various annoyance factors such as multiple tones, speech interference, amplitude and duration of tones, doppler shift, low frequency effects, transient and impulse effects, and the rate of onset and intensity on duration.

- Noise Certification Criteria - Objectives cover development of techniques for noise measurement and analysis for use in certification of all aircraft categories, refinements to FAR Part 36 for CTOL aircraft plus development of criteria for business jets and V/STOL aircraft. Included are considerations of multi-segment or complex flight paths plus data acquisition and analysis systems. Work will include measurement and analysis of the aircraft noise and determination of procedures and equipment which will promote development of measurement and analysis standards.

## SOURCE SONIC BOOM REDUCTION PROGRAMS

FAR Part 91.55 prohibits civil aircraft operations at true flight speeds greater than Mach 1 to prevent any sonic booms from reaching the ground. However, it is known that it is possible to fly up to speeds of Mach 1.4 without causing a sonic boom to reach the ground under certain conditions. Therefore, a demonstration was conducted during 1973 utilizing simulated operational techniques for long-range cross-country supersonic flights at Threshold Mach Number (Between 1.0 and 1.3) which theoretically did not generate sonic booms on the ground. This is Phase II of a four phase effort to develop a definition of the air and ground system requirements for successful supersonic Thresholds Mach Number operation. During 1974, based on Phase II results, conduct a SR-71 (YF-12) or F-111 transcontinental flight at Threshold Mach Number and not produce a sonic boom on the ground. Define and update the system requirements for boomless supersonic transcontinental flight during 1975 through 1977.

## OPERATIONAL SONIC BOOM REDUCTION PROGRAMS

This effort will provide, during 1973, two prototype digital lightweight inexpensive sonic boom recorders for future field use to provide an improved capability to record signature data during sonic boom test and monitoring programs. Based on prototype tests results during 1974, obtain production units for operational test program during 1975. The FAA will also provide atmospheric sounding aircraft during joint FAA, NASA, USAF, and NOAA operational programs to obtain real-time atmospheric data (winds, turbulence, and temperature) for use in long-range Threshold Mach Number operational feasibility studies during 1973 through 1975, i.e., boomless transcontinental supersonic flights. Program schedules are in Tables 3 and 4.

### Sonic Boom Atmospheric Effects

Studies are being conducted to identify measureable features of the atmosphere, both large scale and small scale, which cause statistical variations in sonic boom measurements. Attention will be given during 1974 through 1977 to establishment of a correlation between observed overpressure variability and local atmospheric conditions to provide a basis for prediction of that variability. The program will include theoretical and experimental work aimed at determining sonic

Table 3. SONIC BOOM--SOURCE SONIC BOOM REDUCTION, OPERATIONAL SONIC BOOM REDUCTION
PROGRAM SCHEDULE -- 1972-1977

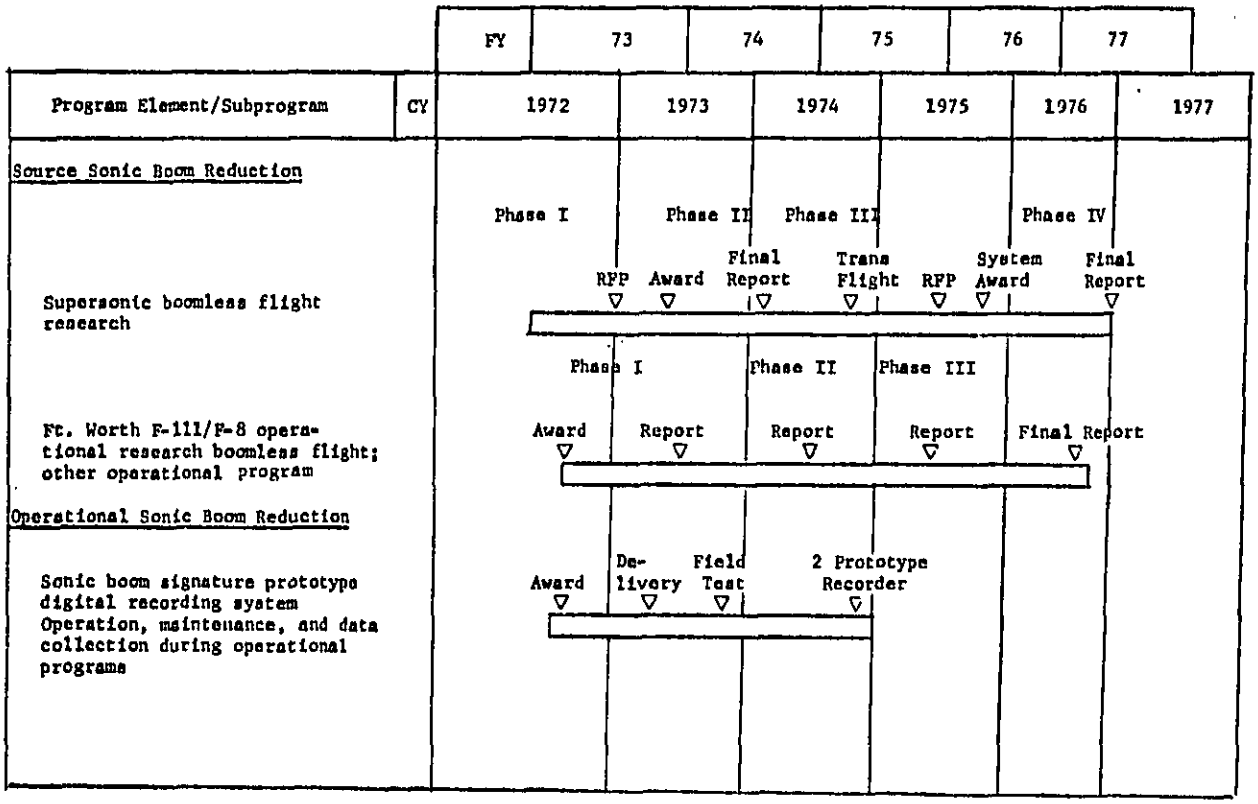
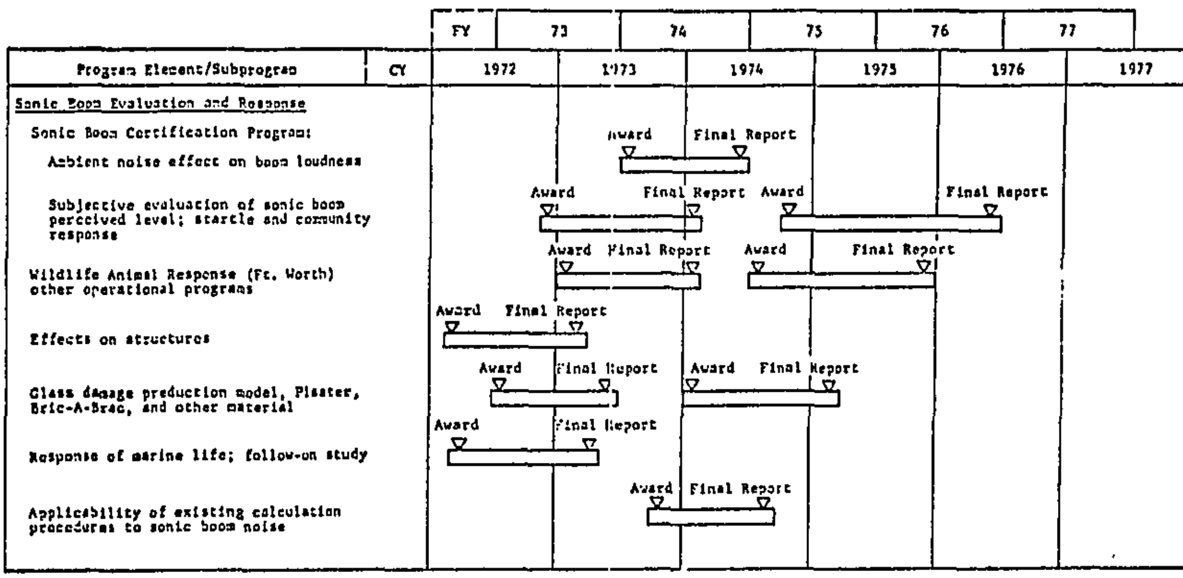


Table 4
SONIC BOOM -- SONIC BOOM EVALUATION AND RESPONSE
Program Schedule -- 1972-1977



boom pressure signatures associated with aircraft operations at or near Threshold Mach Number.

Sonic Boom Criteria

A sonic boom criteria research program is currently working to develop better technical and social criteria for sonic boom in accordance with Public Law 90-411 to form definitive guidelines upon which to base government and industry policies for both the design and regulation of supersonic and transonic commercial aircraft. The objective is to develop a consistent technical rationale based on the multiple technical and social criteria found from research that will assist in revising and updating administrative policies and decisions regarding certification limits and provide industry with a design window for supersonic operations.

Sonic Boom Effects on Structures

Structural damage due to moderate sonic booms has been primarily centered on damage to glass, plaster and bric-a-brac. Glass breakage is of primary importance. During 1974 and 1975 this work will develop sonic boom criteria in terms of equivalent response of windows to such natural forces as wind gusts, thunder and in terms of building codes applicable to window glass installation. This program will include flight programs, as well as simulator studies.

Test of Existing Noise Calculation Procedures Applicability to Sonic Boom

During 1973 and 1974, test the applicability of existing calculation procedures which scale annoyance and loudness reactions to steady state, time varying, and impulse noise. The object is to develop a simple method that would apply equally well to a variety of noises which would then be highly useful for multiple regulatory missions.

2. DOT/FAA JULY 25, 1974 TESTIMONY ON AIRCRAFT NOISE PROGRAMS BEFORE THE HOUSE SUBCOMMITTEE ON AERONAUTICS AND SPACE TECHNOLOGY

STATEMENT OF FREDERICK A. MEISTER, ACTING ASSOCIATE ADMINISTRATOR FOR POLICY DEVELOPMENT AND REVIEW, FEDERAL AVIATION ADMINISTRATION, DEPARTMENT OF TRANSPORTATION, BEFORE THE HOUSE COMMITTEE ON SCIENCE AND ASTRONAUTICS, SUBCOMMITTEE ON AERONAUTICS AND SPACE TECHNOLOGY, JULY 25, 1974, REGARDING AIRCRAFT NOISE ABATEMENT EFFORTS.

Thank you for the opportunity to appear before you today, Mr. Chairman. I am Frederick A. Meister, FAA Acting Associate Administrator for Policy Development and Review. Appearing with me today are Charles R. Foster, Director of the Department of Transportation Office of Noise Abatement, and Richard P. Skully, Director of the FAA Office of Environmental Quality.

In passing the Noise Control Act of 1972 the Congress declared it to be the policy of the United States "to promote an environment for all Americans free from noise that jeopardizes their health or welfare." The Congress further authorized and directed Federal agencies to carry out the programs within their control in such a manner as to further that declared policy of the United States "to the fullest extent consistent with their authority under Federal laws administered by them." Section 7(b) of the Noise Control Act directs the Administrator of the Federal Aviation Administration to prescribe such regulations as the FAA may find necessary to provide for the control and abatement of aircraft noise "in order to afford present and future relief and protection to the public health and welfare." (emphasis added).

By statute it is the FAA which has the responsibility, after consultation with the Secretary of Transportation and EPA, to prescribe standards for measuring aircraft noise and for prescribing regulations for the control and abatement of aircraft noise.

Mr. Chairman, the FAA is taking this Congressional mandate seriously and is in the process of implementing an aggressive program to control and abate aircraft noise. As evidence of our resolve to help achieve a better environment for all Americans, steps have been taken to double the size of the FAA Office of Environmental Quality. In addition, the Administrator has recently released a draft FAA Five Year Environmental Program which defines FAA environmental policy and delineates a five-year program designated to implement that policy.

Three parts of our overall noise abatement program relate to the design and operation of aircraft.

First is the imposition of maximum noise limits for all types of aircraft to insure that individual aircraft noise levels will not increase as newer, more powerful aircraft types are designed, and to insure that the best available noise reduction technology is included in the design of all new aircraft. In 1969, the FAA promulgated Federal Aviation Regulation Part 36 which put a lid on the escalation of aircraft noise levels of new subsonic turbojet transport aircraft. In 1973, Part 36 was amended to include newly produced aircraft, including those of older designs not previously covered. As you know, we have proposed a retrofit regulation to cover all large civil transport aircraft, requiring that older models not previously covered be modified to lower their noise levels to at least Part 36 limits. That proposal will be the subject of detailed discussion in a moment. We will soon promulgate a regulation limiting the noise levels of propeller-driven airplanes. The final Environmental Impact Statement for this regulatory action is in the process of being forwarded to the Council on Environmental Quality. We have solicited public reaction to our proposal to establish noise limits for short haul aircraft, and we are preparing a proposal for noise limits for civil supersonic aircraft. In this step-by-step manner, we are setting maximum noise limits for all categories of civil aircraft.

The second step in our program involves the use of approach and departure operational procedures which will reduce noise impact around our airports. The FAA views the control of aircraft noise through the use of operational procedures to be a promising and practical means for obtaining early noise relief. We have for many years been experimenting with takeoff and approach procedures, passive and dynamic preferential runway procedures, noise abatement routing, and terminal area handling of aircraft to achieve noise control.

Noise abatement takeoff operating procedures designed to provide maximum separation between aircraft and the communities overflown were developed jointly by FAA and ATA and are now in wide use.

Noise abatement approach operating procedures developed jointly by FAA and NASA include a two-segment glide slope which provides noise reduction by use of lower power settings and higher altitudes during the initial phase of an approach. A few airlines have been using two-segment approaches safely and efficiently for over one year during VFR weather conditions. The joint NASA/FAA research on two-segment approaches has reached the point where in-service operational implementation is progressing under instrument flight rule (IFR) conditions as well. In fact, a major airline has conducted in-service operations for NASA with a B-727 aircraft under VFR and IFR weather conditions. NASA is currently working with United Air Lines on two-segment approaches utilizing Douglas DC-8 aircraft. The FAA has recently issued an Advance Notice of Proposed Rule Making seeking advice and comments on this two-segment approach procedure. I will give you a rundown of the comments received to date later on.

Another means of maximizing aircraft to ground separation distances to provide community noise relief is to change allowable minimum altitudes. The utilization of higher minimum altitudes as a means of achieving noise reduction has been implemented and is providing significant noise relief. An Advisory Circular was published in August 1972 to deal directly with VFR flight near noise sensitive areas. This has resulted in pilots making VFR flights near recreational and park areas, churches, hospitals, schools, and similar areas at higher altitudes than previously flown and permitted by regulation in order to reduce aircraft noise impact on the ground.

The third step in our program, oriented more for the future, is the progressive reduction of present permissible noise levels. We are not content with present noise levels -- we are striving constantly to improve the state-of-the-art to lower these noise levels. Part 36 limits have now been in effect four and one-half years, and we are giving serious consideration to proposing a lowering of those limits to increase their stringency. We will of course continue to support effective research to develop and demonstrate just what future reductions may be feasible. And so, in brief, this covers that portion of our aircraft noise abatement program relating to the design and operation of aircraft.

I would like to turn now to a discussion of the retrofitting of the current commercial jet fleet to meet FAR 36 standards.

The technical development of means for quieting the present fleet has been underway for more than six years. This joint industry-government effort has resulted in the expenditure of well in excess of $100 million. The major steps taken in this program were as follows: first, an early NASA program provided proof of the technical concept of using sound-absorbing materials in nacelles, which I shall refer to as SAM, to control aircraft noise; second, an FAA nacelle jet suppression and flight test program was conducted; third, feasibility studies and flight demonstrations were made, followed by actual certification of the Boeing 727 and 737 and the Douglas DC-9; and, finally, a decision was made that we were ready to initiate formal regulatory action as required by law. On March 27, 1974, a Notice of Proposed Rule Making was published which, if adopted, will provide the means of assuring that all currently available acoustic technology is applied to in-service commercial aircraft. The rule would require that subsonic turbojet aircraft, having maximum weights of 75,000 pounds or more, to conform to Part 36 noise levels by not later than July 1, 1978. Behind this proposed rule is our conviction that utilizing the technology of sound absorbing material in engine nacelles is available now for providing additional, significant relief from aircraft noise.

Before we embarked upon this rulemaking procedure, Mr. Chairman, we had to assure ourselves that the SAM nacelle treatment would provide meaningful relief, that is, we were looking for a reduction in noise levels which would be sufficient to significantly reduce annoyance levels for persons living near airports. I would like to point to three important items of evidence which in my view go a long way toward dispelling any doubts that the SAM retrofit program would provide that meaningful relief.

First, it is a fact that today's airport neighbors notice and appreciate the reduced noise levels of the new wide bodied aircraft. These aircraft meet the same Part 36 noise levels as the older aircraft would meet with the SAM retrofit.

Second, a joint FAA-Boeing Company project, which culminated in May 1973 flyover demonstrations for members of Congress and the public at Dulles International Airport, demonstrated that takeoff noise reductions of 11 EPNdB and approach noise reductions of 15 EPNdB were achievable using nacelles quieted with sound absorbing material on a JT3D-powered Boeing 707 aircraft. There was general agreement among those witnessing the flyovers of a B-707 treated with sound absorbing material in a configuration capable of being certificated and a B-707 without such material, that the noise reduction was highly significant and clearly perceivable.

Third, a NASA-sponsored approach noise study conducted by Professor Paul N. Borsky of the Columbia University Noise Research Unit has concluded that significant reductions in annoyance resulted from the use of exposure to synthesized nacelle treatments equivalent to a JT8D-powered Boeing B-727 with the SAM treatment as compared to a standard B-727 aircraft. Professor Borsky, of Columbia's School of Public Health, College of Physicians and Surgeons, is one of the world's leading experts in assessing community response to aircraft noise. He used test subjects living in the vicinity of Kennedy International Airport. Significantly, there was a 50% reduction in the number of test subjects who had expressed highest annoyance to the standard Boeing 727 aircraft as compared to the acoustically treated B-727. This 50% reduction was achieved with a difference of 6 EPNdB between the two aircraft. We would anticipate a very meaningful response for the Boeing 707 mentioned a few moments ago relative to the Dulles flyover demonstrations.

I would also like to point out that in addition to the SAM retrofit it is possible to tailor approach and departure procedures to achieve even greater relief than can be achieved by SAM. The two-segment approach procedure and a power reduction on takeoff are examples of procedures we are investigating.

Next I would like to give you a rundown of the comments received on the fleet retrofit NPRM and the two-segment approach Advance NPRM. Nearly 600 comments were received on the retrofit NPRM, of which some 500 were from private citizens and citizen groups. The overwhelming majority of citizens and citizen groups were for immediate promulgation of the final rule. With regard to the industry, the Air Transport Association and commenting air carriers expressed total opposition to the proposed rule as written. Particular concern was expressed over the possibility of performance penalties and the amount of benefit considering the price tag. Regarding the manufacturers, the Aerospace Industries Association of America and the Boeing Company, while not opposing the rule as such, expressed little enthusiasm and support for an immediate go ahead, while the Douglas Aircraft Company was firm in its opposition to the rule. The international carrier community, represented by IATA, and several foreign governments expressed opposition for several reasons. A further discussion of the international reaction will be given a little later.

U.S. Airport Operators, whose jurisdictions are facing a total of some $4 billion in aircraft noise damage claims, strongly endorsed and urged immediate adoption of the rule. From this group we heard from some 25 city, county and state airport or transportation authorities plus the airport operator associations.

Private aircraft owners and operators did not, in general, support the rule, expressed doubt that SAM would produce appreciable relief and expressed concern over the program's expense.

We also heard from the Department of State, which expressed concern over unilateral U.S. action, and the Environmental Protection Agency, which concluded that the proposed regulation represents a substantial step in the right direction.

By the way, with regard to comments received on the two-segment approach Advance NPRM, the line-up was roughly the same. Private citizens, citizen groups, city governments and airport operators favored adoption of the two-segment approach. Those opposed included ALPA, AOPA, NBAA and the International interests. Those expressing strong reservations were ATA, Boeing and GAMA.

There are two basic problem areas associated with putting the retrofit rule into effect, namely, the international implications of the rule and the problem of how the retrofit program should be financed. I would now like to discuss these two problem areas.

The retrofit NPRM applies not only to U.S. registered aircraft, but also to foreign civil subsonic turbojet powered aircraft of 75,000 pounds or more that land or takeoff in the United States. The inclusion of foreign civil aircraft was considered essential because the airports having the most serious noise problems are generally those served most frequently by foreign operators. The bulk of comments received from the international community took strong exception to the proposed rule on the basis that it amounted to unilateral action in an area which ICAO should coordinate. The Department of State expressed concern over possible proliferation of conflicting standards affecting international civil aviation if the United States took unilateral action without either reaching agreement through ICAO, or at least by coordinating plans with other major civil aviation countries.

The international problems associated with the rule are difficult, but their impact has not been ignored. In fact, last month Administrator Butterfield met in Montreal with ICAO President Binaghi, the Secretary General of ICAO, a number of the members of the Secretariat, Council members and Air Navigation Commissioners. The Administrator made it clear to Dr. Binaghi that it was not the desire of FAA to act unilaterally and that we continued to support a multilateral approach. He did not, however, commit the United States to multilateral agreement with respect to the retrofit requirement because we are still considering foreign aircraft operating into the United States for inclusion in our aircraft noise reduction actions. We are hopeful that our actions in this area will stimulate multilateral action similar to the multilateral action which followed the issuance of Part 36.

The question of financing the retrofit program is central to a decision to put the proposed rule into effect. We know the program will be expensive, some $600 to $700 million to retrofit the existing fleet. I believe this issue, more than any other, accounts for the industry's lack of support.

In issuing the NPRM we solicited recommendations for financing the cost of the retrofit program. A number of suggestions were made, including use of the Airport and Airways Trust Fund, long term, low interest government loans to private operators, surcharges on passenger tickets and cargo way bills and increased air fares to allow the carriers to recover costs.

We have reviewed the various financing alternatives, and, while we have reached no conclusions on the shape of a final plan, some tentative decisions have been made. First we are opposed to direct Federal funding; we believe, instead, that the users of our air transportation system, the passengers and shippers, should, as a matter of principle, pay for the costs of retrofit. At present we believe that the best means to achieve this goal would be the establishment of a special fund, supported by nominal enplanement and cargo way bill surcharges proportionate to the aircraft modification costs for each segment of the air carrier industry. Such a plan would cover only domestic operations; the international operations of U.S. carriers would have to be handled separately.

Mr. Chairman, NASA has played a vital role with us in the abatement of aircraft noise. Through the Joint DOT/NASA Office of Noise Abatement we have an effective vehicle for assuring an integrated research and technology program. We have both supported and worked with EPA in its role in coordinating noise research as specified in the Noise Control Act. The three agencies have worked closely together at the staff and Administrator levels to marshall the Federal aircraft noise abatement effort. For example, this Monday I represented Administrator Butterfield, who was appearing before the Senate Appropriations Subcommittee, in a meeting with Undersecretary Barnum, Administrator Fletcher and Assistant Administrator Strelow representing Administrator Train, to review our efforts, particularly with respect to the refan program and FAA's regulatory actions. The DOT/FAA position expressed at that meeting was that there is more than an adequate technical and economic basis for a decision at this time to proceed with regulatory action. Assuming that all objectives of the refan program would be achieved, the cost-effectiveness picture, in our view, will be unchanged.

In considering the relative merits of SAM versus refan in our rulemaking efforts, we have considered the following factors as being of primary significance.

First, the SAM modification offers the earliest meaningful relief. With reference to time, we believe that completion of a refan retrofit program would be at least three years behind completion of the SAM retrofit program.

Second, the refan program does not apply to the noisiest aircraft in the fleet, the JT3D-powered Boeing 707 and Douglas DC-8.

Third, refan represents at best a promise of future relief since the present program is limited to flight testing of the Douglas DC-9 and ground testing of the Boeing 727. No work is presently being done with the JT8D-powered Boeing 737. Work on the B-737 terminated with the Phase I design effort. Additional work and funding would be required for the refanned B-737 to be a candidate for any future rulemaking.

Fourth, the refan program is considerably more costly than the SAM retrofit program. For example, the SAM retrofit of the entire fleet is estimated to cost approximately $600 to $700 million for investment with total program cost over the remaining life of the modified aircraft approaching $1 billion. In comparison, the combination program of using refan for JT8D-powered aircraft and the use of SAM for

JT3D-powered aircraft would cost approximately $2.8 billion for investment with total program cost of $5 billion. In terms of one aircraft, the Boeing 727, the cost of refanning would be roughly eight to ten times the cost of using the SAM retrofit. The B-727 with the SAM modification provides the same noise reduction on approach as the refanned B-727.

The relative cost-effectiveness of the two aircraft modification programs has, as you know, been a part of our 23 U.S. airport analysis. This effort, begun some time ago, provides the DOT/FAA with information needed to evaluate a wide range of aircraft and airport noise abatement alternatives. We have completed the 23-airport study, and the cost-effectiveness results have not changed substantially from those reported to you last December on the basis of the first six airports.

These results are presented in terms of (1) airport neighbors subjected to two levels of noise exposure, (2) land areas around the 23 airports impacted by airport noise, and (3) effective changes in the noise exposure index. All of these indicators provide the same conclusions: first, the SAM program is significantly more cost-effective than the potential SAM/Refan program; and, second, effectiveness will be obtained earlier with the SAM program.

For example, with respect to the people removed from the noise exposure areas of NEF 30 and NEF 40, and looking forward to 1987, the end period of the study, we find that for an expenditure of $1 billion for SAM, we remove 125,000 of the 300,000 people that would be residing in the NEF 40 area. For an expenditure of $5 billion for refanning the JT8D and SAMming the JT3D, 220,000 people would be removed. An additional expenditure of $4 billion dollars for the refan/SAM program would remove 95,000 people from the NEF 40 area. In the NEF 30 contour, the $1 billion SAM program will remove 600,000 of the 2,700,000 people, whereas the $5 billion refan/SAM program will remove 1,900,000 people.

In brief, the results of this study are consistent with our earlier conclusion that the action proposed in our Notice of Proposed Rule Making on March 27, 1974, will provide the earliest meaningful relief to airport neighbors through a program which is technologically available and economically reasonable. I am submitting a detailed Information Brief describing the results of this study for the record, Mr. Chairman. And, Mr. Foster is prepared to provide a brief summary of this study if you desire.

With regard to the goal of 10 EPNdB reduction per decade identified in the CARD study, we feel that for this first decade we will be able to achieve the goal, generally speaking. Looking ahead to the next and succeeding decades, however, we are reaching the point of diminishing returns with foreseeable technology. We will continue to assess developing noise reduction technology with the idea of keeping our regulatory program apace.

In concluding, I would like to make the following remarks.

Noise is a major problem impeding further growth of the air transportation industry. Aircraft noise has brought increased pressure to limit flight operations and restrict flight paths as well as to impose night curfews. Airport operators are faced with aircraft noise related suits involving potential multimillion dollar judgments.

Congress recognized this serious impediment to air transportation industry growth and the serious implications regarding the health and welfare of the Nation's population when it passed the Noise Control Act of 1972.

We have developed a retrofit program which offers great promise of the earliest relief which Congress mandated be afforded. There has been some concern expressed by Congressional Committees about our moving ahead with the retrofit rule prior to obtaining the final results of the refan test to be completed next year. We of course fully appreciate these views, and before publishing a final rule we will present to those committees our reasons for moving forward. We feel confident that we will have their support for any action that we take to advance our noise abatement program in a cost-effective way. Our present posture is to continue with the regulatory process to work toward a resolution of the difficult problems associated with the proposed rule, such as the financing and international aspects. Only when we are satisfied that we have solved these problems will we be in a position to make a final decision on the rule.

Thank you for your attention to this rather lengthy testimony, Mr. Chairman. I and my associates are available to answer any questions you may have.

# 3. DOT/ONA AIRCRAFT NOISE PROGRAMS

The DOT has university grants for fundamental studies in noise suppression. These studies are briefly described with funding indicated.

1. University of Southern California Contract
DOT-OS-000-2
Title: Modeling Noise

An extremely elaborate and quiet facility has been constructed to isolate the jet noise sources. The elimination of upstream and outside noise contamination will allow for accurate measure of the noise from the jet alone by use of a sophisticated noise collection reflector-microphone combination connected to a traversing device. The sources or distribution contributing to the overall jet noise is thus determined. The large scale structure of jet turbulence is being investigated as a possible major contributor to jet noise.

Funding: (Thousands of Dollars)

| FY 73 | FY 74 | FY 75 | FY 76 |
|---|---|---|---|
| 75 | 75 | 50 | 50 |

2. University of Syracuse New York Contract
DOT-OS-20094
Title: Noise Reduction from Supersonic Jet Flow with Co-Axial Jets

The objective of this program is to study the mechanism of jet noise reduction in co-axial jets when the individual jets are operating under unique conditions that lead to a strong shock formation and hence to subsonic flow conditions a small distance outside the nozzle exit. Under these conditions the jet noise is significantly reduced below that condition of operation that does not form into a strong coalesced shock. The specific objectives will be to (1) verify the existence of the minimum noise condition for larger jets and to study the scaling laws, (2) establish the effects of temperature on noise reduction for co-axial jets, and (3) study those phenomena with 2 and 3 co-axial elements.

Funding: (Thousands of Dollars)

| FY 73 | FY 74 | FY 76 |
|---|---|---|
| 75 | 75 | 75 |

3. California Institute of Technology Contract
DOT-OS-20197
Title: Jet Combustion Noise

The purpose of this study is tò investigate experimentally and theoretically the noise generated by combustion inhomogeneities as they pass through nozzles or turbine buckets. Theoretically, it has been shown that a pressure disturbance gets amplified on passing through a nozzle, likewise a temperature oscillation in the chamber leads to noise generation and it too gets amplified on passing through a nozzle or turbine. These factors will be studied.

Funding: (Thousands of Dollars)

| FY 73 | FY 74 | FY 75 |
|---|---|---|
| 147 | 50 | 50 |

4. Massachusetts Institute of Technology Contract
DOT-OS-30011
Title: Acoustic Material Research

The purpose of this study is to determine the characteristics of acoustic liners in ducts that have an added mechanical inertance that acts to lower the natural frequencies of Helmholtz resonators with a given backing depth thus allowing for the absorption of low frequency acoustic energy in the duct. This development is important for application to problems involving the reduction of low frequency noise from fans and combustion.

Funding: (Thousands of Dollars)

| FY 73 | FY 74 | FY 75 |
|---|---|---|
| 33 | 35 | 35 |

5. The University of Texas at Austin Contract
DOT-OS-4117
Title: Effects of Non-Linearity on Jet Noise Propagation

The purpose of this contract is to study the non-linearity effects in the propagation of intense noise. Non-linearity causes an increased attenuation of the noise, a spectral redistribution of the energy, and decreased cross correlation between the source and receiver waveforms. The question is posed as to whether these effects are important for jet noise propagation. Specific work will include conversion of the already existing plane wave analysis into a spherical spreading one; use of the modified analysis to predict the propagation distortion for noise from an actual intense jet noise source.

Funding: (Thousands of Dollars)

| FY 74 | FY 75 |
| --- | --- |
| 18 | 20 |

6. North Carolina State University Contract
DOT-OS-40056
Title: On the Origin of Combustion Generated Noise

The objective of the program is to present a theory capable of explaining the observed characteristics of combustion noise whose validity does not hinge on the assumptions employed and on the particular situation considered. Starting from the exact multi-fluid equations of a reacting gas mixture, the mechanism of combustion generated noise for open and confined flames is identified. The derivation parallels the procedure employed by Lighthill and Curle and does not depend on simplifying assumptions. It is shown that the pressure fluctuation is a sum of two terms. The first is proportional to the overall density fluctuation and the second is a linear combination of the density fluctuations of the various species. At present, a reliable estimate of combustion noise cannot be made; a complete understanding of the problem first requires the identification of the sources of the noise due to combustion and scaling laws and the effects of confinement on the propagation.

Funding: (Thousands of Dollars)

| FY 74 | FY 75 | FY 76 |
| --- | --- | --- |
| 25 | 30 | 25 |

7. General Electric Company Contract
DOT-OS-30034
Title: High Velocity Jet Noise Source Location and Reduction Program

The overall objective is to investigate the promising suppression concepts that will result in the greatest noise suppression with the least degradation of performance over flight speed ranges of interest for the potential types of engine cycles. The theoretical understanding of these more complex nozzle concepts presents a great challenge and is a fundamental part of the objective of this program.

The detailed investigation of the basic phenomena which affect the source locations, source strength, and noise reduction potential of high velocity jet noise is directed towards the following program objectives:

- Investigation of the aerodynamic and acoustic mechanisms of various jet noise suppressors for subsonic and supersonic jets, including scaling effects.

- Analytical and experimental studies of the acoustic source distribution in such suppressors, including identification of source location, nature and strength, and noise reduction potential.

- Investigation of in-flight effects on the aerodynamic and acoustic performance of these suppressors.

The results of these investigations will lead to the preparation of a prediction guide report for predicting the overall characteristics of suppressor concepts, i.e., for models, full-scale static, and in-flight conditions, as well as a quantitative and qualitative analytical prediction of the phenomena involved.

The work effort in this program is organized under the following major categories:

Task 1 - Activation of Facilities and Validation of Source Techniques

Task 2 - Theoretical Developments and Basic Experiments

Task 3 - Experimental Investigation of Suppression Principles

Task 4 - Development and Evaluation of Techniques for "In-Flight" Investigation

Task 5 - Investigation of "In-Flight" Aero-Acoustic Effects on Suppressed Exhausts

Task 6 - Preparation of Noise Abatement Nozzle Prediction Guide Report.

See Figures 14 and 15 for funding and schedule.

HIGH VELOCITY JET NOISE SOURCE LOCATION AND REDUCTION

• OVERALL PROGRAM PLAN

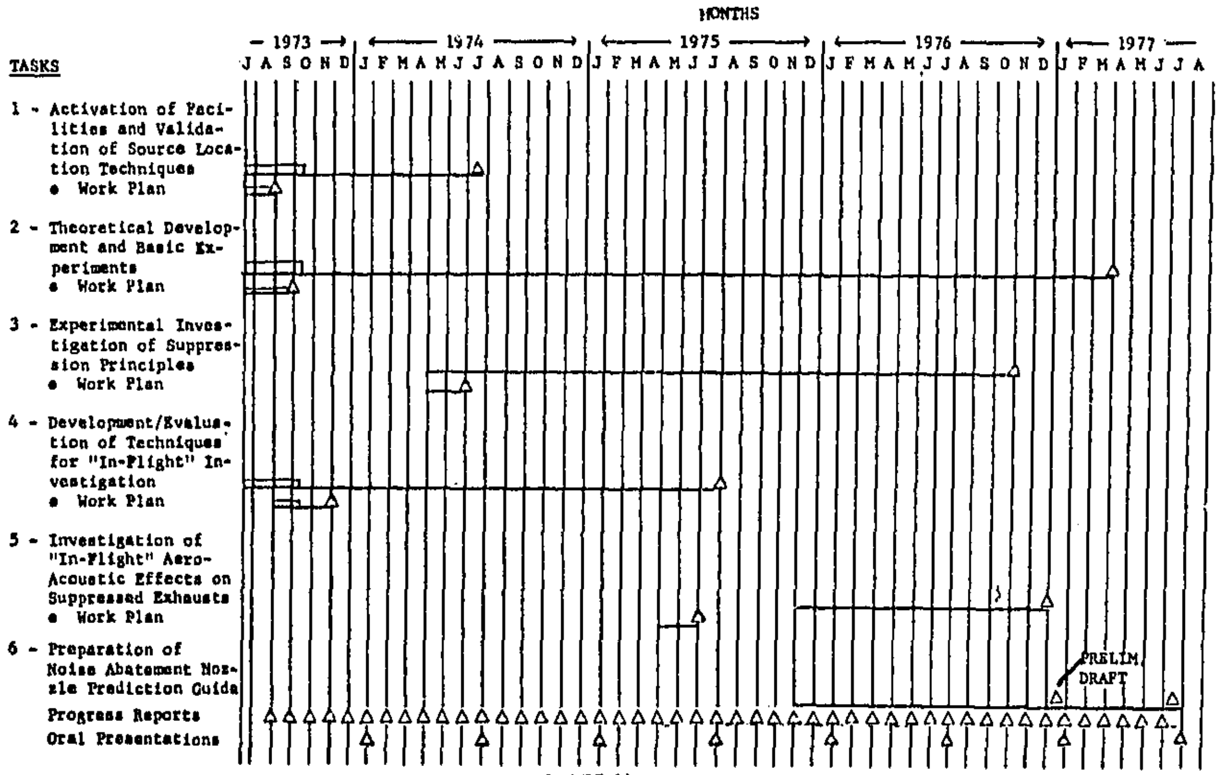



FIGURE 14

ESTIMATED TOTAL PROGRAM EXPENDITURE SCHEDULE

- ALL TASKS (1 - 6)
- CUMULATIVE DOLLARS
- COST INCLUDES IR & D/GA, ETC.

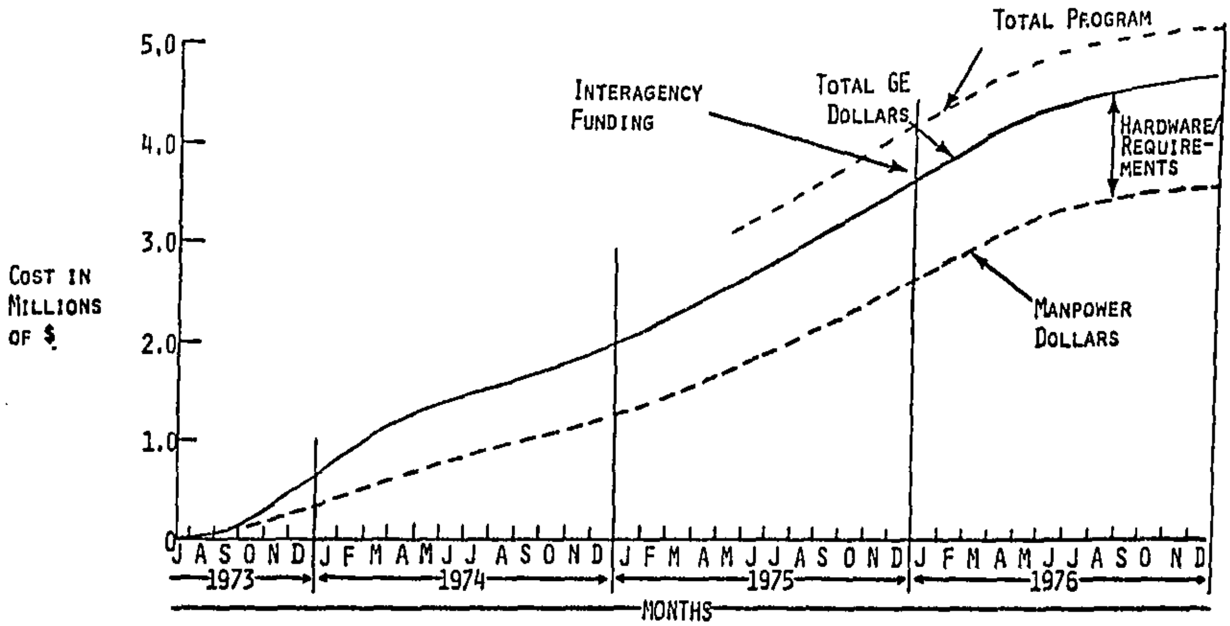



FIGURE 15

8. Virginia Polytechnic Institute Contract
DOT-OS-50047
Title: Suppression of Multiple Pure Tones

This is a program to evaluate an advanced acoustic concept for the suppression of multiple pure tones from supersonic jet engine fans. The concept is based on the dispersion of waves by acoustically treating the duct walls to inhibit the exchange of energy among the harmonics and to counteract the steepening of the waves due to non-linearity. A detailed parametric study will be performed to determine the optimum linear characteristics.

# III. DOD AIRCRAFT NOISE PROGRAMS

## DOD JET EXHAUST NOISE PROGRAMS

| | |
|---|---|
| Department of Defense | Contract F33615-71-C-1661 |
| Air Force | Project 3066, Task 14, |
| SUPERSONIC JET EXHAUST NOISE-PRESSURE MODEL | Work Unit 02 |
| | 7/72 to 6/73 |
| Bolt Beranek & Newman Inc. | Funds $164,000 |

The overall objective of this program is to develop the technology base necessary to significantly reduce aircraft propulsion system noise with minimum associated performance and weight penalties. The specific technical objectives of this effort are (a) to assess the advantages and disadvantages of various competing mathematical models used to explain the supersonic jet noise generation process with particular emphasis on the Ribner/Meecham fluctuating pressure model; (b) to determine the relative importance of the various jet noise generation mechanisms for the range of operating conditions typical of the B-1 system; (c) to experimentally demonstrate the advanced instrumentation techniques required to verify the accuracy of the Ribner/Meecham fluctuating pressure model.

This program involves a comprehensive investigation of all relevant mechanisms of noise generation and emphasized the interrelationships between acoustics and engine cycles and between acoustics and exhaust jet aerodynamics. The experimental investigation features the use of unique transducers to relate the exhaust fluctuating aerodynamic pressures to the radiated noise. A large-scale, high temperature (3000° F) free jet facility will be used to conduct aero/acoustic experiments. This facility makes it possible to compile a comprehensive and exhaustive catalog showing the inter-relationship between nozzle mean and fluctuating aerodynamic and acoustic properties of supersonic jet exhausts.

| | |
|---|---|
| SUPERSONIC JET NOISE | Project 3066, Task 14, |
| INVESTIGATION - VELOCITY MODEL | Work Unit 03 |
| General Electric | Funds $164,000 |

The overall objective of this program is to develop the technology to significantly reduce supersonic aircraft propulsion system noise with minimum associated performance and weight penalties. Emphasis is placed on afterburning and non-afterburning supersonic jet exhaust systems with operating conditions typical of supersonic transport (SST) and long range strategic (B-1) aircraft propulsion systems. The specific technical objective of this research program is to develop a comprehensive mathematical model capable of providing aero/acoustic design data to be used in the development of future supersonic jet exhaust noise suppressors.

SUPERSONIC JET NOISE
INVESTIGATION - DENSITY MODEL
Lockheed, Georgia

Project 3066, Task 14
Work Unit 04
Funds $199,000

The overall objective of this program is to develop the technology to significantly reduce supersonic aircraft propulsion system noise with minimum associated performance and weight penalties. The specific technical objectives of this program are to numerically solve the applicable turbulence and acoustic theories which describe jet noise generation and radiation for the subsonic and fully-expanded supersonic flow regime and to measure the necessary turbulence and acoustic parameters in order to verify the numerical predictions or to supply data to the turbulence/noise theories as necessary.

GENERAL ELECTRIC/LOCKHEED
Contract DOT-AS-20099 / AF Contracts F33615-73-C-203 1/2
Title: Supersonic Jet Noise (Analytical Model)

The overall objective of this program is to develop a fundamental understanding of the mechanisms of jet noise generation. This phase of the work is limited to sound single nozzles in contrast to the complex nozzle configurations of suppressor types. The specific technical objectives are to numerically solve the applicable turbulence and acoustic theories which describe jet noise generation and radiation for the subsonic and fully-expanded supersonic flow regime and to measure the necessary turbulence and acoustic parameters in order to verify the numerical prediction or to supply data to the turbulence/noise theories, as necessary. The program comprised of an experimental and theoretical effort to predict noise from subsonic and supersonic jets with particular emphasis on the turbulent mixing region. Development of promising optical techniques to measure necessary turbulence spectra intensity, and scales is also included. The objectives are intended to lead to a unified theory of jet noise. The work will be performed in four phases:

Phase I - Through review of competing mathematical models.

Phase II - Detailed investigation - relate flow field to acoustic.

Phase III - Investigate effects of upstream perturbations.

Phase IV - Correlation of all results into unified theory.

Contracts are with Lockheed Georgia and General Electric in Cincinnati. This work was started in 1971 and will be completed in March 1975. Total funding by DOT is 1.3 million in the following schedule of expenditure.

| | FY-73 | FY-74 | FY-75 |
|---|---|---|---|
| DOT | $ 425,000 | $ 625,000 | $ 250,000 |
| DOD/Air Force | $ 125,000 | $ 205,000 | $ 60,000 |

JET NOISE REDUCTION FOR MILITARY RECONNAISSANCE/SURVEILLANCE AIRCRAFT
Bell Aerospace Corporation

Project 3066, Task 14, Work Unit 005

The objective of this program is to evaluate and experimentally demonstrate a unique quiet propulsion concept for advanced quiet aircraft systems. The performance and acoustic characteristics of the total propulsion system will be assessed under this effort.

## DOD AIRFLOW SURFACE INTERACTION PROGRAMS

Department of Defense
Air Force
NOISE CONTROL BY LIQUID VAPORIZATION
California Institute of Technology
School of Engineering

DF032080
Contract AF-AFOSR-2068-71
7/73 to 6/74
Funds $31,220

Strategic bombardment, tactical operations, and logistic support are AF functions which require the use of high performance flight vehicles. The operation of such vehicles produces intense noise from sources associated with propulsion systems. Because of a lack of a basic understanding of the physical behavior of sound and the interaction of sound with the fluid medium it is traveling through, rational noise control and avoidance is difficult. This noise can cause degradation in human performance, reduced reliability of structural and equipment subsystems and increased maintenance. The proposed research will investigate the behavior of high intensity sound as it interacts with liquid droplets. Specifically, an analysis will be made of nonlinear acoustic disturbances in a heterogeneous gas-liquid mixture where transition between the two phases constitutes an important element of the problem. Particular stress will be given to the wave steepening beyond the plane of generation, to the attenuation of duct modes and to the effect of phase change attenuation on acoustic fields resulting from gas-dynamic interaction with sharp edges.

AERODYNAMICALLY GENERATED SOUND — Project 9781, Task 02
University of Toronto — Work Unit 001

This research is directed toward developing a comprehensive physical model of jet noise which covers generation, convection, refraction, and spectrum properties. Research is being conducted in the areas of aerodynamically generated sound and subsonic aerodynamics. In the area of sound the following projects are being conducted:

(a) Correlation of sound with hot wire measurements in a jet. A direct correlation between the turbulence (the cause) and the sound (the effect) is being attempted.

(b) Shielding flap scheme of jet noise suppression. The effectiveness of a wing as a shield for jet noise is being examined experimentally.

(c) Wind noise in vehicles. An experiment is being conducted to determine the relation between the jet flow over a cavity and the noise generated by the flow.

(d) Model of Mach wave noise emanating from the lip of a supersonic jet. A mathematical analysis is being made to delineate the mechanisms of noise generation of a rocket nozzle.

(e) Extended near-field concept for sonic boom alleviation. The possibility of delaying the transition of the near field signature to the far field pressure signature is being examined. In the area of subsonic aerodynamics the lift distribution and moment of wing cutting obliquely through a simulated trailing-vortex of another airplane is being determined.

Department of Defense
Air Force
DYNAMICS OF VORTICES AND SHOCK-WAVES IN NONUNIFORM MEDIA
California Institute of Technology
School of Engineering

DF032500
Contract AF-AFOSR-2092-71
Project 9781, Task 02
7/73 to 6/74
Funds $40,900

Aircraft operations in all flight regimes involve vortices in flow field and wakes. The behavior of vortices has profound influence on aerodynamic forces and the trailing vortices are the crucial phenomenon in the notorious aircraft wake turbulence hazard. This effort has made significant progress in theoretical understanding of vortex motion. The current effort will extend this work to consider the influence of various nonlinearities in the equations of motion. Also, water tunnel experiments will be performed in which the detailed structure of trailing vortices behind lifting surfaces will be studied by means of a laser doppler velocimeter. The shockwave aspects of the past research will also be continued with an experimental investigation of focussed shockwave propagation through the focal point. The shockwave effort is relevant to improved understanding of super booms. It is hoped that the experiments will suggest possible simplifications to the analytical models for focussed shockwaves.

Department of Defense
Air Force
THEORETICAL AND EXPERIMENTAL INVESTIGATIONS IN HIGH SPEED AERODYNAMICS
Cornell Univeristy
School of Engineering

DF001060
Contract F44620-69-C-0063
Code AA
7/73 to 6/74
Funds $165,925

Weapons delivery superiority requires continual refinements in aircraft and missiles. More complete knowledge of aerodynamics is critical to such refinements. This is a broad program of research in aerodynamics, with relevance to low speed performance of tactical aircraft, aerodynamic noise and sonic boom minimization, aerodynamic optimization of aircraft, and high altitude hypersonic flight. Problems are being studied in the areas of boundary layer flows, including unsteady boundary layer separation and flows with variable viscosity - gas dynamics, including fluid dynamic processes in gas laser, blast wave experiments, and rarefied hypersonic leading edge flow - aerodynamic noise, including non-uniform cascade theory, non-uniform flow over blunt bodies and propagation of non-linear waves - supersonic drag with emphasis on analytical techniques for positioning of nacelles and stores for an overall optimum area-rule shaping.

Department of Defense
Navy
TIP VORTEX EFFECTS IN ROTARY-WING AERODYNAMICS
Sage Action Incorporated

DN223260
Contract N00014-72-C-0200
7/72 to 6/73
Funds $48,116

To significantly reduce undesirable rotor blade noise signatures, and alleviate the blade-tip vortex interaction problem. The role of the tip vortex in rotary-wing aerodynamics will be investigated and possible means of control of the tip vortex will be examined. If this exploratory effort is successful, an extremely useful technique will be available for solution of severe rotary-wing aerodynamic, structural, and noise problems.

The total flowfield including the tip vortex of a model rotor blade will be investigated by means of an advanced helium bubble flow visualization technique. Techniques to reduce the blade vortex interference effects will be evaluated. The new idea in this research of examining the interference of a tip vortex from a preceeding blade by means of a second blade positioned upstream in a wind tunnel should reveal for the first time the violent changes in angle of attack and stall in the interference region.

Department of Defense
Army
GLARE AND NOISE REDUCTION OF HELICOPTER ROTOR BLADES
McCoy Electronic Corporation

DAOK3720
Contract DAAK02-72-C-0623
7/72 to 6/73
Funds $25,000

To develop various materials and compositions capable of reducing the glint, glare, and noise from helicopter rotor blades without impairing lift or increasing weight or drag.

Task envisions the making of a working model rotor blade upon which an acoustic surface wave will be generated by means of metal electrode transducer excited by the acoustic bulk-waves from piezoelectric vibrators (i.e. quartz crystals). The generated acoustic surface wave will then be propagated along a thin piezoelectric sheet which when lead-phased should regulate the movement of the bound-vortex layer of air increasing the rotor blades lift while simultaneously reducing the glint and glare. In addition, possible method of noise reduction via bow wave extension and creation of a potential gradient across the airfoil will be included in the model, but not be capable of demonstration.

Department of Defense
Army
UNSTEADY AERODYNAMICS OF BLADE-VORTEX INTERACTION 6495-E
Massachusetts Institute of Technology
School of Engineering

DAOB9173
Contract DA-31-124-ARC(D)-471 Code RB
7/73 to 6/74
Funds Unknown

To study the unsteady aerodynamic mechanisms responsible for helicopter noise. Improved understanding of the aerodynamic noise generation of a helicopter could lead to new methods of improving the aerodynamic performance and decreasing the amount of noise generated by helicopters. Both are of vital importance in improving the usefulness of the helicopter for Army missions.

Approach - work will begin with simpler two-dimensional models and will be extended to an exact treatment of the three-dimensional problem in both steady and unsteady flow. The treatment will be concerned primarily with inviscid flow; however, an investigation of the effects of viscosity will be included in determining the vortex curve boundaries. The approach, while numerical in character, may be described as exact in the sense that true boundary locations will be accounted for and the exact solution will be obtained as the computational network is refined.

Department of Defense
Army
INVESTIGATION OF NOISE GENERATION ON A HOVERING ROTOR 8704-RN-8704
Boeing Company

DAOC9091
Contract DAHC04-69-0087
7/72 to 6/73
Funds Unknown

To define the noise field generated by a rotor. Investigation of noise generation of a helicopter rotor is important for the Army's effort to make its helicopters less noisy for more effective field operations. This research is important to the Army in that it represents a long range effort to reduce Army aircraft detection time.

Noise level tests and vortex visualization tests will be made with a set of rotor blades mounted on a whirl tower. Smoke generation in the blade and high speed motion picture photography will be employed for vortex visualization tests. Near and far field acoustical data will be collected. Following data reduction, an analysis will be made of the relative levels and frequency distributions of rotational noise, vortex noise and of any blade slap noise that might occur during tests. The relative positions of smoke will be evaluated at the points where the noise is generated as determined from acoustical measurements.

Department of Defense
Air Force
INSTABILITY AND NOISE GENERATION IN
AIR-BREATHING PROPULSION SYSTEMS
Ultrasystems Incorporated

DF032400
Contract F44620-71-C-0104
7/73 to 6/74
Funds $37,661

Effective weapon delivery, defense, reconnaissance, and transport vehicles require propulsion systems with stable operating characteristics and minimal noise levels. Results obtained from this research will aid in understanding and controlling combustion instability in air-breathing main and auxilliary combustors, in providing guidelines and techniques for modifying the combustion processes for minimum noise levels, and in establishing criteria for engine design, development, and control. This research encompasses studies of fundamental physical mechanisms driving combustion instability, of mechanisms by which combustion affects the general sound field surrounding an engine, and of coupling between these mechanisms and combustor operating conditions. Included will be studies of the detailed phenomenological processes which determine the nature of the interactions of initially small disturbances and discrete, discernible combustion zones existing in the combustor. Existing contractor chemical and fluid mechanical computer programs will be used in conjunction with data and qualitative observations obtained from laboratory experiments. Particular emphasis will be placed on fundamental fluid mechanics and combustion of vortex stabilized combustors, e.g., V-gutter and dump combustors. A computer model of these processes will be formulated, validated by experiment, and used as the basis for developing a combustor stability prediction program based on combustor geometry and operating conditions. Dominant modes of instability will be predicted and recommendations made concerning effectiveness of stabilizing measures. Mechanisms by which combustion affects the general sound field surrounding an engine will also be investigated and guidelines provided for modifying the combustion processes to obtain minimum noise levels.

Department of Defense
Air Force
COMBUSTION GENERATED IN
TURBO-PROPULSION SYSTEMS
Georgia Institute of Technology
School of Aerospace Engineering

DF034900
Contract AF-AFOSR-2365-72
7/72 to 6/73
Funds $24,200

For specific missions involving weapon delivery and defense, transport, reconnaissance and rescue, advanced efficient air-breathing and hybrid engines are required with minimal noise emission levels to deter detection and avoid aircraft component damage and reduced efficiency of and hazard to ground and flight personnel. Also to maintain environmental pollution within tolerable limits it is mandatory that aircraft noise emissions be minimized. This research on fundamental physical mechanisms and processes involved in combustion noise production and transmission in primary and augmentor air-breathing combustors will aid in providing guidelines and techniques for modifying the combustion process for minimal noise output and development of effective combustor noise suppressing devices for these advanced engines. This program encompasses theoretical and experimental studies directed toward isolating the origins and transmission of combustion noise in turbo-propulsion combustors. Included will be studies of various aspects of free flame, flameholder flame, and primary combustor can combustion noise. Sound power output, spectral content and directionality characteristics will be determined. Scaling rules will be generated and compared with various theoretical approaches to the problem. Diagnostic emission measurements will be made to isolate the origin of combustion noise. Theoretical acoustics will be used to solve the problems of sound radiation from afterburner and primary combustors to the surrounding atmosphere.

NOISE GENERATION BY A TRANSONIC COMPRESSOR ROW
Cornell Aeronautical Laboratory Inc.

Project 9781, Task 02, Work Unit 003

The Air Force is presently and will continue to be in the foreseeable future a large user of high subsonic jet aircraft. The principal means of propulsion of such aircraft is the high bypass-ratio turbofan engine. An undesirable byproduct of these engines is the generation of noise which causes such adverse effects as degradation in human performance, reduced reliability of structural and equipment subsystems, and increased maintenance cost. The design of vehicle parts and soundproofing which alleviate these effects requires accurate definition of the intensity and occurrence of the noise. In order to partially fulfill this requirement a theoretical study of the problem of fan-noise generation in a high bypass-ratio turbofan engine is being made. The main emphasis in this study is the noise aspect of the three-dimensional, transonic flow through a single blade row. A linear acoustic theory for the case of non-lifting blades is being applied to the problem of noise generation. An effort is being made to extend the theory to lifting blades and to examine the effect of more realistic duct geometries.

HIGH INTENSITY SOUND
University of Texas

Project 9781, Task 02,
Work Unit 002

This research is concerned with investigating the behavior of high-intensity sound and applying the understanding gained to problems of interest to technology such as sonic boom, propagation of intense noise from jet engine compressors, underwater propagation, etc. This is a theoretical and experimental effort on high-intensity sound and its interaction with a real media. The purpose of the work is to study the phenomena that distinguish nonlinear acoustics from linear acoustics and to apply the knowledge gained to physical problems. Specific topics being studied are:

(a) Stability of the acoustic boundary layer. The object is to predict the threshold at which a transition from laminar to turbulent flow takes place. The frequency dependence of this threshold is of particular interest.

(b) Standing waves of finite amplitude. Chester's theoretical predictions are being checked by experiments.

(c) Quasi-plane-wave mode for finite-amplitude waves in a tube. Experimental tests are being conducted to check past theoretical solutions.

(d) Finite-amplitude waves in relaxing media.

(e) Electrical transmission-line analogs of acoustical propagation problems, such as progressive waves in relaxing media, random in homogeneous, turbulent media, or nonlinear media.

SMALL TURBINE ENGINE NOISE REDUCTION
Garrett Corporation

Project 3066, Task 14,
Work Unit 001

The purpose of this program is to develop the technology base necessary to effectively reduce the noise signature of existing small turboprop and turbofan engines. Although the program is primarily aimed at light aircraft propulsion, the technology generated is directly applicable to auxilliary power unit silencing. The specific technical objectives of the effort are to accurately predict the radiated acoustic signature and aural detectability of existing turboprop and turbofan propulsion systems in the 80 to 1000 shaft horsepower class for turboprops and the 400 to 5000 pound thrust class for turbofans, to develop effective methods to minimize propulsion system aural detectability, and to determine the engine performance and weight penalties associated with the various suppression methods.

ROTATING MACHINERY NOISE GENERATION | Project 3066, Task 03, Work Unit 34

The overall objective of this program is to develop an improved understanding of noise in axial flow compressors so that design rules may be formulated for reduced noise. The specific technical objectives of the effort are:

(a) To develop a direct lifting surface theory for compressible, linearized flow through a rotating blade row.

(b) To develop approximate models for noise generation by rotor-stator interaction.

(c) To correlate results of lifting surface theory with experiment.

(d) To analyze dominant nonlinear effects in the inviscid, three-dimensional flow through a rotating blade row.

| | |
|---|---|
| Department of Defense | DN123475 |
| Navy | Contract N00014-67-0151-0029 |
| Office of Naval Research 473 | Subgroup |
| AIRCRAFT COMBUSTION GENERATED NOISE | 7/73 to Cont |
| Princeton University | Funds $64,022 |
| Aerospace, Mech. Sci. Dept. | |

Within the Navy aircraft, missile and space power and propulsion program, this effort offers the possibility of alleviating jet engine noise by research on nonsteady combustion and gas dynamics phenomena. This research makes use of past efforts on nonsteady combustion coupled with nonsteady gas dynamics as applied to aircraft combustor and afterburner generated noise with emphasis on causes of suppression of such noise. The study seeks quantitative descriptions of the driving mechanisms as well as methods of predicting and minimizing such noise.

Special instrumentation will be utilized in conjunction with an anechoic chamber and a combustion rig to conduct diagnostic measurements designed to elucidate sources of sound in a combustor-jet combination, to measure effects of controlled changes and to observe relationships between flow pattern and noise characteristics. Concurrent theoretical report will involve modeling and treat noise generation from turbulent mixing regions, interactions of such turbulent flow with shock waves and unsteady rough burning processes. Information will be compared with typical jet engine firing tests involving various operating parameters.

Department of Defense
Army
INVESTIGATION OF GEARBOX DESIGN
MODIFICATION FOR REDUCING NOISE,
ARMY AIRCRAFT TRANSMISSION SYSTEMS
Mechanical Technology Inc.

DA0C4046
Contract DAAJ02-72-0040
7/73 to 6/74
Funds $26,456

The objective of this program is to identify practical gearbox design modifications which will help alleviate the gearbox noise problem in the CH-47 transmission. In addition, analytical methods for predicting and reducing gearbox noise sidebands will be developed to permit design analysis of this significant noise source.

Select component modifications, based on Contract DAAJ02-70-C-0035, to be investigated for noise attenuation in the CH-47 helicopter transmission. Perform vibration calculations so that candidate configuration is optimized from the standpoint of noise and vibration reduction. Identify modifications having greatest noise reduction potential. Utilizing test results obtained under Contract DAAJ02-71-C-0020. Determine the mechanamisms producing planet-pass sidebands and then modify existing computer programs accordingly to develop analytical methods to reduce sideband amplitudes.

COMPUTERIZED PROCEDURE TO ASSESS
TURBINE ENGINE PERFORMANCE/NOISE
TRADES

Project 3066, Task 14,
Work Unit 06

The objective of this program is to develop an effective design procedure relating aircraft engine performance and noise. The specific technical objectives of this program are: (a) to develop effective uninstalled engine noise prediction methods applicable to current and future gas turbine engines, (b) to develop techniques for the prediction on installed engine noise levels including the effects of special noise reduction devices, and (c) to develop methods to assess propulsion performance and weight penalties as a function of noise level reduction.

DOD DUCT ACOUSTICS AND SUPRESSION PROGRAMS

SOUND TRANSMISSION THROUGH DUCTS

Project 3066, Task 14,
Work Unit 09 (AF)

The purpose of this effort is to develop a numerical procedure to predict the effects of engine ducting on sound propagation. The specific technical objectives of the effort are to review existing theoretical and empirical methods for the prediction of sound propagation through and radiation from ducts and to develop a unified general theory based on this review. This prediction theory will then be incorporated into a general computerized procedure to assess turbine engine noise/performance trades.

Department of Defense
Army
DEVELOPMENT OF NOISE
ATTENUATING SUBSTANCE
Lehigh University

DAOC4924
Contract DAAD05-72-C-0175
7/73 to 6/74
Funds $19,950

To develop a paint-like substance which will damp thin panel vibration.

A Latex substance consisting of two layers - a viscoelastic latex IPN undercoating having damping capabilities at the temperature and frequency range of interest and a reinforced plastic constraining layer which has a high modulus. Steel tests panels will be coated, evaluated, and compared to commercial materials at frequent intervals. The best paint will be recommended for Army use on material where personnel are exposed.

DOD STRUCTURAL RESPONSE AND INTERIOR NOISE PROGRAMS

Department of Defense
Army
STRUCTURAL MATERIALS WITH DAMPING
CHARACTERISTICS FOR APPLICATION TO
HELICOPTERS
U.S. Army

DAOD4751
7/72 to 6/73
Funds Unknown

The objective is to produce a material that can be used to dampen noise in helicopters (engine mounts, driveshafts, honeycomb linings).

Titanium-nickel alloys in the 50-50 range will be fabricated and tested to determine their yield strength and damping capacity. Acoustical attenuation as a function of frequency (0-20 percent) and temperature (-60 degrees centigrade to 100 degrees centigrade) will be measured and by alloying or heat treatment the yield strength and damping characteristics will be optimized. X-ray studies will be made to correlate the lattice arrangement with the damping characteristics and yield strength.

DOD FLIGHT AND INSTALLATION EFFECTS PROGRAMS

Department of Defense
Army
ANALYTICAL STUDIES OF HELICOPTER
ROTOR BROADBAND NOISE GENERATION
10299-E
Sikorsky Aircraft

DAOD8982
Contract DAHC04-72-C-0040
7/73 to 6/74
Funds $33,861

An analytical study will be made to establish a closed form solution for predicting the broadband noise intensity radiated by helicopter rotors. This research should develop techniques which will reduce the aerodynamically generated noise made by helicopters.

Experimental studies will be made of isolated airfoils in an existing acoustic-wind tunnel. The data obtained and other existing data will be statistically analyzed to provide an empirical equation which will then serve as a measure by which the validity of the theoretical equation will be examined.

Department of Defense
Army
STUDIES IN LOW SPEED FLIGHT
10233-E
Georgia Institute of Technology
School of Aerospace Engineering

DAOD9005
Contract DA-ARO(D)-31-124-71-G-17
7/72 to 6/73
Funds $120,000

Investigation of problems associated with low speed flight of helicopters, such as the hovering rotors, vortex wake, blade slap noise, rotor flutter, and the instability of tensioned sheets with cutouts. The Army helicopter program has a definite need to improve the capability of its helicopters to hover near the ground so as to take off and land precisely at a surface location with maximum payload. The present vortex wake and rotor flutter of the vehicle interferes with ground personnel as well as reduces the payload capability of the vehicle. Blade slap noise alerts the enemy to the helicopter's presence and must be reduced significantly to improve the element of tactical suprise.

(a) Develop a method for calculating vortex wakes in the hovering performance of multi-bladed helicopter rotors, (b) the interaction of the helicopter blade with the vortex field shed from the preceding blades as a cause of blade slap, (d) the structural dynamic characteristics of the rotor-blade system that gives rise to flutter due to the unsteady air loads on the blade, (C) the instability of thin sheets with cutouts and cracks.

Department of Defense
Army
SYSTEMS STUDY OF HELICOPTER NOISE
REQUIREMENTS 8713-E
Massachusetts Institute of Technology
School of Engineering

Contract DAHCO4-69-C-0086
7/72 to 6/73
Funds $73,864

To establish a new methodology for systems analysis which includes noise criteria and to develop a new wind tunnel facility for making useful noise measurements on V/STOL aircraft types. It is important for the Army to reduce the noise levels of its helicopters so that the missions of surveillance, reconnaissance and target acquisition can be performed better without giving too much warning of approach to the enemy. The mission accomplishment may still be performed better if just the right combination of noise reduction and performance of the helicopter existed. The question that remains unanswered is - What is the most desirable combination of these parameters so the mission effectiveness will be maximized. This project is aimed towards answering this question.

The initial system studies will be performed, assessing the effect of noise criteria on mission performance. Experimental data on the noise radiated by helicopter rotors in high forward speed flight will be obtained. Emphasis will be in determining the effect of helicopter operating conditions upon the directivity, frequency content and time signature of the noise.

## DOD SOUND PROPAGATION PROGRAMS

NOISE FROM LINEAR ARRAY
OF LARGE TURBOJET ENGINES
AFFDL (In-House)

Project 1471, Task 02,
Work Unit 011

The purpose of this program is to determine the interaction effects of multiple turbojet exhause noise sources in determining the near-field acoustic environment. Data were obtained in the form of sound pressure levels and frequency spectra at various microphone locations. Analog data were recorded on tape for later analysis.

RADIATED NOISE FROM SAILPLANES
AFFDL (In-House)

Project 1471, Task 02,
Work Unit 013

The objective of this effort is to identify the noise associated with a powerless aircraft and to relate this noise to area and velocity parameters of the aircraft. The flyby noise from three sailplanes, Schweizer 2-32, Schweizer 2-33, and Libelle, has been recorded on tape and one-third octave and overall bandwidth analyses obtained. The noise levels from each of the sailplanes follows a sixth power of the velocity and appear to be directly proportional to the turbulent area on the wing. A test report has been prepared which presents the results obtained to date.

Department of Defense
Army
RESEARCH ON HELICOPTER
NOISE 9372-E
Cornell University
School of Engineering

DAOC9164
Contract DAHCO4-74-C-0001
7/73 to 6/74
Funds $30,615

To discover, refine and exploit techniques for the analysis and predictions of aerodynamic noise, in particular the noise produced by helicopters and similar-AIRTRAFT, for the purpose of finding techniques for reduction of such noise. The successful field operation of Army helicopters is jeopardized by the noise environment in three ways. Helicopter noise increases the vulnerability of both the machine and crew to ground fire, distracts the crew in the performing of their duties, and induces sonic fatigue in construction elements. Thus, this investigation has a high degree of relevance to effective utilization of rotorcraft since it will identify noise sources and describe noise propagation relative to helicopters.

## DOD PROPELLER NOISE PROGRAMS

PROPELLER TECHNOLOGY

Project 3066, Task 12

Significant propeller system technology advancement is an area of major importance for V/STOL and light aircraft. The propeller technology task consists of three areas:

(a) lighweight propeller and propeller/gearbox development;

(b) improvement of propeller aerodynamic performance and analytical prediction techniques;

(c) prediction and reduction of propeller and gearbox system noise.

More specifically, near term areas of concern are: decreasing propeller/gearbox system weight through the use of high strength-to-weight ratio materials and composites; improving propeller system performance through the application of cyclic pitch and variable geometry; improving basic airfoil design for optimum performance; determining accurate static thrust prediction methods; improving noise prediction techniques through improved basic noise source theory; and improving propeller noise scaling techniques and noise reduction through utilization of unique propeller designs based on noise source theory information.

PROPELLER ACOUSTICS RESEARCH — Project 3066, Task 12, Work Unit 07

The overall objective of this program is to experimentally determine the noise generation mechanisms for low tip speed propeller airfoils. The specific technical objectives of the effort are: (a) to determine the relative effects of upstream turbulence, boundary layer fluctuations and vortex shedding on radiated noise, and (b) to experimentally verify the theoretical prediction models developed under contract F33615-70-C-1135 and presented in AFAPL-TR-71-55 entitled "Propeller Noise at Low Tip Speeds."

QUIET PROPELLER CONCEPT EVALUATION — Project 3066, Task 12, Work Unit 08

The objective of this program is to evaluate the noise characteristics of various tail rotor configurations to determine the noise reduction potential of various new designs. Variables to be investigated include number of blades, blade to hub phasing angles and blade length.

LOW NOISE PROPELLER TECHNOLOGY DEMONSTRATION

Project 3066, Task 12, Work Unit 12

The objective of this exploratory research program is to develop a reliable design procedure for quiet propellers applicable to reconnaissance/surveillance aircraft. The specific technical objectives of this effort are: (a) to modify existing Air Force propeller noise prediction computer programs to account for forward flight effects, and (b) to produce a series of design charts that will be useful in design of future propeller driven quiet aircraft.

## IV. NSF PROGRAMS

Note that these are not discussed in the main text.

National Science Foundation
Div. of Engineering
AN INVESTIGATION OF ACOUSTIC
FEEDBACK FOR THE REDUCTION OF
JET NOISE
University of Michigan
School of Engineering

GK-33801
4/72 to 4/73
Funds $60,000

This project will investigate the part acoustic feedback (resonance) plays in the generation of noise from supersonic jets with special consideration given to the possibility of shifting the frequency of a significant part of the radiated acoustic energy outside the range of the human ear.

Phase relationships between movements of shock waves and disturbance created will be determined using ultra-high-speed Schilieren or shadow photographs. Local flow properties will be measured and the sound reflecting and absorbing surfaces in various geometries will be examined.

National Science Foundation
Div. of Engineering
RESEARCH INITIATION-APPLICATION
OF UNSTEADY AIRFOIL THEORY
Widener College
Graduate School

GK-37433
3/73 to 8/74
Funds $17,000

This research project will investigate the pressure fluctuations on blade surfaces of a single stage compressor. In particular it will be clarified whether the chopping effect of blades moving at high speeds relative to one another without the presence of low momentum flow is the predominant source of noise or the mere interference of blades with flow perturbations.

Experimental tests will be aimed to separate the sources of pressure fluctuations. Using high response pressure transducers a quantitative answer of the magnitude of these fluctuations is to be obtained. An integration of these results over the blade surface will give answers as to the magnitude of the experienced lift fluctuations which will then be compared with existing theories.

National Science Foundation
Div. of Engineering
COMPRESSOR NOISE REDUCTION
WITH A SONIC INLET
South Dakota State University
School of Arts

GK-5030 A#1
10/71 to 10/72
Funds $19,350

The purpose of this investigation is to develop some fundamental understanding of the aerodynamic-problems associated with the sonic inlet. Specific emphasis will be given the following: (a) A theoretical and experimental verification of a method for optimizing the design of center body. (b) Experimental investigation of the effects of splitters and vortex generators on secondary air injections. (c) Verification of the theoretical studies on shock stability.

National Science Foundation
Div. of Engineering
COMBUSTION GENERATED NOISE
Georgia Inst. of Technology
School of Aerospace Engineering

GK-32544
2/72 to 2/73
Funds $13,950

A combined experimental-theoretical program will be undertaken to isolate the origin of combustion generated noise and to discover appropriate scaling rules associated with this noise. Primary attention is to be focused on premixed turbulent flames, although several aspects of diffusion flame noise will also be investigated.

An extension of the principal investigator's original theory of combustion generated noise will be attempted to include the effects of approach flow turbulence level, directional radiation as caused by refraction and dipole source effects, and the effects of diffusion flames. Information gained from this analysis will be used to direct experiments on free flames. An analysis will also be initiated to determine the effects of reflecting surfaces on the combustion noise source behavior. Suggestions for appropriate experimental variables will be made to extract the effects of reflecting surfaces.

The data obtained on free flames will be analyzed and compared with the theory. Correlations will be obtained for sound power output, directionality, and spectral content. Furthermore, the relation between the reaction rate fluctuations and the sound power output will be determined. An analysis will be completed for the radiation of noise from a flame-containing enclosure to the surroundings. The modification to sound power output, spectral content and directionality will be determined as compared with free flame generated noise.

National Science Foundation
Division of Engineering
RANDOM VIBRATIONS OF ALMOST
PERIODIC STRUCTURES
University of Illinois
School of Engineering

GK-34136X
5/72 to 3/73
Funds $44,900

The first part of this research will consider the random variation of periodic units from the designed (or norm) configuration. One objective will be to determine the probability distribution of each natural frequency and the corresponding normal mode of the structure from the probability distribution of the varied geometrical and material parameters. The investigation will then be extended to the response of such a structure to random forcing fields. The convected frozen noise field and convected but slowly changing noise field which have been used as mathematical models for boundary layer turbulence will be included among several other types of random excitation.

National Science Foundation
Division of Engineering
RANDOM VIBRATIONS OF ALMOST
PERIODIC STRUCTURES
University of Illinois
School of Engineering

GK-34126 X1
4/73 to 3/74
Funds $44,100

The first part of this research will consider the random variation of periodic units from the designed (or norm) configuration. One objective will be to determine the probability distribution of each natural frequency and corresponding normal mode of the structure from the probability distribution of the varied geometrical and material parameters. The investigation will then be extended to the response of such a structure to random forcing fields. The convected frozen noise field and convected but slowly changing noise field which have been used as mathematical models for boundary layer turbulence will be included among several other types of random excitation.

This action provides a second year of support for a continuing grant.

National Science Foundation
Div. of Engineering
ENLARGEMENT OF ANECHOIC CHAMBER
FOR NOISE RESEARCH
Syracuse University
Graduate School

GK-32585
2/72 to 2/73
Funds $24,800

An existing anechoic chamber facility (wedge-tip to wedge-tip size 12' x 10' x 9') will be enlarged to 20 feet by 15 feet by 11 feet wedge-tip to wedge-tip. The enlarged anechoic chamber facility will serve as a more reliable tool for the noise research listed below, both because of its greater capacity and lower effective cut-off frequency characteristics.

(a) Noise experiments in a hard room.

(b) Compressor and turbine noise.

(c) Traffic noise control.

(d) Effect of impulsive noise on the auditory system.

National Science Foundation
Div. of Engineering
PREDICITION AND MEASUREMENT OF
SOUND PROPAGATION IN LINED FLOW
DUCTS
University of Minnesota

Proposal P2K0644
FY 72 - 12 months
Funds $37,800

The theoretical portion of this project will include the analysis of two-dimensional steady flow in a porous wall duct and to initiate a study of acoustic wave propagation in the same porous duct. The experimental portion will include the development of and the measurement of pressure spectrum in the porous wall ducts.

**TECHNICAL REPORT DATA**
*(Please read Instructions on the reverse before completing)*

| | | |
|---|---|---|
| 1. REPORT NO. 600/2-75-003 | 2. | 3. RECIPIENT'S ACCESSION NO. |
| 4. TITLE AND SUBTITLE Federal Aircraft Noise Research, Development and Demonstration Programs: FY'73 - FY'75 | | 5. REPORT DATE March, 1975 |
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| 7. AUTHOR(S) Interagency Aircraft Noise Research Panel | | 8. PERFORMING ORGANIZATION REPORT NO. |
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| | | 11. CONTRACT/GRANT NO. |
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| | | 14. SPONSORING AGENCY CODE |

15. SUPPLEMENTARY NOTES

EPA Contact: Eugene E. Berkau, 202-755-0449

16. ABSTRACT

The Interagency Aircraft Noise Research Panel was established by the Environmental Protection Agency to aid EPA in fulfilling its responsibility for coordinating the Federal noise research activities. This report is the first prepared by the Panel and provides an inventory of current and planned Federal aircraft noise RD&D programs. The Federal agencies which sponsor aircraft noise RD&D are the National Aeronautic and Space Administration, the Department of Transportation, the Department of Defense, the National Science Foundation, and the EPA. The report is organized by technical areas with each agency's programs presented under the appropriate technical area. Emphasis is on fiscal years 1974 and 1975, but summary information on fiscal years 1973 and 1976 is also included. The Appendix contains detailed programmatic information as furnished by the Federal agencies on their aircraft related RD&D activities.

17. KEY WORDS AND DOCUMENT ANALYSIS

| a. DESCRIPTORS | | b. IDENTIFIERS/OPEN ENDED TERMS | c. COSATI Field/Group |
|---|---|---|---|
| Acoustics | Research | Federal noise RD&D | 2001 |
| Noise (Sound) | Research projects | Federal noise coordination | 1406 |
| Noise reduction | Federal budgets | Research program | 1903 |
| Jet aircraft noise | | Aircraft | |
| Jet engine noise | | Transportation | |
| Aerodynamic noise | | | |

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APPENDIX E

Federal Surface Vehicle Noise Research, Development, and Demonstration Programs: FY73–FY75, Report EPA-600/2-75-002, Prepared by Interagency Surface Vehicle Noise Research Panel, March 1975

EPA-600/2-75-002
MARCH 1975

Environmental Protection Technology Series

# Federal Surface Vehicle Noise Research, Development, and Demonstration Programs: FY 73 - FY 75

Office of Research and Development
U.S. Environmental Protection Agency
Washington, D.C. 20460

## RESEARCH REPORTING SERIES

Research reports of the Office of Research and Development, Environmental Protection Agency, have been grouped into five series. These five broad categories were established to facilitate further development and application of environmental technology. Elimination of traditional grouping was consciously planned to foster technology transfer and a maximum interface in related fields. The five series are:

1. Environmental Health Effects Research
2. Environmental Protection Technology
3. Ecological Research
4. Environmental Monitoring
5. Socioeconomic Environmental Studies

This report has been assigned to the ENVIRONMENTAL PROTECTION TECHNOLOGY series. This series describes research performed to develop and demonstrate instrumentation, equipment and methodology to repair or prevent environmental degradation from point and non-point sources of pollution. This work provides the new or improved technology required for the control and treatment of pollution sources to meet environmental quality standards.

This report has been reviewed by the Office of Research and Development. Approval does not signify that the contents necessarily reflect the views and policies of the Environmental Protection Agency, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

Report 600/2-75-002
March 1975

# FEDERAL SURFACE VEHICLE NOISE RESEARCH, DEVELOPMENT, AND DEMONSTRATION PROGRAMS FY73 - FY75

Prepared by

Interagency Surface Vehicle Noise Research Panel

Program Element No.
1GB090

Project Office:
Noise Technology Staff
Office of Research & Development
U.S. Environmental Protection Agency
Washington, D.C. 20460

Prepared for

U.S. Environmental Protection Agency
Office of Research and Development
Washington, D.C. 20460

ABSTRACT

The Interagency Surface Vehicle Noise Research Panel was established by the Environmental Protection Agency to aid EPA in fulfilling its responsibility for coordinating the Federal noise research activities. As its initial task, the Panel prepared this report summarizing the Federal governments' surface vehicle noise research, development, and demonstration activities. The Federal agencies which sponsor and/or conduct the major portion of the surface vehicle noise RD&D are represented on the Panel. They are the Department of Transportation, the Department of Commerce/National Bureau of Standards, the Department of Defense, and the EPA. Other agencies which sponsor surface vehicle noise research are the Department of Agriculture and the National Science Foundation. The report contains brief descriptions and fiscal data for the agencies' programs. Emphasis is on fiscal years 1973 through 1975. Also included are references and bibliographies of reports and publications which have resulted from the Federal surface vehicle RD&D activities.

TABLE OF CONTENTS

TABLE OF CONTENTS (Cont'd)

TABLES

TABLES (Cont'd.)

# 1. SUMMARY

In partial fulfillment of its responsibility for coordinating Federal noise research, the Environmental Protection Agency has established an interagency Surface Vehicle Noise Research Panel. The Panel membership includes Federal representatives from the Department of Transportation, the Department of Commerce (National Bureau of Standards), the Department of Defense, the Department of Housing and Urban Development, and the Environmental Protection Agency. With the exception of HUD these agencies sponsor and conduct the vast majority of the surface vehicle noise research, development and demonstration (RD&D) activities in the Federal Government. Other Federal agencies known to be sponsoring surface vehicle noise research, are the U.S. Department of Agriculture and the National Science Foundation. In addition, this Panel has been charged with the responsibility for addressing the Federal research supporting land use policies.

The initial task of this panel was the preparation of a report on the Federal Government's surface vehicle noise RD&D and land use related research activities. This report, however, will only address the Federal surface vehicle RD&D activities as no Federal research programs reported were specifically identified with land use. The report reflects the views of the panel members as experts in the field and does not necessarily represent the policies or viewpoints of the agencies represented.

Table 1.1 is a summary of the major surface vehicle noise research programs being sponsored by the Federal Government. The total noise dedicated resources are shown to peak at $3,374,000 in FY 1974. However, it should be noted that the resource commitments for FY 1975 are known to be incomplete, and resources allocated to noise for research programs not dedicated to noise and for DOT in-house research are not included in any of the fiscal year data.

The DOT is the principal Federal agency sponsoring surface vehicle noise RD&D. These activities are primarily concerned with transportation systems and are associated with three major programs. They are Highway Noise Reduction, Urban Transportation System Noise Reduction, and Conventional Railroad and Intercity High Speed Systems. With emphasis being control of highway noise, the major efforts have concentrated on the control of heavy duty truck and bus noise. Future research efforts emphasize truck tire and engine mechanical and combustion noise.

Although the DOT resource allocations to reduce noise from urban transportation and conventional and high speed railway transportation

Table 1.1 SUMMARY OF THE FEDERAL SURFACE VEHICLE NOISE RD&D PROGRAMS

| SPONSORING AGENCY | DESCRIPTIVE TITLE OF PROGRAM | FISCAL YEAR FUNDING ($1,000) PRIOR TO 1973 | 1973 | 1974 (est) | 1975 (2) |
|---|---|---|---|---|---|
| DOT | Highway Noise Reduction | 2,066 | 1,798 | 1,429 | 935 |
| | Urban Transportation System Noise Reduction Program | (1) | 356 | 577 | (1) |
| | Conventional Railroad & Intercity High Speed Systems | (1) | (1) | 150 | 200 |
| | TOTAL DOT | 2,066 | 2,154 | 2,156 | 1,135 |
| DOD/ARMY | Conformance with Regulatory Requirements | | 215 | 270 | |
| | Vehicle Signature Reduction | 100 | 100 | 95 | |
| | Noise Reduction Program for U.S. Army Construction Vehicles | | 369 | 300 | 160 |
| | TOTAL DOD/ARMY | 100 | 684 | 665 | 160 |
| EPA | Interstate Motor Carriers | | 170 | | |
| | Interstate Rail Carriers | | 199 | | |
| | New Medium & Heavy Duty Trucks | | | 178 | |
| | TOTAL EPA | | 369 | 178 | |
| USDA | Reduction of Vehicle (snowmobile) and Equipment Noise Levels | | | 25 | 39 |
| | The Use of Trees and Shrubs in Noise Abatement | | | 20 | |
| | Noise & Vibration of Off-Road Equipment | | 4 | 28 | |
| | TOTAL USDA | | 4 | 73 | 39 |
| NSF | Effects of Building and Other Boundaries on Motor Vehicle Noise | | | 30 | |
| | Noise and Vibration from Transportation Vehicles and Other Machinery | | | 272 | |
| | TOTAL NSF | | | 302 | |
| | TOTAL FEDERAL EFFORT | $2,166 | $3,211 | $3,374 | $1,334 |

(1) Resources for inhouse research and noise portions of advanced transportation systems development are not included.
(2) FY 75 estimates are known to be incomplete.

proposals. Currently, there are two NSF research grants specific to surface vehicle noise. They are entitled "The Effects of Building and Other Boundaries on Motor Vehicle Noise" and "Noise and Vibration from Transportation Vehicles and Other Machinery." A third grant entitled, "Basic and Applied Studies of Noise," has a minor portion of the study addressing sound generation by automotive tire designs.

The total Federally sponsored surface vehicle noise research activities can be classified into the following six research categories: highway vehicle noise control technology, railway vehicle noise control technology, off-highway vehicle noise control technology, noise system studies, noise regulations development and enforcement, and advanced systems development. For noise dedicated activities, the emphasis in the Federal efforts has been roughly equal between highway vehicle noise control technology development and noise regulations development and enforcement. In these areas the principal efforts have been control of heavy truck and bus noise. However, there is a significant Federal effort addressing noise generated by off-highway vehicles, principally those used in construction. Although not dedicated to noise, there are also major Federal programs (exclusively DOT) to develop advanced, future mass transportation systems which give significant attention to noise control and have potential applications to conventional systems. Total resource distributions for these categories are given in Table 4.1.

## 2. INTRODUCTION

### 2.1 BACKGROUND

Early in 1974 the Office of Research and Development of the Environmental Protection Agency invited Federal government agencies concerned with noise pollution research to designate representatives of their technical staff to serve as members on four noise research panels: aircraft, surface vehicles, machinery, and health effects. The requested agency representation on the panel is shown in Table 2.1.

Table 2.1 STRUCTURE OF EPA RESEARCH PANELS

| Noise Research Panel | Current Agency Membership |
|---|---|
| Aircraft | NASA, DOT, DOD, HUD, DOC, EPA |
| Surface Vehicles* | DOT, HUD, DOD, DOC/NBS, EPA |
| Noise Effects | HEW, (NINDS, NIOSH, NIEHS), DOT NSF, HUD, NASA, DOD, DOL DOC/NBS, EPA |
| Machinery | HEW/NIOSH, DOL, DOI/Bureau of Mines, NSF, DOD. DOC/NBS, EPA |

*This panel was also charged with the responsibility for the Federal research supporting land use policies.

These panels were convened to provide the means for interagency coordination of research in the four technical areas. In addition to exchange of information the functions of the panels in their respective areas are:

- Review and assessment of the current state of technology.
- Review and assessment of the status of research and technology development.

- Preparation of recommendations concerning ongoing research activities.
- Recommendation of noise research programs and projects, and methods for their accomplishments.
- Preparation of reports on the status and/or progress of on-going noise research activities.
- Receipt and review of pertinent scientific and programmatic advice from communicating with other standing bodies.

The names and addresses of the Surface Vehicle Noise Research Panel members are listed in Appendix A.

## 2.2 PURPOSE

Each of these panels of experts has met to charter its course of action as a consultative body, and it was agreed that each panel would generate a report on the Federal noise research, development, and demonstration (RD&D) activities and the noise research needs in the specific area of consideration by the panel. To prepare the report, the EPA requested each of the panel members to provide information on their agency's noise RD&D activities. With the request EPA offered an example of the type of information desired but indicated that the information could be provided in a form most convenient to the agency (i.e. their agency's project and program information forms or over-views). Appendix B contains a copy of the EPA example and the program and project information desired.

This report is the first to be prepared by the Surface Vehicle Noise Research Panel. Its purpose is to present a description of Federally supported RD&D which is directed toward control of noise problems attributable to surface vehicles or support of Federal land use policy development. This document will be used by the Environmental Protection Agency in preparing a report to satisfy Section 4(c)(3) of the Noise Control Act of 1972. EPA is required to report on the status and progress of Federal activities relating to noise research and noise control and the contribution of such activities to the Federal Government's overall efforts to control noise. The panel report is a digest and analysis of information provided by the Federal agencies involved in surface vehicle noise RD&D. The report reflects the collective opinions of the panel members and does not necessarily represent the policy or viewpoints of the respective agencies.

## 2.3 SCOPE

In the current Federal effort most surface vehicle noise RD&D on surface transportation systems is being sponsored by the Department of Transportation. Other agencies sponsoring research on surface vehicle noise are the Department of Defense/Army, the National Science Foundation, the Environmental Protection Agency, and the U.S. Department of Agriculture. There were no Federal research programs identified which were specifically concerned with land use policy development.

In presenting the current Federal activities, emphasis has been placed on the RD&D activities in FY 1973 and 1974. Previous efforts and future projections for major programs are also presented where such information was provided. Fiscal data reported is accurate as of July, 1974, but may not reflect the complete resources available for each program or project. This is principally because resources allocated to salaries, equipment, and other services for in-house studies have not been reported by all of the agencies. Because of FY 1974 carryover money, the FY 1974 resource allocations are best estimates in many cases. For FY 1975, not only are the resources identified estimates in most cases, but some detailed program and project planning is not complete. Therefore, the FY 1975 resource estimates are also incomplete. Although it is probably unavoidable to omit some related Federal activities, it is the consensus of the panel members that no major Federal research programs in the area of surface vehicle noise have been overlooked.

The program and project descriptions of the Federal surface vehicle noise RD&D are presented in Section 3 by agency. In Section 4 the current programs are briefly analyzed and grouped into the categories of specific surface vehicle noise control technology development, noise systems studies, research directly supporting regulations development and enforcement and advanced transportation systems development.

## 2.4 SURFACE VEHICLE NOISE SOURCES

Surface vehicles include mobile systems used in transportation, construction, defense, recreation, and agriculture. These systems can generally be classified according to three all inclusive noise source categories. They are highway vehicle noise, railway vehicle noise, and off-highway vehicle noise. The relative noise levels associated with these sources of surface noise are illustrated in Table 2.2. Noise emitted from these sources, however, is derived from the components of the source, the vehicle's subsources. Table 2.3 illustrates the contribution of the subsources to the total noise levels emitted by diesel trucks, motorcycles, and snowmobiles.

Table 2.2 COMPARISON OF TYPICAL NOISE LEVELS FOR SURFACE VEHICLES (1)

| CATEGORY | Average Noise Levels (2) (dB(A) at 15.24 Meters (50')) |
|---|---|
| HIGHWAY VEHICLES | |
| Medium and Heavy Duty Trucks | 84 (88) |
| Motorcycles (Highway) | 82 (88) |
| Utility and Maintenance Vehicles | 82 (88) |
| Highway Buses | 82 (86) |
| Sports Cars | 75 (86) |
| City and School Buses | 73 (85) |
| Light Trucks and Pickups | 72 (86) |
| Passengers Cars (Standard) | 69 (84) |
| RAIL VEHICLES | |
| Locomotives | 94 |
| Passenger Trains | 85 |
| Rapid Transit | 87 |
| Trolley Cars (Old) | 80 |
| Trolley Cars (New) | 66 |
| OFF-HIGHWAY VEHICLES | |
| Recreational | |
| Motorcycles | 85 |
| Snowmobiles | 85 |
| Inboard Motorboats | 80 |
| Outboard Motorboats | 80 |

(Continued)

Table 2.2 (Con't.)

| CATEGORY | Average Noise Levels (2) (dB(A) at 15.25 Meters (50')) |
|---|---|
| Construction | |
| Trucks | 88 |
| Scraper | 88 |
| Dozer | 87 |
| Concrete Mixer | 85 |
| Paver | 89 |

(1) The average noise levels reported in Table 2.2 were obtained from an unpublished EPA contractor report entitled "Rationale for the Identification of Major Noise Sources" Table A-1. The values were originally obtained from EPA document NTID 300.13, December 31, 1971, and HUD Departmental Circular 1390.2, August 1971.

(2) Values in parentheses are typical for maximum acceleration. All other values are normal cruising speeds. Variations of 5dB can be expected.

Table 2.3 SUBSOURCES OF NOISE FOR TYPICAL SURFACE VEHICLES

| Subsource | Typical Noise Levels (dB(A) at 15.24 Meters (50')) Diesel (1) Trucks | Motorcycles (2) | Snowmobiles (2) |
|---|---|---|---|
| Engine Mechanical & Combustion | 78 | 78 | 76 |
| Exhaust | 85 | 86 | 82 |
| Air Intake | 75 | 82 | 85 |
| Cooling Fan | 82 | - | 80 |
| Tires | 75 (95) | 69 | - |
| Track | - | - | 72 |
| Total | 88 (96) | 88 | 88 |

(1) Values in parentheses are for trucks operating above 35 mph, source of information: Close, W.H., DOT Truck Noise Reduction Program, Internal DOT Description Document.

(2) The noise levels indicated for these sources were obtained from EPA document NTID 300.13, December 31, 1971.

# 3. FEDERAL SURFACE VEHICLE NOISE RD&D PROGRAMS

## 3.1 DOT SURFACE TRANSPORTATION NOISE ABATEMENT PROGRAMS

There are three major DOT noise research programs. They are entitled the Highway Noise Reduction Program, the Urban Transportation Systems Noise Reduction Program, and the Conventional Railroad and Intercity High Speed Systems. The sub-program tasks, projects and fiscal data associated with these programs are listed in Tables 3.1, 3.2, and 3.3 respectively. The tables indicate that the major noise dedicated efforts are in highway noise reduction. Significant noise RD&D activities are identified in the other two programs but generally noise is only one of several considerations. Many of these latter activities are associated with the development of advanced, future mass transportation systems. Brief descriptions of these programs and their component projects are contained in the following sections.

### 3.1.1 Highway Noise Reduction Program

Since 1970 the Department of Transportation has been actively engaged in a multifaceted effort to reduce the impact of noise generated by heavy duty trucks and buses upon the community adjacent to the nation's public highways. The results of this program to date are numerous and further information is forthcoming. Pertinent reports developed under this program are available and reflect the degree of noise reduction achievable through the application of the best available technology considering cost of compliance.

Summary description documents (references 1,2) have been prepared which set the DOT program of truck noise reduction into perspective and delineate the plans for and accomplishments of the program realized as of late 1972. Since that time the program has developed according to the plan, but with some expansion of efforts.

Quiet Truck Program - An investment of approximately $1.25 million dollars has been made on three DOT contracts with the Freightliner Corporation, International Harvester Co., and the White Motor Co. to develop and demonstrate the lowest practical noise levels achievable on selected heavy duty diesel powered truck tractors.

Table 3.1 SUMMARY OF DOT HIGHWAY NOISE REDUCTION PROGRAM

| Descriptive Title | Investigator (s) | Fiscal Year Funding ($1,000) Prior to 1973 | 1973 | 1974 (est.) | 1975 (est.)* |
|---|---|---|---|---|---|
| Quiet Truck Program | Freightliner<br>International Harvester Co.<br>White Motor Co. | 1,046 | 100 | 100 | - |
| Exhaust/Intake Mufflers | Donaldson Co.<br>Stemco Manufacturing Co. | 75 | 28 | - | - |
| Truck Noise Handbook | Cambridge Collaborative | | 15 | 20 | - |
| Construction Equipment Mufflers | Vehicle Research Institute | | | 50 | |
| Engine Noise Support | Bureau of Mines/DOI | | 80 | 40 | - |
| Truck/Bus Retrofit | General Motors<br>PACCAR<br>International Harvester<br>Rohr Industries<br>McDonnel-Douglas Co. | | 450 | 72 | - |
| Basic Engine Noise Reduction | Not specified | | | 245 | 245 |
| In-Cab Noise Tests | In-House &<br>National Bureau of Standards | - | - | | - |
| Truck Tire Noise Study | National Bureau of Standards | 468 | 100 | 100 | 200 |
| Truck Tire Noise Basic Research | North Carolina University | 119 | - | 150 | 250 |
| Highway Noise Enforcement Training & Equipment | California Highway Patrol | - | 450 | 70 | - |
| Roadside Enforcement Sites | Not specified | | | 100 | 50 |
| BMCS Training/Equipping | Not specified | | | | |
| NCHRP Project III (highway noise models) | Bolt, Baranek, & Newman | 120 | 120 | 180 | - |

Table 3.1 (Cont'd)

| Descriptive Title | Investigator (s) | Fiscal Year Funding ($1,000) Prior to 1973 | 1973 | 1974 (est.) | 1975 (est.)* |
|---|---|---|---|---|---|
| Magnitude of Transportation Noise Generation and Abatement | Serendipity | ++ | - | - | - |
| Scale Modeling Highway Noise | Ling-Temco-Vought | 79 | - | - | - |
| Scale Modeling Urban Traffic Noise | Massachusetts Institute of Technology | - | 112 | - | |
| Development of Highway Noise Standards PPM-2 | In-house | + | + | + | |
| PPM 90-2 Training Manual Course | Bolt, Baranek, & Newman | - | 132 | + | + |
| FHWA Highway Design Manual | Urban Systems | - | 54 | - | - |
| Construction Equipment Standards | California Division of Highways | 57 | 90 | 80 | 80 |
| Highway Barrier Effectiveness | California Division of Highways | 43 | 7 | - | - |
| Acoustic Material Applications | Bolt, Baranek, & Newman | | | 115 | 110 |
| Barrier Parametrics | In-House | + | + | 50 | + |
| Traffic Noise Study | State of Maryland | 43 | 37 | 37 | - |
| Community Noise Study | State of New Jersey | 16 | 20 | 20 | - |
| Passenger Car Tire Noise | In-House and State of Colorado | - | 3 | + | |
| | TOTALS | 2,066 | 1,798 | 1,429 | 935 |

* FY 75 estimates known to be incomplete
\+ Primary in-house funds
++ Not dedicated to surface vehicle noise, noise resources not available

Table 3.2 SUMMARY OF DOT URBAN TRANSPORTATION SYSTEMS NOISE REDUCTION PROGRAM

| Descriptive Title | Investigator(s) | Fiscal Year Funding ($1,000) Prior to 1973 | 1973 | 1974 (est.) | 1975* |
|---|---|---|---|---|---|
| Transit Bus Noise Reduction Potential | WMATA | - | 26 | - | - |
| Purchase Specifications - Transit Coaches | MITRE | - | - | 22 | - |
| TRANSBUS Program | Not specified | ++ | ++ | ++ | ++ |
| Personal Rapid Transit Program | Not specified | ++ | ++ | ++ | ++ |
| Dual Mode Program | Not specified | | | ++ | ++ |
| Rapid Transit Systems Noise Environment | In-House | | | | |
| New York City Transit System Study | PINY | | | 125 | - |
| Chicago Transit Authority Study | University of Illinois | | | 60 | - |
| Other Transit Authority Study | Not specified | | | 120 | |
| Wheel/Rail Noise & Vibration Study | Bolt, Baranek, & Newman | | 184 | - | |
| Elevated Structures Noise & Vibration | Cambridge Collaborative | | 146 | - | |
| In Service Noise Abatement Test & Evaluation | Not specified | | - | 250 | - |
| New System's Specifications - Capital Grants | Not specified | ++ | ++ | ++ | ++ |
| State-of-the-Art-Car | Not specified | ++ | ++ | ++ | ++ |
| Screech Loop - Pueblo Facility | In-house | + | + | ++ | ++ |
| TOTALS | | | 356 | 577 | |

* FY 75 estimates known to be incomplete
\+ Primary in-house funds
++ Not dedicated to noise, noise resources not available

Table 3.3 SUMMARY OF DOT CONVENTIONAL RAILROAD AND
INTERCITY HIGH SPEED SYSTEMS NOISE RELATED PROGRAMS

| Descriptive Title | Fiscal Year Funding ($1,000) Prior to 1973 | 1973 | 1974 (est.) | 1975* |
|---|---|---|---|---|
| Measurement of Railroad | + | + | | |
| Joint DOT/AAR Railroad Noise Research | - | - | 150 | 200 |
| Linear Induction Motor Research Vehicle | ++ | ++ | ++ | ++ |
| Magnetical Levitated Research Vehicle | - | - | + | + |
| Tracked Air Cushion Research Vehicle | ++ | ++ | ++ | + |
| Prototype Tracked Air Cushion Vehicle | ++ | ++ | ++ | ++ |
| TOTALS | | | 150 | 200 |

* FY 75 estimates known to be incomplete
\+ Primarily in-house funds
++ Not dedicated to noise, noise resources not available

In the general work statement (reference 3) for the "Quiet Truck Program" the contractors were obliged to establish their own contract target noise level limits for each of the two truck configurations to be evaluated. Listed below is a table of goals proposed by each of the contractors (which became part of the contracts) and results of the contract research to date.

Table 3.4 QUIET TRUCK PROGRAM NOISE CONTROL GOALS AND ACCOMPLISHMENTS

| Contractor | Goals* | Accomplishments* |
|---|---|---|
| Freightliner | (1) 75-78dB(A) | 72dB(A) |
| International | (1) 75-78dB(A) | 77-78dB(A) |
| | (2) 78-80dB(A) | 79-80dB(A) |
| White Motor Co. | (1) 75-78dB(A) | 77dB(A) |
| | (2) 81-83dB(A) | 79dB(A) |

*Maximum sound level per SAE J366a test
(1) Enclosed engine version
(2) Unenclosed engine version

Two reports (references 4,5) of the many to emanate from this project have been completed. In anticipation of the demand for public information on these efforts, technical sessions at two professional society meetings were arranged in which the summary findings of the project could be conveyed to the public prior to completion of the detailed DOT project reports. Papers were presented at the Society of Automotive Engineers (SAE) National West Coast Meeting (references 6,7,8) in August of 1973, at Noise Con 73 (references 9,10,11,12,13) in October 1973, and at Inter-Noise 74 (reference 14).

A number of detailed reports are presently in preparation to delineate the specific tests, design considerations, operational implications, and costs associated with the development of these quieted trucks. In addition, nine trucks, as indicated below, are currently in field service evaluation with line haul carriers to proof test the noise reduction concepts and verify the estimates of operational and cost implications.

Table 3.5 FIELD SERVICE EVALUATION BY LINE HAUL CARRIERS

| Contractor | Number of Trucks | Operator |
|---|---|---|
| Freightliner | 1 | Mid American Lines |
| International | 4 | Ryder Truck Lines |
| White | 1 | Overnite Transport |
| White | 3 | Carolina Lines |

Following approximately one year of service evaluation on each truck, final reports will be prepared and published to document the experience gained in line haul service of the quieted trucks as compared to comparable production trucks. Completion of the service evaluation will occur in July of 1974 for the first trucks and February 1975 for the last trucks introduced into service.

As a further adjunct to this program, the International Harvester contract has been expanded to encompass fleet testing of 24 different installations of "demand" fan drives. This will provide an extensive evaluation of the duty cycle of such fan-noise obviation and energy saving installations in service across the country. Reference 15 is a listing of the 23 installations currently under test.

Exhaust/Intake Muffler - Rather than rely solely on long term future solutions to the problems of truck noise, the DOT also undertook a series of closely related efforts to produce information upon which near term decisions could be based: (1) for new product standards; and (2) for retrofitability of noise reduction components to current fleets of trucks and transit coaches powered by the popular diesel engines.

The first contracts in this effort were intake and exhaust muffler performance evaluation tasks. The Donaldson Co. and the Stemco Manufacturing Co. were awarded parallel contracts to acquire and evaluate available intake air cleaners and mufflers for acoustic performance and to document cost and ancillary performance effects (pressure restriction, etc.) The results of these two contracts are contained in final DOT reports (references 16,17). The results of the Donaldson study are also reported in a professional society report,(reference 18). These tests validated the contention that an ample supply of commercial mufflers exists to significantly reduce intake and exhaust noise of production trucks. Table 3.6 illustrates the general capabilities of better mufflers being used on the most popular diesel engines. The same reports place intake noise and component cost versus performance into a new, clearer perspective.

Table 3.6 SOUND LEVELS OF BASIC EXHAUST SYSTEMS

| | Sound Level dB(A) (1) | | | | |
|---|---|---|---|---|---|
| Type System | NHC-250 | NTC-350 | 6-71 | 8V-71 | ENDT-675 |
| Unmuffled | 95 | 93 | 105 | 104 | 82 |
| SVVTP | 96.0 | 79.0 | 78.0 | 82.0 | 72.5 |
| SVVTP + Wye (3) | | | | 80.0 | |
| CVVTP | | | | 80.0 | |
| SHVTP | 75.0 | 79.5 | 78.0 | 81.0 | 70.5 |
| DHVTP | | | | 81.5 | |
| SHHTP | 81.0 | 80.0 | 81.0 | | (2) |
| DHHTP | | | | 74.0 | |

(1) "A" weighted sound level reference 20 micronewtons per square meter. Measured at 15.24 meters (50').
(2) All mufflers tested exceeded back pressure limits.
(3) Wye muffler is used to join the two exhaust banks into a single system.
Exhaust System Code "XY ABC"
XY donoted muffler configuration; S single, D dual, V vertically mounted, H horizontal.
ABC donotes tail pipe system, V vertical, H horizontal.

Truck Noise Handbook - A task order contract with Cambridge Collaborative is being used to write a popularized version of the results of the two muffler contracts, the cooling system results from the "quieted" trucks, and general noise testing procedures into one comprehensive handbook for field use in implementing truck noise reduction. This effort is nearing the publication stage and a final handbook was scheduled for completion July 1974.

Construction Equipment Mufflers - A contract is presently being negotiated with the Vehicle Research Institute (VRI) of the SAE to study and evaluate the applicability of the muffler and cooling system technology to construction equipment. Recommendations for dissemination to that industry will be made by VRI.

Engine Noise Support - An interagency agreement with the Bureau of Mines, 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.

Truck/Bus Retrofits - Most directly applicable to the regulatory process for new trucks is the series of five contracts recently awarded by the DOT to determine the degree of noise reduction possible through optimum selection of air cleaner/inlet mufflers, exhaust mufflers, and cooling system components. Contracts have been written with: General Motors Truck and Coach Division, PACCAR (parent corporation including Kenworth and Peterbilt), International Harvester, Rohr Industries (Flexible Coach), and McDonnel-Douglas Co. (with White Motor Co. as subcontractor). Ten trucks and two transit coaches will be evaluated and quieted through detailed studies. Ten other trucks will be evaluated as to the applicability of the hardware developed for the primary study vehicles. $500,000 of Federal funds are being augmented by $325,000 of industry cost sharing to perform this effort. Final reports are scheduled to be finished by mid calendar year 1975. On the basis of the information (reference 19) supplied to prospective bidders regarding the tasks to be performed in this truck and bus retrofit study, it is evident that DOT is seeking technology answers to the problems of typical vehicles but, in addition, is also seeking definitive studies of vehicles known to possess atypical noise problems. Accordingly, some of the results expected from this effort will quite possibly delineate a number of truck models which simply cannot be expected to be made as quiet as the "typical" truck. From this information, the impact of regulatory decisions should be much clearer for both the "typical" heavy duty vehicle, and vehicles which may have to be prematurely retired due to excessive costs to quiet.

To facilitate dissemination of information resulting from these efforts, the contractors are obligated to prepare service bulletins pertinent to the test vehicles and to distribute these notifications to all owners of record of the affected vehicles. DOT anticipates that these service bulletins will establish a precedent in the industry which will be followed by broad voluntary dissemination of noise information by all manufacturers to their customers.

Basic Engine Noise Reduction - For even longer term considerations, DOT has initiated procurement activities to study the options available in reducing inherent diesel engine noise through engine design modifications. The efforts of the Bureau of Mines and the so called "Quiet Trucks" have provided the initial information for this effort as well as options to encapsulate engines for noise reduction purposes. This study will delve more deeply into the basic mechanisms of noise generation and radiation by diesel engines and the potential abatement techniques applicable to present and future engine designs. This will be a three year laboratory and field test program which is expected to cost a half million dollars. From this effort, it is anticipated that engine design parameters will be developed which will provide a full option to the encapsulation techniques developed in the previous DOT research and/or provide means to lower engine noise beyond that achieved solely by engine shields and encapsulation if needed.

In-Cab Noise Tests - The DOT has exercised its safety responsibilities in various areas affecting heavy duty trucks and buses. One of these areas of responsibility includes regulating the noise exposure of drivers of commercial vehicles. In keeping with the authorization and direction of the Congress as expressed in the Noise Control Act of 1972, DOT has carried out its program of operator noise exposure protection through research and development to the regulation stage.

In October of 1970 an advanced notice of proposed rule making by the DOT Bureau of Motor Carrier Safety (BMCS) regarding sound levels in commerical vehicle cabs was issued. A field measurement and analysis effort was undertaken the following summer of 1971 to ascertain interior sound levels and to develop simplified test procedures. Through the cooperation of Regular Common Carrier Conference and the American Trucking Associations, sixteen trucks were made available for testing. (Due to interest in community noise on the part of the truckers and the DOT, the exterior noise levels were measured as well as the interior noise levels of the test trucks).

Interior and exterior noise level data were acquired by the National Bureau of Standards (NBS) for DOT for a variety of truck operating procedures which included: stationary low idle, stationary engine acceleration, stationary high idle (governed rpm), SAE J366a acceleration, SAE J366a deceleration, and SAE J366a engine brake deceleration (reference 20).

An analysis of the significance of the various tests and a recommended enforcement procedure for interior noise level has been reported (reference 21). A methodology to relate the simplified procedure to driver exposure and the hearing conservation criterion of the Occupational Safety and Health Act was proposed. Sample measurements of typical over-the-road driver sound level exposure were also reported.

Subsequently a Notice of Proposed Rule Making (reference 22) was issued by the BMCS on January 4, 1973, based upon the results of the above research, to limit interior truck noise with specific performance standards and compliance testing specified. In-house studies documented by BMCS (reference 23) and independent studies by the Motor Vehicle Manufacturers Association (MVMA) confirmed the validity of the compliance testing procedure relative to the desired exposure control. On November 8, 1973, the Director of the Bureau of Motor Carrier Safety issued new Part 393.94 establishing maximum interior sound level limits for newly-manufactured and in-service trucks and buses operated in interstate commerce.

The BMCS has also undertaken research to relate noise and other commerical vehicle environmental factors (vibration, heat, etc.) to driver fatigue, etc. The results of this effort have been reported (reference 24).

Truck Tire Noise Study - The very first item of surface transportation noise research undertaken by the DOT Office of Noise Abatement was a comprehensive study of tire noise. DOT undertook this program in 1969 as the first phase of its highway vehicle noise research because it had been determined that: (1) tire noise is speed dependent, thus it is typically the dominant high speed truck noise source; (2) Interstate highway construction progress has generated a continuing increase in average truck speed; (3) tire noise to some degree is dependent upon road surface and; (4) the majority of the remaining Interstate system to be constructed is in urban areas. The course of action taken was to enter into an interagency agreement with the Office of Vehicle Systems Research (OVSR) of the National Bureau of Standards to conduct pilot studies of auto tire noise (due to their heavy involvement with auto tire safety standards for DOT).

From this pilot effort and information obtained from General Motors, it was determined that meaningful data could be acquired using coast-by test procedures. With this base of understanding and experience, DOT and NBS prepared a test plan for a parametric examination of truck tire noise through field testing.

During the performance of this study, the OVSR was transferred enmasse from NBS to DOT and the tire noise program execution was redirected by DOT to the Applied Acoustics Section of NBS. No significant disruption of the program was experienced by this transition which was planned in anticipation of the organizational change. An excellent test site was made available at Wallops Island, Virginia, by the National Aeronautics and Space Administration. Test tires were provided gratis by several trucking companies through the American Trucking Associations. NBS acquired the necessary acoustic equipment, became familiar with its operation and conducted initial tests at Wallops Island in 1970. Testing during the summers of 1970 and 1971 resulted in the acquisition of the largest known data base of truck tire noise. The first (references 25,26) of a series of reports based upon these data document the variation of truck tire noise with: tire tread type, vehicle speed, vehicle loading, tire wear, and to a limited degree road surface, number of tires, and effects of water on the road surface.

Currently in preparation are several additional reports derived from this data base covering the subjects of: regulatory and use implications, spectral and directional characteristics of truck tire noise, and implications of the data in regards to the mechanisms of tire noise generation. In addition, evaluation tests of candidate tires for standard military procurement were evaluated and were reported (reference 27).

A substantial number of professional society papers have been written by DOT and NBS on the subject of tire noise. (See references 28,29,30,31,32 for examples). The findings of this program to date served as input data for the EPA proposed Interstate Motor Carrier Noise Regulations (reference 33). It is anticipated that the findings will further serve as the basis for tire noise regulations to be written by the California Highway Patrol (CHP) in accordance with Sections 27502 and 27503 of the California Motor Vehicle Code (reference 34) and possible future tire noise regulations to be written by EPA.

Truck Tire Noise Basic Research - While the above tire noise efforts have quantified the important factors pertaining to selective use of tires, road surface implications and regulatory implications, the matter of specific tire noise generation mechanism would remain unanswered unless more specific research into this point was successfully conducted. Accordingly DOT has awarded a four year $270,000 grant to the North Carolina State University (NCSU) to undertake a theoretical and experimental study of tire noise generation. Through the first two years of this grant, tire vibration (as opposed to air pumping or other turbulent aerodynamic phenomena) has been identified as a major noise source mechanism in many truck tires. Subsequent tasks have been planned which are necessary for the design of quiet tires. These tasks are: isolation of tire vibration and sound sources through coherence function analysis of tire sound, vibration, and road surface roughness signals; road surface roughness measurement and modeling; and tire analytical vibration and noise models. A status report (reference 35) through August 1973 is available from NCSU.

Highway Noise Enforcement Training and Equipment - In the various aspects of the DOT program of truck noise reduction, numerous procedures of sound measurement and data presentation have been employed. The DOT has elected to use one common base of testing throughout this program to ensure complete communications with the various participants and to ensure comparability of results. This common base has been the Society of Automotive Engineers Recommended Practice J366a or the latest version, J366b (reference 36) revised for editorial reasons. As illustrated in reference 20, DOT is very much attuned to the need to constantly review the adequacy of present testing techniques. The sensitivity of J366a relative to vehicle operation and/or microphone location was investigated and reported, noting that nowhere in the data were levels greater than J366a plus 3dB recorded at microphone locations other than that prescribed by J366a. The average difference in levels recorded 4.57 meters (15') to either side of the SAE microphone location was 0. The average difference in levels recorded 9.14 meters (30') to either side of the SAE microphone location was 0 to 0.5dB lower than at the SAE microphone location. The ranges of data were also small. A concluding statement, therefore, was made relative to J366a that: "This data serves to substantiate the validity of the SAE test procedure as a measure of maximum vehicle noise". Subsequent to that study in 1971 no data has been generated which would change the conclusions as to validity of J366 within a nominal $\pm$2dB tolerance. Higher test speeds would be detrimental to the process of reliably determining maximum truck noise (exclusive of tire noise).

As noted above, DOT is presently preparing a report on tire noise regulatory implications which will endeavor to provide supporting information for California standards to be developed on truck and automobile tire noise. In this effort leading up to the preparation of this report, DOT has concluded that tires need to be regulated in a totally separate fashion from trucks. DOT further concludes that with the exception of substituting "fast meter response" for the "slow meter response", the procedures and concepts of SAE J57 (reference 37) testing are adequate for truck tire noise rating.

In accordance with scientifically sound and practical approaches which exist for the specification and enforcement of motor vehicle noise control measures, DOT undertook the sponsorship of a training program for state and local officials concerned with this problem. In May and June of 1973, the California Highway Patrol (CHP) conducted six, four day courses to convey the background and experience gained by the CHP in developing and adopting legislation for the control of motor vehicle noise and in developing and enforcing specific new product and in-service vehicle noise regulations. The DOT also offered to make available basic instrumentation for the states to use in such enforcement programs which the states would undertake following completion of the DOT/CHP courses.

A total of 212 state and local officials attended the training courses at the Sacramento, California Academy of the CHP. A few representatives of the Environmental Protection Agency also attended, as did other DOT officials and a few industry officials.

The course material and the audio/visual training aids provided each attendee are contained in references 38 through 41. The object of the program was multifold, however, one primary objective was to determine if a well structured program, conducted by personnel possessing extensive background and experience could effectively convey the essence of vehicle noise enforcement techniques to a generally uninformed group of state and local officials, upon whom responsibility for such enforcement would possibly be placed in the near future. As the final report (reference 42) indicates, the program was an overwhelming success. The examination scores were raised from an average of 64.5% at entrance to 91.3% upon completion of the course. This report has been edited to preserve anonimity of the attendees thus permitting public disclosure of the program results.

Roadside Enforcement Sites - Further, in regards to measurement methodology, the DOT is initiating a program of roadside site categorization which will involve the measurement of control vehicles and traffic at a number of representative roadside enforcement locations to categorize the acoustic effects of such sites as are typically found adjacent to the nations highways and streets. Measurements during the summer of 1974 will provide pertinent data for this activity leading to the development of initial compliance regulations to be written by the DOT under authority of Section 18 of the Noise Control Act. This activity will, in all probability, be an on-going, low level, in-house effort to continually upgrade enforcement techniques, thus permitting enforcement measurements in more restricted spaces and accounting for other factors which at present would rule out sites for measurement purposes.

BMCS Training/Equipping - In fiscal year 1975, in-house and contractor efforts will provide expanded training of Bureau of Motor Carrier Safety (MBCS) inspectors for enforcement of the In-Cab Noise Regulation and Interstate Motor Carrier Noise Regulation. In addition, equipment to supplement that presently available for BMCS inspectors will be provided.

National Cooperative Highway Research Program (NCHRP) Project III - Dating back to fiscal year 1970 the DOT Federal Highway Administration (FHWA) has supported the NCHRP Project III for the development of information pertaining to highway noise and its associated problems. This is a jointly funded effort with the Association of State Highway Officials through the Highway Research Board and has, to date, produced three pertinent reports, NCHRP Reports 78, 117, and 144. Each report addresses the proposition of highway noise generation and provides information for the transportation and urban planner to perform his function appropriately in light of these predicted noise levels and community reactions. Other activities within the DOT have addressed this problem and have resulted in the development of highway noise prediction models. Under contract to the Office of the Secretary of Transportation in 1970, Serendipity Incorporated developed a sophisticated highway noise model which took into account many factors as specific inputs which have been averaged in the succeeding NCHRP models. Reference 43 is the highway noise volume of the series of reports resulting from this study of the magnitude of the transportation noise problem. References 44, 45 and 46 document the computer program as refined and used by DOT Transportation Systems Center (TSC) and the short approximate method developed in-house at DOT/TSC. On-going effort has been directed towards updating these models and providing programs for different computers to accept either the NCHRP 117 model (computerization performed by the Michigan State Highway Department) or the DOT-Transportation System Center Model.

Scale Modeling Highway and Urban Traffic Noise - In many circumstances the topography is of such a complex nature as to invalidate the generalized assumptions used in computer modeling, hence, the use of small scale physical models has been applied on two DOT contracts. In 1969 a contract was written with Ling-Temco-Vought (LTV) to study the scale modeling problem of complex highway interchanges and to develop the sound source and measurement methodology to permit reliable small scale modeling. Corporate organizational problems resulted in the transfer of numerous key personnel away from the project, consequently, adequate final reports have not been prepared documenting this study. Subsequently, the Massachusetts Institute of Technology (MIT) has had a DOT grant to study scale modeling of urban traffic situations. Final reports are in preparation (should be available before the end of calendar year 1974) documenting the results of this study of traffic flow in simulated urban canyons.

Development of Highway Noise Standards PPM 90-2 - Section 136(b) of the 1970 Federal Aid to Highway Act specified that the DOT/FHWA promulgate by July 1, 1972, standards for highway noise levels, compatible with different land uses. Accordingly on April 26, 1972, the DOT Federal Highway Administration issued an advanced copy of its Policy and Procedures Memorandum PPM 90-2 entitled Interim Noise Standards Procedures for Implementing 109 (i) of Title 23 United States Code. This was updated in February 8, 1973, by final version PPM 90-2 entitled Noise Standards and Procedures (reference 47). The development of these standards was performed primarily in-house with the assistance of consultants in the employ of the DOT and under the auspices of the Association of State Highway officials.

PPM 90-2 Training Manual and Course - To assist in the understanding and implementation of PPM 90-2 the FHWA made provisions for preparing a one-week training course in the fundamentals and abatement of highway traffic noise. This course was prepared under contract by Bolt, Beranek and Newman (BBN) and initial courses were given under the leadership of BBN. Subsequently the same course is being made available through the Federal Highway Administration Regional Structure and is being conducted in-house by FHWA employees with the assistance of a few consultants.

A manual (reference 48) has been prepared that serves as a textbook for training courses.

The Highway Noise Standards and the training course are directed to those location, site, and design aspects of highway construction which are pertinent to the control of vehicular noise as it exists on today's highways. The computer programs mentioned above are based on empirical measurements on today's highways of today's vehicular noise levels, but adjustments to reflect vehicular noise control can be made in these programs.

FHWA Highway Design Manual and Construction Equipment Standards - Other activities include the preparation of design manuals for the construction of highway roadside barriers, and the exploratory research by the state of California Division of Highways regarding the establishment of feasible noise levels for construction and maintenance equipment utilized for highway construction.

Highway Barriers: Effectiveness, Acoustic Materials, Parametrics - A variety of Federal Highway Contracts and state research projects under the Highway Trust Fund allocation for Highway Planning and Research are, and have been, underway relating to design features of highways to abate existing highway noise. The state of California has completed a project relating to traffic noise near highways and the effects of design and environmental variables, including the development and demonstration of highway barriers near impacted residential areas. A contract has been let by the DOT/FHWA with BBN to explore the ramifications of using sound absorbing material on existing highway noise barriers and within tunnels. In addition, the DOT/TSC under the DOT, Office of the Secretary has conducted in-house theoretical studies and is preparing a field measurement program to evaluate the effectiveness of highway barriers relative to the line source of noise generated by a stream of heavy flowing traffic.

Traffic and Community Noise Studies - The state of Maryland has undertaken a project relating to highway design and abatement of traffic noise and the state of New Jersey has undertaken a program of community noise measurements.

Passenger Car Tire Noise - Other activities involving the Western Region Federal Highway Administration field force and the state of Colorado pertain to the noise generated by passenger car tires on various road surfaces. The design implications of tire/roadway interaction have been discussed above in the truck noise reduction program. While the problem is somewhat different, the results of the truck and passenger car tire research have been carefully coordinated and integrated insofar as the implications of highway surfacing are concerned from the standpoint of safety and noise.

### 3.1.2 Urban Transportation Systems Noise Reduction Program

Transit Bus Noise Reduction Potential - Within the broad area of mass transportation vehicles and systems development, numerous activities are underway relating to advancing the state-of-the-art of noise control. As mentioned previously, two transit coaches are included within the DOT Truck/Bus Retrofits programs and, in addition, a demonstration project by the Washington Metropolitan Area Transit Authority (WMATA) completed in 1972 demonstrated that significant noise reduction could be achieved in current "new look" transit coaches by the application of noise control engineering. The WMATA "quick and dirty" demonstration program illustrated the need to work on engine, exhaust, intake, and cooling system aspects of coaches to achieve noise reduction. The demonstration did not include the development of practical hardware to achieve these reductions as will be the case in the project presently underway.

Purchase Specifications: Transit Coaches - Currently underway is a low level effort by MITRE Corporation to more closely examine the test procedures and specification for community and passenger noise levels associated with transit coaches. The DOT Urban Mass Transportation Administration (UMTA) provides capital grants covering some 80% of all transit coach purchases. This contract with MITRE Corporation is being conducted in conjunction with the Society of Automotive Engineers Bus Noise Subcommittee.

TRANSBUS Program - Looking further to the future, the DOT is presently developing technology for future transit coaches in the forty foot urban design category. Three parallel contracts have been awarded for the development and demonstration of such coaches. Included within the design goals and specifications are very progressive interior and exterior noise level specifications. This program is presently in the acceptance test and evaluation phase of the demonstrator transit coaches produced by three suppliers: Rohr, Inc., General Motors Truck and Coach, and AM General Corporation. The portion of the twenty-three million dollar total effort which is devoted to noise control is not known since noise is but one of many integrated specifications for the project. However, the attainment of the seventy-five dBA exterior maximum noise goal will do much to forward the state-of-the-art and is considered by the DOT as a significant activity in the noise abatement area.

Personal Rapid Transit (PRT) Program - Other systems development and exploratory efforts in the area of personal rapid transit systems (PRT'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. Contracts with Uniflow and Pullman Standard, for example, include noise oriented activities related to rail personal rapid transit design concepts. 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.

Dual Mode Program - Another activity is the so called dual mode technology development within the mass transit area. A variety of activities exploring the feasibility of integrating various modes of transportation to relieve the dependence upon automobiles includes, among other things, environmental compatibility; hence, a low level of in-house consultation and contractor effort in the noise area is included to assure noise compatibility of such systems.

Rapid Transit Systems Noise - In the area of rail rapid transit a concerted effort has been mounted to address the problems of noise in the community and the noise environment of riders and customers waiting in stations. In FY 1972 and 1973, measurement methodologies were developed to characterize the noise environment of rapid rail transit systems. The Massachusetts Bay Transportation Authority (MBTA) Lines were used as subjects for measurement and exploratory study. A final report is in preparation describing the noise climate of the MBTA. Subsequently, grants have been 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 (along the lines of the study previously conducted by TSC/DOT of the MBTA). Request for proposals have been issued for similar studies of the Cleveland, Philadelphia, and San Francisco rapid transit systems.

Wheel/Rail and Elevated Structures Noise and Vibration - Contracts have been let for studies of (1) the development of wheel/rail noise and vibration control technology and (2) the development of track and elevated structure noise and vibration control technology with Bolt, Beranek and Newman and Cambridge Collaborative, respectively.

In-Service Noise Abatement Test and Evaluation - In 1974, the in-service test and evaluation of state-of-the-art noise control techniques will be conducted including: resilient wheels in Chicago, station acoustical treatment in Philadelphia, resilient fasteners in New York, and barriers in San Francisco. The in-service test and evaluation program has as its overall objectives the definition of cost and performance data of the various techniques as well as the evaluation of each technique considering safety, maintainability, etc., for application in future corrective programs and new systems designs.

Future plans call for the development and demonstration of applications of known technology as well as heretofore unproven technology in one or more transit authorities. The producers of these efforts will feed back through the cost and abatement documentation similar to that mentioned previously for the MBTA, NYCTA, and the CTA studies. Thus an integrated time phased program is well underway for the assessment of noise impact of existing rapid rail transit systems, and the means are at hand to begin to identify and resolve environmental incompatibilities.

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 new transit systems which are being developed with massive federal support. Examples include the Bay Area Rapid Transit District, the Washington Metro Systems, the Baltimore Transit System, and Atlanta Rapid Transit System. Such specifications, developed by the system consultants and approved by the DOT, exhibit incremental noise improvements with time. Estimates of the costs of such specifications cannot be provided, however, the noise reduction contributions of such system specifications will be significant.

Other 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.

### 3.1.3 Conventional Railroad and High Speed Ground Inter-City Transportation Noise Related Programs

Measurement of Railroad Noise - Prior to the passage of the Noise Control Act of 1972, conventional railroad noise complaints ranked relatively low on the list of priorities in the DOT (as measured by the frequency or number of community complaints and/or legal actions taken). The conventional rail network is contracting rather than expanding, and much of the land use adjacent to conventional rail lines has long been established and has acclimated to the noise of conventional railroads. Due to the desire of railroads to have uniformity of control and in reaction to a growing body of regulatory attempts by cities and states, the railroads lobbied for inclusion of Section 17 in the Noise Control Act of 1972 which requires the EPA to establish standards for noise emission of railroad equipment and facilities and for the DOT to write compliance regulations. Accordingly, the DOT undertook an accelerated program of in-house measurements of railroad noise to explore the magnitude of the problem and the means by which measurements and/or enforcement procedures could be developed. A number of measurements in the field were made of conventional and high speed trains between

Washington and New York and New York and Boston which encompass conventional freight, conventional passenger, Metroline and Turbo Train. One report (reference 49) has been published and an article (reference 50) based upon the data was published in "Sound and Vibration." In addition, an exploratory research program utilizing a load cell facility was undertaken to acquire baseline information on locomotive noise as a function of throttle position and fan operating cycle. Measurements of property line and specific source noise emissions were made during a one-week period in the Argentine yards of the Atchison, Topeka, and Santa Fe Railroad in Kansas City. Extensive data were acquired reflecting the property line noise levels as a function of noise source and operating mode. These data were acquired in a cooperative venture to support the EPA standards setting responsibility under Section 17 of the Noise Control Act and will be published shortly (reference 51).

Joint DOT/Association of American Railroads (AAR) Noise Research - Currently underway is a railroad noise research program in cooperation with the Association of American Railroads. This program will investigate locomotive noise characteristics under various operating modes with the prime objective being the development of simple, but effective, locomotive noise tests techniques. Also to be studied in this program is the effect of multiple locomotive units and propagation across adjacent terrain in order to allow efficient and equitable enforcement of EPA noise standards. Finally within the program, the demonstration of the effectiveness of retarder noise barriers is planned.

The above railroad noise research program will be initiated in FY 1974 and will carry through FY 1975 and portions of FY 1976. From this study it is expected that simple and reliable test techniques for evaluating railroad/locomotive noise, identification of individual sources of locomotive noise, identification of site variables pertinent to the measurement of locomotive/rail car noise, and demonstration of railroad retarder barriers to abate the excessive noise of these facilities will be accomplished. Cooperation on the part of the nation's railroads is anticipated through the gratis supply of equipment and operating personnel. From this base of information more specific actions in the future can be taken to identify the need to reduce railroad noise further and the means by which such reductions, if required, can be made.

High Speed Inter-City Dedicated Guideway Transportation Systems - Also within the DOT program of exploratory research and demonstration are activities associated with high speed intercity dedicated guideway type of transportation systems. Within these engineering demonstration efforts are a number of noise specifications and specific noise abatement tasks. For example, the Linear Induction Motor Research Vehicle, which is a steel wheel rail/linear induction motor propelled test vehicle operating at the Pueblo High-Speed Test Site, is being subjected to evaluation of noise sources with emphasis on rail wheel noise and if feasible, exploration of linear induction motor and reaction rail noise generation. In conjunction with the Federal Republic of Germany and their high-speed ground research program, DOT anticipates acquiring data from tests of German magnetically levitated vehicles centering on the evaluation of aerodynamically generated noise of high speed vehicles. Engineering development programs of prototype tracked air cushion vehicle (PTACV) will provide additional information on the noise generation of air movers for such vehicle, cushions, and once again linear induction motor components. Noise specifications previously set for the PTACV have been factored into the design. Evaluation and, if necessary, corrective measures in future years will reveal significant findings regarding the peculiar apparatus of such high-speed ground transportation vehicles.

## 3.2 DOD SURFACE VEHICLE NOISE CONTROL PROGRAMS

The surface vehicle noise research programs identified within the DOD are those sponsored by the U.S. Army Tank Automotive Command (TACOM) and the U.S. Army Mobility Equipment Research and Development Center (MERDC). The TACOM Noise Control Program is divided into two program areas: Conformance with Regulatory Requirements and Vehicle Signature Reduction. Both are funded by the Army Materiel Command under the Tank and Automotive Technology Effort and are classified within the DOD as Exploratory Development Projects. The MERDC program is entitled "Noise Reduction Program for U.S. Army Construction Equipment" and includes mobile and stationary construction equipment. However, this report will only describe the portion of the program concerned with construction vehicles. The stationary construction equipment considered in the MERDC Program is addressed in the Federal Machinery Noise Panel Report entitled "Federal Machinery Noise Research, Development, and Demonstration Programs: FY73-FY75." Copies of this report are available from EPA. The projects associated with these programs are listed in Tables 3.7, 3.8, and 3.9. The substance of the programs is also briefly described in Sections 3.2.1 and 3.2.2.

Table 3.7 SUMMARY OF DOD/TACOM CONFORMANCE WITH REGULATORY REQUIREMENTS PROGRAM

| Descriptive Title of Task | Investigator | Fiscal Year Funding ($1,000) 1973 | 1974 | 1975 |
|---|---|---|---|---|
| TACOM Noise Measurements, Standards and Coordination | In-House | 50 | 120 | |
| Construction of an Anechoic Test Facility For Vehicle and Vehicle Components | Eckel Corporation | 90 | | |
| Noise Measurement Test of Military Fleet Vehicles | In-House | | 53 | |
| Isolation and Measurement of Component Noise Emissions of a M813 5-ton Cargo Truck | Cummins Engine Company | | 9 | |
| TACOM/DOT Noise Measurements of Non-Directional Cross Country & New Military Tires | National Bureau of Standards | | 20 | |
| Purchase of Sound and Vibration Measurement and Analysis Equipment | In-House | 75 | 13 | |
| Noise Reduction of an M813 5-ton Cargo Truck | H. L. Blachford, Inc. | | 23 | |
| Modification of a Mobile Laboratory Van | PSI, INC. | | 32 | |
| | TOTALS | 215 | 270 | - |

Table 3.8 SUMMARY OF DOD/TACOM VEHICLE SIGNATURE PROGRAM

| Descriptive Title | Investigator(s) | Fiscal Year Funding ($1,000) | | | |
|---|---|---|---|---|---|
| | | Prior to 1973 | 1973 | 1974(est) | 1975 |
| Noise Signature Measurement Program | In-House | 100 | 50 | | |
| TACOM Analysis of Armored Reconnaissance Scout Vehicle Contractor Program to Reduce Exhause System Noise, Noise Reduction of the M561 GAMA Goat, & Information Dissemination | In-House | | 50 | | |
| Vehicle Noise Specifications and Field Tests of Het-70 and M520 Goer Pilot Vehicles | In-House | | | 37 | |
| Military Vehicle Track Modelling Noise and Vibration Study | Bolt, Baranek & Newman | | | 28 | |
| Computer Correlation of Vehicle Detectability | Bolt, Baranek & Newman | | | 30 | |
| | TOTALS | 100 | 100 | 95 | |

Table 3.9 SUMMARY OF DOD/MERDC NOISE REDUCTION PROGRAM FOR U.S. ARMY CONSTRUCTION VEHICLES

| Descriptive Title | Investigator | Fiscal Year Funding ($1,000) 1973 | 1974 | 1975 |
|---|---|---|---|---|
| Off-Road Vehicle Noise Survey | | | | |
| Operator Noise Exposure | In-House and Dayton T. Brown, Inc.* | 44 | + | |
| Exterior Noise | In-House** | + | + | + |
| Noise Specification/Standard Development | In-House | + | + | + |
| | Total | (44) | (+) | (+) |
| Vehicle Noise Control | | | | |
| D7 Crawler Tractor | Caterpillar Tractor Co. and In-House | 130 | | |
| 6K Rough Terrain Forklift Truck | Dayton T. Brown, Inc. and In-House | 75 | 30 | |
| 10K Rough Terrain Forklift Truck | H. L. Blachford, Inc. and In-House | 75 | 30 | |
| 830 MB Wheeler Tractor | Kamperman Associates, Inc. and In-House | | 60 | 80 |
| 6K Warehouse Forklift | Allis-Chalmers | | 140 | 65 |
| | Total | (280) | (260) | (145) |
| Component Noise Control/Control Components | | | | |
| Hydraulic Noise | Oklahoma State University | 20 | 40 | 10 |
| Accoustical Materials | Dayton T. Brown, Inc. and H. L. Blachford | 25 | | 5 |
| | Total | (45) | (40) | (15) |
| | GRAND TOTAL | 369 | 300 | 160 |

* Subcontract to Kamperman Associates, Inc.
** Also in conjunction with the "Vehicle Noise Control Program"
\+ Not dedicated to noise

3.2.1 TACOM Surface Vehicle Noise Reduction Program

Conformance with Regulatory Requirements - The objective of this effort is to measure and reduce noise levels of all military vehicles that fall within the jurisdiction of military and commercial noise standards. Both interior and near field exterior noise emissions are considered. The following standards are among those that are addressed:

Table 3.10 SUMMARY OF MILITARY AND COMMERCIAL NOISE STANDARDS

| Title | Source | Portion of the Vehicle Affected Int. | Exc. | Nondetectability |
|---|---|---|---|---|
| MIL STD 1474 (MI) Noise Limits for Army Material | Army | X | X | X |
| TB 251 | Army | X | | |
| Public Law 92-574 Noise Control Act of 1972 | Federal | X | X | |
| MIL H 46855 Human Engr Request for Military Systems | Army | X | | |
| MIL STD 1472 Human Engr Design Criteria | Army | X | | |
| EPA Proposed Standards | Federal | | X | |
| Federal Motor Carrier Safety Regulation | Federal | X | | |
| Occupational Safety & Health Act (OSHA) | Federal | X | | |

The Conformance with Regulatory Requirements Program was initiated in FY 73. The following represents a distribution of the resources by tasks and the work accomplished:

TACOM Noise Measurements, Standards and Coordination - This in-house project consisted of a number of tasks. For example an Army Materiel Command (AMC) Working Group on noise formulated Military Standard (MIL STD) 1474 (reference 52). Existing military vehicle noise test data were compiled and additional "quick" tests were run at the Yuma Proving Ground (YPG). Two TACOM reports were published (references 53,54). A coordination effort on interior noise included developmental measurements and noise reduction cost estimates on M551, M746, M123, M578, and M114 vehicles. Cooperative efforts were undertaken with other TACOM agencies to establish the following ranking of vehicles requiring measurement of interior and exterior noise emission.

| | |
|---|---|
| (1) M35A2 Cargo Truck | (6) M561 Gama Goat |
| (2) M818 Tractor Truck | (7) M746 Heavy Equipment Transporter |
| (3) M813 Cargo Truck | (8) M520 Cargo Goer |
| (4) M817 Dump Truck | (9) M559 Tanker Goer |
| (5) M151A1 Jeep | (10) M553 Wreaker Goer |

In addition, TACOM transferred $10,000 to the U.S. Army Test and Evaluation Command (TECOM) at the Aberdeen Proving Ground (APG) for a MIL STD 1474 interior and exterior noise measurement of 3 new samples each of M151A2 and M561 vehicles (this was a "piggy back" measurement on a vehicle product assurance test). Resources for this effort were increased to $100,000 in FY 74. Emphasis was in assisting in revisions to MIL STD 1474, support of measurement and suppression of noise on several types of high mobility tactical vehicles, and coordination of contract efforts.

Anechoic Test Facility Construction - This project resulted from the transfer of $165,000 from another TACOM Division for truck engine noise reduction work (DA Project 1G563621DG07). The effort was as follows: A $90,000 contract was awarded Eckel Corporation for the construction of a semi-aechoic test facility. Noise measurements on vehicles, engines and transmissions may be accomplished in this facility which will accomodate vehicle sizes up to and including the 5-ton M809 series truck. $75,000 was utilized for noise measurement equipment for the chamber.

Noise Measurement Test of Military Fleet Vehicles - A TECOM noise measurement test of military fleet vehicles was initiated in FY 74 using MIL STD 1474 test criteria. The test location was the Aberdeen Proving Ground. Five vehicles, each of seven types, were tested. The types were M151A1, M561, M35A2, M35A2C, M818, M813, and M817. The testing was completed in July 1974.

Isolation and Measurement of Component Noise Emissions of an M813 5-ton Cargo Truck - This contract with Cummins Engine Company was initiated in July 1973 and was designed to isolate and measure component noise emission on one M813 5-ton cargo truck. The testing was completed in August 1973.

TACOM/DOT Noise Measurement of Non-Directional Cross/Country (NDCC) & New Military Tires - This joint effort was conducted by NBS at Wallops Island, Virginia. The tests were run from July through September 1973, and a report (reference 55) was published.

Purchase of Sound and Vibration Measurement and Analysis Equipment - This equipment was purchased for in-house use in FY 1973 and FY 1974.

Noise Reduction of an M813 5-ton Cargo Truck - A contract was let with H. L. Blachford, Inc., for the period of September 1973 to June 1974 to reduce the interior and exterior noise levels of an M813 5-ton cargo truck to conform with MIL STD 1474 criteria and to provide data on cost versus noise reduction achieved. A report (reference 57) has been published on this work.

Modification of a Mobile Laboratory Van - A contract was negotiated with PSI, Inc., to facilitate installation of new noise measurement equipment in the TACOM mobile laboratory van. The contract duration was December 1973 to July 1974.

## Vehicle Signature Reduction

Noise Signature Measurement Program - This in-house effort by TACOM directly assisted the project manager of Remote Battlefield Sensor Systems (REMBASS) by providing data reduction and a report on a classified signature program. Noise signatures were measured on the following military vehicles:

| Tracked | Wheeled | Aircraft |
|---|---|---|
| M60 | M151A2 | UH1H |
| M551 | M35A2 | CH46 |
| M113A1 | M813 | T33 |
| M114 | M561 | C130 |
| M578 | GAZ59 | |
| M109 | ZIL157 | |
| PT76 | | |

A TACOM report (reference 56) was published. Previously obtained data on combat vehicles were analyzed to determine the attenuation of various frequencies of the noise signatures with distance. Transcription of vehicle noise data tapes were transmitted to the Naval Air Development Center (NADC), the U.S. Air Force Rome Air Development Center (RADC), the U.S. Army Mobility Equipment Research and Development Center (MERDC), and the Army Crop of Engineer's Waterway Experiment Station (WES).

TACOM Analysis of the Armored Reconnaissance Scout Vehicle (ARSV) Contractor Program to Reduce Exhaust System Noise, Noise Reduction of the M561 GAMA Goat, and Information Dissemination - The ARSV (XM800) contractor tests of the plans for reducing exhaust system noise were reviewed and recommendations transmitted to the project manager. Evaluation and reduction of noise sources on the M561 Gama Goat was partially accomplished (continued in FY 74). As the Research and Engineering Directorate's prime proponent for noise reduction, information was disseminated to and technical inquiries answered from other TACOM organizations.

Vehicle Noise Specifications and Field Tests of HET - 70 and M520 Goer Pilot Vehicles - This in-house task involved providing assistance to project managers on noise inputs to vehicle specifications and performing noise field tests on HET-70 and M520 Goer pilot vehicle.

Military Vehicle Track Modelling Noise and Vibration Study - This contract is with Bolt, Beranek, and Newman (BBN) of Chicago and involves the reduced scale modelling of a combat vehicle track to determine the contribution of various track and suspension components to vehicle noise.

Computer Correlation of Vehicle Detectability - This contract is also with BBN and has produced a computer program for the prediction of vehicle detection ranges. A report (reference 58) of this work has been published.

Future Objectives of the TACOM Program - For the period of FY 75-78, the DOD/TACOM noise research program objectives can be summarized as follows:

1. Continue TECOM-APG Vehicle Noise Measurement Program.

2. Isolate and measure component noise on all offending vehicles measured in the Conformance with Regulatory Requirements Program.

3. Conduct cost effective noise reduction work on offending components measured in the Vehicle Signature Program.

4. Continue liaison with other government and commercial organizations involved in noise standards and noise reduction.

5. Continue work with Army Vehicle Project Managers and engineers on new vehicles under development and on vehicle product improvement programs.

6. Investigate computer modeling techniques for prediction of component noise contribution to the total vehicle noise output and for prediction of vehicle aural security distances.

### 3.2.2 MERDC Noise Reduction Program for U.S. Army Construction Vehicles

#### Off-Road Vehicle Noise Survey

Operator Noise Exposure - To evaluate the average noise reduction requirements of much of MERDC construction equipment, a noise exposure monitoring program was initiated. This noise program required evaluation of several instrumentation systems to measure average noise levels. These systems included tape recordings analyzed by digital computer, analysis of noise on site with a statistical distribution analyzer, and analysis with commercially available noise dosimeters. The first noise exposure monitoring site was the Army Engineer Training Center at Fort Leonard Wood, Mo. In general, these techniques showed the average noise level to be lower than that determined by simple sound level (reference 67) over a short interval (reference 69,74).

Exterior Noise - Exterior noise measurements were made on U.S. Army construction vehicles at Ft. Belvoir, Virginia. Measurements were made at 15.24 meters (50') in accordance with SAE criteria (reference 70). In addition similar measurements were made in conjunction with the "Vehicle Noise Control Program."

Noise Specification/Standard Development - An informal evaluation and study of noise standards and criteria was carried out over a period of time in conjunction with other government agencies and industry groups. Primary criterion that had to be met was the noise exposure criterion of the Army Surgeon General (i.e., no soldier should be exposed to more than an average of 85dB(A) over an 8 hour period). This criterion dictated the need to evaluate the energy average of the machine noise reaching the operator's ear. This evaluation was rather difficult because the average, normal, or typical use of the equipment was not defined. To overcome this problem, a baseline noise exposure monitoring program was carried out as described in the "Operator Noise Exposure" project above. The results of these studies were incorporated in MIL STD 1474A to be published in March 1975 (reference 71). This standard will present design guidelines for implementing usage standards such as the Army Surgeon General Criterion and the OSHA noise regulations.

## Vehicle Noise Control

D7 Crawler Tractor - An initial effort was made to determine the major problems that would be anticipated in requiring a low noise polluting vehicle and what were the practical limitations. In 1972, a contract was awarded to Caterpillar Tractor Co. to study a military version of the D7 crawler tractor with the following goals:

1. Measure the variation of noise on production line vehicles and develop baseline data.

2. Determine each major source of noise and establish the noise level of each.

3. Reduce the noise at each source as far as practical and determine the effects on vehicle performance.

4. By use of external means, reduce the noise level to 90dB(A).

5. Provide a feasibility study of reducing the noise to 90dB(A) in the operator's compartment while the vehicle is moving.

6. Reduce the noise level to the lowest possible level.

7. Develop practical means of reducing the noise level effect resulting from the addition of rollover protective structures (ROPS).

This report provided a voluminous amount of information (reference 72), thus, only a summary of the results is provided here.

The major noise sources identified in the study were engine block, fan, exhaust, hydraulic pump, drive train, power train, and track. In addition to noise reduction work on the engine, exhaust, fan, and hydraulic system, work was performed on the overall machine configuration to block off the noise. Two major areas considered were the engine and operator compartments. The end result was that the noise level was reduced substantially from 99 to 91dB(A). This was a relatively simple package in respect to maintenance and almost met the original objective of 90dB(A). Reducing the fan speed 10% met the objective but provided insufficient airflow and cooling. The only other major sources of noise which could not be adequately addressed were the hydraulics and track.

The overall result (reference 73) was a package for retrofit of the basic vehicle noise but did little for track noise. The level did not meet the goal of 90dB(A), let alone the Surgeon General's criterion of 85dB(A), and cost would have been several thousand dollars. As a result, it was felt that retrofit of these machines in the field would not be appropriate.

6K Rough Terrain Forklift Truck - The program on the 6000 lb. capacity (6K) truck was awarded under a time and materials contract to Dayton T. Brown, Inc. The contractor was to proceed step by step as directed by the MERDC. The initial noise level of the vehicle was 99dB(A) at high idle (HI), and after initial noise reduction modifications were accomplished, the HI noise level was about 88dB(A). From this configuration several additional noise reduction methods were sought, and the initial modifications were reworked to make them more practical. The dominant noise source at this point was the fan, since its complete removal reduced the overall noise level to 86dB(A) and no other source was as significant. In accordance with previous findings, major emphasis was placed on a new shroud system. This, in conjunction with additional absorption material in the engine compartment, reduced the overall noise level to 87dB(A) at HI (reference 73).

10K Rough Terrain Forklift Truck - The 10,000 lb. capacity (10K) forklift noise control program was awarded as a fixed price level-of-effort contract to H. L. Blachford, Inc. Blachford was to proceed without knowledge of the work of the 6000 lb. capacity forklift program contractor. The initial HI noise level for this vehicle was 102dB(A) but this was reduced to 91dB(A) using similar treatments as with the 6K vehicle. In addition, a shield was placed behind and to the side of the operator, providing an additional 4dB(A) reduction to 87dB(A) (references 68,80).

The average noise levels of both of the 6K and 10K forklifts in typical operation were within the 85dB(A) requirement. Since these two items of equipment are relatively large materials handling vehicles and are similar to construction vehicles, particularly loaders, it is felt that almost any item of wheeled equipment can be reduced to a safe average noise level.

830 MB Wheeler Tractor - The 830 MB noise control program was initiated in January 1974 to reduce the operator noise of the tractor to 85dB(A) average. In conjunction with other efforts in the Vehicle Noise Control Program, a methodology for conducting similar programs is being developed. The 830 MB Wheeler Tractor study and the status and results of the Vehicle Noise Control Program are reviewed in reference 75. The 830 MB Wheeler Tractor program is to be completed in FY 1976.

6K Warehouse Forklift - This program was initiated to determine the average noise level of this commercially available vehicle, to reduce the average noise levels to 85dB(A), and to evaluate the feasibility of reducing the noise level to 85dB(A) maximum. Engineering is to be completed by FY 1976.

Hydraulic Noise - One of the more difficult problems is the reduction of hydraulic noise. Major efforts were involved in isolating mounts and covering up components, but it was felt that further basic work was needed. The initial approach was to try to select a "quiet" pump, but it was determined that there were no satisfactory standards for measuring the noise of pumps. Work was done in conjunction with Oklahoma State University (OSU) and the National Fluid Power Association (NFPA) to develop a procedure which has subsequently been submitted to the International Organization of Standardization (ISO). As the vehicle studies progressed, it became apparent that although most pumps are rated as to the amount of noise they emit to the air, the real problem is the amount of "noise" that is fluidborne and is released downstream at the hoses, valves, and reservoirs. Levels reached the equivalent of over 200dB(A). It is interesting to note that in either case the noise is more adversely dependent upon the shaft speed than system pressure, but this is more true for fluidborne noise. In this study, no attempt was made to develop a "quiet" pump but rather to give an effective means to tradeoff performance parameters in order to reduce noise. Present work has been generally to study the phenomenon of noise in hydraulic systems. This will continue in the future along with the development of practical means to reduce noise (references 76,77).

Acoustical Materials - During the studies on various vehicles, it was necessary to use a wide range of absorption, damping, and barrier materials. An attempt was made to select materials that would be compatible with field operations. Construction equipment operates in a severe environment, and military equipment has special problems of temperature extremes, long periods of non-usage, and limited cleaning facilities. Some difficulty was experienced in obtaining data on materials relating to the effects of solar radiation, impregnation with dust and oil mist, steam-cleaning battery acid, etc.

A series of tests were developed to simulate field conditions and these were put in typical sequence. For example, one test related to placing oil on a material exposed to high temperature and steam-cleaned. Test procedures are given in reference 78.

## 3.3 EPA SURFACE VEHICLE NOISE RD&D PROGRAMS

### 3.3.1 Support of Regulations Development

The surface vehicle noise RD&D sponsored by the EPA is principally associated with the development of surface transportation regulations specified in the Noise Control Act of 1972. Specifically, the EPA research has supported the development of regulations for control of noise from interstate motor carriers, interstate rail carriers, and new medium and heavy duty trucks. A summary of the EPA research on surface vehicle noise is presented in Table 3.11. The details of these activities are described below.

Interstate Motor Carriers - A contract effort with Wyle Laboratories was undertaken in June 1973 to conduct a cost and technology assessment of the motor carrier industry with regard to noise abatement applications. The contractor was to review all major noise emitting operations of interstate motor carriers and describe them. This description was to include, but not be limited to, a characterization of the noise profile, an estimate of the number of people impacted by the noise, and an assessment of how these people are impacted. In describing the technology available to retrofit interstate motor carriers for compliance with varying degrees of noise control, cost estimates were made of each level of noise control achieved. Final reports (references 82,83) on this contract have been submitted to EPA. The cost of this contract was $130,000.

The services of Bolt, Beranek and Newman (BBN) were obtained through the basic ordering agreement procedure for direct analysis work on the dockets submitted during the development of the interstate motor carrier regulation. No specific reports were produced but the output from this effort was recorded in memorandums on a continuing basis during the period of the contract and has been incorporated in the EPA background document (reference 84) for the interstate motor carrier noise regulation. Value of the basic ordering agreement for this effort was $30,000.

Interstate Rail Carriers - Bolt, Beranek & Newman was awarded a contract to assess the technology and cost of retrofit of the interstate rail carrier fleet for compliance with various noise control levels as determined by the availability of technology. This contract included an assessment of available technology and the cost incurred to apply those specific elements of available technology. Also, this contract involved an analysis of the impact on the population from railroad noise and the projected incremental changes in that impact as a result of technology application to railroad noise sources. A series of draft reports were prepared by the contractor and submitted to EPA for review. The result of this study in major part was included in the background document (reference 85) prepared by EPA and made available to the public at the time of the publication of the proposed railroad regulation. This contract effort is now complete and the level of funding was $134,000.

As a result of additional requirements to refine the data base in support of the proposed rail carrier regulation, BBN was contracted through a basic ordering agreement to do additional specific work on the

Table 3.11 SUMMARY OF EPA SURFACE VEHICLE NOISE RESEARCH ACTIVITIES

| | | Total Fiscal Year Funding ($1,000) | | |
|---|---|---|---|---|
| Descriptive Title | Investigators | 1973 | 1974 | 1975 (1) |
| Interstate Motor Carriers | Wyle, BBN | 170 | | |
| Interstate Rail Carriers | BBN & NBS | 199 | | |
| New Medium and Heavy Duty Trucks | Wyle, BBN, A. T. Kearney & NBS | | 178 | |
| | TOTALS | 369 | 178 | |

(1) No FY 75 fiscal data available

application of mufflers to the in-use locomotive fleet and to assist with the analysis of the railroad docket. This effort is still underway although several informal memorandums including additional data have been submitted to EPA. Some of the information generated by this effort is included in the background document (reference 85) published in support of proposed rail carrier regulation. The amount of this contract effort was $40,000.

The National Bureau of Standards through an interagency agreement conducted a series of studies on railroad noise emission levels and has published a joint EPA/NBS report (reference 86) on the results of their study. The level of funding for this study was $25,000.

New Medium and Heavy Duty Trucks - Wyle Laboratories was contracted to conduct an initial assessment of the cost and technology required to produce new trucks having various levels of noise emissions. This was an initial state-of-the-art study to assess available noise control technology and to provide cost estimates representing the application of this control technology. This study has been completed and a final report (reference 87) is available. Cost of this study was $17,000.

Bolt, Beranek & Newman was contracted to continue the work in technology and cost assessment initiated by Wyle Laboratories in refining the data base upon which the medium and heavy duty truck regulation could be developed. This effort involved a more detailed look at the available technology and specific cost estimates to apply that technology and was conducted in conjunction with the economic analysis by A. T. Kearney (see below). The overall objectives were to provide a total assessment of potential regulatory levels of noise control on the industry and to form a basis for the Federal regulatory action. This contract was completed in January 1974. The amount of this contract effort was $110,000.

A. T. Kearney was contracted to do an indepth economic analysis based on the cost estimates established during the study on the impact of various strategies of noise control on medium and heavy duty trucks. This analysis included both domestic and import/export impacts as a result of various noise control strategies. This contract has been completed. The resources required for this contract were $41,000. The results of the BBN and A. T. Kearney studies have been combined and included in the EPA background document (reference 88) for the proposed medium and heavy truck noise regulation.

The National Bureau of Standards was asked, through interagency agreement, to assess measurement methodologies which had highest potential for use in a noise control regulation for medium and heavy duty trucks. The final report (reference 89) of this study has been completed and is available from either NBS or EPA. The amount of resources for this study was $10,000.

## 3.4 USDA SURFACE VEHICLE NOISE RD&D PROGRAMS

Surface vehicle noise RD&D activities are sponsored by the USDA Forest Service and Cooperative State Research Service. Their programs are summarized in Table 3.12 and are briefly described below.

### 3.4.1 Forest Service Programs

The broad mission and objective of the Forest Service is to manage and enhance the value of National Forests for the benefit of all U.S. citizens. Forest Service Research is undertaken to develop the knowledge and technologies required to accomplish this mission for all of America's forests and related lands. The Forest Service noise abatement programs are directed to improving both our living and working environments (a) by effectively using trees and shrubs in the reduction of outdoor noises and (b) by systematic development efforts directed toward reducing vehicle and equipment noise levels. Accordingly the Forest Service has undertaken the following two programs.

Use of Trees and Shrubs in Noise Abatement - Currently this program is being carried out at Lincoln, Nebraska, in cooperation with the Department of Engineering Mechanics, University of Nebraska. It is supported by a cooperative grant of $20,000 (FY 74). It is the purpose of this study to determine means for controlling intrusive noise by combining trees and shrubs with land-forms or other solid barriers. The combined use of solid barriers and plant material provide a usable and practical approach for reducing noise levels under a number of conditions. This study will develop guidelines for intrusive noise control. Additional studies of this type are not planned following completion of the current series of investigations. References 90, 91, and 92 are recent publications.

Reduction of Vehicle and Equipment Noise Levels - This program is being carried out at the Equipment Development Center, San Dimas, California, with current expenditures of: FY 74, $25,000, and FY 75, $39,000. Equipment development efforts are directed toward reducing the noise level of equipment used in and about forested areas both for improving the environment and for the improved health and safety of forest workers. This is an ongoing program of the Forest Service and funding is expected to remain at about this level in the future. Special equipment for this program is currently available at the San Dimas Equipment Development Center. References 93 and 94 are recent publications.

Table 3.12 SUMMARY OF USDA SURFACE VEHICLE NOISE RD&D PROGRAMS

| Descriptive Title | Investigator | Fiscal Year Funding ($1,000) 1973 | 1974 | 1975 |
|---|---|---|---|---|
| Use of Trees and Shrubs in Noise Abatement | Univ. of Nebraska | | 20 | |
| Reduction of Vehicle and Equipment Noise Levels | In-House | | 25 | 39 |
| Noise and Vibration of Off-Road Equipment(1) | Univ. of Illinois | 4(29) | 28(58) | |
| | TOTALS | 4 | 73 | 39 |

(1) Values in parentheses are total resources for the project. Other values are the Federal contribution to the study.

### 3.4.2 Cooperative State Research Service Program (CSRS)

Research on noise is supported as individual scientists or engineers submit projects that are approved by CSRS. The Director of the Agricultural Experiment Station, the Administrative-Technical Representative of Forestry Schools where the research is located is responsible for allocations of CSRS administered formula funds to approved projects. Grant funds are allotted to projects generated again by university scientists.

The CSRS program for noise research encourages research activities that are sound from the standpoint of science and engineering, reviews projects submitted for funding approval, and coordinates research activities among the States and with other USDA research programs.

The noise research project pertinent to surface vehicle noise is entitled, "Noise and Vibration of Off-Road Equipment". The study is being conducted at the University of Illinois, Urbana and extends from 1-7-70 to 3-6-73.

## 3.5 NSF SURFACE VEHICLE NOISE RESEARCH

NSF sponsors research based upon the merits of unsolicited proposals. Of these, there are three NSF noise research studies relating to surface vehicles. These are identified in Table 3.13 and are briefly described below.

Basic and Applied Studies of Noise - Specific work supported under this grant will be basic research on the mechanics of tire noise, sound generation and propagation in internal flows, and practical applications of pitch sequencing. In the surface vehicle related portion a study will be made of the sound generation by tire automotive tread patterns under controlled laboratory situations. The objective will be to determine the amplitude and phasing of the directional sound generation from single tread configurations, with a view towards using this information in a superposition analysis of more complex patterns eventually leading to quieter system designs.

Since the emphasis in this work is in noise from internal flows, the resource allocations have not been included in the Federally sponsored surface vehicle RD&D.

Effects of Building and other Boundaries on Motor Vehicle Noise - The goal of the investigation is to find ways and means to reduce the spread of noise pollution resulting from motor vehicles on highways, thoroughfares, and urban rapid transit systems. The program will utilize large models in an anechoic chamber, supplemented by field studies.

Table 3.13 SUMMARY OF NSF SURFACE VEHICLE NOISE STUDIES

| | | Fiscal Year Funding ($1,000) | | |
|---|---|---|---|---|
| Descriptive Title | Investigators | 1973 | 1974 | 1975 |
| Basic and Applied Studies on Noise(1) | Stanford Univ. | | (87) | |
| Effects of Buildings and Other Boundaries on Motor Vehicle Noise | UCLA | | 30 | |
| Noise and Vibration from Transportation Vehicles and Other Machinery | Purdue Univ. | | 272 | |
| | TOTALS | | 302 | |

(1) Only minor portions of this study are related to surface vehicle noise. Therefore, the total resources in parentheses are not included in the totals.

Noise and Vibration from Transportation Vehicles and Other Machinery - To complement the ongoing research at the Ray W. Herrick Laboratories of Purdue University, a broad range of research projects in noise control and accoustics will be undertaken. These include: enclosure design, automobile engine noise source identification and reduction, noise attenuation measurements in mufflers, tire noise generation, appliance noise reduction, machine tool noise reduction, barrier design, community noise from rapid transit vehicles, and other projects. A new addition, a semi-anechoic facility will be built to accommodate many of the new projects. It has been assumed that the principal activities in this effort will relate to surface vehicle noise and therefore have included all of the identified resource commitments in the Federal surface vehicle noise RD&D category.

## 3.6 NBS SURFACE VEHICLE NOISE RD&D

There is currently no surface vehicle noise RD&D being sponsored by the NBS. However, NBS does conduct research on surface vehicle noise through interagency agreements. The description of work is provided in Appendix D. Table 3.14 is a listing of these studies. The resources identified are included in the sponsoring agencies resource allocations for surface vehicle noise RD&D.

Table 3.14 SUMMARY OF NBS SURFACE VEHICLE RD&D SPONSORED THROUGH INTERAGENCY AGREEMENTS

| Sponsoring Agency | Descriptive Title | Fiscal Year Funding ($1,000) | | | |
|---|---|---|---|---|---|
| | | Prior ot 1973 | 1973 | 1974 | 1975 |
| DOT | Truck Tire Noise Studies (1) | 468 | 100 | 100 | 200 |
| DOD | Noise Evaluation Tests of Military Truck Tires | | | 20 | |
| EPA | Train Noise Study | | 25 | | |
| | Methodology for the Measurement of Noise from Trucks | | | 10 | |
| | TOTALS | 468 | 125 | 130 | 200 |

(1) Includes interior/exterior truck noise and automobile tire noise.

## 4. ANALYSIS OF THE FEDERAL SURFACE VEHICLE NOISE RD&D ACTIVITIES

The Federal research activities to control surface vehicle noise have been presented in Section 3 as integrated programs and/or projects as developed and implemented by the agencies. As such, Section 3 provides the perspective by which each agency views and treats the noise problem associated with surface vehicles.

It is also useful, however, to examine the Federal programs collectively to identify related and/or complementary activities which are addressing specific sources or systems of surface vehicle noise. From such an analysis, the emphasis in the current Federal efforts can be ascertained. Section 4 provides a brief analysis to identify the surface vehicle sources or systems which are receiving major emphasis in the current Federal effort.

Surface vehicle sources of noise include mobile systems used in transportation, construction, defense, recreation, and agriculture. The Federal surface vehicle noise control technology RD&D programs can generally be classified according to three, all inclusive noise source categories. These are highway vehicle noise, railway vehicle noise, and off-highway vehicle noise. Highway vehicle noise sources include trucks, buses, passenger cars, motorcycles. Railway sources encompass conventional and highspeed or rapid transit railroad systems. Off-highway vehicles include construction and agricultural equipment, snowmobiles, and motorboats.

In addition to the development of noise control technology for individual sources, there are other Federal research activities dedicated to noise. They are those associated with the characterization and/or control of collective or area noise sources such as highways, construction sites, and railway yards, and with the development and enforcement of standards and regulations. Federal research in these areas can be classified as those concerned with systems studies of noise and with regulations support and enforcement.

Other Federal RD&D programs which are associated with noise are the development of future or advanced surface vehicle systems. Although not dedicated to noise, these programs can have a major impact on the control of surface vehicle noise. Consequently, these programs have been separately identified. However, specific noise tasks identified in these programs will be related to the appropriate noise dedicated activity.

Table 4.1 is a summary of the Federal resource commitments for RD&D programs addressing highway vehicle, railway vehicles and off-highway vehicles noise control technology development, surface vehicle noise systems studies, and regulations and enforcement. Federal allocations

Table 4.1 SUMMARY OF FEDERAL SURFACE VEHICLE NOISE RD&D ACTIVITIES

| Noise Category | Agency | | Fiscal Year Funding ($1,000) Prior to 1973 | 1973 | 1974 (est) | 1975* |
|---|---|---|---|---|---|---|
| Highway Vehicle Technology | DOT | TOTAL | 1,708 | 802 | 727 | 695 |
| Railway Vehicle Technology | DOT | TOTAL | - | 330 | 250 | |
| Off-Highway Vehicle Technology | DOT | | - | | 50 | |
| | DOD/ARMY | | 100 | 469 | 395 | 160 |
| | USDA | | - | 4 | 53 | 39 |
| | | TOTAL | 100 | 473 | 498 | 199 |
| Noise Systems Studies | DOT | | 301 | 350 | 857 | 310 |
| | NSF | | - | - | 302 | - |
| | USDA | | - | - | 20 | - |
| | | TOTAL | 301 | 350 | 1,179 | 310 |
| Regulations and Enforcement | DOT | | 57 | 672 | 272 | 130 |
| | EPA | | - | 369 | 178 | - |
| | DOD/ARMY | | - | 215 | 270 | - |
| | | TOTAL | 57 | 1,256 | 720 | 130 |
| Advance Systems | DOT | | Noise resource allocations not available | | | |
| | | TOTAL | 2,166 | 3,211 | 3,374 | 1,334 |

*FY 75 estimates known to be incomplete

for the noise portions of advanced surface vehicle systems development are not separable from other development costs and have not been estimated. A brief discussion of the federal research activities in these categories is presented in the following sections. There are programs which have activities which relate to more than one category. In these cases, the programs have been identified with resources assigned to the category of greatest emphasis. However, the programs are also listed in the other pertinent categories if appropriate.

## 4.1 HIGHWAY VEHICLE NOISE CONTROL TECHNOLOGY RD&D

Table 4.2 contains a listing of Federal RD&D activities associated with the development of control technology for highway noise sources. The primary emphasis in these efforts is truck noise, although major efforts are indicated for control of bus noise. The majority of the Federal efforts are those sponsored by DOT and address all of the major component sources of truck noise. Future emphasis in control of truck noise is in truck tires and engine mechanical and combustion noise.

## 4.2 RAILWAY VEHICLE NOISE CONTROL TECHNOLOGY RD&D

The Federal RD&D programs directed toward the development of noise control technology for railway noise sources are listed in Table 4.3. While only one technology development program has been identified specifically for conventional rail vehicles, several major programs have been identified for rapid transit systems. DOT is the only agency sponsoring noise control RD&D for railway vehicles.

## 4.3 OFF-HIGHWAY VEHICLE NOISE CONTROL TECHNOLOGY RD&D

The Federal RD&D programs directed toward the development of noise control technology for off-highway vehicle noise sources are listed in Table 4.4. These efforts address tracked and wheeled military combat and construction vehicles, snowmobiles, and conventional diesel-engine-powered construction equipment and are sponsored by DOD/ARMY, USDA, and DOT. Although not identified specifically, there is evidence that DOD/Navy sponsors some noise control technology RD&D in this category, principally for watercraft. However, much of the DOD sponsored noise control RD&D is classified and therefore not presently available for general use. Much of the noise control technology being developed for off-highway vehicles will have potential applications to the similar highway vehicles and vice-versa.

Table 4.2 FEDERAL CONTROL TECHNOLOGY RD&D PROGRAMS FOR HIGHWAY NOISE SOURCES

| Noise Sources | Descriptive Title of Program | Sponsoring Agency | Fiscal Year Funding ($1,000) Prior to 1973 | 1973 | 1974(est) | 1975* |
|---|---|---|---|---|---|---|
| Trucks | Quiet Truck Program | DOT | 1,046 | 100 | 100 | - |
| | Truck/Bus Retrofit | DOT | | 450 | 72 | - |
| | Exhaust/Intake Mufflers | DOT | 75 | 28 | - | - |
| | Truck Noise Handbook | DOT | | 15 | 20 | - |
| | Basic Engine Noise Reduction | DOT | | | 245 | 245 |
| | Truck Tire Noise Study | DOT | 468 | 100 | 100 | 200 |
| | Truck Tire Noise Basic Research | DOT | 119 | - | 150 | 250 |
| | Engine Noise Support | DOT | | 80 | 40 | - |
| | Vehicle Signature Program (See Table 4.4) | DOD/ARMY | | | | |
| Buses | Truck/Bus Retrofit (see above) | DOT | | | | |
| | Transit Bus Noise Reduction Potential | DOT | | 26 | | |
| | Transbus Program (Advanced System) | DOT | ++ | ++ | ++ | ++ |
| Passenger Cars | Passenger Car Tire Noise | DOT | | 3 | + | |
| | Basic and Applied Studies of Noise (See Table 3.13) | NSF | | | | |
| | TOTAL | | 1,708 | 802 | 727 | 695 |

* FY 75 estimates known to be incomplete

\+ Primarily inhouse effort

++ Program is not dedicated to noise resource allocations not available.

Table 4.3 FEDERAL CONTROL TECHNOLOGY RD&D PROGRAMS FOR RAILWAY NOISE SOURCES

| Noise Sources | Descriptive Title of Program | Sponsoring Agency | Fiscal Year Funding ($1,000) Prior to 1973 | 1973 | 1974(est) | 1975* |
|---|---|---|---|---|---|---|
| Conventional Railway | Joint DOT/AAR Noise Research | DOT | (Noise Systems Study, Table 4.5) | | | |
| Rapid Transit | Wheel/Rail Noise & Vibration Study | DOT | - | 184 | | |
| | Elevated Structures Noise and Vibration | DOT | - | 146 | | |
| | In service Noise Abatement Test and Evaluation | DOT | - | - | 250 | |
| | TOTALS | | | 330 | 250 | |

* FY 75 estimates are known to be incomplete
\+ In-House
++ Programs not dedicated to noise; noise resource allocations not available

Table 4.4 FEDERAL CONTROL TECHNOLOGY RD&D PROGRAMS FOR OFF-HIGHWAY VEHICLE NOISE SOURCES

| Descriptive Title of Program | Sponsoring Agency | Noise Sources | Fiscal Year Funding ($1,000) Prior to 1973 | 1973 | 1974(est) | 1975* |
|---|---|---|---|---|---|---|
| Vehicle Signature Reduction | DOD/ARMY | Tracked Combat Vehicle<br>Wheeled Combat Vehicle | 100 | 100 | 95 | |
| Noise Reduction Program for U.S. Army Construction Vehicles | DOD/ARMY | Construction Vehicles | | 369 | 300 | 160 |
| Reduction of Vehicle & Equipment Noise Levels | USDA | Snowmobile<br>Engine Cooling Fans<br>Exhaust | | | 25 | 39 |
| Noise and Vibration of Off-Road Equipment (see Table 3.12) | USDA | Farm Equipment | | 4 | 28 | |
| Construction Equipment Mufflers | DOT | Construction Vehicles | | | 50 | |
| | | TOTALS | 100 | 473 | 498 | 199 |

*FY 75 estimates are known to be incomplete

## 4.4 SYSTEM STUDIES OF SURFACE VEHICLE NOISE

A number of Federal research programs have been identified which address noise generated by surface vehicle systems. These studies are dedicated to noise and are generally multifaceted. They can encompass development and testing of noise measurement methods, characterization of noise generated and noise systems, modeling of noise, identification of noise control methods, and RD&D of noise control technology. Since these studies are of a broad nature, the results can have many applications. However, portions of those studies which have specific noise source control technology development and demonstration objectives are identified with the appropriate individual noise sources in previous sections.

Table 4.5 is a listing of the known Federal noise studies of surface vehicle systems. These relate primarily to highways and rapid transit systems.

## 4.5 NOISE REGULATION AND ENFORCEMENT RESEARCH PROGRAMS

These research programs have been identified by the Federal agencies as direct support to the development of specific standards and regulations and the enforcement of regulations. While each study generally addresses a specific objective, collectively the projects encompass a broad range of subjects (i.e., measurements of source and area noise levels development of measurement methodologies, training, state-of-the art technology, capital grants, etc.). However, the programs can be grouped by their relationship to highway, railway, or off-highway noise control. The identified Federal research projects relating to the development and enforcement of surface vehicle regulations are listed in Table 4.6. The emphasis in the current Federal efforts has been in support of highway noise regulations and enforcement.

## 4.6 ADVANCED SURFACE VEHICLE SYSTEMS DEVELOPMENT PROGRAMS

A number of Federal RD&D programs have been identified which relate to the development of advanced or future surface vehicle systems. These programs pertain exclusively to transportation systems and none are dedicated to noise. Consequently, resource allocations for the noise portions of the programs could not be readily ascertained. However, where specific noise related tasks or objectives were identified, they have been described in the appropriate sections on dedicated noise RD&D. Generally, however, the programs are of a very comprehensive nature and noise is considered principally as a design specification. Table 4.7 is a listing of the advanced surface transportation systems RD&D programs. The emphasis is on future mass transit systems and all are sponsored by DOT.

Table 4.5 FEDERAL SYSTEMS STUDIES OF SURFACE VEHICLE NOISE

| Area of Study | Descriptive Title of Program | Sponsoring Agency | Fiscal Year Funding ($1,000) Prior to 1973 | 1973 | 1974(est) | 1975* |
|---|---|---|---|---|---|---|
| Surface Transportation | Magnitude of Transportation Noise General & Potential Abatement | DOT | (1) | - | - | - |
| | Effects of Buildings and Other Boundaries on Motor Vehicle Noise | NSF | | | 30 | |
| | Noise and Vibration from Transportation Vehicles & Other Machinery | NSF | | | 272 | |
| Highway | NCHRP Project III | DOT | 120 | 120 | 180 | |
| | Scale Modeling Highway Noise | DOT | 79 | | - | - |
| | Scale Modeling Urban Traffic Noise | DOT | - | 112 | - | - |
| | Barrier Parametrics | DOT | + | + | 50 | + |
| | FHWA Highway Design Manual | DOT | - | 54 | - | - |
| | Highway Barrier Effectiveness | DOT | 43 | 7 | - | - |
| | Traffic Noise Study | DOT | 43 | 37 | 37 | - |
| | Community Noise Study | DOT | 16 | 20 | 20 | - |
| | Acoustic Materials Applications | DOT | - | - | 115 | 110 |
| | The Use of Trees and Shrubs in Noise Abatement | USDA | - | - | 20 | - |
| Railways | Joint DOT/AAR Noise Research | DOT | - | - | 150 | 200 |
| | Rapid Transit System Noise Environment | DOT | + | | | |
| | New York City Transit System Study | DOT | | | 125 | |
| | Chicago Transit Authority Studies | DOT | | | 60 | |
| | Other Transit Authority Studies | DOT | | | 120 | |
| | TOTALS | | 301 | 350 | 1,179 | 310 |

+ Primarily in-house
* FY 75 estimates known to be incomplete
(1) See Table 3.1

Table 4.6 FEDERAL RESEARCH PROGRAMS IDENTIFIED WITH NOISE STANDARDS AND REGULATIONS ENFORCEMENT

| | | | Fiscal Year Funding ($1,000) | | | |
|---|---|---|---|---|---|---|
| Program Area | Descriptive Title of Program | Sponsoring Agency | Prior to 1973 | 1973 | 1974(est) | 1975* |
| Highway | In Cab Noise Tests | DOT | - | - | | |
| | Highway Noise Enforcement Training and Equipment | DOT | - | 450 | 70 | - |
| | Roadside Enforcement Sites | DOT | - | - | 100 | 50 |
| | BMCS Training/Equipping | DOT | | | | |
| | Development of Highway Noise Standards PPM 90-2 | DOT | + | + | + | |
| | PPM 90-2 Training Manual & Course | DOT | - | 132 | + | + |
| | Purchase Specifications - Transit Coaches | DOT | - | - | 22 | - |
| | Interstate Motor Carrier Regulation | EPA | | 170 | + | + |
| | New Medium & Heavy Duty Trucks Regulation | EPA | | | 178 | + |
| | Conformance with Regulatory Requirements | DOD/ARMY | - | 215 | 270 | - |
| Railway | New System Specifications - Capital Grants | DOT | ++ | ++ | ++ | ++ |
| | Measurement of Railroad Noise | DOT | | | | |
| | Interstate Rail Carrier Regulation | EPA | | 199 | | |
| Off-Highway | Construction Equipment Standards | DOT | 57 | 90 | 80 | 80 |
| | TOTALS | | 57 | 1,256 | 720 | 130 |

+ Primarily in-house
++ Program is not dedicated to noise, noise resource allocations indeterminate
* FY 75 estimates known to be incomplete

Table 4.7 FEDERAL RD&D OF ADVANCED SURFACE VEHICLE SYSTEMS: TRANSPORTATION

| Type of System | Descriptive Title of Program | Sponsoring Agency | Fiscal Year Funding ($1.000) Prior to 1973 | 1973 | 1974 | 1975* |
|---|---|---|---|---|---|---|
| Bus | Transbus Program | DOT | ++ | ++ | ++ | ++ |
| Rapid Transit | Personal Rapid Transit (PRT) Program | DOT | ++ | ++ | ++ | ++ |
| | Linear Induction Motor Research Vehicle | DOT | ++ | ++ | ++ | ++ |
| | Magnetical Levitated Research Vehicle | DOT | | | + | + |
| | Tracked Air Cushion Research Vehicle | DOT | ++ | ++ | ++ | + |
| | Prototype Tracked Air Cushion Vehicle | DOT | ++ | ++ | ++ | ++ |
| | State of Art Car | DOT | ++ | ++ | ++ | + |
| | Screech Loop-Pueblo Facility | DOT | + | + | ++ | ++ |
| Mass Transit (General) | Dual Mode Program | DOT | | | ++ | ++ |

\+ Primarily in-house

++ Program is not dedicated to noise, noise resource allocations indeterminant

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# 6. APPENDICES

CONTENTS: PAGE NO.

APPENDIX A
SURFACE VEHICLE NOISE RESEARCH PANEL MEMBERS

| | |
|---|---|
| Osman A. Shinaishin (Chairman)<br>Noise Technology Staff, RD-681<br>U.S. Environmental Protection Agency<br>401 M Street S.W.<br>Washington, D.C. 20460 | 202-755-0449 |
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| William Leasure<br>Applied Acoustics Section<br>National Bureau of Standards<br>Room A149 Sound Building<br>Washington, D.C. 20234 | 301-921-3381 |
| Donald W. Rees (TACOM)<br>Department of the Army<br>U.S. Army Tank-Automotive Command<br>Warren, Michigan 48090 | 313-573-1653 |
| William Roper<br>Office of Noise Abatement and Control (AW-571)<br>U.S. Environmental Protection Agency<br>1921 Jefferson Davis Highway<br>CM-2<br>Arlington, Va. 20460 | 703-557-1180 |
| George Winzer<br>Manager, Environmental Research<br>Room 4210<br>Department of Housing and Urban Development<br>451 Seventh St., S.W.<br>Washington, D.C. 20410 | 202-755-5597 |

APPENDIX B

INFORMATION REQUESTED BY

EPA ON THE FEDERAL NOISE

RD&D PROGRAMS AND PROJECTS

## INSTRUCTIONS

The objectives of this information-gathering document is to assemble the data necessary to describe the over-all efforts within the Federal Government dealing with noise research, development and demonstration programs. The results will be used as a portion of the EPA report to the President and Congress on the status of Federal noise programs and to aid in coordination of Federal noise research efforts within Government agencies. The process is dynamic requiring that the data base be updated periodically to reflect changes in efforts, emphasis, expenditure of funds or completion of programs or projects.

The information requested on noise related programs and projects deal with the following areas:

- Program (Project) description.
- Technical goals and achievements.
- Financial and manpower resources devoted and required.
- Facilities used or required, and
- Key personnel.

The enclosed questionnaire is designed to reflect, as clearly as possible, the type of information required, but is not intended as a rigid format, hence, any agency forms that will furnish the required information easier than the questionnaire should be used by all means. If the questionnaire is used, notice should be made that:

1. Additional sheets may be used, and are encouraged, to furnish more details if the space provided is not adequate.

2. There is always a risk of not supplying enough information for the desired visibility of any program (project), but there is no risk of giving too lengthy information since this can easily be adapted to the overall report intensity or detail.

3. If the questionnaire forms miss entire aspects of program information, it is encouraged, in fact necessary, that you add these aspects under additional proper titles.

4. If your agency has a documented (or computer-stored) plan-program-project outlay with the required information it is strongly urged that it be included in the response.

5. The program (project) information supplied should reflect actual FY 73 funding, allocated FY 74 and projections for FY 75 and later years.

6. For programs (projects) in which noise is only a part or a consideration it is requested that information should be given on:

   A. Program (project) specifics as outlined in the questionnaire.
   B. Additional statement on the relationship of the noise-related effort to the over-all scope of the program (project).

7. Finally, for any desired clarification of questions on this document, please call Dr. Eugene E. Berkau of the EPA at 202-755-0449.

The response to this questionnaire is requested by April 19, 1974.

Definitions in Responding
to the Form Titled

"FEDERAL NOISE RD & D PROGRAM SUMMARY"

| Item | Remarks |
|---|---|
| 1. Program Title | The formal agency title of record |
| 2. Agency Program Number | The formal number of record; if programs are not numbered, write 'none'. |
| 3. Agency or Department | Parent organization (e.g., DOT, DHEW). |
| 4. Interagency Agreements in Effect | Identify other agencies or departments participating in the program and a brief description of their tasks. |
| 5. Subdivision Directing Work | Organizational element where program responsibility exists (NIOSH/Physical Agent Branch) Name of Head. |
| 6. Other Key Personnel | Additional leading personnel involved in administrative or technical management of overall program. |
| 7. Principal Contractors | Identify contractors doing work for agency at the program (not the project) level. |
| 8. Technical Program Goals | Those considered environmental goals, like quieting a specific machine by 10dB, or improving the reliability and sensitivity of needed instrumentation systems. |
| 9. Method of Approach | Plans or Methodology for achieving program objectives. |
| 10. Problem Areas | Identified technical, funding, and/or facilities problems. |
| 11. Total Resource Allocation | |
| • Funding | The level of program funding devoted to noise RD&D distributed with time. |

| Item | Remarks |
| --- | --- |
| • Man-Years | The level of program manpower resources devoted to noise RD&D distributed with time. |
| 12. Component Projects | A list of descriptive titles of those noise related projects within this program. |
| 13. Schedules and Milestones | Show the current schedule and milestones; the "revised" column is for future use. |
| 14. Principal Accomplishments | State achievements accomplished or within reach. |
| 15. Program Reports, etc. | Confine this to those stemming from the overall program rather than the individual project. Include proceedings of symposia and conferences and papers in the professional literature as well as project reports and documents. |

Note: A Federal noise RD&D program includes each program in which noise is a significant (one or more projects), identifiable program element.

Environmental Protection Agency
Office of Research and Development
FEDERAL NOISE RD&D PROGRAM SUMMARY

| | |
|---|---|
| LEAD AGENCY | Agency or Department |
| | Subdivision Directing Program/Head's Name, Title and Address |
| | Name, Title, Address of Program Manager |
| | Names and Titles of Other Key Program Personnel |

Cooperating Agency or Department and Subdivision (if any)

Program Contractor or Grantee (if any)

| | |
|---|---|
| Program Title | Agency Program Number |
| Authority (e.g., Public Laws, Agency/ Department Directives, etc.) | Date This Form is Filled |
| Date of Program Start | Scheduled Date of Program Completion. |

Check appropriate classification(s) of program

☐ Research ☐ Development ☐ Demonstration

☐ Operations Research and/or Economic Benefit ☐ Other (Describe)

Program General Objectives

Program Specific Goals:

Planned Approach: (Attach additional sheets if necessary)

Problem Areas:

| Total Resource Allocation | Fiscal Year | Cumulative through FY 72 | Actual FY 73 | Allocated FY 74 | Projected FY 75 | FY 76 | FY 77 | FY 78 | FY 79 |
|---|---|---|---|---|---|---|---|---|---|
| | Funding $Thousand | | | | | | | | |
| | Man-Years | | | | | | | | |

| Program Schedules and Milestones (Detailed schedules and milestones may also be cited and appended to this response.) | Status | | |
|---|---|---|---|
| Milestone | Scheduled Completion Date | Date Completed | or Date Revised |
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Component Projects

| Agency/Project No. | Descriptive/Project Title | Project Manager |
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Principal Accomplishments to Date (Include accomplishments relative to program goals or attained from combined project achievements)

Program Reports, Documents and Papers Published to Date: (List items attributed to the program. Complete biliographic reference is desired/author, title, date, agency, document.)

## APPENDIX C

## GLOSSARY OF ACRONYMS

I. Federal Departments and Agencies

| | |
|---|---|
| AMC | - Army Materiel Command |
| BMCS | - Bureau of Motor Carrier Safety/DOT |
| BuM | - Bureau of Mines/DOI |
| CSRS | - Cooperative State Research Service/USDA |
| DOC | - Department of Commerce |
| DOD | - Department of Defense |
| DOI | - Department of Interior |
| DOL | - Department of Labor |
| DOT | - Department of Transportation |
| EPA | - Environmental Protection Agency |
| FHWA | - Federal Highway Administration/DOT |
| HEW | - Department of Health, Education, and Welfare |
| HUD | - Department of Housing and Urban Development |
| MERDC | - U.S. Army Mobility Equipment Research and Development Center/DOD |
| NADC | - Naval Air Development Center/DOD |
| NASA | - National Aeronautics and Space Administration |
| NBS | - National Bureau of Standards/DOC |
| NIEHS | - National Institute for Environmental Health Sciences/HEW |
| NINDS | - National Institute of Neurological Diseases and Stroke/HEW |

NIOSH - National Institute for Occupational Safety and Health/HEW

NSF - National Science Foundation

ONAC - Office of Noise Abatement and Control/EPA

ORD - Office of Research and Development/EPA

OSHA - Occupational Safety and Health Administration/DOL

OVSR - Office of Vehicle Systems Research/NBS

RADC - Air Force Rome Air Development Center/DOD

TACOM - U.S. Army Tank Automotive Command/DOD

TECOM - U.S. Army Test and Evaluation Command/DOD

TSC - Transportation Systems Center/DOT

UMTA - Urban Mass Transportation Administration/DOT

USDA - U.S. Department of Agriculture

WES - Army Corp of Engineer Waterway Experiment Station/DOD

II. Trade Associations

AAR - Association of American Railroads

ASHO - Association of State Highway Officials

HRB - Highway Research Board/OSHO

MVMA - Motor Vehicle Manufacturers Association

NFPA - National Fluid Power Association

SAE - Society of Automotive Engineers

# APPENDIX D

# NBS RESEARCH ON SURFACE VEHICLE NOISE

Table D-1 SUMMARY SURFACE VEHICLE NOISE RESEARCH CONDUCTED BY NBS

| Funding Agency | Title | Objectives | Fiscal Year Funding ($1,000) Prior to 1973 | 1973 | 1974 | 1975(est) |
|---|---|---|---|---|---|---|
| DOT | Truck Tire Noise Studies (includes passenger car tire noise, interior/exterior sound levels from over-the-road trucks, and feasibility of an acoustical grading system for tires). | To provide a scientific basis for designing quieter tires. | 468 | 100 | 100 | 200 |
| DOD | Noise evaluation tests of military truck tires. | To develop a data base on tire noise levels of selected military and commercial truck tires. | | | 20 | |
| EPA | Train Noise Study | To develop a data base on railroad noise emission. | | 25 | | |
| | Methodology for the measurement of noise from trucks. | Develop appropriate measurement methodology for use by EPA in the regulation of new trucks. | | | 10 | |

## NBS RESEARCH ON SURFACE TRANSPORTATION NOISE

NBS FUNDING: No current programs.

OTHER AGENCY FUNDING:

1a. Sponsoring Agency: U.S. Environmental Protection Agency/ Office of Noise Abatement and Control

Objectives: Develop appropriate measurement methodologies as technical support to the EPA in their implementation of the Noise Control Act of 1972, and, where necessary, conduct research to provide EPA with a defensible posture as regards to measurement methodology.

Approach: Establish and conduct meetings with an ad-hoc task force of experts (acousticians, manufacturers and users) in order to develop the rationale and necessary input for the measurement methodology for medium and heavy trucks. Conduct field measurements to characterize rail line and yard operations and retarder noise.

Future Plans: Conduct work where necessary and as requested by the U.S. Environmental Protection Agency.

Accomplishments: Completed the field measurement portion of the rail yard and line noise characterization study. Assembled and met with task forces in the area of interior rapid rail transit noise and construction noise -- especially crawler and wheeled tractors -- for the purpose of developing the rationale and inputs for an appropriate measurement methodology. A preliminary draft measurement methodology resulted from each of the meetings. Assembled and met with task force in the area of medium and heavy trucks. Developed and appropriate measurement methodology and supporting documentation for medium and heavy trucks.

Publications:

Fath, J. M., Blomquist, D. S., Heinen, J. M., and Tarica, M., "Measurements of Railroad Noise - Line Operation, Yard Boundaries, and Retarders", December, 1974, Joint EPA/NBS report NBS 74-488, EPA 550/9-74-007.

Leasure, W. A., Jr., and Quindry, T. L., "Methodology and Supporting Documentation for Measurement of Noise from Medium and Heavy Trucks", NBSIR 74-517, June, 1974.

| Allocations: | FY-73 | FY 74 | FY 75(est) | FY 76(est) |
|---|---|---|---|---|
| k$: | 23 | 12 | - | - |
| Man-Years: | 0.6 | 0.3 | - | - |

1b. Sponsoring Agency: Office of Noise Control, U.S. Department of Transportation

Objectives: Identify and quantify the physical parameters which affect the noise generated by surface transportation, especially trucks and truck tires, and develop appropriate information bases and standardized testing procedures which may lead to highway noise reduction criteria, standards, and regulations.

Approach: (1) Expand the existing data base on truck tire noise to include both passenger car and military truck tires. (2) Evaluate the spectral and directional characteristics of truck tires and of their relationship to tire-noise generation mechanisms. (3) Establish the effect of surface roughness on generated noise levels by correlation studies of surface texture (as characterized by profile spectral analysis) with passby noise levels for tires. (4) Prepare a report on tire noise measurement methodology which will serve the State of California as the basis for their regulations on allowable noise levels permissible for truck and passenger car tires.

Future Plans: Conduct work as necessary and where requested by the U.S. Department of Transportation.

Accomplishments: (1) Complete (contract) work on the characterization of pavement macrotexture by profile spectral analysis, (2) completed preliminary measurements and analysis of automobile tire noise, (3) complete narrow band analysis and plot generation needed for the reports on appropriate measurement methodology for tire certification testing and the spectral and directionality characteristics of truck tire noise which will be published, (4) completed the data acquisition portion of a truck tire noise versus pavement surface study, (5) developed an empirical model for the prediction of in-service tire noise levels for over-the-road vehicles based on A-weighted sound level versus time (or distance) data for a 50 mph (80 kmh) coastby certification test utilizing a single chassis vehicle, (6) completed studies of military truck tire noise and automobile tire pavement interaction, and (7) initiated reports on expanded data base for truck tire noise and on measurement methodology for tire certification.

Publications:

Leasure, W. A. Jr., et. al., Truck Noise I Peak A-Weighted Sound Levels Due to Truck Tires - Addendum, Report Number OST/TST-72-1, July 1972, U.S. Department of Transportation, Washington, D.C.

Corley, D. M., "Test of a Proposed Method for Vehicle Noise Measurement" Proceedings of Noise-Con 73, Washington, D.C., 230-235 (Oct. 15-17, 1973).

Leasure, W. A., Jr., "Automobile Tire Noise: A Review of the Open Literature", Proceedings of Noise-Con 73, Washington, D.C., 187-195 (Oct. 15-17, 1973).

Leasure, W. A., Jr., and Mathews, D. E., "Pecos Truck Tire Noise Study: A Summary of Results", NBSIR 74-446, National Bureau of Standards, Washington, D.C. (January 1974).

Leasure, W. A., Jr., Mathews, D. E., and Rinkinen, W. J., "Noise Evaluation Tests of Military Truck Tires", submitted for publication as a Department of Transportation report.

| Allocations: | FY 73 | FY 74 | FY 75(est) | FY 76(est) |
|---|---|---|---|---|
| k$: | 100 | 100 | - | - |
| Man-Years: | 2.0 | 2.0 | - | - |

**TECHNICAL REPORT DATA**
*(Please read Instructions on the reverse before completing)*

| | | |
|---|---|---|
| 1. REPORT NO. 600/2-75-002 | 2. | 3. RECIPIENT'S ACCESSION NO. |
| 4. TITLE AND SUBTITLE Federal Surface Vehicle Noise Research, Development and Demonstration Programs FY73-FY75 | | 5. REPORT DATE MARCH, 1975 |
| | | 6. PERFORMING ORGANIZATION CODE |
| 7. AUTHOR(S) Interagency Surface Vehicle Noise Research Panel | | 8. PERFORMING ORGANIZATION REPORT NO. |
| 9. PERFORMING ORGANIZATION NAME AND ADDRESS Interagency Surface Vehicle Noise Research Panel(RD-681) Office of Research and Development Environmental Protection Agency Washington, D.C. 20460 | | 10. PROGRAM ELEMENT NO. 1GB090 |
| | | 11. CONTRACT/GRANT NO. |
| 12. SPONSORING AGENCY NAME AND ADDRESS | | 13. TYPE OF REPORT AND PERIOD COVERED Final, FY73 through FY75 |
| | | 14. SPONSORING AGENCY CODE |

15. SUPPLEMENTARY NOTES

EPA Contact: Eugene E. Berkau, 202-755-0449

16. ABSTRACT The Interagency Surface Vehicle Noise Research Panel was established by the Environmental Protection Agency to aid EPA in fulfilling it's responsibility for coordinating the Federal noise research activities. As its initial task, the Panel prepared this report summarizing the Federal governments' surface vehicle noise research, development, and demonstration activities. The Federal agencies which sponsor and/or conduct the major portion of the surface vehicle noise RD&D are represented on the Panel. They are the Department of Transportation, the Department of Commerce/National Bureau of Standards, the Department of Defense, and the EPA. Other agencies which sponsor surface vehicle noise research are the Department of Agriculture and the National Science Foundation. The report contains brief descriptions and fiscal data for the agencies' programs. Emphasis is on fiscal years 1973 through 1975. Also included are references and bibliographies of reports and publications which have resulted from the Federal surface vehicle RD&D activities.

17. KEY WORDS AND DOCUMENT ANALYSIS

| a. DESCRIPTORS | | b. IDENTIFIERS/OPEN ENDED TERMS | c. COSATI Field/Group |
|---|---|---|---|
| Acoustics | Research projects | Federal noise RD&D | 2001 |
| Noise (sound) | Ground transportation equipment | Federal noise coordination | 1406 |
| Noise reduction | Ground vehicles | Research coordination | 1306 |
| Engine noise | Water vehicles | Surface vehicle | 1303 |
| Internal combustion engine | Construction vehicles | Surface transportation | 1903 |
| Research | Combat vehicles Federal budgets | | |

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| 18. DISTRIBUTION STATEMENT Release Unlimited | 19. SECURITY CLASS *(This Report)* Unclassified | 21. NO. OF PAGES |
| | 20. SECURITY CLASS *(This page)* Unclassified | 22. PRICE |

EPA Form 2220-1 (9-73)

## APPENDIX F

Federal Noise Effects Research: FY73–FY75, Report EPA-600/1-75-001
Prepared by Interagency Noise Effects Research Panel, March 1975

EPA-600/1-75-001
MARCH 1975

Environmental Health Effects Research Series

# Federal Noise Effects Research: FY 73 - FY 75

Office of Research and Development
U.S. Environmental Protection Agency
Washington, D.C. 20460

## RESEARCH REPORTING SERIES

Research reports of the Office of Research and Development, Environmental Protection Agency, have been grouped into five series. These five broad categories were established to facilitate further development and application of environmental technology. Elimination of traditional grouping was consciously planned to foster technology transfer and a maximum interface in related fields. The five series are:

1. Environmental Health Effects Research
2. Environmental Protection Technology
3. Ecological Research
4. Environmental Monitoring
5. Socioeconomic Environmental Studies

This report has been assigned to the ENVIRONMENTAL HEALTH EFFECTS RESEARCH series. This series describes projects and studies relating to the tolerances of man for unhealthful substances or conditions. This work is generally assessed from a medical viewpoint, including physiological and psychological studies. In addition to toxicology and other medical specialities, study areas include biomedical instrumentation and health research techniques utilizing animals-but always with intended application to human health measures.

This report has been reviewed by the Office of Research and Development. Approval does not signify that the contents necessarily reflect the views and policies of the Environmental Protection Agency, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

Report 600/1-75-001
March 1975

# FEDERAL NOISE EFFECTS RESEARCH
FY 73-FY 75

Prepared by

Interagency Noise Effects Research Panel

ROAP 21AXV
Program Element 1GB090

Project Office:
Noise Technology Staff
Office of Research & Development
U.S. Environmental Protection Agency
Washington, D.C. 20460

Prepared for

U.S. Environmental Protection Agency
Office of Research and Development
Washington, D.C. 20460

ABSTRACT

Potential effects of noise on the public health and welfare are described, limitations and gaps in necessary knowledge of those effects are identified as research needs, and eight categories for analyzing noise effects research are presented. The current Federal research programs are summarized for each of the eight categories.

The Noise Effects Research Panel through its collective knowledge of the needs and the current research has identified specific research areas which need additional emphasis in order to provide accurate and thorough information on effects of noise. The Panel concluded that the current programs need continued and in some instances expanded support in order to provide necessary information on the effects of noise. Some areas of concern which are not currently being addressed are also identified.

TABLE OF CONTENTS

FEDERAL NOISE EFFECTS RESEARCH



(Cont.)

APPENDICES

TABLES

# I. SUMMARY

Potential effects of noise on the public health and welfare are described, limitations and gaps in necessary knowledge of those effects are identified as research needs, and eight categories for analyzing noise effects research are presented. The current Federal programs are summarized for each of the eight categories, and research needing additional emphasis is identified.

Known or suspected effects of noise discussed included effects on hearing, other effects which may (or may not) lead to permanent health impairment, effects on behavior such as performance or annoyance, speech and other communication interference, sleep disturbance, social/economic/political/legal/behavioral community responses, and effects on animals. Cause-effect relationships, however, have been identified by the Federal government only for hearing, annoyance, and speech interference. The information identified in these three areas is also discussed. Limitations in this information and lack of information in other areas are shown and research needed to provide thorough and accurate information on all effects of noise is identified. Such information is necessary for setting standards for protection of public health and welfare, assessment of the benefits to be derived from noise reduction in light of the costs, assurance of safe, productive work environments and adequate communications, and decisions at all levels affecting the quality of life. A way of categorizing current and needed noise effects research is presented. The current Federally-supported noise effects research is summarized for each of eight categories.

Although an in-depth analysis and assessment of the current Federal noise effects programs is not made, the Noise Effects Research Panel through its collective knowledge of the needs and the current research has identified specific research subjects which need additional emphasis in order to provide accurate and thorough information on effects of noise. These include subjects not currently receiving enough attention and those not currently being addressed. It is further pointed out that the current programs need continued and in some instances expanded support in order to provide necessary information on effects of noise.

## II. INTRODUCTION

EPA has established four noise research panels consisting of representatives from Government departments and agencies to provide informational exchange, a forum for interagency discussion, and advice to aid EPA in its role as coordinator of Federal noise research in accordance with the Noise Control Act of 1972. The panels and panel membership reflect the major thrusts of the Federal noise research programs as follows:

| Noise Research Panel | Current Agency Membership* |
|---|---|
| Aircraft | NASA, DOT, DOD, HUD, DOC, EPA |
| Surface Vehicles | DOT, HUD, DOD, DOC(NBS), EPA |
| Noise Effects** | HEW (NINDS, NIOSH, NIEHS), DOT, NSF, HUD, NASA, DOD, DOL, DOC(NBS), EPA |
| Machinery | HEW (NIOSH), DOI(Bureau of Mines), DOD, DOL, DOC(NBS), NSF. |

These panels provide the formal mechanisms for interagency consideration, review and assessment of research in the four technical areas. The primary functions of the panels in their respective areas are:

- Review and assessment of the state of science and technology relating to noise.
- Review and assessment of the status of noise research and technology development.
- Identification of technology gaps and research needs.
- Preparation of recommendations concerning ongoing research activities.
- Receipt and review of pertinent scientific and programmatic advice from communicating with other standing bodies and experts in the field of noise.

Noise effects includes not only health effects of noise such as hearing loss, but also many other known or suspected effects of noise on the well-being of humans and animals such as interference with

* Glossary of Agency Acronyms in Appendix B.
** List of Noise Effects Panel Members in Appendix C.

communication, disturbance of sleep, annoyance, and any other results of noise exposure which can affect the quality of life. For the purposes of this report and this research panel, the term "noise effects" does not include effects on structures or other inanimate objects.

## A. PURPOSE AND SCOPE

This is the first report prepared by the Noise Effects Research Panel. It will serve as an information base for developing a coordinated national plan for research leading to needed information on the effects of noise. Such information relating the various effects of noise to the physical characteristics of noise exposure such as level, frequency, and duration, as well as to the psychological content of the noise is needed for several reasons. These cause-effect relationships provide the necessary bases for setting standards to protect the public health and welfare, the data for assessing the benefits of noise reduction in light of the costs, and guidelines for personal and Government decisions affecting the quality of life.

A coordinated national plan with the various involved agencies working in cooperation can achieve the following objectives:

- research funds targeted on critical problems and issues
- coordinated and complementary efforts
- research accomplished in the most productive and scientifically viable manner.

To develop such an overall plan, limitations and gaps in the current understanding of the effects of noise must be identified. The current programs must be examined to determine which subject areas are not being adequately addressed. Programs and projects can then be identified for correcting inadequacies and addressing the gaps. The agencies' capabilities for and interests in undertaking these programs and projects can also be determined. Finally, priorities of research needs must be established. Then a national plan for noise effects research can be developed in a meaningful manner. To this end, the report specifically addresses:

- Effects of noise
- Current Federal information on effects of noise
- Limitations in the information and research needs
- A way of classifying noise effects research
- The current Federally-supported noise effects research
- Research needing additional emphasis.

The report does not consider:

- The adequacy of current research
- Detailed programs and projects for addressing gaps

- Capabilities of various agencies for addressing research gaps
- Priorities of research needs
- Development of a coordinated national plan.

This document also will be used by the Environmental Protection Agency to satisfy Section 4(c)(3) of the Noise Control Act of 1972. EPA is required to report on the status and progress of Federal activities relating to noise research and control and to assess the contribution of such activities to the Federal Government's overall efforts to control noise.

Activity for fiscal year (FY)1974 is emphasized, program continuation through fiscal year 1975 is noted where possible, and funding and work carried out during fiscal year 1973 is reported.

The data on which the report is based came from two sources, agencies' responses to a 1972 request* from EPA on Federal noise activities, and information supplied by the panel members in the spring of 1974. The fiscal data is reported consistent with each agency's budgetary process. As there are variations in the way agencies report the costs for their in-house research, exact comparisons between agencies' fiscal data cannot be made. A chart illustrating this problem is contained in Appendix D.

The data for FY 75 estimated funding is incomplete for two reasons. First, the DOD computer data base used to generate the agency fiscal data did not include FY 75 estimates. Therefore, at the DOD panel member's suggestion, the FY 75 levels have been estimated the same as FY 74. Secondly, NSF carries out research only through unsolicited grants. Thus, is it impossible for NSF to predict what research proposals may be received and funded.

Care must also be exercised in examining project and program titles and funding. Titles often do not convey the extent and kind of research being funded and convey no information of the scope of work. Thus, similar titles may involve very different work scopes and furthermore may not mean the subject is being adequately addressed.

Conclusions and recommendations made in this report are the collective opinions of the panel members and do not necessarily represent their agencies' policies.

*In December of 1972, a questionnaire survey of Federal noise research and noise control activities was initiated by EPA. A contract report was prepared from this data in October 1973 but was not published.

B. EFFECTS OF NOISE

Exposure to noise may have various effects on the public health and welfare. Some of these are well-known but the complexity of both exposure and response has prevented definitive cause-effect relationships in many areas. Other effects are suspected but not yet well-proven.

1. Hearing Damage

It has been well established that noise exposure of sufficient intensity and duration can produce hearing damage. Hearing loss resulting from intense noise exposure can either be temporary or permanent. In general, it is believed that noise of brief exposure that can produce a significant temporary hearing loss or threshold shift is capable of producing permanent hearing loss if the noise exposure is extended in duration or recurrence. That is, daily exposure to a noise which produces a temporary hearing loss presents a risk of permanent hearing loss because the ear may not be able to fully recover to its original threshold from recurrent exposures. The exact relationship between temporary and permanent hearing loss, however, is not yet clearly defined.

Hearing loss which is caused by noise occurs first in the high frequency ranges. This impacts seriously on speech understanding, and good hearing in the higher frequencies is necessary for discriminating the information-carrying, consonant sounds of human speech. Hearing loss is known to result from exposures to: continuous noise in industrial settings, impulsive sound, gunfire, and loud music for extended periods, the last is found especially among young people. The effect from fluctuating, intermittent or shorter-term exposures is not completely understood.

2. Other Health Effects

The only permanent adverse effect upon health from noise exposure that is well-established is noise-induced hearing loss. However, there is evidence, although incomplete, to indicate other effects can result from exposure of sufficient intensity and duration. Noise can alter the function of the endocrine, cardiovascular and neurologic systems. It may effect equilibrium and may produce changes such as: constriction of blood vessels in the body and vaso-dilation in the brain, rise in blood pressure and changes in heart rhythm, and change in rate of stomach acid secretions. Noise also has been shown to produce the same physiological reactions as other stressors, such as emotional stress and pain. There is not clear evidence, however, to indicate that continued activation of any of these responses leads to irreversible changes and permanent health effects.

3. Behavior Effects

When a task requires the use of auditory signals, noise that masks these signals will interfere with the performance of the task. High level continuous noise exposures appear to have potentially detrimental effects on human performance, particularly vigilance tasks, information gathering, and analytical processes. Noise may also increase the variability of work rate and affect the accuracy of work requiring mental concentration. Additionally, noise may be disruptive of performance if the noise is high frequency, intermittent, or unexpected. Noise throughout the audible range can, under various circumstances, be annoying and disruptive of activity. However, prediction of individual annoyance due to noise is difficult, probably due to the many psychological and social factors that contribute to individual sensitivity.

4. Sleep Interference

Noise can interfere with sleep by preventing sleep, by causing awakening, and by changing the level or pattern of sleep. Any of these kinds of interference may have effects on behavior and performance during waking hours as well as long term health effects if repeated. Survey data indicate that sleep disturbance is often the principal reason given for annoyance, and some experts believe that sleep disturbance is one of the most severe effects of noise on health.

5. Communication Interference

In addition to the reduced understanding of speech resulting from noise-induced hearing loss, noise can interfere directly with speech communications. Verbal communication in terms of noise level and vocal effort is extremely difficult in backgrounds of high noise level and can adversely affect the accuracy, frequency, and quality of verbal exchange. This can be important in formal education in schools, occupational efficiency, family life patterns, and quality of relaxation.

6. Community Reaction

The preceding effects of noise all deal with various effects on individuals, although statistical descriptors must be used to average out individual differences in reaction or response. However, when a community of individuals is exposed, a different kind of reaction may take place. This reaction may take several forms such as complaints to authorities, political action against noisy activities, reduction in land values or socio-economic level, high property turnover rates, or changes in family recreational patterns. Thus the consequences of community response to noise can be social, political, and economic, as well as the collective individual responses noted above. To date, only community annoyance responses to aircraft noise have been studied extensively and have been shown to correlate well with noise exposure.

The number of complaints due to noise in a community, however, is small in comparison to the number of people annoyed.

### 7. Effects on Animals

In general, noise has the same types of effects on animals as it does on humans. Hearing loss and physiologic changes have been noted in laboratory animals. Possible effects on farm animals include changes in size, weight, reproductivity, and behavior. Changes in mating behavior, predator-prey relationships, and territorial behavior have been observed in some wildlife species exposed to noise.

## C. CURRENT FEDERAL INFORMATION ON NOISE EFFECTS

There are at present three informational documents relative to health effects from noise exposure which have been published by Federal agencies. The first to be published was "Criteria for a Recommended Standard...Occupational Exposure to Noise" in 1972 by the National Institute for Occupational Safety and Health (NIOSH), Department of Health, Education and Welfare. This was in accordance with Section 20(a)(3) of the Occupational Safety and Health Act of 1970 (29 U.S.C. 656). In 1973, the Environmental Protection Agency published "Public Health and Welfare Criteria for Noise" in accordance with Section 5(a)(1) of the Noise Control Act of 1972 (PL 92-574). In addition, Section 5(a)(2) of the same act called for a document identifying environmental noise level goals. That document, "Information on Levels of Environmental Noise Requisite to Protect the Health and Welfare with an Adequate Margin of Safety" (EPA Levels Document) which was published in March 1974, along with the EPA Criteria Document, are to serve as the basis for establishing standards and regulations called for by the Noise Control Act.

The NIOSH document, specifically directed to the occupational environment, presented information about various effects of noise exposure, but information for support of their recommended standard was available only in the area of noise-induced hearing loss. The EPA "Public Health and Welfare Criteria for Noise" defines criteria as "descriptions of cause and effect relationships." The document addressed direct effects of noise on the physical and mental well-being of human populations, including hearing loss and other health effects, and indirect effects such as annoyance and communication interference, as well as noise effects on wildlife and other animals. Nevertheless, EPA identified only three areas for which criteria exist. According to the EPA Levels Document,

> "There are a multitude of adverse effects that can be caused by noise which may, both directly or indirectly, affect public health and welfare. However, there are only three categories of adverse relationships in which the cause/effect relationships are adequately known and

can be justifiably used to identify levels of environmental noise for protection of public health and welfare. These are: (1) the effect of noise on hearing, (2) the effect of noise on the general mental state as evidenced by annoyance, and (3) the interference of noise with specific activities."

Although information in these three areas was presented in the EPA Criteria Document and used in the EPA Levels Document, both documents indicated limitations in the information. A short description of the current Federal information in each of the three areas, as contained by the three documents, is presented below.

1. Noise-Induced Hearing Loss

The Criteria Document produced by NIOSH for employee protection during the work period addressed recommendations for a work place standard to protect against hearing impairment. No attempt is made toward the protection of the worker from non-auditory effects of noise exposure; however, the producers of this document have stated that meeting proposed criteria for the protection of auditory effects will reduce the risk of non-auditory effects. Thus, the major aim of this document is to recommend and support a work place noise exposure standard for the protection of hearing, i.e., that the effective noise level permitted during a normal eight hour work period should not exceed 90 dBA for the time being and should be reduced to 85 when technologically feasible. At this time the Department of Labor has proposed a revised standard with the 90 dBA eight hour exposure level and hearing conservation measures beginning at 85 dBA. In support of the NIOSH recommendation, incidence of hearing impairment was compared between noise exposed and non-noise exposed employee groups of comparable ages and experience.

The EPA Criteria Document presented information for predicting permanent hearing loss resulting from exposure to continuous noise of certain levels for eight hours a day over 10 and 40 years. The information, like the NIOSH criteria, also compared noise exposed and non-noise exposed employee groups. Further, like the NIOSH document, the EPA criteria is based only on industrial exposures.

The EPA Levels Document used this information to identify noise levels requisite to protect the human population from significant noise-induced hearing loss with an adequate margin of safety. The levels identified do not include consideration of economic and technological feasibility and thus should not be construed as Federal standards.

In identifying its level for protection against hearing loss, however, EPA found certain limitations in the available data. Thus, EPA had to extrapolate from industrial exposure data to community noise as it affects hearing, from eight hour exposure to 24 hour environmental exposure, and from exposure data mainly above 80 dBA to levels below 80.

2. Community Annoyance

Although community reaction to noise may be evidenced by social or economic measures as well as political or legal action, the available information, as reported in the EPA Criteria Document, deals mainly with statistical surveys of annoyance. The document concluded, among other things, that (1) "the degree of annoyance due to noise exposure expressed by the population average for a community is highly correlated to the magnitude of noise exposure in the community," and (2) "the numbers of complaints about noise registered with the authorities is small compared to the number of people annoyed, or who wish to complain. However, the number of actual complaints is highly correlated with the proportion of people in the community who express high annoyance." The EPA Levels Document used this available information about community annoyance to supplement speech interference data, discussed in the next section.

3. Communication Interference

The EPA Criteria Document identified data which predict fairly accurately how noise will affect the perception of speech in the outdoor environment. The data represents conditions in which talker and listener speak the same dialect and presumably hear normally. The document also indicated that data are available in the literature to suggest a reasonable background noise level for the design of rooms where oral communication is important.

The EPA Levels Document used these data to identify levels of noise requisite to protect public health and welfare against activity interference with an adequate margin of safety, since "the primary effect of noise on human health and welfare due to interference with activity comes from its effect on speech communication." The document also identified speech interference as one of the primary reasons for adverse community reactions to noise and long-term annoyance. It is again important to note that the levels thus identified to protect against activity interference do not include consideration of economic and technological feasibility and thus should not be construed as Federal standards.

D. RESEARCH NEEDS

Although information has been identified and/or used in three Federal documents for three of the many known or suspected effects of noise, the documents plainly pointed out the limitations and deficiencies in the available information. The lack of necessary information on other effects of noise was also discussed as well as the lack of methodologies available to adequately relate the noise exposures to the effects. Even though there are many gaps in today's knowledge on the effects of noise, some states and many local governments are in the process of setting noise limits in regulations/ordinances to reduce noise. Accurate and comprehensive information relating noise and other contributing factors to all its effects is needed to insure that the extent of the reductions is appropriate, and that the reductions may be accomplished with minimum expenditures of public and private money. Such information is also needed to assess the cost of noise reduction in light of benefits and to provide guidelines for personal decisions affecting the quality of life or corporate decisions affecting working conditions. Limitations in or lack of needed information on the various effects of noise are discussed below.

The research needs discussed are for information on which to base protection of public health and welfare in the general sense. It is important to note that in comparing these general needs with the research conducted by the various agencies, it should be remembered that specific agency missions dictate the research that agency conducts and supports, and that specific research projects, while fulfilling an important agency objective, may not be specifically directed toward fulfilling one or more of the general needs discussed below.

1. Noise-Induced Hearing Loss

The current Federal information on noise-induced hearing loss, as presented in both the NIOSH and the EPA Criteria Document and used in support of the NIOSH recommended standard and the EPA identified levels, is based on several cross-sectional industrial studies that have been criticized for various reasons. These criticisms include: insufficient determination of daily noise exposure, problems in or lack of screening for evidence of ear disease, inconsistent test practices, audiological testing in noisy areas, and audiological testing without sufficient time for recovery from temporary hearing loss. The studies also mainly considered continuous eight hour exposures. Thus, there is limited information on intermittent or partial daily exposures and practically no data on exposure to noise beyond an eight hour period. Inconclusive information exists as to whether older people or younger ones are more susceptible to noise-induced hearing loss. Little evidence is available on exposures to various other types of noise, such as impulsive noise, ultrasound, and infrasound. Little is known, also, about the effects on hearing of the combination of noise and other factors such as heat, vibration, and ototoxic (hearing damaging) drugs and chemicals.

2. Health Effects Other Than Hearing Loss

The EPA Criteria Document identified several short-term physiological effects which may result from noise exposure. It is known that noise can elicit different physiological responses, but there is not clear evidence to indicate that continued activation of these responses leads to irreversible changes and permanent health effects. Adequate scientific data are not available to confirm or refute speculations that noise may be a contributor to circulatory difficulties or heart diseases. There are not any well-established data relating noise exposure to fatigue or insomnia, even though it is believed that noise exposure can contribute to these factors. Noise has been considered to be detrimental to the recovery of hospital patients.

Although noise exposure, either alone or in conjunction with other stressors, is presumed to cause general stress, neither the threshold noise level nor duration at which stress may appear has been adequately determined. Further, the effects of chronic noise-produced stress are not known.

Thus, some indicators of potential effects of noise on health have been studied and some have shown definite cause-effect relationships over the short term. Quantitative relationships need to be determined for many indicators of noise effects on health, and all potential effects of noise on health must be studied over the long term. Clear relationships between noise exposure and its potential effects on health must be proved or disproved, so that decisions - government, corporate, or private - may be made on protection of health from noise.

### 3. Effects on Individual Behavior

Most information available on individual behavior effects of noise concerns either performance or annoyance. Noise is also considered as contributing to other behavior effects such as irritability, instability, argumentativeness, reduction in sex drive, anxiety, and nervousness, but quantitative evidence is lacking in these areas.

Although effects of noise on performance have been shown in the laboratory, little work has been done in real-life situations. As performance effects of noise could be significant and costly in today's economy, there is a pressing need for field studies under typical conditions. The information derived is needed for determining the extent of noise reduction that is cost-beneficial in performance situations.

As individual annoyance in response to noise can lead to the economic or social effects or the political or legal actions discussed under community reaction, as well as to general effects on mental or physical health, a better understanding is needed of the factors that control the degree of annoyance of individuals. Further, as most of the available information on noise/annoyance relationships deal mainly with conventional aircraft noise, annoyance in response to other major sources of noise, as well as new and future aircraft, needs to be determined.

Other behavioral effects of noise mentioned above are less clear-cut and noise is but one of many factors which could contribute to these effects. These effects, however, are serious indicators of reduction in quality of life and could be significant contributors to deterioration of mental and physical health. The relationship of noise to these effects as well as the relative contribution of noise in combination with other causes needs to be determined in order that government, corporate, or private decisions may be made concerning health and the quality of life.

4. Effects on Sleep

Disturbance of sleep by noise resulting in changes in level, patterns, or quality of sleep, or even awakening may affect behavior during waking hours and cause long-term health effects. Most of the available information on effects of sleep interference, according to the EPA Criteria Document, "comes from laboratory experiments that involve very few people, and 'responses' are evaluated in terms of physiological measurements such as EEG" (electroencephalogram, a measure of electrical voltages in the brain). As it is difficult to generalize from the laboratory to real-life conditions, but also very costly to study sleep in everyday settings, both types of studies are needed to develop definitive relationships between noise from various sources and its effects on sleep, both in the short-term and long-term.

5. Communication Interference

The available information concerning a cause-effect relationship for noise interference with speech represents conditions for normally hearing young male adults speaking the same dialect, when they are in a non-reverberant noise field, whereas the actual cause-effect relationship may change with many variables. The EPA Criteria Document states, "lower noise levels would be required if the talker has imprecise speech (poor articulation) or if the talker and the listener speak different dialects. Children have less precise speech than do adults, and their relative lack of knowledge of language often makes them less able to 'hear' speech when some of the cues in the speech stream are lost. Thus, adequate speech communication with children requires lower noise levels than are required for adults. One's ability to understand partially-masked or distorted speech seems to begin to deteriorate about age 30 and declines steadily thereafter. Generally, the older the listener, the lower the background must be for nearly normal communication...it is known that persons with hearing losses require more favorable speech-to-noise ratios than do those with normal hearing." The data available have no information on the reception of female speech or on the effect of time-varying noise on speech understanding. Quantitative data are lacking which show how all these variables affect the relationship between noise and interference with speech.

The available data on speech interference furthermore do not account for the reverberant buildup of sound by reflections from the walls of a room, and thus are not valid for design criteria. According to the EPA

Levels Document, "Recommended values for acceptable sound levels in various types of spaces have been suggested by a number of authors over the past two decades. These recommendations generally have taken into consideration such factors as speech intelligibility and subjective judgments of space occupants. However, the final values recommended were largely the result of judgments on the part of the authors..."

Finally, noise can interfere with the reception of auditory warning signals. However, there are little data to show how loud the signal should be in various noise fields in order to effectively perform its safety function.

Research is needed in order to quantify design criteria which can assure proper reception of speech and warning signals in a variety of situations, e.g., in offices, schools, workplaces, and recreational areas, and for a variety of human characteristics, such as poor or dialectic speech, age, and hearing ability.

## 6. Community Response

Although information is available relating noise exposure fairly well to community annoyance and resulting complaints to authorities, the data are based mainly on responses to conventional takeoff and landing aircraft noise. The information needs to be expanded to include response to other environmental noise sources, such as vertical or short takeoff and landing aircraft, military aircraft and other vehicles, industrial plants, surface transportation, construction equipment, home appliances, and more. Since annoyance has been shown to lead to complaints, not only does its relation to these other sources of noise need to be studied, but also its relation and the relation of noise exposure to responses such as legal or political actions, change in land values, neighborhood stability, feeling of community, and other social or economic measures. Studies are also needed to determine effect on overall community health and other possible group responses. These relationships are needed to provide input for local government decisions on land-use, corporate decisions on plant location, and private decisions on home and recreational locations, to name a few.

## 7. Effects on Animals

Although some studies have indicated that noise affects animals in the laboratory in the same way as humans, and behavior changes resulting from noise have been observed in some wildlife species, few quantitative cause-effect relationships have been established. Relationships between noise and changes in reproduction, weight gain, egg and milk production, for example, should be determined so that the economic benefits of reducing the noise exposure of domestic animals may be evaluated. Further, the effect on wildlife is important for preservation of endangered species and conservation and thus should be determined.

8. Measurement

Determination of definitive, quantitative cause-effect relationships demands accurate and reproducible measurement of both cause and effect. Further, the appropriate characteristics of noise must be emphasized in terms of the various effects, but at the same time, inexpensive instrumentation and easily used methods must be available for characterizing the noise environment and for enforcement.

Thus, instrumentation needs to be developed for monitoring noise exposures and standard methodologies developed for characterizing various noise environments and sources in terms of their possible effects. To refine and support hearing loss data, audiometric instrumentation, methodologies, and calibration procedures need to be improved. Finally, a national baseline of community noise levels is needed in order to compare various communities in terms of noise levels and to determine whether the overall national noise levels are improving or deteriorating.

## E. RESEARCH CATEGORIES

To address, analyze, and make recommendations effectively on noise effects research in terms of the needs identified above, a system for classifying the research had to be devised. Such a system has been developed by the Noise Effects Research Panel. By consensus, the Panel identified the eight major categories outlined in Table II-1.

Table II-1

CATEGORIES OF NOISE EFFECTS RESEARCH

I. <u>Noise-Induced Hearing Loss</u>
   A. Epidemiologic
   B. Human
   C. Animal
   D. Mechanisms of Hearing Loss
   E. Protection

II. <u>Non-Auditory Health Effects</u>
   A. Epidemiologic
   B. Human
   C. Animal

III. <u>Individual Behavior Effects</u>
   A. Annoyance
   B. Performance
   C. Other

IV. <u>Noise Effects on Sleep</u>

V. <u>Communication Interference</u>
   A. Speech Communication
   B. Effectiveness of Auditory Warning Signals in the Presence of Noise

VI. <u>Community or Collective Response</u>

VII. <u>Domestic Animals and Wildlife</u>

VIII. <u>Measurement Methodology and Calibration</u>
   A. Noise Environment
   B. Noise Source Characterization
   C. Audiometry

## III. SUMMARY OF CURRENT PROGRAMS

The current Federal research programs and projects on effects of noise address all but one of the research categories identified in Table II-1. At the present time there is no ongoing research reported on the effects of noise on domestic animals and wildlife. The funding for research in the other categories, however, is presented in Table III-1. Table III-2 shows the overall effort of each agency in effects of noise, and Table III-3 relates each agency's involvement in categories of research. The following discussions summarize the current effort of the Federal government in addressing the research needs in each category of noise effects research. Each agency's current program is described in Appendix D.

### A. NOISE-INDUCED HEARING LOSS

Noise has long been known as a contributor to hearing loss, and many studies in the past few decades have attempted to establish a definitive cause-effect relationship, particularly in the occupational environment. However, the effects of different types of noise and exposure patterns are still not well understood. Variations in susceptibility due to age, drugs, and environmental factors further complicate the problems.

The need for knowledge about noise-induced hearing loss is reflected in the current fiscal data. Almost $1.4 million, over one-quarter of the total Federal expenditures on health effects of noise, was spent on noise-induced hearing loss research in FY 74. Current research programs in this area, carried out by five different agencies, are addressing the following specific problems:

- Cross-sectional studies in various environments (occupational, military, recreational, etc.).
- Relationships between permanent and temporary threshold shifts.
- Susceptibility to hearing loss.
- Combination of noise and other stressors (work, heat, vibration, etc.).
- Combination with ototoxic drugs, other ototoxic agents, and abnormal physiology.
- Effects on children.
- Impulse noise, intermittent noise, and high intensity noise.

Table III-1

NOISE EFFECTS RESEARCH FUNDING BY CATEGORY
(Thousands of Dollars)

| Category | FY 73 | FY 74 | FY 75* |
|---|---|---|---|
| Noise-Induced Hearing Loss | 1,084 | 1,366 | 1,979 |
| Non-Auditory Health Effects | 126 | 294 | 61 |
| Individual Behavior Effects | 381 | 361 | 443 |
| Noise Effects on Sleep | 217 | 254 | 159 |
| Communication Interference | 275 | 316 | 296 |
| Community or Collective Response | 410 | 821 | 1,114 |
| Domestic Animals and Wildlife | 0 | 0 | 0 |
| Measurement Methodology and Calibration | 1,073 | 1,344 | 916 |
| TOTALS | 3,566 | 4,756 | 4,968* |

Table III-2

NOISE EFFECTS RESEARCH FUNDING BY AGENCY
(Thousands of Dollars)

| Agency | FY 73 | FY 74 | FY 75* |
|---|---|---|---|
| HEW(NINDS) | 526 | 622 | 1,157 |
| HEW(NIEHS) | 153 | 258 | 239 |
| HEW(NIOSH) | 395 | 507 | 481 |
| DOD | 984 | 930 | 930* |
| NASA | 1,127 | 1,154 | 1,200 |
| DOT | 50 | 130 | 50 |
| NSF | 20 | 0 | 0 |
| DOC(NBS) | 98 | 117 | 142 |
| HUD | 117 | 638 | 460 |
| EPA | 24 | 377 | 309 |
| DOI(BuMines) | 72 | 23 | 0 |
| TOTALS | 3,566 | 4,756 | 4,968* |

*DOD FY 75 Estimated the same as FY 74

Table III-3

CURRENT AGENCY INVOLVEMENT IN RESEARCH CATEGORIES

| Research Category \ Agency | HEW(NINDS) | HEW(NIEHS) | HEW(NIOSH) | DOD | NASA | DOT | DOC(NBS) | HUD | EPA | NSF | DOI(BuMines) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Noise-Induced Hearing Loss | x | x | x | x | | | | | x | x | |
| Non-auditory Health Effects | | x | x | x | | | | | x | | |
| Individual Behavior Effects | | | x | x | | x | x | | x | | |
| Noise Effects on Sleep | | | | | x | | | | x | | |
| Communication Interference | x | | | x | | | | | x | | x |
| Community or Collective Response | | | | x | x | x | | x | | | |
| Domestic Animals and Wildlife | | | | | | | | | | | |
| Measurement Methodology and Calibration | | | x | x | x | | | x | x | | x |

- Permanent effects of occupational and longer environmental exposures.

- Mechanisms of hearing loss (biochemical, physiological, etc.).

- Hearing protection.

Funding levels for noise-induced hearing loss research are shown in Table III-4.

B. NON-AUDITORY HEALTH EFFECTS

Many studies have been conducted which tend to indicate noise to be a cause of numerous non-auditory health effects in humans which might influence physical or mental health. These include: orientation and startle reflexes, disturbed sense of balance, pain, and general stress.

One cannot rule out the possibility that noise exposure may pose some non-auditory health hazard if no attempt is made to reduce individual exposure to noise. Caution must be exercised in interpreting the results of studies in this area, however, for controls are exceptionally difficult to exercise. It is also extremely difficult to quantify the non-auditory health effects of noise because of the following complexities and conditions: the wide variety of conditions and mental states involved in personal health; the complexity of the human body and the human mental function; individual and temporal variations in susceptibility to physical and mental health conditions; and the occurrence of noise in combination with other stresses.

Despite many questions that cannot now be answered regarding the non-auditory health effects of noise, Federal expenditures in this category have been modest. Current and recent research in this category, conducted by four different agencies, address the following problems:

- Worker safety and health.

- Susceptibility to mental and physical illness.

- Cardiovascular and other physiological changes.

- Effects on the vestibular (sense of balance), cardiovascular (heart and circulatory), endocrine (internally-secreting glands), and neural systems.

- Effects on drug uptake.

Funding levels for non-auditory health effects research are shown in Table III-5.

Table III-4

FEDERAL RESEARCH FUNDING FOR NOISE-INDUCED HEARING LOSS
(Thousands of Dollars)

| Agency | FY 73 | FY 74 | FY 75 |
|---|---|---|---|
| HEW(NINDS) | 447 | 482 | 1,057 |
| HEW(NIOSH) | 224 | 341 | 352 |
| HEW(NIEHS) | 145 | 192 | 199 |
| DOD | 248 | 301 | 301* |
| NSF | 20 | 0 | 0 |
| EPA | 0 | 50 | 70 |
| TOTALS | 1,084 | 1,366 | 1,979* |

*DOD FY 75 data estimated the sames as FY 74

Table III-5

FEDERAL RESEARCH FUNDING FOR NON-AUDITORY HEALTH EFFECTS OF NOISE
(Thousands of Dollars)

| Agency | FY 73 | FY 74 | FY 75 |
|---|---|---|---|
| HEW(NIEHS) | 8 | 66 | 40 |
| HEW(NIOSH) | 108 | 42 | 21 |
| DOD | 10 | 0 | 0* |
| EPA | 0 | 186** | 0 |
| TOTALS | 126 | 294 | 61* |

*DOD FY 75 data estimated the same as FY 74
**2 year project

## C. INDIVIDUAL BEHAVIOR EFFECTS

Individual behavior effects are of interest in a variety of environments where adverse reflex actions or behavior may result in accidents or unfavorable performance, e.g., occupational, military and vehicle handling. Various studies have indicated that noise may have negative, neutral, or even positive effects on performance.

The effects of noise on performance have been studied in the laboratory and in the actual work situation, with more emphasis on laboratory research. Generalizing from the laboratory to real life situations is difficult since, in the laboratory, exposures are short and the novel tasks employed cause subjects to be fairly well motivated. By contrast, office and factory workers usually work below their maximum efficiency and respond to noise in combination with other stimuli. The lack of well-controlled field studies is still a very real problem in the evaluation of the effects of noise on human performance.

Current research programs in this category, conducted by five agencies, are addressing the following specific problems:

- Annoyance factors, e.g., loudness, noisiness, and aversiveness

- Performance capability in:
  High levels of noise exposure
  Environmental noise (from transportation systems, etc.)
  Occupational noise levels
  Combination with other stressors (heat, vibration, etc.) in various environments

- Startle effects on performance

- Human adaptation to noise

- Measures of aversiveness and annoyance

Funding levels for research on individual behavior effects of noise are shown in Table III-6.

## D. NOISE EFFECTS ON SLEEP

Survey data indicate that sleep disturbance is often the principal reason given for noise annoyance.

There are indications that sleeping in noisy surroundings does produce some effects on sleep, either in the form of awakening, if the noise is loud enough, or in the form of shifts in the stages of sleep. Usually, however, much of our data comes from laboratory experiments that involve few people and "responses" are evaluated in terms of physiological measurements such as the electroencephalogram, which measures nervous system electric voltages in the brain. Caution must therefore be exercised in drawing conclusions regarding the effect of noise on sleep for the general population. Even greater caution must be exercised in making references about the long-range effect of sleep disturbance since there exist very little experimental data regarding these effects.

Two agencies reported research directed solely or primarily to noise effects on sleep.

Table III-6

FEDERAL RESEARCH FUNDING FOR INDIVIDUAL BEHAVIOR EFFECTS OF NOISE
(Thousands of Dollars)

| Agency | FY 73 | FY 74 | FY 75 |
|---|---|---|---|
| HEW(NIOSH) | 0 | 28 | 0 |
| DOD | 233 | 166 | 166* |
| DOT | 50 | 0 | 0 |
| EPA | 0 | 50 | 135 |
| DOC(NBS) | 98 | 117 | 142 |
| TOTALS | 381 | 361 | 443* |

*DOD FY 75 data estimated the same as FY 74

Table III-7

FEDERAL RESEARCH FUNDING FOR NOISE EFFECTS ON SLEEP
(Thousands of Dollars)

| Agency | FY 73 | FY 74 | FY 75 |
|---|---|---|---|
| NASA | 217 | 254 | 142 |
| EPA | 0 | 0 | 17 |
| TOTALS | 217 | 254 | 159 |

Current research in this category is being addressed to the following specific problems:

- Nonawakening effects (change in pattern and quality of sleep)

- Sleep disturbance by aircraft noise

- Correlational analysis of foreign and domestic scientific data on the effects of noise on human sleep.

Funding levels reported for research directed solely or primarily to noise effects on sleep are shown in Table III-7, Page 22.

## E. COMMUNICATION INTERFERENCE

Noise can interfere with speech by changing its perceived quality, shifting its apparent location or loudness, or by making it partially or completely inaudible.

Unfortunately, most of the available knowledge is often of limited assistance in predicting the intelligibility of ordinary speech which actually consists of a complex sequence of sounds whose overall intensity and spectral distribution are constantly varying. The intelligibility of ordinary speech is rather complex and must often be predicted on the basis of results with isolated words.

Current Federal research in communication interference by noise, conducted by four different agencies, is addressing the following problems:

- Effects of noise on speech production

- Methods for predicting speech intelligibility in noise

- Speech communication in special environments

- Speech discrimination in normal and pathological hearing groups

- Hearing aid performance in noisy environments

- Warning signals in coal mines.

Funding levels for research in communication interference by noise are shown in Table III-8.

Table III-8

FEDERAL RESEARCH FUNDING FOR COMMUNICATIONS INTERFERENCE OF NOISE
(Thousands of Dollars)

| Agency | FY 73 | FY 74 | FY 75 |
|---|---|---|---|
| HEW(NINDS) | 79 | 140 | 100 |
| DOD | 124 | 109 | 109* |
| EPA | 0 | 59 | 87 |
| DOI(BuMines) | 72 | 8 | 0 |
| TOTALS | 275 | 316 | 296* |

*DOD FY 75 data estimated the same as FY 54.

Table III-9

FEDERAL RESEARCH FUNDING FOR COMMUNITY OR
COLLECTIVE RESPONSE TO NOISE
(Thousands of Dollars)

| Agency | FY 73 | FY 74 | FY 75 |
|---|---|---|---|
| DOD | 32 | 0 | 0* |
| NASA | 378 | 491 | 654 |
| DOT | 0 | 130 | 50 |
| HUD | 0 | 200 | 410 |
| TOTALS | 410 | 821 | 1,114* |

*DOD FY 75 data estimated the same as FY 74.

F. COMMUNITY OR COLLECTIVE RESPONSE

Numerous techniques have also been devised to measure annoyance from a simple scale of annoyance level to complicated techniques involving social surveys. Many studies have addressed the relation between noise and annoyance. Most of this work has been related to conventional aircraft operations. Other noise sources exist which appear to warrant additional consideration. Other social and economic responses such as political actions or change in land values also need to be examined.

Four different agencies were conducting research in community or collective response in the FY 73-74 time period, addressing the following problems:

- National baseline data bank of environmental noise levels-unified measurement system
- Community response studies
- Military operations noise.

Funding levels for research in community or collective response to noise are shown in Table III-9, Page 24.

G. DOMESTIC ANIMALS AND WILDLIFE

Noise produces the same general types of effects on animals as it does on humans, namely: auditory, masking of communication, behavioral, and physiological. These effects have not yet been definitely described. No criteria have been developed for these effects.

Recent research in this category, one project concluded in FY 73, was addressed to hearing levels of fowls. No funding data are listed herein for that project.

H. MEASUREMENT METHODOLOGY AND CALIBRATION

Research in measurement methodology and calibration is conducted by agencies to support noise health effects research programs, to support implementation of noise control legislation, and to maintain a defensible posture regarding measurement technology.

This entails a broad range of activities involved in establishing measurement systems to define the environments and determine the effects on humans: defining measurement requirements, analysis and evaluation of alternate methodologies, and the development of hardware, software and procedures.

The significance of this effort is reflected in the current fiscal data. More than $1.2 million, 28 percent of total Federal funding on noise effects research, was expended on research in measurement methodology and calibration in FY 74. Six agencies conducted research in this category in FY 74, largely directed to the following problems:

- Defining the noise environment through:
  Monitoring methodology
  Monitoring instrumentation
- Noise source characterization - rating schemes
- Audiometry
- Characterization of vertical/short takeoff and landing aircraft noise
- Portable calibration of Audiodosimeters.

Funding levels for research in measurement methodology and calibration are shown in Table III-10.

Table III-10

FEDERAL RESEARCH FUNDING FOR NOISE MEASUREMENT METHODOLOGY AND CALIBRATION
(Thousands of Dollars)

| Agency | FY 73 | FY 74 | FY 75 |
|---|---|---|---|
| HEW(NIOSH) | 63 | 96 | 108 |
| DOD | 337 | 354 | 354* |
| HUD | 117 | 438 | 50 |
| EPA | 24 | 32 | 0 |
| DOI(BuMines) | 0 | 15 | 0 |
| NASA | 532 | 409 | 404 |
| TOTAL | 1,073 | 1,344 | 916* |

*DOD FY 75 data estimated the same as FY 74

## IV. CONCLUSIONS

### A. SUMMARY OF DISCUSSIONS

Known or suspected effects of noise include effects on hearing, other effects which may (or may not) lead to permanent health impairment, effects on behavior such as performance or annoyance, speech and other communication interference, sleep disturbance, social/economic/political/legal/behavioral community responses, and effects on animals. Quantitative cause-effect relationships, however, have been provisionally defined by the Federal government only for hearing, annoyance, and speech interference. The information identified in these three areas is also discussed. Limitations in this information in other areas are shown and research needed to provide thorough and accurate information on all effects of noise is identified. Such information is necessary for setting standards for protection of public health and welfare, assessment of the benefits to be derived from noise reduction in light of the costs, assurance of safe, productive work environments and adequate communication, and decisions at all levels affecting the quality of life. A way of categorizing current and needed noise effects research is presented. The current Federally supported noise effects research is summarized for each of eight categories.

### B. RESEARCH SUBJECTS NEEDING ADDITIONAL EMPHASIS

Although an in-depth analysis and assessment of the current Federal noise effects programs has not been made, the Noise Effects Research Panel through its collective knowledge of both needs and current research has identified specific research subjects which need additional emphasis in order to provide accurate and thorough information on effects of noise. These include subjects not currently receiving enough attention and those not currently being addressed. They are compared for each category with a summary of the current research (as discussed in Chapter 3) in Table IV-1. Since the adequacy of the current research has not been addressed, it should not be assumed that the subjects listed under current research are being thoroughly covered. On the contrary, the current programs need continued, and in some instances expanded, support in order to provide necessary information on effects of noise.

### C. FUTURE PANEL ACTIVITIES

Since the Noise Effects Research Panel has been in existence only a short time, its work has just begun. In the future, it expects to address: adequacy of current research, new starts, agency interests and capabilities, and priorities of research needs. With these activities, the panel hopes to move toward a coordinated plan for Federal noise effects research which can direct research toward critical problems and issues, assure coordinated and complementary efforts, and promote research accomplished in the most productive and scientifically viable manner.

Prior to establishment of the panel in early 1974, the various agencies accomplished much in gaining understanding of the effects of noise. The panel hopes that the overall rate of research progress will accelerate as these agencies participate mutually in this planning process.

Table IV-1

SUMMARY OF NOISE EFFECTS RESEARCH NEEDS BY CATEGORY

I. Noise-Induced Hearing Loss

| Current Research | Research Needing Additional Emphasis |
| --- | --- |
| 1. Cross-sectional studies in various environments, (occupational, military, recreational, etc.) | 1. Longitudinal studies of normal hearing |
| 2. Relationships between permanent and temporary threshold shifts | 2. Longitudinal studies of noise exposed populations |
| 3. Susceptibility to hearing loss | 3. Analysis of cross-sectional and retrospective audiometric data from known occupational exposure |
| 4. Combination of noise and other stressors (work, heat, vibration, etc.) | 4. Definition and quantification of presbycusis |
| 5. Combination with ototoxic drugs, other ototoxic agents, and abnormal physiology | 5. Possible high-risk and susceptible populations |
| 6. Effects on children | 6. Social and economic impact of noise-induced hearing loss |
| 7. Impulse, intermittent, and high intensity noise | |

Table IV-1 (Cont.)

| Current Research | Research Needing Additional Emphasis |
|---|---|
| 8. Permanent effects of occupational and longer environmental exposures | |
| 9. Mechanisms of hearing loss (biochemical, physiological, etc.) | |
| 10. Hearing protection | |

### II. Non-Auditory Health Effects

| Current Research | Research Needing Additional Emphasis |
|---|---|
| 1. Worker safety and health | 1. Non-Auditory long-term health effects<br>a. Epidemiologic (physiological and mental health)<br>b. Longitudinal studies on subhuman primates |
| 2. Susceptibility to disease | 2. Health effects of impulse noise |
| 3. Cardiovascular and other physiologic changes | 3. Health effects of infrasound and ultrasound |
| 4. Effects on the vestibular, cardiovascular, endocrine, and neural systems | |
| 5. Effects on drug uptake | |

### III. Individual Behavior Effects

| Current Research | Research Needing Additional Emphasis |
|---|---|
| 1. Annoyance - loudness, noisiness and aversiveness | 1. Effects on task performance in specific environments |
| 2. Performance capability in:<br>a. High level exposure<br>b. Environmental noise<br>c. Occupational noise<br>d. Combination with other stressors in various environments | 2. Pure tone and time-varying corrections for annoyance evaluation |
| | 3. Effects of noise in learning situations |

Table IV-1 (Cont.)

III. Individual Behavior Effects (Cont.)

| Current Research | Research Needing Additional Emphasis |
|---|---|
| e. Intermittent and impulse noise | 4. Annoyance in susceptible populations (e.g., hospital environments) |
| 3. Startle effects on performance | 5. Cognitive components of annoying noise |

IV. Noise Effects on Sleep

| Current Research | Research Needing Additional Emphasis |
|---|---|
| 1. Non-awakening effects | 1. Chronic sleep interruption by noise |
| 2. Sleep disturbance by aircraft noise | 2. Sleep interruptions on special populations (ill, aged, etc.) |
| 3. Home environment | |

V. Communication Interference

| Current Research | Research Needing Additional Emphasis |
|---|---|
| 1. Effects on speech production | 1. Everyday speech communication in real-life noise situations |
| 2. Methods for predicting speech intelligibility in noise | a. Various vocabularies<br>b. Various populations (children, females, aged, foreign dialect, hearing impaired, etc.) |
| 3. Speech communication in special environments | |
| 4. Speech discrimination in normal and pathological hearing groups | 2. Criteria for speech communication in rooms |
| 5. Hearing aid performance in noisy environments | 3. Effects of noise on speech and message production |
| | 4. Effectiveness of auditory warning signals in the presence of noise |

Table IV-1 (Cont.)

## VI. Community Collective Response

| Current Research | Research Needing Additional Emphasis |
|---|---|
| 1. National baseline data bank of environmental noise levels-unified measurement system | 1. Community surveys to address annoyance as a function of exposure patterns |
| 2. Community response studies | 2. Noise, its sociological effects in relation to quality of life |
| 3. Military operations noise | 3. Criteria for land use compatibility |

## VII. Domestic Animals and Wildlife

| Current Research | Research Needing Additional Emphasis |
|---|---|
| 1. Hearing levels of fowls | 1. Identification and development of criteria with respect to behaviorial effects of:<br>a. Endangered species<br>b. Other wildlife<br>c. Domestic animals |

## VIII. Measurement Methodology and Calibration

| Current Research | Research Needing Additional Emphasis |
|---|---|
| 1. Noise Environment<br>a. Monitoring methodology<br>b. Monitoring instrumentation | 1. Development of standard methodologies |
| | 2. Characterization of noise in terms of environmental impact |
| 2. Source characterization-noise rating schemes | 3. Characterization of noise effects of specific sources |
| 3. Audiometry | 4. Development of monitoring instrumentation for evaluation of complex noises |

## APPENDIX A

## GLOSSARY

| Term | Definition |
|---|---|
| Audiometry | The measurement of hearing. |
| Auditory | Relating to or pertaining to the sense of hearing. |
| Broad-band Noise | Noise whose energy is distributed over a broad range of frequency. |
| Cardiovascular | Pertaining to the heart and blood vessels. |
| Chronic | Long term continuous or frequently repeated. |
| Cochlea; Cochlear | A spiral shaped cavity in the temporal bone, resembling a snail shell, which forms part of the inner ear and contains the end organ of hearing; pertaining to the cochlea. |
| Continuous Noise | On-going noise, the intensity of which remains at a measurable level (which may vary) without interruption over an indefinite period or a specified period of time. Loosely, nonimpulsive noise. |
| Cross-sectional | Pertaining to a sample of a population at a given time. |
| Decibel (dB) | A measure on a logarithmic scale, of the magnitude of a particular quantity (such as sound pressure, sound power, or intensity) with respect to a standard reference value (20 micropascals for sound pressure). |
| dBA | A unit of sound level with A-weighted characteristics. |
| Endocrine | Pertaining to the internally-secreting glands whose products are distributed via the blood rather than through ducts. |

| | |
|---|---|
| Epidemiologic | Pertaining to studies of humans in their natural environment. |
| Frequency | The number of times per second that a periodic sound repeats itself. Now expressed in Hertz (Hz), formerly in cycles per second (cps). |
| Hearing Impairment | Hearing loss exceeding a designated criterion (e.g., 25 dB hearing threshold level, averaged from the threshold levels at 500, 1000, and 2000 Hz). |
| Hearing Loss | Impairment of auditory sensitivity; an elevation of a hearing threshold level. |
| Hearing Threshold Level | The amount (in decibels) by which the threshold of hearing for an ear (or the average for a group) exceeds the standard audiometric reference zero (ISO 1964; ANSI 1969). |
| Impulse Noise (Impulsive Noise) | Noise of short duration (typically less than one second) especially of high intensity, abrupt onset and rapid decay, and often rapidly changing spectral composition. NOTE: Impulse noise is characteristically associated with such sources as explosions, impacts, the discharge of firearms, the passage of supersonic aircraft (sonic boom) and many industrial processes. |
| Infrasound | Sound with frequencies below the audible range, traditionally below 16 Hz. |
| Intermittent Noise | Fluctuating noise whose level falls one or more times to very low or unmeasurable values during an exposure. |
| $L_{dn}$ | A one-number scheme for designating the 24-hour equivalent noise exposure adjusted so that nighttime noise is given more weight. |

| | |
|---|---|
| Level | In acoustics, the level of a quantity is the logarithm of the ratio of that quantity to a reference quantity of the same kind. The base of the logarithm, the reference quantity, and the kind of level must be specified. |
| Longitudinal Studies | Long-term surveying and monitoring of a given group of the population. |
| Noise Exposure | A combination of effective noise level and exposure duration. |
| Noise-Induced Permanent Threshold Shift (NIPTS) | A permanent threshold shift (PTS) caused by noise exposure, corrected for the effect of aging. |
| Ototoxic | Poisonous or damaging to the auditory (hearing) organ. |
| Permanent Threshold Shift | A permanent elevation in the hearing threshold level. |
| Physiological | Pertaining to the functions and activities of a living cell, tissue or organism. |
| Sound Level (SL) | Weighted sound pressure level, obtained by the use of metering characteristics and the weightings A, B, or C as specified in the American National Standard Specification for Sound Level Meters, ANSI-S1.4-1971. The weighting employed must be stated. |
| Temporary Threshold Shift (TTS) | A short duration elevation in the hearing threshold level. |
| Threshold of Hearing | The minimum effective sound pressure level of an acoustic signal capable of exciting the sensation of hearing in a specified proporation of trials in prescribed conditions of listening. |
| Ultrasound | Sound with frequencies above the audible range, i.e., above 16,000-20,000 Hz. |
| Vestibular | Pertaining to the sense of balance organs in the inner ear. |

## APPENDIX B

## GLOSSARY OF AGENCY ACRONYMS

| Symbols | Agencies |
|---|---|
| DOC | Department of Commerce |
| DOC(NBS) | National Bureau of Standards |
| DOD | Department of Defense |
| DOI | Department of the Interior |
| DOI(BuMines) | Bureau of Mines |
| DOL | Department of Labor |
| DOT | Department of Transportation |
| EPA | Environmental Protection Agency |
| HEW | Department of Health, Education, and Welfare |
| HEW(NIEHS) | National Institute of Environmental Health Sciences |
| HEW(NINDS) | National Institute of Neurological Diseases and Stroke |
| HEW(NIOSH) | National Institute for Occupational Safety and Health |
| HUD | Department of Housing and Urban Development |
| NASA | National Aeronautics and Space Administration |
| NSF | National Science Foundation |

APPENDIX C

NOISE EFFECTS RESEARCH PANEL MEMBERS

| | |
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## APPENDIX D

## DESCRIPTION OF PROGRAMS AND PROJECTS

TABLES

## DESCRIPTION OF PROGRAMS AND PROJECTS

This appendix presents a summary of Federal research programs and projects in noise effects.

Program and project information is grouped according to agency and, within each agency, according to research categories.

The fiscal data are reported for each agency consistent with its own budgetary process. As there is considerable variation among the various agencies in such processes, comparison of funding levels cannot be made. Table D-1 illustrates this difficulty by showing what is included in each agency's funding reporting.

The project and program titles reported convey little information on scopes of work. Thus similar titles may have widely varying funding levels and may involve completely different kinds and extent of research activities.

Table D-1

IN-HOUSE RESEARCH COST ITEMS BY AGENCY

| | Agency | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Cost Items | NINDS | NIEHS | NIOSH | DOD | NASA | NBS | EPA | HUD | DOT | NSF |
| EQUIPMENT AND SERVICES | X | X | X | X | X | X | X | | | |
| SALARIES | X | X | X | X* | X | X | | | | |
| FRINGE BENEFITS | X | X | X | X | X | X | X | | | |
| ADMINISTRATIVE | | X | | X | X | X | X | | | |
| FACILITIES | | X | | X | X | X | | | | |
| TRAVEL | | X | X | X | X | X | X | | | |
| NO CURRENT IN-HOUSE RESEARCH IN NOISE EFFECTS | | | | | | | | X | X | X |

*Civilian salaries included, but not military salaries

### 1. NINDS

NINDS has major research efforts on-going in two categories, noise induced hearing loss and communication interference, and plans to initiate a major effort in a third category, nonauditory health effects.

## 1.1 Noise Induced Hearing Loss

NINDS has three organizational divisions which relate to noise-induced hearing loss, and ten specific projects (some in the planning phase) dealing with that research category. The program-project relationship and funding are shown in Table D-2.

Effects of Noise on People - The NINDS program, Effects of Noise on People, is part of the directed research program in Communicative Disorders which has as its overall goal the diagnosis, treatment, amelioration, and prevention of communicative disorders. The thrust of the noise program is best understood in the context of the other major program areas which include hearing, sensory aids for the communicatively handicapped, and language and speech problems of children and adults.

Specific noise-related goals include: prevention of handicapping conditions in young children which are attributable to noise exposure; improved understanding of the economic and social impacts of noise-induced hearing loss; improved understanding of the possible interactions between health, nutrition, and noise exposure in producing noise-induced hearing loss; improved understanding of the possible effects of noise on susceptibility to disease.

This noise program has recently been initiated. Through interagency agreement in FY 74, interdisciplinary planning was initiated on the effects of noise on children. Specifically, the National Research Council/National Academy of Sciences Committee on Hearing, Bioacoustics, and Biomechanics (CHABA) is reviewing existing information. NINDS will make the review document available to the general public. New research projects expected to be implemented in FY 75 are: animal studies of the effects of noise on young ears and a study of auditory responses, in noise and in quiet, of children ranging from the very young to age six. Planned for initiation in FY 75 is a detailed study of auditory sensitivity and discrimination among children (8-12 year age range) who have lived in noisy environments for a number of years and of children from quiet environments.

Another research project on noise-induced hearing loss will be initiated in FY 76 (in FY 75, if additional funds become available). This will involve a study of the economic and social impacts of noise-induced hearing loss and will investigate such areas as numbers of persons experiencing noise-induced hearing loss by type of employment activity, reduction in earning potential, reduction in retirement benefit potential, and change in patterns of activity outside the working environment.

Finally, a study of presbycusis and its relationship to noise exposure, circulatory factors, nutrition, etc., is scheduled to be planned in FY 77 and initiated in FY 78.

Table D-2

NINDS RESEARCH ON NOISE-INDUCED HEARING LOSS

| Noise-Induced Hearing Loss Projects | Funding (Thousands of Dollars) | | |
|---|---|---|---|
| Program: Communicative Disorders (Effects of Noise on People) | FY 73 | FY 74 | FY 75 |
| 1. Effects of Noise on Children | 0 | 20 | 0 |
| 2. Experimental Studies of Effects of Noise on Young Ears (Primates) | 0 | 0 | 340 |
| 3. Auditory Responses in Quiet and Noise Among Very Young Children | 0 | 0 | 120 |
| 4. Auditory Sensitivity and Discrimination Among Children Living in Noisy Environments | 0 | 0 | 120 |
| 5. Economic Impacts on Noise-Induced Hearing Loss[1] | 0 | 0 | 0 |
| 6. Presbycusis[1] | 0 | 0 | 0 |
| Laboratory of Neuro-Otolaryngology | | | |
| (Being established) | 0 | 28 | 15 |
| Grants Program | | | |
| 1. Susceptibility to Hearing Loss | 45 | 47 | 49 |
| 2. Causes of Deafness | 365 | 387 | 413 |
| 3. Auditory Communications and Its Disorders | 461[2] | 586[2] | 598[2] |
| 4. Noise Effects on Audiogram and Cochlea | 37 | 0 | 0 |
| TOTALS | 447 | 482 | 1057 |

[1]In planning phase
[2]Project funding covers work not noise-related and is not included in totals.

Laboratory of Otolaryngology - The objectives of this program include increased understanding of the auditory system in order to understand the full significance of noise-induced destruction of cochlear hair cells, to seek possible prevention of noise-induced hearing loss, and to seek methods of treating persons who have already experienced noise-induced hearing loss.

As this program is currently being established, no specific projects have been identified. However, the funds reported are noise-related only.

Grants Program - NINDS support of research on the effects of noise exposure has continued for a number of years through the extramural grant program. These studies, concerning both biologic effects of noise on the auditory system and human responses to noise, constitute a large portion of presently available data.

Several laboratories are presently conducting research on the basic mechanisms of destruction of the cochlea (or inner ear) resulting from exposure to noise. Procedures have been developed for using animals in this work since recordings are made of the electrical responses of cells and histological analyses of cellular tissue can be completed. This means that investigators have also needed to develop procedures for obtaining "hearing tests" from these animals so that the perceptual effects of noise damage could be studied together with the physiological effects. One grantee has demonstrated that levels and durations of noise which do not produce lasting impairment in behavioral response to pure tone (no lasting effect on the "hearing test") are nevertheless sufficient to produce considerable cellular damage to the cochlea. In addition to research on the physiological damage incurred to the hair (or receptor) cells of the cochlea, investigators are attempting to understand the exact process by which this happens. For example, it is not clear whether exclusively mechanical factors are involved in destroying the receptor cells or whether biochemical or bio-electrical factors must also be considered.

Another area under investigation is the relationship between temporary shift of the auditory threshold resulting from noise exposure and permanent noise-induced hearing loss. One investigator has anticipated that measurement of temporary threshold shift in human populations exposed to noise might warn of impending permanent hearing loss, but the usefulness of that diagnostic strategy is now being reconsidered.

## 1.2 Nonauditory Health Effects

NINDS is developing a new program concerned with the effects of noise on health. Initial emphasis, planned to begin in FY 76, will concern increased susceptibility to disease as a result of noise exposure. This new project will utilize all resources of the major NIH facility, located in Bethesda, Maryland. At the present, responsibility for planning this research rests with the Communicative Disorders program.

### 1.3 Communications Interference

Understanding and defining the impact of noise on human communication, with particular emphasis on speech communication, is a major NINDS objective. NINDS is concerned with the intelligibility of everyday speech for both normal listeners and for listeners with communicative disorders. For this latter population, NINDS also emphasizes the objective of ameliorating ability to understand speech in noisy environments.

Through its grants program NINDS has previously funded research on masking and speech interference. Initiated in FY 74, by contract, is research directed to the development of a new test for speech discrimination in noise. This work was undertaken in recognition of the limitations of pure tone tests of auditory sensitivity (i.e., audiograms) and of most existing "speech tests" which do not adequately measure the cognitive aspects of understanding speech. This project is developing an instrument for measuring discrimination in noise of connected speech containing key test words that vary in predictability and familiarity. Speech discrimination will be measured in the presence of a competing speech message at several signal-to-noise ratios and at least two widely different signal levels for groups of subjects with normal hearing, conductive hearing impairment, and acquired sensorineural hearing impairment.

A study of message transmission in noise is planned for initiation in FY 79.

Project funding levels for this effort are shown in Table D-3.

## 2. NIEHS

NIEHS has a major research effort in noise-induced hearing loss and also pursues work in nonauditory health effects.

The Noise Effects Program of the National Institute of Environmental Health Sciences is an integral facet of the Institute's concern with the effects of adverse environmental agents and energy mechanisms. The Noise Effects Program is designed to make maximum use of the Institute's multidisciplinary makeup to facilitate the study of the effects of this ubiquitous environmental insult.

The noise effects laboratory is located in the Environmental Biophysics Branch where personnel with research backgrounds in auditory and neurophysiology, acoustics and medicine form a core from which investigations have been and are being carried out, not only in traditional histopathological and electrophysiological effects of noise on the inner ear, but have extended into teratogenic effects and pharmacologic effects and into the underlying biochemical dysfunctions which precede hearing loss. Other nonauditory effects including endocrine and immuniological disorders are also being studied.

Table D-3

NINDS RESEARCH ON COMMUNICATION INTERFERENCE

| Projects in Communications Interference | Funding Levels (Thousands of Dollars) | | |
|---|---|---|---|
| Communicative Disorders Program (Effects of Noise on People) | FY 73 | FY 74 | FY 75 |
| 1. Development of Test Instrument for Assessing Speech Discrimination in Noise . . . . . . . . . | 0 | 140 | 100 |
| 2. Message Transmission in Noise (in planning phase) . . . . . . . . . . . . . . . . . . . . . | 0 | 0 | 0 |
| Grants Program | | | |
| Noise-Induced Deafness: Masking and Speech Perception . . . . . . . . . . . . . . . . . . . . | 79 | 0 | 0 |
| TOTALS | 79 | 140 | 100 |

Nearly all of the NIEHS work is done via research animals. Fortunately, the peripheral auditory systems of most mammals including man are very similar. Thus research animals can be confidently utilized for the study of the inner ear-sensorineural losses which are the characteristic effect of excessive noise insult.

Most hearing losses from noise are characterized by gradual deterioration from repeated exposures. A major part of the present on-going program is a continuing study of how these repeated exposures affect the ear's ability to recover and what biochemical and physiological disruptions hold the key to understanding the process.

The Institute's interdisciplinary capabilities have recently been focused on the study of synergisms between noise and other ototoxic agents, both intramurally and extramurally. Noise has been found to greatly potentiate the effect of the family of aminoglycoside antibiotics (neomycin, etc.). The mechanisms of this synergism is the subject of an investigation by one of our contractors. Other ototoxic agents studied include salicylic acid (aspirin) and certain heavy metals including lead and mercury.

2.1 Noise-Induced Hearing Loss

NIEHS has one program of studies, initiated about July 1972, on the effects of noise and other ototoxic agents on the auditory and nonauditory systems. Five specific projects in noise-induced hearing loss were in effect on this program in the FY 73-74 period. One additional project in noise-induced hearing loss was performed on a grant in FY 74 under the agency's extramural program. Program/project relationships and funding levels for this effort are shown in Table D-4.

Specific projects conducted in the FY 73-74 period on the NIEHS research program include:

- A comparative investigation of the hearing loss threshold curve for young and mature animals, being conducted in response to evidence indicating greater susceptibility of young cochlea to noise-induced physiological (tissues, muscles, cells, etc.) and pathological (disease) alterations. Firm recommendations regarding criteria for maximum noise exposures for prevention of noise-induced deafness in newborns cannot presently be made because of the paucity of data. It appears medically prudent to take extreme precaution to avoid exposing newborns to excessive noise.

- A study of the combined effects of noise and salicylates (such as aspirin) on cochlear morphology and the auditory threshold. Studies thus far indicate

Table D-4

NIEHS RESEARCH ON NOISE-INDUCED HEARING LOSS

| Noise-Induced Hearing Loss Projects | Funding Level (Thousands of Dollars) | | |
|---|---|---|---|
| Program: Effects of Noise and Other Ototoxic Agents on the Auditory and Nonauditory Systems | FY 73 | FY 74 | FY 75 |
| 1. Investigation of Hearing Loss Threshold Curve for Young vs. Mature Animals . . . . . . | 25 | 25 | 0 |
| 2. Combined Effect of Noise and Salicylates on Cochlear Morphology and Auditory Threshold . . . . . . . . . . . | 20 | 0 | 0 |
| 3. Identification of Physiological Dysfunction in Neurosensory Hearing Loss Induced by Ototoxic Agents . . . . . . . | 0 | 8 | 29 |
| 4. Physiological Study of Auditory Fatigue (Induced by Noise) . . . . . . . . . . | 0 | 8 | 26 |
| 5. Interaction of Noise and Ototoxic Drugs on Hearing Loss in Animals . . . . . . . | 100 | 100 | 100 |
| Extramural Program | | | |
| 1. Combined Impulse-Continuous Noise: Auditory Effect . . . . . . . . . . . . . . . . | 0 | 51 | 44 |
| TOTALS | 145 | 192 | 199 |

that a profound ototoxic interaction is not taking place, though a clinically significant interaction is a distinct possibility.

- A study of the changes in energy utilization and production under the influence of known ototoxic agents (e.g., noise, ethacrynic acid, etc.) by utilizing electrophysiological*, biochemical, and radioactive tracer techniques and to pinpoint the specific mechanism by which these actions occur in the cochlea.

- A study of auditory fatigue in which the loci or nature of the physiological changes underlying the temporary or permanent threshold shift are being investigated, as well as the potential of auditory fatigue by subtoxic doses of antibiotics.

- A study to determine the nature of the interaction between noise and ototoxic drugs in experimental animals, and to investigate the biochemical mechanisms involved in such losses.

The following project was conducted by a grantee on the NIEHS extramural program:

- A study of the effects of combined impulse and continuous noise on hearing sensitivity and cochlear anatomy. The extent of noise-induced trauma from these combined sources cannot be explained by addition of the acoustic power of the sources. These data are a necessary prerequisite for the ultimate establishment of damage risk criteria for impulse-continuous noise combinations.

## 2.2 Nonauditory Health Effects

NIEHS has one current program with five specific projects on nonauditory health effects research. Programs, projects, and funding for this research are shown in Table D-5.

One of the objectives of this NIEHS program is to investigate, through animal models, specific physiologic mechanisms** which may be effected by chronic noise exposure.

*Electrical techniques for measuring responses

**Including endocrine (glandular) immunologic, pharmacologic (drug), teratogenic (spontaneous birth malformation), cardiovascular (heart and circulatory), and others.

Table D-3

NIEHS RESEARCH IN NONAUDITORY HEALTH EFFECTS

| Nonauditory Health Effects Research Projects | Funding Level (Thousands of Dollars) | | |
|---|---|---|---|
| Program: Effects of Noise and Other Ototoxic Agents on the Auditory and Nonauditory Systems | FY 73 | FY 74 | FY 75 |
| 1. Teratogenic Effects of Noise Exposure and Deprivation . . . . . . . . . . . . . . . . . . | 0 | 10 | 8 |
| 2. Effects of Noise on Corticosterone Secretion in the Rat . . . . . . . . . . . . . . . . . . | 0 | 16 | 0 |
| 3. Noise Polymorphonuclear Leukocyte Function | 0 | 12 | 8 |
| 4. Noise and Cellmediated Immunity . . . . . . . | 0 | 28 | 24 |
| 5. Noise in the Hospital . . . . . . . . . . . . | 8 | 0 | 0 |
| TOTALS | 8 | 66 | 40 |

Under this program, NIEHS is concerned with the investigation, through studies on research animals, of effects of noise and noise-drug interaction on physiological systems and processes other than the auditory systems. NIEHS pursued work on noise effects on the cardiovascular and neural functions in animals which is directed toward determining the exact noise levels at which effects occur, the progress of effects with time, and the ultimate extent of functional impairment. Other systems and processes of interest in current research include:

- A study of the effects of continuous and intermittent noises on adrenal corticoid secretion and of the long-term effects after cessation of noise. Experimentation is being conducted with rats.

- Direct study of the effects of noise of differing duration, both constant and intermittent, on leukocyte (white blood cell) functions such as locating and destroying bacteria and viruses.

- An effort to replicate work of foreign scientists which has shown various immunological deficiencies after chronic noise exposure in experimental animals and in human workers.

- Research to determine whether background noise levels in gestating animal quarters have any role in producing spontaneous birth malformations and to assess these teratogenic effects of increased noise stimuli from a controlled source.

FY 73 NIEHS work on noise in hospitals has been published in the professional literature. Results included data on noise levels found in various types of rooms as a function of occupancy and the relationships between these levels and nonauditory health effects on the hospitalized patient.

## 3. NIOSH

NIOSH has a major research effort on noise-induced hearing loss and also does research in three other categories: nonauditory health effects, individual behavior effects, and measurements methodology and calibration.

### 3.1 Noise-Induced Hearing Loss

NIOSH involvement in noise-induced hearing loss stems from the Occupational Safety and Health Act of 1970 (Public Law 91-596) and the Federal Coal Mine Safety and Health Act of 1969 (Public Law 91-973) which charge the agency with undertaking research and related activities basic to assuring safe and healthful workplace conditions. Research directives under this authority emphasize criteria development efforts for furnishing new health and safety standards and acknowledge needs for more effective techniques of hazard control. The NIOSH effort is in accordance with the goal of identifying and characterizing adverse effects of occupational noise exposures for purposes of defining health and safety requirements for setting noise standards at the workplace.

NIOSH has two general research activities in noise-induced hearing loss under which eleven specific research efforts are currently being pursued. Projects and funding levels for these are shown in Table D-6. From 50 to 60% of NIOSH noise research manpower is given to these two general activities with in-house studies being supplemented by grants, contracts and special foreign currency research agreements (Public Law 480).

Items in parentheses in the following tables reflect best estimates of NIOSH funding in FY 73, but may have been drawn from projects whose titles differed slightly from those listed in the tables. Furthermore, there may be some FY 73 funding which was missed in compiling these data because it was funded under projects terminating in FY 73.

Occupational Hearing Loss - NIOSH has conducted numerous field surveys to interrelate noise conditions in various industries, years of exposure to such noise and the incidence and magnitude of hearing loss in working groups. These data, together with that gained from controlled laboratory studies of hearing changes caused by specific exposure variables, became a part of the basis for a NIOSH criteria document and a suggested new occupational noise standard for safeguarding hearing. This recommended standard is currently under review by the Department of Labor.

The applicability of the proposed standard for coal mining is also being considered in light of the results of a joint NIOSH-Bureau of Mines survey of noise and hearing loss in coal miners.

Special efforts currently being pursued on this program include the following:

- Epidemiological studies of hearing loss due to occupational noise, analysis of existent data on the subject, and field studies for development of hearing risk criteria. This emphasizes intermittent, fluctuating, and impact noise and exposures greater than eight hours per day.

- Development of a coal mine audiogram data bank and analysis of data from a hearing and noise survey of coal miners. This work is aimed toward development of coal mine noise standards.

- Epidemiological study of noise-induced hearing loss and vibration disease among workers using powered saws, being pursued on a foreign currency agreement with Poland.

Table D-6

NIOSH RESEARCH ON NOISE-INDUCED HEARING LOSS

| Specific Noise-Induced Hearing Loss Efforts[1] | Funding (Thousands of Dollars) | | |
|---|---|---|---|
| General Research Activities:[1] Epidemiological Studies, Data Evaluation and Development of Health Criteria | FY 73 | FY 74 | FY 75 |
| 1. Evaluation of Hearing Risk Due to Industrial Noise | (75)[5] | 79 | 104 |
| 2. Short-Term Physical Agents Research: Coal Mine Noise | (35)[5] | 10 | 0 |
| 3. Effects of Noise and Vibration on Health of Woodcutters[2] | -- | -- | -- |
| 4. Exposure to Noise in the Cotton and Flax or Textile Industry[3] | -- | -- | -- |
| 5. Noise and Hearing in the Paperworking Industry | 0 | 0 | 41 |
| General Research Activities:[1] Experimental Studies of the Effects of Occupational Noise on Hearing | | | |
| 1. Laboratory Studies of Noise-Induced Hearing Loss | 0 | 87 | 91 |
| 2. Combined Effects of Noise, Work, and Heat on Human Hearing | (24)[5] | 18 | 0 |
| 3. Aspects of Ear Tolerance to Noise | 50 | 0 | 0 |
| 4. Laboratory and Field Study of Impact Noise | 40 | 0 | To be determined |
| 5. Damage Risk Criteria for Intermittent Noise Exposure | 0 | 56 | 47 |
| 6. Noise and Heat Effects on Man[4] | -- | -- | -- |
| 7. Effects of Impulse Noises on the Auditory System | 0 | 91 | 69 |
| TOTALS | 224 | 341 | 352 |

[1]NIOSH does not use the terms "program" and "project" in the same sense as this report. Thus the use of those terms has been avoided.
[2]Total funding of $212,600 for the period 7/68 to 9/74
[3]Total funding of $ 99,400 for the period 7/71 to 7/75
[4]Total funding of $167,000 for the period 5/72 to 4/77
[5]Project titles were not the same in FY 73.

- Epidemiological study of noise levels and hearing acuity of exposed workers to develop safe-level criteria for long-term exposure to steady noise. This project is being conducted on a foreign currency agreement with Egypt.

<u>Experimental Studies of Occupational Noise Effects on Hearing</u> - Research in this problem area for FY 73, continuing through FY 74, and planned for FY 75 is attempting to supply evidence confirming the need for and nature of different exposure limits to take account of certain noise conditions commonly found in industry, e.g., repeated impact sounds as opposed to steady-state sounds, intermittent or variable exposures as distinct from continuous or constant exposures, and work-shift noise exposures lasting longer than eight hours per day.

Other related work expected to end in FY 74 or early FY 75 involves identification of (1) added heat and workload effects on noise-induced threshold shifts, (2) factors underlying increased ear resistance to noise-induced hearing change, and (3) hearing loss and other potential hazards from industrial equipment emitting ultrasonic energy.

Specific research efforts conducted in FY 73-74 include:

- Laboratory studies of occupational noise effects including temporary and permanent hearing loss and anatomical damage to the inner ear. The work emphasizes impact noise, fluctuating noise and methods of measuring hearing loss. Both animal and human subject research are involved. This project includes both in-house and contract effort.

- Evaluation of physiological, audiological, and otological data obtained from selected groups of industrial workers to identify particular factors which differentiate susceptible from nonsusceptible workers in terms of their tolerance to noise exposure.

- Laboratory tests of human subjects and measurement of industrial noise exposures to obtain data to aid in developing criteria for a health standard on impact noise.

- Laboratory studies of temporary hearing threshold shift from intermittent noise exposures in order to evaluate and develop damage risk criteria for occupational exposures.

- A study to determine the health consequences to workers exposed to both heat and noise at the work site and establish under controlled laboratory conditions the auditory and circulatory interactions elicited by noise and heat exposure. This work is being performed on a foreign currency agreement with Poland.

- Studies of changes in anatomy and physiology of the inner ear, as well as temporary hearing loss, due to exposure to impulse or impact noise at high levels. This work involves animal test subjects.

### 3.2 Nonauditory Health Effects

NIOSH has one current general research activity with the three specific research efforts in nonauditory health effects. The goals are to determine whether adherence to occupational noise limits for safeguarding hearing can also minimize problems of performance errors or accidents, stress-related ailments, and sick-absenteeism also reputed to be caused by high workplace noise levels.

Funding levels for the agency's research in nonauditory health effects are shown in Table D-7.

The following specific research efforts are being pursued under the agency's program on extra-auditory effects of occupational noise:

- A study of worker safety and health in which a comparison is made of entries in the medical, attendance, and safety records of workers in noisy jobs before and after the advent of a company hearing conservation program.

- Laboratory studies to examine the effects of noise exposure at maximum permissible occupational levels upon visual, tactile, thermal, vestibular, and kinesthetic sensory functions.

### 3.3 Individual Behavior Effects

NIOSH is concerned with the behavorial response of workers to noise, particularly as it may lead to performance error and accidents.

Funding levels for research in individual behavior effects are shown in Table D-8. These represent NIOSH-sponsored grants.

Table D-7

NIOSH RESEARCH IN NONAUDITORY HEALTH EFFECTS

| Specific Nonauditory Health Effects Research Efforts [1] | Funding Level (Thousands of Dollars) | | |
|---|---|---|---|
| General Activity: Extra-Auditory Effects of Occupational Noise | FY 73 | FY 74 | FY 75 |
| 1. Effects of a Company Hearing Conservation Program on Noise-Related Extra-Auditory Disturbances in Workers . . . . . . . . . . . . . | 0 | 42 | 0 |
| 2. Effects of Noise on Nonauditory Sensory Functions and Performance . . . . . . . . . . | 78 | 0 | 21 |
| 3. Effects of Noise and Heat and Health of Workers in Metal Industry (PL-480 Research Agreement) . . . . . . . . . . . . . . . . . . . | 30 | 0 | 0 |
| TOTALS | 108 | 42 | 21 |

[1] NIOSH does not use the terms "program" and "project" in the same sense as this report. Thus their use has been avoided.

Table D-8

NIOSH RESEARCH ON INDIVIDUAL BEHAVIOR EFFECTS

| Specific Individual Behavior Effects Efforts [1] | Funding Level (Thousands of Dollars) | | |
|---|---|---|---|
| General Activity: Extra-Auditory Effects of Occupational Noise [2] | FY 73 | FY 74 | FY 75 |
| 1. Effects of Three Sound Environments on Human Behavior . . . . . . . . . . . . . . . . . | 0 | 8 | 0 |
| 2. Noise and Human Performance . . . . . . . . . | 0 | 20 | 0 |
| TOTALS | 0 | 28 | 0 |

[1] NIOSH does not use the terms "program" and "project" in the same sense as this report. Thus their use has been avoided.
[2] This NIOSH activity also includes research efforts categorized as nonauditory health effects in this report.

The following grant research projects are just complete or continuing:

- A study of the effects of three sound environments on human behavior, designed to identify the various conditions of a noise stimuli on performance in a realistic work situation. This study was initiated in recognition of the fact that: noise-induced performance effects are specific to the tasks used, and, that work requirements and work schedules of most noise-related research projects have little resemblance to actual work conditions.

- A study of noise and human performance, primarily concerned with the relationship between the meaning which may be associated with particular sounds or noise and the effects of these sounds on human performance. Through various techniques, including conditioning, meaning will be attached to particular sounds. The effects of these sounds on various types of performance tasks, which have a number of built-in subsidiary tasks, will be determined.

Starting in FY 76, NIOSH is planning a new study of worker accidents and near-accidents in noisy job settings relative to implicating noise as a contributing causal factor.

### 3.4 Measurement Methodology and Calibration

NIOSH conducts research to improve instrumentation, test systems and survey methodologies to support research in industrial hearing conservation and occupational noise control and to improve acoustic measurement techniques in general. The agency has two research projects in measurement methodology and calibration. Funding level for this effort are shown in Table D-9.

The following specific research efforts are underway:

- Work on the NIOSH audiometric measurement activity includes the study of alternative methods of measuring occupational hearing loss, construction of a programmable electro-acoustic test system, and investigation of methods for automatic processing of audiometric data.

- The agency's current project on improved methods for occupational noise survey includes: laboratory and field tests on noise dosimeters, development of improved methods for their usage, and development of performance tests for use in the NIOSH certification program.

Table D-9

NIOSH RESEARCH IN MEASUREMENT METHODOLOGY AND CALIBRATION

| Specific Measurement Methodology and Calibration Efforts[1] | Funding Level (Thousands of Dollars) | | |
|---|---|---|---|
| General Activity: Industrial Hearing Conservation Practices, Acoustic Measurements, and Occupational Noise Control | FY 73 | FY 74 | FY 75 |
| 1. Industrial Audiometric, Hearing Conservation Technology and Noise Control . . . . . . . . . . . | (31)[2] | 52 | 80 |
| 2. Measurement of Occupational Noise . . . . . . . | (32)[2] | 44 | 28 |
| TOTALS | 63 | 96 | 108 |

[1]NIOSH does not use the terms "program" and "project" in the same sense as this report. Thus their use has been avoided.
[2]The project titles were not the same in FY 73.

## 4. DOD

DOD pursues current major research efforts in the following categories:

- Noise-induced hearing loss
- Individual behavior effects
- Communication interference
- Measurement methodology and calibration.

DOD also conducts current research efforts in the following categories:

- Nonauditory health effects
- Community or collective response.

### 4.1 Noise-Induced Hearing Loss

Military agencies of DOD are involved in research on noise-induced hearing loss by personnel in a wide variety of environments, including:

- Firing of weapons
- Aeronautical operations
- Shipboard compartments.

The overall goal of this research is the conservation of hearing of personnel by setting and adhering to exposure criteria where possible and providing protective devices in other cases.

The Army, Navy, and Air Force each have research programs in noise-induced hearing loss with a total of thirteen specific projects. These are listed together with project funding levels in Table D-10.

U.S. Army Program - The goals of the Army program in noise-induced hearing loss are to identify the causes and relationships between hearing loss and exposure to noise in the environments of the various army branches and to determine how to protect the hearing of Army personnel.

The Army prepared three technical reports in FY 73 on its work on the relationship of hearing change to acoustic inputs which present findings which seriously question existing theories of auditory damage risk and could result in significant changes in theory if verified.

The following specific projects are being pursued under the Army program of research in noise-induced hearing loss:

Table D-10

DOD RESEARCH IN NOISE-INDUCED HEARING LOSS

| Noise-Induced Hearing Loss Projects | Funding Level (Thousands of Dollars) | | |
|---|---|---|---|
| U.S. Army Program | FY 73 | FY 74 | FY 75* |
| 1. Military Performance-Traumatic Origins of Hearing Loss | 0 | 0 | |
| 2. Relationship of Hearing Change to Acoustic Inputs | 62 | 66 | |
| 3. Prevalence of Hearing Loss Within Selected U.S. Army Branches | 0 | 20 | |
| 4. Hearing Conservation: Intense Acoustic Stimulation and Noise Susceptibility in the Military Environment | 46 | 0 | |
| U.S. Navy Program | | | |
| 1. Communications: Hearing of Naval Personnel as a Function of Noise Exposure | 20 | 0 | |
| 2. Study of Anatomic Changes in the Middle Ear Associated with Noise-Induced Hearing Loss and Acoustic Trauma | 10 | 19 | |
| 3. Middle Ear Compliance and Its Relationship to Military-Related Noise-Induced Hearing Loss and Acoustic Trauma | 8 | 13 | |
| 4. The Incidence of Hearing Loss Among Various Navy Rated Personnel | 0 | 50 | |
| 5. Development of Damage Risk Criteria and Habitability Standards for Exposure to Sonar Transmissions | 20 | 25 | |
| U.S. Air Force Program. | | | |
| 1. Effects of Noise on Air Force Personnel in Operational Environments | 20 | 49 | |
| 2. Research on Permanent and Temporary Shifts in Hearing Thresholds Produced by Exposure to Air Force Noise | 0 | 2 | |
| 3. Auditory Responses to Acoustic Energy Experienced in Air Force Activities | 24 | 22 | |
| 4. Human Subjects for Operating Acoustic Research | 38 | 35 | |
| TOTALS | 248 | 301 | 301* |

*DOD FY 75 data estimated the same as FY 74.

- Analysis of causes of hearing loss, beginning with the cochlea and proceeding to higher levels of the nervous system. Changes in sensitivity are followed as animal ears are exposed to high intensity pure tones and impulses, followed by histology.

- Investigation of the prevalence of hearing loss in selected Army branches (infantry, artillery, and armor) and its relationship to the length of time in the service.

- A study of premature hearing loss by Army troops. This work includes an evaluation of current noise sources and the effectiveness of protective devices and current hearing conservation practices in the field.

U.S. Navy Program - The U.S. Navy program of research in noise-induced hearing loss is directed to development of increased knowledge of the mechanisms of anatomic change involved, to define the incidence of noise-induced hearing loss in Navy job specialties, and to develop hearing conservation standards for specific job specialties. The following specific projects are being pursued under the Navy program:

- A study of anatomic changes in the middle ear associated with noise-induced hearing loss and acoustic trauma. Histologic examinations of temporal bones from autopsies are evaluated for changes in the auditory nerve and organ of corti, results of which are then correlated with the background of noise exposure and acoustic trauma as well as with clinical findings including the audiogram.

- A study correlating middle ear compliance audiograms and noise exposure histories designed to provide new and productive data regarding susceptibility to noise-induced hearing loss in military personnel.

- A study of the incidence of noise-induced hearing loss among Navy personnel working in various Navy rated job specialties.

U.S. Air Force Program - The Air Force research program is directed toward defining risks of noise-induced hearing loss in Air Force environments and for developing regulations and guidelines for hearing conservation.

The Air Force prepared a comprehensive document for establishment of criteria for limiting noise levels to protect hearing of personnel and a review document on infrasound and hearing.

Research on effects of noise on Air Force personnel has resulted in auditory damage risk criteria published in AFR 161-35 titled Hazardous Noise Exposure. It was found that all categories of Air Force aircraft studied contained definite degrees of auditory risk to unprotected ears according to the newly adopted auditory risk limits.

Air Force research on temporary threshold shift for 16-hour exposures has been submitted for publication in the professional literature. Subjects tested showed varying response including some with an asymptote-type response after eight hours, some with a continued sharp rise of TTS for the entire 16 hours and a few with asymptotic effects after one-hour exposure. Data have not been fruitful in predicting noise-induced permanent threshold shift. It was being considered that the magnitude of asymptotic levels of TTS or the rate at which the asymptote is approached may be an appropriate predictor for noise-induced hearing loss.

The following specific projects are being pursued under the Air Force program:

- A study of the hearing status of Air Force personnel in the operational environment and development of special tests for selection and continuance of personnel in career fields involving noisy environments.

- Research on permanent and temporary shifts in hearing threshold produced by exposure to Air Force environments.

- An investigation of hearing loss, personal sound protective devices, infrasonic and impulsive signals, and related subjects. The work is directed toward development of regulations and guidelines for risk to hearing.

### 4.2 Nonauditory Health Effects

The Air Force had a single research project in FY 73 on the effects of acoustical energy on vestibular functioning. Goals of this research were to develop an understanding of the conditions and manner in which high intensity noise affects the equilibrium and produces disorientation and to contribute to the development of threshold criteria for hazardous exposure to high intensity sound.

A review paper on Air Force research on the effects of infrasound on the vestibular system was prepared on this project.

Funding level on this project was $10,000 in FY 73.

### 4.3 Individual Behavior Effects

This agency's research efforts are directed toward defining and analyzing the effects of exposure on personnel, evaluating and optimizing the performance under the exposures encountered in the military services and evaluating protective devices for mitigating response to noise. The Army, Navy, and Air Force each have research programs in this category. The current Air Force program includes research of a more fundamental nature.

Six specific research projects were underway in the FY 73-74 period, for which funding levels are shown in Table D-12.

The following specific project activity was pursued:

U.S. Army - The army project is directed toward developing predictive models of noise effects on soldiers' performance and improving existing noise criteria, including effects of long-term exposure. A new Army Materiel Command noise standard was published and the first Army-wide military standard on noise limits was fully coordinated and published.

U.S. Navy - Current Navy research on individual behavior effects of noise is directed toward evaluating and optimizing human performance under exposure to noise in submarine and aircraft environments.

Laboratory evaluations have been conducted on headsets proposed for use by acoustic sensor operators in antisubmarine warfare patrol and on military noise cancelling microphones. Experiments have been conducted on the effects of high noise levels on sonar doppler and on auditory tracking of a signal under perceptual arrangements. The following two specific projects are currently in progress:

- In its work on auditory performance in submarines, the Navy is studying the physical characteristics of sound systems and the performance of operators. This includes work on hearing sensitivity and auditory vigilance by behavioral and electrophysiological means under various conditions of complex auditory displays. Parameters in target detection are to be specified and their quantitative effect on target detection determined.

- The second project is directed to optimizing auditory performance in naval acoustical environments and minimizing problems arising from the many forms of sound/man interaction, including auditory fatigue due to prolonged exposure to flight operation noises. New tests and procedures are being developed and evaluated to assess man's ability to perform auditory tasks and otherwise enable individuals to operate efficiently in naval aviation acoustical environments.

U.S. Air Force - Air Force concerns regarding individual behavior effects cover a wide range of intense noise environments affecting motor

Table D-11

DOD RESEARCH ON INDIVIDUAL BEHAVIOR EFFECTS

| Projects on Individual Behavior Effects | Funding Level (Thousands of Dollars) | | |
|---|---|---|---|
| U.S. Army Program | FY 73 | FY 74 | FY 75 |
| 1. Improved Weapon Noise Exposure Criteria | 62 | 66 | |
| U.S. Navy Program | | | |
| 1. Optimization of Performance in Submarine | 54 | 44 | |
| 2. Optimization of Auditory Performance in Naval Aviation | 40 | 35 | |
| U.S. Air Force Program | | | |
| 1. Simultaneous Exposure to Acoustic Energy and Other Stressors Found in Air Force Environments | 7 | 3 | |
| 2. Whole Body Effects of Air Force Noise on People | 24 | 18 | |
| 3. Research on Intermittent Noise Effects on Air Force Target Detection Tasks | 46 | 0 | |
| TOTALS | 233 | 166 | 166* |

*FY 75 data estimated the same as FY 74

performance, vestibular functioning, physiological functioning, thought processes, and the contribution to apprehension and fatigue of personnel.

Eight years of in-house research on whole body effects of Air Force noise environments on people were published in Air Force reports and summarized in a paper published in the Proceedings of the International Congress on Noise as a Public Health Problem sponsored by EPA. A study of human performance effects of impulsive noise, randomly varied with respect to intensity, duration and time of occurence, has been prepared.

The following specific projects are currently under underway:

- A research study on simultaneous exposure to acoustic energy and other stresses found in Air Force environments which combines controlled acoustic exposures with mechanical whole body vibration of volunteers to determine effects of the combined exposures on psychomotor task performance, mental or cognitive performance, temporary threshold shift, and possible subjective judgments of acceptability. Single stress effects are being compared to the measured multiple stress effects to determine differential contributions of the respective stress conditions.

- A study of whole body effects of Air Force noise on people that involves investigation of numerous types of noises and exposure conditions in which accomplishment of the Air Force mission may be threatened. The approach is to measure the effects of the many kinds of noise (infrasound, audio frequencies, impulses) on standard and special performance tasks, circulation in the peripheral members, on physiological processes, on mental tasks such as memory, and on various measures of vestibular functioning such as equilibrium, counterrolling of the eyes and nystagmus. Findings are used to establish exposure limits beyond which undesirable effects may occur. Much of this work is possible only because of the unique stimulus generators available at the Aerospace Medical Research Laboratory.

## 4.4 Communication Interference

DOD research in communication interference is directed toward enhancing or optimizing intelligibility of speech and signals in military acoustical environments. Current interests are in air/ground and ground/air communications and personnel communications in submarine and shipboard jobs requiring high levels of auditory acuity. Another goal of DOD research in communication interference is to reevaluate criteria and validate audiometric standards for Navy ships.

The Navy and Air Force have current program activity related to communication interference and the Army has also done prior work in this category. Funding levels for DOD research in this category are shown in Table D-12.

The following specific projects are being pursued on the current DOD programs:

- Work on optimization of speech communication in naval aviation involves development and evaluation of new tests and procedures to assessing the ability of air-crewmen to communicate in various naval aviation acoustical environments and the capability of air-to-ground and ground-to-air communicating systems to transmit intelligible speech. Investigations to date indicate that preferred listening levels for speech of aviators and aircrew personnel probably represent speech levels where maximum intelligibility can be achieved. Preferred signal-to-noise ratios have been identified for certain noise levels.

- A second Navy project is directed toward development of auditory screening and acoustical tolerance standards for submarine and shipboard personnel. Experimental studies are being conducted to assess auditory perception of a variety of speech materials and signal stimuli, embedded in various background sound fields, for personnel of differing levels of acuity. Longitudinal studies are conducted to assess changes in hearing abilities among submarine personnel to identify predictive indices of hearing loss and the habituation process which enhances operator auditory acuity. The latter is of potential benefit in the design of training programs, auditory aids, or acoustical characteristics of submarine environment.

Data were collected to evaluate the proficiency of several different speech reception tests. Four new tests of speech in noise and in quiet have been constructed. Results of this work are published in a series of reports.

- The current Air Force project involves investigation of the response of human subjects to pure tones, speech and noise. Evaluations are being made of new techniques and instruments for measuring the auditory function of flying personnel with or without hearing impairment. Simulated inflight hearing tests are involved.

4.5 Community or Collective Response

Within DOD the Air Force had, in the past, a very considerable involvement in research on community or collective response. However, the USAF had

Table D-12

DOD RESEARCH IN COMMUNICATION INTERFERENCE

| Projects in Communication Interference | Funding Levels (Thousands of Dollars) | | |
|---|---|---|---|
| U.S. Navy Program | FY 73 | FY 74 | FY 75* |
| 1. Optimization of Speech Communication in Naval Aviation | 40 | 40 | |
| 2. Development of Auditory Screening and Acoustical Tolerance Standards for Submarine/Shipboard Personnel | 30 | 33 | |
| 3. Sound Conduction in the Ear Affecting Military Communications | 26 | 0 | |
| U.S. Air Force Program | | | |
| 1. Assessment of Hearing in Flying Personnel | 28 | 36 | |
| TOTALS | 124 | 109 | 109* |

*FY 75 data estimated the same as FY 74

only a single project, Effects of Air Force Noises on Populations Surrounding Air Bases, active in FY 73 at a funding level of $31,600.

4.6 Measurement Methodology and Calibration

The Army, Navy and Air Force each have research programs in measurement methodology. Objectives of this work are to provide specialized support of noise health effects research through development and upgrading of measurement systems, procedures, equipment, and facilities. Activities pursued on these programs include:

- Development of new measurement methodology and test procedures and criteria
- Evaluation/validation of measurement procedures
- Instrumentation development
- Development of conceptual computational procedures and major computer software
- Developing procedures for assessing/predicting effects
- Establishing and operating environmental noise data banks
- Developing instrument calibration techniques and equipment.
- Developing equipment and procedures for evaluating human response.

Seven current research projects are underway. Program/project relations and funding levels for this effort are shown in Table D-13.

The following seven specific projects were underway in the FY 73-74 period:

U.S. Army Program

- The Army's research on psychoacoustic problems in aviation included development of a new measurement methodology and quality control test for real-ear sound attenuation characteristics of helmets and a test for an advanced voice communication system. A new helmet for tank crewmen was tested and accepted as a standard.

Table D-13

DOD RESEARCH IN MEASUREMENT METHODOLOGY AND CALIBRATION

| Projects in Measurement Methodology and Calibration | Funding Levels (Thousands of Dollars) | | |
|---|---|---|---|
| U.S. Army Program | FY 73 | FY 74 | FY 75* |
| 1. Research in Psychoacoustical Problems Medically Significant to Army Aviation . . | 85 | 195 | |
| U.S. Navy Program | | | |
| 1. Airborne Noise Criteria for Ships and Submarines . . . . . . . . . . . . . . . . . | 69 | 74 | |
| U.S. Air Force Program | | | |
| 1. Mechanics of Noise Generation, Propagation and Reception as Related to Air Force Bioacoustic Problems . . . . . . . . . . . | 3 | 2 | |
| 2. Bioacoustic Environments of USAF Aerospace Systems . . . . . . . . . . . . . . . . . . | 92 | 68 | |
| 3. Bioenvironmental Noise/Research Program | 43 | 0 | |
| 4. Development and Updating of Air Force Land Use Planning Procedure with Respect to Aircraft Noise . . . . . . . . . . . . . . | 32 | 0 | |
| 5. Measurement and Analysis of Aircraft Noise Environments for Developing New Air Force Procedures to Forecast Noise Exposure . . | 13 | 15 | |
| TOTALS | 337 | 354 | 354* |

*FY 75 data estimated the same as FY 74

U.S. Navy Program

- The Navy's research on noise criteria for ships and submarines emphasizes the establishment of measurement methods and criteria for limiting airborne noise in ship spaces and enforceable specifications for acceptable noise by equipments produced for use on naval vessels. Work included obtaining and comparing measurements of airborne noise in various ship compartments with measures of performance and habitability, and the evaluation/ validation of the adequacy of measurement procedures under actual shipboard conditions, in the laboratory, in the field, and in equipment contractor plants.

U.S. Air Force Program

- A bioenvironmental noise research project to provide technical procedures, data and software required to define the high-level noise environments generated by Air Force weapons systems, determine the effect on man, and provide such information to user groups.

  This involved establishment and operation of a data bank for storing and retrieving bioenvironmental noise data and developing extensive major software to process and extrapolate measured environmental noise data.

  A wide variety of environmental and laboratory test stimuli were also measured and analyzed, including air bag transients, aircraft engine noise, and speech samples. Equipment and procedures were developed for evaluating effects of noise and performance.

  Special techniques and equipment were developed to calibrate various types of acoustic instrumentation.

- A project on mechanisms of noise generation, propagation and reception to provide engineering methods necessary to compute high noise level environments (e.g., ground runup). This work was undertaken to improve the algorithms used to predict far-field noise levels for application in both the Bioenvironmental Data Handbook and the noise exposure forecast program.

- A study of bioacoustic environments of aerospace systems in which noise environments are measured, analyzed, and simulated by means of precision analog and digital instrumentation.

A very small noise recording system, called Micropak, was developed to be worn by pilots for obtaining noise data where space limitations are severe. A unique pistonphone was developed for calibrating microphones at infrasonic frequencies.

- The measurement of noise from numerous types of military aircraft and analysis and processing for use in calculating noise exposure forecasts. This work was undertaken to improve the accuracy and reliability of noise exposure forecast computations based on data files which had contained only estimated data on many aircraft systems.

- A project to develop a fully computerized computational methodology to automatically plot contours of equal exposure levels about an air base.

## 5. NASA

NASA conducts current major research efforts in three categories, noise effects on sleep, community or collective response, and measurement methodology.

### 5.1 Noise Effects on Sleep

The objective of NASA research in this category is to understand the relationship between aircraft noise exposure and sleep interference. The agency's work in this area is part of an ongoing research program on human response to noise which includes projects devoted largely to aircraft noise effects on sleep as well as other major projects in community and collective response and measurement methodology.

NASA's project on the human response to the aeronautical environment is directed toward understanding the psychophysiological effects of aircraft noise on people and to develop a quantitative understanding of individual response to noise exposure. This includes assessment of subjective reactions and effects on sleep, effects on hearing, and development of research evaluation techniques and measuring scales. Emphasis is placed on laboratory studies with complementary studies in communities exposed to noise and with special overflight programs where selected juries are exposed to noise. Studies are concerned with responses of people during both awake and sleep periods and under background noise conditions associated with outdoor, indoor and inflight situations.

Laboratory studies to evaluate noise effects on sleep are supplemented by initial studies of sleep responses of people living in communities exposed to commercial flight operation noise. Studies are being conducted in contractors' laboratories to evaluate both awakening and nonawakening effects of noise on sleep.

Funding levels for this effort are shown in Table D-14.

Table D-14

NASA RESEARCH ON NOISE EFFECTS ON SLEEP

| Project in Noise Effects on Sleep | Funding Levels (Thousands of Dollars) | | |
|---|---|---|---|
| Program: Human Response* to Noise | FY 73 | FY 74 | FY 75 |
| Human response to the Aeronautical Environment | 217 | 254 | 142 |
| TOTALS | 217 | 254 | 142 |

*Total program includes work in community or collective response and measurements.

Table D-15

NASA RESEARCH IN COMMUNITY OR COLLECTIVE RESPONSE

| Projects in Community or Collective Response | Funding Levels (Thousands of Dollars) | | |
|---|---|---|---|
| Program: Human Response to Noise | FY 73 | FY 74 | FY 75 |
| 1. Acceptance of Aircraft Operations - Technology Assessment | 173 | 172 | 232 |
| 2. Acceptance of Aircraft Operations - Community Noise | 205 | 319 | 422 |
| TOTALS | 378 | 491 | 654 |

## 5.2 Community or Collective Response and Measurements

NASA research is conducted under its Human Response to Noise program whose overall goal is to develop an understanding of the relationship between aircraft noise exposure and annoyance, e.g., to define and quantify those properties of aircraft noise exposure that cause negative individual and community response to air transportation systems.

Specific targets set for the NASA program are:

- Devising proper methodologies for laboratory and field studies of human response to aircraft operations. FY 1975.
- Determining effects of multievent noise exposure characteristics on human response to aircraft operations. FY 1975.
- Quantifying the effects of background environmental noise exposure on the human response to aircraft-generated noise. FY 1975.
- Studying the effects of low frequency noise characteristics generated by present and future aircraft on auditory and nonauditory responses of people. FY 1979.
- Developing a model for reliable prediction of responses of people to aircraft operations that will satisfy laboratory and field conditions. FY 1980.

The NASA program includes two specific projects in community-collective response plus project work in other categories. Program/project relationships and funding levels for NASA research in this category are shown in Table D-15 on page 34.

The following specific projects are currently underway:

- NASA has a technology assessment project for developing an understanding of the social effects of large-scale air transportation systems and to design technology leading to improved safety and comfort of aircraft crew and passengers. This project includes in-house studies of the human response to aircraft sound stimuli. Human test subjects will be asked to give category judgment of aircraft sounds, including STOL signatures.

- NASA also has a current community noise study which includes evaluation of: noise characteristics of advanced VTOL and STOL aircraft; acoustic retrofit systems for CTOL aircraft; and noise alleviation procedures for aircraft and airport operations. This work will provide criteria for prediction of community acceptance of aircraft operations/community noise. Emphasis will be placed on laboratory studies and airport-community studies/surveys which may be supplemented by programmed overflight studies. These studies will be closely interrelated with, or in support of, NASA project activities (STOL) and with the DOT/FAA programs to control aircraft and airport noise. The laboratory techniques employed range from listening room testing with trained subject, to real-life situations where test environments represent the airport-community/home and where the test subjects may be people plagued by aircraft noise. These efforts efforts are summarized in Table D-16

Table D-16

NASA RESEARCH IN MEASUREMENTS

| Project in Measurement Methodology and Calibration | Funding Level (Thousands of Dollars) | | |
|---|---|---|---|
| Program: Human Response to Noise | FY 73 | FY 74 | FY 75 |
| Acceptance of Aircraft Operations (Characterization of V/STOL Noise) | 532 | 409 | 404 |

## 6. DOT

DOT has had recent research efforts in two categories, individual behavior effects and community or collective response.

### 6.1 Individual Behavior Effects

DOT had no project work under way in this category in FY 74. A program on startle effects of sonic boom was underway in FAA in FY 73, consisting of two specific projects. The U.S. Coast Guard also had foghorn aversiveness under investigation at NBS in FY 73. Funding levels for these projects are shown in Table D-17.

Table D-17

DOT RESEARCH ON INDIVIDUAL BEHAVIOR EFFECTS

| Projects on Individual Behavior Effects | Funding Levels (Thousands of Dollars) | | |
|---|---|---|---|
| | FY 73 | FY 74 | FY 75 |
| 1. Field Study of Sonic Boom Startle Effects | 18 | 0 | 0 |
| 2. Determinants of Startle Response to Simulated Sonic Booms | 27 | 0 | 0 |
| Foghorn Aversiveness Study | 5 | 0 | 0 |
| TOTALS | 50 | 0 | 0 |

## 6.2 Community or Collective Response

DOT research in this category is concerned with providing a valid measure of effectiveness for assessing relative benefits of alternative means for reducing transportation-related noises. DOT is concerned with all modes of transportation in this regard.

DOT has had a considerable program involvement in this area in the past. The agency's program now consists of one current project in the category which is scheduled for completion in June 1975. This consists of testing the feasibility of a technique developed on the project to assess the relative importance of various noises to the public, particularly transportation noises, and to determine the validity of a "personal noise exposure index" model for community noise impact representation. Specific research work consists of: developing the "personal noise exposure index" model; measuring the daily noise exposure of 30 to 50 individuals; correlating noise exposure, noise sources and reported annoyance; evaluating the usefulness of the analytical model and developing a plan for its refinement if the concept is judged beneficial.

Two alternative approaches to measuring human response to noise have been tested, and two separate plans developed for a national noise measurement program. Results of this research are published in a series of four Government technical reports.

Funding levels for this project are $130,000 for FY 74 and $50,000 for FY 75; about $295,000 was funded for this program prior to FY 73.

# 7. DOC(NBS)

NBS has a major research effort in individual behavior effects.

NBS' objectives in noise health effects are to: establish a more consistent and valid psychophysical foundation for measuring the effects of sound on people with application to noise abatement and control; develop new measurement procedures for obtaining psychoacoustic data and elaborate through empirical experiments an interlocking system of techniques for assessing human response to sound with built-in opportunities for cross-validation.

The NBS program in psychoacoustic measurement has one current project, titled Psychoacoustic Measurement Techniques, and funded as follows:

FY 73: $ 98,000
FY 74: $117,000
FY 75: $142,000.

Specific NBS project activity on loudness measurement includes: analyzing previous research on loudness, noisiness, and aversiveness of sounds; evaluating the psychoacoustic measurement techniques as applied to standardizing methods for calculating the loudness, noisiness, annoyance, etc., of sound; and developing new psychoacoustic measurement techniques based on operational definitions of behavioral responses with the biases due to verbal instruction minimized.

Equal aversion levels have been established for pure tones and 1/3-octave measures, the aversiveness of three full-octave bands were determined and compared with auditory-evoked potential brain wave recordings from the subjects; the preference relations among various acoustic stimuli were examined by means of a binary switching response not involving verbal descriptors. In addition, a variable interval schedule was used to determine the relative aversiveness of several pure tone stimuli.

Extension of the work calls for establishing preference relations among sounds of varying frequency and intensity using pure tones and white noise; determining the relative aversiveness of sound of different spectral content and cross-validating by different methodologies.

## 8. HUD

HUD has major research efforts in two categories, community or collective response and measurement methodology and calibration.

### 8.1 Community or Collective Response

HUD pursues research in community or collective response in order to provide the necessary RD&D to technically support the Department's policies and operating programs and to provide guidance for land usage near major noise sources. Prior HUD research has provided technical background for the preparation of two documents, "HUD Noise Abatement Guidelines" and "HUD Noise Assessment Guidelines" which have been widely distributed for use in implementing the supporting Department policy.

HUD's current program of research on community or collective response consists of two projects, funding levels for which are shown in Table D-18. The following specific project work is being performed:

- HUD is conducting a comprehensive nationwide study and systematic evaluation of the effectiveness and impact of the Department's noise policy and of its "Noise Assessment Guideline." The work is being pursued with a view toward their revision and improvement.

- HUD also expects to initiate a broad study of the effects of noise on community development in FY 75. This will include work on acoustical criteria for various land use ordinances and building codes, the

Table D-18

HUD RESEARCH IN COMMUNITY OR COLLECTIVE RESPONSE

| Projects in Community or Collective Response | Funding Level (Thousands of Dollars) | | |
| --- | --- | --- | --- |
| | FY 73 | FY 74 | FY 75 |
| 1. Evaluation of HUD Noise Policies and Guidelines | 0 | 200 | 185 |
| 2. Effects of Noise on Community Development | 0 | 0 | 225 |
| TOTALS | 0 | 200 | 410 |

Table D-19

HUD RESEARCH IN MEASUREMENT METHODOLOGY AND CALIBRATION

| Projects in Measurement Methodology and and Calibration | Funding Level (Thousands of Dollars) | | |
| --- | --- | --- | --- |
| | FY 73 | FY 74 | FY 75 |
| 1. HUD Urban Noise Measurement System | 117 | 263 | 0 |
| 2. Development of Noise Attenuation Measures | 0 | 175 | 50 |
| TOTALS | 117 | 438 | 50 |

effects of noise on housing markets and land values, and the noise compatibility of intra- and inter-urban transportation with community development.

## 8.2 Measurement Methodology and Calibration

HUD research in measurement methodology is directed toward developing measurement systems for use in enforcing HUD departmental standards on noise abatement and control. The agency has one program of two specific research projects in this category as shown in Table D-19 on page 40.

Under this program HUD funded a project performed by NBS in FY 74 to develop an inexpensive portable urban noise exposure measurement system which separates potential housing sites into "clearly acceptable" or "clearly unacceptable" for HUD housing and to demonstrate a measurement system for evaluating sites not clearly within either of these categories as an alternative to acquiring needed data through a full-scale survey.

In pursuance of HUD goals, NBS is developing an instrumentation system consisting of two units, an outdoor "monitor" which is left on the building site and a "reader" which interrogates the monitor. The monitor will be a self-contained, battery-operated unit which registers, on internal memory, the times in any 24-hour period during which the noise level exceeded 45, 65, 75, and 80 dBA. Seventeen units are being procured by HUD for field test by NBS in cooperation with HUD field offices. Additionally, the instruction manual developed by NBS will be field tested.

NBS is also assisting HUD in the comprehensive evaluation of the noise measurement systems in HUD Regional, Area and Insuring Offices across the nation.

# 9. EPA

EPA has current research efforts in six of the eight categories of health effects research. This includes a major research effort in individual behavior effects plus research efforts in the following categories:

- Noise-induced hearing loss
- Nonauditory health effects
- Individual behavior effects
- Noise effects on sleep
- Communication interference
- Measurement methodology and calibration.

## 9.1 Noise-Induced Hearing Loss

Determination of effects of noise and vibration on hearing sensations and on human performance. This included investigation of the effects on human performance of whole body vibration combined with a random amplitude modulated pure tone presented to the auditory system (FY 74 $25,000).

Effects of long exposure to noise on hearing threshold. Research includes investigations to determine whether recovery from an asymptotic auditory temporary threshold shift is independent of the duration at which temporary threshold shift is maintained at an asymptotic level. Exposures are made for continuous noise for 24 and 48 hours. Intermittent exposures will be included in subsequent experiments. Other studies are to be conducted in natural living environments under controlled noise exposures of 48-60 hours (FY 74 $25,000), (FY 74 $70,000).

## 9.2 Nonauditory Health Effects

Determination of nonauditory system adaptation effects to long-term repetitive and varying noise. Studies explore the role of various stimulus, psychological and methodological variables in the elicitation and adaptation of nonauditory physiological system reactions to sound or noise. Peripheral blood volume and heart rate of groups of people will be monitored where ambient acoustic conditions are interrupted with intrusive auditory stimuli (FY 74 $186,000-2 year study).

## 9.3 Individual Behavior Effects

Study of behavioral correlates of varying noise environments. A systematic review of the literature for the past five years is being made of the effects of specified noise parameters on motor skills performance. Studies are being conducted to evaluate the behavioral effects of specified noise environments on motor skill tasks of varying complexity across subjects matched on relevant personality and motor skills characteristics (FY 74 $50,000), (FY 75 $50,000).

Studies on the time varying noise effects on human responses. These studies include the relationships between human responses and physical parameters of noise for evaluating descriptions of environmental noise. Verbal and non-verbal descriptors are utilized in determining and evaluating responses (FY 75 $75,000). Vigilance performance in the presence of unwanted intermittent noise is being studied using primates (FY 75 $10,000).

## 9.4 Sleep Interference

Correlational analysis of foreign and domestic scientific data on the effects of noise on human sleep (FY 75 $17,000).

## 9.5 Communication Interference

Determination of improved criteria for verbal communication including schools, home and laboratory. Analyses of speech and ambient noise levels are being made at the ear during normal and relaxed conversations in the home, schools, and laboratory. Additionally, category scale ratings of the noise environments are being conducted in terms of overall rating of the noise environment and in terms of speech communication (FY 74 $59,000), (FY 75 $62,000).

Obtain more complete data on the spectrum and temporal distribution of speech. A wide range of speakers, including male, female, adult, and children, will be used (FY 75 $25,000).

## 9.6 Measurement Methodology and Calibration

EPA's program in measurement methodology included one project titled "Instrumentation and Measurement Systems" (FY 73 $24,000), (FY 74 $32,000). This project was directed toward development of a personal noise exposure meter with the work being performed at NBS. Specific project activity included an evaluation of instruments and measurement systems for recording exposures of individuals and developing and demonstrating the capabilities of a measurement system which will record the integrated level above a threshold of dBA over each one-hour period during a 24-hour day. The system consists of a monitor worn by the individual and a reader which interrogates the monitor.

# 10. DOI(BuMines)

Bureau of Mines has three projects in effects of noise in relation to mine safety and health. Two projects address the problem of the miner's ability to hear "roof talk" warning signals while wearing hearing protection, and the other project is the state-of-the-art in portable calibration of audiodosimeters. The titles and funding are shown in Table D-20.

## 10.1 Communication Interference

The project "Aspects of Noise Generation and Hearing Protection in Underground Coal Mines" was begun in FY 72 and was completed in FY 73. The objective of this study was to quantitatively identify the spectral and amplitude characteristics of coal mine warning signals and assess the feasibility of using personal ear protection to minimize noise exposure but not impair miners' safety. A report (NTIS No. PB219087) with the same title as the project was published in November 1972. Roof talk warning signals and roof talk and speech discrimination with ear protection were quantified for the Pittsburgh coalbed. The study indicated that ear protection is acceptable when there are high background noises but that the ear protection should be removed when noise sources are not present.

Table D-20

DOI(BuMines)
NOISE EFFECTS RESEARCH

| | Funding Levels (Thousands of Dollars) FY 73 | FY 74 | FY 75 |
|---|---|---|---|
| <u>Projects in Communication Interference</u> | | | |
| 1. Aspects of Noise Generation and Hearing Protection in Underground Coal Mines | 1 | 0 | 0 |
| 2. Study of Roof Warning Signals and the Use of Personal Hearing Protection in Underground Coal Mines | 71 | 8 | 0 |
| <u>Projects in Measurement Methodology and Calibration</u> | | | |
| Portable Calibration Instrumentation for Audiodosimeters - Feasibility Study | 0 | 15 | 0 |
| TOTALS | 72 | 23 | 0 |

The project "Study of Roof Warning Signals and the Use of Personal Hearing Protection in Underground Coal Mines" extended the previous study of roof warning signals to other (high-accident) coalbeds. It also determined the effects of personal hearing protection on miners' safety with a larger number of subjects. A training course in the use of personal hearing protection in coal mines was also developed.

## 10.2 Measurement Methodology and Calibration

The Bureau of Mines' project in this category is intended to determine the state-of-the-art in audio acoustic couplers and the associated electronic interface. The output will be a report giving the state-of-the-art tthe specifications achievable with existing technology for a portable calibration instrument for audio dosimeters, and a proposal for design and fabrication of an achievable calibrator.

APPENDIX E

PROJECT LISTING BY AGENCY

TABLES

Table E-1
RESEARCH FUNDING BY AGENCY
(page 1 of 3 pages)
NATIONAL INSTITUTE OF NEUROLOGICAL DISEASES AND STROKE
(Thousands of Dollars)

| Category | Project Number | Project Title | Total Prior to Initial Year Indicated | FY-72 | FY-73 | FY-74 | FY-75 | FY-76 | FY-77 | FY-78 | FY-79 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 4403-12(Grant) | Susceptibility to Hearing Loss | 220 | | 45 | 47 | 49 | 51 | | | |
| | 3705-09(Grant) | Causes of Deafness | 2,480 | | 365 | 387 | 413 | 440 | | | |
| | NO1 NS 03-56-11 (Grant) | Auditory Communications and its Disorders | (3,773)[1] | | (461)[1] | (586)[1] | (598)[1] | (615)[1] | (613)[1] | (642)[1] | |
| Noise-Induced Hearing Loss | NS-09983(Grant) | Noise Effects on Audiogram and Cochlea | 37 | | 37 | | | | | | |
| | Planned Contract | Economic[2] and Social Impacts of Noise Induced Hearing Loss | | | | | | 150 | 300 | 300 | |
| | NS-74-0001 (Contract) | Effect of[3] Noise on Children | | | | 20 | | | | | |
| | In-House Research | Laboratory of[4] Otolaryngology | | | | 28 | 15 | 15 | 20 | 21 | 21 |

Table E-1
RESEARCH FUNDING BY AGENCY
(Page 2 of 3 pages)
NATIONAL INSTITUTE OF NEUROLOGICAL DISEASES AND STROKE
(Thousands of Dollars)

| Category | Project Number | Project Title | Total Prior to Initial Year Indicated | FY-72 | FY-73 | FY-74 | FY-75 | FY-76 | FY-77 | FY-78 | FY-79 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Planned Work | Experimental Studies of Effects of Noise on Young Ears (Primates) | | | | | 340 | 550 | 500 | 600 | 350 |
| | Planned Contract | Auditory Responses in Quiet and Noise Among Very Young Children | | | | | 120 | 250 | 400 | 440 | 500 |
| | | Presbycusis | | | | | | | 40 | 125 | 250 |
| | Planned Contract | Auditory Sensitivity and Discrimination Among Children Living in Noisy Environments | | | | | 120 | 300 | 330 | | |
| Non-Auditory Health Effects | Planned Work | Effects of Noise on Susceptibility to Disease | | | | | | 120 | 200 | 250 | 400 |

Table E-1
RESEARCH FUNDING BY AGENCY
(Page 3 of 3 pages)
NATIONAL INSTITUTE OF NEUROLOGICAL DISEASES AND STROKE
(Thousands of Dollars)

| Category | Project Number | Project Title | Total Prior to Initial Year Indicated | FY-72 | FY-73 | FY-74 | FY-75 | FY-76 | FY-77 | FY-78 | FY-79 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | NS-07908-07 | Noise-Induced Deafness: Masking & Speech Perception | 461 | | 79 | | | | | | |
| Communi-cation Inter-ference | NS-74-2322 (Contract) | Development of Test Instrument for Assessing Speech Discrimi-nation in Noise | | | | 140 | 100 | | 100 | 100 | 100 |
| | | Message Transmission in Noise | | | | | | | | | 130 |
| Subtotals by Category | Noise-Induced Hearing Loss | | | | 447 | 482 | 1057 | 1756 | 1590 | 1486 | 1121 |
| | Non-Auditory Health Effects | | | | | | | 120 | 200 | 250 | 400 |
| | Communication Interference | | | | 79 | 140 | 100 | ___ | 100 | 100 | 230 |
| TOTALS | | | | | 526 | 622 | 1157 | 1876 | 1890 | 1836 | 1751 |

[1]Project funding covers work in other areas and is not included

[2]Initiated in FY-75 only if additional funds become available

[3]Includes study of non-auditory effects of noise

[4]Portion of laboratory's effort oriented towards effects of noise

Table E-2
RESEARCH FUNDING BY AGENCY
(Page 1 of 2 pages)
NATIONAL INSTITUTE OF ENVIRONMENTAL HEALTH SCIENCES
(Thousands of Dollars)

| Category | Project Number | Project Title | Total Prior to Initial Year Indicated | FY-72 | FY-73 | FY-74 | FY-75 | FY-76 | FY-77 | FY-78 | FY-79 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Noise-Induced Hearing Loss | NIEHS-EB-002 | Investigation of Hearing Loss Threshold Curve for Young versus Mature Animals | | | 25 | 25 | | | | | |
| | NIEHS-EB-002 | Combined Effect of Noise and Salicylates on Cochlear Morphology & Auditory Threshold | | | 20 | | | | | | |
| | R01 ES 969 | Combined Impulse-Continuous Noise: Auditory Effect | | | | 51 | 44 | 44 | 45 | | |
| | NIEHS-EB-009 | Identification of Physiological Dysfunction in Neurosensory Hearing Loss Induced by Ototoxic Agents | | | | 8 | 29 | 29 | 29 | 29 | |
| | NIEHS-EB-008 | Physiological Study of Auditory Fatigue (Induced by Noise) | | | | 8 | 26 | 26 | 26 | 26 | |

Table E-2
RESEARCH FUNDING BY AGENCY
(Page 2 of 2 pages)
NATIONAL INSTITUTE OF ENVIRONMENTAL HEALTH SCIENCES
(Thousands of Dollars)

| Category | Project Number | Project Title | Total Prior to Initial Year Indicated | FY-72 | FY-73 | FY-74 | FY-75 | FY-76 | FY-77 | FY-78 | FY-79 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | NOL-ES-2110 | Interaction of Noise & Ototoxic Drugs on Hearing Loss in Animals | | | 100 | 100 | 100 | | | | |
| | NIEHS-EB-011 | Effects of Noise on Corticosterone Secretion in the Rat | | | | 16 | | | | | |
| | NIEHS-EB-012 | Noise Polymorpho-nuclear Leukocyte Function | | | | 12 | 8 | | | | |
| Non-Auditory Health Effects | NIEHS-EB-013 | Noise & Cellmediated Immunity | | | | 28 | 24 | | | | |
| | NIEHS-ET-003 | Teratogenic Effects of Noise Exposure and Deprivation | | | | 10 | 8 | | | | |
| | NIEHS-EB-004 | Noise in the Hospital | | | 8 | | | | | | |
| Subtotals by Category | | Noise-Induced Hearing Loss | | | 145 | 192 | 199 | 99 | 100 | 55 | |
| | | Non-Auditory Health Effects | | | 8 | 66 | 40 | — | — | — | |
| TOTALS | | | | | 153 | 258 | 239 | 99 | 100 | 55 | |

Table E-3
RESEARCH FUNDING BY AGENCY
(Page 1 of 5 pages)
NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY AND HEALTH
(Thousands of Dollars)

| Category | Project Number[2] | Project Title[2] | Total Prior to Initial Year Indicated | FY-72 | FY-73 | FY-74 | FY-75[1] | FY-76 |
|---|---|---|---|---|---|---|---|---|
| Noise-Induced Hearing Loss | | Evaluation[3] of Hearing Risk due to Industrial Noise | | | 75 | 79 | 104 | |
| | | Short Term Physical Agents Research: Coal Mine Noise[3] | | | 35 | 10 | 0 | |
| | HSM 99-72-125 | Evaluation of Industrial Acoustic Radiation above 10 $KH_z$ | | 40 | | | 0 | |
| | HSM 99-72-32 | PTS and TTS Resulting from Industrial Noise Exposure | | 24 | | | 0 | |
| | PL 480 Foreign Currency Agreement No. 05-005-3 | Effects of Noise and Vibration on Health of Woodcutters | 213 7/68-9/74 | X | X | X | | |

Table E-3
RESEARCH FUNDING BY AGENCY
(Page 2 of 5 pages)
NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY AND HEALTH
(Thousands of Dollars)

| Category | Project Number[2] | Project Title[2] | Total Prior to Initial Year Indicated | FY-72 | FY-73 | FY-74 | FY-75[1] | FY-76 |
|---|---|---|---|---|---|---|---|---|
| | PL480 Foreign Currency Agreement #03-002-03 | Exposure to Noise in the Cotton & Flax Textile Industry | 99 7/71-7/75 | X | X | X | X | X |
| | | Laboratory Studies of Noise-Induced Hearing Loss | | | | 87 | 91 | |
| | | Combined Effects[3] on Noise, Work & Heat on Human Hearing | | | 24 | 18 | | |
| | HSM 99-72-131 | Aspect of Ear Tolerance to Noise | | | 50 | 0 | 0 | |
| | NIOSH-IA-73-6 | Laboratory & Field Study of Impact Noise | | | 40 | | 0 | |
| | Grant (EOA) Ro1-OH000350 | Damage Risk Criteria for Intermittent Noise Exposure | | | | 56 | 47 | 41 |

Table E-3
RESEARCH FUNDING BY AGENCY
(Page 3 of 5 pages)
NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY AND HEALTH
(Thousands of Dollars)

| Category | Project Number[2] | Project Title[2] | Total Prior to Initial Year Indicated | FY-72 | FY-73 | FY-74 | FY-75[1] | FY-76 |
|---|---|---|---|---|---|---|---|---|
| | PL480 Foreign Currency Agreement #05-0142 | Noise and Heat Effects on Man | | 167 5/72-4/77 | X | X | X | X |
| | Grant (OEA) 1 R01 OH00364 | Effects of Impulse Noise on the Auditory System | | | | 91 | 69 | 76 |
| | | Noise and Hearing in the Paper Working Industry | | | | | 41 | |
| Non-Auditory Health Effects | | Extra Auditory Consequence to Worker Safety and Health | | | | 42 | | |
| | | Effects of Noise on Non-Auditory Sensory Functions and Performance | | | 78 | | 21 | |
| | | Health Impact of Industrial Noise | | | | | New | |

Table E-3
RESEARCH FUNDING BY AGENCY
(Page 4 of 5 pages)
NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY AND HEALTH

| Category | Project Number[2] | Project Title[2] | Total Prior to Initial Year Indicated | FY-72 | FY-73 | FY-74 | FY-75 | FY-76 |
|---|---|---|---|---|---|---|---|---|
| | | Effects of Noise and Heat on Health of Workers in Metal Industry | | | 30 | | | |
| Individual Behavior Effects | Grant R01 OH-00366 | Effects of Three Sound Environments on Human Behavior | | | | 8 | 0 | |
| | Grant R01 OH-00365 | Noise and Human Performance | | | | 20 | 0 | |
| | | Noise and Industrial Accidents | | | | | New | |
| Measurement Methodology & Calibration | | Industrial[3] Audiometric & Hearing Conservation Technology | | | 31 | 52 | 80 | |

Table E-3
RESEARCH FUNDING BY AGENCY
(Page 5 of 5 pages)
NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY AND HEALTH
(Thousands of Dollars)

| Category | Project Number[2] | Project Title[2] | Total Prior to Initial Year Indicated | FY-72 | FY-73 | FY-74 | FY-75[1] | FY-76 |
|---|---|---|---|---|---|---|---|---|
| | | Measurement[3] of Occupational Noise | | | 32 | 44 | 28 | |
| Sub-totals by Category | | Noise-Induced Hearing Loss | | 64 | 224 | 341 | 352 | 117 |
| | | Non-Auditory Health Effects | | | 108 | 42 | 21 | |
| | | Individual Behavior Effects | | | | 28 | | |
| | | Measurement Methodology and Calibration | | | 63 | 96 | 108 | |
| TOTALS | | | | 64 | 395 | 507 | 481 | 117 |

[1]Figures Approximate

[2]NIOSH does not use the term "Project" for this level of research activity

[3]Project titles were not the same in FY 73

Table E-4
RESEARCH FUNDING BY AGENCY
(Page 1 of 6 pages)
DEPARTMENT OF DEFENSE
(Thousands of Dollars)

| Category | Project Number | Project Title | Total Prior to Initial Year Indicated | FY-72 | FY-73 | FY-74 | FY-75 |
|---|---|---|---|---|---|---|---|
| | DAOA-6082 (USA) | Military Performance - Traumatic Origins of Hearing Loss | | X | | | |
| | DNOA-4956 (USA) | Relationship of Hearing Change to Acoustic Inputs | | | 62 | 66 | |
| | DAOC-7028 (USA) | Prevalence of Hearing Loss within Selected U.S. Army Branches | | | | 20 | |
| | DAOB-7030 (USA) | Hearing Conservation Intense Acoustic Stimulation and Noise Susceptibility in the Military Environment | | | 46 | | |
| Noise-Induced Hearing Loss | DN-123487 (USN) | Communications: Hearing of Naval Personnel as a Function of Noise Exposure | | | 20 | | |
| | DN-240004 (USN) | Study of Anatomic Changes in Middle Ear Associated with Noise-Induced Hearing Loss and Acoustic Trauma | | | 10 | 19 | |
| | DN-240059 (USN) | Middle Ear Compliance and Its Relationship to Military Related Noise-Induced Hearing Loss & Acoustic Trauma | | | 8 | 13 | |

Table E-4
RESEARCH FUNDING BY AGENCY
(Page 2 of 6 pages)
DEPARTMENT OF DEFENSE
(Thousands of Dollars)

| Category | Project Number | Project Title | Total Prior to Initial Year Indicated | FY-72 | FY-73 | FY-74 | FY-75 |
|---|---|---|---|---|---|---|---|
| Noise - Induced Hearing Loss | DN-477001 (USN) | The Incidence of Hearing Loss Among Various Navy Related Personnel | | | | 50 | |
| | DN-140504 (USN) | Development of Damage Risk Criteria and Habitability Standards for Exposure to Sonar Transmissions | | | 20 | 25 | |
| | DF-311650 (USAF) | Effects of Noise on Air Force Personnel in Operational Environments | | | 20 | 49 | |
| | DF-314140 (USAF) | Research on Permanent and Temporary Shifts in Hearing Threshold Produced by Exposure to Air Force Noise | | | | 2 | |
| | DF-313060 (USAF) | Auditory Responses to Acoustic Energy Experienced in Air Force Activities | | | 24 | 22 | |
| | DF-317610 (USAF) | Human Subjects for Operating Acoustic Research | | | 38 | 35 | |

Table E-4
RESEARCH FUNDING BY AGENCY
(Page 3 of 6 pages)
DEPARTMENT OF DEFENSE
(Thousands of Dollars)

| Category | Project Number | Project Title | Total Prior to Initial Year Indicated | FY-72 | FY-73 | FY-74 | FY-75 |
|---|---|---|---|---|---|---|---|
| Non-Auditory Health Effects | DR-313120 | Research on Response of Vestibular System to Acoustic Stimuli | | X | 10 | | |
| Individual Behavior Effects | DAOB-4955 (USA) | Improved Weapon Noise Exposure Criteria | | | 62 | 66 | |
| | DN-840511 (USN) | Optimization of Performance in Submarines | | | 54 | 44 | |
| | DN-040711 (USN) | Optimization of Auditory Performance in Naval Aviation | | | 40 | 35 | |
| | DR-313100 (USAF) | Simultaneous Exposure to Acoustic Energy and Other Stressors Found in the Air Force Environments | | X | 7 | 3 | |
| | DF-313070 (USAF) | Whole-body Effects of Air Force Noise on People | | X | 24 | 18 | |
| | DF-028540 (USAF) | Research on Intermittent Noise Effects on Air Force Target Detection Tasks | | X | 46 | | |

Table E-4
RESEARCH FUNDING BY AGENCY
(Page 4 of 6 pages)
DEPARTMENT OF DEFENSE
(Thousands of Dollars)

| Category | Project Number | Project Title | Total Prior to Initial Year Indicated | FY-72 | FY-73 | FY-74 | FY-75 |
|---|---|---|---|---|---|---|---|
| | DAOA-6085 (USA) | Military Performance: Auditory Perception and Psychophysics | | | X | | |
| | (USA) | Human Engineering Studies of the Head and Headgear, Helmet Acoustics, Weight, plus Other Factors Affecting Performance | | | | X | |
| Communication Interference | (USN) | Sound Conduction in the Ear Affecting Military Communications | | X | 26 | | |
| | DN-040713 (USN) | Optimization of Speech Communications in Naval Aviation | | | 40 | 40 | |
| | DN-140502 (USN) | Development of Auditory Screening and Acoustical Tolerance Standards for Submarine/Shipboard Personnel | | | 30 | 33 | |
| | DF-311640 (USAF) | Assessment of Hearing in Flying Personnel | | | 28 | 36 | |
| Community or Collective Response | DF-313140 (USAF) | Effects of Air Force Noises on Population Surrounding Air Bases | | | 31 | | |

Table E-4
RESEARCH FUNDING BY AGENCY
(Page 5 of 6 pages)
DEPARTMENT OF DEFENSE
(Thousands of Dollars)

| Category | Project Number | Project Title | Total Prior to Initial Year Indicated | FY-72 | FY-73 | FY-74 | FY-75 |
|---|---|---|---|---|---|---|---|
| Measurement Methodology and Calibration | DAOD-6739 (USA) | Research on Psychoacoustical Problems Medically Significant to Army Aviation | | X | 85 | 195 | |
| | DN-612146 (USN) | Airborne Noise Criteria for Ships and Submarines | | | 69 | 74 | |
| | DF-314500 (USAF) | Development and Updating of Air Force Land Use Planning Procedure with Respect to Aircraft Noise | | | 32 | | |
| | DF-316600 (USAF) | Measurement and Analysis of Aircraft Noise Environments for Developing New Air Force Procedures to Forecast Noise Exposure | | | 13 | 15 | |
| | DF-313020 (USAF) | Mechanisms of Noise Generation and Reception as Related to Air Force Bioacoustic Programs | | | 3 | 2 | |
| | DF-313030 (USAF) | Bioacoustic Environments of USAF Aerospace Systems | | | 92 | 68 | |

Table E-4
RESEARCH FUNDING BY AGENCY
(Page 6 of 6 pages)
DEPARTMENT OF DEFENSE
(Thousands of Dollars)

| Category | Project Number | Project Title | Total Prior to Initial Year Indicated | FY-72 | FY-73 | FY-74 | FY-75 |
|---|---|---|---|---|---|---|---|
| | DF-317570 (USAF) | Bioenvironmental Noise Research Program | | | 43 | | |
| Sub-totals by Category | Noise-Induced Hearing Loss | | | | 248 | 301 | 301* |
| | Non-Auditory Health Effects | | | | 10 | 0 | 0 * |
| | Individual Behavior Effects | | | | 233 | 166 | 166* |
| | Communication Interference | | | | 124 | 109 | 109* |
| | Community or Collective Response | | | | 32 | 0 | 0 * |
| | Measurement Methodology and Calibration | | | | 337 | 354 | 354* |
| TOTALS | | | | | 984 | 930 | 930* |

* DOD FY 75 data estimated the same as FY 74

Table E-5
RESEARCH FUNDING BY AGENCY
(Page 1 of 1 page)
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
(Thousands of Dollars)

| Category | Project Number | Project Title | Total Prior to Initial Year Indicated | FY-73 | FY-74 | FY-75 |
|---|---|---|---|---|---|---|
| Noise Effects on Sleep | 504-09-02 | Human Response to the Aeronautical Environment | | 217 | 254 | 142 |
| Community or Collective Response | 504-29-01 | Acceptance of Aircarft Operations-Technical Assessment | | 173 | 172 | 232 |
| | 504-29-11 | Acceptance of Aircraft Operations-Communicy Noise | | 205 | 319 | 422 |
| Measurement Methodology and Calibration | 504-29-11 | Acceptance of Aircraft Operations | | 532 | 409 | 404 |
| Subtotals by Category | | Noise Effects on Sleep | | 217 | 254 | 142 |
| | | Community or Collective Response | | 378 | 491 | 654 |
| | | Measurement Methodology and Calibration | | 532 | 409 | 404 |
| TOTALS | | | | 1,127 | 1,154 | 1,200 |

Table E-6
RESEARCH FUNDING BY AGENCY
(Page 1 of 1 page)
DEPARTMENT OF TRANSPORTATION
(Thousands of Dollars)

| Category | Project Number | Project Title | Total Prior to Initial Year Indicated | FY-72 | FY-73 | FY-74 | FY-75 | FY-76 |
|---|---|---|---|---|---|---|---|---|
| | Work at DOC/ NBS (USCG) | Foghorn Aversiveness Study | | | 5 | | | |
| Individual Behavior Effects | AM-B-73-PSY-41 (FAA) | Field Study of Sonic Boom Startle Effects | | X | 18 | | | |
| | AM-B-73-PSY-31 (FAA) | Determinants of Startle Response to Simulated Sonic Booms | | X | 27 | | | |
| | (DOT/FAA/DOD/ USAF) | Animal Response to Impulsive Acoustic Stimuli | | 38 | 0 | | | |
| Community or Collective Response | Contract 036369 (Trais No.) (ONA) | Measurement of Community Noise and Associated Human Response | 295 | | | 130 | 50 | |
| Subtotals By Category | | Individual Behavior Effects | | 38 | 50 | | | |
| | | Community or Collective Response | 295 | — | — | 130 | 50 | |
| | TOTALS | | 295 | 38 | 50 | 130 | 50 | |

Table E-7
RESEARCH FUNDING BY AGENCY
(Page 1 of 2 pages)
NATIONAL SCIENCE FOUNDATION
(Thousands of Dollars)

| Category | Project Number | Project Title | Total Prior to Initial Year Indicated | FY-72 | FY-73 | FY-74 | FY-75 | FY-76 |
|---|---|---|---|---|---|---|---|---|
| Noise - Induced Hearing Loss | GB-36652 | Noise Trauma, Ototoxicity and the Olivocochlear Bundle | | | 20 | | | |
| | 8-72 | Permanent Effects of Noise on Low and Mid Frequency Hearing | | X | | | | |
| | 01 | Interaction of Ototoxic Drugs with Acoustic Trauma | | X | | | | |
| Non-Auditory Health Response | 01 | Effect of Noise on Cardiovascular Changes in Non-Cardiac patients in ICU | X | | | | | |
| Individual Behavior Effects | GS-33216 | Collaborative Research on Social Psychological Reactions to Stress | | 34 | | | | |
| | GS-2405A #2 | Collaborative Research on Social Psychological Reactions to Stress | | 42 | | | | |

Table E-7
RESEARCH FUNDING BY AGENCY
(Page 2 of 2 pages)
NATIONAL SCIENCE FOUNDATION
(Thousands of Dollars)

| Category | Project Number | Project Title | Total Prior to Initial Year Indicated | FY-72 | FY-73 | FY-74 | FY-75 | FY-76 |
|---|---|---|---|---|---|---|---|---|
| | GS-34329 | Collaborative Research on Social Psycho-logical Reactions to Stress | | 39 | | | | |
| Subtotals by Category | | Noise-Induced Hearing Loss | | | 20 | | | |
| | | Non-Auditory Health Response | | | | | | |
| | | Individual Be-havior Effects | | 115 | | | | |
| TOTALS | | | X | 115 | 20 | | | |

Table E-8
RESEARCH FUNDING BY AGENCY
(Page 1 of 1 page)
NATIONAL BUREAU OF STANDARDS
(Thousands of Dollars)

| Category | Project Number | Project Title | Total Prior to Initial Year Indicated | FY-72 | FY-73 | FY-74 | FY-75 | FY-76 |
|---|---|---|---|---|---|---|---|---|
| Individual Behavior Effects | | Psychoacoustic Measurement Techniques | | 64 | 98 | 117 | 142 | 140 |

Table E-9
RESEARCH FUNDING BY AGENCY
(Page 1 of 1 page)
DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT
(Thousands of Dollars)

| Category | Project Title | Total Prior to Initial Year Indicated | FY-72 | FY-73 | FY-74 | FY-75 | FY-76 | FY-77 | FY-78 |
|---|---|---|---|---|---|---|---|---|---|
| Community or Collective Response | Evaluation of HUD Noise Policies & Guidelines | | | | 200 | 185 | | | |
| | Effects of Noise on Community Development | | | | | 225 | | | |
| Measurement Methodology & Calibration | HUD Urban Noise Measurement System | | | 117 | 263 | | | | |
| | Development of Noise Attenuation Measures | | | | 175 | 50 | | | |
| Subtotals by Category | Community or Collective Response | | | | 200 | 410 | | | |
| | Measurement Methodology & Calibration | | | 117 | 438 | 50 | | | |
| TOTALS | | | | 117 | 638 | 460 | | | |

Table E-10
RESEARCH FUNDING BY AGENCY
(Page 1 of 4 pages)
U.S. ENVIRONMENTAL PROTECTION AGENCY
(Thousands of Dollars)

| Category | Project Number | Project Title | Total Prior to Initial Year Indicated | FY-72 | FY-73 | FY-74 | FY-75 | FY-76 |
|---|---|---|---|---|---|---|---|---|
| Noise-Induced Hearing Loss | IAG | Evaluation of Effects of Noise Exposure Combined with Other Stressing Agents on Hearing & Performance | | | | 25 | | |
| | IAG & Contract | Evaluation of Long-term Noise Exposure on Hearing | | | | 25 | 70 | |
| | | Differentiation between Noise-Induced Hearing Loss and Presbycusis | | | | | | |
| | | Auditory Effects from Moderate Noise Levels | | | | | | |
| | | Auditory Effects from Intermittent Daily Exposures | | | | | | 600 |
| | | Longitudinal Studies of Auditory Effects From Noise Exposure | | | | | | |

Table E-10
RESEARCH FUNDING BY AGENCY
(Page 2 of 4 pages)
U.S. ENVIRONMENTAL PROTECTION AGENCY
(Thousands of Dollars)

| Category | Project Number | Project Title | Total Prior to Initial Year Indicated | FY-72 | FY-73 | FY-74 | FY-75 | FY-76 |
|---|---|---|---|---|---|---|---|---|
| Non-Auditory Health Effects | | Interactive Effects of Noise and Other Influences | | | | | | 700 |
| | Contract | Studies of Non-Auditory Physiological Effects | | | | 186* | | |
| Individual Behavior Effects | IAG | Behavior Correlation of Varying Noise Environments | | | | 50 | 50 | |
| | In-House | Vigilance Task Performance in Presence of Intermittent Unwanted Noise in Primates | | | | | 10 | |
| | IAG | Time-Varying Effects on Human Response | | | | | 75 | 150 |
| | | Effects on Task Performance | | | | | | |
| Noise Effects on Sleep | | Quality of Sleep & Effects Related to Psysiological & Psychological Implications | | | | | | 150 |
| | Contract | Correlation of Foreign & Domestic Data on Human Sleep | | | | | 17 | |

* 2 Year Period

Table E-10
RESEARCH FUNDING BY AGENCY
(Page 3 of 4 pages)
U.S. ENVIRONMENTAL PROTECTION AGENCY
(Thousands of Dollars)

| Category | Project Number | Project Title | Total Prior to Initial Year Indicated | FY-72 | FY-73 | FY-74 | FY-75 | FY-76 |
|---|---|---|---|---|---|---|---|---|
| Communication Interference | Contract | Improved Criteria for Verbal Communication From Noise in Schools and Home Environment | | | | 59 | 62 | |
| | IAG | Voice Levels & Environmental Noise Conditions that Permit Adequate Speech Communication | | | | | 25 | 200 |
| | | Effect of Age, Speech Level, Hearing on Reliable Communication | | | | | | |
| Community or Collective Response | | Effects of Noise on Community Response Related to Annoyance | | | | | | |
| | | Identify Environmental Noise Levels for Determining Cumulative Dose Exposures for Different Population Segments | | | | | | 200 |
| | | Identify Sociological Effects of Noise | | | | | | |

Table E-10
RESEARCH FUNDING BY AGENCY
(page 4 of 4 pages)
U.S. ENVIRONMENTAL PROTECTION AGENCY
(Thousands of Dollars)

| Category | Project Number | Project Title | Total Prior to Initial Year Indicated | FY-72 | FY-73 | FY-74 | FY-75 | FY-76 |
|---|---|---|---|---|---|---|---|---|
| Measurement Methodology & Calibration | Work at DOC(NBS) | Instrumentation & Measurement Systems for Noise Exposure of Individuals | | | 24 | 32 | | |
| Subtotals By Category | Noise-Induced Hearing Loss | | | | | 50 | 70 | 600 |
| | Non-Auditory Health Effects | | | | | 186* | 0 | 700 |
| | Individual Behavior Effects | | | | | 50 | 135 | 150 |
| | Noise Effects on Sleep | | | | | | 17 | 150 |
| | Communication Interference | | | | | 59 | 87 | 200 |
| | Community or Collective Response | | | | | | | 200 |
| | Measurement Methodology & Calibration | | | | 24 | 32 | | |
| TOTALS | | | | | 24 | 377 | 309 | 2,000 |

* 2 Year Period

Table E-11
RESEARCH FUNDING BY AGENCY
(Page 1 of 1 page)
DEPARTMENT OF AGRICULTURE
(Thousands of Dollars)

| Category | Project Number | Project Title | Total Prior to Initial Year Indicated | FY-72 | FY-73 | FY-74 | FY-75 | FY-76 |
|---|---|---|---|---|---|---|---|---|
| Domestic Animals & Wildlife | 0057475 SC-00945 | The Effect of Noise Pollution on the Fowl | X | X | X | X | | |

Table E-12
RESEARCH FUNDING BY AGENCY
DEPARTMENT OF THE INTERIOR
BUREAU OF MINES
(Thousands of Dollars)

| Category | Project Number | Project Title | FY-73 | FY-74 | FY-75 |
|---|---|---|---|---|---|
| Communication Interference | GO 122004 | Aspects of Noise Generation & Hearing Protection in Underground Coal Mines | 1 | 0 | 0 |
| | GO 133026 | Study of Roof Warning Signals & the Use of Personal Hearing Protection in Underground Coal Mines | 71 | 8 | 0 |
| Subtotals for Communication Interference | | | 72 | 8 | 0 |
| Measurement Methodology & Calibration | SO 144091 | Portable Calibration Instrumentation for Audiodosimeters--Feasibility Study | 0 | 15 | 0 |
| | | Agency Total | 72 | 23 | 0 |

## APPENDIX F

## PROJECT LISTING BY CATEGORY

Table F-1
NOISE-INDUCED HEARING LOSS
(Page 1 of 9 Pages)

| Agency | Project No. | Project Title | Total Prior to Initial Year Indicated | FY 72 | FY 73 | FY 74 | FY 75 | FY 76 | FY 77 | FY 78 | FY 79 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Reported Funding, Thousands of Dollars | | | | | | | | |
| HEW/ NINDS | 4403-12 (Grant) | Susceptibility to Hearing Loss | 220 | | 45 | 47 | 49 | 51 | | | |
| | 5785-09 (Grant) | Causes of Deafness | 2,480 | | 365 | 387 | 413 | 440 | | | |
| | R01 NS 03856-11 (Grant) | Auditory Communications and its Disorders | 3,773[1] | | 461[1] | (586)[1] | (598)[1] | (615)[1] | (613)[1] | (642)[1] | |
| | NS-09983 (Grant) | Noise Effects on Audiogram and Cochlea | 36 | | 37 | | | | | | |
| | Planned Contract | Economic and Social Impacts of Noise-Induced Hearing Loss[2] | | | | | 0 | 150 | 300 | 300 | |
| | NS-74-0001 (Contract) | Effect of Noise on Children[3] | | | | 20 | 0 | 0 | 0 | 0 | |
| | In-house Research | Laboratory of Otolaryngology[4] | | | | 28 | 15 | 15 | 20 | 21 | 21 |
| | Planned work | Experimental Studies of Effects of Noise on Young Ears (Primate) | 0 | 0 | 0 | 0 | 340 | 550 | 500 | 600 | 350 |

[1] Project funding covers work in other categories and is not included in totals.
[2] Initiated in FY 75 only if additional funds become available.
[3] Includes study of non-auditory effects of noise.
[4] Portion of laboratory's effort oriented toward noise effects.

Table F-1
NOISE-INDUCED HEARING LOSS
(Page 2 of 9 Pages)

| Agency | Project No. | Project Title | Total Prior to Initial Year Indicated | FY 72 | FY 73 | FY 74 | FY 75 | FY 76 | FY 77 | FY 78 | FY 79 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Reported Funding, Thousands of Dollars | | | | | | | |
| HEW/ NINDS | Planned work | Auditory Responses in Quiet and Noise Among Very Young Children | 0 | 0 | 0 | 0 | 120 | 250 | 400 | 440 | 500 |
| | Planned work | Presbycusis | 0 | 0 | 0 | 0 | 0 | 0 | 40 | 125 | 250 |
| | Planned work | Auditory Sensitivity and Discrimination Among Children Living in Noisy Environments | | | | | 120 | 300 | 330 | | |
| | Subtotals | | 2,737 | | 447 | 482 | 1,057 | 1,756 | 1,590 | 1,486 | 1,121 |
| HEW/[2] NIOSH | | Evaluation of Hearing[3] Risk due to Industrial Noise | | | (75)[3] | 79 | 104[1] | | | | |
| | | Short Term Physical[3] Agents Research: Coal Mine Noise | | | (35)[3] | 10 | 0 | | | | |

[1]Estimated.
[2]NIOSH does not use the term "project" for this level of research activity.
[3]Project titles were not the same in FY 73.

Table F-1
NOISE-INDUCED HEARING LOSS
(Page 3 of 9 Pages)

| Agency | Project No.[2] | Project Title[1] | Total Prior to Initial Year Indicated | FY 72 | FY 73 | FY 74 | FY[1] 75 | FY 76 | FY 77 | FY 78 | FY 79 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Reported Funding, Thousands of Dollars | | | | | | | | |
| HEW/ NIOSH | | Noise and Hearing in the Paperworking Industry | | | 0 | 0 | 41 | | | | |
| | HSM 99-72-125 | Evaluation of Industrial Accoustic Radiation above 10 KH$_z$ | | 40 | | | | | | | |
| | HSM 99-72-32 | PTS and TTS Resulting from Industrial Noise Exposure | | 24 | | | | | | | |
| | PL 480 Foreign Currency Agreement No. 05-005-3 | Effects of Noise and Vibration on Health of Woodcutters | 213 7/68-9/74 | x | x | x | | | | | |
| | PL 480 Foreign Currency Agreement No. 03-002-03 | Exposure to Noise in the Cotton and Flax Textile Industry | 99 7/71-7/75 | x | x | x | x | x | | | |
| | | Laboratory Studies of Noise-Induced Hearing Loss | | | | 87 | 91 | | | | |

[1]Estimated.
[2]NIOSH does not use the term "project" for this level of research activity.

Table F-1
NOISE-INDUCED HEARING LOSS
(Page 4 of 9 Pages)

| Agency | Project No.[2] | Project Title[2] | Total Prior to Initial Year Indicated | FY 72 | FY 73 | FY 74 | FY[1] 75 | FY 76 | FY 77 | FY 78 | FY 79 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Reported Funding, Thousands of Dollars | | | | | | | | |
| HEW/ NIOSH | | Combined Effects of Noise, Work and Heat on Human Hearing[3] | | | (24)[3] | 18 | | | | | |
| | HSM 99-72-131 | Aspects of Ear Tolerance to Noise | | | 50 | | | | | | |
| | NIOSH-LA-73-6 | Laboratory and Field Study of Impact Noise | | | 40 | | | | | | |
| | Grant (OEA) R01-OH000350 | Damage Risk Criteria for Intermittent Noise Exposure | | | | 56 | 47 | 41 | | | |
| | PL-480-Foreign Currency Agreement No. 05-0142 | Noise and Heat Effects on Man | | 167 5/72-4/77 | x | x | x | x | | | |
| | Grant (OEA) 1R01 OH 00364 | Effects of Impulse Noise on the Auditory System | | | | 91 | 69 | 76 | | | |
| | | Subtotals | | 64 | 224 | 341 | 352 | 117 | | | |

[1] Estimated.
[2] NIOSH does not use the term "project" for this level of research activity.
[3] Project titles were not the same in FY 73.

Table F-1
NOISE-INDUCED HEARING LOSS
(Page 5 of 9 Pages)

| Agency | Project No. | Project Title | Total Prior to Initial Year Indicated | FY 72 | FY 73 | FY 74 | FY 75 | FY 76 | FY 77 | FY 78 | FY 79 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Reported Funding, Thousands of Dollars | | | | | | | | |
| HEW/ NIEHS | NIEHS-EB-002 | Investigation of Hearing Loss Threshold Curve for Young vs. Mature Animals | | | 25 | 25 | | | | | |
| | NIEHS-EB-002 | Combined Effect of Noise and Salicylates on Cochlear Morphology and Auditory Threshold | | | 20 | | | | | | |
| | R01-ES-969 | Combined Impulse-Continuous Noise: Auditory Effect | | | | 51 | 44 | 44 | 45 | | |
| | NIEHS-EB-009 | Identification of Physiological Dysfunction in Neurosensory Hearing Loss Induced by Ototoxic Agents | | | | 8 | 29 | 29 | 29 | 29 | |
| | NIEHS-EB-008 | Physiological Study of Auditory Fatigue (Induced by Noise | | | | 8 | 26 | 26 | 26 | 26 | |
| | NOL-ES-2110 | Interaction of Noise and Ototoxic Drugs on Hearing Loss in Animals | | | 100 | 100 | 100 | | | | |
| | | Subtotals | | | 145 | 192 | 199 | 99 | 100 | 55 | |

Table F-1
NOISE-INDUCED HEARING LOSS
(Page 6 of 9 Pages)

| Agency | Project No. | Project Title | Total Prior to Initial Year Indicated | FY 72 | FY 73 | FY 74 | FY 75 | FY 76 | FY 77 | FY 78 | FY 79 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Reported Funding, Thousands of Dollars | | | | | | | | |
| DOD | DAOA-6082 (USA) | Military Performance-Traumatic Origins of Hearing Loss | | x | | | | | | | |
| | DNOA 4956 (USA) | Relationship of Hearing Change to Acoustic Inputs | | | 62 | 66 | | | | | |
| | DAOC 7028 (USA) | Prevalence of Hearing Loss within Selected U.S. Army Branches | | | | 20 | | | | | |
| | DAOB-7030 (USA) | Hearing Conservation Intense Acoustic Stimulation and Noise Susceptibility in the Military Environment | | | 46 | | | | | | |
| | DN-123487 (USN) | Communications: Hearing of Naval Personnel as a Function of Noise Exposure | | | 20 | | | | | | |
| | DN-240004 (USN) | Study of Anatomic Changes in Middle Ear Associated with Noise-Induced Hearing Loss and Acoustic Trauma | | | 10 | 19 | | | | | |

Table F-1
NOISE-INDUCED HEARING LOSS
(Page 7 of 9 Pages)

| Agency | Project No. | Project Title | Total Prior to Initial Year Indicated | FY 72 | FY 73 | FY 74 | FY 75 | FY 76 | FY 77 | FY 78 | FY 79 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Reported Funding, Thousands of Dollars | | | | | | | | |
| DOD | DN-240059 (USN) | Middle Ear Compliance and Its Relationship to Military Related Noise-Induced Hearing Loss and Acoustic Trauma | | | 8 | 13 | | | | | |
| | DN 477001 (USN) | The Incidence of Hearing Loss Among Various Navy Related Personnel | | | | 50 | | | | | |
| | DN 140504 (USN) | Development of Damage Risk Criteria and Habitability Standard for Exposure to Sonar Transmissions | | | 20 | 25 | | | | | |
| | DF-311650 (USAF) | Effects of Noise on Air Force Personnel in Operational Environments | | | 20 | 49 | | | | | |
| | DF-314140 (USAF) | Research on Permanent and Temporary Shifts in Hearing Threshold Produced by Exposure to Air Force Noise | | | | 2 | | | | | |

Table F-1
NOISE-INDUCED HEARING LOSS
(Page 8 of 9 Pages)

| Agency | Project No. | Project Title | Total Prior to Initial Year Indicated | Reported Funding, Thousands of Dollars FY 72 | FY 73 | FY 74 | FY 75 | FY 76 | FY 77 | FY 78 | FY 79 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| DOD | DF-313060 (USAF) | Auditory Responses to Acoustic Energy Experienced in Air Force Activities | | | 24 | 22 | | | | | |
| | DF-317610 (USAF) | Human Subjects for Operating Acoustic Research | | | 38 | 35 | | | | | |
| | | Subtotals | | | 248 | 301 | 301* | | | | |
| NSF | GB-36652 | Noise Trauma, Ototoxicity and the Olivocochlear Bundle | | | 20 | | | | | | |
| | 8-72 | Permanent Effects of Noise on Low and Mid Frequency Hearing | | x | | | | | | | |
| | 01 | Interaction of Ototoxic Drugs with Acoustic Trauma | | x | | | | | | | |
| | | Subtotals | | | 20 | | | | | | |

* DOD FY 75 data estimated the same as FY 74.

Table F-1
NOISE-INDUCED HEARING LOSS
(Page 9 of 9 Pages)

| Agency | Project No. | Project Title | Total Prior to Initial Year Indicated | FY 72 | FY 73 | FY 74 | FY 75 | FY 76 | FY 77 | FY 78 | FY 79 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Reported Funding, Thousands of Dollars | | | | | | | | |
| EPA | IAG | Evaluation of Effects of Noise Exposure Combined with Other Stressing Agents on Hearing. and Performance | | | | 25 | | | | | |
| | IAG and Contract | Evaluation of Long-Term Noise Exposure on Hearing | | | | 25 | 70 | | | | |
| | | Differentiation Between Noise-Induced Hearing Loss and Presbyacusis | | | | | | | | | |
| | | Auditory Effects from Moderate Noise Levels | | | | | | 600 | | | |
| | | Auditory Effects from Intermittent Daily Exposures | | | | | | | | | |
| | | Longitudinal Studies of Auditory Effects from Noise Exposure | | | | | | | | | |
| | | Subtotals | | | | 50 | 70 | 600 | | | |
| | | Totals for Noise-Induced Hearing Loss | 2,737 | 64 | 1,084 | 1,366 | 1,979 | 2,572 | 1,690 | 1,541 | 1,121 |

Table F-2
NON-AUDITORY HEALTH EFFECTS
(Page 1 of 3 Pages)

| Agency | Project No.[1] | Project Title[2] | Total Prior to Initial Year Indicated | FY 72 | FY 73 | FY 74 | FY[1] 75 | FY 76 | FY 77 | FY 78 | FY 79 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Reported Funding, Thousands of Dollars | | | | | | | | |
| HEW/ NIOSH | | Extra-Auditory Effects of Noise of Consequence to Worker Safety and Health | | | | 42 | | | | | |
| | | Effects of Noise on Non-Auditory Sensory Functions and Performance | | | 78 | | 21 | | | | |
| | | Health Impact of Industrial Noise | | | | | New | | | | |
| | | Effects of Noise and Heat on Health of Workers in Metal Industry | | | 30 | | | | | | |
| | | Subtotals | | | 108 | 42 | 21 | | | | |

[1]Estimated.
[2]NIOSH does not use the term "project" for this level of research activity.

Table F-2
NON-AUDITORY HEALTH EFFECTS
(Page 2 of 3 Pages)

| Agency | Project No. | Project Title | Total Prior to Initial Year Indicated | FY 72 | FY 73 | FY 74 | FY 75 | FY 76 | FY 77 | FY 78 | FY 79 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Reported Funding, Thousands of Dollars | | | | | | | |
| HEW/ NIEHS | NIEHS-EB-011 | Effects of Noise on Corticosterone Secretion in the Rat | | | | 16 | | | | | |
| | NIEHS-EB-012 | Noise Polymorphonuclear Leukocyte Function | | | | 12 | 8 | | | | |
| | NIEHS-EB-013 | Noise and Cellmediated Immunity | | | | 28 | 24 | | | | |
| | NIEHS-EB-004 | Noise in the Hospital | | | 8 | | | | | | |
| | NIEHS-ET-003 | Teratogenic Effects of Noise Exposure and Deprivation | | | | 10 | 8 | | | | |
| | | Subtotals | | | 8 | 66 | 40 | | | | |
| HEW/ NINDS | Planned Work | Effects of Noise on Susceptibility to Disease | | | | | | 120 | 200 | 250 | 400 |
| | | | | | | | | 120 | 200 | 250 | 400 |

Table F-2
NON-AUDITORY HEALTH EFFECTS
(Page 3 of 3 Pages)

| Agency | Project No. | Project Title | Total Prior to Initial Year Indicated | FY 72 | FY 73 | FY 74 | FY 75 | FY 76 | FY 77 | FY 78 | FY 79 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Reported Funding, Thousands of Dollars | | | | | | | | |
| DOD | DR-313120 Contract F33615-69-C-1246 (USAF) | Research on Response of Vestibular System to Acoustic Stimuli | | | 10 | | | | | | |
| | | Subtotals | | | 10 | | | | | | |
| NSF | 01 | Effect of Noise on Cardiovascular Changes in Noncardiac Patients in ICU | | | | | | | | | |
| EPA | | Interactive Effects of Noise and Other Influences | | | | | | 700 | | | |
| | Contract | Studies of Non-Auditory Physiological Effects | | | | 186* | | | | | |
| | | Subtotals | | | | 186 | 0 | 700 | | | |
| | | Totals for Non-auditory Health Effects | | | 126 | 294 | 61 | 820 | 200 | 250 | 400 |

*Project funded for 2 year period

Table F-3
INDIVIDUAL BEHAVIOR EFFECTS
(Page 1 of 4 Pages)

| Agency | Project No.[1] | Project Title[1] | Total Prior to Initial Year Indicated | FY 72 | FY 73 | FY 74 | FY 75 | FY 76 | FY 77 | FY 78 | FY 79 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Reported Funding, Thousands of Dollars | | | | | | | | |
| HEW/ NIOSH | Grant R01 OH-00366 | Effects of Three Sound Environments on Human Behavior | | | | 8 | | | | | |
| | Grant R01 OH-00365 | Noise and Human Performance | | | | 20 | | | | | |
| | | Noise and Industrial Accidents | | | | | New | | | | |
| | | Subtotals | | | | 28 | | | | | |

[1]NIOSH does not use the term "project" for this level of research activity.

| Agency | Project No. | Project Title | Total Prior to Initial Year Indicated | FY 72 | FY 73 | FY 74 | FY 75 | FY 76 | FY 77 | FY 78 | FY 79 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| DOD | DAOB-4955 (USA) | Improved Weapon Noise Exposure Criteria | | | 62 | 66 | | | | | |
| | DN 840511 (USN) | Optimization of Performance in Submarines | | | 54 | 44 | | | | | |
| | DN 040711 (USN) | Optimization of Auditory Performance in Naval Aviation | | | 40 | 35 | | | | | |

Table F-3
INDIVIDUAL BEHAVIOR EFFECTS
(Page 2 of 4 Pages)

| Agency | Project No. | Project Title | Total Prior to Initial Year Indicated | FY 72 | FY 73 | FY 74 | FY 75 | FY 76 | FY 77 | FY 78 | FY 79 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Reported Funding, Thousands of Dollars | | | | | | | |
| DOD | DR-313100 (USAF) | Simultaneous Exposure to Acoustic Energy and Other Stressors Found in Air Force Environments | | | 7 | 3 | | | | | |
| | DF-313070 (USAF) | Whole-Body Effects of Air Force Noise on People | | x | 24 | 18 | | | | | |
| | DF-028540 Contract AFOSR-1822-69 (USAF) | Research on Intermittent Noise Effects on Air Force Target Detection Tasks | | x | 46 | | | | | | |
| | | Subtotals | | | 233 | 166 | 166[1] | | | | |

[1] DOD FY 75 data estimated the same as FY 74

| Agency | Project No. | Project Title | Total Prior to Initial Year Indicated | FY 72 | FY 73 | FY 74 | FY 75 | FY 76 | FY 77 | FY 78 | FY 79 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| DOT | AM-B-73-PSY-41 (FAA) | Field Study of Sonic Boom Startle Effects | | x | 18 | | | | | | |
| | AM-B-73-PSY-31 (FAA) | Determinants of Startle Response to Simulated Sonic Boom | | x | 27 | | | | | | |

Table F-3
INDIVIDUAL BEHAVIOR EFFECTS
(Page 3 of 4 Pages)

| Agency | Project No. | Project Title | Total Prior to Initial Year Indicated | FY 72 | FY 73 | FY 74 | FY 75 | FY 76 | FY 77 | FY 78 | FY 79 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Reported Funding, Thousands of Dollars | | | | | | | | |
| DOT | DOT/FAA/DOD/AF | Animal Response to Impulsive Acoustic Stimuli | | 38 | 0 | | | | | | |
| | Work at DOC/NBS (USCG) | Foghorn Aversiveness Study | | | 5 | | | | | | |
| | | Subtotals | | 38 | 50 | | | | | | |
| NSF | GS-33216 | Collaborative Research on Social Psychological Reactions to Stress | | 34 | | | | | | | |
| | GS-2405A #2 | Collaborative Research on Social Psychological Reactions to Stress | | 42 | | | | | | | |
| | GS-34329 | Collaborative Research on Social Psychological Reactions to Stress | | 39 | | | | | | | |
| NBS | In-house | Psychoacoustic Measurement Techniques | | | 98 | 17 | 142 | | | | |

Table F-3
INDIVIDUAL BEHAVIOR EFFECTS
(Page 4 of 4 Pages)

| Agency | Project No. | Project Title | Total Prior to Initial Year Indicated | FY 72 | FY 73 | FY 74 | FY 75 | FY 76 | FY 77 | FY 78 | FY 79 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Reported Funding, Thousands of Dollars | | | | | | | | |
| EPA | IAG | Behavioral Correlates of Varying Noise Environments | | | | 50 | 50 | | | | |
| | In-house | Vigilance Task Performance in Presence of Intermittent Unwanted Noise in Primates | | | | | 10 | | | | |
| | IAG | Time varying effects on human response | | | | | 75 | | | | |
| | | Effects on Task Performance | | | | | | 150 | | | |
| | | Subtotals | | | | 50 | 135 | 150 | | | |
| | | Totals for Individual Behavior Effects | | 217 | 381 | 361 | 443 | 290 | | | |

Table F-4
NOISE EFFECTS ON SLEEP
(Page 1 of 1 Page)

| Agency | Project No. | Project Title | Total Prior to Initial Year Indicated | Reported Funding, Thousands of Dollars FY 72 | FY 73 | FY 74 | FY 75 | FY 76 | FY 77 | FY 78 | FY 79 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| NASA | 504-09-02 | Human Response to the Aeronautical Environment | | | 217 | 254 | 142 | 150 | 150 | | |
| | | Subtotals | | | 217 | 254 | 142 | 150 | 150 | | |
| EPA | Contract | Quality of Sleep & Effects Related to Physiological & Psychological Implications | | | | 0 | 17 | | | | |
| | | Correlation of Foreign and Domestic Data on Noise Effects on Sleep | | | | | | | | | |
| | | Subtotals | | | | 0 | 17 | | | | |
| | | Totals for Noise Effects on Sleep | | | 217 | 254 | 159 | 300 | 150 | | |

Table F-5
COMMUNICATION INTERFERENCE
(Page 1 of 4 Pages)

| Agency | Project No. | Project Title | Total Prior to Initial Year Indicated | FY 72 | FY 73 | FY 74 | FY 75 | FY 76 | FY 77 | FY 78 | FY 79 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Reported Funding, Thousands of Dollars | | | | | | | |
| HEW/ NINDS | NS-07908-07 | Noise-Induced Deafness: Masking and Speech Perception | 461 | | 79 | | | | | | |
| | NS-74-2322 (Contract) | Development of Test Instrument for Assessing Speech Discrimination in Noise | | | | 140 | | | 100 | 100 | 100 |
| | | Message Transmission in Noise | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 130 |
| | | Subtotals | 461 | | 79 | 140 | 100 | 0 | 100 | 100 | 230 |
| DOD | DAOA-6085 (USA) | Military Performance: Auditory Perception and Psychophysics | | | | | | | | | |
| | (USA) | Human Engineering Studies of the Head and Headgear, Helmet Acoustics, Weight plus Other Factors Affecting Performance | | | x | | | | | | |

Table F-5
COMMUNICATION INTERFERENCE
(Page 2 of 4 Pages)

| Agency | Project No. | Project Title | Total Prior to Initial Year Indicated | Reported Funding, Thousands of Dollars FY 72 | FY 73 | FY 74 | FY 75 | FY 76 | FY 77 | FY 78 | FY 79 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| DOD | DN-040713 | Optimization of Speech Communications in Naval Aviation | | | 40 | 40 | | | | | |
| | (USN) | Development of Auditory Screening and Acoustical Tolerance Standards for Submarine/Shipboard Personnel | | | 30 | 33 | | | | | |
| | (USN) | Sound Conduction in the Ear Affecting Military Communications | | | 26 | | | | | | |
| | DF-311640 (USAF) | Assessment of Hearing in Flying Personnel | | | 28 | 36 | | | | | |
| | | Subtotals | | | 124 | 109 | 109[1] | | | | |

[1] DOD FY 75 data estimated the same as FY 74

Table F-5
COMMUNICATION INTERFERENCE
(Page 3 of 4 Pages)

| Agency | Project No. | Project Title | Total Prior to Initial Year Indicated | Reported Funding, Thousands of Dollars FY 72 | FY 73 | FY 74 | FY 75 | FY 76 | FY 77 | FY 78 | FY 79 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| EPA | Contract | Improved Criteria for Verbal Communication from Noise in Schools and Home Environments | | | | 59 | 62 | | | | |
| | IAG | Voice Levels and Environmental Noise Conditions That Permit Adequate Speech Communication | | | | | 25 | | | | |
| | | Effect of Age, Speech Level, Hearing on Reliable Communication | | | | | | 200 | | | |
| | | Subtotals | | | | 59 | 87 | 200 | | | |
| DOI/ BuMines | G0122004 | Aspects of Noise Generation & Hearing Protection in Underground Coal Mines | | | 1 | 0 | 0 | | | | |
| | G0133026 | Study of Roof Warning Signals & the Use of Personal Hearing Protectors in Underground Coal Mines | | | 71 | 8 | 0 | | | | |

Table F-5
COMMUNICATION INTERFERENCE
(Page 4 of 4 Pages)

| Agency | Project No. | Project Title | Total Prior to Initial Year Indicated | FY 72 | FY 73 | FY 74 | FY 75 | FY 76 | FY 77 | FY 78 | FY 79 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Reported Funding, Thousands of Dollars | | | | | | | | |
| | | Subtotals | | | 72 | 8 | 0 | | | | |
| | | Totals for Communication Interference | 461 | | 275 | 316 | 296 | 200 | 100 | 100 | 230 |

Table F-6
COMMUNITY OR COLLECTIVE RESPONSE
(Page 1 of 2 Pages)

| Agency | Project No. | Project Title | Total Prior to Initial Year Indicated | Reported Funding, Thousands of Dollars FY 72 | FY 73 | FY 74 | FY 75 | FY 76 | FY 77 | FY 78 | FY 79 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| DOT | Contract 036369 (Trais No.) | Measurement of Community Noise and Associated Human Response | 295 | | | 130 | 50 | | | | |
| | | Subtotals | 295 | | | 130 | 50 | | | | |
| NASA | 504-29-01 | Acceptance of Aircraft Operations Technology Assessment | | | 173 | 172 | 232 | 160 | 160 | | |
| | 504-29-11 | Acceptance of Aircraft Operations Community Noise | | | 205 | 319 | 422 | 350 | 350 | | |
| | | Subtotals | | | 378 | 491 | 654 | 510 | 510 | | |
| DOD | DF 313140 | Effects of Air Force Noises on Population Surrounding Air Bases | | | 32 | 0 | 0 | | | | |
| | | Subtotals | | | 32 | 0 | 0 | | | | |

Table F-6
COMMUNITY OR COLLECTIVE RESPONSE
(Page 2 of 2 Pages)

| Agency | Project No. | Project Title | Total Prior to Initial Year Indicated | Reported Funding, Thousands of Dollars FY 72 | FY 73 | FY 74 | FY 75 | FY 76 | FY 77 | FY 78 | FY 79 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| HUD | | Evaluation of HUD Noise Policies and Guidelines | | | | 200 | 185 | | | | |
| | | Effects of Noise on Community Development | | | | | 225 | | | | |
| | | Subtotals | | | | 200 | 410 | | | | |
| EPA | | Effects of Noise on Community Response Related to Annoyance | | | | | | | | | |
| | | Identification of Environmental Noise Levels for Determining Cumulative Dose Exposures for Different Population Segments | | | | | | 200 | | | |
| | | Subtotals | | | | | | 200 | | | |
| | | Totals for Community or Collective Response | 295 | | 410 | 821 | 1,114 | 200 | 510 | | |

Table F-7
DOMESTIC ANIMALS AND WILDLIFE
(Page 1 of 1 Page)

| Agency | Project No. | Project Title | Total Prior to Initial Year Indicated | Reported Funding, Thousands of Dollars FY 72 | FY 73 | FY 74 | FY 75 | FY 76 | FY 77 | FY 78 | FY 79 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| DOA | 0057475 SC-00945 | The Effect of Noise Pollution on the Fowl | x | x | x | | | | | | |

Table F-8
MEASUREMENT METHODOLOGY AND CALIBRATION
(Page 1 of 4 Pages)

| Agency | Project No.[2] | Project Title[2] | Total Prior to Initial Year Indicated | FY 72 | FY 73 | FY 74 | FY[1] 75 | FY 76 | FY 77 | FY 78 | FY 79 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Reported Funding, Thousands of Dollars | | | | | | | |
| HEW/ NIOSH | | Industrial Audiometric and Hearing Conservation Technology | | | 31 | 52 | 80 | | | | |

[1]Estimate.
[2]NIOSH does not use the term "project" for this level of research activity.

Table F-8
MEASUREMENT METHODOLOGY AND CALIBRATION
(Page 2 of 4 Pages)

| Agency | Project No. | Project Title | Total Prior to Initial Year Indicated | FY 72 | FY 73 | FY 74 | FY 75 | FY 76 | FY 77 | FY 78 | FY 79 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Reported Funding, Thousands of Dollars | | | | | | | | |
| HEW/ NIOSH | | Measurement of Occupational Noise | | | 32 | 44 | 28 | | | | |
| | | Subtotals | | | 63 | 96 | 108 | | | | |
| DOD[1] | DAOD-6739 (USA) | Research on Psychoacoustical Problems Medically Significant to Army Aviation | | x | 85 | 195 | | | | | |
| | DN-612146 (USN) | Airborne Noise Criteria for Ships and Submarines | | | 69 | 74 | | | | | |
| | DF 313020 (USAF) | Mechanisms of Noise Generation and Reception as Related to Air Force Bioacoustic Programs | | | 3 | 2 | | | | | |
| | DF 313030 | Bioacoustic Environments of USAF Aerospace Systems | | | 92 | 68 | | | | | |
| | DF 317570 | Bioenvironmental Noise Research Program | | | 4 | | | | | | |

[1] DOD FY 75 data estimated the same as FY 74.

Table F-8
MEASUREMENT METHODOLOGY AND CALIBRATION
(Page 3 of 4 Pages)

| Agency | Project No. | Project Title | Total Prior to Initial Year Indicated | Reported Funding, Dollars FY 72 | FY 73 | FY 74 | FY 75 | FY 76 | FY 77 | FY 78 | FY 79 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| DOD | DF 314500 (USAF) | Development and Updating of Air Force Land Use Planning Procedure with Respect to Aircraft Noise | | | 32 | | | | | | |
| | DF 316600 (USAF) | Measurement and Analysis of Aircraft Noise Environments for Developing New Air Force Procedures to Forecast Noise Exposure | | | 13 | 15 | | | | | |
| | | Subtotals | | | 337 | 354 | 354[1] | | | | |

[1]DOD FY 75 data estimated the same as FY 74

| Agency | Project No. | Project Title | Total Prior to Initial Year Indicated | FY 72 | FY 73 | FY 74 | FY 75 | FY 76 | FY 77 | FY 78 | FY 79 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| HUD | | Hud Urban Noise Measurement System | | | 117 | 263 | | | | | |
| | | Development of Noise Attention Measures | | | | 175 | 50 | | | | |
| | | Subtotals | | | 117 | 438 | 50 | | | | |

Table F-8
MEASUREMENT METHODOLOGY AND CALIBRATION
(Page 4 of 4 Pages)

| Agency | Project No. | Project Title | Total Prior to Initial Year Indicated | Reported Funding, Thousands of Dollars | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | FY 72 | FY 73 | FY 74 | FY 75 | FY 76 | FY 77 | FY 78 | FY 79 |
| NASA | 504-29-11 | Characterization of V/STOL Noises | | | 532 | 409 | 404 | | | | |
| EPA | Work at DOC/NBS | Instrumentation and Measurement Systems for Noise Exposure of Individuals | | | 24 | 32 | 0 | | | | |
| DOI/ BuMines | S0144091 | Portable Calibration Instrumentation for Audiodosimeters--Feasibility Study | | | 0 | 15 | 0 | | | | |
| | | Totals for Measurement Methodology & Calibration | | | 1,073 | 1,344 | 916 | | | | |

## APPENDIX G

## ADDENDUM

This appendix is included in the interest of being complete. It contains a project received too late to be incorporated into the report. The project would have been considered in the measurement methodology and calibration category. Fiscal data in the report do not reflect the funding for this project.

Prediction and Reduction of the Noise Impact
Within and Adjacent to Army Facilities

US Army Construction Engineering Research Laboratory

Project No: 896-06-001 1 July 1974

1. TECHNICAL OBJECTIVE: To develop methods to quantitatively predict the noise pollution impact of Army operations, including blasting, helicopter operations, industrial plants, and transportation, on civilian and military populations and to develop and assess means to reduce the noise impact of such operations.

2. APPROACH: In conjunction with other Army and governmental agencies such as the Environmental Protection Agency, the means to predict the noise impact of Army activities and/or facilities will be created and tested. The prediction will be a composite of all noise sources and will form "equal noisiness" contours which can be overlayed upon land use maps to graphically expose incompatible zones. Based upon the predictions, operational and physical means to reduce the noise impact will be considered and evaluated for cost, effect upon Army operations, and effectiveness in noise mitigation.

3. PROGRESS: 73 07 to 74 06. The noise prediction model for blast noise has been completed and initially tested. Field noise measurements have been completed on the Army inventory for rotary wing aircraft. When analyzed, this data will go into the Tri-Service Aircraft Noise Impact Prediction Computer Program and enhance the Army's ability to predict noise impact of rotary wing aircraft operations. Construction has begun on unmanned noise monitoring equipment which will be placed in the environs of a facility to test the noise impact prediction technique. Work has been initiated to quantify the human reaction to blast noise into terms and units recognizable and relatable to other noise sources.

4. OVERALL PLAN:

a. The means to predict and reduce the noise impact of military facilities will be created. One physical measure will be used to rate all of the various noise sources from the following classes:

(1) Blast noise;

(2) Fixed wing aircraft;

(3) Rotary wing aircraft;

(4) Mobile equipment;

(5) Fixed equipment and installations.

To the extent applicable, measures recommended by the Federal Environmental Protection Agency will be employed.

b. This work is patterned after Air Force work on the prediction of noise impact from fixed wing aircraft. Essentially an iterative procedure must be followed for each of the above classes of sources (except fixed wing which the Air Force has completed) in order to develop an accurate prediction method.

c. Actually there are two predictions involved; physical and psychoacoustical with the psychoacoustical prediction based upon the results of the physical prediction. Thus, in the iterative testing for accuracy two specific tests must be employed; one for the overall physical prediction, the other for the predicted psychoacoustical response of the community.

d. The following program steps must occur within each class of sources in order to create an accurate prediction submodel for that class.

(1) First of all, a trial noise impact model is created for the class and a computer prediction program is created based upon the model. Initial deficiencies in the data base are identified. These data deficiencies are of two types: psychoacoustical data and physical data which include data about the source, the path, and the recéiver.

(2) Documentation is prepared for the computer program explaining its use. This documentation includes creation of a manual that informs facilities of the manner in which they are to compile operational data for submission into the computer program and subsequent generation of impact contours, creation of an operations manual dealing with the use and operation of the program, and creation of a programmers manual dealing with the detailed program description such that other military activities can implement the program at various data processing centers.

(3) Computer generated results are obtained for use by the various installations and for testing the accuracy of the prediction. Based upon the prediction model and the computer program, a manual is created so that the facilities are able to interpret the computer results and can understand the noise impact that their facility creates.

(4) Electronic instrumentation is created which monitors the physical (acoustical) energy arriving to various points in space. This measured energy is compared with the physical prediction. Discrepancies in the prediction dictate the need for alteration of the model and the need for additional physical data.

(5) Community surveys are conducted to assess the community response to its acoustical environment. The results of the surveys are compared with the prediction of the community response. Discrepancies in the prediction dictate the need for alteration of the model and the need for additional psychoacoustical data.

(6) A manual is prepared on the means to lessen adverse noise impact.

(a) These means include a variety of methods such as scheduling changes, location of changes, orientation changes, equipment changes, attenuation structures, attenuation devices, and land use changes.

(b) All of the mitigation methods are evaluated with respect to the attributes of ability to reduce noise impact, cost, and impact on Army programs.

e. As the submodels for the various classes of sources are created and tested they will be combined into a single overall prediction model with its associated computer program and implementation manuals. These manuals are similar in nature to the manuals described above but deal with the entire prediction rather than subclass.

5. WORK TO BE ACCOMPLISHED IN FY 75:

(1) Analysis and reduction of physical data including:

(a) Correlation of 20,000 blast data with 800 weather-sound velocity data points. (December 1975)

(b) Reduction of rotary wing data into raw 1/3 octave data and into units which correlate with human response. (April 1975)

(2) Adapt and create software for using complete rotary wing aircraft data using the Air Force Program as a point of beginning. (Air Force Program only considers frequency above 50 hz - helicopter may peak at about 25 hz.) (February 1975)

(3) Psychoacoustical tests and data analysis including:

(a) Results of rotary wing test. (December 1974)

(b) Results of pilot blast noise tests. (January 1974)

(4) User manual to describe form and presentation of helicopter data to the computer from the installation will be created. (July 1975)

(5) Programmer and operations documentation of the blast noise computer program (contour portion) will be created. (February 1975)

(6) As a special consideration of mobile sources, the effects of traffic noise to residential (barracks and family housing) structures (quantified in distance from traffic areas will be considered using HUD data as a base or point of beginning). (June 1975)

(7) Testing of the physical blast noise prediction will be implemented by:

(a) Constructing measuring system (same as being built for EPA) - our testing equipment will include blast monitoring capabilities while EPA's will not. (January 1975)

(b) Test of the system in the field and evaluation of monitoring results. This will be an on-going activity with periodic evaluations.

(8) Set up for new blast measurement to explore the effects of different climate and terrain. The measurements will take place in FY 76. (July 1975)

(9) Initiate by contract community surveys to assess the response to facility blast noise. (March 1975)

6. <u>WORK TO BE ACCOMPLISHED IN FY 76</u>:

(1) Results of initial social survey/community response with respect to blast noise. (January 1977)

(2) Results of blast noise psychoacoustical tests. (January 1977)

(3) Inclusion of vehicular and fixed sources. (All Year)

(4) Additional blast and possible rotary-wing measurements. (All year, including analysis)

(5) Implementation of blast noise and rotary wing aircraft classes with the DOD manual (omit vehicle and fixed noise sources). (All Year)

(6) Continued base monitoring to test physical prediction. (All Year)

(7) Preliminary attenuation and mitigation work with respect to blast noise and rotary wing aircraft. (All Year)

7. Funding Summary (Dollars in Thousands)

| Commit-ment | FY74 | FY75 | FY76 | FY77 | FY78 | FY79 | To Complete |
|---|---|---|---|---|---|---|---|
| | CFY-1 | CFY | BFY | BFY+1 | BFY+2 | BFY+3 | |
| In-House | 195 | 175 | 250 | 250 | 250 | 250 | |
| Out-of-House | 35 | 75 | 45 | 45 | 45 | 80 | |
| Other | 20 | 10 | 85 | 80 | 80 | 80 | |
| | 250 | 260 | 380 | 375 | 375 | 375 | 450 |

## TECHNICAL REPORT DATA
*(Please read Instructions on the reverse before completing)*

| | | |
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15. SUPPLEMENTARY NOTES

EPA Contact: Stephen R. Cordle, 202-755-0448

16. ABSTRACT

Potential effects of noise on the public health and welfare are described, limitations and gaps in necessary knowledge of those effects are identified as research needs, and eight categories for analyzing noise effects research are presented. The current Federal research programs are summarized for each of the eight categories.

The Noise Effects Research Panel through its collective knowledge of the needs and the current research has identified specific research areas which need additional emphasis in order to provide accurate and thorough information on effects of noise. The Panel concluded that the current programs need continued and in some instances expanded support in order to provide necessary information on the effects of noise. Some areas of concern which are not currently being addressed are also identified.

17. KEY WORDS AND DOCUMENT ANALYSIS

| a. DESCRIPTORS | b. IDENTIFIERS/OPEN ENDED TERMS | c. COSATI Field/Group |
|---|---|---|
| Noise (sound), Research Projects, Federal Budgets, Behavior, Auditory Perception, Auditory Masking, Arousal (Sleep Disturbance), Sociopsychological Surveys, Physiology, Speech | Noise effects, Federal noise research coordination | 2001, 1406, 0510, 0616 |

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APPENDIX G

Federal Machinery Noise Research, Development, and Demonstration: FY73--FY75, Report EPA-600/2-75-008, Prepared by Interagency Machinery Noise Research Panel, May 1975

EPA-600/2-75-008
MAY 1975

Environmental Protection Technology Series

# Federal Machinery Noise Research, Development and Demonstration: FY 73 - 75

Office of Research and Development
U.S. Environmental Protection Agency
Washington, D.C. 20460

## RESEARCH REPORTING SERIES

Research reports of the Office of Research and Development, Environmental Protection Agency, have been grouped into five series. These five broad categories were established to facilitate further development and application of environmental technology. Elimination of traditional grouping was consciously planned to foster technology transfer and a maximum interface in related fields. The five series are:

1. Environmental Health Effects Research
2. Environmental Protection Technology
3. Ecological Research
4. Environmental Monitoring
5. Socioeconomic Environmental Studies

This report has been assigned to the ENVIRONMENTAL PROTECTION TECHNOLOGY series. This series describes research performed to develop and demonstrate instrumentation, equipment and methodology to repair or prevent environmental degradation from point and non-point sources of pollution. This work provides the new or improved technology required for the control and treatment of pollution sources to meet environmental quality standards.

This report has been reviewed by the Office of Research and Development. Approval does not signify that the contents necessarily reflect the views and policies of the Environmental Protection Agency, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

Report 600/2-75-008
May 1975

# FEDERAL MACHINERY NOISE RESEARCH, DEVELOPMENT AND DEMONSTRATION PROGRAMS: FY73 - FY 75

Prepared by

Interagency Machinery Noise Research Panel

ROAP/TASK 21AXV
Program Element No. 1GB090

Project Office:
Noise Technology Staff
Office of Research & Development
U.S. Environmental Protection Agency
Washington, D.C. 20460

Prepared for
U.S. Environmental Protection Agency
Office of Research & Development
Washington, D.C. 20460

## ABSTRACT

The Interagency Machinery Noise Research Panel was established by the Environmental Protection Agency to aid EPA in fulfilling its responsibility for coordinating the Federal noise research activities. As its initial task, the Panel prepared this report summarizing the Federal government's machinery noise research, development, and demonstration activities. The Federal agencies which sponsor and/or conduct the major portion of these activities are represented on the panel. They are Department of Defense, National Bureau of Standards, National Science Foundation, Bureau of Mines, National Institute for Occupational Safety and Health, and EPA. Department of Labor is also represented. Other agencies which sponsor machinery noise RD&D are the Department of Agriculture and Consumer Product Safety Commission. The report contains brief descriptions and fiscal data for the agencies' activities. Emphasis is on fiscal years 1973 through 1975. Also included are references and bibliographies of reports and publications which have resulted from the Federal machinery noise RD&D activities.

TABLE OF CONTENTS

TABLES

## 1.0 INTRODUCTION

EPA has established four noise research panels consisting of representatives from Government departments and agencies to provide informational exchange, a forum for interagency discussion, and advice to aid EPA in its role as the coordinator of Federal noise research in accordance with the Noise Control Act of 1972. The panels and panel membership reflect the major thrusts of the Federal noise research programs as follows:

| Noise Research Panel | Current Agency Membership* |
| --- | --- |
| Aircraft | NASA, DOT, DOD, HUD, DOC, EPA |
| Surface Vehicles | DOT, HUD, DOD, DOC (NBS), EPA |
| Noise Effects | HEW (NINDS, NIOSH, NIEHS), DOT, NSF, HUD, NASA, DOD, DOL, DOC(NBS), EPA |
| Machinery** | HEW (NIOSH), DOI (Bureau of Mines), DOT, DOD, DOL, DOC,(NBS), EPA |

These panels provide the formal mechanisms for interagency consideration review and assessment of research in the four technical areas. The primary functions of the panels in their respective areas are:

- Review and assessment of the state of science and technology relating to noise.
- Review and assessment of the status of noise research and technology development.
- Identification of technology gaps and research needs.
- Preparation of recommendations concerning ongoing research activities.
- Recommendations of noise research programs and projects and methods for accomplishments.

For the purposes of this report, the term "machinery" includes all mechanical devices not classified as aircraft or surface vehicles.

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* Glossary of Agency Acronyms in Appendix A.
** List of Machinery Panel Members in Appendix B.

Machinery then means not only industrial machinery, but also household appliances, toys, some construction equipment, electronic devices and equipment, office machines, gardening and power tools, furnaces and air conditioners. As the panel is concerned with noise reduction in general, this report will also deal with research on structural transmission of noise and building acoustics, and the use of noise control materials.

## 1.1 PURPOSE AND SCOPE

This is the first report prepared by the Machinery Noise Research Panel. It presents a summary of current Federal programs and projects which seek to understand and control machinery noise. To view these Federal efforts from a proper perspective, the report also addresses:

- sources of machinery noise
- impact of machinery noise
- private sector efforts in machinery noise RD&D

This report does not address:

- the state of technology for controlling machinery noise
- research needs in machinery noise
- adequacy of current Federal RD&D
- role of the Federal Government in machinery noise RD&D

This document also will be used by the Environmental Protection Agency in preparing a report to satisfy Section 4(c)(3) of the Noise Control Act of 1972. EPA is required to report on the status and progress of Federal activities relating to noise research and control and to assess the contribution of such activities to the Federal Government's overall efforts to control noise.

Activity for fiscal year (FY) 1974 is emphasized, program continuation through FY 1975 is noted where possible, and funding and work carried out during FY 1973 is reported. The data on which the report is based came from two sources: Agencies' responses to a 1974 request from EPA on Federal noise activities and information supplied by the panel members in 1974. Although the data are current as of the end of 1974 and fairly complete, there are variations in the ways agencies calculate the costs of overhead for their in-house research. Thus, comparisons between agencies' reported fiscal data are not exact.

The fiscal data are also incomplete. First, much of the DOD Research Development and Demonstration (RD&D) on machinery noise is classified for national security reasons. However, general research areas and the extent of overall funding is reported. Secondly, NSF carries out research only through unsolicited grants. Thus, it is impossible for NSF to predict what research proposals may be received and funded.

Conclusions and recommendations made in this report are the collective opinions of the panel members and do not necessarily represent their agencies' policies.

## 1.2 SOURCES OF MACHINERY NOISE

Considering the definition of machinery used in this report, there are literally countless sources of machinery noise to which people are exposed. Machinery is found in almost every human environment. In general, exposures in the industrial occupational environment are the most severe in terms of both level and duration. Examples of some machinery noise levels in the worst industries are shown in Table 1.1. It should be noted that these levels are only representative. Many parameters, such as manufacturer, working material, size of the machinery, etc. can affect the noise level. Appendix E, which makes no attempt to be all-inclusive, identifies 357 machines in 20 industries.

Machinery noise also occurs in the home, in hospitals, in office and residential buildings, and in the community. Some general categories of sources include appliances, building equipment, power tools, and toys. Examples of these sources and their noise levels are shown in Table 1.2.

As specified in the Section 5 of the Noise Control Act of 1972 (Public Law 92-574, 86 Stat. 1234), the first step toward promulgation of noise standards for new products is identification of those products which are major sources of noise. On June 21, 1974, EPA designated portable air compressors rated above 2.124 cubic meters (75 cubic feet) per minute and medium and heavy duty trucks as major sources of noise. The designation was based on "air compressors as the major source of sound energy and the most widely used product among pieces of construction equipment contributing to construction site noise" (after medium and heavy duty trucks). (Ref. 1)* The designation was based on environmental noise impact and not occupational noise impact, which is principally concerned with hearing loss.

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* For references, see Section 5.0

Table 1.1 EXAMPLES OF INDUSTRIAL MACHINERY NOISE SOURCES

| INDUSTRY | TYPE SOURCE | NOISE LEVEL (dBA)* |
|---|---|---|
| Construction Equipment 15.2 meters (50 feet) | Air Compressor | 81 |
| | Jack Hammer | 88 |
| | Generator | 78 |
| | Pile Driver | 101 |
| | Crane-Derrick | 88 |
| | Back Hoe | 85 |
| | Rock Drill | 98 |
| | Pneumatic Tools | 85 |
| Metal Working Machinery (Operator position) | Drop Hammers | 111 |
| | Punch Presses | 107 |
| | Riveting Machines | 117 |
| | Chipping Machines | 127 |
| Wood Working Machinery (Operator position) | Planers | 108 |
| | Saws | 111 |
| | Molders | 99 |
| | Tenoners | 95 |
| Textile Manufacturing Machinery (Operator position) | Looms | 102 |
| | Combing Machines | 95 |
| | Reducing Machines | 96 |
| | Bleaching, Dying and Finishing Machinery | 100 |

NOTE: Levels are only representative.

* References and a more comprehensive list are found in Appendices E and F.

Table 1.2 OTHER MACHINERY NOISE SOURCES

| CATEGORY | TYPE SOURCE | NOISE LEVEL (dBA) |
|---|---|---|
| Home Appliance .985 meters (3 feet) (Ref. 2) | Vacuum Cleaner | 73 |
| | Clothes Drier | 63 |
| | Dish Washer | 65 |
| | Shop Tools | 83 |
| | Sewing Machine | 73 |
| | Waste Disposal | 78 |
| | Food Blender | 75 |
| | Electric Can Opener | 66 |
| | Air Conditioner | 58 |
| I.C. Engine Powered Tools 15.2 meters (50 feet) (Ref. 3) | Lawn Mowers | 72 |
| | Chain Saws | 83 |
| | Snow Blowers | 85 |
| | Lawn Edges | 78 |
| | Tillers | 69 |
| | Garden Tractors | 75 |

NOTE: Levels are only representative.

## 1.3 IMPACT OF MACHINERY NOISE

General agreement exists that hearing loss is the most severe health effect of long term exposure to noise. EPA has estimated that as many as 25 million American workers have been exposed to noise potentially hazardous to their hearing. Noise from machinery sources in industry has been shown to affect work performance, cause short term physiological changes, and interfere with warning signals. (Ref. 4)

Estimates of the costs for reducing occupational noise to levels of marginal protection against hearing loss run into billions of dollars. (Ref. 5) However, these estimates are crude at best and little data exist to adequately define the extent of the machinery noise problem in the occupational environment and to assess the availability and cost of technology for industrial noise control. The available data do indicate that the problem is complex in terms of the vast number of different machines in use, severe in terms of numbers of people exposed to hazardous levels of noise, and costly in terms of available control technology.

Although noise exposures in industrial environments are the most severe, machinery sources can impact significantly in other environments. Machinery noise may disturb sleep, annoy, interfere with activities, and contribute to fatigue and irritation in residential, hospital, office, or recreational environments. (Ref. 4) EPA has estimated that 13 million people presently reside in areas where noise levels exceed those potentially hazardous to hearing.

The vast number of machines involved, the large number of people affected, and the costs involved in control of machinery noise would suggest the need for a concerted Federal involvement in this area.

## 1.4 PRIVATE SECTOR EFFORTS IN MACHINERY NOISE RD&D

The sheer magnitude of the noise sources and levels in industrial machinery alone suggest that much research would be going on in the private sector to develop more cost effective noise control technology. The Machinery Noise Research Panel felt than an indication of the RD&D being carried out by industry was needed to determine the Federal Government's role in machinery noise RD&D. The panel, however, identified major problems of data acquisition on private sector work due to the proprietary nature of most industry RD&D and the large number of firms. Trade associations were suggested as an initial way of obtaining an indication of machinery noise research supported by industry.

Consequently, a number of trade associations were contacted and a literature search was conducted for the period 1971-1974. The details of the results are reported in Appendices C and D. The conclusions are as follows:

Noise Abatement Research by Trade Associations - Trade associations are not considered a source for large amounts of quantitized data on noise sources, noise levels and noise treatment technology. However, most of the associations are aware of the noise problems within their industries and are keeping abreast of existing and new noise regulations.

Machinery Noise Literature Search - In a literature search which covered the period 1971-1974, 321 publications were identified as pertinent to machinery noise. The abstracts provided virtually no technical information which could be used in assessing noise levels, noise reduction techniques, or effectiveness of the application of control technology. A distribution of over 20 industries showed that seven industries had no publications at all and seven industries had less than ten each. The majority of the publications were either concentrated in the other six industries or could not be classified. It can be concluded that for most industries there is not much public reporting of machinery noise research results.

In summary, it appears that trade associations are not conducting much research on machinery noise and other industry research will most likely be proprietary. The literature search showed that for most industries there were few publications in the period 1971-1974. Therefore, there is not much ongoing private sector research which will produce publicly available machinery noise control technology.

## 2.0 DESCRIPTION OF FEDERAL MACHINERY NOISE RD&D

Table 2.1 shows that eight Federal agencies, including two components of DOD, are sponsoring machinery noise research. The Navy by far has the largest activity, with about a million dollars per year spent in the machinery noise area. However, the results of this research are classified and thus are not currently publicly available. The other agencies' in FY 74 together spent a total of more than 2 million dollars on machinery noise RD&D. The total Federal effort has been in the range of 2 to 3 million dollars per year and appeared to peak in FY 74. A brief description of each agency's activities is presented below.

### 2.1 DEPARTMENT OF DEFENSE

The DOD research effort in machinery noise reduction follows the traditional methods of establishing criteria, determining the noise producing mechanisms, and developing techniques to reduce such noise. This effort is supplemented, when reduction of the source itself is not possible, by mitigation through use of structural damping, resilient mounts, and the use of acoustical transmission loss and absorptive materials.

The major DOD effort is in the Department of the Navy, in particular Naval Sea Systems Command. This work addresses the quieting of ships to avoid detection, improve sonar listening, and reduce susceptibility of ships to acoustically actuated weapons and energy detection systems. Other DOD efforts are conducted by the Army on various pieces of military equipment. Various military standards: MIL-STD-740 (Ref. 6), which covers naval machinery; MIL-STD-1474 (Ref. 7), which covers Army Material Command equipment; and MIL-D-008806B (Ref. 8), which covers Air Force equipment aboard aircraft, provide guidance in how to measure noise and standards of acceptability.

Table 2.1 MACHINERY NOISE RD&D FUNDING BY AGENCY

(Thousands of Dollars)

| AGENCY | FY 73 | FY 74 | FY 75 |
|---|---|---|---|
| DOI/Bureau of Mines | 337 | 528 | 730[1] |
| DOC/NBS | 138 | 264 | 265 |
| HEW/NIOSH | 16[2] | 226 | 138 |
| NSF | 243 | 356 | - |
| EPA | 60 | 230 | 100 |
| DOD/USN[3] | - | - | - |
| DOD/USA | 178 | 490 | 245[1] |
| CPSC | 0 | 70 | 0 |
| USDA | 0 | 20 | 92 |
| | 972 | 2,184 | 1,570 |

[1] Projected

[2] This figure does not reflect $60.5K funded in FY 72 for work done in FY 73.

[3] Navy funding for specific RD&D activities in Machinery Noise cannot be reported for security reasons. However, the total effort in this area is about $1 million each year.

### 2.1.1 U.S. Navy

In addition to the various military standards mentioned above, noise level requirements are frequently stated in the individual shipbuilding specifications for items of special interest. While the Navy effort is primarily concerned with radiated and sonar self-noise, such effort results in quieter machinery. The principal noise offenders are those associated with propulsion plants. These include internal combustion engines, gears, valves, and auxiliaries such as pumps, motors, generators, etc.

Diesel Engines - The most serious noise producing machinery item is the diesel engine. Noise levels in the vicinity of unquieted diesels as high as 125 dBA are not uncommon. These noises are caused by the exhaust, piston impact, valves and other moving parts. Significant reductions have been obtained as a result of research in muffler design, use of heavier engine parts, lining of intake ducting, acoustical cladding and enclosures. Because noise levels generally increase primarily with speed and to a lesser extent with increase in bore, stroke, and number of cylinders, slower engines are used where feasible.

Hydraulic Systems - Extensive research is being conducted on hydraulic system noise reduction. In addition to the work on specific components such as pumps and valves, studies are being conducted on acoustical filters, flexible pipe connections, pipe hangers, and pipe damping. Handbooks are under development to (a) summarize all physical, acoustical and usage data on flexible pipes and hose connections, and (b) depict the design of noise reducing pipe hangers.

Pneumatic Machinery - Pneumatic machinery is quieted by a combination of damping and careful machining of components.

Rotating Electrical Machinery - Rotating electrical machinery produces noise of three types: mechanical, airflow and magnetic. The mechanical noise can be reduced by careful balancing of the rotors, control of clearances, and lubrication. Brush noise is controlled by using holders of damped material, proper tightening, bearing brushes, polishing of commutators, and correction of eccentricity of slip rings or commutators. Balancing rings are used to facilitate balancing. Air flow noise is essentially fan noise and is discussed in a following paragraph. Magnetic noise, which is caused by variations in the magnetic path, can also be reduced by careful balancing.

Electronic Equipment - Generally noise from electronic equipment is airflow related. The air flow causes vibration of internal components such as elements on circuit boards as well as the items discussed under fan noise. Electronic cabinets, because of their light weight, are quick to resonate. Research is underway to determine the proper applications of air intake and exhaust mufflers, quiet fans, and damping to reduce this noise source.

Sound Path Isolators - Ideally, noise should be reduced by controlling the source, the component itself. If this cannot be done adequately, there is the problem of transmission by a structureborne path and subsequent reradiation. Structureborne transmission of noise can be reduced by the proper use of resilient mounts and mounting material. Mounts have been developed from various types of distributed isolation materials (DIM) and with capacities up to 4,536 kilograms (10,000 pounds). These are commercially available. Research on mounts is in process to improve the resistance of the material to deterioration from ozone and oil and from very high ambient temperatures. Reduction in structureborne paths is also achieved through the use of structural damping. Damping reduces the amplitude of vibration at the resonant frequency of the structure. Damping materials developed under Navy sponsorship are also widely used in non-Navy applications and are commercially available. Research is continuing to develop damping materials suitable for higher temperatures and heavier plate. A design handbook is being prepared for damped foundations.

Gas Turbines - Turbine noise results from many sources including unbalance of the rotor, motion of the rotor blades past the stator blades, and flow through the exhaust and intake ducts. Silencing has been achieved through the use of microbalancing of the rotor, damping of the turbine blades, damping of the reduction gear casing, lining of air intake, and use of splitters and septa in the air intake. In addition, acoustical enclosures have been developed to silence the entire turbine. Reductions of 40 to 50 dB have been obtained in the speech interference bands (500, 1,000, 2,000 Hz octave bands).

Compressors - Research is underway to investigate the noise sources associated with compressors and the application of available noise reduction techniques. These include investigation of pulsation dampers, blowdown silencers, and optimum mounting methods.

Fans - Fans used in ventilation systems and other equipment are principal noise producers. Fan noise is generally tonal at the blade passage frequency or one of its harmonics. It is caused by the blades passing close to the machine structure. It can become particularly serious if the housing or the ventilation ductwork is excited to resonance. Research is being conducted in fan blades, and knowledge obtained from pump impeller design is being applied to quiet fan noise.

Gears - Gear noise is characterized by broadband noise with a number of discrete tones. These are the various harmonics of the gear speed, with those corresponding to multiples of the pinion speed frequency and the tooth contact frequency most prominent. Factors which affect the generation of gear noise include unbalance and eccentricity, improper tooth shape and spacing, helix error, improper alignment, deflection under load, lubricant pumping, tooth friction, bearing reaction, etc. Gear noise has been significantly reduced by more precise machining (removal of burrs, grooves, high spots, etc.), care in alignment, and assuring the removal of any foreign material from the lubricant. Research continues through the use of computer analysis. Further reductions in airborne noise levels are anticipated through use of improved damping, case hardening, and the application of transmission loss treatments to the housing.

Valves - Valves are noise sources because abrupt changes in flow contours cause increased turbulence levels. Valve types have been rated in order of increasing noise generation as follows: plug, gate, check, globe, and diaphragm. The use of frictional reactive elements has greatly reduced valve noise. Research continues through use of mathematical modeling to further decrease valve noise.

Pumps - A pump accelerates a mass of fluid from a region of low pressure to higher pressure. This acceleration is accompanied by an opposing force on the housing. If the acceleration is smooth and uninterrupted, what little noise is produced is due primarily to flow interaction. An axial flow pump most closely approaches such conditions but its internal components generate noise. A centrifugal pump is also an inherently quiet design but noise is generated at blade frequencies. Piston pumps add noise because of the gears themselves. All mechanical pumps are subject to noise from leaks at some shaft seals. Noise control has been achieved by selecting the quietest usuable type pump. Research is being conducted to determine more accurately the characteristics of the pump noise and to develop quiet new components. In particular, impeller design modifications for centrifugal pumps are being studied.

Noise Criteria - Naval research is also underway to develop improved measuring techniques to simplify procedures and to permit measurement of equipment noise in any space configuration in manufacturing plants. The measurement technique will permit noise levels at the operator's position to be determined regardless of the environment and proximity of other machines.

2.1.2 DOD/U.S. Army/MERDC

The Army Mobility Equipment Research and Development Center (MERDC) at Ft. Belvoir, Va., has several noise reduction projects which are listed in Table 2.2. These are briefly described below.

Portable Equipment - A 17 cubic meter per minute (CMM) (600 CFM) portable air compressor and three mobile electric generators (1.5W, 30 KW, and 60 KW) are being addressed in current programs. The compressor project cost $98K in FY 73. The two larger generators were funded at $80K in FY 73 with a supplement of $50K in FY 74. Because the smaller generator project has just begun, the funding has not been determined. The goal for the larger portable electric generators was to obtain a reduction from the present 93-94 dBA at 7.6 meters (25 feet) to the middle of the 70-80 dBA range. So far, the program has accomplished a reduction to 76-77 dBA at 7.6 meters (25 feet). The smaller (1.5KW) generator project has already achieved a prototype with a noise level of 60-64 dBA at 3.05 meters (10 feet). It is said to be practically inaudible at 30.5 meters (100 feet).

Table 2.2 USA MERDC MACHINERY NOISE RD&D

| | Investigator | FY Funding ($K) FY 73 | FY 74 | FY 75 |
|---|---|---|---|---|
| Portable Equipment | | | | |
| Compressor Noise Control | Martin-Marietta Laboratories and Lord Corporation | 98 | | |
| Electric Generator Noise Control | | 80 | 50 | |
| Air Conditioner Noise Control [1] | In-house | | 400 | 200 [1] |
| Equipment Noise Survey & Evaluation [2] | In-house | | | |
| Military Standard Engines, Manifold | | | | |
| Muffler [4] | | | | |
| Rock Drill, Crawler Mounted | | | | |
| 22BM Crane-Shovel [4] | | | | |
| 4.536 metric ton (5 ton) crane, wheeled | | | | |
| Compressor 17 cmm (600 cfm) 2/6V-71N engine [4] | | | | |
| 1.7 cmm (60 cfm), .46 kg/cm$^2$ (6.5 psi) compressor | | | | |
| 21.2 cmm (750 cfm) compressor | | | | |
| Mixer, Rototiller [3] | | | | |
| Radial arm saw [4, 5] | | | | |
| 211 kg/cm$^2$ (3000 psi), .425 cmm (15 cfm) compressor [4] | | | | |
| Concrete Saw | | | | |
| Map Printing Van | | | | |
| Hydraulic Noise [3] | | | | |
| TOTALS | | 178 | 450 | 200 [1] |

[1] Funding approved for future years

[2] Nominal in-house funding, not dedicated to noise

[3] Work carried out relative to surface vehicles but applicable to machinery noise. Covered in surface vehicle report. (Ref. 9)

[4] Prior to FY 73

[5] Operator position only

Air Conditioners - A program has been initiated to reduce the noise level of military standard air conditioners below the speech interference levels of MIL-STD-1474. (Ref. 7) Work will include redesign of components, evaluation of mounting techniques, and other installation and application methods. The goal of the program is to reduce the noise levels of the units to approximately 55 dBA, 57 dB PSIL-4, or NC-60 (approximately equivalent levels).

Equipment Noise Survey and Evaluation - MERDC has also surveyed and partially evaluated the noise levels of a variety of other machinery including military standard engines, rockdrill, crane-shovel, 4.536 metric ton (5 ton) crane, compressor, rototiller mixer, radial arm saw, concrete saw, ditcher, and map printing press. The work has been performed with nominal in-house funding, not dedicated to noise. The survey was concerned with both operator noise exposure and noise levels measured at 15.2 meters (50 feet).

Hydraulic Equipment - MERDC has had two projects on hydraulic pumps and systems in vehicles. These projects are covered in the surface vehicle panel report (Ref. 9) but the hydraulic equipment is identical to that used in many industrial applications. Major efforts involved isolating mounts and covering up components, but further basic work was needed. The initial approach was to try to select a "quiet" pump, but it was determined that there were no satisfactory standards for measuring pump noise. Work was done in conjunction with Oklahoma State University (OSU) and the National Fluid Power Association (NFPA) to develop a procedure which has subsequently been submitted to the International Organization of Standardization (ISO). As the vehicle studies progressed, it became apparent that although most pumps are rated by their airborne noise levels, the real problem is the "noise" that is fluidborne and released downstream at the hoses, valves, and reservoirs. Levels reached the equivalent of over 200 dBA. It is interesting to note that in either case the noise is more adversely dependent upon the shaft speed than system pressure, but this is more true for fluidborne noise. In this study, no attempt was made to develop a "quiet" pump but rather to give an effective means to tradeoff performance parameters in order to reduce noise. Present work generally has been to study the phenomenon of noise in hydraulic systems. This will continue in the future along with the development of practical means to reduce noise.

2.1.3 DOD/U.S. Army/CERL

The U.S. Army Construction Engineering Research Laboratory (CERL) has a single project dealing with measurement methodology for construction sites. Funding was $40K in FY 74 and $45K in FY 75.

Construction Noise: Specification and Control

a. Background information and data will be compiled into a manual for a number of different task areas, which include the noise to be expected from construction sites as a function of the various phases and types of construction, known specifications and regulations dealing with construction site noise, methods to measure the noise of construction sites, background information indicating the need for attention to noise emitted from construction sites, information dealing with the means to lessen the noise impact, and information and data relating to the cost effectiveness of these noise attenuation means. Specifications will be prepared which will be appropriate for different types of construction or localities.

   Various measurement methods will be investigated for their appropriateness in testing for compliance with standards and establishing the noise from construction sites. Existing methods to attenuate noise emitted from construction sites, specifically alternate equipment, alternate methods, and physical attenuation will be reviewed.

b. New methods will be developed to mitigate the noise impact of construction sites with particular emphasis on the current and near future problems of military construction. The cost effectiveness will be determined for the various alternative means to attenuate the noise impact of construction sites.

## 2.2 NATIONAL BUREAU OF STANDARDS

NBS has research activities both in building acoustics and in development of measurement methodologies for sources of machinery noise. A summary of the funding for these activities is shown in Table 2.3.

Table 2.3
NBS MACHINERY NOISE RD&D
(In-house)

| Activity | FY Funding ($K) 73 | 74 | 75 |
|---|---|---|---|
| Building Acoustics | 97 | 144 | 145 |
| Machinery Noise Measurement Methods | 41 | 120 | 120 |
| TOTALS | 138 | 264 | 265 |

Building Acoustics - This activity's objectives are: 1) Improve present methodologies for measuring noise isolation provided by barriers, terrain, vegetation, and building shells. 2) Provide techniques for predicting sound propagation from exterior noise sources into occupied spaces. 3) Evaluate engineering data and information to assist designers in providing protection against noise of exterior origin. 4) Improve present measurement methodologies for measuring and controlling noise generation and propagation between rooms as well as building equipment noise, in order to provide essential, technically reliable noise control measurement procedures to industry and government.

The specific approaches will be to: 1) Develop new or improved measurement methodology for assessing noise generation and propagation within rooms, buildings, and building equipment noise. 2) Characterize the force spectra of "typical" sources of impact excitation, such as footsteps and characterize the vibratory and acoustic response of structural elements for specified excitations. Combine to yield predictions of the response and radiation of floor-ceiling models for "typical" impact excitation. Subject results to experimental verification. 3) Study human response to transient intrusive noises with the objective of correlating physical measures of noise with related subjective measures of acceptability or annoyance. 4) Develop new and earlier measurement methodologies for field measurement of airborne noise propagation between adjacent rooms and compare and extend by analysis and experiment.

Machinery Noise Measurement Methods - This activity will determine the adequacy of present measurement standards for the determination of sound power emitted by noise sources, and develop measurement methods and improvements of these standards in order to reduce measurement errors. A critical review of present American and international measurement standards is being conducted in order to assess the adequacy of these standards for the determination of sound power emitted by noise sources. The technical community and governmental regulatory agencies will be advised of the consequences of this critical review, and changes in the measurement procedures will be suggested as indicated. In order to gain direct familiarity with these procedures, they are being tried using the NBS reverberation room and anechoic chamber facilities. It is intended that by these means both industry and government will be provided a sound technical basis for the regulation and labeling of noise emissions from a variety of products.

## 2.3 NATIONAL SCIENCE FOUNDATION

NSF supports fourteen grants in various areas of machinery noise research. Sources addressed include heat exchangers, pipelines, industrial processes, ducts, nozzles, combustion noise, diesel engines, appliances, and machine tools. Control of the noise path is addressed in several grants on noise propagation, transmission, and absorption. Finally, NSF has funded a grant for computer prediction of noise levels in manufacturing areas. Titles and funding for each project are found in Table 2.4.

Flow-Induced Vibration and Noise in Heat Exchangers - The friction loss, performance, vortex shedding, plate vibration and noise generation in a tubular heat exchanger surface with slotted fins (such as in dry cooling towers) installed in a low turbulence, subsonic wind tunnel will be studied. The loss across the test core and the amplitudes and frequencies of the vortex shedding from perforated holes, plate vibrations and noise generated will be measured and correlated with a theoretical model as functions of the governing parameters. These results will be used to determine the mechanisms which cause flow-induced plate vibration and noise generation; the relationship between the friction coefficient and the flow-induced oscillations; the influence of perforated hole arrangements, in-line and staggered patterns; and the effects of physical parameters, such as the surface and frontal porosities and the flow length to hydraulic diameter ratio, on the flow-induced oscillations.

Table 2.4 NSF SPONSORED MACHINERY NOISE RD&D

| Project Title | Recipient Institution | FY Funding ($K)[1] 73 | 74 |
|---|---|---|---|
| Flow-Induced Vibration and Noise in Heat Exchangers | University of Michigan | | 65.4[2] |
| Cavitation Damage Scale Effects for Sudden Enlargements in Pipelines | Colorado State University | 74.5[2] | - |
| Research Initiation - Impact Mechanics and the Generation of Impulsive Sound | Pennsylvania State University | 17[3] | - |
| Basic and Applied Studies of Noise | Stanford University | 87[3,5] | - |
| Attenuation of High-Intensity Sound in a Condensing Vapor | Syracuse University | 0 | 26 |
| Combustion Generated Noise[4] | Georgia Institute of Technology | - | - |
| Controlling the Noise Radiated from Diesel Engines[4] | Purdue University | - | - |
| Noise and Vibration from Transportation Vehicles and Other Machinery | Purdue University | - | 272[6] |
| Acoustic Propagation in Branched Solids | University of Texas at Austin | 49.5 | 74[2] |
| Sound Transmission in Buildings | Massachusetts Institute of Technology | 15 | |
| Research on Noise Propagation | Massachusetts Institute of Technology | - | 152[2] |
| Acoustically Absorbent Materials[4] | Pennsylvania State University | - | - |
| Optimum Design of Partitions for Minimum Sound Transmission[4] | Carnegie Mellon University | - | - |
| Prediction of Noise Levels in Manufacturing Areas | Virginia Polytechnical Institute | 0 | 39[2] |
| TOTALS | | 243.0 | 356.4 |

[1] NSF Funding cannot be predicted for FY 75
[2] Funding for 24 month period
[3] Funding for 18 month period
[4] Funding in FY 72 for 24 month period
[5] Includes some minor Surface Vehicle related work
[6] Majority of work is Surface Vehicles and funding is not included in the totals.

With these theoretical and experimental results, some guidelines will be recommended for practical design considerations to reduce both plate vibrations and noise. Important new applications will then become feasible for automotive and marine power propulsion systems, commercial and domestic air conditioning and heating systems and the dry cooling tower for electric power plants.

Cavitation Damage Scale Effects for Sudden Enlargements in Pipelines - The purpose of this research project is to determine the incipient cavitation damage index for sudden enlargements of various dimensions and the evaluation of the scale effects from the data taken. Furthermore, studies will be carried out on the vibration and noise levels for cavitation index values between the incipient and incipient damage conditions.

Research Initiation - Impact Mechanics and the Generation of Impulsive Noise - The phenomenon of high speed impact between solid bodies in a fluid medium will be examined in reference to numerous industrial machining processes which produce dangerously high levels of repetitive, impulsive noise. The investigation is three-pronged: 1) Noise tape samples obtained from numerous industrial concerns using forging, blanking, and impact extrusion processes will be examined with respect to spectral content, intensity levels, rise times, and pressure durations to classify and describe impulsive sound characteristics. 2) An impact simulation mechanism will be designed and built to evaluate the degree to which geometric and material modifications of existing impulsive-type machinery could reduce noise levels. 3) An analytical treatment will model and predict characteristics of the impact phenomenon.

Basic and Applied Studies of Noise - Specific work supported under this grant will be basic research on the mechanics of tire noise, sound generation and propagation in internal flows, and practical applications of pitch sequencing.

The sound transmission characteristics of high-speed internal flows (piping, orifices, etc.) and the sound generation characteristics of blockage elements (orifices, diffusers, etc.) will be studies using techniques extended from work on turbulent shear flows in similar devices. The initial work will consist mainly of rig design, construction, and technique development.

A study of applications of the pitch sequencing concept (piecewise frequency modulation as used in tire tread designs) will be made in a variety of systems (sawblades, blowers, etc.).

Attenuation of High-Intensity Sound in Condensing Vapor - Recent experimental evidence suggests that aerodynamic noise in ducts and nozzles is significantly reduced in the presence of small water droplets. It is difficult to account for the observed reduction on the basis of existing theories of sound attenuation in condensing vapors. The proposed research suggests an additional mechanism for attenuation of high-intensity sound in a condensing vapor. This mechanism is enhanced heat and mass transfer between the vapor liquid phases due to acoustic streaming about the droplets at high levels. Other possible phenomena that may account for large sound reduction in duct and nozzle flows containing a condensing vapor will also be considered. It is hoped to provide both an explanation for high sound attenuation in condensing vapors and a means to predict the attenuation. Such a goal, if realized, will have important implications for the evaluation of methods to reduce internal noise in ducts, pipelines, and turbomachinery.

Combustion Generated Noise - A combined experimental-theoretical program will be undertaken to isolate the origin of combustion generated noise and to discover appropriate scaling rules associated with this noise. Primary attention will be on premixed turbulent flames, although several aspects of diffusion flame noise will also be investigated.

The data obtained on free flames will be analyzed and compared with theory. Correlations will be obtained for sound power output, directionality, and spectral content. The relation between the reaction rate fluctuations and the sound power output will be determined. An analysis will be made for the radiation of noise from a flame-containing enclosure to the surroundings. The modification to sound power output, spectral content and directionality will be compared with free flame generated noise.

Controlling the Noise Radiated from Diesel Engines - There are two main sources of noise in diesel engines: combustion noise due to burning of fuel and mechanical noise due to operation of the engine. Aspects of both sources of noise will be examined. The combustion noise will be studied by a simulation method. Here a pressure pulse will be supplied to one cylinder from a pressure source. Both cylinder pressure-time history and the pressure-time history external to the engine will be measured. From these measurements the noise attenuation of the engine will be determined at different frequencies using Fourier analysis. It is also hoped that this attenuation will be checked with the engine running and driving a dynamometer. In the combustion noise simulation study, the effects that structural changes in the engine have on noise attenuation can be examined without masking from mechanical noise. The mechanical noise will be measured by driving the engine with an electric motor. Using this method, certain aspects of the mechanical noise can be examined without masking from combustion noise.

Noise and Vibration from Transportation Vehicles and Other Machinery - To complement the ongoing research at the Ray W. Herrick Laboratories of Purdue University, a broad range of research projects in noise control and acoustics will be undertaken. These include: enclosure design, automobile engine noise source identification and reduction; noise attenuation measurements in mufflers; tire noise generation; appliance noise reduction; machine tool noise reduction; barrier design; community noise from rapid transit vehicles; and other projects. A new addition, a semi-anechoic facility with overall dimensions 9.75 X 20.12 meters, (32 X 66 feet), will be built to accomodate many of the new projects.

Acoustics Propagation in Branched Solids - Experimental and analytical research will be performed on the propagation of sound through branched and interconnected solids. The experimental research will be performed by propagating pulses of acoustical energy at several frequencies along solid waveguides onto which branches will be attached at various angles by various means. The solid waveguides will be made long enough to be investigated and measured without the interference from reflections. As the work progresses, materials with several values of dilatational and shear sound velocities and densities will be used as branches, and several shapes, machined or formed of such materials, will be inserted as diffraction elements in the main waveguides and in the branches. As part of the work, effort will be applied to measuring acoustic beam patterns in solids in order to better define the relationship between the distribution of acoustical energy within a driven solid and the mechanical properties, shape, and size of both the driving and driven solids and the orientation of the former to the latter. Also, the experimental work will include an investigation of various acoustical resistance devices to discover which are most suitable for use as impedance matching terminations for acoustical waveguides. The analytical research will be performed using the results of the experimental work and will extend the theory of acoustic propagation in solids.

Sound Transmission in Buildings - This research is relatively broad -- it is expected to cover the more "conventional" aspects of sound transmission through walls, ceilings, floors, etc., and also sound propagation through corridors, doorways, and "open plan" landscaped areas which are more frequently being used in office buildings.

Research into noise transmission between rooms in buildings has concentrated largely on the acoustic transmission properties of walls and wall building materials. However, with the advent of open plan designs in both living and office spaces the problem of acoustical rather than structural transmission becomes important. Even in the traditional design of building interiors noise transmission from room to room through openings can be an important consideration. Recently there has been an impetus for a better theoretical understanding of transmission loss through walls. This is because of the advent of lightweight construction and emphasis on better acoustical design.

One of the major purposes of this research is to apply newly developed procedures from aerospace studies to the problems of obtaining better acoustical performance of wall structures.

A multiple purpose, semi-anechoic room will be constructed and used for the following experiments: 1) Open plan office psychoacoustical and acoustical measurements. 2) Measurements of acoustical absorption coefficient by reflection-correlation method. 3) Measurements of footfall noise on carpet-like materials.

Research on Noise Propagation - The distribution of sound within buildings and the exterior acoustical environment of buildings will be determined. In the former category, it is proposed to study sound transmission through composite structures which are of interest in newer forms of modular housing and are also used as enclosures for machines and other noise sources in industrial plants. In the latter category, it is proposed to study sound transmission in corridor-like channels which relate to the corridors in buildings and to sound transmission in city streets. An important parameter of corridor propagation is the sound absorption and scattering of the bounding surfaces at particular angles of incidence. A correlation technique for measuring these reflection coefficients will be developed. Finally, research will be performed on a "cellular" model of propagation in complex spaces that applies to sound distributions in open plan offices, certain kinds of industrial plants, and to urban noise systems.

Acoustically Absorbent Materials - The goal of this proposed study is to obtain a deeper understanding of the behavior of sound absorbing materials through a theoretical and experimental program so that optimum use can be made of these materials as duct liners to control noise from larger air moving systems. To meet this goal, a study will be undertaken of the behavior of acoustically absorbent material when subjected to high intensity noise and as a function of flow over the surface. The effectiveness of the material as a function of the angle of incidence at which the sound strikes the material will also be determined. Another important aspect of the proposed work is the determination of the behavior of high intensity complex acoustic modes in ducts in the presence of the cited conditions.

The results of this program will provide new knowledge to design acoustically absorbent materials in optimum geometric configurations for duct liners, and signficantly better acoustic and aerodynamic performance.

Optimum Design of Partitions for Minimum Sound Transmission - The aim of this program is to integrate recent advances in optimal structural design with modern approaches to theoretical architectural acoustics. The specific objective is to develop approaches to optimal design of partitions to minimize the transmission of sound. The acoustical theory techniques considered will include variational methods as well as computer oriented techniques.

Prediction of Noise Levels in Manufacturing Areas - A computer-based acoustical model of typical industrial manufacturing facilities will be developed to enable the prediction of noise levels at specified points in manufacturing areas. The program will be written such that only a limited acoustics background will be required of a user. Basic information on physical plant arrangements and equipment installations are envisioned as input data. The computer will carry out the acoustic computations and give predicted noise levels using superposition, room acoustics, and geometric acoustics concepts. Results will be conveyed to the user in a number of different ways, depending upon the need, computer, or computer terminal capability. The reliability of the program to model industrial noise environments will be field-tested in the plants of a number of firms which have agreed to cooperate in this research effort.

## 2.4 DEPARTMENT OF THE INTERIOR/BUREAU OF MINES

The Bureau of Mines conducts machinery noise RD&D to support its mission of providing a healthful mine environment. It supports research on several pieces of mine machinery and is attempting to characterize the noise in mines from other machines. Table 2.5 gives titles and funding of these projects.

Alternate Conveyor Designs for Mine Machinery - The purpose of this project is to design and develop a new conveyor system which can be adapted to existing machinery to reduce the noise from the conveyor to 90 dBA. A prototype of a quieter conveyor for a specific machine used in underground coal mining will be developed.

Noise Control in Surface Mining Facilities -- Problem Definition - This project is intended to develop economical noise control of chutes, demonstrate utility, survivability, and repairability of such measures in the field and to develop screens that are quieter and no harder to maintain than existing systems. Development of the successful methods would quiet two of the principal sources of noise in surface facilities associated with coal mines.

Abatement of Noise from Pneumatic Rock Drills - This study will examine the use of ferrous and nonferrous damping alloys for reduction of noise by methods suitable for application in the mining environment and will advance toward the goal of a pneumatic percussive drill with a

Table 2.5 BUREAU OF MINES MACHINERY NOISE RD&D

| Project Title | Project Number | Investigator (s) | FY Funding ($K) 73 | 74 | 75 |
|---|---|---|---|---|---|
| Alternate Conveyor Designs for Mine Machinery | H0144078 | Foster-Miller Assoc., Inc. | 0 | 148.8 | - |
| Noise Control in Surface Mining Facilities--Problem Definition | H0133027 | Bolt, Beranek,& Newman, Inc. | 79.4 | 16.7 | 0 |
| Noise Control in Surface Mining Facilities--Chutes and Screens | H0144079 | Bolt, Beranek,& Newman, Inc. | 0 | 112.4 | 0 |
| Abatement of Noise from Pneumatic Rock Drills | 07009 | In-house | 90.1 | 0 | 0 |
| Muffler for Pneumatic Drill: 1. Analysis & Design 2. Analysis of Mechanical Noise 3. Abatement of Mechanical Noise 4. Larger Class Drill | H022048 | United States Steel Corp. | 56.6 | 15.1 | 0 |
| Problem of Coal Mine Noise Generation and Correction | 03009 | In-house | 100.2 | 137.3 | 100 |
| Noise Abatement in Mining Machinery | H0122054 | Apt, Bramer, Conrad,&Assoc.Inc. | 10.4 | 39.5 | 0 |
| Noise Control of Underground Diesel-Powered Equipment--Problem Definition | H0346046 | Bolt, Beranek,& Newman, Inc. | 0 | 58.7 | 0 |
| TOTALS | | | 336.7 | 528.5 | 730 * |

* Projected.

noise level no greater than 90 dBA. The principal accomplishments to date have been a prototype drill with muffler-jacket, alloy rotational chuck and constricted layer on 25 percent of the drill rod. The prototype had a noise level of 104 dBA with a reduction of about 9 percent in efficiency.

Muffler for Pneumatic Drill: 1. Analysis and Design. 2. Analysis of Mechanical Noise. 3. Abatement of Mechanical Noise. 4. Larger Class Drill - This project is intended to design and deliver a prototype muffler to attenuate the air-exhaust noise of a 34-kg.-class (75-pound-class) pneumatic stoper drill to 90 dBA with insignificant back pressure and no icing problems; develop a kinematic model simulating the moving parts of a pneumatic drill; use this model to optimize noise abatement designs of a drill and drill rod; and design and construct prototype mufflers for a large drill (7.1 cmm) (250 cfm) class. To date, the project has resulted in four prototype mufflers which were designed and fabricated for a pneumatic percussive drill of the 34-kg. (75-pound) class and reduced the exhaust noise below 90 dBA with no icing or back pressure problems.

Problems of Coal Mine Noise Generation and Correction - This project will attempt to define the noise problems in various types of mining operations; to develop and evaluate monitoring instrumentation and personal ear protective devices; and to reduce the noise levels of pneumatic drills. So far, this project has produced: a personal, pocket-size audiodosimeter that records the miner's exposure to intermittent noise levels encountered and an earmuff incorporating a special intercom system that allows the wearer to perceive low-level sounds (up to 83 dBA) at full volume but progressively attenuates louder noises to below 90 dBA. It also has demonstrated feasibility of fabricating a noise control system durable enough for the mine environment and capable of reducing the noise level of a pneumatic percussive drill from 115 to 101 dBA at the operator's position.

Noise Abatement in Mining Machinery - This project will define the noise sources from bolters, loaders, and continuous miners and will assess in-mine corrective measures to reduce operating exposure to noise levels of 90 dBA. The proposed measures will be then be experimentally evaluated for effectiveness on a loader, continuous miner, and a rotary roof bolter. The output of the project will be a report describing in detail the three machines selected, the noise sources, the corrective measures applied, and the results from testing the modified machines in a mine for one month.

Noise Control of Underground Diesel-Powered Equipment -- Problem Definition - The project's objectives are to define the magnitude of the noise problem from diesel-powered mining equipment and to evaluate available noise control techniques for effectiveness in reducing noise levels to 90dBA. Hopefully, the project will validate a method to predict anticipated underground noise levels from sound power data obtained on the ground surface. This project is a first step toward reducing noise from diesel-powered mining equipment.

## 2.5 NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY AND HEALTH

The NIOSH effort in machinery noise control RD&D is intended to foster the development of improved control technology for reducing major sources of industrial noise and to formulate and promote procedures for minimizing noise problems in the work environment. This objective is in accordance with the Occupational Safety and Health Act of 1970 (Public Law 91-596) and the Federal Coal Mine Safety and Health Act of 1969 (Public Law 91-173) which charge NIOSH with undertaking research and related activities basic to assuring safe and healthful workplace conditions. In addition to assembling and preparing information on noise control techniques and materials in manuals and easy-to-use guides for coping with occupational noise problems, NIOSH also supports several grants dealing with the development and demonstration of engineering control measures for reducing major sources of machinery noise in the textiles, wood-products and metal fabricating industries. The NIOSH projects are summarized in Table 2.6.

Noise Control Research in Wood Planers - These experimental studies are aimed at reducing noise from woodworking machinery, particularly wood planers.

Coordinated Textile Industry Noise Reduction Program - This project will collect and develop information on noise control methods in the textile industry. Noise levels associated with typical operations will be identified.

Punch Press Noise Reduction - Consideration will be given to all standard noise control techniques, including reduction of noise from vibrating machine parts, gears, clutch and brake operations, air valve exhausts, and punching operations. Force reduction through tool design, use of damping material mufflers, isolation, enclosures, barriers, and absorption as well as innovative concepts will be evaluated. The results will be prepared for utilization by smaller companies which do not have extensive engineering capability.

Industrial Noise Control Manual - This activity will develop a guidebook for reducing occupational noise exposure, using case-history examples of industrial noise control efforts.

Table 2.6 SUMMARY OF NIOSH SUPPORTED MACHINERY NOISE RD&D

| Project Title | Investigator (s) | Funding ($K) FY 73 | FY 74 | FY 75 |
|---|---|---|---|---|
| Punch Press Noise Reduction | N.C. State University | 0 | 53.8 | |
| Noise Control Research in Wood Planers | N.C. State University | 0 | 51.8 | 38.8 |
| Coordinated Textile Industry Noise Reduction Program | N.C. State University | 0 | 120 | 99.5 |
| Industrial Noise Control Manual | Industrial Noise Services Inc. | 16 | 0 | 0 |
| Compendium of Noise Control Materials * | IIT Research Institute | | | |
| Impulse Noise Recording Systems ** | In-house | | | |
| TOTALS | | 16 | 225.6 | 138.3 |

* Funding in FY 72

** Nominal in-house funding

Compendium of Noise Control Materials - This activity will result in a cross-referenced publication of published noise attenuation data for all known building and noise control materials.

Impulse Noise Recording System - Instrumentation was developed to facilitate recording of impulse waveforms in industrial environments, using digital recording techniques.

## 2.6 ENVIRONMENTAL PROTECTION AGENCY

EPA has sponsored several studies to support regulatory needs in machinery noise. The studies have been for defining measurement methodologies, available technology, and cost for compliance specifically for various pieces of construction equipment. Similar studies on pneumatic and hydraulic drills and pavement breakers are expected to begin in FY 75. Table 2.7 lists the studies and funding levels.

Table 2.7 EPA MACHINERY NOISE RD&D

| Project Description | Investigator | Funding ($K) FY 73 | FY 74 | FY 75 |
|---|---|---|---|---|
| Portable Air Compressor Noise Technology and Cost | Bolt, Beranek & Newman Inc. | 0 | 91 | 0 |
| Construction Noise Study | Bolt, Beranek, & Newman Inc. | 0 | 25 | 0 |
| Economic Impact of Portable Air Compressor Noise Emission Standards | A. T. Kearney Inc. | 0 | 50 | 0 |
| Development of Noise Measurement Methodology for Portable Air Compressors | N.B.S. | 60 | 64 | 0 |
| Pneumatic and Hydraulic Drills and Pavement Breakers - Technology, Costs, and Economic Impact | | 0 | 0 | 100 |
| TOTALS | | 60 | 230 | 100 |

Portable Air Compressor Noise Technology and Costs - This study examined the technology currently available for portable air compressors and the attendant costs to achieve various study levels.

Construction Noise Study - This study examined a series of regulatory approaches aimed at quieting construction sites to various study levels. The study considered resource costs to the nation as well as the anticipated effectiveness of the approach.

Development of Noise Measurement Methodology for Portable Air Compressors- This study examined the correlation between far field sound measurements and those taken in the near field. It also provides a recommended sound power measurement procedure for determining the near field noise levels of portable air compressors.

Pneumatic and Hydraulic Drills and Pavement Breakers-Technology, Costs, and Economic Impact - This study will examine the technology available, attendant costs for reducing the noise output to various noise levels and the corresponding economic impact of regulating these products to those levels.

## 2.7 CONSUMER PRODUCT SAFETY COMMISSION

CPSC has the primary responsibility for establishing mandatory product safety standards, where appropriate, to reduce the unreasonable risk of injury to consumers from consumer products. The CPSC in FY 74 supported research to develop a consistent set of product noise regulations, a test protocol for lawn mowers, and test methods for toys. A summary of the project funding is shown in Table 2.8.

Table 2.8 CPSC MACHINERY NOISE RD&D

| Project Title | FY 74 Funding ($K) * |
|---|---|
| Developing a Consistent Set of Product Noise Regulations | 20 |
| Test Protocol for Lawnmower Noise | 15 |
| Noise Measurement Techniques for Toys | 35 |
| TOTAL | 70 |

* Projects supported only in FY 74.

Developing a Consistent Set of Product Noise Regulations - This project will assess current knowledge and recommend additional research to determine patterns of noise exposure due to usage of select products, define practical sound level measurement procedures, define hearing loss from product use, and define potential for product noise to mask auditory warnings.

Test Protocol for Lawnmower Noise - The hazard caused by noise from lawnmowers will be investigated. A maximum sound level will be suggested with methods for measurement at the operator's ear position.

Noise Measurement Techniques for Toys - This project will identify noise-producing toys which are potentially hazardous to children's hearing and/or safety, develop generic test methods by which the noise exposure due to such toys can be determined and acquire data on selected toys. Simple screening procedures will be developed for rapid determination as to whether toys require detailed laboratory testing.

## 2.8 DEPARTMENT OF AGRICULTURE

USDA is funding a research project on agricultural processes noise. It began in FY 74 and is currently in a problem definition phase. The work is being conducted at Richard B. Russell Agricultural Research Center, ARS, USDA, P.O. Box 5677, Athens, Georgia 30604. The funding is $20,000 in FY 74 and $92,470 in FY 75.

Abatement and Control of Noise Associated with Agricultural Processes- The objectives are to determine the degree of noise pollution occurring in various types of agricultural processing plants under normal operating conditions, determine primary vibration sources contributing to high power level noise within processing plants, and develop and implement methods and equipment to abate and control noise levels.

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## 3.0 ANALYSIS OF FEDERAL MACHINERY NOISE RD&D

The current Federal research, development and demonstration activities address a number of specific sources of machinery noise, undertake work in building and structural transmission of noise, and work towards better definition of the machinery noise problem through measurements and development of more accurate and standardized measurement methodology. The general funding in these areas is presented in Table 3.1. It can be noted that the majority of funds are spent on control technology. This observation is further supported by the Navy's million dollar a year program, most of which goes for source control technology. In contrast, the funds in the building and structural category are small. It also appears that the funds for machinery noise RD&D peaked in FY 1974. This apparent peaking may not be actual, however, due to the uncertainty of the FY 1975 data.

Agencies' current involvements in the three categories of machinery noise RD&D activities are shown in Table 3.2. USDA and CPSC currently are involved only in measurement or measurement methodology. NSF, DOD and NIOSH are supporting research in all three areas, while BuMines, NBS, and EPA are involved in two categories. The following discussions summarize the current effort of the Federal Government in addressing these categories of machinery noise.

### 3.1 SOURCE NOISE CONTROL TECHNOLOGY

Five agencies have RD&D activities addressing noise control technology for machines. Table 3.3 summarizes the specific sources addressed by each agency and the funding data (if available). NIOSH is currently funding noise control work on machines that have a significant impact on the occupational environment. The machines presently studied are punch presses, wood planers, and various textile industry machines. NIOSH has also funded the development of an industrial noise control manual. Bureau of Mines supports work on various machines that affect the mine work place. Sources addressed include conveyors, chutes and screens used in coal cleaning, pneumatic drills, diesel powered equipment, continuous miners, loading machines, and roof bolters. The Navy supports work on shipboard machinery because of the need for quiet ships. Although specific activities cannot be reported for security reasons, in general the sources addressed are diesel engines, hydraulic systems, pneumatic machinery, rotating electrical machinery, electronic equipment, gas turbines, compressors, fans, gear valves, and pumps.

Table 3.1 SUMMARY BY AREA OF MACHINERY NOISE RD&D

| RD&D Area | Funding (thousand dollars) FY 73 | FY 74 | FY 75 |
|---|---|---|---|
| Source Noise Control Technology | 529 | 1,307 | 1,168 |
| Building and Structural Noise Transmission and Control | 162 | 370 | 145 |
| Measurements and Measurement Methodologies | 280 | 507 | 257 |
| TOTALS | 971 | 2,184 | 1,570 |

Table 3.2 CURRENT AGENCY INVOLVEMENT IN AREAS OF MACHINERY NOISE RD&D

| Research Area | BUMines | NIOSH | NSF | DOD | NBS | EPA | CPSC | USDA |
|---|---|---|---|---|---|---|---|---|
| Source Noise Control Technology | X | X | X | X | | X | | |
| Building and Structural Noise Transmission and Control | | X | X | X | X | | | |
| Measurements and Measurement Methodologies | X | X | X | X | X | X | X | X |

Table 3.3 SOURCE NOISE CONTROL TECHNOLOGY

| Agency | Source | Funding (thousand dollars) FY 73 | FY 74 | FY 75 |
|---|---|---|---|---|
| NIOSH | Punch Press | 0 | 54 | |
| | Wood Planers | 0 | 52 | 38 |
| | Textile Industry General | 0 | 120 | 100 |
| | Industrial Noise Control Manual | 16 | 0 | 0 |
| | TOTAL | 16 | 226 | 138 |
| BuMines | Mining Machinery Conveyors | 0 | 148.8 | 0 |
| | Surface Facilities Chutes and Screens | 0 | 112.4 | 0 |
| | Pneumatic Drills | 146.7 | 15.1 | 0 |
| | Underground Diesel-Powered Equipment | 0 | 58.7 | 0 |
| | Continuous Miner, Loading Machine, Rotary Roof Bolter | 10.4 | 39.5 | 0 |
| | TOTAL | 157.1 | 374.5 | 730[1] |
| NSF | Heat Exchangers | 0 | 65[2] | - |
| | Pipelines | 74.5[2] | | |
| | Impact Noise-Industrial Machinery Processes | 17[3] | | |
| | Basic & Applied Studies of Noise (Tires, Internal Flows, Pitch Sequencing) | 87[3,5] | | |
| | Ducts and Nozzles | 0 | 26 | |
| | Combustion Noise[3] | | | |
| | Diesel Engines[4] | | | |
| | Appliances, Machine tools, Barrier design[6] | | 272[6] | |
| | TOTAL | 178.5 | 91 | -- |

Table 3.3 SOURCE NOISE CONTROL TECHNOLOGY (continued)

| | | Funding (thousand dollars) | | |
|---|---|---|---|---|
| Agency | Source | FY 73 | FY 74 | FY 75 |
| USN | Diesel Engines | | | |
| | Hydraulic Systems | | | |
| | Pneumatic Machinery | | | |
| | Rotating Electrical Machinery | | | |
| | Electronic Equipment | | | |
| | Gas Turbines | | | |
| | Compressors | | | |
| | Fans | | | |
| | Gears | | | |
| | Valves | | | |
| | Pumps | | | |
| U.S. Army | Air Conditioners | 0 | 400 | 200 [1] |
| | 17cmm (600 CFM) Air Compressor | 98 | 0 | 0 |
| | Electric Generators | 80 | 50 | -- |
| | Various other military equipment [7] | | | |
| | Hydraulic Equipment [8] | | | |
| | TOTALS | 178 | 450 | 200 |

Table 3.3 SOURCE NOISE CONTROL TECHNOLOGY (concluded)

| Agency | Source | FY 73 | FY 74 | FY 75 |
|---|---|---|---|---|
| | | Funding (thousand dollars) | | |
| EPA | Construction Noise | 0 | 25 | 0 |
| | Portable Air Compressors | 0 | 141 | 0 |
| | Pneumatic and Hydraulic Equipment | 0 | 0 | 100 |
| | TOTAL | 0 | 166 | 100 |
| | GRAND TOTALS | 529.6 | 1,307.5 | 1,168 |

[1] Projected

[2] Funding for two year period

[3] Funding for 18 month period

[4] Funding in FY 72 for 24 month period

[5] Includes some minor Surface Vehicle related work

[6] Majority of work is Surface Vehicle and funding is included in that report. (Ref. 9)

[7] Normal in-house funding, not dedicated to noise

[8] Work covered in Surface Vehicles but directly applicable to machinery noise. Covered in surface vehicle report. (Ref. 9)

The Army has several projects which address an air compressor, three portable electric generators, air conditioners, and various other pieces of military equipment (see Table 2.2). EPA in its effort to regulate major sources of noise has developed information on available technology and cost of compliance for portable air compressors. Similar efforts on pneumatic and hydraulic equipment are projected. NSF supports research in a variety of areas. Current work in machinery noise will have application to several sources: heat exchangers, pipelines, ducts and nozzles, industrial machining processes, diesel engines, combustion sources, and appliances.

## 3.2 BUILDING AND STRUCTURAL NOISE TRANSMISSION AND CONTROL

Four agencies are currently involved in different kinds of activities in this area. The various projects and funding are detailed in Table 3.4. NBS has had a program for many years in building acoustics. The thrust of the current activity is to improve both measurements and design guidelines for noise control in buildings. The Navy effort is directed toward the need for quiet ships. The Navy source noise control activity is supplemented by use of structural damping, resilient mounts, and acoustical transmission loss and absorptive materials. NSF supports several research projects in this category to extend the theory of propagation of sound. These include studies of airborne and structural noise propagation in buildings and corridors, behavior of acoustically absorbent materials, design of partitions, and transmission through branched solids. NIOSH has supported a project to compile information on the acoustic and other properties of building materials and acoustical absorption materials.

Table 3.4 BUILDING & STRUCTURAL NOISE TRANSMISSION & CONTROL

| Agency | Description | Funding (thousand dollars) FY 73 | FY 74 | FY 75 |
|---|---|---|---|---|
| DOC/NBS | Building Acoustics Program | 97 | 144 | 145 |
| USN | Radiated and Platform Noise Sound Path Isolators | | | |
| NSF | Acoustic Propagation in Branched Solids | 50 | 74 [1] | |
| | Sound Transmission in Buildings | 15 | 0 | |
| | Research on Noise Propagation | 0 | 152 [1] | 0 |
| | Acoustically Absorbent Materials [2] | | | |
| | Optimimum Design of Partitions for Minimum Sound Transmission | | | |
| NIOSH | Compendium of Noise Control Materials [3] | | | |
| | TOTALS | 162 | 370 | 145 |

[1] Funding for two year period

[2] Funding in FY 72 for two year period

[3] Funding in FY 72

### 3.3 MEASUREMENTS AND MEASUREMENT METHODOLOGIES

All eight agencies which fund machinery noise research have activities either to define the problems in machinery noise or to develop or improve measurement techniques for assessing the noise. NSF has funded the development of a computer-based acoustical model of typical industrial manufacturing facilities which will enable the prediction of noise levels at specified points in manufacturing areas by users with limited acoustics backgrounds. Bureau of Mines has efforts in characterizing noise and identifying problems in both underground and surface mining facilities. NBS is developing and improving methodologies for measuring sound power. EPA has supported efforts to develop measurement methodologies for various noise sources, specifically air compressors. Similarly, CPSC is supporting the development of consistent measurement methodologies for consumer products in general and specifically, lawnmowers and toys. USDA is beginning a noise control RD&D program which currently involves measurement and problem definition. The Navy is developing improved techniques for measuring equipment noise at operators' positions. The U. S. Army is working on measurement and control of construction site noise. NIOSH is developing a system for recording impulse noise. The Federal activities and projects in this category of machinery RD&D are listed in Table 3.5.

Table 3.5 MACHINERY NOISE MEASUREMENTS AND MEASUREMENT METHODOLOGIES

| Agency | Project Title | Funding (Thousand dollars) FY 73 | FY 74 | FY 75 |
|---|---|---|---|---|
| NSF | Prediction of Noise Levels in Manufacturing Areas | 0 | 39 | 0 |
| BUMines | Definition and Correction of Noise in Coal Mines | 100 | 137 | 0 |
| | Noise Control in Surface Mining Facilities-Problem Definition | 79 | 17 | 0 |
| EPA | Development of Noise Measurement Methodologies for Portable Air Compressors | 60 | 64 | 0 |
| NBS | Assessment of Measurement Standards for Determination of Sound Power | 41 | 120 | 120 |
| CPSC | Developing a Consistent Set of Product Noise Regulations | 0 | 20 | 0 |
| | Noise Measurement Techniques for Toys | 0 | 35 | 0 |
| | Test Protocol for Lawnmower Noise | 0 | 15 | 0 |
| USDA | Abatement and Control of Noise Associated with Agricultural Processes | 0 | 20 | 92 |
| NIOSH | Impulse Noise Recording System * | | | |
| USN | Noise Criteria | | | |

Table 3.5 MACHINERY NOISE MEASUREMENTS AND MEASUREMENT METHODOLOGIES (continued)

| Agency | Project Title | Funding (thousands dollars) FY 73 | FY 74 | FY 75 |
|---|---|---|---|---|
| USA | Construction Equipment: Specification and Control | | 40 | 45 |
| | TOTALS | 280 | 507 | 257 |

* Nominal In-House Funding

## 4.0 SUMMARY AND CONCLUSIONS

There are literally countless sources of machinery noise. Machinery noise occurs in the home, hospitals, offices, and the community. Generally, however, exposure to machinery noise in the occupational environment is the most severe. Machinery noise, along with noise from other sources, may produce hearing loss, cause annoyance, affect job performance, and interfere with warning signals. Other deleterious effects may also occur, but hearing loss is generally considered the most severe. Estimates for reducing industrial noise to levels of marginal protection against hearing loss run into billions of dollars. (Ref. 5)

To get a preliminary indication of the private sector efforts in industrial machinery noise RD&D, a number of trade associations were contacted and a literature search was conducted. Conclusions were that trade associations were not a good source of machinery noise reduction technology, and that most industries have little or no on-going machinery noise control RD&D whose results will be generally available to the public.

The Federal effort on machinery noise RD&D is being conducted by eight agencies: DOD, DOC/NBS, NSF, DOI/BuMines, NIOSH, EPA, CPSC, and USDA. The Federal effort has ranged from two to three million dollars over the FY 1973 to 1975 time period and appeared to peak in FY 1974. About a million of this was allocated by the Navy to quiet ships. Much of that work is classified and is not currently available to the public.

Noise control for sources is being addressed in the mine environment, the industrial environment, the military environment and others. Some research also is directed toward building and structural noise transmission and control, and other work is going on to characterize noise environments and sources.

Although an in-depth analysis has not been done, a significant part of these Federal expenditures is directed toward establishing applications of currently available technology for future use. While the Federal Government has machinery noise RD&D activities there is not a national policy toward Federal involvement in machinery noise RD&D. Consequently, each agency conducts research to support its own mission.

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# 6.0 APPENDICES

CONTENTS: PAGE NO.

## APPENDIX A

## GLOSSARY OF AGENCY ACRONYMS

| Symbols | Agencies |
|---|---|
| CPSC | Consumer Product Safety Commission |
| DOC | Department of Commerce |
| DOC (NBS) | National Bureau of Standards |
| DOD | Department of Defense |
| DOD/USN | Department of the Navy |
| DOD/USA | Department of the Army |
| DOI | Department of the Interior |
| DOI/BUMines | Bureau of Mines |
| DOL | Department of Labor |
| DOT | Department of Transportation |
| EPA | Environmental Protection Agency |
| HEW | Department of Health, Education and Welfare |
| HEW (NIEHS) | National Institute of Environmental Health Sciences |
| HEW (NINDS) | National Institute of Neurological Diseases and Stroke |
| HEW (NIOSH) | National Institute for Occupational Safety and Health |
| HUD | Department of Housing and Urban Development |
| NASA | National Aeronautics and Space Administration |
| NSF | National Science Foundation |
| USDA | Department of Agriculture |

APPENDIX B

FEDERAL MACHINERY NOISE RESEARCH PANEL

| | |
|---|---|
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## APPENDIX C
## NOISE ABATEMENT RESEARCH BY TRADE ASSOCIATIONS

Trade associations were contacted to:

- Indicate the level of active interest by trade associations in noise abatement research.
- Indicate the type of noise abatement research being conducted by trade associations.
- Ascertain the availability of the results of the research.

Accordingly, a list of 58 trade associations, distributed over 20 industries, was compiled from Reference 2. "Small" associations, with annual budgets of less than $250,000, were not included. Telephone contacts were made to identify the availability of published results of noise research. These results are compiled in Table C-1. Some of the comments are summarized below.

- Thirty-six of the associations have not done and do not plan to do noise research.
- The research activities of 16 of the remaining 22 associations have been principally noise surveys of machinery.
- Only six of the remaining 22 associations indicated activities in noise reduction. Research included
  - Burner noise reduction by American Gas Association
  - Quiet room application by American Newspaper Publishers Association
  - Appliance quieting by Association of Home Appliance Manufacturers
  - Forging noise reduction by Forging Industry Assn.
  - Vehicle noise reduction by Motor Vehicle Mfr. Assn.
  - Machinery noise reduction by Western Wood Products Assn.
- Four of the six associations indicated that noise research results are considered proprietary and expressed concern about releasing the information to a Government agency.
- The American Trucking Association data is primarily a survey of truck noise levels. Similar, but more extensive, information is available from the Motor Vehicle Manufacturers Association.

Table C-1 SUMMARY OF INDUSTRY/ASSOCATIONS/NOISE RESEARCH ACTIVITY SURVEY

| SIC Code | Industry/Associations | Research Activity | Publications Available |
|---|---|---|---|
| 16 | CONSTRUCTION | | |
| | • Associated Equipment Distributors<br>615 West 22nd Street<br>Oak Brook, Illinois 60521<br>(312)654-0650 | None | None |
| | • Associated General Contractors of America<br>1957 East Street, N. W.<br>Washington, D. C. 20006<br>(202)393-2040 | Research Conducted through State Chapters | None |
| | • Construction Specifications Inst.<br>1717 Massachusetts Avenue, N.W.<br>Washington, D. C. 20036<br>(202)833-2160 | None | None |
| | • Construction Industry Manufacturers Associations<br>Suite 1700, Marine Plaza<br>111 East Wisconsin Avenue<br>Milwaukee, Wisconsin 53202<br>(414)272-0943 | Conducted a Joint Program with Farm and Industrial Equipment Institute | TR-SAE-R4 A Study of Noise Induced Hearing Damage for Operators of Farm and Construction Equipment, 1969. |

Table C-1 SUMMARY OF INDUSTRY/ASSOCIATION/NOISE RESEARCH ACTIVITY SURVEY (continued)

| SIC Code | Industry/Associations | Research Activity | Publications Available |
|---|---|---|---|
| 20 | FOOD AND KINDRED PRODUCTS | | |
| | • Can Manufacturers Institute<br>1625 Massachusetts, N. W.<br>Washington, D. C. 20036<br>(202)232-4677 | Plan to start project on in-plant noise reduction in the near future. | None |
| | • National Canners Association<br>1133 20th Street, N. W.<br>Washington, D. C. 20036<br>(202)311-5900 | None | None |
| | • Packaging Machinery Manufacturers Association<br>2000 K Street, N. W.<br>Washington, D. C. 20006<br>(202)331-8181 | None | None |
| 21 | TOBACCO MANUFACTURERS | | |
| | • Tobacco Institute, Inc.<br>1776 K Street, N. W.<br>Washington, D. C. 20006<br>(202)296-8434 | None | None |
| 22 | TEXTILE MILL PRODUCTS | | |
| | • American Textile Manufacturers Institute, Inc.<br>1501 Johnston Building<br>Charlotte, N. C. 28281<br>(704)334-473 | Survey of Equipment Noise Levels | None, data will be used for OSHA Hearings |

Table C-1 SUMMARY OF INDUSTRY/ASSOCIATION/NOISE RESEARCH ACTIVITY SURVEY (continued)

| SIC Code | Industry/Associations | Research Activity | Publication Available |
|---|---|---|---|
| 22 (continued) | | | |
| | • Carpet and Rug Institute<br>310 Holiday Drive, Box 2048<br>Dalton, Georgia 30720<br>(404)278-3176 | Survey of Equipment Noise | Report Available |
| 23 | APPAREL AND RELATED PRODUCTS | | |
| | • American Apparel Manufacturers Association<br>1611 North Kent Street<br>Arlington, Virginia 22209<br>(703)524-1864 | None | None |
| | • American Footwear Industries Assc.<br>1611 North Kent Street<br>Arlington, Virgina 22209<br>(703)522-8070 | None | None |
| 24 | LUMBER AND WOOD PRODUCTS | | |
| | • American Forest Institute<br>1619 Massachusetts Avenue<br>Washington, D. C. 20036<br>(202)667-7807 | None | None |
| | • American Plywood Association<br>119 A Street<br>Tacoma, Washington 98401<br>(206)272-2233 | None | None |

TABLE C-1 SUMMARY OF INDUSTRY/ASSOCIATIONS/NOISE RESEARCH ACTIVITY SURVEY (continued)

| SIC Code | Industry/Associations | Research Activity | Publications Available |
|---|---|---|---|
| 24 (continued) | | | |
| | • National Forest Products Assoc.<br>1619 Massachusetts Avenue, N.W.<br>Washington, D. C. 20036<br>(202)332-1050 | None | None |
| | • Western Wood Products Assoc.<br>1500 Yeon Building<br>Portland, Oregon 97204<br>(503)224-3930 | Program on Machinery Noise | None, Reports not yet Published (1976) |
| | • National Hardware Lumber Assoc.<br>59 East Van Buren<br>Chicago, Illinois 60605<br>(312)427-2811 | None | None |
| 25 | FURNITURE AND FIXTURES | | |
| | • National Housewares Manufacturers Association<br>1130 Merchandise Mart<br>Chicago, Illinois 60654<br>(312)644-3333 | None | None |
| 26 | PAPER AND ALLIED PRODUCTS | | |
| | • American Paper Institute<br>260 Madison Avenue<br>New York, New York 10016<br>(212)883-8000 | None | None |

Table C-1 SUMMARY OF INDUSTRY/ASSOCIATIONS/NOISE RESEARCH ACTIVITY SURVEY (continued)

| SIC Code | Industry/Associations | Research Activity | Publications Available |
|---|---|---|---|
| 26 (continued) | | | |
| | • Fiber Box Association<br>224 No. Michigan Avenue<br>Chicago, Illinois 60604<br>(312)663-0250 | Conducted Noise Survey | None |
| 27 | PRINTING, PUBLISHINC AND ALLIED PRODUCTS | | |
| | • American Newspapers Publishers Association<br>Post Office Box 598<br>Easton, Pennsylvania 18042<br>(215)253-6155 | Survey of Machine Noise and Potential Treatment | No, information is considered proprietory |
| | • Printing Industries of America, Inc.<br>1730 North Lynn Street<br>Arlington, Virginia 22209<br>(703)527-6000 | None | None |
| 28 | CHEMICAL AND ALLIED PRODUCTS | | |
| | • Chemical Specialties Manufacturers Association, Inc.<br>1001 Connecticut Avenue, N. W.<br>Washington, D.C. 20036<br>(202)872-8100 | None | None |
| | • Oil, Chemical and Atomic Workers Union International<br>1636 Champa Street<br>Denver, Colorado 80201<br>(303)266-0811 | Survey of Machinery Noise and Hearing Damage | No, considered proprietary |

Table C-1 SUMMARY OF INDUSTRY/ASSOCIATIONS/NOISE RESEARCH ACTIVITY SURVEY (continued)

| SIC Code | Industry/Associations | Research Activity | Publication Available |
|---|---|---|---|
| 29 | PETROLEUM AND COAL PRODUCTS | | |
| | • American Gas Association<br>1515 Wilson Boulevard<br>Arlington, Virginia 22209<br>(703)524-2000 | Program to Reduce Burner Noise | No, program Just Started |
| | • American Petroleum Institute<br>1801 K Street, N. W.<br>Washington, D. C. 20006<br>(202)833-5600 | None | None |
| | • Bituminous Coal Research, Inc.<br>350 Hochberg Road<br>Monroeville, Pennsylvania 15146<br>(412)327-1600 | None | None |
| 30 | RUBBER AND MISCELLANEOUS PLASTIC PRODUCTS | | |
| | • Rubber Manufacturers Association<br>1901 Pennsylvania Avenue<br>Washington, D. C. 20006<br>(202)785-2602 | None | None |
| 31 | LEATHER AND LEATHER GOODS | | |
| | • No Associations Identified | | |

Table C-1 SUMMARY OF INDUSTRY/ASSOCIATIONS/NOISE RESEARCH ACTIVITY SURVEY (continued)

| SIC Code | Industry/Associations | Research Activity | Publication Available |
|---|---|---|---|
| 32 | STONE, CLAY AND GLASS PRODUCTS | | |
| | • National Concrete Masonry Association<br>1800 N. Kent Street<br>Arlington, Virginia 22209<br>(703)524-0813 | Machinery Noise Data | If cleared for release by association |
| | • Glass Container Manufacturers Institute<br>1800 K Street, N. W.<br>Washington, D. C. 20006<br>(202)872-1280 | None | None |
| | • Portland Cement Association<br>Old Orchard Road<br>Skokie, Illinois 60076<br>(312)966-6200 | Noise Surveys for Member Companies | Reports considered proprietary |
| 33 | PRIMARY METAL INDUSTRIES | | |
| | • Aluminum Association<br>750 Third Avenue<br>New York, New York 10017<br>(212)972-1800 | None | None |
| | • American Iron and Steel Institute<br>1000 16th Street, N. W.<br>Washington, D. C. 20036<br>(202)223-9040 | Survey of Noise | No survey, just beginning |

Table C-1 SUMMARY OF INDUSTRY/ASSOCIATIONS/NOISE RESEARCH ACTIVITY SURVEY (continued)

| SIC Code | Industry/Associations | Research Activity | Publication Available |
|---|---|---|---|
| 33 (continued) | | | |
| | • American Foundrymen's Society<br>Golf and Wolf Roads<br>DesPlaines, Illinois 60016<br>(312)824-0181 | Participating on Hearing Damage Survey | None |
| | • Forging Industry Association<br>1211 Illuminating Building<br>55 Public Square<br>Cleveland, Ohio 44113<br>(216)781-6260 | Program on Machinery Noise Reduction | Yes - At $50. per copy. Six (6) volumes ready and six (6) not ready. No reproduction rights. |
| | • Gray and Ductile Iron Founders Society<br>Cast Metals Federation Building<br>Rocky River, Ohio 44116<br>(216)333-9600 | Survey of Machinery Noise | No, just started |
| | • Steel Founders Society of America<br>Cast Metals Federation Building<br>Rocky River, Ohio 44116<br>(216)333-9600 | None | None |
| 34 | FABRICATED METAL PRODUCTS | | |
| | • Air Conditioning and Refrigeration Institute<br>1815 North Fort Myer Drive<br>Arlington, Virginia 22209<br>(703)524-8800 | None | None |

Table C-1 SUMMARY OF INDUSTRY/ASSOCIATIONS/NOISE RESEARCH ACTIVITY SURVEY (continued)

| SIC Code | Industry/Associations | Research Activity | Publication Available |
|---|---|---|---|
| 34 (continued) | | | |
| | • American Automobile Association<br>1712 G Street, N. W.<br>Washington, D. C. 20006<br>(202)222-6000 | None | None |
| | • Association of Home Appliance Manufacturers<br>20 North Wacker Drive<br>Chicago, Illinois 60606<br>(312)236-2921 | Equipment Noise Survey | None |
| | • Farm and Industrial Equipment Institute<br>410 North Michigan Avenue<br>Chicago, Illinois 60611<br>(312)321-1470 | Survey of Hearing Damage for Operators | Yes, See CIMA (SIC 16) |
| | • Industrial Research Institute<br>100 Park Avenue<br>New York, New York 10017<br>(212)683-7626 | None | None |
| | • International Snowmobile Association<br>5205 Leesburg Pike<br>Falls Church, Virginia 22041<br>(703)379-9100 | None | None |

Table C-1 SUMMARY OF INDUSTRY/ASSOCIATIONS/NOISE RESEARCH ACTIVITY SURVEY (continued)

| SIC Code | Industry/Associations | Research Activity | Publication Available |
|---|---|---|---|
| 34 (continued) | | | |
| | • National Association of Engine and Boat Manufacturers, Inc.<br>537 Steamboat Road<br>Greenwich, Connecticut 06830<br>(203)661-4800 | None | None |
| | • National Association of Manufacturers<br>1776 F Street, N. W.<br>Washington, D. C. 20006<br>(202)331-3700 | None | None |
| 35 | MACHINERY EXCEPT ELECTRICAL | | |
| | • Machinery and Allied Products Institute<br>1200 18th Street, N. W.<br>Washington, D. C. 20036<br>(202)331-8430 | None | None |
| | • National Machine Tool Builders Association<br>7901 Westpark Drive<br>McLean, Virginia 22101<br>(703)893-2900 | None | None |
| | • National Tool, Die and Precision Machining Association<br>9300 Livingston Road<br>Oxon Hill, Maryland 20022<br>(301)248-6200 | Noise Survey | Yes |

Table C-1 SUMMARY OF INDUSTRY/ASSOCIATIONS/NOISE RESEARCH ACTIVITY SURVEY (continued)

| SIC Code | Industry/Association | Research Activity | Publication Available |
|---|---|---|---|
| 35 | (continued) | | |
| | • National Screw Machine Products Association<br>2860 East 120th Street<br>Cleveland, Ohio 44120<br>(216)751-0909 | Unknown | Unknown |
| 36 | <u>ELECTRICAL AND ELECTRONIC MACHINERY</u> | | |
| | • Electronic Industries Association<br>2001 Eye Street, N. W.<br>Washington, D. C. 20006<br>(202)659-2200 | None | None |
| | • National Electrical Manufacturers Association<br>155 East 44th Street<br>New York, New York 10017<br>(212)682-1500 | None | None |
| 37 | <u>TRANSPORTATION EQUIPMENT</u> | | |
| | • American Trucking Association<br>1616 P Street, N. W.<br>Washington, D. C. 20036<br>(202)797-4000 | Truck Noise Research | Yes |
| | • Association of American Railroads<br>1920 L Street, N. W.<br>Washington, D. C. 20036<br>(202)293-4000 | Railroad Noise Survey | Yes |

Table C-1 SUMMARY OF INDUSTRY/ASSOCIATIONS/NOISE RESEARCH ACTIVITY SURVEY (concluded)

| SIC Code | Industry/Association | Research Activity | Publication Available |
|---|---|---|---|
| 37 (continued) | | | |
| | • Transportation Association of America<br>1101 17th Street, N. W.<br>Washington, D. C. 20036<br>(202)296-2470 | None | None |
| | • Motor Vehicle Manufacturers Association<br>320 New Center Building<br>Detroit, Michigan 48202<br>(313)872-4311 | Survey of Motor Vehicle Noise | Yes |
| 49 | UTILITIES | | |
| | • American Public Power Association<br>2600 Virginia Avenue, N. W.<br>Washington, D. C. 20037<br>(202)333-9200 | None | None |
| | • Edison Electric Institute<br>90 Park Avenue<br>New York, New York 10016<br>(212)986-4100 | None | None |
| | • National Association of Electric Companies<br>1140 Connecticut Avenue, N.W.<br>Washington, D. C. 20036<br>(202)223-3460 | None | None |

APPENDIX D

MACHINERY NOISE LITERATURE SEARCH SUMMARY

Abstracts from "Engineering Abstracts" and "Pollution Abstracts" covering the period of 1971-1974 relating to machinery noise were reviewed and their areas of activity distributed over the 20 industries shown in Table E-1. Abstracts which indicate apparent application to several industries were distributed into a "mixed category." A summary of the publication distribution is given in Table D-1 and the distribution of the publications over the 21 categories is presented in Table D-2. Briefly, the following comments are given:

- Three hundred twenty-one publications are identified as pertinent to machinery noise research; 161 primarily single industry oriented and 160 are in the mixed category. The majority (223) are U.S. publications. Ninety-eight foreign publications from 19 countries are identified.

- United States publications are distributed into 13 of the 20 industrial categories. No publications were identified in:

    - Tobacco manufacturing
    - Apparel manufacturing
    - Furniture and fixtures
    - Printing and publishing
    - Leather and leather goods
    - Electrical machinery
    - Transportation equipment

- The industry with the most publications is chemical and allied products with 42 publications. Petroleum and coal products has 26 publications, utilities has 18 and construction 18. Of the 11 publications in primary metals, only two are from the U.S.

- Foreign publications are primarily from Germany (28) and England (23). Both of these countries' publications are broadly scattered throughout the categories but pockets of concentration appear in primary metals and fabricated metal products industries and in the mixed category.

- The review of the abstracts resulted in virtually no quantitative technical information which could be used in either assessing machine noise levels, noise reduction techniques, or the effectiveness of the application of technology. The reports must be gathered and reviewed before any assessment of this type can be made.

- Generic noise problems seem to be treated by several industries. For instance:

  - Valve Noise - Reduction activity is evident in the utilities, chemical and allied products and in the mixed category.

  - Pump Noise is treated by chemical and allied products and in the mixed category.

  - Piping System Noise reduction techniques are used by utilities, chemical and allied products, petroleum and coal products and in the mixed category.

  - Combustion Noise has literature in construction, paper and allied products, chemical and allied products and in the mixed category.

  For the generic noise problems, it would appear that transfer of technology could be effective and research activities could be defined which have relatively broad applicability to several industries.

Table D-1

SUMMARY OF PUBLICATION DISTRIBUTION

| | |
|---|---|
| 321 | Publications on Machinery Noise. |
| 161 | Publications which are primarily single industry oriented. |
| 160 | Publications in mixed category applicable to several industries. |
| 223 | U.S. publications broadly scattered except weak in primary metals. |
| 28 | German publications broadly scattered throughout. |
| 23 | English publications broadly scattered throughout. |
| 6 | Russian publications in utility and machine noise, noise measurement, combustion noise, health effects and standards. |
| 7 | Japanese publications on fans, turbines, gears, grills and analytical techniques. |
| 6 | Swedish publications in construction, primary metals and fabricated metal products. |
| 5 | French publications in construction, industrial noise sources, noise measurement and circulation pumps. |
| 5 | Polish publications on analysis techniques, pumps and gear noise. |
| 3 | Canadian publications on refinery noise and plant noise standards. |
| 3 | Netherlands publications on refinery and power plant noise. |
| 2 | Australian publications on valve and fan noise. |
| 2 | Indian publications on industrial noise sources. |
| 1 | Austrian publication on noise standards. |

Table D-1 SUMMARY OF PUBLICATION DISTRIBUTION (Continued)

| | |
|---|---|
| 1 | Belgian publication on plant noise control. |
| 1 | Hungarian publication on pump noise. |
| 1 | Iranian publication on oil cushions. |
| 1 | Norwegian publication on construction equipment. |
| 1 | Swiss publication on heat exchanger noise. |
| 1 | Tasmanian publication on water turbines. |
| 1 | Yugoslavian publication on milling and grinding. |

Table D-2

MACHINERY NOISE PUBLICATION DISTRIBUTION

| SIC/ Industry | Number of Publications | Area of Publications |
|---|---|---|
| 16 Construction Equipment | 18 | • Construction site noise (5-U.S.)<br>• Pneumatic rock drill (3 - 2-U.S., 1-Norway)<br>• Pile drivers (2 - 1-Germany, 1 - Sweden)<br>• General discourse (1 - U.S.)<br>• Construction equipment in general (2 - U.S.)<br>• Cooling systems (2 - 1-France, 1 - England)<br>• Compressors (1 -U.S.)<br>• Pneumatic equipment (2 -1-England, 1 -U.S.) |
| 20 Food and Kindred Products | 6 | • Agricultural machinery(3- U.S.)<br>• Bottle cap plant noise (1 -U.S.)<br>• Brewery noise (1 -U.S.)<br>• Agricultural noise (1 -U.S.) |
| 21 Tobacco Manufacturers | None | |
| 22 Textile Mill Products | 5 | • Rotating textile spindles (1 -U.S.)<br>• Textile machinery noise (1 -U.S.)<br>• Textile manufacturers noise sources (1 -U.S.)<br>• Guidelines for noise control (2 -U.S.) |

Table D-2 MACHINERY NOISE PUBLICATION DISTRIBUTION (Continued)

| SIC/ Industry | Number of Publications | Area of Publications |
|---|---|---|
| 23 Apparel | None | |
| 24 Lumber and Wood Products | 3 | • Saws (chain) (1 -U.S.)<br>• Planer (2 -U.S.) |
| 25 Furniture and Fixtures | None | |
| 26 Paper and Allied Products | 6 | • Medical aspects of noise (1 -U.S.)<br>• Stock preparation machinery (1 -U.S.)<br>• Compressors (1 -U.S.)<br>• Gears (3 -U.S.) |
| 27 Printing, Publishing | None | |

Table D-2 MACHINERY NOISE PUBLICATION DISTRIBUTION (Continued)

| SIC/ Industry | Number of Publications | Areas of Publication |
|---|---|---|
| 28 Chemical and Allied Products | 42 | • Valve noise (20 -17 -U.S., 2 - Germany, 1 - Australia)<br>• Piping noise (3 - U.S.)<br>• Combustion noise (2 -U.S.)<br>• Centrifugal compressor (1 -U.S.)<br>• Pumps (3 -2 -U.S., 1 -England)<br>• Heat exchangers (1 -Switzerland)<br>• Exhaust vent (1 -U.S.)<br>• Acoustic insulation (1 -U.S.)<br>• Process noise (10 -U.S.) |
| 29 Petroleum and Coal Products | 26 | • Process machinery noise (2 -U.S.)<br>• Fan noise (2 - 1 -U.S., 1 -Australia)<br>• Furnace and heater noise (2 -U.S.)<br>• Steam pipeline noise (1 -U.S.)<br>• Stack noise (1 -U.S.)<br>• Flare noise (1 -U.S.)<br>• Refinery noise (10 -7 -U.S., 1 -Netherlands, 1 -Canada, 1 -England)<br>• Rock noise location (1 -U.S.)<br>• Noise in coal preparation plants (2 -U.S.)<br>• Noise in underground operations (3 -2 -U.S., 1 -England)<br>• Coal car unloading (1 -U.S.) |
| 30 Rubber and Plastic Products | 6 | • Plant noise sources (2 -U.S.)<br>• Processing plant noise (1 -U.S.)<br>• Materials handling (1 -U.S.)<br>• Combustion (1 -England)<br>• Health aspects (1 -U.S.S.R.) |

Table D-2 MACHINERY NOISE PUBLICATION DISTRIBUTION (Continued)

| SIC/ Industry | Number of Publications | Areas of Publication |
|---|---|---|
| 31 Leather and Leather Goods | None | |
| 32 Stone, Clay and Glass Products | 5 | • Ball-mill noise (1 -U.S.)<br>• Cement plant noise (1 -Germany)<br>• Quarrying noise (3 -U.S.) |
| 33 Primary Metals | 11 | • Electric-arc steelplant (1 -England)<br>• Steel plant noise (1 -Germany)<br>• Forging (3 -1 -U.S., 1 -Germany, 1-England)<br>• Air conditioning (1 -Germany)<br>• Foundry noise sources (5 -2 -Sweden, 1 -Germany, 1 -England, 1 -U.S.) |
| 34 Fabricated Metal Products | 12 | • Impact machines (2 -U.S.)<br>• Metal forming (1 -Germany)<br>• Riveting machines (2 -U.S.)<br>• Cable making machines (2 -Germany)<br>• Punch presses (5 -3 -U.S., 2 -Sweden) |
| 35 Machinery Except Electrical | 3 | • Milling and grinding (1 -Yugoslavia)<br>• Spherical tool against vibrating rod (1 -U.S.)<br>• Scale models of turbomachinery facility (1 -U.S.) |

Table D-2 MACHINERY NOISE PUBLICATION DISTRIBUTION (Continued)

| SIC/ Industry | Number of Publications | Areas of Publication |
|---|---|---|
| 36 Electrical Machinery | None | |
| 37 Transportation Equipment | None | |
| 49 Utilities | 18 | • Fans for utility boilers (1 -Japan)<br>• Switching room (1 -U.S.S.R.)<br>• Power plant noise (4 -U.S.)<br>• Valves for steam plants (1-U.S.)<br>• Machinery noise sources (1 -U.S.)<br>• Gas turbines (2 -U.S.)<br>• New plant noise considerations (5 -1 -U.S., 2 -Netherlands, 2 -Germany)<br>• Steam piping systems (3 -2 -U.S., 1 -England) |
| Mixed Category | 27 | <u>Industrial Noise Sources</u><br>• Identification and surveys (8 -2 -Germany, 2 -England, 2 -India, 2 -U.S.)<br>• Noise criteria (2 -U.S.)<br>• Plant noise control approaches (17 -13 -U.S., 1 -Canada, 1 -Germany, 1 -Belgium, 1 -France.) |

Table D-2 MACHINERY NOISE PUBLICATION DISTRIBUTION (Continued)

| SIC/ Industry | Number of Publications | Areas of Publication |
|---|---|---|
| Mixed Category (continued) | 18 | <u>Noise Measurement Techniques</u><br>• Machines in reverberation rooms (2 -U.S.)<br>• Principles of preception and measurement (1 -France)<br>• Plant noise measurement techniques (2 -U.S.)<br>• Machine noise measurement techniques (12 -9 -U.S., 1 -U.S.S.R., 1 -Germany, 1 -France)<br>• Errors in measurement of machine noise (1 -Germany) |
| | 11 | <u>Noise Criteria and Standards</u><br>• Community impact (4 -U.S.)<br>• Standards (7 -1 -Canada, 1 -U.S.S.R., 1 -Austria, 1 -Sweden, 3 -U.S.) |
| | 5 | <u>Analysis Techniques</u><br>• Nomograms (1 -Germany)<br>• Empirical (1 -Japan)<br>• Dynamic analysis (3 -2 -U.S., 1 -Poland) |
| | 15 | <u>Equipment, Mechanical</u><br>• Conveyors (1 -Germany)<br>• Compressors (7 -6 -U.S., 1 -Germany)<br>• Gas turbines (3 -1 -U.S., 1 -Japan, 1 -England)<br>• Lift truck (1 -U.S.)<br>• Power tools (1 -U.S.)<br>• Prime mover (1 -U.S.)<br>• Dust collectors (1 -England) |

Table D-2 MACHINERY NOISE PUBLICATION DISTRIBUTION (Continued)

| SIC/ Industry | Number of Publications | Areas of Publication |
|---|---|---|
| Mixed Category (continued) | 24 | <u>Equipment, "Pneumatic"</u><br>• Fan Noise (8 - 5-U.S., 2-Japan, 1-Germany)<br>• Combustion Noise (13 - 4-U.S., 1-U.S.S.R., 2-Germany, 6-England)<br>• Noise from airflow through a grill (1-Japan)<br>• Exhaust noise (2-U.S.) |
| | 15 | <u>Equipment, Hydraulic</u><br>• Pumps (5 - 3-Poland, 1-Hungary, 1-U.S.)<br>• Valves (1-U.S.)<br>• Piping systems (1-U.S.)<br>• Water turbines (1-Tasmania)<br>• Oil Cushion (1-Iran)<br>• "Hydraulic equipment" (6 - 5-U.S., 1-England) |
| | 10 | <u>Components</u><br>• Gears (6 - 4-U.S., 1-Poland, 1-Japan)<br>• Rotor (1-England)<br>• Bearings (2-U.S.)<br>• Clutch (1-U.S.) |
| | 8 | <u>Vibration Isolation</u><br>• Correlation of machine vibration and radiated noise (1-England)<br>• Structural damping (1-U.S.)<br>• Machinery foundations (1-U.S.)<br>• Machine noise reduction (5 - 4-U.S., 1-U.S.S.R.) |

Table D-2 MACHINERY NOISE PUBLICATION DISTRIBUTION (Concluded)

| SIC/ Industry | Number of Publications | Areas of Publication |
|---|---|---|
| Mixed Category (continued) | 16 | <u>Acoustical Treatment</u><br>• Barriers and enclosures ( 6 - 5-U.S., 1-Germany)<br>• Ducts and pipes (3-U.S.)<br>• Fluid and electrical components (1-U.S.)<br>• Laminated metal composites (1-U.S.)<br>• Machines (5-U.S.) |
| | 11 | <u>Heating, Ventilating and Air Conditioning</u><br>• Air handling system (1-U.S.)<br>• Residential air conditioner (1-U.S.)<br>• Air conditioner cabinet (1-Germany)<br>• Chiller (2-U.S.)<br>• Cooling tower (1-Germany)<br>• Circulating pump (1-France)<br>• Unducted HVAC equipment (1-U.S.)<br>• Duct systems (2-U.S.)<br>• Fans (1-Germany) |

## APPENDIX E

### INDUSTRIAL MACHINERY NOISE LEVELS

Machine types and noise levels were compiled by industry in order to identify:

- Machine types within each industry.
- Noise levels associated with each machine type.

Accordingly 357 machines, distributed over 20 industries, were identified. Bases for the identification were:

- Department of Commerce reports of the 1972 Census of Manufacturers, Reference 5. These documents formed the primary basis of the machinery and industry distributions.
- References on machine noise (References 1, 3, 4, 8, 9, 10, 11, 12, 13) yielded both noise level data and information on machines used by industry. Machine types of the construction and utility industries were primarily gathered from these reports.

No attempt was made to be all inclusive in identifying machinery because much more data were readily available in some industries, such as the fabricated metal products industry, than in others, such as the tobacco manufacturers industry. Also, there are many species of some generic machine types which are of various manufacture and in various stages of useful life, with varying associated noise levels. The noise levels may also depend on the type of workpiece being handled. Therefore, a rigorous structure of the machine-noise level-industry matrix is very large and beyond the scope of this effort. The machinery noise level presented is an indicator rather than as an absolute value.

A search for machinery noise data indicated that most of the available data is in the form of A-weighted sound pressure levels (SPL). Little noise spectra data was found, with the exception of that in Reference 4.

Table E-1 is a summary of the machinery noise by industry. The complete machine-industry-noise level matrix is given in Tables E-2 to E-18. Table E-1 is a compilation of the SIC code for each industry, the industry, the number of machines identified with each industry, the number of machines for which SPL's were available, and the mean SPL for the machines identified. The mean SPL is intended to serve as a gross indicator of the noise level of the machines in the industry and should not be taken as an indicator of the noise level of the industry (which must be related to the number of machines of each type within the industry and the typical plant acoustics).

Noise levels were identified for approximately 67 percent of the machines. This is a relatively high value primarily because many of the machines within the industries could not be readily identified during this effort and many of those machines which were identified were drawn from the noise measurement data base.

Mean SPL's for the machines range from 85 dBA for the leather and leather goods industry machines to 109 dBA for the construction industry machines. Most of the high mean SPL values (above 95 dBA) are associated with industries in which metal forming and cutting are the predominant operations. Noise levels of the petroleum and coal products industry machines are primarily the noise of the machines associated with mining operations.

Table E-1 SUMMARY OF MACHINE NOISE BY INDUSTRY

| SIC Code | Industry | Number of Machines Identified | Number of Machines With SPL Data | Mean SPL for Machines, dBA (2 - 5 ft.) (.61-1.52 mtrs.) |
|---|---|---|---|---|
| 16 | Construction | 36 | 19 | (85)* |
| 20 | Food and Kindred Products | 42 | 18 | 94 |
| 21 | Tobacco Manufacturers | 6 | 0 | N.A. |
| 22 | Textile Mill Products | 15 | 10 | 93 |
| 23 | Apparel and Related Products | | Included in SIC 22 | |
| 24 | Lumber and Wood Products | 15 | 11 | 96 |
| 25 | Furniture and Fixtures | | Included in SIC 24 | |
| 26 | Paper and Allied Products | 21 | 9 | 91 |
| 27 | Printing, Publishing, & Allied Products | 22 | 11 | 90 |
| 28 | Chemical and Allied Products | 15 | 15 | 88 |
| 29 | Petroleum and Coal Products | 29 | 7 | 99 |
| 30 | Rubber and Misc. Plastic Products | | Included in SIC 28 | |
| 31 | Leather and Leather Goods | 10 | 10 | 85 |
| 32 | Stone, Clay and Glass Products | 12 | 12 | 91 |
| 33 | Primary Metal Industries | 38 | 38 | 98 |

* 15.2 meters (50 feet)

Table E-1 SUMMARY OF MACHINE NOISE BY INDUSTRY (Concluded)

| SIC Code | Industry | Number of Machines Identified | Number of Machines With SPL Data | Mean SPL for Machines, dBA (2 - 5 ft) (.61-1.52 mtrs) |
|---|---|---|---|---|
| 34 | Fabricated Metal Products | 41 | 27 | 99 |
| 35 | Machinery Except Electric | 21 | 17 | 101 |
| 36 | Electrical & Electronic Machinery | 13 | 12 | 99 |
| 37 | Transportation Equipment | 13 | 12 | 99 |
| 49 | Utilities | 8 | 8 | 95 |
| | TOTALS | 357 | 236 | - |

Table E-2 INDUSTRY-MACHINE-NOISE LEVEL DISTRIBUTION (SIC Code 16)

| Industry | Machine | Overall Level dBA | Ref. No. |
|---|---|---|---|
| Construction Other Than Building Construction | Bulldozers | 80* | 8 |
| | Scrapers | 88* | 8 |
| | Trucks (Construction) | 91* | 8 |
| | Pavers Self-Propelled | 89* | 8 |
| | Backhoes | 85* | 8 |
| | Compacters | | |
| | Graders | 85* | 8 |
| | Frontloaders | 79* | 8 |
| | Shiploaders | | |
| | Concrete Mixers | 85* | 8 |
| | Conveyors | | |
| | Vibrators | 76* | 8 |
| | Concrete Pumps | 82* | 8 |
| | Rock Crushers | | |
| | Cranes | 83* | 8 |
| | Pile Drivers | 101* | 8 |
| | Drop Hammers | | |
| | Pneumatic Tools | 85* | 8 |
| | Off-Highway Tractors | 80* | 8 |

Table E-2 INDUSTRY-MACHINE-NOISE LEVEL DISTRIBUTION (Concluded)
(SIC Code 16)

| Industry | Machine | Overall Level dBA | Ref. No. |
|---|---|---|---|
| Construction Other Than Building Construction | Draglines | | |
| | Shovels | | |
| | Street Sweeper | | |
| | Rock Drill | 98* | 8 |
| | Derrick | 88* | 8 |
| | Clamshell | | |
| | Ripper | | |
| | Pipe Layer | | |
| | Roller | | |
| | Trencher | | |
| | Fork Lift | | |
| | Travel Lift | | |
| | Compressor | 81* | 8 |
| | Generator | 78* | 8 |
| | Jack Hammer | 88* | 8 |
| | Stripping Pump | | |
| | Well-Point Pump | | |

* SPL Measured at 15.2 meters (50 feet) from machine.

Table E-3 INDUSTRY-MACHINE-NOISE LEVEL DISTRIBUTION (SIC Code 20)

| Industry | Machine | Overall Level dBA | Ref. No. |
|---|---|---|---|
| Food and Kindred Products | Bottling & Packaging Machinery | 93 | 9 |
| | Washing & Sterilizing Equipment | | |
| | Pasteurizers | | |
| | Homogenizers | 93** | 9 |
| | Ice Cream Freezers | | |
| | Butter & Cheese Processing Machinery | | |
| | Dry Milk Processing Machinery | | |
| | Slicers | | |
| | Choppers | 92* | 4 |
| | Grinders | | |
| | Dicers | | |
| | Mixers | | |
| | Tenderizers | | |
| | Ovens | | |
| | Continuous Bread-Making Equipment | | |
| | Wrapping Machines | | |
| | Bottling Equipment | | |
| | Meat & Poultry Processing Equipment | | |

Table E-3 INDUSTRY-MACHINE-NOISE LEVEL DISTRIBUTION (Cont'd)
(SIC Code 20)

| Industry | Machine | Overall Level dBA | Ref. No. |
|---|---|---|---|
| Food and Kindred Products | Fruit & Vegetable Canning Machinery | | |
| | Flour & Grainmill Machinery | | |
| | Sugar Plant Machinery | | |
| | Oilseed Crushing & Extract. Machinery | | |
| | Bottle Washers & Sterilizers | 93** | 9 |
| | Uncasers & Casers | | |
| | Capping Machines | | |
| | Packing & Packaging Machines | | |
| | Carbonators | | |
| | Filling & Labeling Machines | | |
| | Molding Machine | 86* | 4 |
| | Peanut Blanching Machine | 85* | 4 |
| | Bottle Fillers | 96** | 9 |
| | Lift Truck | 91** | 9 |
| | Peanut Sizing Machine | 95** | 9 |
| | Salt Pulverizor | 95* | 9 |

Table E-3 INDUSTRY-MACHINE-NOISE LEVEL DISTRIBUTION (Concluded)
(SIC Code 20)

| Industry | Machine | Overall Level dBA | Ref. No. |
|---|---|---|---|
| Food and Kindred Products | Vibrating Conveyor | 91** | 9 |
| | Metal Conveyor for Bottles | 94** | 9 |
| | Pecan Shell Cracker | 101** | 9 |
| | Paper Container Shear | 100** | 9 |
| | Candy Cane Twister | 95** | 9 |
| | Wash Tank | 100** | 9 |
| | Refrigeration Compressor | 100** | 9 |
| | Candy Print Machine | 99** | 9 |

* SPL measured .61 - 1.52 meters (2 - 5 feet) from machine.
** SPL measurement distance not specified.

Table E-4 INDUSTRY-MACHINE-NOISE LEVEL DISTRIBUTION (SIC Code 21)

| Industry | Machine | Overall Level dBA |
|---|---|---|
| Tobacco Manufacturers | Conveyors | |
| | Driers | |
| | Fans | |
| | Cutting Equipment | |
| | Washing Equipment | |
| | Packaging Equipment | |

Table E-5 INDUSTRY-MACHINE-NOISE LEVEL DISTRIBUTION (SIC Code 22)

| Industry | Machine | Overall Level dBA | Ref. No. |
|---|---|---|---|
| Textile Mill Products (Includes apparel and other finished products, SIC 23) | Cleaning & Opening Machinery | | |
| | Carding & Combing Machines | | |
| | Drawing & Roving Frames | | |
| | Spinning Frames | 82* | 4 |
| | Twisting Frames | 83* | 4 |
| | Yarn Preparing Machines | 97* | 4 |
| | Power Looms | 102* | 4 |
| | Knitting Machines | | |
| | Bleaching, Dyeing & Finishing Machinery | 100** | 4 |
| | Drying Machinery | | |
| | Reducing Machines | 96* | 4 |
| | Reducer Transfer Machines | 89* | 4 |
| | Combing Machines | 95* | 4 |
| | Pin Drafters | 92* | 4 |
| | Preparers | 90* | 4 |

* SPL measured .61 - 1.52 meters (2 - 5 feet) from machine.
** SPL measurement distance not specified.

Table E-6 INDUSTRY-MACHINE-NOISE LEVEL DISTRIBUTION (SIC Code 24)

| Industry | Machine | Overall Level dBA | Ref. No. |
|---|---|---|---|
| Lumber and Wood Products (Includes furniture & Fixtures, SIC 25) | Veneer & Plywood-Making Machinery | | |
| | Saws | 111* | 4 |
| | Jointers | 88* | 4 |
| | Matchers | | |
| | Molders | 99* | 4 |
| | Mortisers | | |
| | Shapers | 89* | 4 |
| | Tenoners | 95* | 4 |
| | Lathes | 98* | 4 |
| | Planing Machines | 108* | 4 |
| | Surfacing Machines | 98* | 4 |
| | Drills | | |
| | Barkers | 91* | 4 |
| | Slashers | 97* | 4 |
| | Sanders | 85* | 4 |

* SPL measured .61 - 1.52 meters (2 - 5 feet) from machine.

Table E-7 INDUSTRY-MACHINE-NOISE LEVEL DISTRIBUTION (SIC Code 26)

| Industry | Machine | Overall Level dBA | Ref. No. |
|---|---|---|---|
| Paper and Allied Products | Barkers | 91* | 4 |
| | Chippers | | |
| | Knotters | | |
| | Splitters | | |
| | Chipscreens | | |
| | Grinders | | |
| | Deckers | | |
| | Digesters | | |
| | Beaters | | |
| | Jordans | | |
| | Calenders | 93* | 4 |
| | Fourdriniers | | |
| | Bagmaking Machines | | |
| | Corrugated Box Making Machines | 97* | 4 |
| | Box, Carton & Shipping Container Making Mach. | 85* | 4 |
| | Toilet Roll and Napkin Making Machines | | |
| | Slashers | 97* | 4 |
| | Pulp Preparation Machine | 82* | 4 |
| | Mixers | 94* | 4 |
| | Paper Machines | 88* | 4 |
| | Pumps | 92* | 4 |

* SPL measured .61 - 1.52 meters (2 - 5 feet) from machine.

Table E-8 INDUSTRY-MACHINE-NOISE LEVEL DISTRIBUTION (SIC Code 27)

| Industry | Machine | Overall Level dBA | Ref. No. |
|---|---|---|---|
| Printing, Publishing & Allied Products | Lithographic Printing Presses | | |
| | Newspaper Presses | 92* | 4 |
| | Business Form Presses | | |
| | Commercial Presses | | |
| | Gravure | | |
| | Flexographic | | |
| | Typesetting Machinery | 81* | 4 |
| | Saddle Binding Equipment | | |
| | Perfect & Hard Case Binding Equipment | | |
| | Electrotyping Machines | | |
| | Stereotyping Machines | | |
| | Paper Cutting Machines | | |
| | Collating Machines | 90* | 4 |
| | Gathering Machines | | |
| | Printer-Slotters | 98* | 4 |
| | Stitchers | 85* | 4 |
| | Folders | 94* | 4 |
| | Shears | 103* | 4 |
| | Ink Mills | 91* | 4 |
| | Cleaning Tanks | 87* | 4 |
| | Newsprint Rewinders | 85* | 4 |
| | Air Ejectors | 83* | 4 |

* SPL measured .61 - 1.52 meters (2 - 5 feet) from machine.

Table E-9 INDUSTRY-MACHINE-NOISE LEVEL DISTRIBUTION (SIC Code 28)

| Industry | Machine | Overall Level dBA | Ref. No. |
|---|---|---|---|
| Chemical and Allied Products (Includes rubber & misc. plastic products, SIC 30) | Ink Mills | 93* | 4 |
| | Pigment Mills | 91* | 4 |
| | Pebble Mills | 80* | 4 |
| | Mixers | 80* | 4 |
| | Drum Cleaners | 78* | 4 |
| | Five-Roll Mills | 97* | 4 |
| | Hammer Mills | 98* | 4 |
| | Compounding Rolls | 92* | 4 |
| | Ball Mills | 99* | 4 |
| | Fabric Coaters | 81* | 4 |
| | Rewind, Fabric Beaming | 80* | 4 |
| | Rotary Kilns | 82* | 4 |
| | Rubber Mills | 86* | 4 |
| | Tread Tubers | 90* | 4 |
| | Curing Presses | 94* | 4 |

* SPL measured .61 - 1.52 meters (2 - 5 feet) from machine.

Table E-10 INDUSTRY-MACHINE-NOISE LEVEL DISTRIBUTION (SIC Code 29)

| Industry | Machine | Overall Level dBA | Ref. No. |
|---|---|---|---|
| Petroleum and Coal Product | Rotary Drilling Surface Equipment | | |
| | Rotary Drilling Subsurface Equipment | | |
| | Cable Tool Drilling Machinery | | |
| | Flowing Well Equipment | | |
| | Rod Lifting Machinery | | |
| | Pumping Units | | |
| | Oil & Gas Separating, Metering & Treating Equipment | | |
| | Well Surveying Machinery | | |
| | Crushing, Pulverizing & Screening Machinery | 86** | 10 |
| | Drills | 110** | 10 |
| | Cutting Machines | 96* | 12 |
| | Longwall Mining Machines | | |
| | Gathering Arm Loading Machines | 99* | 12 |
| | Slusher Hoists Loading Machines | | |
| | Continuous Mining Machines | 97* | 12 |
| | Borers | | |
| | Rippers | | |

Table E-10 INDUSTRY-MACHINE-NOISE LEVEL DISTRIBUTION (Concluded)

| Industry | Machine | Overall Level dBA | Ref. No. |
|---|---|---|---|
| Petroleum and Coal Product | Shuttle Cars | 93* (Loading) | 12 |
| | Mine Cars | | |
| | Flotation Machines | | |
| | Wet Cyclones | | |
| | Centrifugal Driers | | |
| | Scrubbers | | |
| | Thermal Driers | | |
| | Feeders | | |
| | Grinding Mills | | |
| | Screens | | |
| | Shakers | | |
| | Roof Bolter | 112* | 11 |

* SPL measured within .914 meters (3 feet).

** SPL measurement distance not specified.

Table E-11 INDUSTRY-MACHINE-NOISE LEVEL DISTRIBUTION (SIC Code 31)

| Industry | Machine | Overall Level dBA | Ref. No. |
|---|---|---|---|
| Leather & Leather Products | Fleshing Machines | 89* | 4 |
| | Hair Driers | 88* | 4 |
| | Lime Mixing Tubs | 77* | 4 |
| | Setting Out Machines | 103* | 4 |
| | Splitting Machines | 85* | 4 |
| | Coloring Drums | 90* | 4 |
| | Plating | 81* | 4 |
| | Seasoning Machines | 80* | 4 |
| | Spraying Machines | 78* | 4 |
| | Measuring Machines | 77* | 4 |

* SPL measured .61 - 1.52 meters (2 - 5 feet) from machine.

Table E-12 INDUSTRY-MACHINE-NOISE LEVEL DISTRIBUTION (SIC Code 32)

| Industry | Machine | Overall Level dBA | Ref. No. |
|---|---|---|---|
| Stone, Clay & Glass Products | Clay Crushers | 92* | 4 |
| | Clay Till Extrusion Machines | 82* | 4 |
| | Packing Machines | 86* | 4 |
| | Bottle Forming Machines | 98* | 4 |
| | Mixers | 93* | 4 |
| | Pneumatic Chippers | 84* | 4 |
| | Cut Off Saws | 89* | 4 |
| | Stone Planers | 98* | 4 |
| | Cranes | 84* | 4 |
| | Stone Saws | 99* | 4 |
| | Concrete Aggregate | 89* | 4 |
| | Clay Tile Kiln (Unloading) | 97* | 4 |

* SPL measured .61 - 1.52 meters (2 - 5 feet) from machine.

Table E-13 INDUSTRY-MACHINE-NOISE LEVEL DISTRIBUTION (SIC Code 33)

| Industry | Machine | Overall Level dBA | Ref. No. |
|---|---|---|---|
| Primary Metal Industries | Grinders | 90* | 4 |
| | Pneumatic Chippers | 117* | 4 |
| | Furnaces (Ingot Heating) | 93* | 4 |
| | Furnaces (Oil Heating) | 93* | 4 |
| | Wood Planers | 107* | 4 |
| | Friction Saws | 107* | 4 |
| | Shake Outs | 103* | 4 |
| | Pneumatic Rams | 84* | 4 |
| | Tumblers | 99* | 4 |
| | Push Up Machines | 99* | 4 |
| | Core Blowers | 116* | 4 |
| | Core Draw Vibrators | 108* | 4 |
| | Air Hoists | 108* | 4 |
| | Electric Furnaces | 96* | 4 |
| | Sand Slingers | 96* | 4 |
| | Jolt Squeeze Machines | 97* | 4 |
| | Crucible Heaters | 81* | 4 |
| | Roughing Mills | 102* | 4 |
| | Levelers | 90* | 4 |
| | Decoilers | 116* | 4 |
| | Anealing Furnaces | 93* | 4 |
| | Lectromelt Furnaces | 95* | 4 |
| | Open Hearth Furnaces | 80* | 4 |

Table E-13 INDUSTRY-MACHINE-NOISE LEVEL DISTRIBUTION (Concluded)
(SIC Code 33)

| Industry | Machine | Overall Level dBA | Ref. No. |
|---|---|---|---|
| Primary Metal Industries | Scarfing Equipment | 36* | 4 |
| | Bloomer Mills | 90* | 4 |
| | Strip Mills | 97* | 4 |
| | Conveyors | 98* | 4 |
| | Forging Hammers | 109* | 4 |
| | Coke Ovens | 93** | 1 |
| | Sinter Plants | 100** | 1 |
| | Blast Furnaces | 93** | 1 |
| | Basic Oxygen Furnaces | 95** | 1 |
| | Soaking Pits | 98** | 1 |
| | Rolling Mills | 95** | 1 |
| | Continuous Picklers | 95** | 1 |
| | Pipe Mills | 96** | 1 |
| | Wire Drawing | 95** | 1 |
| | Nail Mills | 98** | 1 |

* SPL measured .61 - 1.52 meters (2 - 5 feet) from machine.

** SPL measurement distance not identified.

Table E-14 INDUSTRY-MACHINE-NOISE LEVEL DISTRIBUTION (SIC Code 34)

| Industry | Machine | Overall Level dBA | Ref. No. |
|---|---|---|---|
| Fabricated. Metals Product | Boring Machines | 97* | 4 |
| | Drilling Machines | 98* | 4 |
| | Gear-Cutting Machines | 88* | 4 |
| | Grinding Machines | 106* | 4 |
| | Polishing Machines | 95* | 4 |
| | Lathes | 107* | 4 |
| | Milling Machines | 89* | 4 |
| | Saws | 107* | 4 |
| | Broaching Machines | | |
| | Planers | | |
| | Shapers | 93* | 4 |
| | Cut Off Machines | 103* | 4 |
| | Tapping Machines | 94* | 4 |
| | Threading Machines | | |
| | Automatic Chucking Lathes | | |
| | Screw Machines | 90* | 4 |
| | Station & Transfer Machines | | |
| | Electric Discharge Machines | | |
| | Electrochemical Machines | | |
| | Honing & Lapping Machines | | |
| | Welding Machines | 82* | 4 |

Table E-14 INDUSTRY-MACHINE-NOISE LEVEL DISTRIBUTION (Concluded)
(SIC Code 34)

| Industry | Machine | Overall Level dBA | Ref. No. |
|---|---|---|---|
| Fabricated Metals Product | Punches | 98* | 4 |
| | Shears | 93* | 4 |
| | Bending Machines | 92* | 4 |
| | Forming Machines | 108* | 4 |
| | Mechanical Presses | 107* | 4 |
| | Hydraulic Presses | | |
| | Pneumatic Presses | 101* | 4 |
| | Extrusion Presses | | |
| | Headers & Upsetters | 106* | 4 |
| | Swaging Machines | | |
| | Gear & Spline Rolling Machines | 89* | 4 |
| | Thread Rolling Machines | 89* | 4 |
| | Marking Machines | | |
| | Riveting Machines | 117* | 4 |
| | Die Casting Machines | | |
| | Impact Wrenches | | |
| | Power Driven Hand Tools | 95** | 4 |
| | Drop Hammers | 111* | 4 |
| | Sand Blast Machines | 121* | 4 |
| | Vibrators | 104* | 4 |

* SPL measured .61 - 1.52 meters (2 - 5 feet) from machine.

** SPL measurement distance not specified.

Table E-15 INDUSTRY-MACHINE-NOISE LEVEL DISTRIBUTION (SIC Code 35)

| Industry | Machine | Overall Level dBA | Ref. No. |
|---|---|---|---|
| Machinery, Except Electric | Milling Machines | 89* | 4 |
| | Boring Machines | 97* | 4 |
| | Pneumatic Presses | 101* | 4 |
| | Hob Grinders | 89* | 4 |
| | Multiple Drills | 96* | 4 |
| | Turret Lathes | 107* | 4 |
| | Welders | 112* | 4 |
| | Riveting Machines | 125* | 4 |
| | Chippers | 127* | 4 |
| | Grinders | 95* | 4 |
| | Shears | 94* | 4 |
| | Punch Press | 99** | 4 |
| | Drilling Machines | 98* | 4 |
| | Gear-Cutting Machines | 89* | 4 |
| | Lapping, Polishing & Buffing Machines | | |
| | Broaching Machines | | |
| | Planers | | |
| | Shapers | 93* | 4 |
| | Tapping Machines | 94* | 4 |
| | Saws | 107* | 4 |
| | Thread Machines | | |

* SPL measure .61 - 1.52 meters (2 - 5 feet) from machine.

** SPL measurement distance not specified.

Table E-16 INDUSTRY-MACHINE-NOISE LEVEL DISTRIBUTION (SIC Code 36)

| Industry | Machine | Overall Level dBA | Ref. No. |
|---|---|---|---|
| Electrical and Electronic Machinery | Drilling Machines | 98* | 4 |
| | Grinding Machines | 106* | 4 |
| | Polishing Machines | 95* | 4 |
| | Saws | 107* | 4 |
| | Tapping Machines | 94* | 4 |
| | Threading Machines | | |
| | Welding Machines | 82* | 4 |
| | Punches | 98* | 4 |
| | Shears | 93* | 4 |
| | Bending Machines | 92* | 4 |
| | Forming Machines | 108* | 4 |
| | Riveting Machines | 117* | 4 |
| | Power Driven Hand Tools | 102** | 4 |

* SPL measured .61 - 1.52 meters (2 - 5 feet) from machine.

** SPL measurement distance not specified.

Table E-17 INDUSTRY-MACHINE-NOISE LEVEL DISTRIBUTION (SIC Code 37)

| Industry | Machine | Overall Level dBA | Ref. No. |
|---|---|---|---|
| Transportation Equipment | Riveting Machines | 133* | 4 |
| | Drills | 88* | 4 |
| | Saws | 107* | 4 |
| | Routers | 86* | 4 |
| | Welding Machines | 82* | 4 |
| | Punches | 98* | 4 |
| | Shears | 93* | 4 |
| | Bending Machines | 92* | 4 |
| | Forming Machines | 108* | 4 |
| | Mechanical Presses | 101* | 4 |
| | Hydraulic Presses | | |
| | Pneumatic Presses | 101* | 4 |
| | Impact Wrenches | | |
| | Power Driven Hand Tools | 95** | 13 |

* SPL measured .61 - 1.52 meters (2 - 5 feet) from machine.

** SPL measurement distance not specified.

Table E-18 INDUSTRY-MACHINE-NOISE LEVEL DISTRIBUTION (SIC Code 49)

| Industry | Machine | Overall Level dBA | Ref. No. |
|---|---|---|---|
| Utilities | Fans | 110** | 3 |
| | Gas Turbines | 90** | 3 |
| | Oil Burners | 85** | 3 |
| | Diesel Engines | 100** | 3 |
| | Rotary Blowers | 120** | 3 |
| | Turbo-Alternators | 85** | 3 |
| | Feed Pumps | 90** | 3 |
| | Transformers | 60-100** (size dependent) | 3 |

** Noise measurement distance not specified.

## APPENDIX F

## REFERENCES (within Appendices)


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APPENDIX G

LIST OF TABLES (within Appendices)

APPENDIX G

LIST OF TABLES (within Appendices) (Cont'd.)

## TECHNICAL REPORT DATA
*(Please read Instructions on the reverse before completing)*

| | | |
|---|---|---|
| 1. REPORT NO. 600/2-75-008 | 2. | 3. RECIPIENT'S ACCESSION NO. |
| 4. TITLE AND SUBTITLE Federal Machinery Noise Research, Development, and Demonstration: FY 73 - FY 75 | | 5. REPORT DATE May 1975 |
| | | 6. PERFORMING ORGANIZATION CODE |
| 7. AUTHOR(S) Interagency Machinery Noise Research Panel | | 8. PERFORMING ORGANIZATION REPORT NO. |
| 9. PERFORMING ORGANIZATION NAME AND ADDRESS Interagency Machinery Noise Research Panel (RD-681) Office of Research and Development Environmental Protection Agency Washington, D.C. 20460 | | 10. PROGRAM ELEMENT NO. 1GB090 |
| | | 11. CONTRACT/GRANT NO. |
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16. ABSTRACT The Interagency Machinery Noise Research Panel was established by the Environmental Protection Agency to aid EPA in fulfilling its responsibility for coordinating the Federal noise research activities. As its initial task, the Panel prepared this report summarizing the Federal government's machinery noise research, development, and demonstration activities. The Federal agencies which sponsor and/or conduct the major portion of these activities are represented on the panel. They are Department of Defense, National Bureau of Standards, National Science Foundation, Bureau of Mines, National Institute for Occupational Safety and Health, and EPA. Department of Labor is also represented. Other agencies which sponsor machinery noise RD&D are the Department of Agriculture and Consumer Product Safety Commission. The report contains brief descriptions and fiscal data for the agencies' activities. Emphasis is on fiscal years 1973 through 1975. Also included are references and bibliographies of reports and publications which have resulted from the Federal machinery noise RD&D activities.

17. KEY WORDS AND DOCUMENT ANALYSIS

| a. DESCRIPTORS | | b. IDENTIFIERS/OPEN ENDED TERMS | c. COSATI Field/Group |
|---|---|---|---|
| Acoustics | Federal budgets | Federal noise RD&D | 2001 |
| Noise (sound) | Compressor noise | Federal noise coordination | 1406 |
| Noise reduction | Gear noise | Research coordination | 1309 |
| Engine noise | Machinery | | 1303 |
| Research | Construction | | 1301 |
| Research projects | Industrial equipment | | 1313 |

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16. Abstracts
Issued in compliance with Section 4(c)(3) of the Noise Control Act of 1972 (PL 92-574), this report describes Federal noise control and research activities and establishes a baseline of agency program information that may be used in subsequent years to assess progress in the Federal Government's noise control efforts. Thirty-nine Federal agencies were requested to submit information on their noise related activities to EPA. Volume I of the report contains a summary and assessment of reported activities which are described both by agency and by the following functional areas: noise standards and regulations, noise abatement, hearing conservation, technical assistance, and research. Volume II consists of four reports describing Federal agency noise research, development, and demonstration programs in the areas of surface vehicle noise, aviation noise, noise effects, and machinery noise. The reports include project descriptions and fiscal data and were prepared jointly by the membership of four interagency research panels, formed in 1974 by EPA.

17. Key Words and Document Analysis. 17a. Descriptors

Standards and Regulations
Hearing Conservation Programs
Noise Abatement Programs
Technical Assistance
Research, Development, and Demonstration Programs
Federal Noise Research Coordination
Machinery Noise
Aircraft Noise
Surface Vehicle Noise
Noise Effects
U.S. Government Agencies

17b. Identifiers/Open-Ended Terms

17c. COSATI Field/Group

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