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FEDERAL RESEARCH, TECHNOLOGY AND DEMONSTRATION PROGRAMS

IN

AVIATION NOISE

PREPARED BY

**THE FEDERAL INTERAGENCY
AVIATION NOISE RESEARCH PANEL**

MARCH 1978

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

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

PREFACE

The Noise Control Act of 1972 directs EPA to establish the effective coordination of Federal research and development activities in noise control, and to compile and publish periodic reports on the status and progress of these actions.

The Federal noise research coordination activity was initiated in early 1974. Four interagency research panels were established in the areas of:

(1) Aviation
(2) Surface transportation
(3) Machinery
(4) Noise effects.

The panels issued reports in the March-June 1975 time period summarizing the fiscal year 1973 through 1975 on-going and planned noise research, technology, and demonstration (RT&D) programs within the various agencies of the Federal Government.

During 1976, the four panels were reestablished to develop an up-to-date summary of Federally-sponsored noise RT&D programs, to assess their adequacy to meet national objectives for noise abatement, and to identify technology needs to support a national noise abatement strategy.

The Federal Interagency Aviation Noise Research Panel included representatives of the agencies principally concerned with aviation noise abatement and research. They include the National Aeronautics and Space Administration (NASA); the Department of Defense (DOD), Departments of the Air Force, Army, and Navy; and the Environmental Protection Agency (EPA/ONAC). The Department of Housing and Urban Development (HUD) was also represented because of their interest in aircraft noise abatement through land use planning and noise attenuating building practices. HUD sponsors no research in aircraft source noise reduction. Mr. Harry W. Johnson, Director of NASA's Aeronautical Propulsion Division, served as chairman of the panel. NASA currently sponsors the bulk of aviation noise research programs within the Federal Government. EPA served as the secretariat.

The information, assessments, conclusions, and recommendations in this report are the consensus of the panel members and are not necessarily the official views of the agencies.

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1. INTRODUCTION

1.1 PURPOSE AND SCOPE OF THE REPORT

The United States Government, through a number of its agencies and departments, conducts and sponsors research, technology, and demonstration (RT&D) activities related to aviation noise abatement and control. Agency program objectives vary according to overall agency charters, statutory authorities, and priorities. Individual programs also vary in size and complexity.

With the reconvening of the Federal Interagency Aviation Noise Research Panel, each member agency has reexamined its noise programs in the light of national noise abatement goals. This report summarizes each of the Federal agency RT&D programs in aviation noise abatement and control research since FY 75, and the plans for FY 78. It includes a qualitative assessment of the adequacy of these activities for developing technology needed for the eventual achievement of aircraft noise levels compatible with the health and welfare needs of the nation, and it notes the recommendations of the panel.

The scope of this report is limited to RT&D activities, and thus it does not include summaries of aviation noise regulatory standards, regulatory proposals, and studies specifically related to the development of standards; neither does it summarize or assess noise abatement practices, procedures, and technology applications implemented by industry and by national or local authorities.

1.2 ORGANIZATION OF THE REPORT

Agency aviation noise program projects are categorized into principal areas as presented in Table 1-1.

The remainder of this report includes the summary in Chapter 2, an overview of each agency's program in Chapter 3, and an assessment of the agency and overall Federal aviation noise RT&D programs in Chapter 4. Appendices A through E include summary tables of program funding and descriptions of the individual projects comprising each agency's aviation noise RT&D program. Appendix F is a bibliography.

TABLE 1-1
Aviation Noise RT&D Program Categories

RESEARCH AND TECHNOLOGY

- Propulsion Noise
- Rotor Noise
- Interior Noise
- Airframe Noise
- Noise Prediction Technology
- Atmospheric Propagation and Ground Effects
- Other

DEMONSTRATION PROGRAMS AND SYSTEMS STUDIES*

- CTOL (Subsonic)
- CTOL (Supersonic)
- STOL
- Rotorcraft/VTOL
- General Aviation

* Includes flight operational procedures

2. SUMMARY

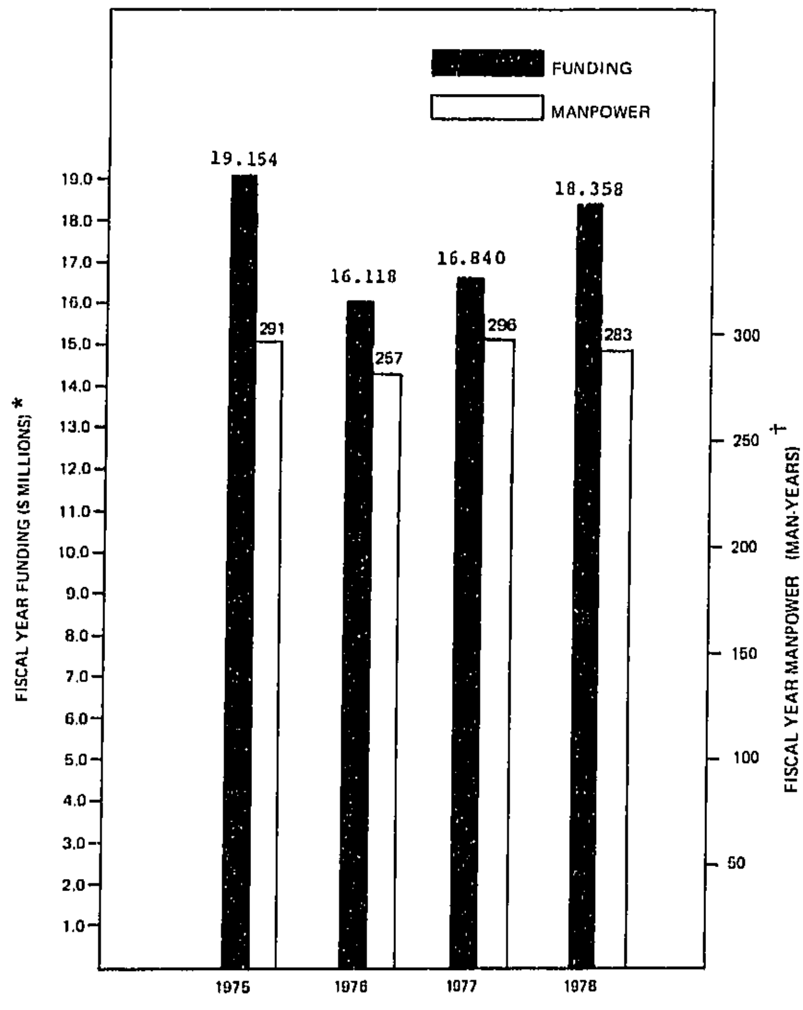
This report is a compilation of the research, technology, and demonstration (RT&D) activities of Federal agencies and departments in the area of aviation noise during the period FY 75-77, and planned activities for FY 78. This report also contains assessments of these activities as well as recommendations for future areas of work.

Federal agencies and departments with programs in aviation noise RT&D during this time period are as follows:

- National Aeronautics and Space Administration (NASA)
- Department of Transportation (DOT)
  - Federal Aviation Administration (FAA)
- Department of Defense (DOD)
  - Department of the Air Force
  - Department of the Army
  - Department of the Navy
- Environmental Protection Agency (EPA)

Aviation noise RT&D activities reported herein are grouped into two types of programs to facilitate review. The first group comprises Research and Technology Programs. It encompasses acoustic fundamentals and noise generation, suppression, transmission, and prediction. It includes both analytical and experimental activities supporting the development of practical technology for aircraft noise abatement. The second group is that of Demonstration Programs and Systems Studies. Programs in this group are intended to explore the actual effectiveness and appropriateness of applied technology for aircraft noise abatement with realistic hardware.

Agency aviation noise program projects are categorized further according to the scheme presented in Table 1-1. Total Federal aviation noise RT&D funding and manpower are shown in Figure 2-1 from FY 75 through FY 78. Funding levels shown for DOD includes manpower costs. Manpower costs for



* DOD FUNDING DATA INCLUDE MANPOWER COSTS

† MANPOWER COSTS ARE TREATED SEPARATELY BY NASA, DOT/FAA, AND EPA

FIGURE 2-1
Total Federal Fiscal Year Funding and Manpower for Aviation Noise RT&D

NASA, DOT/FAA and EPA are accounted for separately and are listed in manyears. As shown in Figure 2-1, total Federal funding and manpower allocated to aviation noise RT&D have not varied more than approximately ± $1.5M and ± 20 man-years within the period FY 75 - 78. Major variations are primarily related to the magnitude of the more expensive demonstration programs. The NASA program accounts for 80 to 85 percent of the funding and approximately 98 percent of the civil service manpower indicated. NASA's aviation noise RT&D programs are conducted by the Langley, Lewis, and Ames Research Centers; Dryden Flight Research Center; Wallops Flight Center; and the Jet Propulsion Laboratory. The Langley Research Center is the primary NASA center for acoustic and aircraft noise reduction research. All of these NASA centers occasionally co-sponsor research programs with each other to fulfill NASA's noise research responsibilities depending upon the expertise needed. NASA's noise research efforts include source noise phenomena, transmission and path phenomena, receiver (community) reaction phenomena, operational techniques, and aircraft interior noise reduction.

The aviation noise RT&D activities of the Department of Defense are conducted by the Air Force, Army, and Navy. Air Force programs generally comprise research and technology studies relative to propulsion, airframe, high-lift or thrust-augmentation devices, and the development of noise prediction technologies. Army programs are principally concerned with helicopters. The Army's studies include propulsion noise, rotor noise, noise prediction technology, and atmospheric propagation. Navy programs are primarily in jet engine noise suppression and also airframe noise.

DOT's responsibilities relative to aviation noise RD&D are carried out by the Federal Aviation Administration (FAA). FAA's efforts are in the areas of propulsion and rotor noise, noise prediction technology, and acoustic propagation. FAA also has activities that are conducted principally to support the regulatory process for aircraft. These activities include aircraft classification and certification procedures, technology assessment, flight path control, land use studies, and establishment of a source noise data base for regulatory use.

EPA's one aviation noise RT&D program is a joint project with NASA to determine the noise emission levels of production propeller-driven aircraft and to demonstrate the technological feasibility and economic reasonableness of advanced-concept propeller designs. This activity is jointly funded with NASA in FY 78 to augment NASA's general aviation propeller noise investigations. EPA's other aviation noise efforts directly support regulations and are not included in this report.

The Panel's assessment and recommendations (elaborated in Section 4) are, briefly:

- Achieving near-term and longer-range national aviation noise abatement goals will require the exercise of all four noise abatement options (source and path control, airport operations and compatible land use), not merely source control. A systems approach for greatest cost effectiveness and earliest applicability is needed. Systems studies of feasible alternatives are recommended.

- There has been no undesirable duplication of effort among the different Agency programs. Interagency coordination is satisfactory, but continuing coordination functions of the Panel should continue. Each Agency undertakes good program review and planning.

- Scope, content and priorities of current RT&D program seem basically adequate. Additional efforts in source noise control should include flight effects, jet nozzles and suppressors. Additional effort on operational techniques is also recommended. In all areas, emphasis should be on cost effectiveness and compatibility with competing aviation economic requirements, environmental constraints and other national priorities such as energy conservation.

- Timing of noise reduction RT&D is important to support future new type aircraft development decisions (STOL, VTOL, advanced SST), and programs should be reviewed in this light.

- Noise "floors" should be better assessed to guide planning of RT&D and goals.

- Relative roles and importance of single event vs cumulative noise exposures should be reexamined.

3.0 AGENCY PROGRAMS

Noise research programs conducted or sponsored by each agency, while contributing to the national objectives of noise reduction in general, are primarily focused on the specific agency's needs for complying with its basic mission and/or subsidiary legislative mandates. This section discusses the overall noise program objectives of each agency.

3.1 NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

The National Aeronautics and Space Administration (NASA) was established by the National Aeronautics and Space Act of 1958 (PL 85-568). This Act requires NASA to conduct aeronautical research and technology activities. Among the stated purposes of such activities is the objective that they contribute materially to the improvement of the usefulness, performance, speed, safety, and efficiency of aeronautical vehicles. This responsibility encompasses aircraft noise research and technology because of the importance of noise reduction to the future usefulness of aviation and because of the interactions of aircraft performance, safety, and efficiency with noise reduction technology.

NASA's aircraft noise projects include research into noise source characteristics, transmission and path phenomena, prediction techniques, operational noise abatement techniques, aircraft interior noise reduction, and receiver (community) reaction phenomena (this latter area is reported in the Noise Effects Panel report). The NASA program represents about 85 to 90 percent of the Federal government's activities in aviation noise RT&D. All program results are made available to the industry as well as regulatory agencies.

NASA's objectives in noise research are to increase the basic understanding of the physics of aircraft noise characteristics, generation, propagation, transmission and suppression; to evolve practical technologies to reduce noise in aircraft; and to selectively demonstrate technological advances in source noise reduction and aircraft noise abatement believed to have high application potential.

The NASA facilities involved in aviation noise RT&D during the relevant period include Langley, Lewis, and Ames Research Centers, the Jet Propulsion Laboratory, and the Wallops Flight Center.

Langley Research Center, Hampton, Virginia, has the primary responsibility for research on acoustic fundamentals, aircraft noise research (excluding engine internal noise generation), and human effects (subjective response). Research and technology programs reported herein for which Langley has lead responsibility include:

Research and Technology

- Forward Velocity Effects on Fan Noise
- Duct Acoustic Treatment Projects
- Propeller Studies
- General Cabin Noise
- Sound/Structure Interaction
- General Airframe Noise
- Aerodynamic Noise of Airframes
- Noise Prediction Techniques
- Noise Propagation Studies
- Acoustic Instrumentation and Measurement Techniques.

In addition, Langley has the responsibility for conducting the following demonstration and systems programs:

Demonstration Programs and Systems Studies

- Advanced Acoustic Composite Nacelle Flight Program
- Flight Operational Procedures
- New CTOL (Supersonic) Aircraft Studies
- STOL Systems and Design Studies

Langley Research Center is also managing the joint EPA/NASA Small Propeller Technology project.

Lewis Research Center, Cleveland, Ohio, has the primary responsibility for propulsion noise source research, engine noise suppression technology, and engine system noise reduction technology demonstrations. RT&D programs include:

Research and Technology

- Combustion Noise Characterization
- Jet Noise Suppressors
- Forward Velocity Effects on Jet Engine Exhaust Noise
- Fan/Compressor/Turbine Noise Reduction
- Internal Noise Transmission through Turbines and Nozzles
- Flow Interaction/Propulsive-Lift Noise

Demonstration Programs and Systems Studies

- Refan Program
- New CTOL (Subsonic) Propulsion Studies
- Quiet, Clean, Short-Haul Experimental Engine (QCSEE)
- Quiet, Clean General Aviation Turbofan (QCGAT).

Ames Research Center, Mountain View, California, has the responsibility for investigating unique noise problems associated with STOL, VTOL and rotorcraft. In addition, unique test facilities at Ames, primarily the 40 x 80 ft. low speed tunnel, make possible large scale tests simulating flight effects on noise. RT&D Programs for which Ames is taking the lead include:

Research and Technology

- Helicopter Rotor Noise Control
- Noise Shielding

Demonstration Programs and Systems Studies

- STOL Aircraft Operational Systems
- Quiet Propulsive Lift Technology
- Rotorcraft/VTOL Aircraft Operational Systems

- Rotor Systems Research Aircraft (RSRA)
- Tilt Rotor Research Aircraft (TRRA).

Jet Propulsion Laboratory, Pasadena, California, conducts noise research in the areas of jet noise fundamentals, correlation of far field measurements with internal noise sources, and flight effects on jet noise. In the time frame of this report, JPL is involved with NASA's Combustion Noise Characterization program, which is also being conducted at Lewis Research Center and also with NASA's Aerodynamic Noise of Airframes program in conjunction with Langley and Ames Research Centers.

Wallops Flight Center, Wallops Island, Virginia, has no noise research responsibilities, but is a convenient base for flight noise measurements and has an instrumented noise range used for this purpose primarily in connection with Langley Research Center flight research programs. Currently, the CTOL (Subsonic) Flight Operational Procedures program is being conducted at Wallops.

Dryden Flight Research Center, Edwards, California, also has no noise research responsibilities at present, but has served to support full scale flight experiments in which noise suppressors were tested. The YF-12 research aircraft was tested with an advanced noise suppressor in FY 76. In the past Dryden has studied approach and take-off noise levels of business jets for a number of operational procedures and airframe noise investigations for various size aircraft in full scale flight experiments.

Noise RT&D activities at the several NASA Research Centers are complementary and coordinated, utilizing available research personnel and research facilities to greatest advantage. Funding and manpower of the NASA aviation RT&D program is summarized in Table 3-1 for the entire agency, rather than by Research Center. Appendix B describes the principal noise research, technology and demonstration projects and associated resources.

Table 3-1

Funding and Manpower Summary,
National Aeronautics and Space Administration

Category	1975	1976	1977	1978
	Fiscal Year Funding in $1,000 (Agency Manpower in Man-Years)			
Research and Technology				
Propulsion Noise	2,943	3,433	3,982	4,460
	(80)	(106)	(116)	(118)
Rotor Noise	178	1,300	1,141	1,272
	(7)	(11)	(19)	(13)
Interior Noise	617	339	701	653
	(7)	(6)	(9)	(14)
Airframe Noise	1,324	2,371	2,702	2,815
	(20)	(44)	(59)	(53)
Noise Prediction Technology	228	172	410	283
	(8)	(4)	(8)	(6)
Atmospheric Propagation and Ground Effects	489	369	549	481
	(12)	(12)	(14)	(16)
Other	321	276	317	293
	(3)	(6)	(3)	(7)
Subtotal	6,100	8,260	9,802	10,257
	(137)	(189)	(228)	(227)

Table 3-1 (Continued)

Category	Fiscal Year Funding in $1,000 (Agency Manpower in Man-Years) 1975	1976	1977	1978
Demonstration Programs and Systems Studies				
CTOL (Subsonic)	3,500	732	148	163
	(50)	(1)	(1)	(1)
CTOL (Supersonic)	-	662	1,409	2,729
	(-)	(10)	(8)	(8)
STOL	7,000	2,107	644	303
	(98)	(30)	(39)	(33)
Rotorcraft/VTOL	-	790	110	130
	(-)	(11)	(7)	(2)
General Aviation	-	808	1,100	1,327
	(-)	(11)	(8)	(8)
Subtotal	10,500	5,099	3,411	4,652
	(148)	(63)	(63)	(52)
TOTAL	16,600	13,359	13,213	14,909
	(285)	(252)	(291)	(279)

3.2 DEPARTMENT OF DEFENSE

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

Military aircraft operations are not required to meet civil aircraft noise certification requirements and cannot always be consistent with guidelines on noise control. DOD has, however, recognized its responsibility to develop cleaner burning, quieter operating aircraft that do not compromise performance requirements and thus do not sacrifice military mission capability and efficiency.

The most pressing DOD problem regarding national aviation noise research and that given the highest priority is the reduction of aircraft noise where community reaction is unfavorable. DOD is including increasing community involvement in its decision-making process to realign base flying missions and bed down newly operational aircraft at existing bases. This has required DOD to develop standardized methodologies for dealing with and predicting environmental, economic, and social parameters of such mission decisions. Considerable research and development funds have been invested in attempting to resolve community impact problem areas associated with aircraft. Research in community reaction to noise has become a mature technology resulting in noise prediction models that are routinely applied to environmental assessments. These models have been successfully adopted by the civilian sector and will be applied eventually on an international basis, thus providing a technical-legal baseline for assessing aircraft noise impact.

Aviation activities, and the concern relative to noise emissions resulting from these activities, are a significant aspect of the missions of the three component military departments of DOD, the Departments of the Air Force, the Army, and the Navy (which includes the Marine Corps). The aviation noise RD&D programs of each of these departments are presented in the following subsections. A funding summary for DOD which includes the Army, Navy and Air Force is shown in Table 3-2. Program activities and funding for the DOD aviation noise RT&D are included in Appendix C. Discussions of the component organizations of DOD follow.

TABLE 3-2
Funding Summary, Department of Defense
(Air Force, Army, and Navy)

CATEGORY	Fiscal Year Funding ($1,000) 1975	1976	1977	1978
RESEARCH AND TECHNOLOGY				
PROPULSION NOISE	1,510	874	433	319
ROTOR NOISE		14	695	610
AIRFRAME NOISE	63	208	76	32
NOISE PREDICTION TECHNOLOGY	22	410	703	658
TOTAL	1,595	1,506	1,907	1,619

Department of the Air Force

During the report period, the Air Force has undertaken the following aviation noise RT&D programs:

Research and Technology

- Supersonic Jet Exhaust Noise Investigation (Density Model)
- Supersonic Jet Exhaust Noise Investigation (Velocity Model)
- Sound Transmission through Supersonic Jets
- Duct Acoustics Research
- Noise Suppression in Jet Inlets
- Validation of Aircraft Noise Exposure Prediction Procedures
- Excess Sound Attenuation Model
- Measurement, Prediction and Evaluation of Bioenvironmental Noise in Support of Air Force Systems and Operations
- Computerized Procedure to Assess Turbine Engine Noise/Performance Tradeoffs
- Acoustics Research
- Noise and Sonic Fatique of High Lift Devices
- Acoustics of Transonic Walls.

Funding levels for these activities are listed in Table 3-3, while Appendix C describes the programs, which are conducted largely under university grants and industry contracts.

TABLE 3-3
Funding Summary, Department of the Air Force

	Fiscal Year Funding ($1,000)			
	1975	1976	1977	1978
Research and Technology				
Propulsion Noise	315	76	62	68
Airframe Noise	63	188	66	22
Noise Prediction Technology	22	378	383	366
TOTAL	400	642	511	456

Department of the Army

The Army depends upon helicopter operations to provide a significant part of the firepower and mobility required to win the land battle. Helicopter noise, however, poses a major limitation in the effectiveness of certain types of combat operations, degrades crew performance and is a source of environmental noise pollution at Army installations.

During the report period the Army has undertaken aviation noise RT&D in the following areas:

Research and Technology

- Propulsion System Noise
- Helicopter Rotor Noise
- Helicopter Noise Propagation, Prediction and Mitigation.

Funding levels for these activities are shown in Table 3-4 while Appendix C describes the investigations.

Department of the Navy

During the report period the Navy has undertaken aviation noise RT&D in the following areas:

Research and Technology

- Jet Engine Ground Run-up Noise Suppression
- Airframe Noise Investigation, using an Anechoic Flow Facility
- Naval Air Facilities Noise Prediction.

Funding levels for these activities are shown in Table 3-5, while Appendix C describes the investigations.

TABLE 3-4
Funding Summary, Department of the Army

CATEGORY	Fiscal Year Funding ($1,000) 1975	1976	1977	1978
RESEARCH AND TECHNOLOGY				
PROPULSION NOISE			71	86
ROTOR NOISE		14	695	610
NOISE PREDICTION TECHNOLOGY		32	160	172
TOTAL		46	926	868

TABLE 3-5
Funding Summary, Department of the Navy

CATEGORY	Fiscal Year Funding ($1,000) 1975	1976	1977	1978
RESEARCH AND TECHNOLOGY				
PROPULSION NOISE	1,195	798	300	165
AIRFRAME NOISE		20	10	10
NOISE PREDICTION TECHNOLOGY			160	120
TOTAL	1,195	818	470	295

3.3 DEPARTMENT OF TRANSPORTATION

The Department of Transportation (DOT) was created by the authority of the Department of Transportation Act of 1966 (PL 89-670, October 15, 1966). Section 4 of the Act outlines the responsibilities of the Secretary of Transportation, which include those to

> "promote and undertake research and development relating to transportation, including noise abatement. . . ."

To accomplish these basic mission goals and other specific congressional mandates, DOT is expected to integrate noise control into its policy, program criteria, and project requirements.

DOT's responsibilities relative to aviation noise RT&D programs are presently carried out by the Federal Aviation Administration (FAA). The FAA derives its authority to conduct aircraft noise research from the Federal Aviation Act of 1958. This Act was amended in July 1968 by Public Law 90-411, which established the responsibility of the FAA for control and abatement of aircraft noise.

In addition to its responsibility for the development, promulgation, and enforcement of Federal aircraft noise regulations, FAA funds selected aviation noise research activities and noise technology demonstration programs. During the report period the FAA has undertaken the following aviation noise RT&D programs:

Research and Technology

- Jet Noise Research
- Core Engine Noise Control
- Aircraft Source Noise Data Base
- Atmospheric Attenuation, Data Acquisition

Demonstration Programs and Systems Studies

- Jet Noise Suppression for CTOL (Subsonic)

Funding levels for these activities are listed in Table 3-6, while Appendix D describes each project.

TABLE 3-6
Funding and Manpower Summary,
Department of Transportation
(Federal Aviation Administration)

CATEGORY	Fiscal Year Funding ($1,000) (Agency Manpower in Man-Years) 1975	1976	1977	1978
RESEARCH AND TECHNOLOGY				
PROPULSION NOISE	700	917	770	
NOISE PREDICTION TECHNOLOGY	95	86		
DEMONSTRATION PROGRAMS AND SYSTEMS STUDIES				
CTOL (SUBSONIC)	164	250	950	1,730
TOTAL	959 (6)	1,253 (5)	1,720 (5)	1,730 (4)

3.4 ENVIRONMENTAL PROTECTION AGENCY

The Environmental Protection Agency (EPA) was established in the Executive Branch of the Federal Government as an independent agency pursuant to Reorganization Plan No. 3 of 1970. EPA's mission is to abate and control pollution systematically by integration of a variety of research, monitoring, standard-setting, and enforcement activities.

EPA derives its noise control authority primarily from the Noise Control Act of 1972 (PL 92-574, October 1972). The Noise Control Act of 1972 amends Section 611 of the Federal Aviation Act of 1958 (49 U.S.C. 1431; 82 Stat. 395) to include the concept of "health and welfare" and to define the responsibilities of and interrelationships between the Federal Aviation Administration (FAA) and EPA in the control and abatement of noise. Under Section 7 of the Noise Control Act, EPA is required to study the adequacy of present aircraft noise emissions standards (including recommendations on retrofit); implications of achieving levels of cumulative noise exposure around airports; and additional measures available to airport operators and local governments to control noise. The FAA's power to prescribe and amend aircraft noise measurement and noise emission regulations under Section 611 of the Federal Aviation Act of 1958 is preserved. However, EPA is required to submit recommendations for regulations to FAA that EPA feels necessary to protect the public health and welfare. A detailed process for public dissemination of information regarding FAA's action on EPA's recommendations is specified. Section 14 of the Noise Control Act defines EPA's primary responsibilities relative to noise abatement and control research programs and authorizes the Administrator of EPA to complement as necessary the noise research efforts of other Federal agencies by conducting and financing research on the effects, measurement, and control of noise.

EPA has the responsibility, in accordance with its mandate, to propose aviation noise regulatory actions, to be aware of, to encourage, and to conduct, as appropriate, research on aviation noise evaluation and control for the purpose of providing protection to the public health and welfare. The agency does not plan to undertake aviation noise RT&D on a broad scale, relying instead on other Federal agencies to conduct the necessary activities. Accordingly, the EPA has no aviation noise RT&D program as such at this time; its sole action in this area has been to transfer funds and provide guidance to NASA to accelerate research and demonstration of advanced low-noise propeller concepts for general aviation aircraft. Funding is shown in Table 3-7, while Appendix E describes the activity.

TABLE 3-7
Funding and Manpower Summary,
Environmental Protection Agency

CATEGORY	Fiscal Year Funding ($1,000) (Agency Manpower in Man-Years)			
	1975	1976	1977	1978
RESEARCH AND TECHNOLOGY				
PROPULSION NOISE	-	-	-	100
	-	-	-	(-)*
TOTAL				100
				(-)*

* Less than 1 manyear.

3.5 DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT

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

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

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

Aviation noise is a significant factor in the contemporary urban environment across the nation. Local governments and legal institutions have frequently proved inadequate to deal with the expanding and intensified impact of aircraft noise. The Federal Government has funded research directed toward developing quieter aircraft engines for many years and the results have been promising. However, the new, more powerful engines still generate sufficient noise, particularly in light of increasing air traffic volumes, to create a serious impact in surrounding communities.

HUD has set noise standards applicable to its program approvals, the most recent of which are published in HUD Circular 1390.2, dated August 4, 1971, which established standards for new residential construction. Under this standard HUD discourages building structures in noise impacted areas by withholding funding support for structures planned on sites that are subject to unacceptable noise exposure.

The Department's activities in the area of environmental quality and environmental planning include development and implementation of HUD environmental policies and procedures, development of environmental assessment criteria, and coordination with other Federal departments and agencies with the Council on Environmental Quality (CEQ). Other environmental functions encompass development of strategies for the amelioration of environmental problems such as noise pollution. Emphasis is placed on environmental and land-use planning and environmental management practices. In the area of research, HUD is concerned with developing policies and techniques for land use and building construction practices.

HUD is not currently funding any research activities related directly to aviation noise abatement and control. HUD's current research activities in noise abatement through compatible land use planning and noise attenuating building practices are described in another report, Federal Research Development and Demonstration Programs in Transportation Noise, EPA 550/9-78-305, February, 1978.

4.0 ASSESSMENT

4.1 Introduction

This section contains the Panel's views on the federally sponsored aircraft noise abatement research, technology and technology demonstration (RT&D) program summarized in this report. It encompasses activities during Fiscal years 1975-1978 and future program plans. The Federal program has been examined as a whole and not merely by individual department or agency activities.

The Panel's primary objective was to assess the total program's adequacy and its contribution to basic knowledge and technology for aircraft noise abatement beyond that which could be realized by the application of existing technology. In this connection, the relationship and value of the program to the achievement of national aviation noise abatement goals was considered. Other Panel objectives were to evaluate research priorities within the program, and to decide whether there were deficiencies in scope or pace or any unnecessary duplication of effort. The product of the Panel's assessment is the group of conclusions and recommendations included in this section.

It is appropriate to note again here, as in the Introduction to this report, that the Panel confined its attention to research, new technology evolution and technology demonstration activities--in short, to those activities which provide a new or better technical basis for improvements in aircraft noise abatement. Other aspects of aircraft noise abatement, notwithstanding their great importance, were considered to be beyond the scope of this Panel assignment and were not addressed. Thus excluded were matters specifically related to the development and promulgation of regulations for aircraft noise certification and noise abatement procedures, as well as any actions taken by municipalities, airport operators, airlines and aircraft manufacturers to abate noise during the report period, inasmuch as these matters are not research, technology evolution nor technology demonstration.

4.2 Techniques Available for Aircraft Noise Abatement

The Panel accepted the conventional view of the different techniques available for aircraft community noise abatement:

1. Source control consisting of the application of basic design principles or special hardware to the engine/airframe combination which will minimize the generation and radiation of noise;

2. Path control consisting of the application of flight operational procedures which will minimize the generation and propagation of noise;

3. Airport Operations Control (Receiver control) consisting of the application of procedures at the airport or noise exposed communities including restrictions on the type and use of aircraft, preferential runway use and curfews on operations to reduce community noise exposure surrounding airports; and

4. Land use control consisting of the development or modification of airport surroundings for maximum noise compatible usage.

It was noted by the Panel that the largest portion of aviation noise abatement RT&D over the years has emphasized source control, although it was agreed that all four techniques together represent a system for noise abatement and that all techniques must be used in a balanced, cost-effective manner.

4.3 Source Noise Abatement Technology Use Considerations.

A considerable body of aircraft noise technology has been developed, much of it based on government sponsored RT&D. The actual use of this technology is governed by regulations and economics, and as in many technical areas, there is usually a significant time lag--frequently as much as ten years--between the emergence of new noise technology and its appearance in commercial aircraft service.

Industry has used noise reduction technology for compliance with Federal noise regulations and has embodied it in their design of derivative aircraft and new aircraft types to the maximum extent they believe economically justifiable in the competitive marketplace. Except for the introduction of the by-pass turbofan engine (which improved both noise and fuel economy) other source noise control technology used to date has been accompanied by additional costs, weight, and performance penalties. Furthermore, any noise margins between certification noise requirements and lower noise levels which may have been achieved in new aircraft types can be expected to be used up in derivative aircraft growth.

These practices are natural of course; it would be unreasonable to expect the aviation industry to apply noise technology beyond that needed for noise rule compliance when to do so would result in economic penalties of any magnitude. Therefore, greater noise reduction through more extensive use of existing noise reduction technology can be expected to occur only when required to meet more stringent noise regulations.

The Panel recognized that the growing importance of fuel conservation and rising fuel costs, together with continuing needs for emission reductions, increased safety and greater system reliability, are factors which must be properly accounted for in considering the suitability of noise technology applications. These factors also highlight the importance of seeking source noise control technology which enhance, not degrade performance.

The Panel noted the great importance of noise technology timing to support future aviation market needs and opportunities. To illustrate this, it was noted that future advanced aircraft types, particularly STOL, VTOL and the next generation SST aircraft, may eventually be developed for commercial use depending on the proper combination of circumstances. While it is difficult to predict when that time might come for any of these vehicle types, it is evident that the necessary prerequisite RT&D must be in hand before development decisions can be made.

In each case, strict requirements will exist for noise control and compatibility with noise environments where these aircraft would operate. Noise reduction technology will be vital for their successful development, and in the Panel's view thorough early RT&D planning and implementation is necessary in these areas to facilitate future development program decision making.

4.4 National Aviation Noise Abatement Goals

The Panel decided that in order to place the role of aviation noise abatement RT&D in correct perspective, it would be necessary to relate these activities to national aviation noise abatement goals or objectives. Both near term and longer range objectives (stated below) were therefore selected which are consistent with previously published recommendations by both EPA and FAA. It must be noted here that goals selected by the Panel for purposes of their assessment do not constitute an official position of the Federal government.

- Near term objective - To confine severe aircraft noise exposure contours (NEF >40 or $L_{dn}>75$) around U.S. airports to those areas included in the airport boundary or under the direct control of the airport proprietor by 1985.

- As a longer range objective - To confine aircraft noise exposure contours (NEF>30 or $L_{dn}>65$) within compatible land-use areas around airports by the end of this century.

The Panel considered the question of whether these objectives could be achieved. It was recognized that a thorough examination of this question would require an extensive analysis of a variety of scenarios with many variables including Federal noise regulations, airport boundaries and compatible land use assumptions, operational constraints including curfews, fleet size and composition by aircraft type, the availability and utilization of noise abatement technology, projections of air traffic growth, distribution and control, and a careful evaluation of the economic factors involved. Analyses of all these variables were not available to the Panel, so rather than attempt a quantitative evaluation, the Panel only considered probable trends and limiting assumptions.

The following observations and conclusions were made with respect to achieving the near term goal.

1. Present regulations (FAR 36) require that by 1985 all civil aircraft operating in the U.S.A. must comply with Stage 2 or Stage 3 noise levels, depending on aircraft type and certification application date.

2. As an upper limit case, it was observed that if the fleet noise were reduced simply by bringing current

noisy (Stage 1) aircraft into compliance with Stage 2 levels, this would have the effect of reducing by approximately 40 percent the noise impacted area at the NEF 40 level outside current boundaries of the country's aircarrier airports today. This action alone would therefore not achieve the near-term goal.

3. The FAA has projected moderate growth of civil aviation, by 1985, in the number of aircraft and the number of operations at airports. In this fleet growth, the fraction of aircraft meeting Stage 3 requirements would also increase relative to 1978. However, in the cumulative noise exposures used here to represent noise impact and goals, the increase in forecast operations would largely offset the effect of individual-event aircraft noise reductions, and result in no significant reduction in noise impacted area outside current airport boundaries compared to the upper limit case (2, above).

4. Noting the time lag between new technology emergence and application, the Panel considers it unlikely that any new technology for noise reduction made available within the last several years would find its way to any significant degree into the commercial aircraft fleet by 1985. And, if it should be introduced in new aircraft in the next few years, such new technology would have to affect a large fraction of existing aircraft in order to reduce projected cumulative noise exposure levels in 1985 to any significant extent.

5. The clear conclusion from the above considerations is that if the near-term noise abatement goal is to be achieved, it must require a combination of the four techniques described in Section 4.2, above, in a systems sense, not merely source noise control achieved by aircraft meeting Stage 2 and Stage 3 noise levels, or by any near-term applications of other new technology now available.

Panel observations and conclusions regarding the longer range goal are as follows:

1. The FAA has projected increases of more than 50 percent by the end of the century in the numbers of civil commercial aircraft, including substantial increases of commuter carrier operations. FAA has also projected up to 25 percent increases in the number of aircraft used in general aviation, including more than a five-fold increase in high performance turbojet/turbofan powered general aviation aircraft, and more than a two-fold increase in helicopters. Little major new airport construction is antici-

pated by the end of the century. Predictions of military aircraft fleet numbers and composition at the end of the century are more speculative, and no estimates of change were made for this assessment.

2. It is expected that the majority of aircraft added to the commercial fleet after 1985 will meet FAR 36 Stage 3 requirements and that by the end of the century a substantial portion of the entire civil fleet would meet those levels. No revisions to FAR 36 were assumed which would require lower noise levels for certification, or for operation. Such changes were not ruled out, but were recognized as being dependent on future assessments of all the factors involved in rule making including considerations of economic reasonability and appropriateness of using any improved new noise reduction technology which may become available. It is noted again (as in Section 4.3 above) that a more extensive use of available and future source noise abatement technology is not predicted unless regulations require it or unless it can be utilized without significant economic penalties.

3. Based on the foregoing considerations and assumptions, the Panel recognized that cumulative noise exposure indices within a given geographical area around busy U.S. airports could actually increase by the end of the century to values greater than those of 1985 due to increased aircraft operations, even if most aircraft met current FAR 36 Stage 3 noise requirements. As in the case of near-term goal, it was concluded that achieving the longer-range noise goal would require systematic use of all noise abatement techniques, not merely source noise control. A more thorough study of this issue is clearly in order.

4.5 Summary and Analysis of Agency Programs

4.5.1 NASA

The NASA program represents over 85 percent of the total Federal program. Source noise control of engines and airframes is the primary objective, with activities ranging from fundamental understanding of basic phenomena through engineering technology. Annual funding and in-house manpower levels have not varied substantially during the report period, but there have been shifts of emphasis, with a larger fraction of the effort now on research and technology evolution rather than large scale technology demonstrations.

1. Research and Technology Program Accomplishments in the report period are noted in the detailed program descriptions in Appendix B. Some of the major highlights are noted below:

Jet Noise. Wind tunnel tests of core and fan stream mixer nozzles indicate the potential for noise reduction with modest performance improvements on some existing engine types. Tests with a P&W JT8D engine indicated a noise reduction potential of approximately 4 dB.

An inverted velocity profile co-annular flow nozzle has been identified as a promising concept for future SST type applications. An empirical model prediction method for calculating the noise from co-annular jets, including flight effects, has been developed. The model also takes into account shock noise from both streams and the mixing noise from the merged and premerged regions.

In-flight jet exhaust noise predictions now can be performed more accurately by taking into account engine internally generated noise radiating from the exhaust.

Recent experience in which data were collected with multiple phase-match microphones have produced new insight into the generation, propagation and prediction of jet exhaust noise. There is evidence to indicate that the noise arises from a large number of highly directive, short duration sources in motion. These results have had an important influence on recent aeroacoustic noise theory development.

Fan Noise. The major cause of the difference between the noise signatures of fans tested statically on the ground and those obtained during flight has been found to be due to ingestion of turbulence that is near the ground. Inlet screens have been tested that show that ground test results now can be more accurately extrapolated to flight conditions. This research will lead to improved fan and acoustic treatment designs with less reliance on expensive flight tests.

Duct Liners. Acoustic liners with noise absorption properties which vary either in an axial direction or around the periphery of the duct are found to provide more noise reduction for a given weight or volume of liner than current liners which have uniform acoustical properties.

Core Noise. Combustor far-field noise from an engine was measured directly for the first time using correlation and coherence techniques. In addition, correlation measurements within an engine combustor were used to show that far-field combustor noise is related to the second time derivative of the combustor pressure.

Atmospheric Absorption. A study on atmospheric absorption was completed, verifying an existing analytical model up to 100,000 Hertz.

Noise Prediction of Aircraft. A computerized method for predicting flyover noise based on a knowledge of the aircraft configuration and its operating conditions is being developed for a wide variety of aircraft. A complete working system is now available for jet powered CTOL aircraft. Component noise sources can be modeled and then summed at the ground to obtain an estimate of the overall noise signature.

Acoustic Range. An acoustic range at Wallops Island has been developed for making a large number of simultaneous, time-synchronized acoustic measurements during aircraft flyover. It is being used for defining the ground noise footprint for evaluation of various noise abatement flight procedures and for validation of noise prediction methods.

Rotor Noise. Research to reduce helicopter blade slap noise showed that tip air-mass injection and ogee tip shape modifications have some noise reduction potential.

2. <u>Technology Demonstration Program Highlight Accomplishments</u> are noted below:

<u>QCSEE</u>. The Quiet, Clean, Short-Haul Experimental Engine (QCSEE) program objective is the evolution and demonstration of short-haul STOL propulsion technology for the 1980's but technology applications for conventional aircraft may exist. Test stand noise measurements for the QCSEE upper surface blowing engine configuration indicate high potential for the noise reduction features of the engine. Test data indicate, for example, that a 150,000 lb. STOL aircraft, fully utilizing the QCSEE technology, may achieve a noise footprint area less than 3 percent of a current CTOL aircraft of the same size. Tests on the QCSEE Under-the-Wing blown flap engine configuration are still in progress.

<u>REFAN</u>. The Refan program was completed, demonstrating the effectiveness of major modifications to the P&W JT8D engine in combination with balanced sound suppression nacelles, as a noise abatement retrofit option. Ground tests in a B-727 aircraft and flight tests in a DC9 aircraft were accomplished. This program provided the basis for subsequent industry-proposed derivative engine and airframe combinations.

<u>Noise Abatement Landing Approach</u>. A program demonstrating the effectiveness of two-segment landing path approach for community noise abatement was completed, involving the demonstration of the necessary airborne and ground electronics and realistic operational flight procedures in both DC-8 and B-727 aircraft. Any potential future applications will require satisfactory resolution of terminal area safety-related issues and terminal area instrument landing system decisions.

3. <u>Current and planned activities</u>.

Research and technology activities are continuing in each of the basic areas as outlined in Appendix B, and several areas of investigation deserve special comment.

In-flight effects on fan noise. A major augmentation of work in this area is being undertaken following the discovery, noted above, that inlet turbulence in ground static tests is a major factor introducing basic differences between ground and flight engine noise measurements. The current and projected effort includes a flight test program to provide new information on noise characteristics.

Correlation on the same engine with wind tunnel tests and with carefully controlled ground tests with turbulence controlling inlet screens will be investigated.

- Helicopter transmission noise. Design techniques for minimizing this noise source will be investigated in a cooperative program with the Army.

- Variable Cycle Engine technology. Previous system studies for defining superior advanced SST configurations emphasized noise reduction and fuel efficiency objectives. Variable cycle engine critical component testing has been initiated, and will provide major tests of co-annular inverted velocity profile noise suppression jet nozzles.

4. <u>Areas requiring further emphasis:</u>

- Forward velocity effects. The present effort emphasizes fan noise phenomena, but also needed is an extension of prior work related to jet noise (including suppressors) and core noise effects.

- Jet nozzles and noise suppressors. Additional effort on both subsonic and supersonic jet nozzles and noise suppressors is needed, particularly for mixer type and co-annular inverted velocity profile nozzles.

- Noise abatement operational techniques. Systems research in terminal area procedures involving advanced avionics and operational techniques should include additional emphasis on noise abatement.

4.5.2 DOD

The DOD program in aviation noise research and development has shown a relatively constant level of funding since FY 1975. The individual projects are directed at the priority areas of DOD activity including military mission capability and the effect of base operations on the community. Emphasis has been placed on source control of propulsion and rotor noise, and on problems relating to unique STOL designs. The earlier work addressed noise fundamentals and prediction methods, while a major emphasis currently is in Army sponsored research on helicopter rotor noise. During the report period studies related to path control, receiver control and land use were also undertaken.

1. Accomplishments during the report period are summarized in Appendix C. Several highlights are noted below:

Department of the Air Force

Jet Noise. Research on sound transmission from within a supersonic jet to the surroundings yielded information on directivity factors needed for evaluation of acoustical theories.

Duct Acoustics. Dependence of sound levels within aircraft engines upon duct geometry and sound absorbing properties, type of noise source, and flow within the duct were evaluated. Results are being used to develop mathematical models.

Noise Prediction. Techniques applicable to operational problems were developed. System studies of seven aircraft types were completed, and several RPV's were evaluated.

Department of the Army

Helicopter Transmission Noise. Tests completed to date evaluating propulsion system noise have shown that substantial reductions in transmission noise can be made by selective stiffening of present transmission cases and proper design of new cases.

Rotor Noise. In the area of rotor noise, methodology has been developed for calculating high frequency noise and a simplified scaling law based upon geometric parameters of the rotor. Prediction of helicopter noise is being assessed in a preliminary model. This model incorporates terrain effects and measured frequency signatures of various helicopters.

Department of the Navy

Ground Runup Suppressors. Two noise suppression systems for jet engine ground runup noise have been developed, the COANDA equipment and the Brauburgh dry system. These systems are being tested to meet the pressing problem associated with jet engine ground runup operations both in and out of airframes.

Rotor Noise. In cooperation with the U.S. Army, laboratory tests on 70 samples of helicopter noise have been completed.

2. Current and planned activities.

- Source control efforts need to be continued to support environmental as well as tactical mission needs.

- The DOD has a large inventory of helicopters in each of the departments and is likely to continue to maintain a large force. It is in their interest, for both personnel protection and mission security, to expand their activity in helicopter noise RT&D. Accomplishments in the helicopter and VSTOL areas could eventually lead to spin-offs to the commercial market.

- Continued aviation noise research in the path, receiver, and land-use control areas is required to support both tactical mission and environmental needs. Encroachment of civilian communities towards DOD aviation facilities as well as excessive noise of aircraft can pose a threat to the existence of present operational facilities.

3. Applications and actions.

This report is not intended to address applications of aviation noise RT&D. Nevertheless, the unique problem of the DOD military departments (maintaining effective military capabilities while minimizing environmental impact on communities) and their response to this problem warrant comment because this issue is somewhat different from that of civil aviation noise abatement, to which most of the work covered by Federal programs is directed. During the report period the DOD has developed noise measurement and noise isolation techniques and has predicted changes in operational procedures through the use of computer models, including the Air Installations Compatibility Use Zone (AICUZ). Through utilization of land use planning and cooperative programs with local jurisdictions, DOD has effectively modified operational procedures to meet standards. In the area of ground engine maintenance the use of engine test cells has received considerable attention.

4.5.3 DOT (FAA)

FAA under DOT, sponsors aviation noise research in support of regulatory responsibilities. Emphasis is placed on providing a data base from which to develop rulemaking, certification procedures, and compliance techniques for the control of aviation noise. The FAA has conducted jointly funded programs with industry to demonstrate the technological feasibility and economic reasonableness of specific projects which may be effective for the near term reduction of aircraft generated noise. Program funding during the reporting period, while increasing, reflects the high cost of a current demonstration project.

1. Accomplishments during the report period are summarized in Appendix D. Highlights from the various program elements are listed below:

Jet Noise. Results of contract research on high velocity jet noise have contributed to the data base used in developing proposed noise requirements for civil supersonic transport aircraft (NPRM 77-23).

Scale model tests of mixer nozzles (complimentary to the NASA work noted previously) showed favorable results. These tests were precursors to a mixer nozzle demonstration program with the P&W JT8D engine now being planned.

Core Noise. Engine core noise research provided data used in the development of FAR 36 Stage 3 noise level requirements for new aircraft type certification.

Helicopter Rotor Noise. Flight noise measurements are being used in current development of noise certification requirements.

2. Current and planned activities.

- With completion of recent core and jet noise research contracts, FAA plans to depend more heavily on NASA for future research and technology in these areas, but will continue to review and study available technology on source noise control in search of methods which are economically reasonable, technically practical and suitable for air worthiness certification. Practical application and demonstration of such technology will be considered.

- Expansion of aircraft noise data base and aircraft noise prediction capabilities will be continued.

- A full scale static and flight test technology demonstration program for mixer nozzles is planned with the JT8D engine in FY 78/79. Objectives include both reduction and performance improvement.

- With respect to path control options, efforts to improve the FAA Integrated Noise Model accuracy by use of improved atmospheric and ground effects data will be continued. NASA propagation research results will be integrated with the work.

4.5.4 EPA

The EPA, through its Office of Noise Abatement and Control (ONAC), is principally a user of the research and technology results generated by the other Federal agencies. These results help provide the basis for the aviation noise regulatory actions proposed to the FAA. In this respect, studies are sponsored or conducted by ONAC to support its regulatory proposals and to identify future needs. These regulatory support noise control studies are not described in this panel report since they are not considered to be research or technology development programs.

Section 14 of the Noise Control Act authorized EPA to conduct or finance research by contract to complement, as necessary, the noise research programs of other agencies. In the past, EPA has elected not to request RT&D funding but to depend upon the resources and research commitments of other agencies (NASA, DOT, DOD, and HUD) to provide support for their regulatory activities. A recent exception stemmed from their anticipation of future noise problems from propeller driven general aviation aircraft. Because of this, EPA initiated a joint program with NASA in FY 1978 for research and demonstration testing of low noise, efficient propellers for future aircraft. This program supplements previous work done by NASA and provides for an accelerated demonstration program. Despite this exception, EPA believes that RT&D programs pertaining to the source, path, and receiver control of aircraft noise should be the responsibility of the agencies having the most experience and direct involvement in the particular subject matter. However, EPA believes that they should continue to be involved in an advisory capacity in the planning, monitoring, and evaluation of the RT&D programs.

4.5.5 HUD

HUD has been de-emphasizing noise research. However, there is a role for HUD in the aviation noise control picture. This is particularly so in light of the recognized limitations to source control technology. HUD has the potential for influencing land use and building construction. Major changes in building construction techniques will occur as a result of energy utilization requirements. These changes must be compatible with aviation noise requirements and goals. Cost-effective building construction and land-use policies and practices must be developed if there is to be adoption into the marketplace.

The only RT&D aircraft noise control programs that appear appropriate to HUD's mission would lie within the receiver control option, and would pertain to land use controls and to noise-insulation and vibration-isolation techniques in building construction. However, that type of noise technology research would be pertinent not only to aircraft but to surface transportation, construction equipment, factories, etc., as well. HUD is conducting such RT&D, and the programs are described and assessed in the Federal Interagency Surface Transportation Noise Research Panel report and will not be repeated here.

4.6 Program Assessment

In reviewing the Federally sponsored aviation noise research technology evolution and technology demonstration program as a whole, the Panel made the following assessment:

1. Scope: All areas of source noise that have been identified are being investigated in the various research and technology programs.

2. Priorities: In terms of application importance, noise reduction for commercial aviation should continue to have the highest priority, followed by general aviation, rotary wing and VSTOL aircraft requirements. Although the priorities of the present program are not specifically stated nor always clearly seen, the priorities as evidenced by internal program emphasis and funding seem reasonable. The needs for military aircraft noise abatement should be accorded high priority by DOD to insure ever-improved compatibility with community noise requirement around military installations.

   - With respect to noise control option priorities, the Panel judged that highest priority should still be given to source noise control, since it appears that there are still significant needs and opportunities for reducing source noise. These include propulsion system improvements and also airframe noise reduction benefits (at least for large aircraft). Path control including atmospheric propagation and ground effects phenomena should also be continued with high priority.

   - With respect to specific source noise control topics, flight effects on noise, core noise phenomena, airframe noise, and helicopter rotor and transmission noise were viewed as having highest priorities.

3. Timing: As noted previously, noise RT&D planning and implementation timing is essential to prepare for future new aircraft type development decisions. The panel felt that this fact is, in general, properly accounted for in the Federal program (which is largely the NASA program in this regard), partiularly with respect to the advanced SST and for STOL, though less evident for VTOL.

4. Duplication: It is apparent that NASA, DOT/FAA and DOD have pursued similiar objectives within several of the same areas of noise RT&D, particularly in jet noise and helicopter noise. Examination of the individual activities did not reveal any repetition or actual duplication in the work, however. Many of these are cooperative programs. Insofar as could be determined all projects in areas of common interest have been complementary, each seeking incremental knowledge or specific technology for a special agency purpose.

5. Planning and Review: Each of the Federal agencies, NASA, DOD, and FAA, uses a number of processes to identify aviation noise RT&D needs and to establish RT&D plans. As an example, NASA solicits the ideas of industry, universities, and the other Federal agencies and holds technology workshops on special topics to bring experts together to discuss future needs. All three Federal organizations develop future research plans which are regularly reviewed and updated.

6. Interagency Coordination: Interagency coordination of programs was judged to be satisfactory, at least in areas of common interest or mutual high priority for more than one agency. Two instances of good coordination are noteworthy. The first is in the area of jet noise research which has been undertaken by NASA, DOT/FAA and the Air Force. The second is in helicopter rotor research which is being investigated cooperatively by NASA and the Army.

   - It was also noted that the reactivated Federal Interagency Aviation Noise Research Panel itself has, through the current review, fulfilled an important need for interagency program coordination, and it is recommended that the function be continued in the future.

7. Technical Assesment: On balance, the Panel judged the aviation noise RT&D program to have been basically adequate during the report period, and the reported accomplishments were considered good. No breakthroughs in understanding or technology came to light during the report period which will in themselves provide major changes in future expectations for aircraft noise abatement.

Accomplishments were generally more of an evolutionary nature and added to the country's ability to achieve incremental noise abatement for the future more efficiently and economically than in the past. The Panel endorsed ongoing programs and plans with certain recommendations which are noted in the following Section.

4.7 Conclusions and Recommendations

The Panel concluded its assessment with the following conclusions and recommendations:

1. If the postulated near-term and longer-range national aviation noise abatement goals are to be achieved circa 1985 and 2000, respectively, they will not likely be achieved merely by projected individual aircraft compliance with FAR 36 Stage 2 and Stage 3 levels, nor by additional improvements in source noise reductions affecting only a limited number of aircraft making up the total fleet. Instead, noise goal achievement will require the exercise of all four noise control options (source, path, airport operations and compatible land use), ideally in an optimal systems sense, so that maximum benefits can be achieved soonest with lowest costs. Systems studies, of the type FAA is now undertaking, are strongly endorsed, since these can explore the nature of optimal solutions considering a range of scenarios and variables. Such studies are important for future agency planning of noise abatement RT&D as well as future regulatory and implementation requirements, and to place the relative roles and importance of the four noise control options in better perspective.

2. It is important that aviation source noise reduction RT&D be pursued vigorously, not just because of the major role source control will probably continue to play, but also in recognition of the inevitable time-lag which exists between technology discoveries and technology implementation. The Panel noted that RT&D costs are minor compared to the costs of noise regulation compliance and to the potential costs of court judgments rendered against noise offenders.

3. Current and future noise reduction RT&D activities must continue to strive for results which bring maximum cost effectiveness or minimum economic penalties in their applications, to make the technology more attractive for voluntary use by industry as well as for noise rulemaking by government. The growing importance of fuel conservation and rising fuel costs, together with continuing needs for emission reductions, increased safety and greater system reliability, are factors which must be properly accounted for in considering the suitability of noise technology applications.

4. The Panel noted that the scope and content of the total program seemed basically adequate, but that there were several areas in which additional resources should be applied. While recognizing the usual problem of fiscal budgetary limitations, they recommend augmentations in the areas of flight effects on noise, jet noise and suppressors, and aircraft operational techniques for noise abatement.

5. Timing of noise research to support future development decisions on possible new civil aircraft types, including STOL, VTOL and an advanced SST, is very important. The agencies (principally NASA and DOT/FAA) should carefully examine projected noise RT&D planning against desired technology readiness goals for future aircraft types.

6. The Panel recommends that NASA more completely study the question of feasible "noise floors" which represent, at any particular time, assessments of the limits of practicability of achievement in source noise control; and that they update their assessment periodically. It was recognized that statements of "noise floors" can be misunderstood or misused by those not familiar with the physical bases involved; nevertheless such estimates could have great value for long range planning and realistic assessment of future goals.

7. The relative roles and significance of single-event noise exposures versus cumulative exposures in assessing aviation noise impact and in setting noise abatement research goals should be re-examined.

APPENDIX A

SUMMARY TABLES

AVIATION NOISE RT&D FUNDING AND MANPOWER

This appendix presents summary tables of aviation noise RT&D program funding for the National Aeronautics and Space Administration; the Department of Defense, including the Departments of the Air Force, the Army, and the Navy; the Department of Transportation; and the Environmental Protection Agency for fiscal years 1975 through 1978. The Department of Housing and Urban Development reported no ongoing aviation noise RT&D programs in the relevant period. Aviation noise funding is summarized first by agency in total and then by program category and agency in Tables A-1 and A-2.

Funding figures for the National Aeronautics and Space Administration (NASA), the Department of Transportation (DOT), and the Environmental Protection Agency (EPA), are exclusive of agency manpower. Consequently, Table A-1 includes manpower figures for these agencies in parentheses, and these manpower figures should be considered additional to the funding figures shown. Manpower figures for NASA are also shown in parentheses in Table A-2. DOT, however, reported total manpower only, and, as a result, their manpower could not be identified by program category in Table A-2.

Funding for FY 76 includes the transition quarter (July 1, 1976 to September 30, 1976). Funding cited for FY 77 and FY 78 includes estimates. Projects for FY 78 have not been finalized.

TABLE A-1
SUMMARY OF AVIATION NOISE RT&D FUNDING
AND MANPOWER BY AGENCY

AGENCY	Fiscal Year Funding in $1,000* (Agency Manpower in Man-Years) 1975	1976	1977	1978
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION	16,600 (285)	13,359 (252)	13,213 (291)	14,909 (279)
DEPARTMENT OF DEFENSE				
• DEPARTMENT OF THE AIR FORCE	400	642	511	456
• DEPARTMENT OF THE ARMY		46	926	868
• DEPARTMENT OF THE NAVY	1,195	818	470	295
SUBTOTAL: DEPARTMENT OF DEFENSE	1,595	1,506	1,907	1,619
DEPARTMENT OF TRANSPORTATION	959 (6)	1,253 (5)	1,720 (5)	1,730 (4)
ENVIRONMENTAL PROECTION AGENCY				100 (-) †
TOTAL	19,154 (291)	16,118 (257)	16,840 (296)	18,358 (283)

* DOD funding data includes manpower costs.

† Less than 1 man-year

TABLE A-2
SUMMARY OF AVIATION NOISE RT&D FUNDING
AND MANPOWER BY PROGRAM CATEGORY AND AGENCY

CATEGORY	Fiscal Year Funding in $1000 (Agency Manpower in Man-Years) 1975	1976	1977	1978
RESEARCH AND TECHNOLOGY				
PROPULSION NOISE				
. NATIONAL AERONAUTICS AND SPACE ADMINISTRATION	2,943 (80)	3,433 (106)	3,982 (116)	4,460 (118)
. DEPARTMENT OF DEFENSE	1,510	874	433	319
. DEPARTMENT OF TRANSPORTATION	700	917	770	
. ENVIRONMENTAL PROTECTION AGENCY				100 (-)*
SUBTOTAL: PROPULSION NOISE	5,153 (80)	5,224 (106)	5,185 (116)	4,879 (118)
ROTOR NOISE				
. NATIONAL AERONAUTICS AND SPACE ADMINISTRATION	178 (7)	1,300 (11)	1,141 (19)	1,272 (13)
. DEPARTMENT OF DEFENSE		14	695	610
SUBTOTAL: ROTOR NOISE	178 (7)	1,314 (11)	1,836 (19)	1,882 (13)

* Less than 1 man-year.

TABLE A-2 (Continued)

CATEGORY	Fiscal Year Funding in $1000 (Agency Manpower in Man-Years) 1975	1976	1977	1978
INTERIOR NOISE				
• NATIONAL AERONAUTICS AND SPACE ADMINISTRATION	617 (7)	339 (6)	701 (9)	653 (14)
AIRFRAME NOISE				
• NATIONAL AERONAUTICS AND SPACE ADMINISTRATION	1,324 (20)	2,371 (44)	2,702 (59)	2,815 (53)
• DEPARTMENT OF DEFENSE	63	208	76	32
SUBTOTAL: AIRFRAME NOISE	1,387 (20)	2,579 (44)	2,778 (59)	2,847 (53)
NOISE PREDICTION TECHNOLOGY				
• NATIONAL AERONAUTICS AND SPACE ADMINISTRATION	228 (8)	172 (4)	410 (8)	283 (6)
• DEPARTMENT OF DEFENSE	22	410	703	658
• DEPARTMENT OF TRANSPORTATION	95	86		
SUBTOTAL: NOISE PREDICTION TECHNOLOGY	345 (8)	668 (4)	1,113 (8)	941 (6)
ATMOSPHERIC PROPAGATION AND GROUND EFFECTS				
• NATIONAL AERONAUTICS AND SPACE ADMINISTRATION	489 (12)	369 (12)	549 (14)	481 (16)
OTHER				
• NATIONAL AERONAUTICS AND SPACE ADMINISTRATION	321 (3)	276 (6)	317 (3)	293 (7)
SUBTOTAL: RESEARCH AND TECHNOLOGY	8,490 (137)	10,769 (189)	12,479 (228)	11,976 (227)

TABLE A-2 (Continued)

CATEGORY	Fiscal Year Funding in $1000 (Agency Manpower in Man-Years) 1975	1976	1977	1978
DEMONSTRATION PROGRAMS AND SYSTEMS STUDIES				
CTOL (SUBSONIC)				
. NATIONAL AERONAUTICS AND SPACE ADMINISTRATION	3,500 (50)	732 (1)	148 (1)	163 (1)
. DEPARTMENT OF TRANSPORTATION	164	250	950	1,730
SUBTOTAL: CTOL (SUBSONIC)	3,664 (50)	982 (1)	1,098 (1)	1,893 (1)
CTOL (SUPERSONIC)				
. NATIONAL AERONAUTICS AND SPACE ADMINISTRATION	- (-)	662 (10)	1,409 (8)	2,729 (8)
STOL				
. NATIONAL AERONAUTICS AND SPACE ADMINISTRATION	7,000 (98)	2,107 (30)	644 (39)	303 (33)
ROTORCRAFT/VTOL				
. NATIONAL AERONAUTICS AND SPACE ADMINISTRATION	- (-)	790 (11)	110 (7)	130 (2)
GENERAL AVIATION				
. NATIONAL AERONAUTICS AND SPACE ADMINISTRATION		808 (11)	1,100 (8)	1,327 (8)
SUBTOTAL: DEMONSTRATION PROGRAMS AND SYSTEMS STUDIES	10,664 (148)	5,349 (163)	4,361 (63)	6,382 (52)
TOTAL: ALL RT&D PROJECTS	19,154 (291)*	16,118 (257)*	16,840 (296)*	18,358 (283)*

* Includes total manpower for DOT/FAA; individual project manpower was not reported.

APPENDIX B

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

AVIATION NOISE RT&D PROGRAMS

This appendix describes NASA's aviation noise program in terms of research and technology and demonstration programs and systems studies projects. Where more than one NASA research center is listed as a project sponsor, the first named is the primary sponsor.

NASA funding figures are exclusive of manpower; therefore, manpower figures, in man-years, are included in parentheses below the fiscal year funding for each project and should be recognized as additional costs. Funding for FY 76 includes the transition quarter (July 1, 1976 to September 30, 1976). Funding cited for FY 77 and FY 78 includes estimates. Projects for FY 78 have not been finalized.

FUNDING AND MANPOWER SUMMARY,

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

CATEGORY	Fiscal Year Funding in $1000 (Agency Manpower in Man-Years) 1975	1976	1977	1978
RESEARCH AND TECHNOLOGY				
PROPULSION NOISE	2,943	3,433	3,982	4,460
	(80)	(106)	(116)	(118)
ROTOR NOISE	178	1,300	1,141	1,272
	(7)	(11)	(19)	(13)
INTERIOR NOISE	617	339	701	653
	(7)	(6)	(9)	(14)
AIRFRAME NOISE	1,324	2,371	2,702	2,815
	(20)	(44)	(59)	(53)
NOISE PREDICTION TECHNOLOGY	228	172	410	283
	(8)	(4)	(8)	(6)
ATMOSPHERIC PROPAGATION AND GROUND EFFECTS	489	369	549	481
	(12)	(12)	(14)	(16)
OTHER	321	276	317	293
	(3)	(6)	(3)	(7)
SUBTOTAL: Research and Technology	6,100	8,260	9,802	10,257
	(137)	(189)	(228)	(227)

NASA FUNDING AND MANPOWER SUMMARY (Continued)

CATEGORY	Fiscal Year Funding in $1000 (Agency Manpower in Man-Years) 1975	1976	1977	1978
DEMONSTRATION PROGRAMS AND SYSTEMS STUDIES				
CTOL (Subsonic)	3,500	732	148	163
	(50)	(1)	(1)	(1)
CTOL (Supersonic)	-	662	1,409	2,729
	(-)	(10)	(8)	(9)
STOL	7,000	2,107	644	303
	(98)	(30)	(39)	(33)
ROTORCRAFT/VTOL	-	790	110	130
	(-)	(11)	(7)	(2)
GENERAL AVIATION	-	808	1,100	1,327
	(-)	(11)	(8)	(8)
SUBTOTAL: Demonstration Programs	10,500	5,099	3,411	4,652
	(148)	(63)	(63)	(52)
TOTAL: All Programs	16,600	13,359	13,213	14,909
	(285)	(252)	(291)	(279)

CATEGORY - COMBUSTION NOISE

Combustion Noise Characterization

The nature of combustion generated noise is being investigated through suitably designed experiments on engine combustors operating both in-situ and in development test facilities. This is a relatively new technology area, and a significant aspect of the current program is the design of the experiments and instrumentation to make meaningful measurements. Also, because of the complexity of combustor systems and of the physics of the combustion process therein, mathematical modeling is virtually impossible. This makes the work inherently experimental.

Need for Study: Existing experimental data indicate that for many propulsion systems the engine core can be a significant contributor to the total engine noise signature after fan and jet noise are reduced, and in the case of some unique systems such as a duct burner. Work in this area is necessary to improve the prediction methodology and to understand the nature of the generation process with an ultimate goal of effecting noise reduction.

Approach: The work is conducted both in-house and by contract. The most pertinent data are obtained from in-situ engine tests. In-situ engine tests are expensive due to the problems of installing probes in the combustor, and because of the high operational costs of engines. Combustor noise tests are therefore often piggybacked onto other engine and component research tests. Because component tests are less expensive and more suited to parametric investigations, significant attention is being paid to the relationship between measurements made in-situ and in component development rigs.

Engine tests are used to contribute to a reliable data base on far-field noise generation. Pioneering measurements are also being made using signal analysis (correlation, coherence) techniques between pairs of simultaneously obtained signals within the combustor and between the combustor and far-field.

If the relationship between engine internal measurements and component rig measurements can be reliably established, it will become possible to conduct component rig parametric investigations into the nature and physics of combustor noise generation. This in turn may lead to an assessment of the possibility of combustor noise reduction through design.

Schedule: Combustion noise studies were initiated in 1973 with a grant to the Georgia Institute of Technology. This was followed by contracts to both General Electric and Pratt and Whitney Aircraft for component rig tests.

Combustion Noise Characterization (Continued)

Contract procurement was initiated in FY 78 for combustor noise tests on a CF6 engine. These tests will entail simultaneous internal and far-field measurements.

Accomplishments: Extensive combustor noise measurements in component test rigs have been obtained by General Electric and by Pratt and Whitney by contract addenda to the Experimental Clean Combustor Program (ECCP).

An in-house program has been completed using the Lycoming YF-102 engine wherein simultaneous internal and far-field measurements were made. This program saw the successful development of instrumentation technology to obtain combustor fluctuating internal pressures in-situ. Correlation and coherence signal analysis techniques were used in pioneering measurements to discriminate combustor-associated noise in the total engine far-field noise signature. Such signal analysis techniques have also shed new light on the nature of the combustor noise source characteristics.

Acoustic data have also been obtained with the YF-102 combustor in the Lycoming component test rig. These data presently are being analyzed and will be compared with the previously obtained engine data using identical near-field instrumentation and air flow rates. The results of these investigations have influenced and guided the procurement of the CF6 test program.

Sponsor: Lewis Research Center and Jet Propulsion Laboratory

Fiscal Year:	1975	1976	1977	1978
Funding ($1000):	82	160	100	96
Agency Manpower (Man-Years):	2	5	3	3

NASA - RESEARCH AND TECHNOLOGY PROGRAMS

CATEGORY - PROPULSION NOISE

Jet Noise and Suppressors

This program is directed at building the technology base for reducing aircraft jet engine exhaust noise. The emphasis is on basic research into the relationships between jet flow processes and the near- and far-field jet flow noise characteristics. Improved understanding of basic mechanisms is expected to lead to new noise reduction concepts.

Need for Study: In present subsonic aircraft, the propulsion noise sources (engine inlet, combustor and exhaust) are roughly in balance. Further advances in jet noise reduction technology are needed as these aircraft already utilize all currently available technology. Significant advances in supersonic jet exhaust noise control technology are also needed if an economically viable supersonic transport is ever to become a reality.

Jet exhaust noise has been the subject of intense research since 1950. Further advances in technology at this stage can only come through invention or basic research aimed at improving our understanding of the fundamental noise generation mechanisms.

Approach: The traditional approach of coordinated experiments, numerical analysis and theoretical development is being followed. Carefully controlled scale model experiments are used for validating theory and suppressor concepts. Several innovative concepts such as the inverted flow coannular jet, plug nozzles, and porous nozzles with boundary layer control are under study in addition to standard nozzle configurations. Precision measurements describe the flow and its correlation with the near- and far-field noise components.

Forward motion effects and the effect of engine mounting on jet noise are studied by means of high speed ground vehicles, free flight aircraft tests in an anechoic wind tunnel, and through theoretical analysis.

Schedule: The research in this area is of a continuing nature with the experimental verification of promising approaches at appropriate stages. Over the next fiscal year the plans are to: conduct experiments on jet/body combination (static and moving) to validate theory, complete experimental evaluation of porous plug nozzle suppressor, measure the effects of finite amplitude wave distortion on far-field noise spectra of supersonic jets, and complete detailed mapping of flow field of coannular jets.

Accomplishments: Achievements of the basic jet noise research program are incremental additions to the knowledge of this noise source and occur on a more or less continuous basis. One example is the development of the "flash-light" theory of jet noise sources. Another is the development and application of the two-point correlation measurement technique, Jet Noise and Suppressors (Continued)

which has given new insights into the generation of jet noise. The completion of a controlled source-in-motion experiment with a jet mounted on top of a moving auto confirmed the theoretical expectation that relative jet velocity is the major determiner of forward motion effects on subsonic jet noise. The existence of both large-scale coherent and small-scale random flow structures in jets has also been experimentally validated. The experimental results have been accompanied by significant improvements in the capability for analytical and numerical modeling of jet noise generation processes.

Sponsor: Lewis Research Center and Langley Research Center

Fiscal Year:	1975	1976	1977	1978
Funding ($1000):	572	651	657	492
Agency Manpower (Man-Years):	16	18	17	13

CATEGORY - PROPULSION NOISE

Forward Velocity Effects on Jet Engine Exhaust Noise

This program is aimed at improving the data base and interpretation of the effect of aircraft velocity on jet noise. Improved understanding of forward velocity effects will result in more accurate predictions of aircraft noise reaching the ground, and in the design of effective noise suppressors.

Comparisons between flight-measured and static test jet noise fields show that simulation of inflight conditions by static measurements at a reduced jet velocity equal to the relative velocity experienced in flight does not result in an adequate representation of the actual conditions, even for the case of a simple round conical nozzle. While the peak noise is predictable by this technique, the noise in the forward quadrant is not. The effect of flight is not readily predictable even at the peak noise location for noise suppressing nozzles. The net effect is that the noise in flight is generally higher than predicted when the aircraft noise signature is dominated by jet noise.

Need for Study: Research on flight effects on jet noise is essential for two reasons. One is that flight effects must be predictable or the certification of a jet noise dominated aircraft becomes an unacceptable risk. The other reason is that the effects must be understood to design noise suppressors which are effective in flight.

Approach: Research on flight effects consists of documentation of the problem through high quality flight tests and tests in ground facilities such as wind tunnels and free jets. Having documented the problems, the next step is to isolate and understand the reason for the discrepancies through diagnostic tests in ground facilities. These diagnostic tests include signal processing to locate noise sources, laser velocimeter measurements of the turbulent properties of the jet, and visualization techniques. With the understanding gained from the diagnostic tests, prediction procedures will be improved, and more effective inflight jet noise suppressors can be developed.

It is expected that this research program will reduce the Effective Perceived Noise Levels (EPNL) approximately 4dB below presently attainable levels for jet noise dominated aircraft. It may also lead to simpler, more efficient noise suppressors.

Schedule: Establishment of the data base and certification of ground based facilities will be completed in 1979. Diagnostic measurements and their interpretation will be completed in 1982. Next, improved prediction methods for flight effects will be developed. Finally, improved jet noise suppressors will be available in 1985.

Forward Velocity Effects on Jet Engines Exhaust Noise (Continued)

Accomplishments: Certification of the 40- by 80-foot Wind Tunnel as a jet noise research tool, including development of appropriate measurement techniques, has been completed. A data base has been established for a large number of suppressors including: round conical nozzles (both full-scale engine and model tests), multi-element suppressor nozzles, shrouded nozzles, and inverted flow nozzles.

Sponsor: Lewis Research Center and Langley Research Center

Fiscal Year:	1975	1976	1977	1978
Funding ($1000):	320	633	449	175
Agency Manpower (Man-Years):	9	20	13	5

CATEGORY - PROPULSION NOISE

Fan/Compressor/Turbine Noise Reduction

The physical nature and relative strengths of rotor/stator and rotor/inflow interactions are being studied to understand turbomachinery noise source mechanisms. The program will define new noise reduction concepts and evaluate designs embodying these concepts. Test conditions will be controlled in such a way that results can be validly extrapolated to actual community noise levels during aircraft flyovers.

Need for Study: With the introduction of high bypass turbofan engines, the fan component is often the dominant noise source contributing to community aircraft noise exposure during landing approach. Future turbofan engines are projected to have still higher bypass ratios which will further emphasize the importance of the fan. Some evidence also exists that the turbine can contribute significantly to the approach noise signature of some current high bypass turbofans. Attacking the noise generation at the source through stage design features offers the possibility of arriving at a quieter propulsion system having lower cost and weight than could be obtained by using acoustic treatment alone.

Approach: The turbomachinery noise programs are pursued through a mixture of in-house, contract and university grant research.

Experimental and analytical investigations are conducted to characterize the interaction of flow fields with the rotor and stator blades that generates and radiates noise. Fundamental studies include the analysis of noise generation by rotor interaction with the inherent disturbances present in the inflow, the measurement of unsteady surface pressures on rotor and stator blades, measurement and modeling of rotor blade wakes in terms of rotor design parameters, measurement of inlet flow distortion and turbulence properties, and development of airfoil lift response functions. Random signal analysis techniques are applied to both near- and far-field noise measurements to define average behavior of the fluid dynamic and acoustic fields and the magnitude of the random fluctuations.

An experimental data base has been accumulated on a series of nine full scale fans over a range of pressure ratios, tip speeds and fan loadings. Full scale experiments investigated rotor/stator interaction by varying rotor/stator spacing, and designing a fan stage to reduce stator lift fluctuations due to rotor wakes. Full scale fan blades instrumented with surface pressure transducers were used to characterize the inlet flow field fluctuations due to distortion and turbulence.

Empirical knowledge and analytical models of generation mechanisms are used to devise low noise fan stage designs. Twenty inch scale models based on these designs are being used for experimental evaluation.

Fan/Compressor/Turbine Noise Reduction (Continued)

Noise control concepts under study include rotor sweep and shock swallowing or containment in the rotor blade passages for multiple pure tone reduction, stator sweep for reduced rotor/stator interactions, and high specific inflow for overall inlet quieting. In addition, methods of increasing wake dissipation by blade vortex generators and effects of cowl boundary layer control are being investigated. The 20-inch fan noise evaluations are being conducted in the Lewis anechoic chamber.

Methods of controlling the static noise test conditions are being investigated so that tests in facilities such as the anechoic chamber will produce fan noise signatures similar to those which would be measured in flight. Inlet flow control devices are being developed to smooth inflow disturbances and reduce inlet turbulence intensities and scales. Two such devices under investigation are a hemispherical honeycomb screen and an annular suction ring around the outside of the inlet cowl.

Schedule: Development of experimental procedures, an anechoic chamber for testing 20-inch fans, and acquisition of full scale fan data were completed in 1975. An interim fan noise prediction procedure was developed from the full scale static fan data.

During 1976, refinement of the analytical tools and experimental scale model data acquisition took place.

In 1977, the sensitivity of fan noise to inflow disturbances was determined and the first honeycomb screen inflow control device was tested in the anechoic chamber. A swept rotor was tested. Cutoff and rotor/stator spacing effects were measured with inflow control. A high specific inflow fan was constructed and full scale fan inflow analysis completed.

During 1978, it is planned to complete the analysis of the swept rotor data; test the high specific inflow fan, swallowed shock fan, annular cowl suction concept; determine rotor wake characteristics with loaded fan; and begin a second series of inflow control tests.

Accomplishments: A data base on fan noise was acquired in a series of nine full scale fans covering the range of pressure ratios from 1.2 to 1.6 and tip speeds from 700 to 1550 ft/sec. These data formed the basis of an empirical prediction procedure for fan noise which was adopted as the initial input to the NASA Aircraft Noise Prediction Program (ANOPP).

Full scale fan experiments were conducted to study methods of reducing rotor/stator interaction noise. These studies included spacing, long chord stators and stage redesign to minimize stator lift fluctuations. It was determined that second harmonic levels and broad-band

Fan/Compressor/Turbine Noise Reduction (Continued)

levels could be reduced and that fundamental tone levels were controlled by inflow distortion and turbulence rather than rotor/stator interaction.

Blade surface pressure data acquired on the full scale fan rotor and stator blades were analyzed to characterize the inflow disturbances which were controlling fan fundamental levels. Time series analyses techniques such as amplitude probability density function analysis were applied to blade pressure data to determine the relative amount of periodic and random content in the pressure signals. For example, it was determined that the amplitudes of rotor wakes striking a stator blade have a strong random content at the blade passing frequency indicating high rotor wake turbulence.

An anechoic chamber for testing 20 inch diameter fans became operational in 1975. To date, fan tests have demonstrated scaling correspondence with full scale data, and experiments have explored inflow control with honeycomb/screen structures which have shown substantial reductions of inflow generated tone noise. Reductions in inlet turbulence intensities by more than a factor of five were measured. Effects of cutoff and rotor/stator spacing on inlet noise have also been determined with inflow control. Model fans incorporating unique acoustic design concepts such as swept blading and high specific inflow have been designed and built under contract. The first of these, the swept rotor, is being tested.

The importance of inflow disturbances in an anechoic chamber facility has also been explored, both in-house and under contract. The sensitivity of fan noise to inlet vortices and large scale turbulence was shown to be greatest at subsonic fan tip speeds, and the studies lead to proposed control concepts involving cowl contouring and boundary layer suction. Preparation for tests of these ideas is underway.

In the fundamentals area, contracts, grants and in-house efforts have modeled rotor/distortion and rotor/turbulence noise; developed a blade lift response model and applied it to rotor/stator interaction analysis; measured rotor wake characteristics as a function of rotor loading; and applied time series analysis techniques to noise and pressure signals to characterize the random nature of the generation processes.

Sponsor: Lewis Research Center and Langley Research Center

Fiscal Year:	1975	1976	1977	1978
Funding ($1000):	507	715	700	731
Agency Manpower (Man-Years):	14	23	21	20

CATEGORY - PROPULSION NOISE

Forward Velocity Effects on Fan Noise

Accurate ($\pm$ 1 dB) static-to-flight noise predictions are a prime objective of this program. A basic understanding of the flight effects on fan noise and the development of experimental techniques using ground facilities and wind tunnels are therefore required.

Need for Study: It has been found that noise signatures of fans tested statically on the ground do not correspond to those found in flight. Because of this, static noise tests have practically ceased in the industry. An understanding of the flight effects and the ability to predict them from static tests is therefore needed to accurately evaluate new fan noise reduction methods and materials by economical static tests.

Approach: The general approach to solving these problems will be to carefully evaluate the relative merits of static testing and wind tunnel testing by using flight data. Three NASA Centers (Langley, Lewis and Ames) will conduct this program. It will consist of a combination of in-house and contract research activities. The in-house research will consist of JT15D engine static tests outdoors, JT15D fan static tests in the anechoic chamber, flow duct turbulence control experiments and inlet radiation studies using a spinning mode synthesizer and flow duct, and flight tests of an experimental airplane specially fitted with an engine identical to the one used for ground tests. The contract activities will include, but not be limited to, JT15D engine modifications and instrumentation by the P&WA Company; OV-1B airplane modifications by the Grumman Corporation; a research technology contract by the P&WA and Boeing companies; grants on the study of the fundamentals of turbulence and its control; a contract for an advanced noise source theory; and a contract for advanced suppressor concepts.

The emphasis of this program is on developing reliable methods for extrapolating fan noise data measured in a ground test facility to flight. However, the opportunity is also being utilized to collect ground static, wind tunnel, and flight data on the jet and core component noise sources of a turbofan engine to enhance understanding of forward speed effects on these other noise sources. The results of this program will lead to more efficient noise reduction in engine inlets and fan exhaust ducts since less conservatism will be required in noise treatment. Several promising noise reduction concepts that failed to show the expected results because of a lack of understanding of the vagaries of static testing will now be retested and probably applied to design problems. It is anticipated that the static and wind tunnel testing techniques produced by this program will allow engine manufacturers to guarantee fan noise levels of their engines to much closer tolerances than before. Finally, the results of this program will allow

Forward Velocity Effects on Fan Noise (Continued)

a certain amount of "fine-tuning" of fan noise control by optimizing the tradeoff between noise reduction and weight and performance penalties.

Schedule:

Completed Grumman feasibility study - (Langley)	December 1977
Initiate JT15D static tests, in-house - (Lewis)	January 1978
Complete initial 40'x 80' wind tunnel tests - (Ames)	October 1978
Complete OV-1B modification by Grumman - (Langley)	April 1979
Complete Phase I of JT15D static tests - (Lewis)	April 1979
Initial flight tests	October 1979

Accomplishments: The major accomplishments to date have been to identify the problems to be solved and the resolution of an approach. In particular, a common engine, the JT15D, has been identified and procured. Modifications and instrumentation of these engines is under way at the Pratt and Whitney Aircraft Company. A feasibility study completed in December 1977 determined that it was possible to attach the JT15D engine under the wing of an OV-1B airplane for noise tests. A new streamlined static test stand has been fabricated for the static engine tests which are scheduled to begin in January 1978.

Sponsor: Langley Research Center and Lewis Research Center

Fiscal Year:	1975	1976	1977	1978
Funding ($1000):	351	205	366	1,487
Agency Manpower (Man-Years):	10	6	11	38

CATEGORY - PROPULSION NOISE

Internal Noise Transmission Through Turbines and Nozzles

This work involves experiments and mathematical analysis to determine the characteristics of acoustic propagation of internally generated engine noise to the far field. The research is focused on acoustic transmission through the turbine and through the engine nozzles and associated flow fields. The acoustic sources contributing to internal noise include the combustor, turbines, and support/flow transfer struts.

It is expected that the results of this research will yield engineering methods that can be used to compute the attenuation of upstream-generated low frequency noise by the turbine. The nozzle/flow transmission investigations will also lead to engineering prediction methods which will permit calculations to be made of engine far-field noise due to the engine core, given the acoustic power output of the core components.

Need for Study: Noise radiating from the exhaust core of a gas turbine engine includes components transmitted by the internal components, contributing to the far-field overall perceived noise level particularly at approach. This work is essential to an understanding of the nature of core noise generation and to the development of quantitative core noise prediction methods.

Approach: The work is being done principally by contract. Transmission of sound through turbines is being investigated by the General Electric Company.

Transmission of sound through nozzles and their associated flow fields is being investigated by Lockheed-Georgia. The contractors are conducting both analytical and experimental investigations.

The experimental portion of the turbine transmission work encompasses measurements of the attenuation of low frequency sound by a high-pressure single stage turbine, and low-pressure turbine operated both as a single-stage and as a 3-stage machine. The results of the experimental investigations are compared with the predictions from a rather basic actuator-disc turbine model theory. Under a separate contract, work is being undertaken to improve the actuator-disc analytical model and to develop a new finite-chord model that implicitly incorporates frequency dependence.

Internal Noise Transmission Through Turbines and Nozzles (Continued)

The nozzle/flow transmission work involves experimental measurement of acoustic radiation from artificial sound sources embedded in coaxial nozzle/flow systems. A parallel mathematical analysis is being conducted to guide the conduct of the experiments and to develop a suitable model.

Other contracts with General Electric and with Lockheed-GA on combustor noise tests of the CF6 engine and on free-jet forward velocity simulation, respectively, will also materially contribute to this technology area. In addition, this research is being complemented by FAA-sponsored work at General Electric on turbine noise generation and its transmission through successive turbine stages.

Schedule: Contracts with General Electric are nearing completion. Contract with Lockheed-Georgia commenced in August 1977.

Accomplishments: The final report by G. E. on attenuation of upstream-generated low frequency noise by gas turbines (CR-135219) has been issued. In the program, the influence of inlet temperature and turbine speed on attenuation was evaluated; and the effects of turbine pressure ratio, blade-row choking, and additional downstream blade rows were determined. Preliminary identification of pertinent aeroacoustic correlating parameters was made. Comparisons of the test data were made with theoretical predictions to establish the limits of the actuator-disc theory.

The G.E. draft report on a theory of low frequency noise transmission through turbines is being reviewed. A new finite-chord analytical model has been developed which accounts for adjacent blade row interactive effects, higher order spinning modes, blade passage shocks, and duct area variations.

In the Lockheed-GA contract, the nozzle designs have been approved, and fabrication is underway.

Sponsor: Lewis Research Center and Langley Research Center

Fiscal Year	1975	1976	1977	1978
Funding ($1000):		76	140	120
Agency Manpower (Man-Years):		3	4	3

CATEGORY - PROPULSION NOISE

Duct Acoustic Treatment Projects

Acoustic treatment of aircraft engine nacelles has proven to be very successful during the past 10 years. Refinement of this technology has the potential for significant additional noise reduction as well as the possibility of achieving specified noise levels with minimum weight and performance penalties. This requires that the noise sources need to be accurately described, the mechanism of duct propagation in the presence of airflow up to Mach 1 be fully understood, and the performance of acoustic duct liner materials be understood and improved.

The noise reduction lining treatment used in aircraft gas turbine engine ducts usually consists of a honeycomb backing covered with a perforated sheetmetal facesheet. The major mechanism of noise reduction is the conversion of acoustic energy into heat energy through acoustic resonance phenomena in the honeycomb cavities. Another type of acoustic treatment being reexamined for aircraft use is the bulk absorber. This is the familiar material often found in insulation applications. A major portion of the acoustic energy is converted into heat energy during the process of propagation through the bulk material.

High subsonic inlet flow is another noise reduction approach being explored in conjunction with acoustic treatment. As the airflow velocity approaches Mach 1 in a direction opposite to the noise propagation, the noise is attenuated. The physical process that causes this attenuation is not fully understood at present.

Need for Study: Continued reduction in all propulsion noise sources is required in order to reduce the community noise of the next generation of commercial transports and to meet more stringent federal noise regulations. In particular, further reductions in fan and compressor noise must be achieved. Research indicates that appreciable gains in engine noise reduction are possible through the use of more efficient nacelle acoustic treatments and carefully designed high-speed inlets. Data on liner and inlet performance taken under carefully controlled aerodynamic and acoustic conditions are needed to illuminate the physical processes involved, to serve as a basis for planning flight demonstrations of new concepts, and to provide preliminary information for the design engineer.

Approach: The approach is multi-faceted and includes advanced theoretical work and extensive experimental work done both in-house and under

Duct Acoustic Treatment Projects (Continued)

contract. The major portion of the in-house experimental research is conducted with a spinning mode synthesizer (S.M.S.) apparatus in which is produced a computer-controlled acoustic field in the presence of airflow. This allows investigations of advanced acoustic treatment concepts, noise attenuation as a function of high subsonic flow, and inlet radiation as a function of geometry. In addition to the S.M.S. apparatus, use is made of an advanced flow-impedance tube for the precise evaluation of the acoustic properties of various candidate materials. The theoretical approaches are closely coupled to the experiments. They are currently concentrating on solutions for noise propagation in ducts with high subsonic flow and changing cross-sectional area and on solutions for noise radiation from inlets with different geometries.

The eventual results of the duct acoustics program will be to significantly reduce gas turbine engine noise propagation without adversely affecting aircraft performance.

Schedule:

Completion of flow impedance experiments of bulk absorbing materials, in-house	October 1978
Completion of S.M.S. experiments of segmented bulk absorbers - General Electric	June 1978
Completion of radiation theory for simple geometrically shaped inlets, in-house	July 1978
Complete no-flow inlet radiation experiments, in-house	November 1978
Complete analytical study, high subsonic flow using wave-envelope method - VPI&SU	November 1978
Complete finite element theory for compressible flow - Wyle Laboratories	December 1978
Complete initial experiments to demonstrate impedance control of acoustic material	January 1979
Complete S.M.S. study of advanced hybrid inlet	July 1979

Accomplishments: Two major duct acoustic facilities, the Spinning Mode Synthesizer and Flow Duct (S.M.S.) and the Flow-Impedance Tube, became operational in 1977.

A study of the acoustic properties of a bulk absorber with water repellant properties was completed in-house. Other in-house accomplishments include the development of a two-dimensional finite element technique for calculation of normal modes in a duct in the presence of non-uniform mixed boundary conditions for application to segmented liner design, and a systematic study on the effect of measurement errors on specifying acoustic impedance material.

Duct Acoustic Treatment Projects (Continued)

A finite element theory for ducts with compressible mean flow was developed under contract by Wyle Laboratories. An experimental study completed by the Boeing Company demonstrated that inlet noise directivity can be controlled by changes in inlet geometry. Sound and high-speed flow interaction studies were completed by the University of Tennessee, for application to hybrid inlet design.

Sponsor: Langley Research Center and Lewis Research Center

Fiscal Year:	1975	1976	1977	1978
Funding ($1000):	981	807	1,066	828
Agency Manpower (Man-Years):	26	25	32	22

CATEGORY - PROPULSION NOISE

Propeller Studies

This research area will develop and demonstrate noise reduction technology for propeller driven general aviation aircraft that minimizes performance penalties without degrading flight safety. The projects are specifically aimed at developing capability for including noise constraints into propeller design. An element of this research is also aimed at determining the noise characteristics, validating prediction methods, and developing low-noise concepts for propellers designed for cruise at transonic speeds (M ~.8).

Need for Study: The large numbers of propeller-driven general aviation aircraft and their growing operations from small airports near suburban residential areas are causing increasing community noise impacts. The dominant noise source from all the turbine-powered vehicles and most of the reciprocating-engined vehicles is the propeller. Propeller noise technology has been neglected in recent years although a substantial base had been established prior to the advent of the turbojet engine. However, the early technology base did not include the effects of forward speed on noise. Newer, better predictive methods and computer technology are also now available. In addition, the revived interest in the application of propellers to transonic cruise aircraft (M ~.8) for fuel economy introduces a new and relatively unexplored range of operating parameters where propellers are known to be noisy. For such vehicles to be economically viable, efficient propeller concepts must be evolved that are quieter both in cruise for passenger comfort and in terminal operations for community acceptability.

Approach: Theoretical and experimental studies will be undertaken inhouse and under contract to refine and validate existing propeller noise prediction methods. Flight and wind tunnel experiments will be conducted with specially instrumented propellers and the results compared with theory to relate noise radiation to fluctuating pressure measurements on the blade surface. Exploratory wind tunnel experiments will be conducted for novel concepts such as acoustically-designed shrouded propulsors and performance designed propellers. A parametric wind tunnel study of a family of quiet propellers in simulated flight will expand the noise data base to include forward speed effects. The noise signatures of typical general aviation aircraft will be documented as required to identify the separate noise source contributions of the propeller and power plant.

Parametric studies and several critical experiments in flow facilities and flight will be conducted on propeller configurations specially designed for transonic cruise to establish noise characteristics and validity of the predictive methods.

Propeller Studies (Continued)

Schedule: The general aviation propeller study is jointly funded with EPA. The research in this area is of a continuing nature and the near term plans (FY 78) are as follows:

- Complete comparative wind tunnel noise/performance tests on a Cessna 327 having a standard free propeller and a quiet-fan shrouded propulsor
- Initiate development of a general aviation propeller noise data base including forward speed effects in the Langley Quiet Flow Facility
- Complete software development and initiate parametric study of high speed propellers using Farassat's theory
- Conduct Phase I of three phase joint EPA/NASA program to demonstrate general aviation propeller noise/performance technology
- Obtain near field noise data on M ~.8 propeller in UARL facility

Accomplishments: A new general aeroacoustic theory for propellers operating at all speeds has been developed (the Farassat theory). Initial applications to general aviation propellers where data exists have been very encouraging. A static test of propellers having four different airfoils specifically designed to test this theory has been completed wherein the propeller tip speed range from M = .4 to M = 1.1 was covered. A flight test of a general aviation aircraft, where both near-field noise and oscillating surface pressure on the propeller blade were measured, has been completed and documented.

Sponsor: Langley Research Center and Lewis Research Center

Fiscal Year:	1975	1976	1977	1978
General Aviation Propeller Projects Agency				
Funding ($1000)	130	120	350*	360*
Manpower (Man-Years)	3	4	10	10
Mach 0.8 Propeller Projects				
Funding ($1000)	-	66	154	171
Manpower (Man-Years)		2	5	4

* A total of $150,000 of this funding is being applied by NASA to the joint EPA/NASA small Propeller Technology program, described on page E-3.

CATEGORY: ROTOR NOISE

Helicopter Rotor Noise Control

The helicopter has many sources of noise with the principal ones associated with the main rotor, tail rotor, and their interactions. The dominant noise source depends on the configuration and operating conditions. Therefore, rotor noise control requires that a multitude of configurations and operational variables be considered. This research area is aimed at sorting, ranking, and understanding the various sources of rotor noise, developing and validating methods for predicting the noise, evolving noise control concepts and methods, and providing engineering design methods.

Need for Study: To be economically viable, helicopters must be operated in urban areas and from small landing areas. This requirement means that their noise characteristics must be non-intrusive to achieve community acceptability. The current demand for rotor noise control technology is driven by pending national and international noise regulations that recognize that making the helicopter a better neighbor will increase opportunities for its utilization.

Approach: In-house and contract projects are addressing both analytical and experimental questions. Experiments are being designed and conducted specifically to verify the applicability and limits of recently developed rotor aeroacoustic theory (Farassat theory). These critical experiments will be conducted with scale models in wind tunnels and at full scale in flight. One of the most annoying rotor noise sources is blade slap. Special attention is given to its understanding and reduction. Laboratory and flight experiments are also conducted to define poorly understood noise problems such as main rotor/tail rotor interaction noise.

It is expected that vortex interaction blade slap, the most annoying rotor noise source, will be eliminated on future helicopters by configuration changes. High speed blade slap, due to transonic rotor tip speeds will continue to set a noise limit for cruise flight. It is also expected that the emerging analytical tools, when validated, will provide a new plateau of noise design capability to the rotorcraft industry.

Schedule: The research in this area is of a continuing nature and short range plans are as follows:

Helicopter Rotor Noise Control (Continued)

Conduct Huey Cobra Noise Experiment in V/STOL Tunnel for comparison with flight	FY 1978
Report noise radiation patterns of Civil Helicopter	FY 1978
Systematic noise tests with Rotor Tip Modifications in V/STOL Tunnel	FY 1978
Main Rotor/Tail Rotor Interaction Experiments in Quiet Flow Facility	FY 1979
Exploratory Acoustics Tests of Advanced Rotor Concepts	FY 1979

Accomplishments: Wind tunnel tests have demonstrated that the tip air mass injection scheme will successfully reduce blade slap due to vortex interactions. An alternate passive concept for blade slap alleviation, the OGEE tip modification, has been successfully demonstrated in flight on a UH-1H. Initial tests on the main rotor/tail rotor interaction noise project have been completed with indications of the geometrical configurations that generated the minimum noise. Ground noise footprints and directivity patterns for two different configurations have been measured with the ROMAAR system at Wallops Flight Center. The major theoretical achievement has been the development and partial validation of the Farassat non-compact source theory for rotors.

Sponsor: Ames Research Center and Langley Research Center

Fiscal Year:	1975	1976	1977	1978
Funding ($1000):	178	1,300	1,141	1,272
Agency Manpower (Man-Years):	7	11	19	13

CATEGORY - INTERIOR NOISE

General Cabin Noise Research

The objective of this research program is to provide design guidelines for reduction of aircraft interior noise through attenuation of airborne and structural transmission of noise and vibration. The emphasis will be on the development of analytical procedures for general aviation and high speed turboprop aircraft, with decreasing emphasis on powered lift vehicles.

Need for Study: The interior noise levels of commercial transport aircraft are, for the most part, acceptable in terms of passenger comfort and aircrew efficiency. However, the interior noise levels of general aviation propeller aircraft, helicopters, powered-lift vehicles, and turboprop transport aircraft are considerably higher. Such high levels can seriously compromise crew efficiency and passenger comfort and, if experienced for sufficiently long periods of time, can contribute to hearing damage. The current procedure for reducing noise levels is to add soundproofing material which appears to provide acceptable results for conventional commercial aircraft. However, excessive weight and performance penalties are expected if the same approaches are used to reduce the levels of the noisier aircraft to acceptable levels. Since the noise spectra of these aircraft contain more energy in the low-frequency range where soundproofing material is inefficient, further research is needed to arrive at efficient solutions.

Approach: Research is being conducted in-house and through contracts and grants. Characteristics of the source such as spectral content, spatial distribution, and point-to-point correlations are determined through wind tunnel and flight tests. Vehicles included in the program are propeller-driven general aviation aircraft powered-lift vehicles (specifically, the YC-14 upper-surface-blown and YC-15 externally-blown flap systems); helicopters (with emphasis on noise from the main gear box), and high speed turboprop aircraft utilizing supersonic tip speed "propfans."

The major thrust of the program is the development of analytical methods for predicting interior noise, and the application of these methods to develop low-weight, low noise transmission sidewall concepts. Detailed analytical models of the structural response to acoustic inputs are being developed that include the influence and coupling of the acoustic (cabin) space. The models range in complexity from cavity-backed simple panels to stiffened panels and stiffened cylinders. In all cases, the validity of the analytical model is being verified by comparison with experiments.

General Cabin Noise Research (continued)

The effectiveness of various add-on noise reduction treatments is also being examined. Treatments being studied include absorptive materials, double walls, septum, damping tapes, constrained layer damping, composites for stiffness control. The emphasis is on the development of maximum noise attenuation per unit weight and cost. Full-scale flight tests incorporating noise reduction concepts will finally verify the analytical techniques and the passenger/crew acceptability.

Schedule:

Propeller/propfan acoustic input measured	FY 1978
Responses to acoustic input measured	FY 1978
Transmission loss of stiffened cylinders measured	FY 1979
Analytical procedures for transmission loss developed	FY 1980
Mach 0.8 turboprop structure/treatment defined	FY 1979
Mach 0.8 turboprop verified in flight	FY 1982
Quiet General Aviation aircraft demonstrated	FY 1980

Accomplishments: Progress to date suggests that the accurate prediction of aircraft interior noise is feasible. A number of flight tests to define interior noise environments of typical vehicles have been completed and the data published. Included are a single and twin engine general aviation vehicle, the CH-53 civil helicopter with and without interior noise treatment, and the YC-14/YC-15 powered-lift vehicles. Analytical results have been compared with experiment, demonstrating the effects of curvature, pressure, cavity backing, and stiffening on panel transmission loss.

Sponsor: Langley Research Center

Fiscal Year:	1975	1976	1977	1978
Funding ($1000):	141	94	331	262
Agency Manpower (Man-Years):	3	2	7	5

CATEGORY - INTERIOR NOISE

Sound/Structure Interaction

Short takeoff and landing (STOL) aircraft proposed for future use in the U.S. transportation system feature direct impingement of the jet engine exhaust on the wing and flap system to redirect the high velocity jet downward to obtain the high lift required for STOL operation. The direct impingement subjects wing, flap, and fuselage structures to higher acoustic loads than for non-STOL aircraft and requires new technology to adequately design for prevention of acoustic fatigue and for quiet crew and passenger cabins. This program combines flight testing, scale model testing, and analytical scaling studies to develop and validate methods for predicting acoustic loads on current powered-lift aircraft as well as future STOL aircraft.

Need for Study: The successful utilization of powered-lift STOL aircraft requires designs with acceptable acoustic fatigue lifetime and passenger environments. The acoustic phenomena associated with powered-lift engine/wing configurations require development of advanced technologies for prediction of the acoustic loads and the resultant structural response and fuselage noise transmission. The random and configuration-dependent nature of the acoustic loads associated with the jet exhaust and its impingement on the wing and flaps precludes purely theoretical prediction methods and forces reliance on empirical methods based on model tests and scaling to full-size aircraft.

Approach: Experimental programs have been conducted on full-scale aircraft, large-scale models utilizing jet engines, and small-scale laboratory models using air jets to simulate the engine exhaust. Theoretical and empirical scaling studies have been conducted to develop scaling laws. The full-scale aircraft studies were conducted with the Air Force AMST aircraft; namely, the Boeing YC-14 aircraft which features the upper-surface-blowing (USB) powered-lift concept and the Douglas YC-15 aircraft which features the externally-blown-flap (EBF) powered-lift concept. In a cooperative NASA/Air Force program, acoustic loads; structural response of wing, flaps, and fuselage; and interior noise were measured during flight and ground operations. A preliminary ground test utilized a full-scale YC-14 engine-flap system to measure acoustic loads and flap accelerations. Large-scale model tests have included an approximately one-half scale EBF wing/flap system with an 8,000 pound thrust turbofan engine and an approximately one-quarter scale USB wing/flap system with a 2,000 pound thrust turbofan engine. Laboratory tests utilized airjets of about 2 inches diameter to simulate the engine exhaust, with both USB and EBF wing/flap systems of about one-sixteenth scale.

Sound/Structure Interaction (Continued)

Current emphasis is on analysis and interpretation of the results from the various tests to establish scaling and prediction methods. Work ongoing at Boeing and Douglas is focused on flight test results and is expected to be completed in FY 78. Correlation of all results from the various model tests with full-scale data and scaling theories is also planned for completion in FY 78. The final output of this project will be a published, high quality data base for acoustic loads on powered lift, vehicles, validated scaling methods, and empirical prediction methods.

Schedule:

Complete analyses of flight data:	
Boeing YC-14	July 1978
Douglas YC-15	August 1978
Complete analyses of data from large-scale models	March 1978
Complete scaling studies	October 1978

Accomplishments: All testing has been completed. Data from most model tests have been published. Flight tests on the Douglas YC-15 airplane were conducted in January-February 1976 and the flight tests on the Boeing YC-14 were done in October-November 1976. Results from the large-scale model and flight programs have been analyzed and are being published to display the level and spectrum of the actual acoustic loads for use of designers. A preliminary assessment was released at an AIAA Meeting in July 1976. Comparisons of the results from the models at various scales with scaling parameters have already been made for development of prediction procedures. Progress reports on scaling methods and their comparison were presented at conferences in May 1976 and June 1977.

Sponsor: Langley Research Center

Fiscal Year:	1975	1976	1977	1978
Funding ($1000):	476	245	370	391
Agency Manpower (Man-Years):	4	4	2	9

CATEGORY - AIRFRAME NOISE

General Airframe Noise

Airframe noise is the nonpropulsive noise of an aircraft in flight. The generation of turbulence by flow separation, the impingement of wakes on wings and flaps, and the passage of turbulence thru gaps in high lift devices and across trailing edges are believed to be significant sources of airframe noise. These mechanisms are present and most effective during landing approach operations when leading and trailing edge flaps and slats are deployed, landing gear are lowered, and various cavities and cutouts in the airframe are open or partially exposed.

Need for Study: Airframe noise sets a lower limit to which aircraft noise can be reduced by the elimination of propulsion system noise. Measurements of commercial jet transport airframe noise during landing approach indicates that this noise source is only about 10 EPNdB below FAR-36 1969 certification requirements for approach operations. Thus, to realize the full benefits from future quiet engines, airframe noise must be reduced below its current level. Airframe noise increases with landing speed, gross weight, and wing area and thus, is expected to be most serious for very large, heavy, advanced transport aircraft.

Approach: Both theoretical and experimental investigations are being conducted. Experimental studies employ models of individual aircraft components and complete aircraft to identify the principal noise generating mechanisms, locate the components most responsible for airframe noise, and identify and test noise reduction concepts. The current focus is on trailing edge and leading edge high lift devices, landing gear and wheel wells. Considerable testing is carried out in quiet open-jet anechoic flow facilities such as the Langley Aircraft Noise Reduction Laboratory (ANRL). A testing technique using radio-controlled geometrically and aerodynamically scaled models of commercial and advanced design transports is also under development as a means of studying scaling effects while avoiding the acoustic data interpretation problems of testing in wind tunnels. Full-scale flight data from commercial aircraft are obtained and analyzed under contracts with the airframe manufacturers.

Theoretical studies consist of the analysis and correlation of measured data to obtain empirical prediction schemes and scaling laws as well as computerized theories for calculating turbulent flow fields and noise from the fundamental equations of fluid dynamics, unsteady aerodynamics and acoustics.

Throughout, the focus of this research effort is on very large transport aircraft.

General Airframe Noise (Continued)

Schedule:

Report results of SCAR tests	FY 1978
Initiate definitive trailing-edge noise experiments	FY 1978
Identify sources of interaction noise	FY 1978
747 noise measurements using R/C model	FY 1979
Test low-noise, high-lift devices	FY 1979
Noise Tests of Spanloader	FY 1979

Accomplishments: Airframe noise tests of a 2-foot span SCAR concept have been completed in the four-foot diameter open-jet anechoic noise facility in ANRL. A powered model of a 747 and a two-engine recoverable lifter have been constructed and test flown in the radio controlled model development activity. These models are being used to develop and check out onboard instrumentation and flight procedures. Extensive overall sound pressure level (OASPL), spectra and directivity measurements have been made on cavity noise. The spectral data has been used to identify the mechanism of cavity noise generation at low flow speeds, and develop and verify prediction formulae for tones. The extensive directivity data now undergoing analysis is the only such data available on cavity noise. A contract has been awarded to United Technologies Research Center (UTRC) to conduct an experimental study of airframe component interaction noise. The purpose of the study is to pinpoint the interactions which are principally responsible for landing approach airframe noise and to collect definitive acoustic and flowfield data to relate noise to specific physical processes. A preliminary study by Bolt Beranek & Newman, Inc. (BBN) of the potential of panel vibrations for generating high frequency (~1,000 Hz) airframe noise has arrived at a negative conclusion. Predicted panel noise, based on vibration spectra measured on a rectangular panel, is much too low to account for observed levels. This conclusion leaves the source of high frequency "airframe" noise unexplained.

An acoustic mirror technique for locating noise sources in a turbulent flow has been applied to study noise generation by various combinations of a model of a landing-gear-cavity flap arrangement. The arrangement simulates the underside of a transport wing in landing approach. Flap side edges and wake closure regions have been found to be regions of high frequency noise production.

Sponsor: Langley Research Center

Fiscal Year:	1975	1976	1977	1978
Funding ($1000):	374	401	767	789
Agency Manpower (Man-Years):	4	9	8	20

CATEGORY - AIRFRAME NOISE

Aerodynamic Noise

This research area is directed toward a better understanding of turbulence—sound interactions with particular emphasis on noise generation by unsteady fluid flows in the presence of surfaces. Much of the activity is basic research which has direct input to a broad spectrum of more applied research on aircraft noise problems.

The emphasis of the current research effort is to bring the best existing experimental and theoretical tools of turbulent flow field prediction and aerodynamic noise generation to bear on the problem of trailing edge noise production. This is a technically important problem of extensive interest since trailing edge noise is believed to be a primary contribution to propulsive lift noise as well as landing approach and cruise configuration airframe noise.

Need for Study: Aerodynamic or turbulence induced noise and vibration are associated with all types of aircraft and all flight regimes. Some specific examples are: jet noise, trailing-edge noise, propulsive lift noise, core noise generated by exhaust flows over duct splitters and struts, and aircraft interior noise arising from structurborne sound and boundary layer-induced panel vibrations. Some fan, rotor, and propeller noise is the result of blade-turbulence interactions—large coherent eddies produce tones whereas small scale turbulence appears responsible for broadband noise generation. Aerodynamically generated noise can be objectionable within an aircraft interior and in the surrounding airport community. High acoustically-induced vibration levels can be detrimental to aircraft structures. Therefore, this research is necessary to create the basic understanding of the mechanics underlying the generation of noise by aerodynamic flows and eventually lead to the reduction or elimination of many of the individual aircraft noise sources for passenger and community acceptability.

Approach: A wide range of basic experimental and theoretical research is required to solve aerodynamic noise problems. Primary emphasis will be placed in three areas: (i) understanding noise producing turbulent flow fields, (ii) developing aerodynamic noise prediction theories, (iii) conducting definitive experimental studies.

Methods for predicting the mean and time-dependent properties of turbulent flows around bodies will be developed and applied. These methods include finite element, finite difference, stability analyses and vortex model approaches to solving appropriate forms of the Navier-Stokes equations. For the foreseeable future, empirical inputs

Aerodynamic Noise (Continued)

and flow field simulations must be used in these studies to supplement methods based on first principles. The applicability of existing turbulence models for predicting aircraft generated flow fields and the associated aerodynamic noise will be determined. The need to develop new turbulence models—in particular models appropriate for three-dimensional flows—will be identified.

Practical noise prediction methodologies will be formulated. Approaches to be followed include the method of matched asymptotic expansions, vortex models, direct evaluation of the Lighthill integral, and the Bernoulli Enthalpy formulation of the aeroacoustic equations. This latter formulation appears to provide a unified analytical basis for investigating the generation, refraction, and scattering of sound by flow as well as acoustically induced flow modification. These various noise prediction methods will first be applied to shear layer and cavity flows and to noise production by large scale structures. The more successful and tractable methods will be brought to bear on trailing-edge noise fields.

Carefully conducted and thorough experiments of trailing-edge flow fields and noise will be carried out. Extensive measurements of the flow and acoustic field will be made. This data will provide a complete statistical characterization of the turbulence, be used to validate turbulent flow field and noise prediction methodologies, and make it possible to relate noise generation to the fluid dynamics. Successful convergence of the theoretical and experimental studies will then provide the background for identifying and testing noise reduction concepts. These might involve turbulence modification or suppression schemes such as flow additives, compliant or porous surfaces, and fluid injection (trailing-edge blowing). In the case of noise generated by aircraft components it is desirable, whenever possible, to relate noise to gross aerodynamic parameters and performance, in particular drag, since the tradeoffs between noise reduction and mission capability must be evaluated.

Schedule:

Initiate definitive trailing edge flow and noise experiments	1978
Measurement of Large Scale Structures using vorticity probe	1978
Complete finite element prediction of trailing-edge flow field	1978
Fabricate electronics (VORCOM) for real time application of vorticity probe	1979
Compare trailing-edge flow field calculations and measurements	1979
Apply Bernoulli Enthalpy formulation of aerodynamic noise theory	1979

Aerodynamic Noise (Continued)

Accomplishments: The Bernoulli Enthalpy formulation of the aerodynamic noise equations has been applied to problems of noise generation and sound scattering by vortices as well as the excitation and resonance of pairs of turbulent eddies by sound. It is significant that the theory provides a unified basis for such a wide variety of problems. Current effort is to incorporate the effects of mean flow into the analysis and investigate the effects of convection on sound generation and scattering.

A parabolic approximation to the Navier-Stokes equations and a supplementary set of turbulence equations have been solved using finite element methods to predict the mean and turbulent flow fields of a USB configuration. Comparison of calculations with existing measurements of wake turbulence were encouraging. Several improvements in the prediction method are now being made—allowance for curved surfaces, a better turbulence model, inclusion of a surface pressure prediction module, and a more accurate solution very close to the edge. The computer program will be used to make extensive calculations for comparison with upcoming trailing edge noise experiments.

Analytical studies of the noise generation by large-scale structures in shear layers and of the excitation of a shear layer by incident sound have been completed. The analyses use matched asymptotic expansions and stability theory. The theory predicts the directivity of the sound generated by large-scale instability waves in a shear layer and estimates their sensitivity to a beam of externally imposed sound.

Measurements of the refraction of sound by the shear layers of free jets have been made as part of a contract effort with UTRC. The measurements confirm existing theories being used to predict shear layer angle and amplitude corrections. These corrections must be applied to noise data obtained from models placed in open-jet flow facilities to simulate forward speed.

A hot wire probe for directly measuring vorticity in a flow has been developed under a grant with Michigan State. A prototype has been delivered to Langley researchers. Data reduction software is now being written and proof-of-concept experiments are planned.

Experiments to identify the fluid dynamic processes involved in the generation of trailing edge noise on an USB configuration have been completed and the data analyzed. The interaction of large coherent eddies in the upper mixing region of the jet with the trailing edge and its wake was pinpointed as being of major importance for the sound generation. A follow-on experiment to modify the large eddies and thereby alter the noise is now being conducted. A phase averaged method of predicting the evolution of large scale structures in a

Aerodynamic Noise (Continued)

turbulent shear layer has been completed. The scheme predicts the growth and eventual decay of these structures. The flow model is now being used to evaluate the Lighthill integrand in order to predict the noise from large-scale structures.

Sponsor: Langley Research Center, Ames Research Center, and Jet Propulsion Laboratory

Fiscal Year:	1975	1976	1977	1978
Funding ($1000):	584	975	846	925
Agency Manpower (Man-Years):	6	23	34	19

CATEGORY - AIRFRAME NOISE

Flow Interaction/Propulsive Lift Noise

The objective of this effort is to identify the noise sources associated with jet/surface interaction noise and to examine means of suppression, including the shielding of jet noise associated with the engine-over-the-wing (OTW) concept. The established data base is being extended on the near-field and far-field acoustics, surface pressure fluctuations, and aerodynamics, for various jet/surface applications such as under-the-wing (UTW) and OTW powered lift, thrust reversal, and thrust vectoring. Included are the effects of noise directly generated by jet/surface interaction, jet noise modification through the use of mixer nozzles, surface treatment, source modification devices, and forward velocity effects. Prediction methods have been developed and are being improved to facilitate the integration of this technology into the design of practical, low-noise, jet powered-lift aircraft.

Need for Study: In order to evaluate a goal of 95 EPNdB at a 152 meter sideline distance for future Short Take-Off and Landing (STOL) aircraft, the noise sources for STOL configurations needed identification. It was determined that jet/flap interaction and thrust reversal are dominant noise sources for powered-lift jet short- and reduced-takeoff-and-landing (STOL and RTOL) aircraft. The QCSEE* and AMST** jet powered-lift projects each include both UTW and OTW configurations. The UTW configuration appears to be simpler and may have better cruise performance. The OTW configuration remains of interest, for both STOL and CTOL, because of the high-frequency exhaust noise shielding benefits attainable. This benefit, however, must be balanced against the increased low-frequency noise generated. Because of the low noise levels required for commercial STOL aircraft, thrust reverser noise is a serious concern. In addition, jet/surface noise such as that produced by thrust reversers may become important for other aircraft categories if noise regulations more stringent than present are enacted.

Approach: Experimental and theoretical studies have been conducted in-house, by contract, and by grant. The in-house work included small scale (5 cm nozzle diameter) and large scale (TF-34 engine) experimental studies. The experimental OTW and UTW studies included the effects on noise of nozzle location, nozzle shape, wing size, flap deflection, flap number, jet exhaust velocity, and forward speed.

* Quiet, Clean, Short-Haul Experimental Engine.

** Advanced, Medium STOL Transport.

Flow Interaction/Propulsive Lift Noise (Continued)

Prediction methods have been developed in-house and under contract by United Technologies.

Presently planned cross-correlation and coherence in-house studies will determine the far-field contributions of the various noise sources associated with STOL aircraft concepts. This information, together with the large acoustic and aerodynamic data base that has been provided by in-house and contract efforts, should lead to an improved, unified method for prediction methodology. Trade-off studies can also be made to assess the merits of design changes on both acoustics and aerodynamic performance.

The parameters evolved in correlating the test data and the analytical studies to date should point the way toward reducing jet/flap interaction noise for future STOL aircraft using powered lift concepts. Schedule: An in-house effort was initiated in 1970 and is still in progress. A study of impingement and scrubbing noise was conducted by United Technologies in 1973 through 1977. A study of acoustic source location for a jet-blown flap was conducted by the University of Tennessee Space Institute in 1973 through 1977 under a NASA grant.

Accomplishments: Work under this program has already provided an early assessment of OTW and UTW jet/flap interaction noise and thrust reverser noise in support of powered-lift programs, and interim prediction methods for externally blown flap noise and thrust reverser noise have been developed.

Static scale model tests of QCSEE-OTW flyover and thrust reverser noise and performance have been conducted and the validity of acoustic scaling for geometrically similar models has been tested in-house. An analytical model for UTW externally blown flap noise has been developed and its validity demonstrated for models of various size and for the TF34 engine. Other accomplishments are the development of suppression mechanisms for UTW application; in-house test of a large-scale model segment of an augmentor wing designed by Boeing under a NASA Ames contract; verification that fundamental theory predicted the correct noise levels, spectra, and directivity patterns for jet flow impingement on struts; and the development of a predictive model for flow/surface interaction noise both inside and outside the engine.

Sponsor: Lewis Research Center

Fiscal Year:	1975	1976	1977	1978
Funding ($1000):	366	995	1,089	1,101
Agency Manpower (Man-Years):	10	12	17	14

CATEGORY - NOISE PREDICTION TECHNOLOGY

Noise Prediction Techniques

An integrated computer software system for aircraft noise prediction (ANOPP) is being developed. It features state-of-the-art technology in both noise prediction and computer software. Prediction is based upon semi-empirical methods which are used to compute one-third octave spectra vs. time for individual aircraft noise sources such as jet noise, turbine noise, or airframe noise. Noise from individual sources is then summed, the effects of propagation through the atmosphere and ground reflection are included, and the noise received at arbitrarily selected observer positions is calculated. Perceived noise level, effective perceived noise level, or other noise measurement scales may be used for the computations.

Need for Study: The capability to accurately predict the noise of both current and future technology aircraft is essential to the agency, the industry, and the country in order to quantify the noise benefits from proposed noise reduction technology programs, to identify the research areas where present knowledge of noise generating mechanisms is deficient, to support the formulation of reasonable noise standards for future aircraft, and to predict the community noise impact of proposed aircraft early in their design cycle.

Approach: ANOPP development rests upon three key concepts: (1) an executive and data base software system architecture that provides maximum problem solving flexibility and user-oriented features, (2) modular noise component prediction methodology that can easily be modified, updated, or replaced by an engineer-user as the state of the art in prediction technology advances, and (3) complete documentation to allow independent use of ANOPP by organizations outside of NASA.

Emphasis has been and will continue to be placed on prediction methodology for jet powered CTOL aircraft. Noise prediction methodology required by V/STOL, helicopter, and propeller aircraft will be added when possible. It is expected that by FY 80, ANOPP development will be essentially complete and that future effort will consist of adapting the system to new computer hardware and software and of updating the various prediction modules as improved methods are developed through NASA noise reduction and basic research programs.

Schedule: ANOPP is now operational. Executive and data base software system development is complete and prediction modules for CTOL jet aircraft noise have been programmed and installed. Documentation including Theoretical, User's, Demonstration, and Programmer's manuals

Noise Prediction Techniques (Continued)

should be completed in early FY 79. Updates of present prediction modules and the addition of modules for rotor and propeller noise are planned during FY 79. Validation of ANOPP predictions against measured data have commenced and will continue through FY 79.

Accomplishments: ANOPP has been successfully demonstrated for use in the preliminary design loop for advanced SST aircraft studies. The Aircraft Noise Prediction Office and Langley Advanced Supersonic Transport Office have defined and demonstrated an interface for ANOPP in the design process. The two project offices, working in unison, will complete in FY 78 a comprehensive inhouse study of probable noise levels of future SST aircraft. The results of this study will be used by the FAA in support of a U.S. position to be placed before an ICAO rule making committee.

Sponsor: Langley Research Center and Lewis Research Center

Fiscal Year:	1975	1976	1977	1978
Funding ($1000):	228	172	410	283
Agency Manpower (Man-Years):	8	4	8	6

CATEGORY - ATMOSPHERIC PROPAGATION AND GROUND EFFECTS

Noise Propagation

This research is improving the ability to predict the effects of the atmosphere and ground on noise generated by an aircraft as it is radiated to an observer. Effects of particular concern under study in the program are randomness in the atmosphere, extremes of temperature and humidity, mechanisms of absorption of acoustic energy by the atmosphere, and procedures for determining the impedance properties of ground reflecting surfaces.

Need for Study: Knowledge of atmospheric propagation is adequate for noise transmission over relatively short distances and for a restricted range of known, stable atmospheric conditions. However, the ability to accurately determine propagation effects must be improved for several aircraft applications. The greatest need is for the ability to accurately predict the transmission of aircraft noise at shallow angles and over relatively long distances during terminal area operations. The state of the art in this particular case causes deviations between prediction and actual airport community noise by over 10 decibels. In addition, unpredictable variations in community noise from flight to flight, or during a single flyover, from the random character of the atmosphere, vary by the same order of magnitude and are readily detectable by the listener. Even for certification-type measurements, significant cost and time savings could be realized if the presently approved temperature-humidity-wind constraints could be relaxed through better information about atmospheric propagation effects.

Approach: Airplane flight tests, towers with fixed noise sources and atmospheric instruments, shock tube decay tests at high pressures, and specially developed noise sources and microphone arrays are used in these experiments. Acoustic and atmospheric data are being correlated with analytical methods for predicting atmospheric sound propagation that takes into account refraction, scattering, absorption, diffusion and ground reflection mechanisms. Existing flight test data is used wherever feasible to extract data on atmospheric effects.

The emphasis in this program is in establishing the effects of the atmosphere, over a wide range of temperature, humidity, and turbulence, on the propagation of noise into aircraft communities. The results are expected to enable the relaxation of certification test requirements and to increase the confidence with which airport community noise can be predicted. The results are also expected to be applicable to the propagation of noise from other sources such as highways and railroads.

Noise Propagation (Continued)

Schedule:

Conduct Flight Experiment to Determine the Effect of Propagation Angle and Distance on Sideline Noise	FY 1978
Conduct Flight and Fixed Source Experiments at the Outdoor Anechoic Test Apparatus (OATA) for a Range of Realistic Ground Impedances	FY 1978

Accomplishments: The NASA program provided the basic data that led to an improved standard for acoustic absorption by the atmosphere. A flyover experiment using a helicopter was conducted at Wallops Flight Center to measure the sideline propagation to relative large distances at shallow angles. Aircraft noise data collected in cooperation with the FAA in operations at Fresno-Yuma have led to revisions in the procedures used for propagation corrections in certification testing. Flyover data collected during REFAN project flight test have been analyzed and are giving insights into how noise data may be corrected over wide ranges of temperature and humidity.

Sponsor: Langley Research Center

Fiscal Year:	1975	1976	1977	1978
Funding ($1000):	489	369	549	481
Agency Manpower (Man-Years):	12	12	14	16

NASA - RESEARCH AND TECHNOLOGY PROGRAMS

CATEGORY - OTHER

Acoustic Instrumentation and Measurement Techniques

The purpose of this effort is to provide the necessary support for experimental research activities by developing instrumentation and data analysis techniques.

A Remotely Operated Multiple Acoustic Array Range (ROMAAR) has been developed and is in operation.

Sponsor: Langley Research Center and Ames Research Center

Fiscal Year:	1975	1976	1977	1978
Funding ($1000):	254	265	280	247
Agency Manpower (Man-Years):	2	5	2	6

CATEGORY - OTHER

Noise Shielding

A physical entity placed between a noise source and a receiver can reduce the noise at the receiver by providing a physical barrier that blocks the propagation of the sound waves. On an aircraft, this can be a wing blocking the sound from an overhead engine.

Need for Study: Designing an aircraft to take advantage of shielding can reduce the overall noise signature of the aircraft, therefore it is a method that can be used for noise abatement.

Approach: The effectiveness of noise shielding has been demonstrated both in laboratory tests and on full scale engine installations. Prediction methods for realistic noise sources and configurations must now be worked out. This requires development of a sophisticated computer program and the experimental verification of that program.

Development of prediction techniques will permit noise configuring an aircraft so that the overall noise signatures can be reduced. While the predictive capability will be beneficial for all noise barrier problems, the emphasis is on shielding by aircraft structures.

Schedule:

Develop computer program by 1981.

Experimental verification of program by 1983.

Accomplishments:

Many large and small scale shielding experiments have been completed.

A simplified computer program for predicting the shielding of simple noise sources was developed, followed by the development of an "exact" computer program for shielding predictions.

Sponsor: Ames Research Center and Lewis Research Center

Fiscal Year:	1975	1976	1977	1978
Funding ($1000):	67	11	37	46
Agency Manpower (Man-Years):	1	1	1	1

CATEGORY - CTOL (SUBSONIC)

Refan Program

The objective of the Refan program, which ended in 1975, was to demonstrate the technical feasibility of substantially reducing the noise levels of production JT8D engine powered aircraft, such as the Boeing 727 and 737 series, and the Douglas DC-9 series. The program consisted of the design, fabrication, and ground and flight testing of the refan engines with modified nacelles.

Need for Study: One of the major problems confronting civil aviation today is public exposure to noise generated by aircraft in the vicinity of airports. The principal sources of airport noise are identified with the large number of narrow-body aircraft representing about three-fourths of the domestic commercial fleet. The narrow-body aircraft fleet is comprised of the DC-8's and B707's powered by the JT3D turbofan engine and the DC-9's, B727 and B737's powered by the JT8D turbofan engine. The JT8D powered aircraft, which are newer and are still in production, are estimated to number about 1600 by 1985 compared to about 400 JT3D powered aircraft. The reduction of the noise in the JT8D powered aircraft, therefore, would represent a significant reduction in overall noise exposure in communities across the nation.

Approach: A principal objective of the Refan program was to provide engine and air-frame modifications that will make the aircraft significantly quieter. Another objective was to retain a retrofit capability at minimum cost. Accordingly, the changes were limited to modifications of the low pressure spool and the nacelle, while the engine core was not altered. The basic approach was to replace the existing low bypass ratio two-stage fan with a larger higher bypass ratio single-stage fan. The higher bypass ratio fan with its attendant lower fan pressure ratio reduced fan jet discharge velocity and noise. The engine and nacelle design featured a full-length fan duct which provided considerable surface area for acoustic treatment. The tailpipe of the new nacelles provided additional surface area for sound treatment.

Pratt and Whitney Aircraft performed the feasibility studies, design and fabrication of refanned engines, component testing, endurance testing for limited flight qualification, and ground testing to establish acoustical characteristics.

Feasibility studies and subsequently engineering and fabrication of the refanned 727 nacelle for ground testing were performed by the Boeing Company. The ground test nacelle was configured to simulate both the center engine and the outboard engines. Component tests included evaluations of the modified center engine "S" duct. Ground acoustical tests

Refan Program (Continued)

were conducted with the baseline configuration and the refanned engine center and outboard configurations. Based on these ground test data, refanned engine B727 fly-over noise predictions were made.

Similarily, McDonnell Douglas Company conducted feasibility studies and subsequently designed and fabricated refanned nacelles for the DC-9 airplane and associated airplane pylon modifications. This was followed by extensive flight tests of both the JT8D baseline configuration and the refanned configuration.

Supporting contracts were let with United Air Lines and American Airlines to provide valuable input regarding airline operational constraints, airline economics and retrofit costs.

In-house tests were performed by the Lewis Research Center on model fans, with and without the Boeing center engine "S" duct and with and without distortion screens. The Lewis Research Center also conducted altitude performance tests on a full-scale refan JT8D-9 engine in the Propulsion System Laboratory.

Schedule: Major program milestones have been as follows:

Pratt and Whitney

Complete Component Tests	November 1974
Complete Engine Design	December 1974
Sea Level Tests of Refanned Engines	April 1975

Boeing

Complete Component and Model Tests	April 1974
Complete Nacelle Design	September 1974
Complete Nacelle Manufacture	February 1975
Complete 727 Ground Tests	March 1975

McDonnell Douglas

Complete Nacelle Design	February 1974
Complete Nacelle Manufacture	December 1974
Complete Flight Tests	April 1975

Refan Program (Continued)

Accomplishments: Boeing fly-over noise predictions based on refan engine and nacelle ground test data indicate that the refan engine equipped 727-200 will be in full compliance with FAR Part 36 (1969). Refan engine noise improvements compared to the baseline airplane ranged from 7 EPNdB at approach to 8.5 EPNdB at takeoff. This means that the 95 EPNdB noise exposure contour area would be reduced by 67 percent and the 90 EPNdB noise exposure contour area would be reduced by 74 percent.

The Douglas fly-over noise comparisons indicate the refanned DC-9 to be also in full compliance with FAR Part 36 (1969). Noise reductions compared to the baseline airplane ranged from 5 EPNdB at approach to 10 EPNdB at takeoff. The 90 EPNdB noise exposure contour area would be reduced by 61 percent.

The takeoff thrust of 16,600 pounds for the refanned engine was demonstrated, compared to a rated thrust of 14,500 pounds for the baseline engine. The durability, reliability, and operational suitability of the refanned engines was demonstrated through extensive ground testing and flight testing.

Retrofit programs involving retrofitting existing airplanes with refanned engines have not emerged, primarily because there has been no compelling regulation. However, Pratt and Whitney, Boeing, and Douglas have pursued marketing activities aimed at the sale of new airplanes with JT8D engines incorporating refan features. The Pratt and Whitney/ Douglas effort recently met with success and Douglas has announced the introduction of the DC-9-Super-80, utilizing JT8D-209 refanned engines. Douglas has announced 27 firm orders and 9 options, with first flight planned for mid-1979 and first delivery planned for early 1980. Douglas has announced that these airplanes will be 5 to 6 EPNdB quieter than required by FAR part 36 (1969), and that they will meet the noise regulations established by the ICAO Committee on Aircraft Noise (CAN-5) for new aircraft produced in the 1980's. The DC-9-Super-80 features a 20,000 pound increase in takeoff gross weight, an increase of about 32 passengers, and a reduction in fuel consumed per passenger mile of about 20 percent.

Sponsor: Lewis Research Center

Fiscal Year:	1975	1976	1977	1978
Funding ($1000):	1,000			
Agency Manpower (Man-Years):	14			

NASA - DEMONSTRATION PROGRAMS AND SYSTEMS STUDIES

CATEGORY - CTOL (SUBSONIC)

Advanced Acoustic Composite Nacelle Flight Program

This program demonstrated the application of advanced interwoven acoustic absorbent and composite structural materials to an engine nacelle on a modern wide-body transport in airline operation.

Approach: Various design concepts for the integration of composite materials with nacelle acoustic treatment were evaluated 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. In addition, ground tests and commercial service flight tests of production composite/acoustic nacelles were conducted to provide sufficient data on performance, maintenance requirements, and maintenance costs to establish airline industry confidence in the application of composites to engine nacelles.

Sponsor: Langley Research Center

Fiscal Year:	1975	1976	1977	1978
Funding ($1000):	500			
Agency Manpower (Man-Years):	8			

CATEGORY - CTOL (SUBSONIC)

New Propulsion Systems Studies

Studies are currently underway investigating the application of advanced technologies to allow for the development of future small transport and commuter aircraft with significantly reduced initial and operating costs and improved operational capability, energy efficiency, and environmental compatibility.

Need for Study: Historically, advanced technology has been applied to the larger transport aircraft operated by the trunk and local service airlines. As these aircraft have grown in size, service to the small communities has become increasingly less economic for these airlines. In some cases this service has been provided by commuter airlines. However, the choice of aircraft available to the commuter airlines is very limited and, for the most part, reflects older technology. There is a need to closely examine the requirements for this class of aircraft and identify areas where advanced technology can be cost-effectively applied to provide significant improvements.

Approach: Design and system studies will determine the most promising advanced technologies. The advantages of the selected technology will then be verified by more detailed analysis or experimental testing.

All indications are that the application of advanced technology--structure, propulsion, aerodynamics, and systems--can result in greatly improved future small transport aircraft.

Schedule: The initial contracted design studies are underway and will continue through 1978. Wind tunnel testing has begun on advanced airfoils and will continue through 1979.

An expanded effort in this area is being considered for 1980 or 1981.

Accomplishments: Final oral review of first phase of a design contract with Boeing was presented at NASA Ames on November 10, 1977.

A symposium on short-haul small community air service was held at Ames on November 9-10, 1977.

Sponsor: Lewis Research Center

Fiscal Year:	1975	1976	1977	1978
Funding ($1000):	800	196	94	120
Agency Manpower (Man-Years):	11	.1	.5	.5

NASA - DEMONSTRATION PROGRAMS AND SYSTEMS STUDIES

CATEGORY - CTOL (SUBSONIC)

Flight Operational Procedures

Two flight procedures for reducing the community impact of aircraft landing operations were thoroughly tested. Operational avionics and flight procedures were developed for the "two-segment" landing approach, and the "delayed flap" approach.

Flight operational procedures have been proposed as an immediate solution to the increasing community noise problem around airports. The delayed flap approach reduces both noise impact and fuel consumption by remaining at high airspeeds and low drag configurations until late in the approach.

Need for Study: It is necessary to demonstrate the avionics for the two-segment and delayed flap procedures under instrument flight conditions during routine scheduled service. The actual noise reductions to be realized, and the feasibility of using area navigation equipment also need to be evaluated.

Approach: To develop the two-segment approach procedure, the avionics were developed and flight evaluated using ILS co-located DME and barometric altitude for vertical guidance in a Boeing 727. Similar flight tests were also conducted in a commercial R-NAV system in a DC-8. Both aircraft were operated in routine commercial service with two-segment concept operational procedures to gain experience.

For the delayed flap procedure, flight tests were conducted on NASA's Convair 990 aircraft with NASA and industry pilots. Piloted simulations were conducted on a Boeing 727, and ATC simulations were conducted with high density traffic mixes to evaluate compatibility with conventional type approaches.

The results of these programs indicated that the procedures will probably not be implemented by commercial carriers because of cost of installing the new equipment in the airline fleet. Safety is another important consideration. The two-segment approach increases the probability of wake vortex encounters by trailing aircraft, while the delayed flap approach poses ATC compatibility problems.

Schedule: Two-segment approach procedures were studied between 1972 to 1975. Delayed flap procedures were evaluated from 1975 to 1977.

Accomplishments: Equipment and two segment approach were certified for routine operations in commercial service and were successfully operated for 6 months in a UAL DC-8 and a VAL 727. Significant reductions in ground perceived noise under the approach path were achieved.

Flight Operational Procedures (Continued)

The 90 EPNdB noise contour area of a delayed flap approach was measured to be 33% of that of current airline procedures in both CV-990 flight tests and B-727 simulations.

Fuel savings per approach was measured to be 1% to 2% of typical mission fuel loads in both CV-990 flight tests and B-727 simulations.

Delayed flap procedures were generally rated as having good pilot acceptability.

High density traffic ATC simulations indicated a sharp drop off of fuel savings and actually increased overall fuel consumption at traffic rates higher than 35 aircraft per hour.

Sponsor: Langley Research Center

Fiscal Year:	1975	1976	1977	1978
Funding ($1000):	1200	536	54	43
Agency Manpower (Man-Years):	17	1	.5	.5

CATEGORY - CTOL (SUPERSONIC)

New Propulsion Systems Studies

The objective of this program is to demonstrate the critical component technology required for supersonic cruise engines affording high propulsive efficiency together with reduced noise and emission levels. The technology thus demonstrated will minimize the costs and risks of follow-on programs and remove some of the critical technical barriers which now inhibit the development of an advanced supersonic cruise aircraft. Large-scale component testing under simulated engine conditions will be supported by aero/acoustic nozzle model tests and rig testing of critical components prior to installation in test engines.

Need for Study: One of the major challenges facing civil aviation in the future will be to allow all the passengers to fly to their destinations without overcrowding the available airspace. The solution to this problem can be approached in two ways: making the airplanes larger, or faster. The second alternative is being addressed in the Supersonic Cruise Aircraft Research/Variable Cycle Engine (SCAR/VCE) programs. Not only is the airspace problem addressed by flying faster at supersonic speeds at higher altitudes, but the convenience to the user of the service is greatly enhanced, especially when city pairs separated by great distances are considered. For example, an advanced SST flying from San Francisco to Tokyo could reduce the present 11-hour flight time to about four hours.

The problems with existing first-generation SST's are poor economics (small payload, limited range) and environmental considerations such as noise and pollution. The NASA SCAR program, which was started in 1972 was intended to provide our airframe and aircraft propulsion industry with the technology readiness to begin an advanced SST development program should it ever be determined to be in the national interest to do so.

Maximum propulsive efficiency at supersonic conditions dictates a cycle with high specific thrust. Lower specific thrusts, however, are optimum at subsonic conditions and also from the standpoint of alleviating the takeoff jet noise problem. These conflicting propulsion system objectives are difficult, if not impossible, to meet with a fixed engine cycle but are best reconciled with a Variable Cycle Engine (VCE). Such an engine exhibits many of the characteristics of an advanced leaky turbojet at supersonic conditions and those of a moderate bypass turbofan at subsonic cruise and takeoff conditions. In both advanced VCE concepts under consideration, an inverted flow coannular exhaust system has been identified having the potential to significantly reduce takeoff jet noise without unduly compromising weight or performance. High turbine temperatures and advanced materials are required in both VCE concepts to meet the stringent performance and weight objectives required for a viable second-generation SST.

New Propulsion Systems Studies (Continued)

Since the advanced VCE has been identified as the pacing item in any future SST development program that may ensue, a VCE Component Technology Program has been initiated by NASA to address the most critical VCE component technologies not being addressed by any other engine programs.

Approach: Early studies on airplane and propulsion system concepts have indicated that, indeed, with the proper development of identifiable advanced technologies, the deficiencies of existing first-generation SST's can be overcome. The payload-range characteristics can be significantly enhanced, with resultant operating costs competitive on a seat-mile basis with those of the current wide-body subsonic fleet. Jet noise, too, can be reduced to be at or slightly below FAR 36 (1969) limits. The emissions problems can also be alleviated with the application of burner concepts derived from the NASA ECCP program.

The challenge presented to the engine designer was to provide an advanced engine that would offer excellent supersonic cruise performance, and yet provide good off-design subsonic cruise performance while at the same time having the capability to provide high takeoff thrust at noise levels significantly lower than the current first-generation SST engines. In addition, these engines had to be light-weight and be within a certain dimensional envelope so that they could be properly integrated with the airframe for good overall airplane aerodynamic performance.

Certain component technologies have been identified as critical to the successful development of proposed VCE concepts. In order to provide the required development and testing necessary to assess the feasibility and readiness of these most critical technologies a VCE Component Test Program was initiated through a series of contracts to the two engine companies, Pratt and Whitney Aircraft (P&WA) and the General Electric Company (G.E.).

VSCE/F100 Component Test Program (P&WA): The Variable Stream Control Engine (VSCE) is essentially a duct burning turbofan in which the flow and exhaust velocity profile can be optimally tailored for a given flight condition through variable geometry, rotational speed, and fuel flow control. P&WA will simulate the VSCE cycle using an existing F100 high-technology engine. The unmodified engine is used to provide the appropriate high-flow high-temperature air to a quiet coannular ejector nozzle and a low-emission duct burner. A new boilerplate tailpipe will be added to separate the bypass stream from that of the core flow. A coannular ejector nozzle with a cylindrical shroud configured for takeoff conditions will be attached to the tailpipe, and a low-emission duct burner will be located in the outer bypass duct to accelerate the bypass

New Propulsion Systems Studies (Continued)

flow to demonstrate the acoustic benefits of an inverted velocity profile. The coannular nozzle and duct burner configurations for this test program will be based on current VCE supporting technology programs.

Design and long-lead material and hardware procurement have been initiated for the duct burner and coannular nozzle. Fabrication, assembly and testing are scheduled for the 1978-1979 time period.

Scale models of the product engine nozzle will be tested in the Lewis 8- by 6-Foot Wind Tunnel to provide thrust performance at takeoff, subsonic and supersonic cruise conditions.

The results of an analytical screening study to identify advanced duct burner concepts was completed were used to select the three-stage vorbix configuration for the F100 component test engine. Experimental evaluation of this duct burner in a two-dimensional segment rig is in progress. Results of this experimental program will be applied to the design of the low-emission duct burner for the VSCE/F100 component test engine.

A low-emission duct burner and a low-noise coannular nozzle are being procured for the Pratt and Whitney VSCE/F100 Component Test engine. It is expected that the first large-scale verification of the coannular jet noise benefit of an inverted velocity profile will be accomplished in September 1978. This noise test will be followed by measurements of advanced duct burner emissions in May 1979.

DBE/YJ101 Component Test Program (G.E.): The General Electric Component Test VCE will validate some of the critical technologies peculiar to their Double Bypass Engine (DBE) concept. The test engine will be built around a military YJ101 low-bypass turbofan. It will be modified to incorporate a split fan with an additional bypass duct emanating from between the two fan sections. This second duct later is merged with the inner bypass duct from the last fan stage before being discharged into either the main flow downstream of the turbines in the high performance mode, or supplied to the interior of a coannular plug nozzle to provide the low-energy inner exhaust flow in the low-noise mode of operation. Appropriate valving in the bypass ducting, and variable geometry features in the inner nozzle and certain turbomachinery components are required for this demonstration of mode-switching capability. An aeroacoustic test of this exhaust concept used in conjunction with the modified YJ101 will take place in September 1978. This test will provide the first large-scale demonstration of the significant jet noise reductions found in small-scale model tests of similar coannular nozzles with inverted velocity profiles.

New Propulsion Systems Studies (Continued)

A model nozzle program to investigate the static aeroacoustic performance and the low-speed aerodynamic performance of coannular plug nozzles has been completed. G.E. is testing model high-radius-ratio coannular plug nozzles in a free jet noise test facility which provides an acoustic test at simulated takeoff freestream velocities. An acoustic prediction methodology for coannular plug nozzles will be developed from the results of these tests and used to refine the design of the component test engine exhaust nozzle.

In order to fully demonstrate all the advantages of the DBE system, however, a new variable geometry front block fan designed for greater airflow capability than that of the YJ101 fan is needed. A detailed aerodynamic design and preliminary mechanical design of such a fan has already been completed. A contract for the detailed mechanical design, fabrication, assembly, and rig test of this fan will be awarded in the summer of 1978. The rig testing of this fan would be completed in 1980.

A contract is presently underway with G.E. to define a core-driven-second-block-fan testbed engine. A design, fabrication and test program is planned to begin in the late summer of 1978. This would be the first time for the test of a fan stage on the high-pressure spool of an engine—a promising element of the recommended DBE product engine cycle identified in the NASA-sponsored SCAR/VCE propulsion system studies. The front block fan in this test would consist of the first two stages of the existing YJ101 fan driven by the low-pressure turbine.

A bypass control valve and a coannular acoustic plug nozzle are being procured for the G.E. DBE/J101 Component Test engine. It is expected that the first large-scale verification of the coannular acoustic model test data for high radius-ratio plug nozzles will be accomplished in September 1978. It is also expected that a double bypass engine with a J101 core-driven third stage fan will be assembled and tested for aero/acoustic performance and component interactions and controllability evaluation in calendar year 1980. Rig testing of the first two stages (front block) of the double bypass engine's variable-geometry fan is also expected to occur in 1980.

Schedule: Major program milestones are tabulated below.

Pratt and Whitney Aircraft

Complete Duct Burner Segment Rig Tests	April 1978
Complete Nozzle Aero/Acoustic Model Tests.	August 1978
Demonstrate Coannular Noise Benefit With Large-Scale Hardware	September 1978
Demonstrate Duct Burner Emissions Reduction With Large-Scale Hardware	May 1979

New Propulsion Systems Studies (Continued)

General Electric Company

Complete Nozzle Aero/Acoustic Model Tests	June 1978
Complete Forward Valve Test	June 1978
Demonstrate Coannular Noise Benefit With Large-Scale Hardware	September 1978
Core Engine Test	February 1980
Variable Flow Fan Rig Test	April 1980
Double Bypass Engine Performance/Acoustic Test	June 1980

Accomplishments: Coannular nozzle noise reduction benefit has been verified via model tests at static conditions and with forward velocity effects. Nozzle thrust coefficients at Mach numbers up to 0.45 have been measured and it has been verified that performance was at an acceptable level.

Preliminary design of a high-speed multistage variable-geometry fan for G.E. Double Bypass Engine has been completed. The segment rig test program of low-emission duct burner for Pratt & Whitney Variable Stream Control Engine has been initiated. Design and procurement of long-lead hardware for VSCE/F100 and DBE/J101 testbed engines have been completed to provide large-scale coannular noise tests in September 1978.

All technology thus verified and demonstrated will minimize the costs and risks of follow-on programs and remove some of the critical technical barriers which now inhibit the development of an advanced supersonic cruise aircraft.

Sponsor: Lewis Research Center

Fiscal Year:	1975	1976	1977	1978
Funding ($1000):		300	1,137	2,457
Agency Manpower (Man-Years):		5	7	7

NASA - DEMONSTRATION PROGRAMS AND SYSTEMS STUDIES

CATEGORY: CTOL (SUPERSONIC)

New Aircraft Studies

This program addresses three objectives. It will provide the data necessary to enable rational decisions relative to the consideration of future operations of civil supersonic aircraft in the United States. An expanded technology base is expected to result that will provide data necessary to assess the environmental impact of present and future foreign supersonic cruise aircraft.

It will establish a supersonic propulsion technology base, in parallel with other disciplinary technologies, that permits reduction in noise in takeoff and landing to levels consistent with other heavy, long-range aircraft such as the Boeing 747.

And finally, research will be conducted on low-sonic-boom aircraft configurations. The development of capability for computer-aided analysis and synthesis will be undertaken. The computer tools and methodology will be applied to Supersonic Cruise Aircraft Research (SCAR) configurations.

Sponsor: Langley Research Center and Lewis Research Center

Fiscal Year:	1975	1976	1977	1978
Funding ($1000):		362	272	272
Agency Manpower (Man-Years):		5	1	1

CATEGORY: STOL

Aircraft Operational Systems

The purpose of this project is to provide information to aid in the choice of STOL terminal area guidance, navigation and control systems and operational procedures to minimize noise and fuel use and maximize operational safety.

Need for Study: The flight path requirements as a function of system capability to contain the 90 EPNdB noise footprint within the airport boundary need to be defined. Onboard avionic system concepts (hardware and software) that will allow STOL aircraft to steep, curved and decelerating approaches will be needed for safety.

The usability of TRSB MLS in terminal are RNAV for performing such complex approaches also needs to be determined.

Approach: Avionic system concepts using TRSB MLS, VORTAC and barometric altitude for lateral and vertical guidance in an Augmentor Wing Jet STOL Research Aircraft (Modified DeHaviland C-8 Buffalo) and a DeHaviland Twin-Otter are under development, with flight tests planned for 1978. The data so obtained will be used in the development of avionics systems for future powered lift and light wing-loading STOL aircraft.

Certification criteria for STOL flight director and autoland systems will be developed, and terminal area RNAV requirements will be established.

Schedule: The current program phase is planned to be completed by 1979.

Accomplishments: Four autoland system concepts have been developed for the Augmentor Wing aircraft utilizing various control configurations. Flight tests to establish system performance will be initiated in May 1978.

Two flight director system concepts have been developed for the Augmentor Wing aircraft to facilitate flying complex flight paths and reduce pilot work load. Flight tests have been completed which indicate that curved flight paths within 1 mile radius of the airport can be flown with reasonable workload in simulated IFR conditions.

Two autoland system concepts are being developed for the Twin-Otter. Flight tests to establish system performance will be initiated in February 1978.

NASA - DEMONSTRATION PROGRAMS AND SYSTEMS STUDIES

Aircraft Operational Systems (Continued)

RNAV system concepts have been developed and flown. Data is being analyzed.

Sponsor: Ames Research Center and Langley Research Center

Fiscal Year:	1975	1976	1977	1978
Funding ($1000):		63	71	68
Agency Manpower (Man-Years):		1	4	7

CATEGORY: STOL

Quiet, Clean, Short-Haul Experimental Engine (QCSEE)

The overall objective of the QCSEE program is the development of propulsion system technology suitable for powered-lift short-haul aircraft for the 1980's time period. The program requires the design, fabrication, and ground testing of two engines, an under-the-wing (UTW) engine and an over-the-wing (OTW) engine by the General Electric Company. Following completion of the General Electric acoustic tests, NASA-Lewis will perform aerodynamic and acoustic tests with an engine-wing-flap system.

Need for Study: Public acceptance of the short-haul STOL type aircraft requires a minimal environmental impact by operation of such aircraft from small airports that are close to metropolitan centers. Primary environmental concerns are low noise and low exhaust pollutants. Further, economically viable short-haul aircraft require good propulsion system performance.

Although directed toward short-haul commercial applications, it is evident that QCSEE technology has a potentially broad range of application. Low noise and low pollution are of interest for conventional long-haul aircraft. Improved propulsion system performance is important to energy conservation requirements. And finally, many of the QCSEE engine features are applicable to propulsion systems for U.S. Navy V/STOL type aircraft which are currently under study.

Approach: Two powered-lift, short-haul aircraft propulsion systems were designed and fabricated. The engine location for the UTW system is conventional. The OTW or over-the-wing concept offers a distinct acoustic advantage. In this arrangement the wing serves as an acoustic shield, and reduces the propagation of aft-end noise to the ground. Consequently, for a given noise level, the OTW system can be designed for a higher fan pressure ratio than the UTW system. This favors low engine weight and drag for a given thrust level. However, the UTW engine is compatible with a reverse thrust system achieved by reversing the fan blade pitch to exhaust fan flow air forward from the engine inlet. This type of thrust reverser represents a significant weight advantage over the target type reverser system employed on the OTW engine. QCSEE test results will help to determine which of these powered-lift systems is best for future applications.

The very stringent noise goals of the QCSEE program include an aircraft noise level of 95 EPNdB during takeoff and approach and a reverse thrust maximum level of 100 PNdB, all measured on a 500 foot sideline. In addition, a 95 EPNdB contour area of less than 0.5 square miles is desired. To attain such goals a number of advanced acoustic concepts were employed.

Quiet, Clean, Short-Haul Experimental Engine (QCSEE) (Continued)

The QCSEE acoustic designs incorporate low source noise features such as low fan tip speed, low fan pressure ratio (for low jet/flap noise and low fan exhaust noise), high bypass ratio, and large rotor to outlet guide vane (OGV) spacing. Fan inlet noise suppression is obtained by a near-sonic (0.79 throat Mach number) inlet with multiple-thickness treated walls. Fan exhaust suppression is provided by multiple-thickness treated exhaust walls, a 40 inch acoustically treated splitter, acoustic treatment on the fan discharge passage walls between the rotor and OGV's, and acoustic treatment on the pressure surface of the OGV's. Core noise suppression is provided by using a "stacked treatment" concept in which thick low-frequency combustor noise treatment is located under and integral with thin high-frequency turbine noise treatment panels.

The QCSEE acoustic designs and the predicted noise levels and suppression estimates were supported by various engine and scale-model tests. The model tests were conducted in the General Electric anechoic chamber test facility and the Lewis 9- by 15-foot acoustic wind tunnel.

The QCSEE engines are being designed to meet the proposed EPA 1979 emission standards. A double annular dome combustor is being adapted to the F101 combustor of the UTW engine in a series of combustor rig tests. Both engines currently use a modified F101 core engine combustor.

To help attain the high installed thrust/weight ratios of 4.3 and 4.7 for the UTW and OTW engines respectively, some QCSEE engine parts are fabricated from light weight composite materials. The UTW engine has composite fan blades and will also be tested with a composite nacelle. Both engines use a composite fan frame.

Other features of the engines include digital control systems and main reduction gears. Also featured are fast thrust response times from approach to takeoff thrust and from approach to reverse thrust.

<u>Schedule</u>: Major program milestones are:

General Electric Company	
Initiate Contract	January 1974
Complete UTW Engine Design	January 1975
Complete OTW Engine Design	July 1975
Complete OTW Engine Tests	June 1977
Complete UTW Engine Tests	March 1978

Quiet, Clean, Short-Haul Experimental Engine (QCSEE) (Continued)

NASA - Lewis	
Initiate Preparations for Engine Tests	December 1975
Complete OTW Engine Tests	June 1978
Complete UTW Engine Tests	March 1979

Accomplishments: Aerodynamic and acoustic testing of the UTW and OTW engines is nearing completion at General Electric. Preliminary noise test results indicate the OTW system noise level at takeoff to be 96.5 EPNdB, about 1.5 EPNdB above the goal. The approach noise level of 93.2 EPNdB is well below the 95 EPNdB goal. The reverse thrust level of 107 PNdB maximum exceeds the noise goal by 7 PNdB. The projected 95 EPNdB footprint area of 0.33 square miles meets the 0.5 square mile goal.

The significance of the OTW acoustic technology can be illustrated by comparison of the QCSEE OTW engine with conventional engines. An OTW-powered aircraft takeoff noise level, if extrapolated to the FAA sideline condition, would be about 22 EPNdB below the FAA limit. It would also be about 12 EPNdB lower than the DC-10 aircraft, which is representative of the modern wide body jet aircraft.

Combustor rig test results indicate that the exhaust emission goals will either be achieved or be very close to being achieved.

Installed forward thrust requirements were met by both engines, (20,300 lbs for the OTW, 17,400 lbs for the UTW engine). The OTW reverse thrust of 35% of takeoff met the design goal. The UTW value of 25% fell below the goal. However, there is a possibility of improvement in later tests employing different engine parameters.

Fan performance met or exceeded specifications for both engines. The digital control performance was, in general, good. The main reduction gears on both engines have performed without difficulty.

Sponsor: Lewis Research Center

Fiscal Year:	1975	1976	1977	1978
Funding ($1000):	5,000	1,500	488	90
Agency Manpower (Man-Years):	71	21	30	10

NASA - DEMONSTRATION PROGRAMS AND SYSTEMS STUDIES

CATEGORY: STOL

Systems and Design Studies

The objective of this work is to help develop a sound technological base for future decisions relating to the design, development, and operations of STOL commercial air transportation systems. This will be achieved through studies and experiments that examine the relationships between aircraft technology, airline economics, and environmental constraints.

Potential applications of advanced technologies such as prop fans, powered lift, and simplified designs, to future commuter aircraft will be identified and evaluated in terms of cost reduction, operational capability, fuel efficiency, and environmental acceptability.

Sponsor: Langley Research Center and Lewis Research Center

Fiscal Year:	1975	1976	1977	1978
Funding ($1000):				50
Agency Manpower (Man-Years):				6

NASA - DEMONSTRATION PROGRAMS AND SYSTEMS STUDIES

CATEGORY: STOL

Quiet, Propulsive Lift Technology

NASA's continuing search for a practical means to alleviate aircraft noise impact on the airport community will be enhanced by a versatile new research aircraft now being built for NASA by the Boeing Commercial Airplane Company. The Quiet Short-Haul Research Aircraft (QSRA), which is utilized to investigate the quiet propulsive lift technology, will be the quietest four engine jet aircraft built to date, with a 90 EPNdB noise footprint area of approximately 0.3 sq. mi. QSRA technology applied to a 150,000 lb. aircraft would yield a footprint of less than one sq. mi., versus about 30 sq. mi. for current civil transports of equivalent size. This technology could permit future aircraft operations with no excessive noise levels extending beyond the boundaries of hundreds of large and small airports in the U.S., many of which are now threatened by restricted operations due to noise.

Need for Study: STOL aircraft are viewed as a means for improving the National Transportation System through delivering the passenger closer to his house and relieving congestion at major airports. Since the aircraft would be operated near small suburban communities, a low noise aircraft is an absolute requirement. This requirement is especially difficult to meet because STOL aircraft are relatively high powered.

Approach: The QSRA employs the upper-surface-blowing propulsive-lift concept in order to achieve good low-speed performance at noise levels acceptable to the community. With the lift augmentation provided by four engines mounted over the wing plus an advanced flap and boundary layer control system, the QSRA will be able to safely takeoff and land in field lengths ranging from 5000 ft. to under 1500 ft., and to fly steep approach and climb angles or curved flight paths with a turn radius of as little as 700 ft. The aircraft will be used by NASA to investigate new flight procedures that can be used in combination with advanced air traffic control concepts to reduce airport community noise, relieve air traffic congestion, and increase terminal-area flight safety.

Construction of the research aircraft is nearly complete. Flight investigations will begin in July 1978. During the next several years, flight experiments conducted in cooperation with the FAA and private industry will establish design criteria and certification criteria needed for future development of civil and military transports and business aircraft utilizing QSRA technology.

The total cost of the program at completion is estimated at $32 million.

Quiet, Propulsive Lift Technology (Continued)

Schedule: QSRA is expected to first fly in mid-1978. Flight tests and noise evaluations are planned through 1979. Modifications will be made in 1980, with renewed flight tests in 1981.

Accomplishments: Accomplishments to date are the development of the upper surface blowing technology and the design of the aircraft.

Sponsor: Ames Research Center

Fiscal Year:	1975	1976	1977	1978
Funding ($1000):	2,000	544	85	95
Agency Manpower (Man-Years):	27	8	5	10

NASA - DEMONSTRATION PROGRAMS AND SYSTEMS STUDIES

CATEGORY: ROTORCRAFT/VTOL

Aircraft Operational Systems

This project will be conducted to develop avionics and procedures for quiet helicopter terminal area operations. The project will proceed through stages of analysis and simulation into actual flight tests. One facet of this project is concerned with alleviating airport community noise for VTOL operations through the tailoring of airport approach paths.

Need for Study: Reduction of both interior and exterior noise is of key importance in advancing helicopter air transportation, particularly in terminal area operations at high density metropolitan heliports. By approaching airports above pattern altitude and using spiral descents in airport areas adjacent to the CTOL active runways, ground noise can be confined to within the airport boundaries.

Approach: Flight path trajectories and procedures that minimize noise will be developed through stages of analysis and simulations prior to actual flight tests.

Onboard digital avionics systems will generate noise abatement flight paths in real time along with the required navigation and guidance for providing automatic flight path tracking.

Noise measurements will be made and compared to noise generated during conventional procedures.

ATC simulations will be conducted to evaluate operational compatibility at city-center heliports and hub-airports. Techniques for VTOL spiral descents and terminal approaches to VTOL landing pads will be flight evaluated using peripheral MLS Azimuth coverage for horizontal guidance and barometric/radio altitude and DME for vertical guidance.

During the operating experiments phase, spiral descent techniques with the VSTOLAND integrated research avionics system will be implemented and flight tested in the UH-1H helicopter and in the XV-15 Tilt-Rotor research aircraft.

Schedule: The testing and evaluation program is expected to commence in 1978 and continue on to 1983.

Accomplishments: The VSTOLAND systems for both the UH-1H and the XV-15 have been fabricated and delivered to Ames. The UH-1H system has been installed and checked out in the helicopter. The XV-15 system is being installed in the Ames S-19 Simulator for checkout.

Aircraft Operational Systems (Continued)

Sponsor: Ames Research Center

Investigator: Not Cited

	1975	1976	1977	1978
Fiscal Year:				
Funding ($1000):		80		
Agency Manpower (Man-Years):		1		

CATEGORY: ROTORCRAFT/VTOL

Rotor Systems Research Aircraft (RSRA)

The Rotor Systems Research Aircraft (RSRA) Program is a joint project with the Army that will provide research on a wide variety of promising new quiet rotor concepts.

An in-flight rotor test facility is being developed for the investigation of advanced rotor systems technology in the actual flight environment including maneuvering flight. In addition, the facility will provide a basis for the in-flight verification of advanced analytical methods and noise reduction studies.

Full-scale helicopter rotor blades are being constructed using a soft tooling concept which will allow relatively easy modification of basic parameters such as airfoil section, twist and tip shape. This program is intended to improve noise and aerodynamic characteristics of helicopter rotors.

Need for Study: Helicopter noise is a particular problem, both in civil and military operations, because of its peculiar signature and long duration. The impulsive noise from the advancing tip and from blade tip vortex intersection is a primary problem.

Approach: The research rotor system will be constructed at full scale, and performance and acoustic characteristics will be measured in the 40- by 80-Foot Wind Tunnel. Modifications to the rotor will be guided by generic research in airfoils for rotorcraft and research on rotor noise sources.

The emphasis of this program is on reduction of helicopter noise by aerodynamic refinement of the rotor.

Schedule: The rotor will be delivered in January 1980. Test of the basic rotor is scheduled for April 1980, with rotor test with modified airfoil sections in September 1981, and rotor tests with modified tip sections in September 1982.

Accomplishments: Evaluation of acoustic signatures for several tip shapes was completed in 1973. Evaluation of acoustic signatures for a compliant rotor with several tip shapes was completed in 1977.

Rotor Systems Research Aircraft (RSRA) (Continued)

Sponsor: Ames Research Center

Fiscal Year:	1975	1976	1977	1978
Funding ($1000):		510	30	100
Agency Manpower (Man-Years):		7	2	1

NASA - DEMONSTRATION PROGRAMS AND SYSTEMS STUDIES

CATEGORY: ROTORCRAFT/VTOL

Tilt Rotor Research Aircraft (TRRA)

An integrated flight vehicle is being developed to demonstrate the technology readiness of the tilt-rotor concept for quiet civil operations. An objective is to establish a safe operating envelope and initially assess the handling qualities of the XV-15 Tilt Rotor Research Aircraft.

The Tilt Rotor concept uses large diameter (low disc loading) prop rotors mounted on wing-tip nacelles, which operate in the horizontal plane for hover and helicopter operations and are tilted forward to the normal propeller position for airplane type flight.

Furthermore, the tilt rotor aircraft's extensive reduction of rotor RPM for airplane mode results in a predicted noise level at below 65 PNdB for a 1000 ft. altitude fly-by at 200 knots—a noise level below most urban ambient conditions.

Approach: One of the principal flight research objectives of this program includes the evaluation of hover mode noise over a range of tip speeds and disc loading (gross weight). Preliminary sound level data recorded, at a 500 ft. distance during the initial flight of the XV-15, confirm predictions that the hover noise generated by the tilt rotor's highly twisted blades is lower than the noise produced by a conventional (Bell Model 206L) helicopter of approximately one-third the tilt rotor's gross weight, and about 6dB below the noise level of equivalent weight helicopters. The broad conversion corridor, the rapid speed of conversion, and the steep descent and climb capabilities of the tilt rotor aircraft will be examined during the impending flight test program for verification of what is predicted to be a significant reduction of the 90 and 95 EPNdB terminal area footprint areas compared to other V/STOL and CTOL aircraft. The tilt rotor research program is jointly funded with the Army. The noise portion of the program is funded by NASA.

Sponsor: Ames Research Center

Fiscal Year:	1975	1976	1977	1978
Funding ($1000):		200	80	30
Agency Manpower (ManYears):		3	5	1

CATEGORY: GENERAL AVIATION

Quiet, Clean General Aviation Turbofan (QCGAT)

The objective of the QCGAT Project is to demonstrate the applicability of large turbofan engine technology to small turbofan engines and to obtain significant reductions in noise and pollutant emissions while reducing or maintaining fuel consumption levels. Engine modifications using existing gas generator cores will be developed through component tests and engine ground tests. Nacelles, which will be integrated with the modified engines, will be designed and fabricated. Analyses will be made of the design, performance, emission and acoustic benefits of the engine and nacelle systems installed in typical general aviation aircraft.

Need for Study: The turbine powered general aviation aircraft fleet size is increasing at a greater rate than the rest of general aviation aircraft. Jet powered general aviation aircraft numbered approximately 1400 in 1974. Annual sales are expected to grow from a current figure of around 200 in 1975 to over 400 within the next ten years.

The airlines serve approximately 500 airports across the nation. General aviation serves these 500 airports plus over 12,000 additional airports that are served exclusively by general aviation. These airports are more apt to be located in small communities where background noise and pollution are low. Therefore, the increasing use of small aircraft has the potential to create a very widespread adverse community reaction.

The small turbine engines used in general aviation and business aircraft generally produce the same type of noise that is produced by the larger commercial and military aircraft engines. Engine quieting and emission reduction technology and, more recently, means for improving fuel economy have been directed primarily at the larger engines used in the commercial carriers. It is, therefore, important to determine the suitability of the large engine technology to small turbine engines and develop new technology where required.

Although existing FAR 36 noise restrictions probably can be met by new production aircraft, it is probable that this regulation will be modified to require reduced noise levels for the next generation of aircraft, possibly by as much as 10 PNdB at each of the measuring stations.

Approach: This systems technology program will provide reference data necessary for establishing feasible approaches and probable limits to emissions and noise reduction of general aviation turbofan engines in time to relieve the effects of the predicted increase in aircraft using this type of engine.

Quiet, Clean General Aviation Turbofan (QCGAT) (Continued)

A principal objective of the QCGAT program is to demonstrate the technology required to provide quiet turbofan engines for general aviation. One of the ground rules for the program was that each contractor use an existing core for the QCGAT engine. Therefore, the quieting technology is primarily limited to modifications of the low pressure spool and the nacelle, while the core engines are not altered. Noise reduction features in the QCGAT engines include: no inlet guide vanes, medium-to-high bypass ratio fan resulting in low jet velocities, single-stage fan with low fan-tip speed and low pressure ratio, large rotor-stator spacing, optimum number of vanes and blades, mixer nozzle, and acoustic treatment.

An additional objective of the QCGAT program is to reduce engine emissions to meet the 1979 EPA standards for the T_1 class engines. This is to be accomplished through design changes to the combustor liner and injector nozzles. Component testing and results of the NASA Lewis Research Center T_1 Combustor Program will be utilized.

The program is being conducted in two phases. In the first phase, which was completed in October 1975, six-month studies by three manufacturers of small turbine engines, AiResearch, AVCO-Lycoming and General Electric, provided NASA with information required to prescribe an effective experimental engine program. These studies included an assessment of the applicability of existing large turbofan quieting and emission control techniques, how this technology can be scaled, and its applicability to small general aviation turbofan engines.

The second phase is an experimental program that consists of design, fabrication, assembly, ground tests, and delivery of experimental engines and nacelles to NASA Lewis. Similar contracts were awarded to Garrett-AiResearch and to AVCO-Lycoming. Lewis Research Center plans to perform testing upon delivery of the two engines. This will include altitude performance tests, emissions tests and acoustic tests.

<u>Schedule:</u> Major program milestones are given below:

<u>Study Phase</u>

Awarded Contracts	April 1975
Completed Studies	December 1975

Quiet, Clean General Aviation Turbofan (QCGAT) (Continued)

Experimental Phase

Awarded Contracts	Nov. & Dec. 1976
Final Design Reviews	September 1977
Begin Engine Testing	July & Oct. 1978
Engine Deliveries	Feb. & July 1979

Accomplishments: Both contractors have completed final engine design and fabrication has started. Analyses based on these final engine designs indicate that both engines will meet the QCGAT Program goals in acoustics and emissions.

Sponsor: Lewis Research Center

Fiscal Year:	1975	1976	1977	1978
Funding ($1000):		808	1,100	1,327
Agency Manpower (Man-Years):		11	8	8

APPENDIX C

DEPARTMENT OF DEFENSE

(AIR FORCE, ARMY AND NAVY)

AVIATION NOISE RT&D PROGRAM

This appendix describes DOD's aviation noise programs in terms of research, technology and demonstration projects. The activities of each of the three military departments within DOD: Air Force, Army, and Navy, are grouped separately.

Funding for FY 76 includes the transition quarter (July 1, 1976 to September 30, 1976). Funding cited for FY 77 and FY 78 includes estimates. Projects for FY 78 have not been finalized.

FUNDING SUMMARY

DEPARTMENT OF DEFENSE
(Air Force, Army and Navy)

CATEGORY	Fiscal Year Funding ($1000) 1975	1976	1977	1978
RESEARCH AND TECHNOLOGY				
PROPULSION NOISE	1,510	874	433	319
ROTOR NOISE	-	14	695	610
AIRFRAME NOISE	63	208	76	32
NOISE PREDICTION TECHNOLOGY	22	410	703	658
TOTAL: All Projects	1,595	1,506	1,907	1,619

FUNDING SUMMARY

DEPARTMENT OF THE AIR FORCE

CATEGORY	Fiscal Year Funding ($1000) 1975	1976	1977	1978
RESEARCH AND TECHNOLOGY PROGRAMS				
PROPULSION NOISE	315	76	62	68
AIRFRAME NOISE	63	188	66	22
NOISE PREDICTION TECHNOLOGY	22	378	383	366
TOTAL: All Projects	400	642	511	456

FUNDING SUMMARY

DEPARTMENT OF THE ARMY

CATEGORY	Fiscal Year Funding ($1,000) 1975	1976	1977	1978
RESEARCH AND TECHNOLOGY				
PROPULSION NOISE	-	-	71	86
ROTOR NOISE	-	14	695	610
NOISE PREDICTION TECHNOLOGY	-	32	160	172
TOTAL: All Projects	-	46	926	868

FUNDING SUMMARY

DEPARTMENT OF THE NAVY

CATEGORY	Fiscal Year Funding ($1000) 1975	1976	1977	1978
RESEARCH AND TECHNOLOGY				
PROPULSION NOISE	1,195	798	300	165
AIRFRAME NOISE	-	20	10	10
NOISE PREDICTION TECHNOLOGY	-	-	160	120
TOTAL: All Projects	1,195	818	470	295

CATEGORY - PROPULSION NOISE

Supersonic Jet Exhaust Noise Investigation (Density Model)

This project was undertaken 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 project are to solve numerically the applicable turbulence and acoustic theories that 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.

Sponsor: U.S. Air Force

Investigator: Lockheed Aircraft Corporation

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

U.S. AIR FORCE - RESEARCH AND TECHNOLOGY PROGRAMS

CATEGORY - PROPULSION NOISE

Supersonic Jet Exhaust Noise Investigation (Velocity Model)

This project was initiated to develop the technology to significantly reduce supersonic aircraft propulsion system noise with minimum associated performance and weight penalties. Emphasis was 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 the research project was to develop a comprehensive mathematical model capable of providing aeroacoustic design data to be used in the development of future supersonic jet exhaust noise suppressors.

Sponsor: U.S. Air Force

Investigator: General Electric Company

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

CATEGORY - PROPULSION NOISE

Sound Transmission Through Supersonic Jets

This study will investigate the manner in which sound is transmitted from within a supersonic jet to the surroundings.

Need for Study: Under the Air Force function to improve aerospace vehicles, a better understanding of the phenomena and mechanism of sound transmission is required in order to design aircraft which are quieter without incurring a performance penalty.

Approach: The primary quantity to be measured is the spatial distribution of sound pressure, as a function of frequency, in the field outside the jet due to a simple sound source within the jet. The major effort of this project is experimental; however, consideration was given to a theoretical description of the phenomena.

Schedule: The completion date is Oct. 1977.

Accomplishments: A continuous run facility has been constructed. It consists of a room with highly absorbing walls, a convergent-divergent nozzle, settling chamber and appropriate controls for the air supply. Measurements of the sound field of the jet without a synthetic sound source have been made using a half-inch exit diameter convergent nozzle at speeds ranging from 500 to 900 ft per sec. Hot wire measurements of the jet showed that the jet had a very flat velocity profile at the nozzle exit. Comparisons of the overall sound pressure level as a function of jet speed agree closely with the semi-empirical prediction formulae of previous investigators. Analysis of the spectra confirmed the satisfactory performance of the facility. This indicated that despite the simplicity of the facility, the jet sound field behaves much like those of more sophisticated facilities. Measurements have been made of the sound field due to the combination of the jet and the synthetic sound source, for a range of jet speeds, driving frequencies, and measurement angular locations. It is seen that the sound pressure level peaks sharply at the driving frequency of the loudspeaker and reduces to the sound pressure level of the jet alone at frequencies away from the driving frequencies. The theoretical directivity factors have been chosen to pass through the 90 degree points and it was seen that the Ffowcs-Williams directivity factor applied to the Lighthill noise theory agreed with the data only qualitatively, whereas the directivity factor predicted more recently by Goldstein and Howe agreed with the data quite well.

Sound Transmission Through Supersonic Jets (Continued)

Sponsor: U.S. Air Force

Investigator: Case Western Reserve University

Fiscal Year:	1975	1976	1977	1978
Funding ($1000):	40	30	29	

CATEGORY - PROPULSION NOISE

Duct Acoustics Research

The objective of this research investigation is to understand the dependence of sound levels within aircraft engine ducts upon such factors as duct geometry, sound absorbing properties of the duct walls, type of sound source, and flow within the duct. The research will lead to new aeroacoustic models and solution techniques for general duct acoustics problems.

Need for Study: This work will be a significant contribution to the Air Force Aero Propulsion Laboratory's (AFAPL) efforts to reduce turbine engine noise levels. Current engine noise levels are hazardous to personnel and structures, detrimental to tactical operations, and annoying to the general public. Eventually, there is a need to assess engine performance/noise trades in the design of aircraft engines.

Approach: To handle variable area ducts with no flow, a method of conformal mapping in conjunction with a finite difference method is used. As an alternative approach for the same problem an integral equation potential theory method is appropriate. For the more general problem of variable area ducts containing fairly general flows, a finite element method may be required. The acoustic equation for this general problem must be derived, and an efficient numerical method must be implemented using local computer facilities.

Schedule:

Initiate Research (In-House)	December 1975
End Preliminary Phase	February 1977
Estimated Completion	June 1979

Accomplishments: In October 1975 issues of the AIAA Journal, the method of conformal mapping in conjunction with finite differences was presented in a paper authored by the principal investigator. In 1976, a second paper by the principal investigator appeared in the Progress in Astronautics and Aeronautics series. This second paper compared uniform and multisectional duct lining to determine optimum attenuation characteristics. In July 1976, at the AIAA 3rd Aero-Acoustics Conference in Palo Alto, CA, a paper summarizing the integral equation method as applied to duct acoustics was presented. This paper has appeared in the AIAA Journal, Vol. 15, February 1977. The publication of these papers concludes the preliminary phases of this work unit. The final phase has now begun, namely to develop a method for solving the general acoustics equation which take into account nonuniform duct geometrics and general flows within these nonuniform ducts. A least

Duct Acoustics Research (Continued)

squares finite element approach is generating solutions of duct acoustics problems, and the computer programs are being tested for rectangular ducts without flow.

Sponsor: U.S. Air Force

Investigator: Air Force Flight Dynamics Laboratory

Fiscal Year:	1975	1976	1977	1978
Funding ($1000):		46	9	28

CATEGORY - PROPULSION NOISE

Noise Suppression In Jet Inlets

This effort will develop an analytical technique that will allow the accurate prediction of the far field noise levels of an engine inlet and changes to this level due to inlet duct treatment or inlet geometry without the costly cut and try full scale testing that is presently required.

Need for Study: Under the Air Force function to improve aerospace vehicles a better understanding of the coupling mechanisms of the noise generated in the engine inlet ducting (fans and compressor noise) with the far field radiated noise is required. Also methods of evaluating the effects of various duct wall acoustic treatments and engine-inlet configurations are needed.

Approach: An integral formulation of the Hemholtz equation will be developed, discretized and solved numerically; this formulation will couple the sound source with the radiated far field and will account for changes in the far field due to inlet geometry and wall acoustic liner treatments. Experimental data will be obtained of the radiated sound field from several simple inlet configurations to evaluate the theoretical predictions.

Schedule: Estimated date of completion is March 1979.

Accomplishments: None to date.

Sponsor: U.S. Air Force

Investigator: Georgia Institute of Technology

Fiscal Year:	1975	1976	1977	1978
Funding ($1000):			24	40

CATEGORY - AIRFRAME NOISE

Acoustics Research

The objective is to develop methods for the prediction and control of exterior and internal noise of military aircraft. The known physical and geometric parameters of sources will be correlated to the characteristics of the noise and aeroacoustic fields. Accurate prediction of spectra, acoustic power, and directivity, is the aim.

Emphasis of this effort is the correlation of physical and geometric parameters of known noise sources in aircraft with characteristics of the emitted noise and aeroacoustic field. Results of this endeavor will provide aircraft designers with methods to predict noise emanations and engineers with the information necessary to control noise. Products will be design charts, computer programs, specifications, and acoustic and vibration criteria.

Need for Study: Various problems encountered in the development of AF weapon systems are related to the noise generated by the propulsion systems and pseudo-noise associated with flight through the atmosphere. These problems include degradation of the structural integrity, equipment reliability, crew health and performance, and aircraft survivability. Additionally, aircraft generated noise may have a deleterious effect on ground structures or the population.

Approach: Existing methods of noise source estimation will be used to prepare design charts and write computer programs that will enable users to commute easily the near-field aircraft source noise levels. Vibration and pseudo-noise level measurements on the X24B will be used to develop boundary layer pressure oscillation prediction methods.

Weapons bay cavity pressure oscillation problem will be studied. Suppression devices and slender cavity noise prediction methods will be flight-test demonstrated for the Air Launched Ballistic Missile (ALBM).

YC-14 and YC-15 noise prediction efforts will include analyses of internal noise and measurement of STOL flap loads. (It is possible that the latter efforts may not be funded).

Another area of this effort will be the prediction of total radiated airframe acoustic power.

Part of this program involved a cooperative effort with NASA.

Schedule:

Start of In-House Laboratory Effort - AFFDL	April 1977
Estimated Completion	March 1980

Acoustics Research (Continued)

<u>Accomplishments</u>: Planning for the effort is underway.

Sponsor: U.S. Air Force

Investigator: Air Force Flight Dynamics Laboratory

Fiscal Year:	1975	1976	1977	1978
Funding ($1000):		86	42	22

CATEGORY - AIRFRAME NOISE

Noise and Sonic Fatigue of High Lift Devices

Current Air Force interest in STOL aircraft includes designs using externally blown flaps with over-the-wing and under-the-wing blowing. Other concepts such as internally blown flaps, augmentor wing, and cold thrust augmentation with hypermixing nozzles are also being investigated. A prediction methodology was developed for the fluctuating pressure characteristics of surfaces exposed to the jet, and the results are reported in AFFDL-TR-77-40, "Noise and Sonic Fatigue of High Lift Devices," July 1977. The data will be useful to STOL aircraft designers in developing concepts and selecting configurations with higher structural durability, lower maintenance, and minimum noise generation.

Need for Study: Noise predictions for these concepts have indicated potential problems associated with community noise, sonic fatigue, and internal noise. The objective of this effort is to investigate selected high lift or thrust augmentation systems as they pertain to noise generation and to define the associated noise field as it relates to performance and engine operating parameters.

Approach: Powered lift and thrust augmentation systems will be reviewed and practical systems design parameters will be determined. Consideration will be given to thrust, by-pass ratio, mass flow, exit velocity, exit temperature, jet diameter, engine flap geometry, engine flap spring, etc. The most promising configuration will be selected for further investigations including both analytical and experimental phases. Model studies will investigate the practical range of design parameters and determine the ascoustic loading for near field noise and infra-sound effects.

Schedule:

Start (McDonnell Douglas Astronautics Co.)	- AFFDL	March 1975
Completion	- AFFDL	July 1977

Accomplishments: An extensive experimental program, applicable to externally blown flaps (EBF) of STOL vehicles, was conducted providing detailed information on the surface loads produced during jet impingement. Test specimens used in the program were varied from a simple flat plate to a complicated wing-flaps configuration, simulating under-the-wing blown flaps (UBF) and over-the-wing blown flaps (OBF) configurations. The test program considered five categories of parameters, namely (1) jet Mach number, (2) temperature of the jet, (3) nozzle configuration, (4) relative position between nozzle and specimen, and (5) deflection angle at downstream edge of specimen. From the test results, a method was developed for predicting the fluctuating pressure characteristics. Considered in the program were (1) overall rms level, Noise and Sonic Fatigue of High Lift Devices (Continued)

(2) frequency at the peak of the power spectrum, (3) halfpower frequency of the power spectrum, (4) peak amplification or peakedness of the power spectrum, (5) high frequency rolloff rate of the power spectrum, (6) maximum magnitude of the narrow band correlation spectrum for separated locations, (7) frequency at the maximum of the narrow band correlation spectrum, and (8) narrow band convection speed. The results for each test case have been tabulated on layouts of the specimen surfaces showing them in their proper spatial relation to each other. The results have also been plotted for ease in recognizing trends produced from parametric variations.

Sponsor: U.S. Air Force

Investigator: McDonnell-Douglas Astronautics Company

Fiscal Year:	1975	1976	1977	1978
Funding ($1000):	63	102	24	

CATEGORY - NOISE PREDICTION TECHNOLOGY

Validation of Aircraft Noise Exposure Predictive Procedures

A research project was undertaken to validate the major aircraft noise exposure prediction algorithms contained in Noisemap, a predictive procedure used to describe the noise environment around airbases.

Approach: All aircraft noise exposure maps previously prepared were reviewed to recommend four air bases where noise exposure validation measurements should be made. Noise measurements were conducted on and about the bases to acquire the data necessary to validate and/or modify the noise predictive algorithms in Noisemap for runup, traffic pattern, takeoff, and landing operations. Noisemap conputations were then made and compared with the measured values, and detailed error analyses were performed to account for the differences between measured and predicted values.

Schedule: The project was completed in FY 1976.

Sponsor: U.S. Air Force

Investigator: Bolt, Beranek and Newman, Inc.

Fiscal Year:	1975	1976	1977	1978
Funding ($1000):		82	23	

U.S. AIR FORCE - RESEARCH AND TECHNOLOGY PROGRAMS

CATEGORY - NOISE PREDICTION TECHNOLOGY

Excess Sound Attenuation Model

The program will develop analytical models for predicting the generation and propagation of noise produced by ground run-ups for Air Force aircraft and will account for the excess and attenuation caused by ground cover, topography, and obstacles.

The emphasis of this program is on determining the effects of various air base noises on personnel, on establishing exposure criteria, and evaluating/developing personal protective devices. It is anticipated that this work will result in guidelines, specifications, and regulations to control noise exposure within acceptable limits.

Need for Study: The noise produced on base and in communities by Air Force air base operations is a major environmental concern. The Air Staff, MAJCOMS, and air bases assess the impact of such noise by applying community noise predictive models and noise data. The accuracy of these predictive models and data depend in large part on the accuracy of the algorithms used to account for Excess Sound Attenuation (ESA) caused by reflection/absorption of sound by the earth's surface/ground cover (e.g., sand, grass, crops), scattering caused by wind turbulence, obstacles (e.g., buildings, trees), and other factors. Although the ESA model presently used is the best available, it has significant uncertainties which cause corresponding uncertainties in the environmental noise assessments.

Approach: The approach is to conduct air base noise measurements over a one- to two-year period using six to ten all-weather acoustic measuring stations. Data taken will define ESA over a range of 75 m to several kilometers from the source for all times of day and night, all seasons, various weather conditions, and for the flat farm land and urban/suburban areas. Statistical analyses will provide the basis for new empirical ESA models which better define such attenuation for specific classes of conditions.

Schedule:

Complete data collection	January 1979
Complete model and incorporate into NOISEMAP	July 1980

Accomplishments: The test plan has been completed and approved. Data is being collected from ground run-up noise over mowed grass on flat land. The tests are being conducted at Wright-Patterson AFB, OH.

Excess Sound Attenuation Model (Continued)

Sponsor: U.S. Air Force

Investigator: Aerospace Medical Research Laboratory

Fiscal Year:	1975	1976	1977	1978
Funding ($1000):			108	

CATEGORY - NOISE PREDICTION TECHNOLOGY

Measurement, Prediction and Evaluation of Bioenvironmental Noise From Air Force Systems and Operations

Technical support is provided to System Program Offices, commands, bases, laboratories, and others on specific environmental noise problems.

Need for Study: Problems involving noise are commonplace and many must be dealt with immediately. The expertise of the 6570th Aerospace Medical Research Laboratory is required for environmental impact statements, facility siting, real estate decisions, monitoring of air base noise, sound propagation, run-up suppressors, and identifying hazardous noise areas. Their expertise is not available in other organizations.

It is expected that this work will benefit not only the Air Force but all parties concerned with environmental noise problems.

Approach: The appoach is to measure and evaluate the customer's specific noise problem by applying the instrumentation, measurement methods, NOISE-BANK, OMEGA software, predictive methods and other tools developed by AMRL. Travel/per diem costs will generally be paid by the customer. Results will usually be documented in the form of letter reports or memoranda.

Schedule: Work is accomplished as required and within existing priorities of efforts and resources.

Accomplishments: Approximately 250 customers were provided with the noise data and/or guidance necessary to evaluate the impact of the noise produced by existing or planned Air Force systems and operations on crew members and nearby community populations. The third and final measurement of a Titan III launch was accomplished to obtain the noise data required by Space and Missile Systems Operations (SAMSO) in writing an Environmental Impact Statement for the Space Shuttle Program. Consultation was provided to Air Force to assist them in making preliminary environmental assessments of various KC-135A engine retrofits.

Sponsor: U.S. Air Force

Investigator: Aerospace Medical Research Laboratory

Fiscal Year:	1975	1976	1977	1978
Funding ($1000):		268	246	366

U.S. AIR FORCE - RESEARCH AND TECHNOLOGY PROGRAMS

CATEGORY - NOISE PREDICTION TECHNOLOGY

Computerized Procedure to Assess Turbine Engine Noise/Performance Tradeoffs

A computer code was developed in-house with previous funding to perform noise/performance trades. The current funding provides for further work in analyzing noise propogation in ducts for installed noise refinements and exercising tradeoffs. The program capabilities include: uninstalled engine noise prediction applicable to current and future aircraft gas turbine engines; prediction of installed engine noise levels, including the effects of special noise reduction devices; and assessment of propulsion performance and weight penalties as a function of noise level reduction.

Need for Study: Current systems and proposed systems require data on performance/noise trades to make decisions on buying engineering changes, performing system studies, and performing source selections. Also, the military is attempting to comply with FFA noise requirements wherever possible.

Approach: The AF Aero Propulsion Laboratory has already developed the capability for uninstalled predictions and installed predictions (previously developed in-house). Further work is being done under contract to a local university. Evaluations/trade studies will be made on various engine-airframe configurations and further refinements on installed engine noise calculations will be made through improved duct propagation models.

Schedule:

Complete duct noise propagation work - Univ. of Dayton	December 1978
Integrate duct propagation into installed trade model - (AFAPL) and Univ. of Dayton	December 1979
Final integration of all elements and final reports - Univ. of Dayton	December 1980

Accomplishments: System studies for F15, F-16, B-1, A-7, A-10, YC-14, YC-15, and RPVs have been accomplished. The F101 engines were evaluated for the B-1, reduced throttle take-offs were evaluated for the A-7 and A-10, liner treatment was evaluated for the A-10, the YC-14 and YC-15 were "compared," as well as JT8D-209 vs CFM-56 engine, new engines for the KC-135 were evaluated and compared with B-52 noise patterns, and some RPV configurations were evaluated.

Computerized Procedure to Assess Turbine Engine Noise/Performance Tradeoffs (Continued)

Sponsor: U.S. Air Force

Investigator: Air Force Aero-Propulsion Laboratory

	1975	1976	1977	1978
Fiscal Year:	1975	1976	1977	1978
Funding ($1000):	20	28	6	

CATEGORY - PROPULSION NOISE

Propulsion System Noise

Methods for reducing the helicopter cabin noise generated by the propulsion/transmission system of Army helicopters are being developed.

Need for Study: The noise and vibration caused by the propulsion/drive train system of helicopter contributes to crew fatigue and obstructs effective communication between crew members. The transmission system is the major source of cabin noise. There is a need to develop new transmission case designs to minimize contributions to cabin noise.

Approach: Areas where structural characteristics of transmission cases develop resonances are determined through analysis and experimentation. These resonances are transmitted to the airframe or generated noise directly. Stiffening of the transmission case is being evaluated to eliminate the resonances. New composite casing materials will also be evaluated.

Schedule: The project was initiated in FY 1977.

Accomplishments: Tests have shown that substantial reduction in transmission noise can be made by selective stiffening of existing cases and proper design of new cases. Material research in composite metal matrix patches and structures for helicopter gear boxes is underway.

Sponsor: U.S. Army

Investigator: Boeing Vertol Co. and Bell Helicopter Co.

Fiscal Year:	1975	1976	1977	1978
Funding ($1000):			71	86

U.S. ARMY - RESEARCH AND TECHNOLOGY PROGRAMS

CATEGORY - ROTOR NOISE

Helicopter Rotor Noise

This program will develop the analytical methodology, and techniques necessary to gain an understanding of the fundamental sources and mechanism of generation of rotor noise. The program will examine rotor configuration, materials, and interaction with ambient environment at both subsonic and transonic mach numbers in hover and forward flight.

Need for Study: The suppression of the aural signature of Army helicopters is necessary for effective nap-of-the-earth mode of employment of Army helicopters. The helicopter rotor is a primary element in this signature, producing the characteristic "blade slap" impulsive noise that can alert the enemy to approaching helicopters. This characteristic noise also contributes to the environmental noise pollution generated at military installations during training operations. The noise must be controlled if community pressure to curtail or relocate training operations is to be avoided.

Approach: Several complementary theoretical investigations and analytical studies are being performed to develop improved analytical formulations for identifying and quantifying the primary factors that cause rotor noise. Analysis efforts are supported by scale-model and full scale whirl and wind tunnel tests. An open jet test section of an anechoic room will be utilized to determine the effects of blade number, advance rotation, thrust and rotor disk tilt angle on rotational noise and blade slap. Comparative studies of sources of broad band noise are used to determine mechanisms leading to random blade loading and associated boradband noise. Rotortip geometry (ogee tip) is evaluated for reduction of implusive and blade-vortex noise. The use of materials having vectored porosity to improve laminar flow over airfoils for noise reduction is also being investigated. This is a joint program with NASA.

Accomplishments: Methodology has been developed for calculating high frequency rotor noise due to random forces and a simplified mach number scaling law has been developed for rotational and high frequency broadband noise based upon geometric parameters of the rotor. Full scale flight tests have confirmed that forward flight propeller noise levels are lower than those experienced under static conditions. The use of electronic beam drilling techniques to produce vectored porosity in wood-metal laminate samples has been demonstrated. The ogee tip rotor geometry has been evaluated on the UH-1H.

Helicopter Rotor Noise (Continued)

Sponsor: U.S. Army

Investigator: George Washington University, Polytechnic Institute of New York, Massachusetts Institute of Technology, and In-House

Fiscal Year:	1975	1976	1977	1978
Funding ($1000):	-	14	695	610

CATEGORY - NOISE PREDICTION TECHNOLOGY

Helicopter Noise Propagation, Prediction and Mitigation

This program studies the effects of terrain geometry and ground cover on helicopter noise propagation and develops methods for prediction and mitigation of helicopter noise.

Need for Study: The need for detection and suppression of the aural signature of helicopters in nap-of-the-earth operations, crew comfort and the need for reducing the environmental impact of noise generated by helicopter operations on military and civil communities requires a better understanding of noise propagation. Methods for predicting and mitigating helicopter noise also need development.

Approach: A method for modeling the effects of terrain features on aural detection of helicopters is being developed. Tests will be conducted to determine the influence of soil type and vegetation height on theoretical helicopter noise levels.

Noise frequency signatures of various types of military helicopters are recorded and human response to the frequency spectrum evaluated and used as the basis for noise prediction. Finally methods and guidelines for mitigation of noise from helicopter operations at military installations will be developed, based upon flight path constraints in areas of community development.

Accomplishments: Preliminary theoretical model of terrain effects on noise propagation, and a test set-up for investigation of soil and vegetation absorption effects on noise have been developed. Guidelines have been developed for mitigation of helicopter noise at military installation by establishment of flight path constraints for helicopter operations in areas of community housing. Frequency signatures of various Army, Navy and Air Force helicopters have been recorded and human response to helicopter noise has been incorporated into the helicopter prediction submodel.

Sponsor: U.S. Army

Investigator: CERL, Boeing, University of Mississippi

Fiscal Year:	1975	1976	1977	1978
Funding ($1000):	-	32	160	172

U.S. NAVY - RESEARCH AND TECHNOLOGY PROGRAMS

CATEGORY - PROPULSION NOISE

Jet Engine Ground Run-up Noise Suppression

The objective of this program is to provide the Navy with the capability to reduce noise levels from jet engine ground run-up operations. This must be accomplished in the most responsible and cost-effective manner by developing the technical base for supporting alternate systems/concepts and for optimizing current design developments.

Need for Study: One of the most pressing noise problems confronting the Navy is that associated with post-maintenance jet engine ground run-up operations both in and out of airframes, at Naval Air Rework Facilities and Naval Air Stations. The fundmental issue is how best to deal with the unabated high noise levels and concomitant effects on Navy military and civilian personnel working in the immediate vicinity of the run-up spots. These effects have included hearing loss, physiological and psychological damage, and general reduction in morale. These problems obviously affect the Navy's mission and the need is for a unified advanced development program to deal with these problems.

Approach: Specific program objectives are to develop a materials and fabrication technology base for increasing the life cycle of suppressor designs to conduct model studies to optimize the acoustic design of current and alternate systems/concepts, to test promising system solutions, to provide guidelines and safety requirements for operating personnel, and to develop life cycle costs and benefit impacts for each reasonable technical solution to the jet engine ground run-up noise problem.

Schedule:	Date
Start air-intake de-icing tests	Apr 77
Metal liner fatigue test and design	Sep 77
Record low frequency noise from hush-house, etc.	Apr 78
Fabricate scale models of various acoustical enclosures for aerothermodynamic and acoustic tests	Jun 78
Cost/benefit analysis, phase II	Jun 78
Response to compressor stall tests	Jul 78
Laboratory tests of ground run-up noise	Jul 78

Accomplishments: the primary concern of the U.S. Navy relative to aviation noise during the relevant period was the suppression of jet engine ground run-up noise. This has resulted in the development of jet engine noise suppression equipment and an alternate, the Brauburgh dry jet engine noise suppression system. An advanced

Jet Engine Ground Run-up Noise Suppression (Continued)

development plan, considering the alternate systems, has been issued and cost/benefit analyses have been initiated.

Sponsor: U.S. Navy

Fiscal Year:	1975	1976	1977	1978
Funding ($1000):	1195	798	300	165

CATEGORY - AIRFRAME NOISE

Anechoic Flow Facility Airframe Noise Experiment

The U.S. Navy and the National Aeronautics and Space Administration are conducting an interagency project to estimate the airframe radiated noise of a scale-model Boeing 747 aircraft during landing. The Navy is providing the test facility, support personnel, and instrumentation; NASA will report the results.

The airframe noise experiments were conducted in September 1977.

The next phase of the program includes studies of airframe radiated noise during aircraft landings.

Sponsor: U.S. Navy and National Aeronautics and Space Administration/Langley Research Center

Investigator: David Taylor Naval Ship R&D Center

Fiscal Year:	1975	1976	1977	1978
Funding ($1000):		20	10	10

CATEGORY - NOISE PREDICTION TECHNOLOGY

Naval Air Facilities Noise Prediction

Methodology and instruments for acquisition and prediction of environmental noise data in the vicinity of air installations are being developed. Corrections to the tri-service NOISEMAP model for ground run-up and helicopter blade-slap noise are being determined.

Need for Study: Accurate prediction of environmental noise levels around naval air installations is essential for future planning and maintaining community acceptance of aviation activities.

Approach: Portable noise monitoring equipment with digital printout is being evaluated. Data using this equipment will be compared with conventional instruments.

Operations at NAS Miramar have been monitored for a period of one year. This data will be analyzed in light of the local topography and weather.

Ground map and helicopter blade slap corrections will be determined in cooperation with U.S. Army helicopter studies.

Schedule:

Complete documentation of noise data systems	May 77
Report on helicopter blade-slap	Feb 78
Report on "average busy day" at NAS's	Mar 78

Accomplishments: One year of operations data, noise data, and telephone complaints at NAS Miramar has been compiled. Laboratory tests on 70 samples of helicopter noise with various degrees of blade-slap have been completed.

Sponsor: U.S. Navy

Fiscal Year:	1975	1976	1977	1978
Funding ($1000):			160	120

APPENDIX D

DEPARTMENT OF TRANSPORTATION

(FEDERAL AVIATION ADMINISTRATION)

AVIATION NOISE RT&D PROGRAM

This appendix describes DOT's aviation noise program in terms of its research, technology and demonstration projects. Aviation noise activities concerning DOT/FAA's regulatory and rulemaking responsibilities are not included in this report.

Funding for FY 76 includes the transition quarter (July 1, 1976 to September 30, 1976). Funding cited for FY 77 and FY 78 includes estimates. Projects for FY 78 have not been finalized.

FUNDING AND MANPOWER SUMMARY

DEPARTMENT OF TRANSPORTATION
(FEDERAL AVIATION ADMINISTRATION)

CATEGORY	Fiscal Year Funding ($1,000) (Agency Manpower in Man-Years) 1975	1976	1977	1978
RESEARCH AND TECHNOLOGY				
PROPULSION NOISE	700	917	770	-
NOISE PREDICTION TECHNOLOGY	95	86	-	-
ATMOSPHERIC PROPAGATION AND GROUND EFFECTS	-	-	-	*
SUBTOTAL: Research and Technology	795	1,003	770	-
DEMONSTRATION PROGRAMS AND SYSTEMS STUDIES				
CTOL (Subsonic)	164	250	950	1,730
TOTAL: All Projects	959 (6)	1,253 (5)	1,720 (5)	1,730 (4)

* In-house project, with 1.5 man-year effort only.

CATEGORY - PROPULSION NOISE

Jet Noise Research

This project examines promising noise suppression concepts to determine the probable noise reduction benefits, the potential effects on flight performance over flight speeds and jet velocity ranges of practical interest.

Need for Study: An improved understanding and ability to predict noise performance of turbojet aircraft is necessary to support aircraft noise regulation.

Approach: This project includes both theoretical and experimental research of high-velocity jet noise suppressors, including inflight effects. The goal is the development of a fundamental understanding of jet noise suppression, including the effects on inflight performance, and thrust losses.

Schedule: This project began in FY 1973, under a $5 million research contract, by the Office of the Secretary of Transportation. In FY 1976, the project was transferred to the FAA for continued funding and completion. The project should be completed and reports available early in FY 1979.

Accomplishments: Early analytical and ground testing have provided insight into noise suppression performance, including the effects of forward motion on those suppressors.

Sponsor: Federal Aviation Administration

Investigator: General Electric

Fiscal Year:	1975	1976	1977	1978
Funding ($1,000):		782	720	

CATEGORY - PROPULSION NOISE

Core Engine Noise Control

This project develops information on source noise levels of aircraft turbofan engines, examining in particular the internal noise sources.

Need for Study: An improved understanding and knowledge of engine core noise characteristics is necessary to support aircraft noise regulations.

Approach: This project will identify, evaluate, and attempt controls for the component noise sources (e.g.: combustion, turbine, jet interaction) inherent in the core or gas generator portion of a turbofan engine. The effort includes both theoretical and experimental investigations of these noise sources.

Schedule: The project is expected to be completed in late FY 1978.

Accomplishments: Accomplishments to date include a rank ordering of the significant noise sources and a core engine noise prediction capability, which includes prediction models for the major core engine noise components.

Sponsor: Federal Aviation Administration

Fiscal Year:	1975	1976	1977	1978
Funding ($1,000):	700	135	50	

CATEGORY - NOISE PREDICTION TECHNOLOGY

Aircraft Source Noise Data Base

This project collects and maintains noise data for various types of aircraft, such as STOL, VTOL, and conventional aircraft. Component noise source data, such as airframe noise, is also being obtained.

Need for Study: These data are necessary to support aircraft noise regulation.

Approach: This effort is conducted largely as an in-house FAA activity, but some contract support is included. An aircraft noise measurement and test range is being established for the measurement of flight noise data under conditions which can be controlled and measured accurately. These data are then used to improve source noise prediction capabilities and noise certification test techniques.

Schedule: This is a continuing project, with periodic data reports as appropriate.

Accomplishments: A series of helicopter noise measurements has been completed in support of the drafting of VTOL noise certification requirements. An airframe noise prediction model has also been developed.

Sponsor: Federal Aviation Administration

Fiscal Year:	1975	1976	1977	1978
Funding ($1,000):	95	86		

CATEGORY - ATMOSPHERIC PROPAGATION AND GROUND EFFECTS

Atmospheric Attenuation, Data Acquisition

This project is intended to provide reliable measurements of attenuation effects on the propagation of aircraft noise. The data will increase the accuracy of aircraft noise prediction for use in the FAA's Integrated Noise Model.

Need for Study: Accurate noise predictions are essential in developing land-use noise plans for airports, and in assessing alternative noise impacts of proposed airport projects and noise abatement policies.

Approach: Noise measurements of selected aircraft will be taken under controlled conditions of flight and meteorology, utilizing in-house FAA capabilities. Measured data will then be compared with computed data to determine the computational accuracy, and corrections applied as warranted.

Schedule: This is a continuing project, which began in FY 1978. Results will be available beginning in FY 1979.

Accomplishments: The first series of flyover measurements, using a business jet aircraft, have been completed.

Sponsor: Federal Aviation Administration

Investigator: In-house

Fiscal Year:	1975	1976	1977	1978
Funding:				1½myr

CATEGORY - CTOL (SUBSONIC)

Jet Noise Suppression

This project involves the application and demonstration of available technology for noise suppression devices, to demonstrate what is technologically practicable, economically reasonable, and capable of airworthiness certification.

Need for Study: Demonstration of practicable noise suppression devices is necessary to support aircraft noise regulation.

Approach: Efforts involve studies and analyses, scale model experiments, static engine testing, and flight demonstrations. The major current effort involves application of mixer technology to the JT8D turbofan engine. Is is hoped to demonstrate the noise benefits achievable from the efficient mixing of core engine exhaust and fan bypass air flow in a common exhaust nozzle.

Schedule: The results of static engine tests of JT8D mixer nozzles are expected by late FY 1978. Flight test results are planned by mid FY 1979.

Accomplishments: A study of the noise suppression capabilities for business jet aircraft has been completed. Studies and scale model tests for the mixer nozzle in the JT8D have also been completed. Full-scale static testing is about to begin.

Sponsor: Federal Aviation Administration

Investigator: Pratt & Whitney Aircraft

Fiscal Year:	1975	1976	1977	1978
Funding ($1,000)	164	250	950	1730

APPENDIX E

ENVIRONMENTAL PROTECTION AGENCY

AVIATION NOISE RT&D PROGRAM

This appendix describes EPA's aviation noise research and technology projects.

FUNDING AND MANPOWER SUMMARY

ENVIRONMENTAL PROTECTION AGENCY

CATEGORY	Fiscal Year Funding ($1000) (Agency Manpower in Man-Years) 1975	1976	1977	1978
RESEARCH AND TECHNOLOGY				
PROPULSION NOISE	-	-	-	100
	-	-	-	(-)*
TOTAL				100
				(-)*

* Less than 1 man-year

CATEGORY - PROPULSION NOISE

Small Propeller Technology

This project will support efforts towards lowering the noise levels of propeller driven aircraft through the application of aeroacoustic theory to the design of propellers. The project is designed to complement other NASA propeller studies reported on page B-20.

Need for Study: Current projections indicate that general aviation aircraft noise impacts will increase significantly by the year 2000 unless small aircraft noise levels are lowered below current levels. The dominant noise source from all turbine-powered vehicles and most of the reciprocating-engined vehicles is the propeller. Updated design methods and technology need to be developed and demonstrated from the analytical tools that exist today but were not available before the jet engine era.

Approach: NASA Langley Research Center, which posesses the necessary qualified staff expertise in this area, will manage the jointly funded project. The work will be performed under contract by the Massachusetts Institute of Technology. It is divided into three phases, with each phase dependent on the success of the previous one. The goal is to lower the propeller noise levels three to five decibels below current noise levels, while maintaining propeller efficiency.

Phase I, Background Studies and Design, will involve the development of the analytical tools necessary for low noise propeller design. Aeroacoustic theory will be integrated with other propeller design criteria such as aerodynamic performance and mechanical characteristics (shape, number of blades, diameter and rpm) to develop a complete design calculation procedure.

During Phase II, scale models of quiet propeller designs will be tested in a semi-anechoic wind tunnel at MIT. The anechoic characteristics of the wind tunnel will permit the simulation of outdoor test conditions with very low background noise levels. The noise produced by the test propeller will be compared with the known noise characteristics of current technology propellers.

Under Phase III, a full scale test propeller will be fabricated and flight tested and actual noise level reduction will be demonstrated. The full scale test data, along with the scale model data obtained in Phase II, will permit the verification of scaling laws important in the development of generalized design procedures. Finally, design charts will be developed to facilitate future quiet propeller designs.

Small Propeller Technology (Continued)

Schedule: The program will start in January 1978, with completion of all phases scheduled for December 1979.

Sponsor: The program will be funded jointly by EPA Office of Noise Abatement and Control and NASA. NASA will also be responsible for the management and technical direction of the program.

Investigator: Massachusetts Institute of Technology

Fiscal Year:	1975	1976	1977	1978
Funding ($1,000):				100*
Agency Manpower: (Man-Years)				¼

*EPA share of funding for FY 78. See Page B-20, Propeller Studies for NASA funding share.

APPENDIX F

BIBLIOGRAPHY

This appendix contains a list of the prinicpal NASA and DOT/FAA aviation noise RT&D publications, as well as some selected general interest publications. There are, in addition, numerous other RT&D related technical memoranda, contractor progress reports, and professional society and journal presentations.

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