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NOISE SOURCE ABATEMENT TECHNOLOGY AND COST ANALYSIS INCLUDING RETROFITTING

ENVIRONMENTAL PROTECTION AGENCY
AIRCRAFT/AIRPORT NOISE STUDY REPORT

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WILLIAM C. SPERRY, TASK GROUP CHAIRMAN

A-96-01
II-A-276

PREFACE

The Noise Control Act of 1972 (Public Law 92-574) directs the Environmental Protection Agency (EPA) to study the adequacy of current and planned regulatory action taken by the Federal Aviation Administration (FAA) in the exercise of FAA authority to abate and control aircraft/airport noise. The study is to be conducted in consultation with appropriate Federal, state and local agencies and interested persons. Further, this study is to include consideration of additional Federal and state authorities and measures available to airports and local governments in controlling aircraft noise. The resulting report is to be submitted to Congress on or before July 27, 1973.

The governing provision of the 1972 Act states:

> "Sec. 7(a). The Administrator, after consultation with appropriate Federal, state, and local agencies and interested persons, shall conduct a study of the (1) adequacy of Federal Aviation Administration flight and operational noise controls; (2) adequacy of noise emission standards on new and existing aircraft, together with recommendations on the retrofitting and phaseout of existing aircraft; (3) implications of identifying and achieving levels of cumulative noise exposure around airports; and (4) additional measures available to airport operators and local governments to control aircraft noise. He shall report on such study to the Committee on Interstate and Foreign Commerce of the House of Representatives and the Committees on Commerce and Public Works of the Senate within nine months after the date of the enactment of this act."

Under Section 7(b) of the Act, not earlier than the date of submission of the report to Congress, the Environmental Protection Agency is to:

> "Submit to the Federal Aviation Administration proposed regulations to provide such control and abatement of aircraft noise and sonic boom (including control and abatement through the exercise of any of the FAA's regulatory authority over air commerce or transportation or over aircraft or airport operations) as EPA determines is necessary to protect the public health and welfare."

The study to develop the Section 7(a) report was carried out through a participatory and consultive process involving a task force. That task force was made up of six task groups. The functions of these six task groups were to:

1. Consider legal and institutional aspects of aircraft and airport noise and the apportionment of authority between Federal, state, and local governments.

2. Consider aircraft and airport operations including monitoring, enforcement, safety, and costs.

3. Consider the characterization of the impact of airport community noise and to develop a cumulative noise exposure measure.

4. Identify noise source abatement technology, including retrofit, and to conduct cost analyses.

5. Review and analyze present and planned FAA noise regulatory actions and their consequences regarding aircraft and airport operations.

6. Consider military aircraft and airport noise and opportunities for reduction of such noise without inhibition of military missions.

The membership of the task force was enlisted by sending letters of invitation to a sampling of organizations intended to constitute a representation of the various sectors of interest. These organizations included other Federal agencies, organizations representing state and local governments, environmental and consumer action groups, professional societies, pilots, air traffic controllers, airport proprietors, airlines, users of general aviation aircraft, and aircraft manufacturers. In addition to the invitation letters, a press release was distributed concerning the study, and additional persons or organizations expressing interest were included into the task force. Written inputs from others, including all citizen noise complaint letters received over the period of the study, were called to the attention of appropriate task group leaders and placed in the public master file for reference.

This report presents the results of the Task Group 4 effort devoted to the investigation of the status of current and future noise control technology. It also provides a technical basis for recommending regulations, as proposed by Public Law 92-574.

The membership of Task Group 4 was made up of representatives of the Federal Government, airport operators, airlines, airframe manufacturers, general aviation, and environmental groups. The task group met six times in Washington, D.C. during the period February 15, 1973 to June 22, 1973. The members presented information pertinent to the problem, presented comments on information supplied by other members, generally discussed the problem and possible solutions, and reviewed and commented on draft reports. EPA requested that all data submitted be in writing; all documents are listed in the References and Bibliography and are available for inspection in the Airport/Aircraft Study files.

Reference to a specific item in the listing is made by providing the page number and the group acquisition number of the item being referenced. For example, "Reference (4. 1-56)" refers to the document numbered 56 on page 4. 1 in the Bibliography. Position papers of the task group participants are included in Appendix A and the list of participants is provided as Appendix B.

The conclusions and recommendations of this report are the responsibility of the Chairman and staff and are based on the information supplied by task group participants and on consideration of protection to the public health and welfare. The difficult and controversial subjects of the task group assignment precluded complete agreement among task group members. EPA sincerely appreciates the wholehearted efforts the task group members have put forth and without which this report could not have been prepared.

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SECTION 1
INTRODUCTION AND BACKGROUND

This report reviews the technological developments that have contributed to the historical growth of the civil aviation industry and looks to the present and future technology to nurture its continued growth. Future expansion of air transportation is now dependent upon resolving the problem created by its Achille's heel--aircraft generated noise.

One of the principal avenues available for reducing noise impacted areas resulting from aircraft operations is by treating the source of the noise--the aircraft and its contributing components.

The remaining portion of Section 1 reviews how we got where we are and presents forecasts of where industry is headed in terms of future aircraft types, and fleet sizes which are demand-oriented. Section 2 addresses the problem of how to reduce the noise of the existing fleet so that the various elements of the industry, (e.g., the airport operator, airline operator and the aircraft and engine manufacturers) can move ahead on plans for accommodating the projected increasing demand for air service. The various technical options are discussed in terms of their current status and anticipated performance levels. Section 3 looks to the next generation of aircraft. Current aircraft and engine component development programs will provide the technology for quieter aircraft in the future. The most difficult part of the study is to predict the cost of doing something as a function of time and benefits to be obtained. Equally discomforting is the fact that there is a cost tied to doing nothing. Quantification of the noise reduction options in terms of cost, availability date and effectiveness are presented in Section 4. While the data presented is not presumed to be absolute, significant conclusions can be drawn therefrom. Section 5 presents a concise summary of the key points developed in the preceding four sections of the report. Finally, specific R&D programs are identified in Section 6 which, if effected in a continuing aggressive program of timely implementation, will insure the continued growth and community acceptance of a prime national asset, the U.S. aviation industry.

TECHNOLOGY EVOLUTION & DEVELOPMENT

The present civil aviation system includes a wide variety of aircraft sizes and types designed to serve the varying needs of each of the market segments; the commercial air carriers, air taxi and commuters and general aviation. Over the years, the characteristics of these aircraft have undergone periodic changes, with the implementation of advanced technological developments, which have improved the performance and operational efficiency of these vehicles.

Technological advances in the civil fleet have historically been applied to the air carrier fleet initially and then subsequently adopted by other categories of the civil air system.

Most current commercial aircraft engines are civil derivatives of engines developed under government funding for military applications as indicated in Figure 1-1. This technology transfer cycle is still visible in the more recent aircraft and propulsion developments. The high bypass turbofan engines utilized in the DC-10 transport aircraft were developed as the direct result of a competitive military engine development program which was initiated to provide an efficient power plant for a new, large intertheatre military transport (C-5). The development of the JT9D high bypass engine (which powers the B747) was based upon the technology developed under an Air Force-sponsored engine demonstrator program, which preceded the C-5 engine development program. Some of the performance and noise reduction advantages of the high bypass engine technology has also been passed down to the general aviation fleet. The JT15D engine powering the Cessna Citation and the Garrett TFE731 planned for the new Falcon 10 are representative of the use of the high bypass fan technology in this market arena.

Many cost benefits to both military and commercial users resulted from this evolutionary practice. However, increasing noise and pollution environment constraints on civil aircraft have introduced a divergent trend in design characteristics which might make civil derivatives of future military engines less certain or not even feasible. (See Section 3)

A brief review of the technological progress to date and the resultant effect on fleet composition and aircraft noise is appropriate here as a prelude to the discussion of future options.

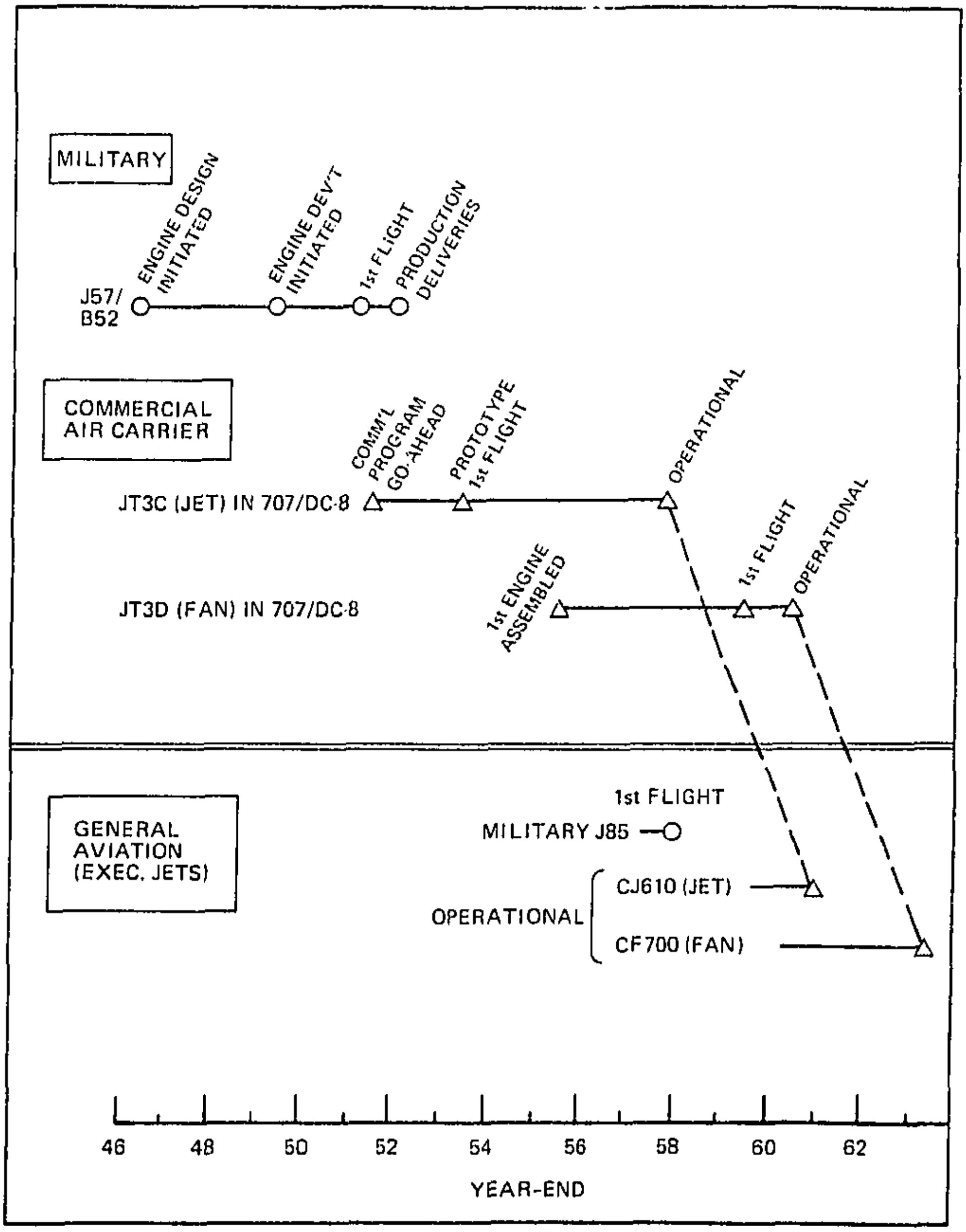


Figure 1.1. Military-Civil Technology Transfer

COMMERCIAL AIR CARRIER FLEET

The initial round of commercial jet aircraft were powered by engines that had been originally developed for high performance military aircraft (e.g., the 707, 720, and DC-8 aircraft utilized a modification of the J57 turbojet engine). This meant that the engine frontal area (or diameter) was small (for minimum drag), thereby limiting the quantity of air that could be introduced into the engine, which led to high velocity exhaust conditions required to develop the necessary thrust. These high exhaust velocities produced high jet noise characteristics. The initial (and costly) noise abatement program consisted of adding noise suppressors at the rear of the engine. Various approaches to the problem were pursued, but the most effective suppression method involved changes to the jet nozzle. The single nozzle was replaced by a cluster of small nozzles having the same total equivalent area as the original. This concept provides some attenuation of the deep-toned rumble of the unsuppressed jet. This device, however, added weight and decreased performance, which in turn led to higher operating costs.

The addition of a fan to the basic engine provided additional air at low velocity. This fan exhaust air either surrounded the primary jet exhaust (as in the JT3D engine), or the two were mixed in a common nozzle (as in the JT8D engine), to reduce overall exhaust velocity. Also, more exhaust energy was extracted by the larger turbine, which was required to drive the fan, thereby reducing the engine core velocity as well. This resulted in exhaust noise reductions which were an order of magnitude better than had been demonstrated with the earlier suppressors. While the addition of the fan added weight to the installation, the thrust and specific fuel consumption were improved so that the operating costs of the turbofan powered aircraft were appreciably lower than that of the pure turbojet. Both the JT3D and JT8D turbofan engines were modifications of existing military turbojets. The JT3D engine was developed for installation on existing DC-8 and 707 aircraft. The maximum fan diameter and hence the bypass ratio (ratio of the weight flow of air discharged from the fan-exhaust duct to the weight flow of air passing through the core engine) on the JT3D were therefore set by engine-installation considerations as much as the capabilities of the available technology. The bypass ratio on both the JT3D and JT8D was relatively low, being approximately 1.4 on the JT3D and 1.0 on the JT8D.

Whereas the addition of the fan reduced the exhaust rumble at takeoff, the fan became a significant new noise source, radiating from the inlet and fan exhaust portions of the engine. Fan noise became predominant at all operating conditions except takeoff and was particularly noticeable during landing approach.

The addition of suppressors and fans to these relatively inefficient (by commercial aviation standards) engines represent sincere industry attempts to attack the noise problem at the source during the period from 1958-1965, within the limitations presented by the non-optimum engine cycles and the physical limitations of the installations, while trying to respond to the exigencies of the times. Recent technology developments indicate that additional noise reduction is technically feasible for these existing systems and these will be discussed in Section 2.

During the same period that the low-bypass fan was being introduced into the then existing commercial fleet, the engine industry began exploring the characteristics of high bypass fans aimed at a new generation of jet transports, which would not be initially constrained by fan size limitations. The results of these studies, and component development programs, proved conclusively the benefits in performance, operating cost and noise from this type of propulsion system when applied to high subsonic transport aircraft.

Fortunately, the Air Force had come to the same conclusion and sponsored a competitive engine demonstrator program between Pratt and Whitney and General Electric. Based upon the results of this demonstrator program, the Air Force initiated a design competition for a powerplant to meet their requirements for an intertheatre logistics transport. This competition led to the development of the GE TF39 engine, which was the progenitor of the CF-6 engine now powering the DC-10 commercial transport. After losing the Air Force design competition, Pratt and Whitney designed and developed a new commercial engine (JT9D) that included all of the noise reduction technology known at that time, based upon the results of their participation in the engine demonstrator program. Here was the case once more where the commercial aviation industry was provided with new engines as the result of a military initiated program.

The characteristics of the newest transport aircraft of Boeing, McDonnell-Douglas and Lockheed (B-747, DC-10, L-1011) have demonstrated dramatic improvements in noise technology (Figure 1-2)* as well as efficiency and productivity, over those of the first generation jet transports. These aircraft will represent a significant portion of the fleet by 1980. The growth and composition change of the U. S. Fleet, historically and projected, is discussed in a subsequent part of Section 1.

Typical baseline noise levels for the existing air carrier jet fleet are provided on Figures 1-3 through 1-5 relative to the FAR 36 standard. (See Task Group V Report for discussion of the implications of the FAR 36 rule.)

GENERAL AVIATION

General aviation is defined as all civil flying that does not require a certificate of public convenience and necessity issued by the Civil Aeronautics Board. As such, general aviation contains many different use categories as well as many different types of aircraft. It varies from personal flying and transportation of personnel and cargo by business firms in corporate-owned aircraft and by air taxi operators to special uses of aircraft, such as crop dusting, power and pipeline patrol, and aerial advertising.

Over the past 15 years, the growth of the U.S. general aviation fleet has closely paralleled the economic growth of the country as indicated in Figure 1-6. A periodic surge in the economy has been historically reflected in a surge of new aircraft procurement in the following year.

As indicated previously, the technological developments that have been introduced into the air carrier fleet was subsequently adapted to specific segments of the general aviation fleet. The most obvious has been the development and modification of the turbojet engine to the low-bypass fan and more recently the introduction of the high-bypass turbofan concept for application in business aircraft.

The fastest growing segment of the general aviation market is that of the relatively more sophisticated turbojet/turbofan powered aircraft which are primarily utilized for more efficient business transportation. Accounting for less than 1 percent of the general aviation fleet today, industry forecasts indicate a growth to approximately 2.5 percent of the fleet by 1985. These percent numbers are deceptively low--the

*Figure 1-2 cannot be utilized as a predictive tool for future systems. It merely represents the time-phased trend in aircraft noise reduction for different classes of aircraft.

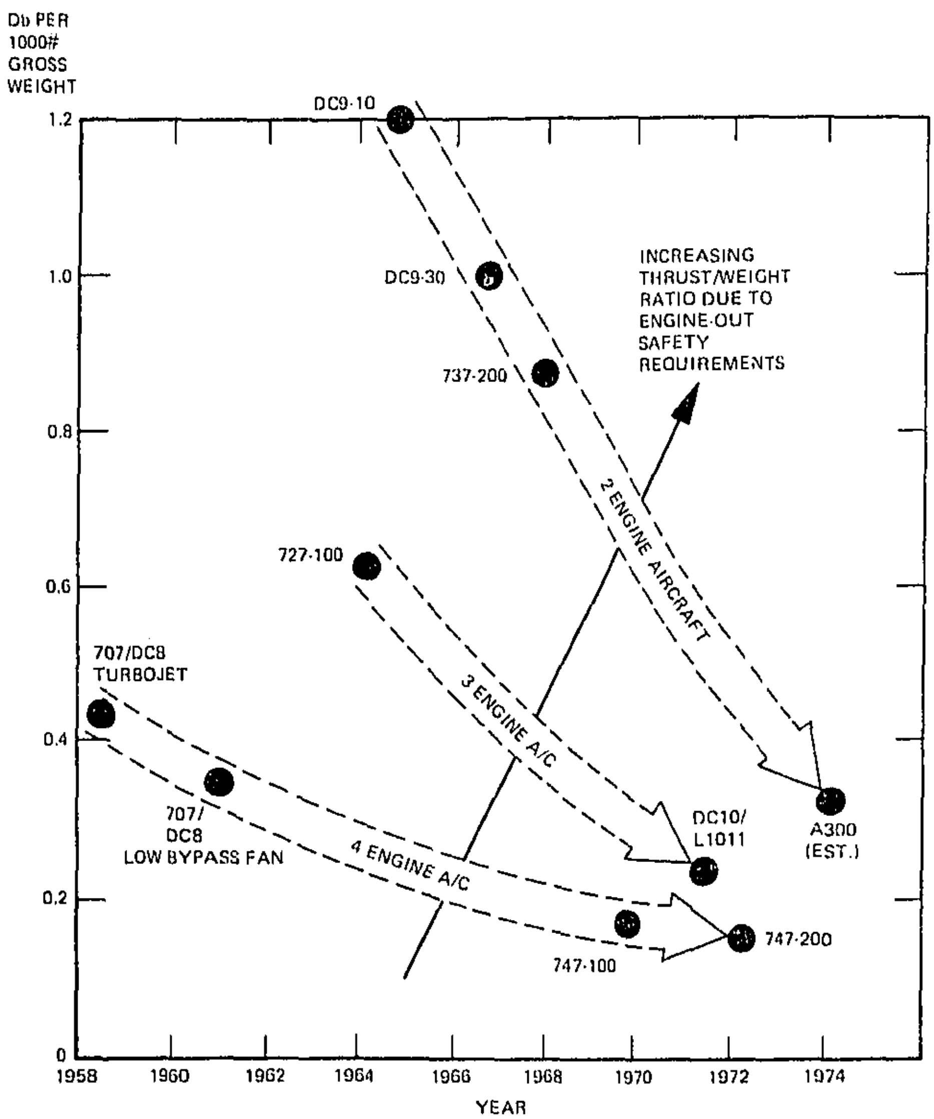


Figure 1-2. Noise Reduction Technology Trend (TAKEOFF)

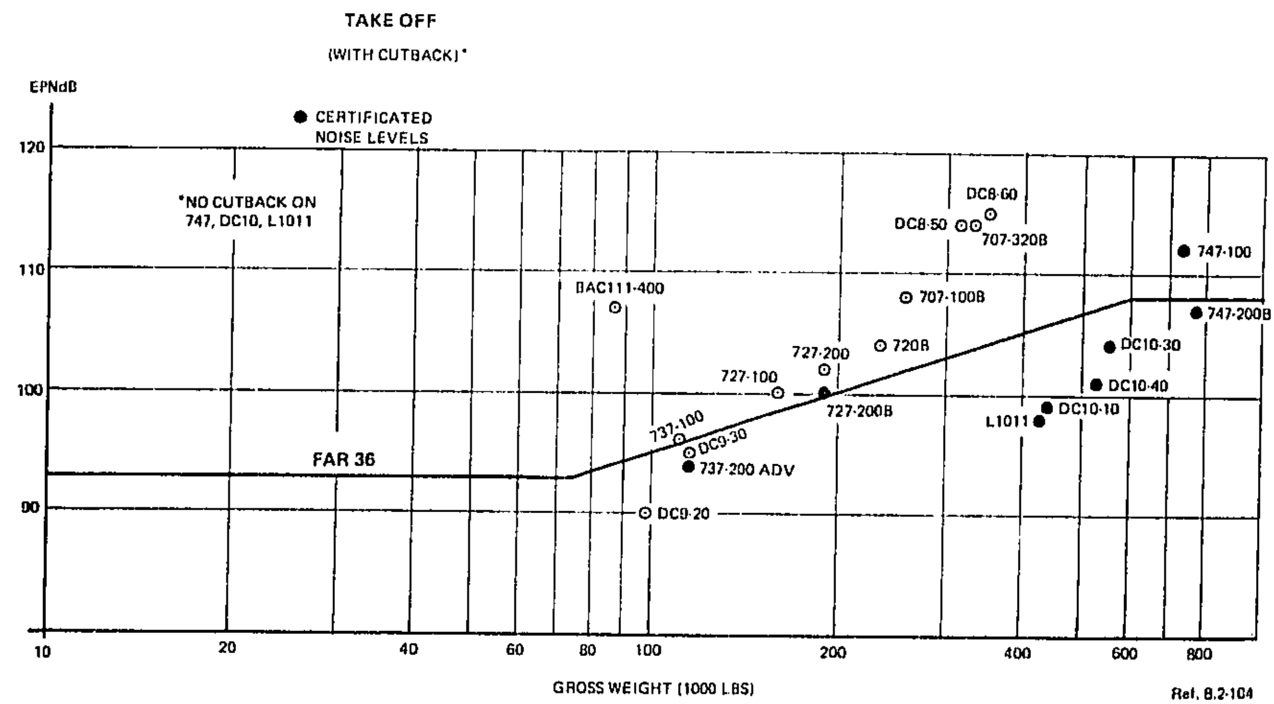


Figure 1-3. U.S. Air Carrier Fleet-Take Off Noise Levels

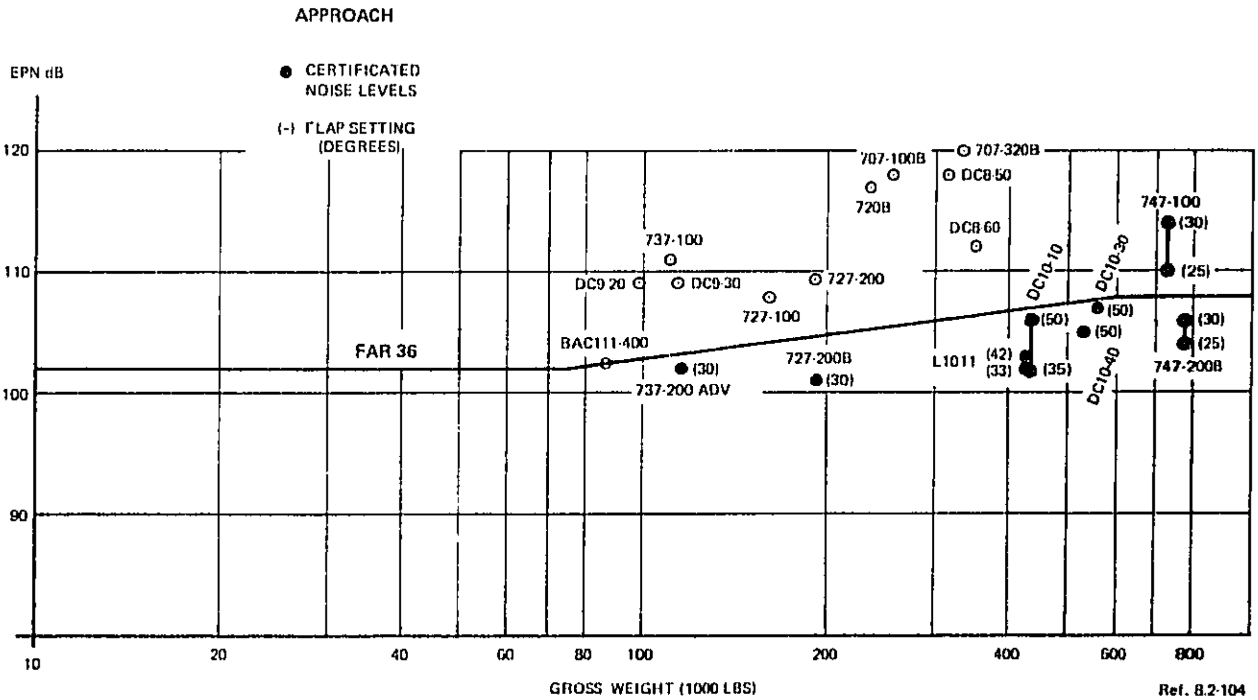


Figure 1-4. U.S. Air Carrier Fleet - Approach Noise Levels

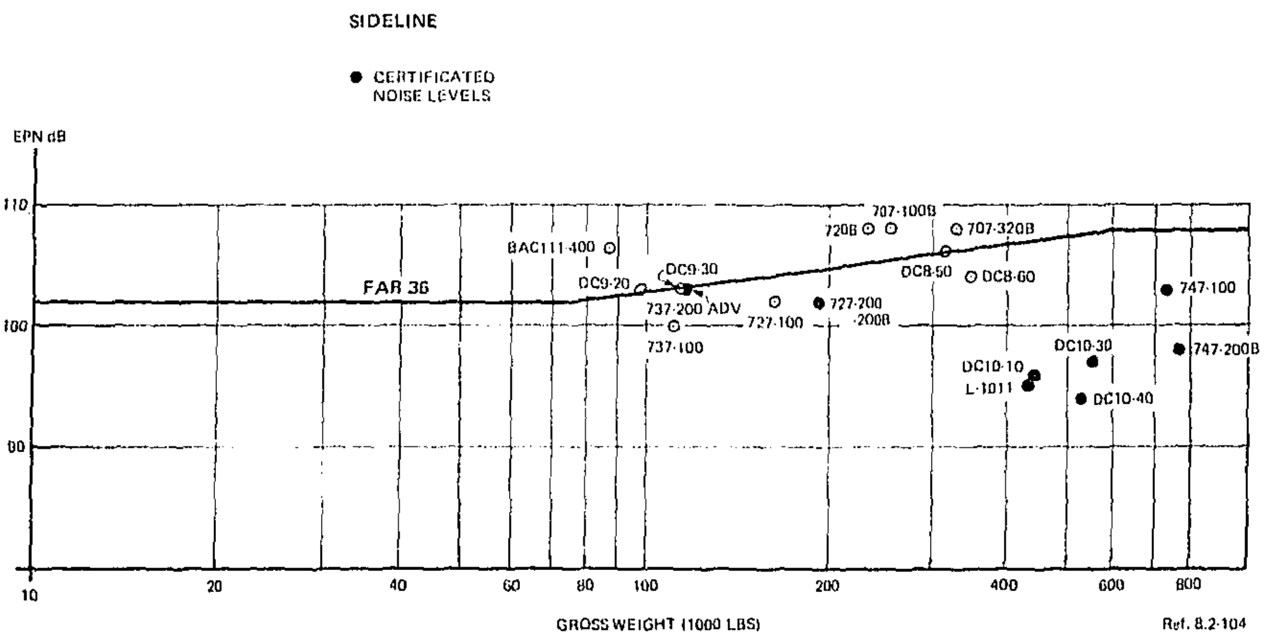


Figure 1-5. U.S. Air Carrier Fleet - Sideline Noise Levels

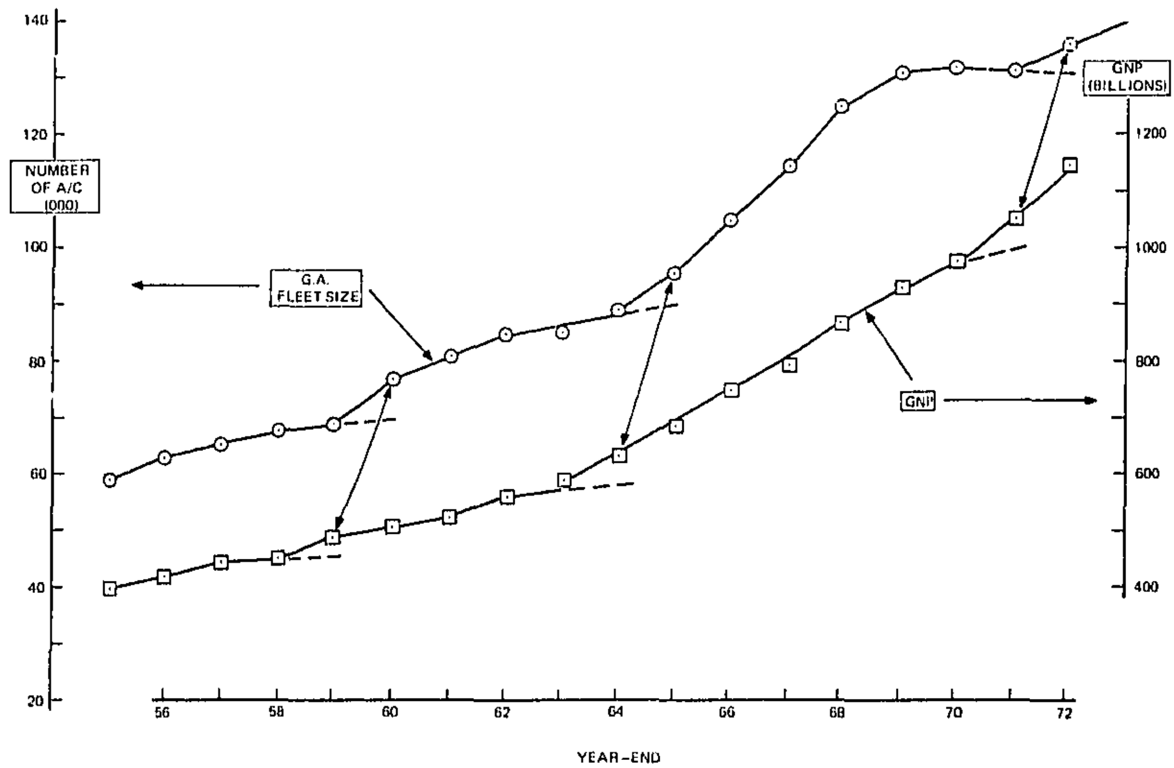


Figure 1-6. General Aviation Fleet Size and Gross National Product (GNP)

absolute quantity of aircraft involved is significant, particularly when compared with the present and projected air carrier jet fleet. (See the following discussion on Aircraft Fleet Size Forecasts.)

When these aircraft operate out of the major air carrier airports, their current contribution to the overall noise impact is minimal due to their relatively low operational utilization at these airports when compared with air carrier fleet operations.

However, many of these aircraft also operate out of smaller suburban airports with little or no air carrier operations. Here, they represent the dominant aircraft noise source and may impact quite significantly on the residential community. In addition, when the noise generated by the air carrier fleet is diminished, the business jets will contribute more significantly, even at the major airports, unless noise abatement techniques are applied to these aircraft as well.

Figure 1-7 presents the estimated noise levels for the current fleet of general aviation jet aircraft. The Cessna Citation and Falcon 20 are the only aircraft in the business jet fleet that have been certificated to the noise requirements of FAR 36, Appendix C. The Fokker-VFW F 28 at 65000 #GW is currently being marketed as a short haul transport. It too has been certificated in compliance with FAR 36. At least one of these aircraft has already been procured by a U.S. industrial firm for business use.

It is expected that the future expansion of the business jet fleet, (as indicated earlier), will occur with the introduction of new aircraft powered by turbofan engines having significantly reduced noise characteristics. However, as in the case of the commercial carrier fleet, there will still be 1000-1500 of the current type of turbojet powered business aircraft still operational in the late 1970's and early 1980's.

The current options available for reducing the noise levels of these aircraft are discussed in Section 2.

VERTICAL TAKEOFF AND LANDING AIRCRAFT (VTOL)

The lifting forces in VTOL aircraft are provided by

1. Rotors, propellers, or fans operating in a horizontal plane.
2. Vertically directed exhaust energy developed by turbine engines, wherein the lift energy (or thrust) generated is in excess of the gross weight of the aircraft.

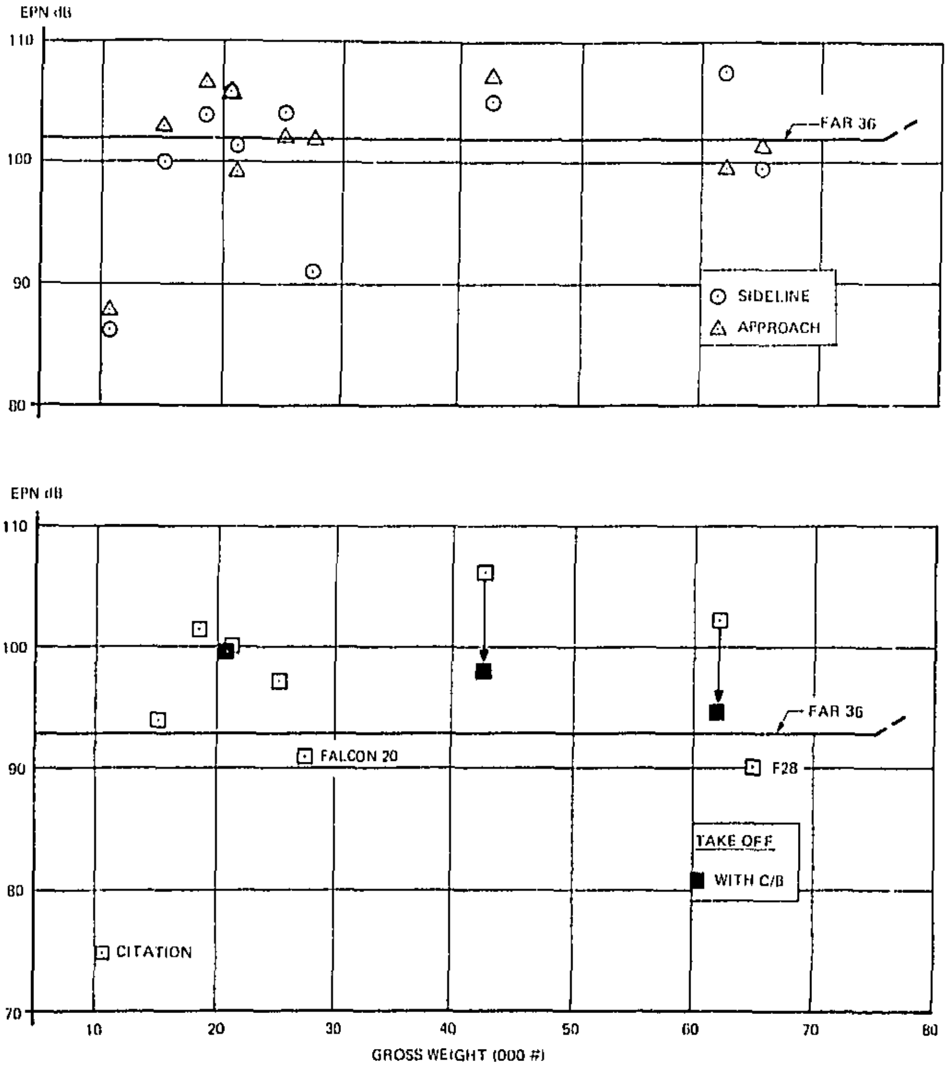


Figure 1-7. Current Business Jet Noise Levels

The unique capability provided by VTOL aircraft has been fully demonstrated in military operations and for a variety of missions. Surveillance, rescue, and transport of men and materials are typical military applications with analogous requirements in the civil sector. Today, 33 years after the initial demonstration of the first practical VTOL vehicle (the Sikorsky VS-300), the helicopter remains the only viable VTOL operational system that has been developed to meet these needs.

The utilization of the helicopter in the general aviation sector has grown by an order of magnitude since 1955 and is forecast to more than double by 1985 (Figure 1-20 on page 1-32). The vast majority of the current fleet consists of the small (less than 4000 #GW) piston powered type. However, as in the other segments of civil aviation, the turbine engine has become the primary power source for these aircraft (approximately two-thirds of the currently produced helicopters are turbine powered).

The principal source of helicopter noise normally is the rotor system rather than the engine. The high velocity jet noise generally associated with the turbine engine is not present in a helicopter installation. Much of the exhaust energy developed in the engine is dissipated by the addition of a "free" turbine stage in the exhaust stream which absorbs this energy to drive the rotor system. The noise levels of the helicopter in hover are in the range of 75 to 105 PNdB @ 500' (Figure 1-8), however, the unique characteristic rotor "slap" can be a sensitive irritant in a residential community. Current efforts to reduce this effect are discussed in Section 3.

The commercial air carrier helicopter fleet has decreased from a peak of 26 vehicles in 1957 to 14 vehicles in 1972. Many abortive attempts were made to develop and expand the use of the helicopter in commercial passenger service without success. Stability problems, vibration, and noise have restricted passenger acceptance, and relatively high direct operating costs (DOC) due to the low speed and payload capability of those aircraft that have been offered has been the inhibiting factors restricting their revenue service potential.

The use of auxiliary engines for more efficient lift and propulsion in forward flight has been demonstrated. Their application would permit higher flight speeds (250 to 300 mph) and improved operating economics over that of the slower, less efficient pure helicopter. This class of vehicle has been termed the "compound helicopter."

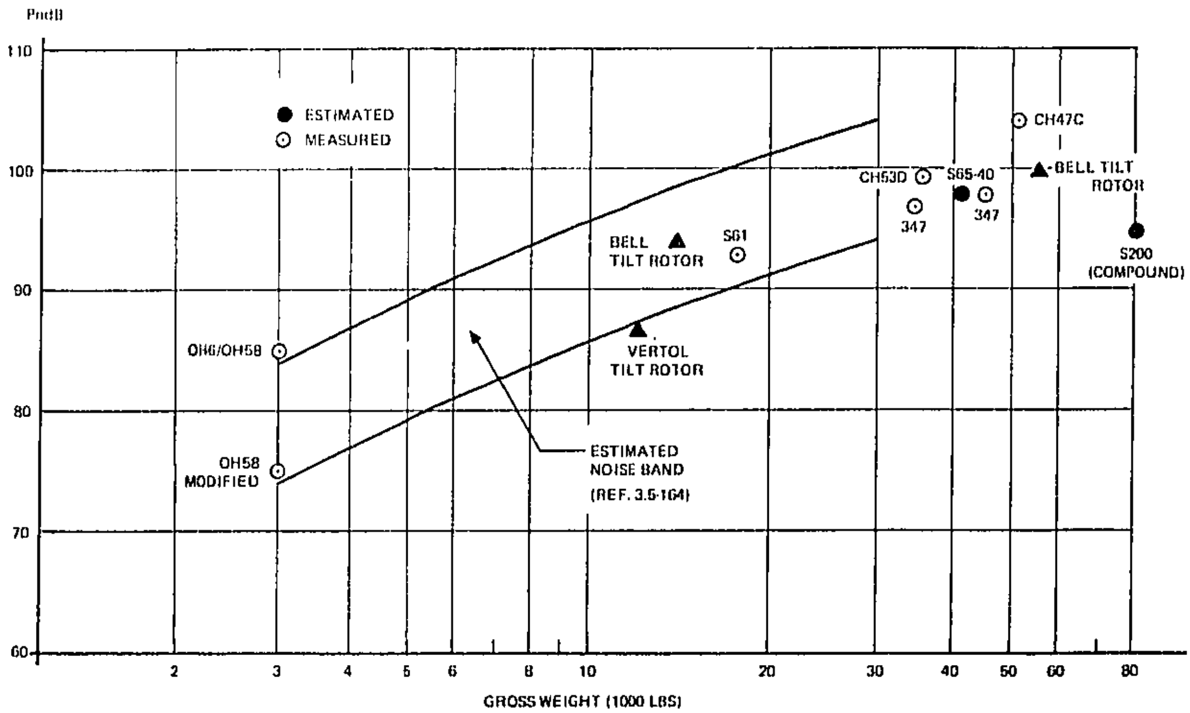


Figure 1-8. Helicopter Hover Noise at 500'

The Army, Air Force, NASA and industry have been pursuing tilt rotor technology for many years. The tilt rotor concept offers another opportunity for extending the proven performance capability of the helicopter. Conceptually, the tilt rotor possesses the best characteristics of both the helicopter and the fixed-wing aircraft.

A joint NASA/Army tilt rotor development program now underway will result in flight tests of a research vehicle by 1976. The objectives of the program are to substantiate the technical and operational feasibility of this concept for cruise speeds of 350 to 400 mph. If these tests are successful, development of commercial versions could follow. Lift fans, retracted rotors, stowed rotors, etc., are additional VTOL concepts which could yield higher subsonic performance characteristics but additional development and demonstration testing is required.

The potential benefits to civil aviation due to vertical takeoff and landing capability are reduced noise impact on the airport community, and reduced airport congestion, as a result of utilizing small airfields and other landing sites not available to conventional aircraft.

SHORT TAKEOFF AND LANDING AIRCRAFT (STOL)

The current, generally accepted definition of a STOL aircraft is one having the capability for a maximum payload takeoff and landing utilizing a 2000-foot (or less) runway. This capability would provide access to essentially all of the public airports in the U.S. The objective is to relieve congestion at the major hub airports by utilizing additional suburban sites and, in addition, provide improved service to smaller communities.

With the restraints being placed on the air system due to the noise characteristics of the existing fleet, it is apparent that any new air vehicle that is brought into the system must be compatible with its operating environment. As the runway requirements and airport size decrease, the noise constraints become more severe since the aircraft become more closely interactive with the community.

At this time, there is no standard or regulation establishing the noise criteria for STOL (or for that matter, VTOL) aircraft. A noise goal for the NASA quiet, clean, STOL, experimental engine (QCSEE) program has been tentatively suggested as 95 EPNdB at 500 feet from the source of the noise. This is a significant technological challenge, particularly for high performance vehicles, as indicated in Figure 1-9. Note that the goal for the QCSEE is approximately 30 EPNdB lower than existing regulations and 9 dB less than was achieved in the NASA Quiet Engine experimental test program.

In attempts to reduce takeoff distances and landing roll, high lift devices have been developed and utilized to supplement the aerodynamic lift provided by the wing surfaces. Figure 1-10 provides an indication of the improved lift capability realized with the progressive developments in flap design which effectively modified the wing geometry in low speed flight regimes. These devices obtain their increased lift capability solely from the free stream air flow.

An additional and effective means for increasing wing lift is the application of engine power (or energy) to the lifting surfaces. This is currently identified as the "powered lift" concept. Early development of this theory was applied to propeller driven air vehicles, wherein the propeller slipstream was directed over the wing and flap devices. This was termed the "deflected slipstream" concept. This technology was utilized in the Breguet 941 STOL aircraft development program.

Current technology efforts are directed at employing the deflected slipstream concept, but utilizing the efflux from turbofan engines, instead of the propellers, as indicated in Figure 1-11. A more detailed discussion of the status of these potential propulsive lift options is presented in Section 3.

REDUCED TAKEOFF AND LANDING AIRCRAFT (RTOL)

The limiting runway lengths for reduced takeoff and landing aircraft has been tentatively identified as between 3,000 and 4,000 feet. RTOL capability is important in order to permit expanded utilization of existing airports, and access to smaller airports, without incurring the economic penalties associated with much more sophisticated STOL class aircraft. The use of high-lift devices as discussed earlier, or improved braking or landing system, may be all that is necessary to obtain this capability. The concept of "overpowering" the aircraft by increasing the engine thrust or decreasing payload for a given installation may also provide this capability. The McDonnell Douglas Corporation has indicated in a submission to the Aviation Advisory Commission that a certified RTOL version of the current DC-9 aircraft could be available 2 years from go-ahead.

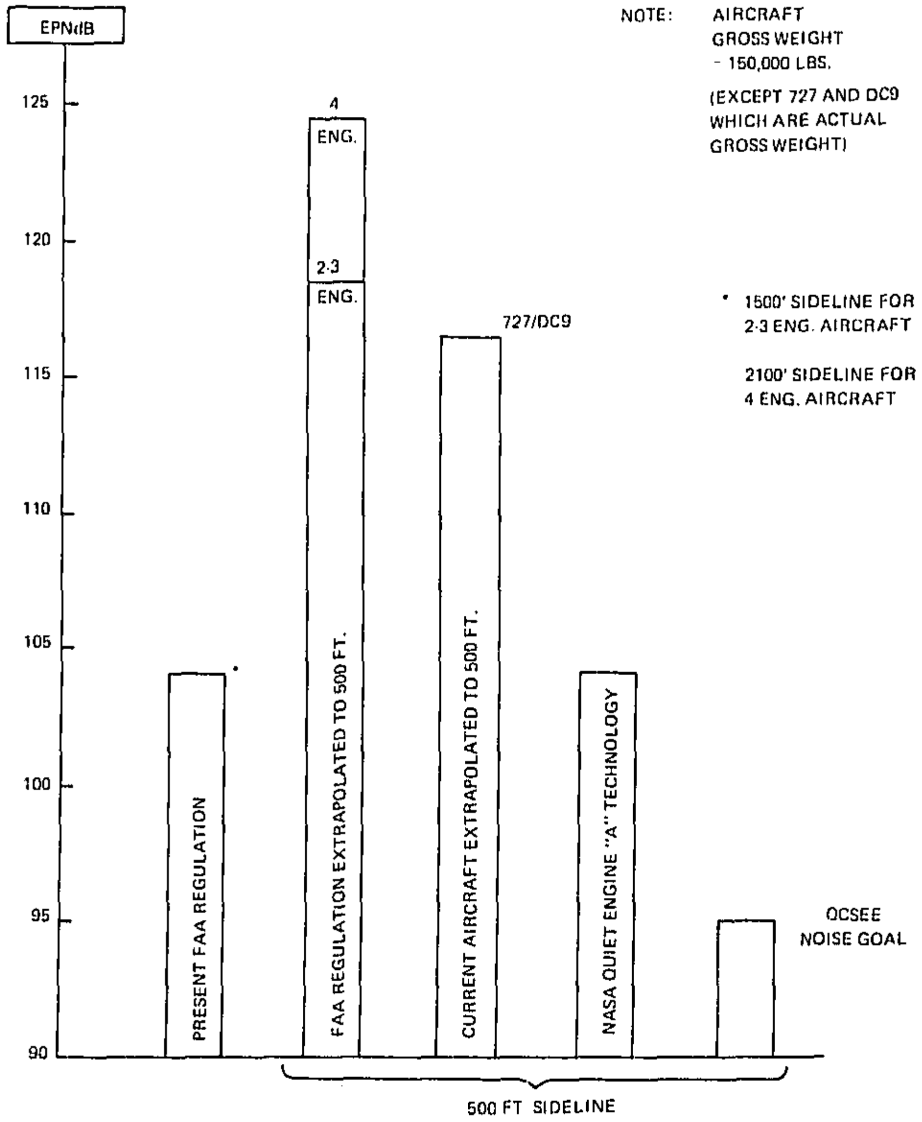


Figure 1-9. QCSEE Noise Goal Related to Current CTOL Technology

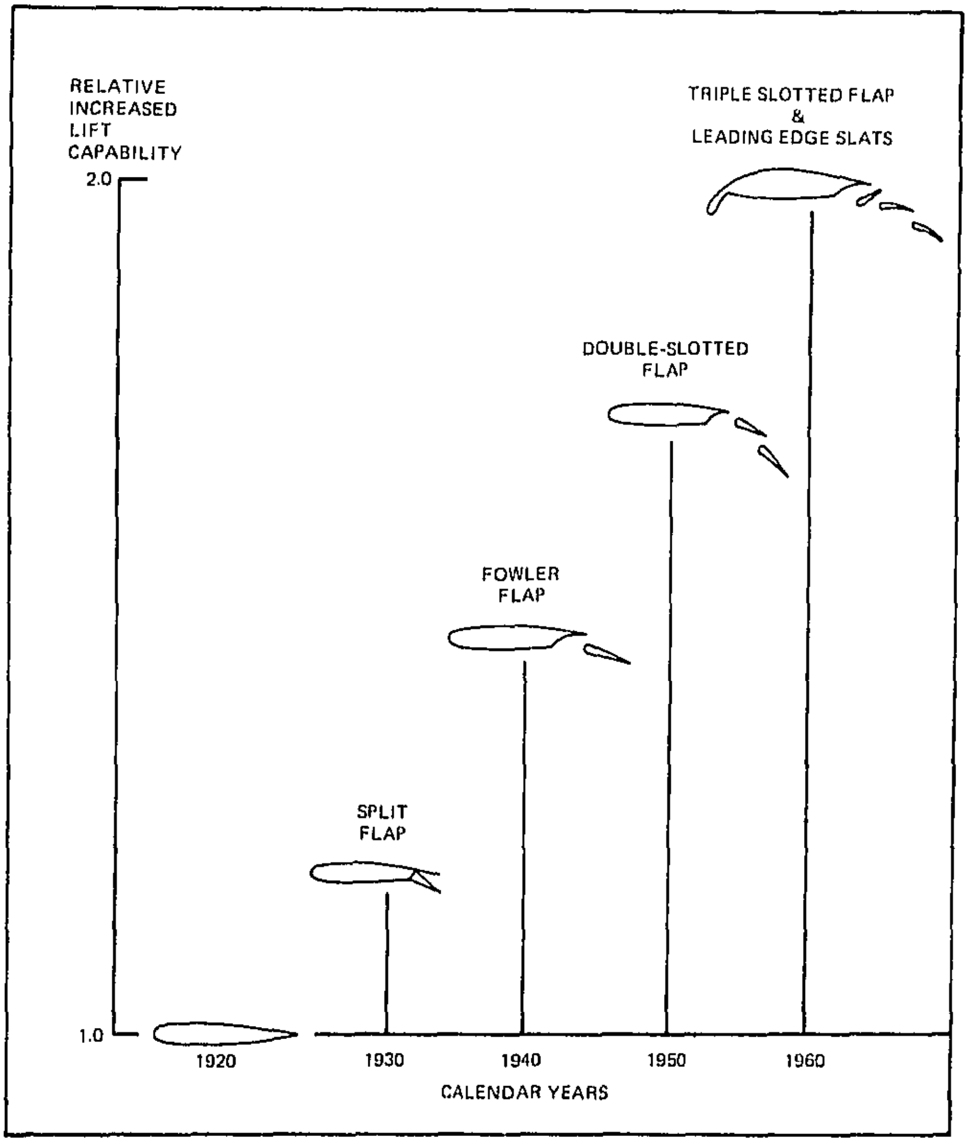


Figure 1-10. High Lift Flap Development

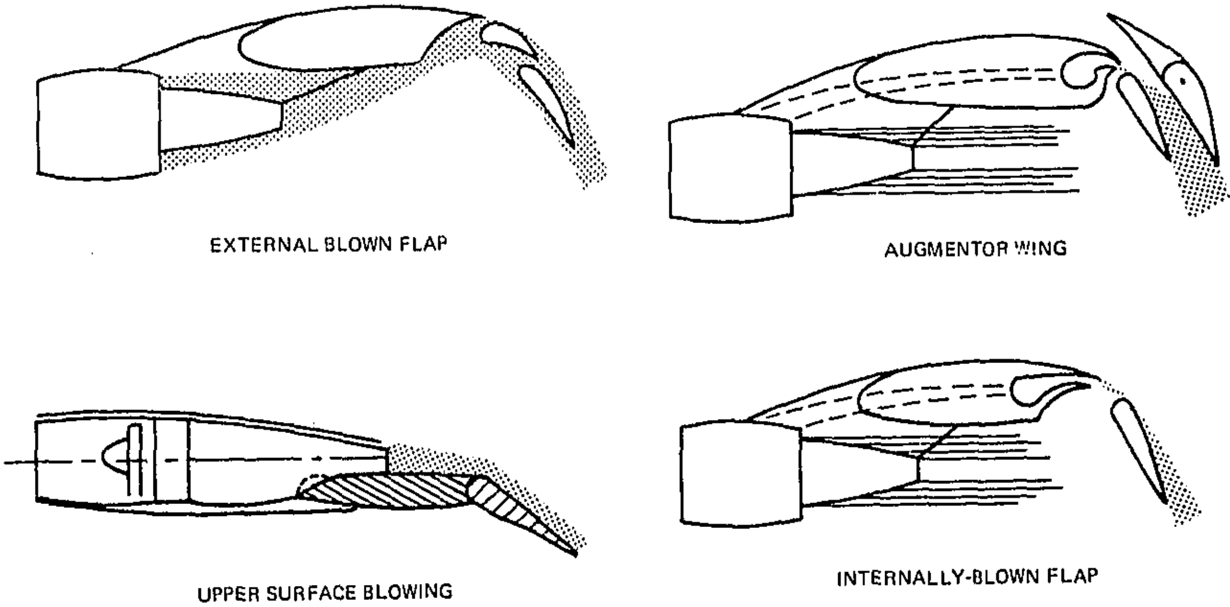


Figure 1-11. Typical Powered Lift Concepts

AIRCRAFT FLEET SIZE FORECASTS

U.S. AIR CARRIER FLEET

The number of aircraft in the U.S. air carrier fleet, historically and as projected by the Air Transport Association (ATA) and the Federal Aviation Administration (FAA), is indicated in Figure 1-12. This figure illustrates the composition of the fleet by aircraft types, the phenomenal growth of jets during the mid-1960s, the recent cessation of this growth, and the introduction of the wide-body (747, DC-10 and L1011) series of jet aircraft. As indicated by the ATA projection, the growth is expected to resume and be based primarily on the introduction of the wide-body types meeting the increase in demand and replacing the older narrow-body (707 and DC-8) types of jet powered aircraft. The FAA projection also indicates a resumption of the growth of jets; however, this projection, when compared with that of the ATA, indicates that it will start later and be more rapid in the late seventies. The fleet size and composition projections have implications relative to possible noise retrofit options and future airport noise exposure levels; therefore, the historical and projected numbers of the major current types are illustrated in greater detail in Figures 1-13 through 1-17.

The number of aircraft of the DC-8 type, including all series of this type, are illustrated in Figure 1-13. The figure illustrates the worldwide fleet size as a function of time using three assumptions about the life span of the aircraft. The three assumptions are:

1. Each aircraft has a fixed structural life of 20 years.
2. Each aircraft has a fixed competitive life of 15 years.
3. Aircraft are retired as a result of analysis of route structures in conjunction with air service demand forecasts and airline plans and surveys.

The figure also illustrates the U.S. air carrier DC-8 fleet size based upon the third assumption as provided in Reference 3.4-132 and a projection provided by the ATA, Reference 13.3-92. The number of DC-8s in the U.S. fleet as of January 1973 as provided by the Pratt and Whitney Aircraft Company in Reference 2.1-67 is also shown.

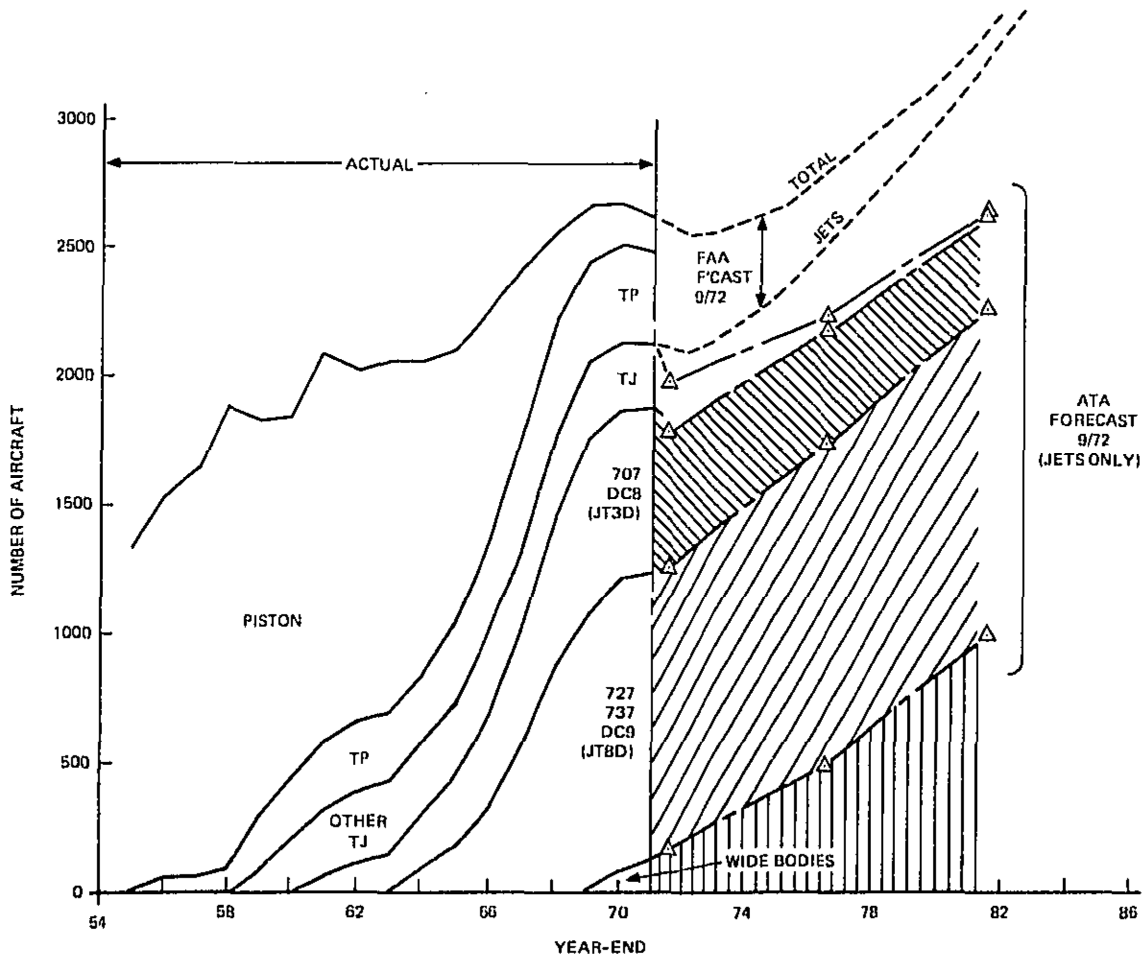


Figure 1-12. U.S. Air Carrier Fleet - Number of Aircraft

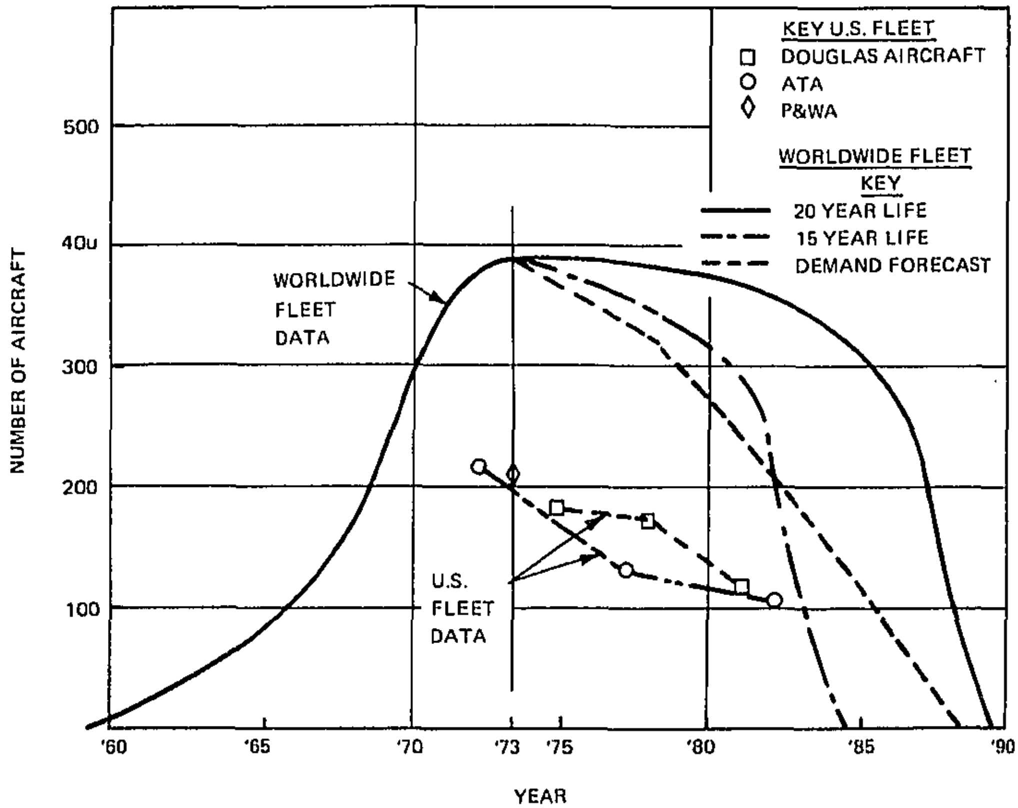


Figure 1-13. Worldwide and U.S. Fleet Levels, DC-8 Type (All Series)

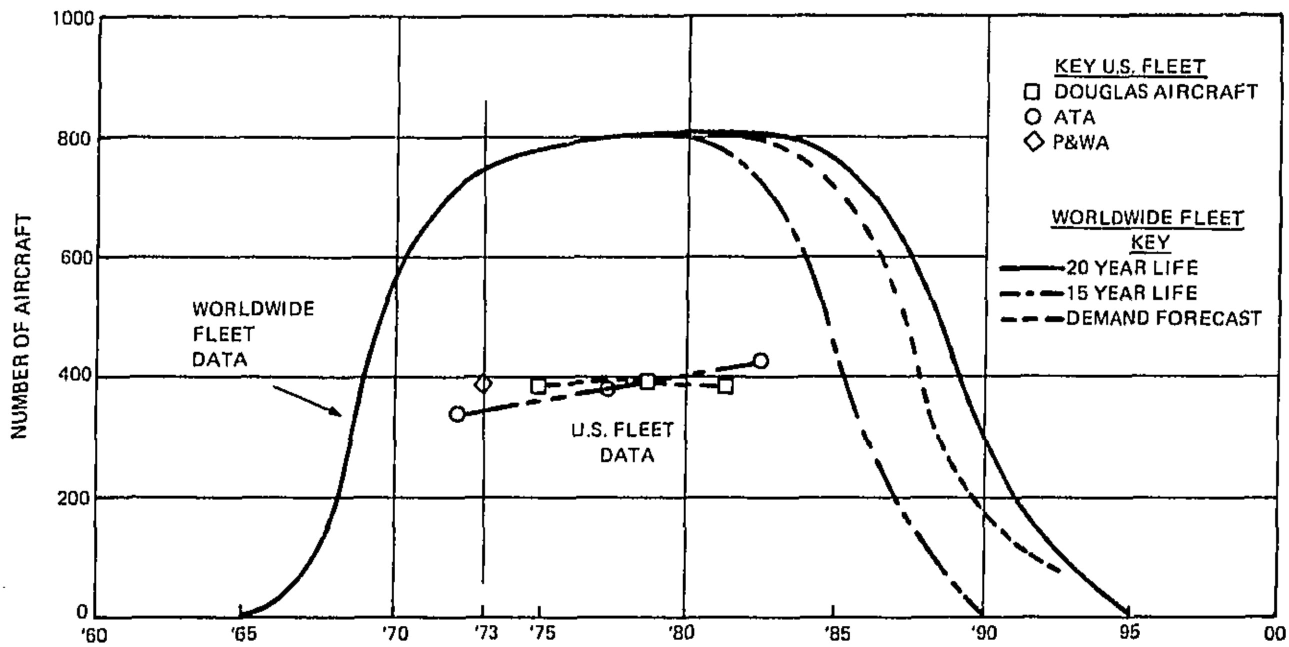


Figure 1-14. Worldwide and U. S. Fleet Levels, DC-9 Type (All Series)

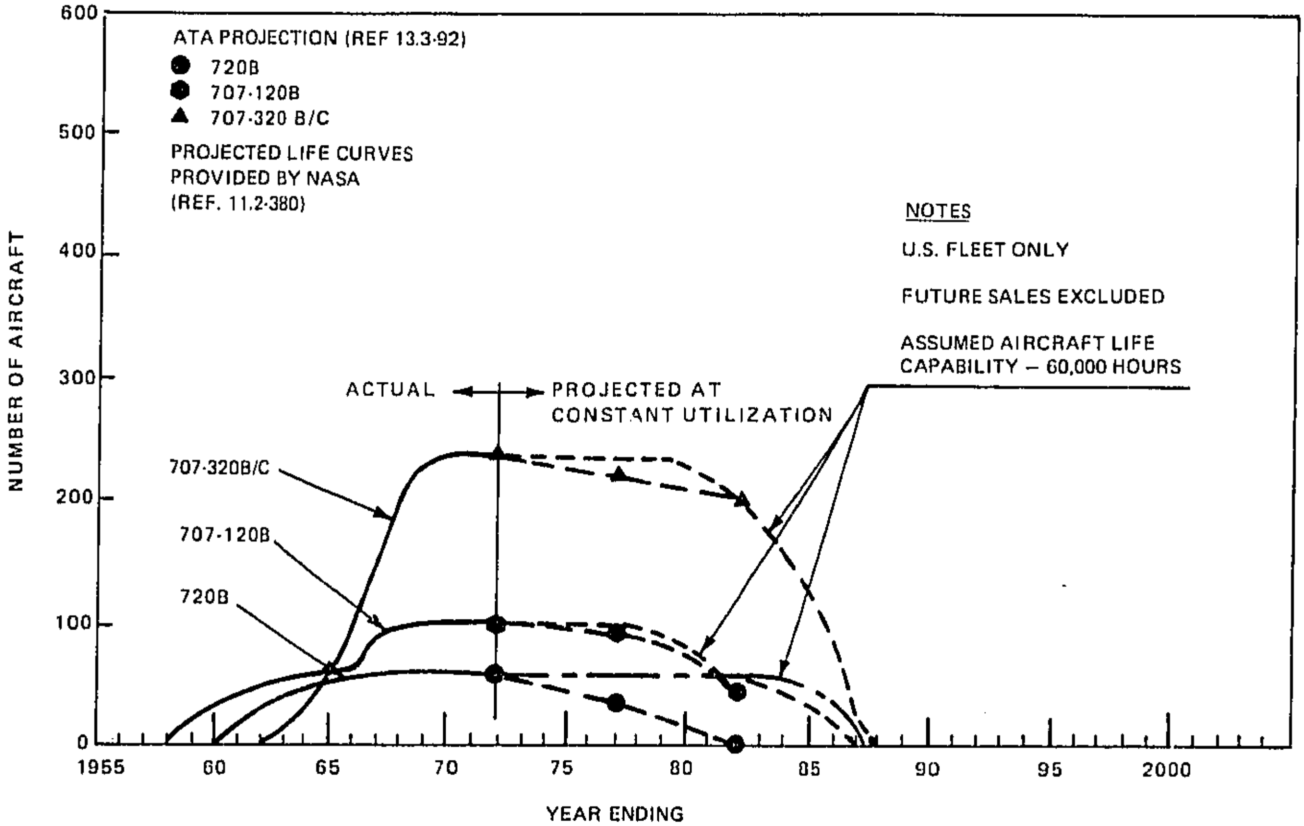


Figure 1-15. U.S. Fleet Levels; Actual and Projected, 720B & 707 Series

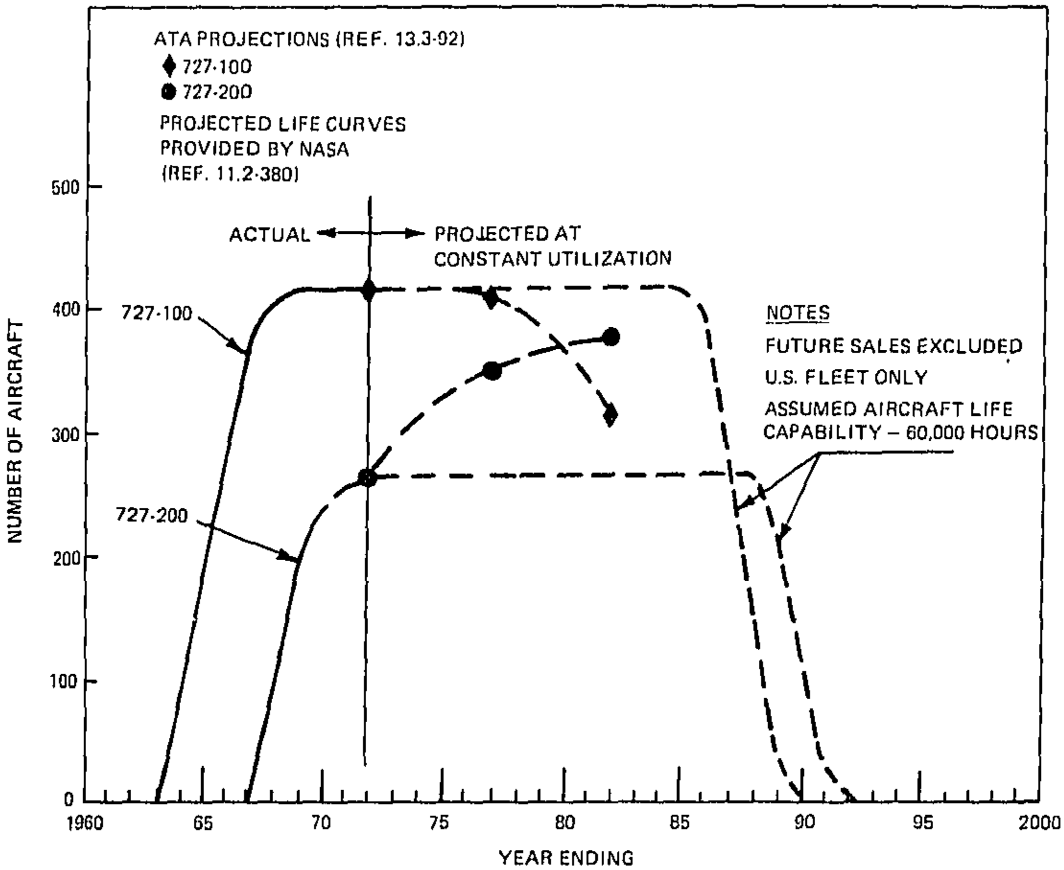


Figure 1-16. U.S. Fleet Levels; Actual and Projected, 727-100 & 200

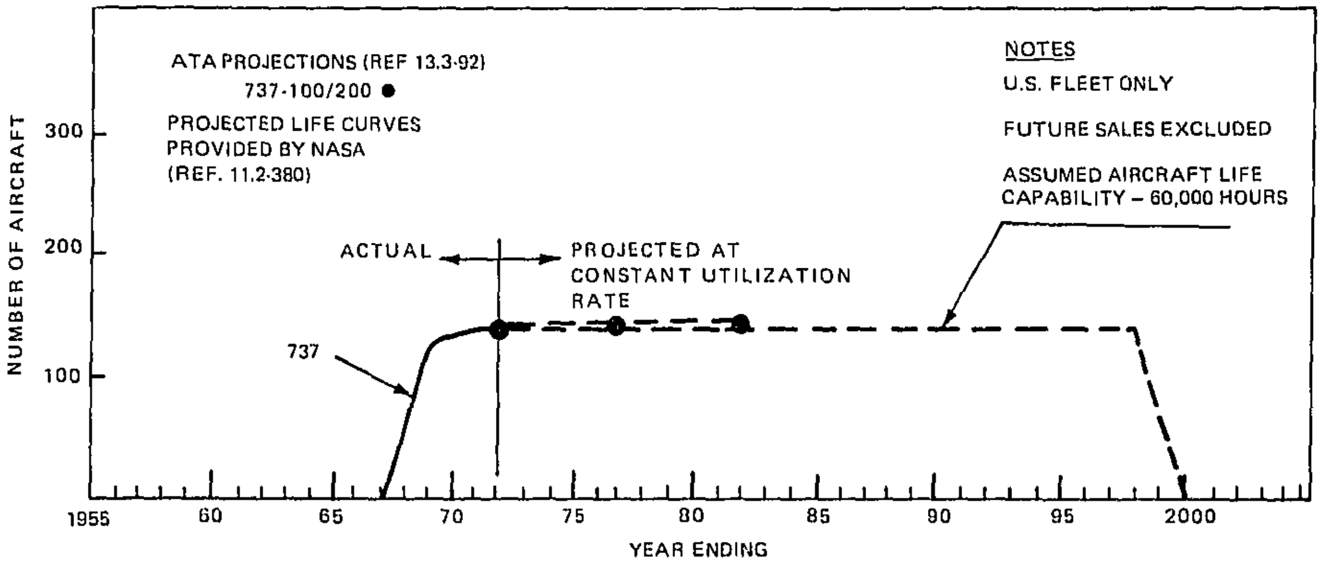


Figure 1-17. U.S. Fleet Levels; Actual and Projected, 737 Series

Figure 1-14 illustrates the same information on the DC-9 aircraft type, including all series within this type, as provided by the Douglas Aircraft Company, the Pratt and Whitney Aircraft Company and the ATA in the above cited references.

Figures 1-15 through 1-17 illustrate similar information on the Boeing 707, 727 and 737 series of aircraft, respectively, as provided in Reference 11.2-380. *

U.S. GENERAL AVIATION FLEET

The numbers of turbine powered aircraft in the U.S. general aviation fleet as provided by the FAA aviation forecast documents are illustrated in Figure 1-18. Historical or actual data extracted from the FAA documents are provided through 1971. An insert in the figure illustrates the actual percentage of the total turbine powered fleet represented by the turbojet and turbofan powered aircraft. As shown, this percentage has averaged at slightly more than forty percent since 1965. The FAA forecast for the 1973-1984 period, as provided in Reference 8.5-348, lists only the total turbine powered fleet numbers. This projection and 40 percent of this projection, representing the anticipated number of jet powered aircraft based upon the historical data are also shown in this figure.

The size of the jet powered, general aviation fleet has been estimated and projected by R. Dixon Speas (Reference 13.3-360), Mitchell Research Associates (Reference 7.1-54) and General Electric (unpublished data). As shown in Figure 1-18, these projections indicate that the business jet portion of the turbine fleet will represent a much higher percentage in the future than it has in the past. For comparison, seventy percent of the total turbine powered fleet as forecasted by the FAA is also shown in the figure.

If the trend is truly toward jet powered aircraft for this class of aviation, and it appears that it is, and the numbers will be close to those estimated by the above cited sources, then the number of jet powered, general aviation aircraft can be expected to exceed the number of jet powered, air carrier type aircraft in the mid to late 1970s and possibly be twice as many in the mid 1980s. This comparison is

*Data, subsequently provided by Boeing (3.8-374) indicates only minor differences. Additional data provided by Boeing (3.10-456) indicates significant changes with respect to the 727 life span.

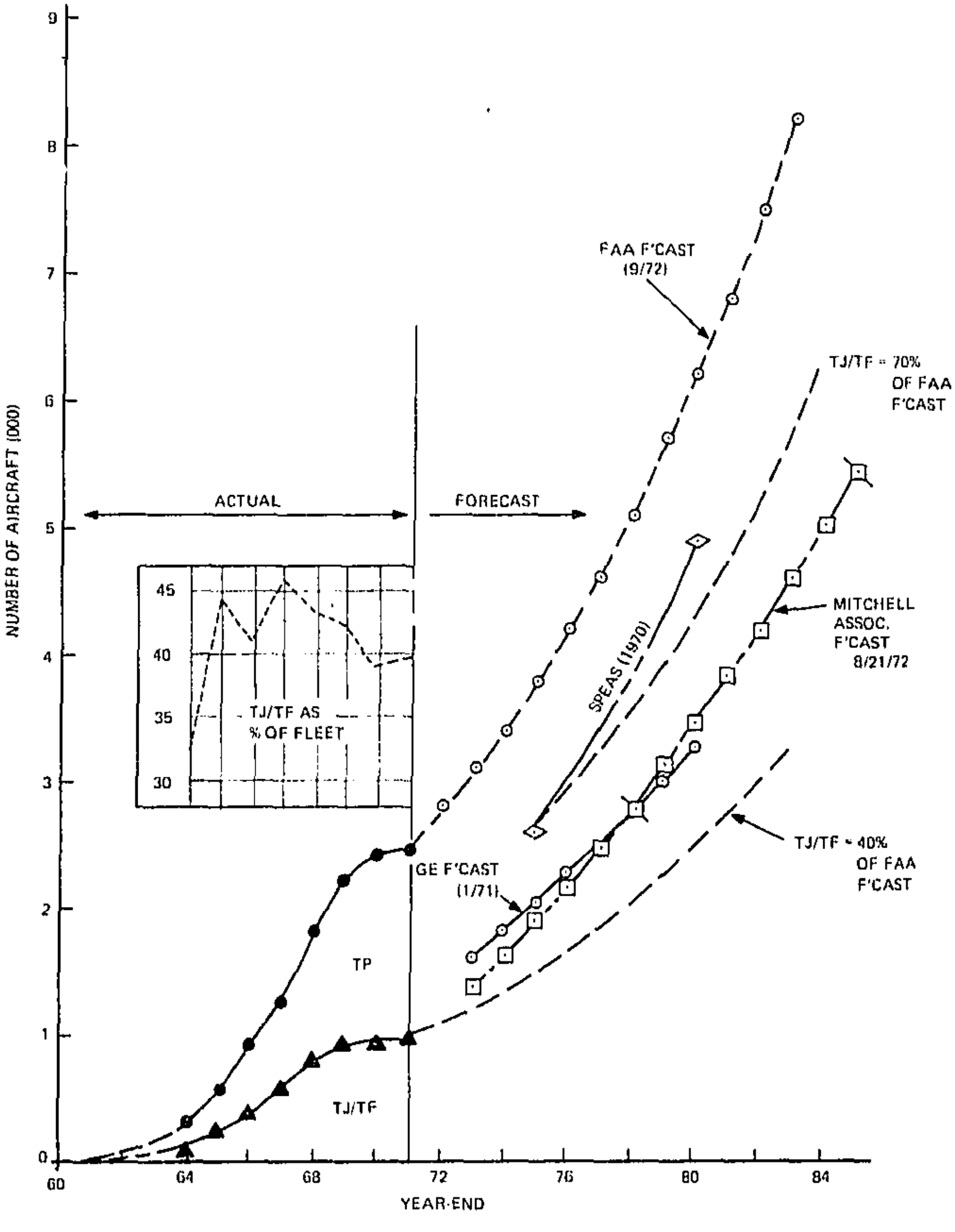


Figure 1-18. Turbine Powered General Aviation Fleet (U.S.)

illustrated in Figure 1-19 and is significant to the formulation of aircraft/airport noise abatement programs and regulations.

U.S. CIVIL HELICOPTER FLEET

As noted in the previous section, civil use of the helicopter has been growing steadily and is expected to grow at least as rapidly in the forseeable future. Figure 1-20 indicates the U.S. civil helicopter fleet size (total and turbine powered) as provided in the FAA forecast for the period 1973 to 1984 (Reference 8.5-348). Another forecast made by R. Dixon Speas Associates (Reference 13.3-360) is also shown. The projection developed by Speas in 1970 appears to be an extension of a rate of growth that was prevalent in the short period between 1966 and 1969.

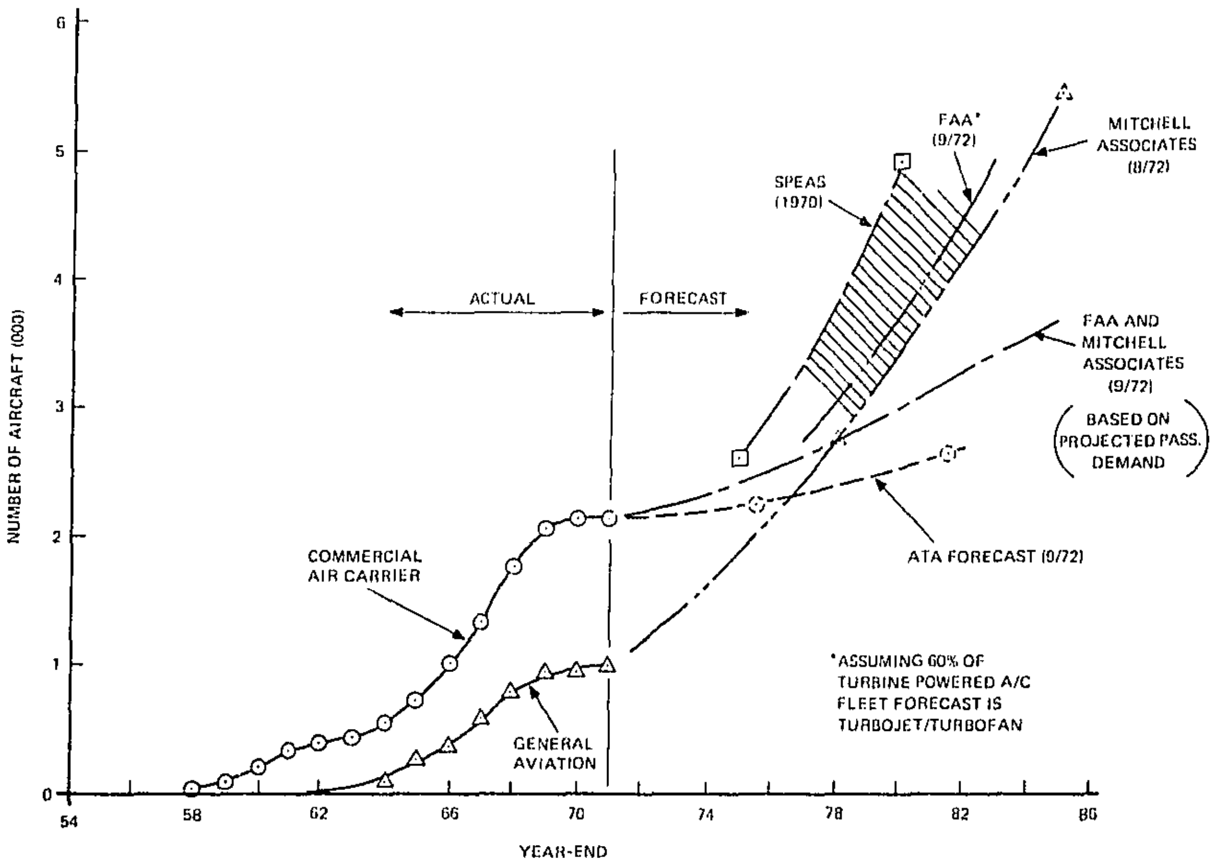


Figure 1-19. U.S. Civil Jet Aircraft Fleet Size

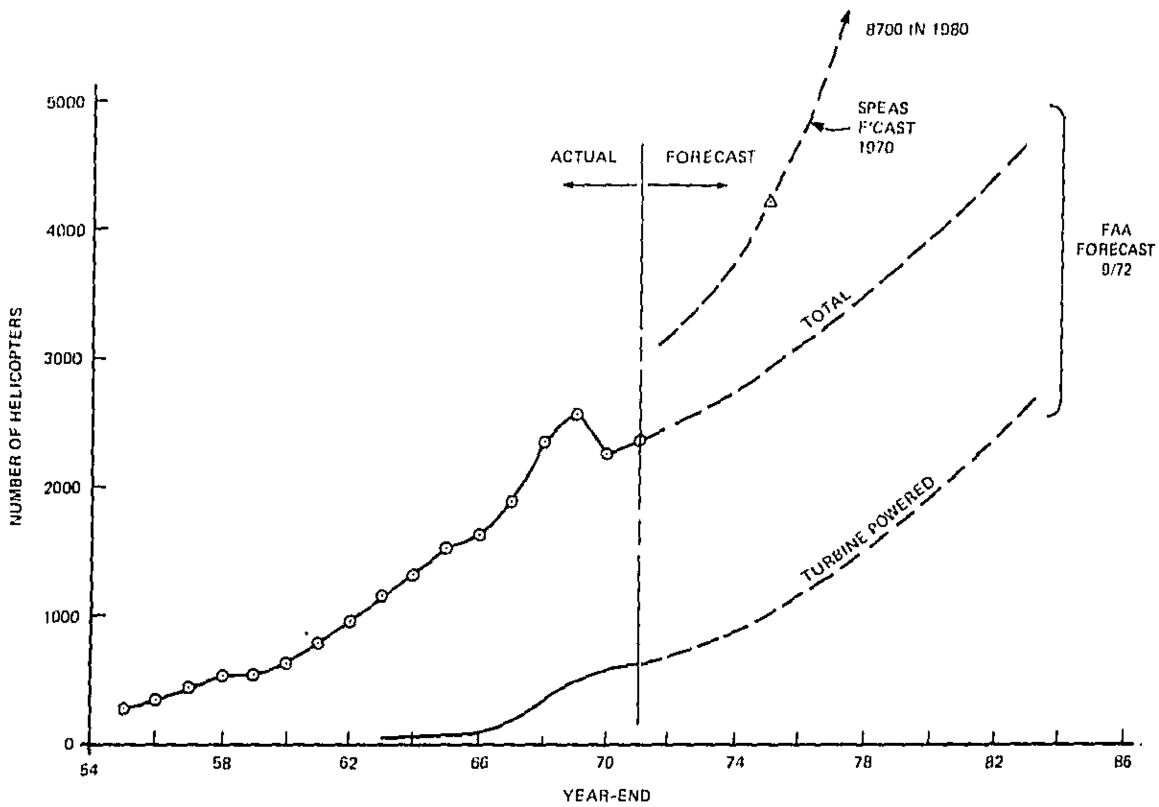


Figure 1-20. U.S. Civil Helicopter Fleet Size

SECTION 2

CURRENT TECHNOLOGY OPTIONS

The present state-of-the-art in aircraft technology can provide several alternatives for modifying the current civil jet aircraft fleet, in order to further reduce the community impact of aircraft-generated noise.

The development of improved light-weight, low-cost, efficient sound absorption materials provides the potential for relatively simple nacelle and engine acoustical treatment.

The demonstrated noise reductions achieved with advanced technology high bypass fans has led to the possibility of modifying the low bypass fan engines that are predominant in the air carrier fleet today with a higher bypass capability.

Replacement of the engines in current aircraft, or even replacement of the aircraft itself, with available improved technology systems is also being considered.

It is probable that no single alternative represents a noise panacea. An optimum course of action will undoubtedly be represented by some combination of these options.

JET ENGINE NACELLE RETROFIT

JT3D and JT8D ENGINES

In May 1967, NASA contracted with the McDonnell Douglas Corporation and the Boeing Company to investigate nacelle noise control modifications for operational Douglas and Boeing transports powered by JT3D turbofan engines. The NASA program successfully demonstrated by flight tests in 1969, conceptual feasibility of nacelle modifications for controlling both approach and takeoff noise of JT3D propelled aircraft.

In June 1971 the FAA initiated a nacelle noise control project directed to retrofit of the current fleet of narrow body aircraft. This project extended the NASA program to include research and development of takeoff and approach noise control for both JT3D and JT8D propelled aircraft. The purpose of this project is to provide test data to assist in determining whether certain classes of turbofan propelled airplanes in the current fleet can be modified for meaningful noise reduction in a feasible manner. Feasibility relates to three key instructions contained in Public Law 92-574; that is, the noise abatement methods must be technologically practicable, economically reasonable, and appropriate for the particular type of aircraft, aircraft engine, appliance, or certificate to which it will apply. The effort is directed to providing acoustical treatment, designed to conform to specified noise reduction goals, that is flight worthy, flight weight, and capable of being certificated. The acoustical treatment may be any hardware or mechanical device, applied, either singly or combined, to the inlet and primary and secondary exhausts that will either absorb sound or otherwise effect a noise reduction at the FAR 36 measurement positions.

The project is being implemented by means of three separate contracts with appropriate airframe manufacturers. The first is with Boeing Wichita on 707 aircraft, the second with Boeing Seattle on 727 and 737 aircraft, and the third with Douglas on DC-9 aircraft. In addition, all three prime contractors have subcontracts with Pratt and Whitney on engine compatibility testing; Boeing Wichita has a subcontract with Douglas on 707/DC-8 nacelle generality studies; and Douglas has a subcontract with Rohr on fabrication and ground testing of DC-9 nacelles. The FAA, therefore, has most aspects of nacelle retrofit feasibility investigations for JT3D and JT8D aircraft covered by the airframe, engine, and nacelle manufacturers most involved with the narrow-bodied civil aircraft fleet.

The FAA has established a task force to direct and monitor the progress of the retrofit feasibility contracts. The task force consists of representatives from the research and development, regulatory, and airworthiness services of the FAA. It is most important that the latter area be thoroughly covered to insure that a judgment of the feasibility of noise abatement retrofit modifications is based upon production hardware and commercial operations that will not compromise safety in any way.

The progress of the FAA nacelle retrofit project has been excellent. The first contract was initiated in June 1971 and the last one is scheduled for completion in December 1973, a total span of only two and one half years. The work includes ground testing of JT3D and JT8D production and modified nacelles and flight testing of 707, 727, and DC-9 aircraft installed with both production and modified nacelles. It is anticipated that all models of JT3D and JT8D propelled aircraft can be analyzed for modified nacelle noise and propulsion performance and installation cost based upon the results of the nacelle retrofit project.

The results of the FAA nacelle retrofit project will produce noise, performance, and cost data for one or more nacelle retrofit options for each of the 707, DC-8, 727, 737, and DC-9 type aircraft. That is, the entire narrow bodied fleet of JT3D and JT8D propelled aircraft will have at least one option to be considered for retrofit application. The options with the minimum complexity and least cost are those that will enable the aircraft to conform to the specified noise levels of FAR Part 36. The effects of the minimum options will result in a significant reduction in airport community noise exposure, particularly for approach operations.

The nacelle options with the maximum complexity, those denoted in the contractual requirements as the upper goal configurations, have the capability of decreasing the noise to levels considerably below the requirements of FAR Part 36, and represent the maximum state-of-the-art for nacelle retrofit. The minimum retrofit options have a negligible effect on aircraft performance and, if implemented, would insure that the older narrow bodied commercial aircraft would comply with the FAR Part 36, Appendix C, noise criteria, as do the newer wide bodied aircraft, with no appreciable degradation in range, field length requirements, and direct operating costs. However, the maximum retrofit options, in addition to costing more per shipset, would introduce substantial degradation in performance, but all of these performance losses are not necessarily irrevocable. Uprating the airframe for loading and the engine for thrust (e.g., JT8D-9 to JT8D-15) will increase the range and reduce the required field length to values approaching those of the baseline production version.

The noise reduction expected to be realized at the FAR 36 measuring points by nacelle modifications are shown in Figures 2-1 through 2-3 (8.2-72 and 8.3-120).* The nacelle options with the minimum complexity contain sound absorption material (SAM) only, and the options with the maximum complexity contain both SAM and some sort of jet noise reducer (JNR). The nacelle retrofit options for SAM have been completed for the 737 and 727 aircraft and the values shown in the Figures are FAR 36 certificated levels for these aircraft. In addition, the nacelle retrofit option for

*Although additional inputs have recently been received from various sources (3.6-411, 3.7-412, 3.10-450, and 3.9-408), the data contained therein indicated inconsistencies, therefore Figures 2-1 through 2-3 have not been modified. The values in the figures, however, are representative of the noise levels of the indicated aircraft types, whereas the inconsistencies in the data can be attributed, at least in part, to variations in specific aircraft models, engine models, power settings, flap settings, etc.

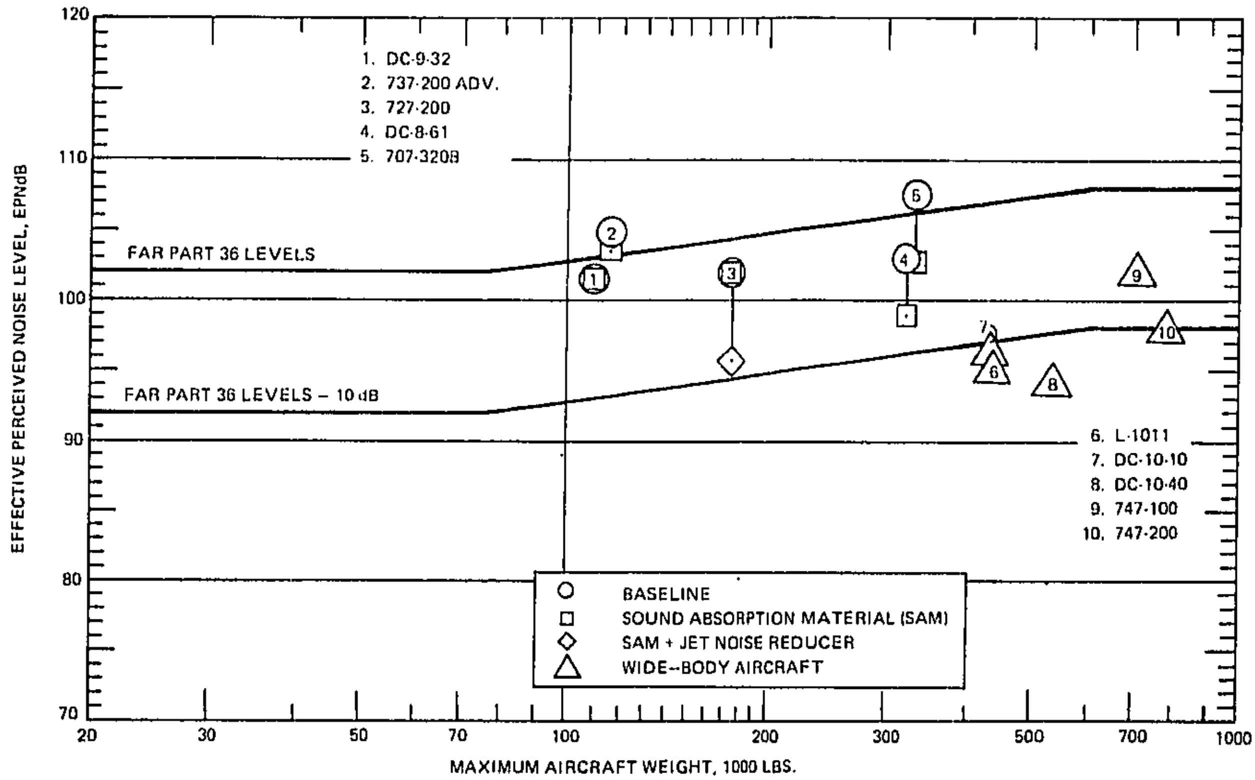


Figure 2-1. Current and Estimated Nacelle Retrofit Noise Levels - Sideline

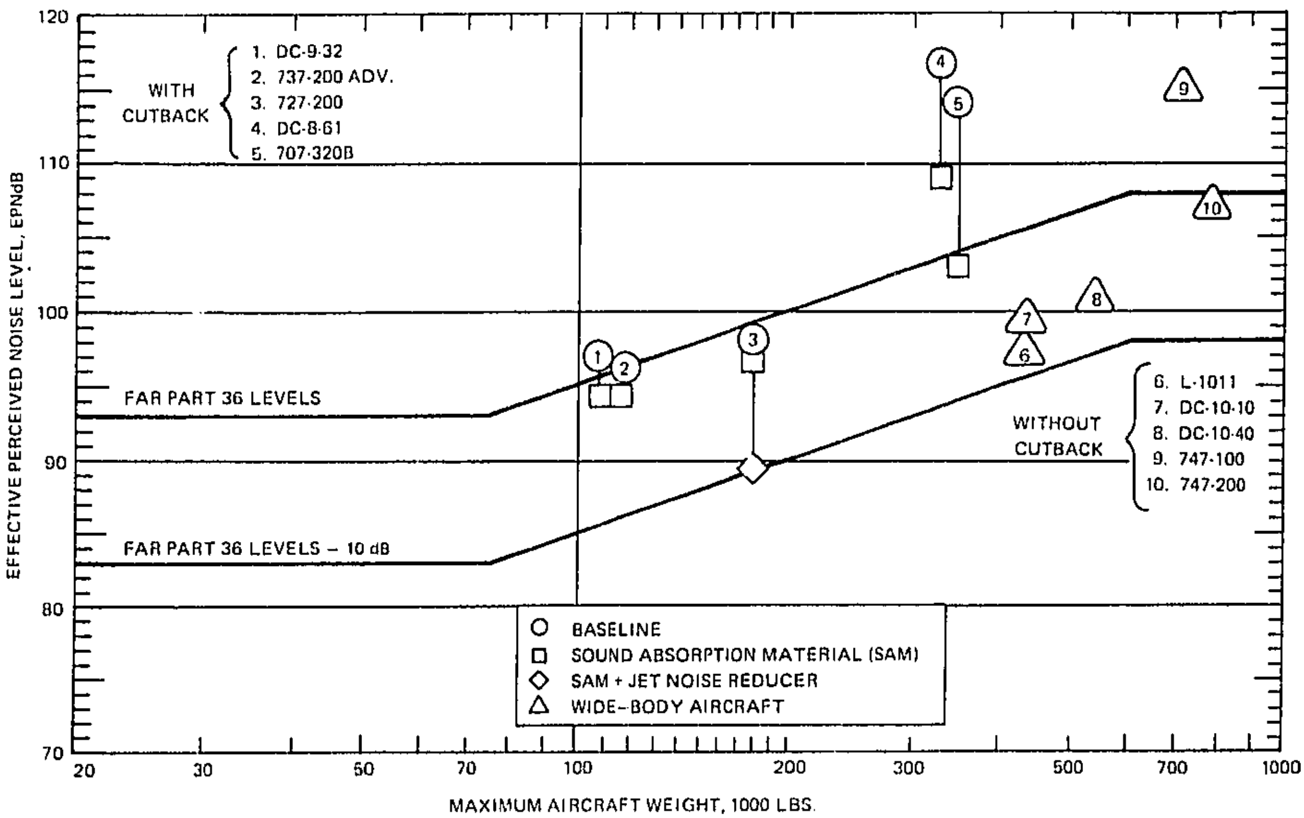


Figure 2-2. Current and Estimated Nacelle Retrofit Noise Levels – Takeoff

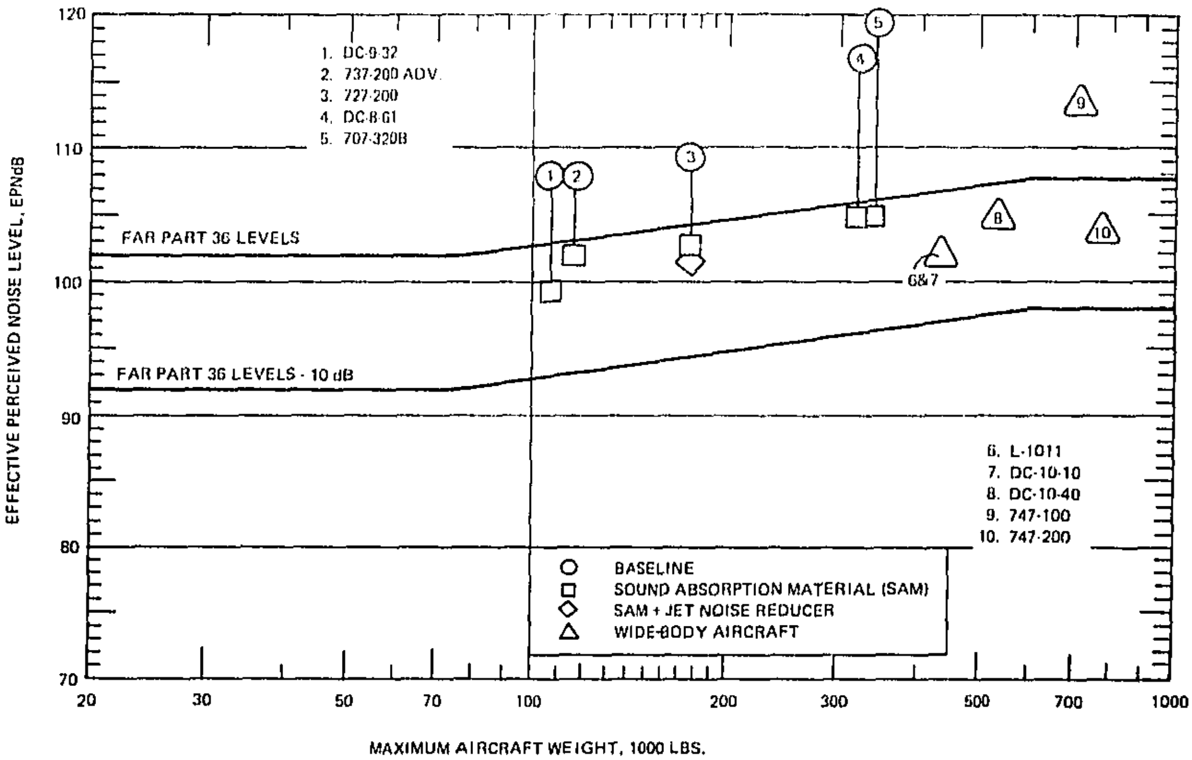


Figure 2-3. Current and Estimated Nacelle Retrofit Noise Levels - Approach

SAM + JNR has been completed for the 727 aircraft and the levels shown were measured in accordance with FAR Part 36. The levels shown for the DC-9 are measured values reported by the manufacturer and those for the DC-8 and 707 are the manufacturers' estimates. Both the DC-9 and 707 eventually will have SAM + JNR treatment, but the estimates are not sufficiently firm at this time to include them in the Figures.

It is interesting to note that retrofit of the narrow-bodied aircraft with SAM results in FAR 36 noise levels comparable to those of the wide-bodied aircraft. Futhermore, all SAM retrofit aircraft meet or exceed the Appendix C noise-level requirements of FAR Part 36, except for the DC-8-61 at the takeoff point. The FAA prototype nacelle on the 707-320B achieved approximately 11 EPNdB noise reduction as shown in Figure 2-2. An 8 EPNdB noise reduction is depicted in Figure 2-2 for the SAM treatment on the DC-8-61 aircraft. To continue investigations of SAM retrofit, the FAA has funded McDonnell Douglas, through a subcontract with Boeing Wichita, to study the problems associated with installing the Boeing nacelle on short- and long-duct versions of turbofan-powered DC-8 aircraft.

Examples of typical SAM treatment for JT8D and JT3D engine aircraft are shown in Figure 2-4 and 2-5. For 727 aircraft, the treatment is minimal; the noise reduction benefits are negligible for sideline and takeoff but significant on approach, and the costs and performance losses are so modest that it is unreasonable not to include such treatment on all new aircraft. For 707 aircraft, the treatment is much more extensive; the noise reduction benefits are substantial at all three measuring positions but especially dominant at approach, the performance losses are very small, and the costs are significant but not necessarily unreasonable from a cost effectiveness viewpoint.

Figure 2-6 illustrates the SAM + JNR treatment for 727 aircraft. It is clear that this is a complex system that enables nacelle retrofit to accomplish substantial noise reduction for sideline and takeoff with negligible reduction at approach beyond that accomplished by SAM alone. The performance losses and costs are large if the treatment is applied to an existing aircraft type. However, performance recovering techniques (upgrading the engine and airframe) can overcome much of the loss but at considerable increase in cost. The SAM + JNR treatment is a noise abatement retrofit option that results in substantial benefits, is capable of being certificated for airworthiness, but does not appear to be viable because of the large cost and performance

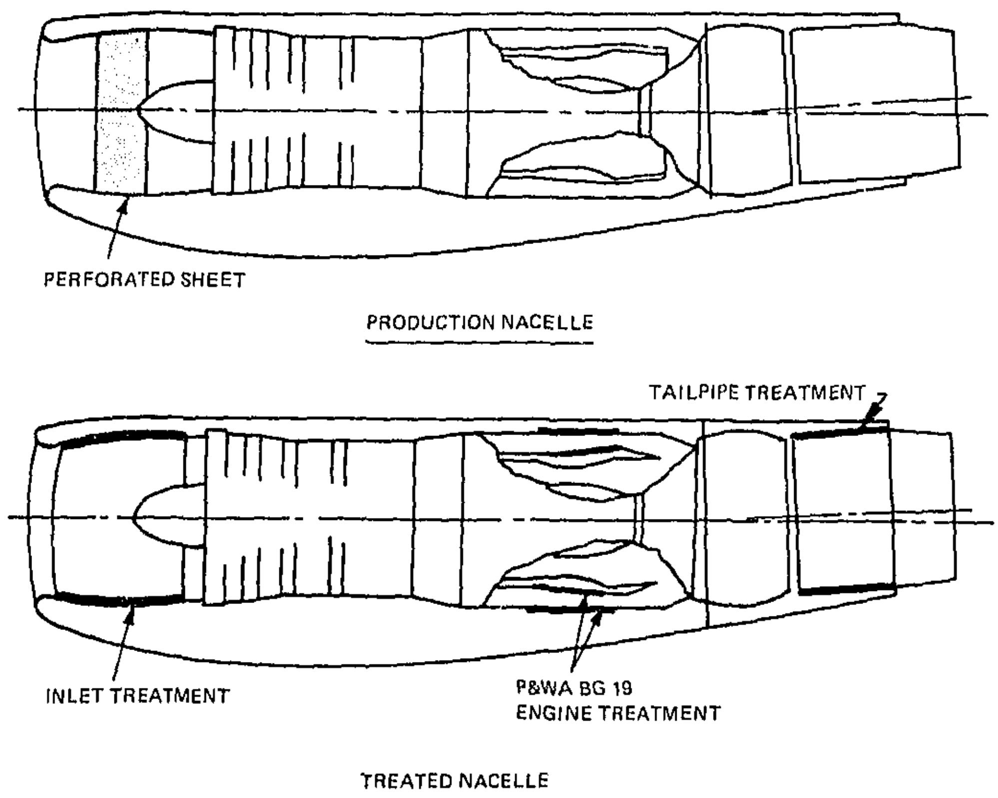


Figure 2-4. 727 Nacelle Retrofit Lower Goal (SAM) Configuration

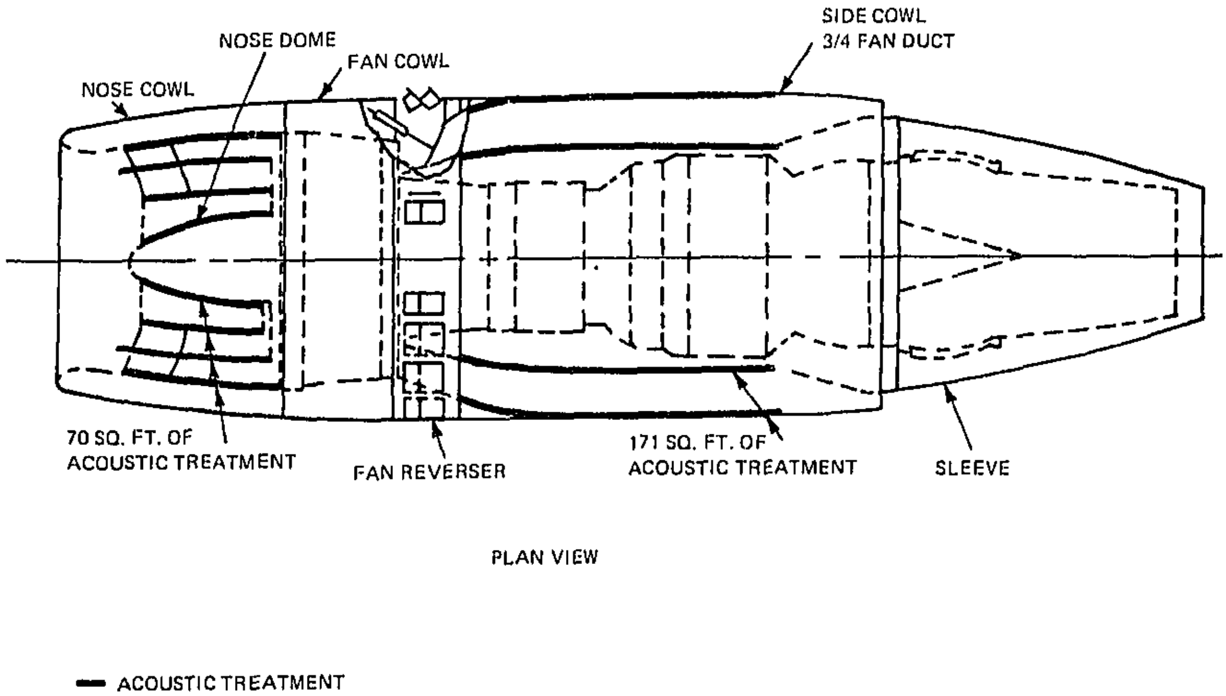


Figure 2-5. 707 Nacelle Retrofit Lower Goal (SAM) Configuration

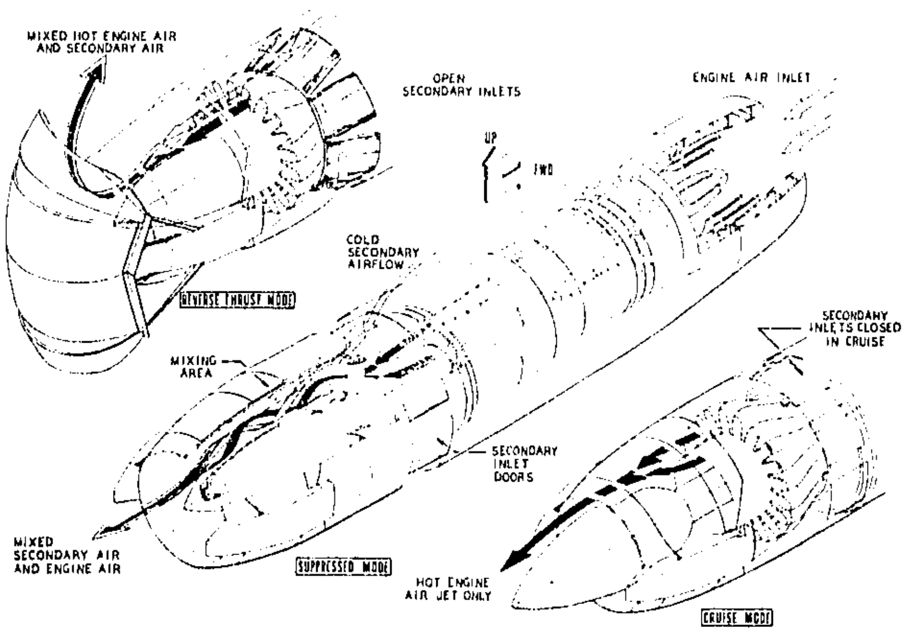


Figure 2-6. 727 Nacelle Retrofit Upper Goal
(SAM + JNR) Configuration

degradation. Nevertheless, it is available if the need arises and does represent the maximum state of the art of nacelle noise abatement retrofit. Noise reduction retrofit beyond what can be achieved by SAM alone, probably can best be accomplished by engine modifications; i.e., refan.

In summary, the FAA retrofit feasibility project presents a number of nacelle retrofit options for consideration in reducing the noise level of the narrow bodied civil aircraft fleet. These options must be carefully considered with respect to installation cost, operating cost, and cost of alternatives. The alternatives include any possible future options such as the new front fan, fleet replacement, as well as the option of doing nothing and accepting such public initiated local airport regulations as night curfews, aircraft type restrictions (power plant, number of engines, gross weight, etc.) preferential runway usage, and restrictions on the expansion of existing airports and the development of new airports.

OTHER AIR CARRIER ENGINES

The JT3D and JT8D engines power two thirds of the current air carrier fleet. Of the remainder, approximately 20 percent are powered by reciprocating engines and turboprops which are not being considered for nacelle retrofit. The pure jet 707, DC-8 and 880 (approximately 150 aircraft) are scheduled to be retired from the fleet by the end of the decade and no consideration is being given to the development of retrofit kits for these aircraft. The BAC 111 and the 747's delivered prior to December 1971 are expected to remain in the fleet well into the 1980's; therefore, potential nacelle retrofit options for these aircraft are discussed below.

British Aircraft Corporation, BAC 111

The BAC 111 is powered by the low bypass Rolls Royce (RR) Spey engine. As indicated in Figures 1-3 through 5, these aircraft currently do not meet the FAR 36 noise standards. A joint program between BAC and RR has been initiated to develop retrofit kits for the BAC 111 enabling the aircraft to meet the FAR 36 standard (with tradeoff). The kit includes a six-chute suppressor nozzle, an acoustically lined 40-inch jet pipe extension, acoustically lined bypass duct and intake. A development kit will be flight tested early in 1974 with production kits planned for early 1976 availability. The delta weight of the kit is approximately 418 lb. with an estimated performance penalty of 1 percent loss in T.O. thrust and 3.3 percent increase in SFC.

Boeing 747

Early models of the 747-100 (delivered prior to December, 1971) were not subject to the FAR 36 Appendix C noise requirements. Later models of the 747 have been certificated to these requirements (See Figures 1-3 through 5). A joint Boeing/P&W noise reduction program is currently underway to determine the potential for further noise reduction for the early 747's as well as for future growth versions. Initial test results indicate additional inlet noise reduction is possible with the addition of splitter rings. Current research effort on improved acoustic materials, providing higher effectiveness at reduced weight, is a potential option for future engine growth programs. (Ref 3.1-1)

McDonnell Douglas (DC-10) and Lockheed (L 1011)

All models of these aircraft have been certificated well below the requirements of FAR 36. However, similar R&D activity, as indicated above, has been initiated for these aircraft which will also provide the potential for noise reductions for future growth engine programs.

GENERAL AVIATION JET ENGINES

Approximately 20 percent of the aircraft in the general aviation jet fleet (represented by two aircraft — the Falcon 20 and the Cessna Citation) are powered by moderate bypass turbofan engines and have been certificated in accordance with the FAR 36 requirements. The remaining 80 percent are powered by turbojet or very low bypass turbofan engines (with noise characteristics similar to that of the turbojet).

The Gulfstream II, the largest aircraft in this class, utilizes a version of the Spey engine having a bypass ratio of 0.64. The takeoff and sideline noise levels are in excess of the FAR 36 standards (Figure 1-7). Grumman, in concert with Rolls Royce, has defined a program to develop a noise suppression kit for the Gulfstream II aircraft, utilizing hardware developed by RR for the F 28 and BAC 111 aircraft, which is expected to meet the FAR 36 requirement. A prototype flight test is scheduled for the last quarter of 1973 with a certification flight test approximately 1 year later. Production kits could be available by mid-1975. Acoustic linings are not included in the program at this time but are being considered as backup, if necessary.

The rest of the aircraft in the fleet are powered by small (3000 to 3500 lb. thrust) turbojet engines that are extremely compact engines.

Since small engines are less tolerant of disturbances to the basic cycle, small size in itself can be a problem with regards to the application of sound absorption materials (SAM) in the engine nacelle. Since this type of acoustic treatment is concerned only with the audible frequencies, and since turbomachinery, combustion noise, fan multiple pure tones, etc., fall generally into the same frequency ranges regardless of engine size, SAM treatments fabricated of resonator cavity type materials will not vary substantially in thickness from one engine to another. As a result, the weight and costs associated with small engine SAM treatments will undoubtedly represent a larger share of the total propulsion system installation than those for large engines. Further, a higher overall penalty to airplane performance will result, not only due to the extra weight but also to the increased nacelle drag and engine inlet blockage.

For those aircraft that are marginally shy of meeting the FAR 36 standards (Learjet, for example) a modified exhaust nozzle may be all that is necessary to meet the current standard. Such a program is being investigated at this time with the potential to certify the Learjet to the FAR 36 noise requirement with a redesigned exhaust nozzle.

A noise suppression kit has been developed for the BH125-600 aircraft. Development flight test is scheduled for June 1973, with the objective of meeting the noise requirements of FAR 36 by July 1974 for new production aircraft.

For the Jetstar, Sabreliner and Commodore, the performance penalties associated with the amount of acoustical nacelle treatment that would be required to enable these aircraft to meet the FAR 36 noise standards may deteriorate their operational effectiveness to an intolerable level. There are, however, other options available to these aircraft. (See Page 2-27.)

ENGINE REFAN RETROFIT

BACKGROUND AND PROGRAM STATUS

This noise source control option is significantly different than those previously discussed in this chapter inasmuch as it involves modification and replacement of certain engine, as well as nacelle, components. The most significant, but not the only, engine component to be replaced is the bypass fan; thus the program is referred to as "refan".

The refan program, as established under NASA sponsorship in August, 1972, benefits from, and is based upon, both engine and noise technology developed since 1968. At that time, when it became apparent that efficient and effective jet noise reduction could be achieved best through reduction of the primary jet exit velocity, the Pratt and Whitney Aircraft Division (P&WA) began their studies on the JT3D engine. Variations of this basic engine are used on the Boeing 707 and the McDonnell Douglas DC-8 series of aircraft. This engine, as opposed to the JT8D, was investigated first as it was the more conservative design and therefore had the greater possibility of doing additional work which is fundamental to the refanning concept.

Early parametric studies of potential single-stage and two-stage fans showed that the refan requirements could be satisfied by either two-stage fans of moderately larger diameter or single-stage fans with a greater increase in diameter. The initial engine studies resulted in the JT3D Configuration III, which was studied by the two aircraft manufacturers as part of the IIT Research Institute (IITRI) Study in 1969. This configuration had a larger diameter two-stage fan, which increased the engine length and installed weight. Although this engine provided a moderate reduction in jet noise, there was no improvement in performance and it was not considered an acceptable configuration at that time. Study of the refanning of the JT3D engine continued with internal funding on an intermittent basis until 1972. During the period 1968 to 1972, P&WA studied 10 possible configurations of this engine. The direct studies also benefitted from the P&WA JT9D engine (powerplant for the Boeing 747 aircraft) development as well as an FAA sponsored study of low, medium, and high, fan tip speed noise characteristics. The ninth configuration of the JT3D studied by P&WA had an increased diameter single-stage fan and no inlet guide vanes. This configuration formed the basis for the NASA sponsored refan program when proposed.

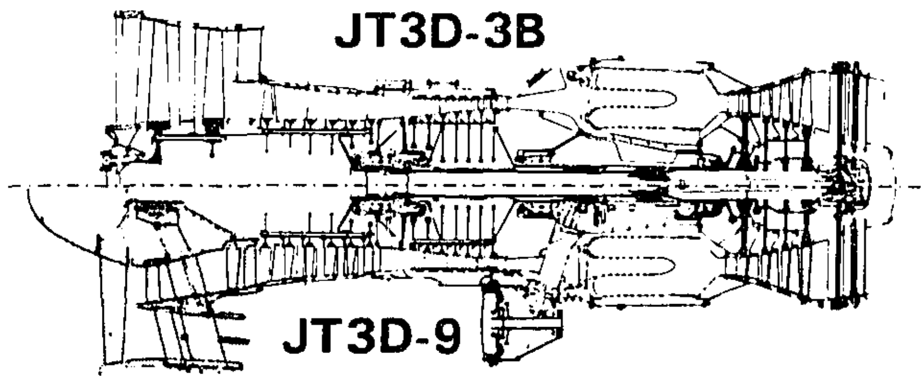
Prior to initiation of the NASA program, it was determined that, with modification, the JT8D could also be refanned. This engine is used on the various models of the Boeing 727 and 737 and the McDonnell Douglas DC-9 aircraft. Within the initial scope and funding of the NASA refan Program (Reference 11.1-186), Phase I contracts were let for design and analysis of the engine and nacelle modifications with three major contractors: Pratt and Whitney Aircraft, a Division of United Aircraft Corporation; The Boeing Company; and the Douglas Aircraft Company, a Division of McDonnell Douglas Corporation. Small contracts were also let with American Airlines and United Airlines for consulting work to assure that the modifications being considered incorporated as many requirements of the user airlines as possible.

In January, 1973, program funding curtailment forced limiting the scope of the program to only one engine type. The joint NASA/DOT/FAA decision was to proceed with the JT8D rather than the JT3D. The basic reason given for this choice was that the JT8D-powered aircraft will have a larger impact on the aircraft noise exposure in the 1980's.

As of this writing, the program to develop a refan kit for the JT3D powered aircraft is not being actively pursued. As far as can be determined, the technical/engineering approach is sound and of low risk, the economic reasonableness/unreasonableness has not been developed, and the ground and flight test to demonstrate flight worthiness and safety will not be performed. The refanned engine design had been designated the JT3D-9. The significant differences between this engine and the JT3D-3B, from which it was derived are shown in Figure 2-7. A similar comparison of the refanned JT8D-9, currently designated as the JT8D-109, is shown in Figure 2-8.

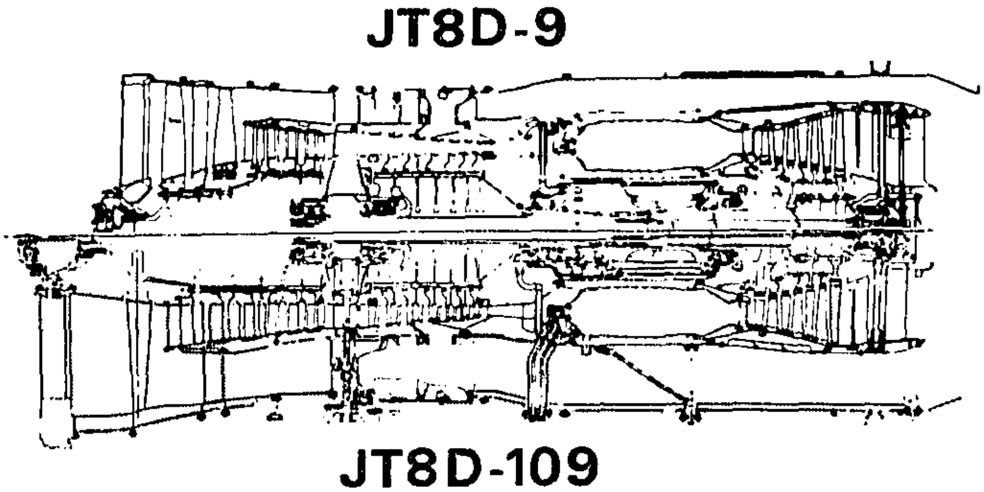
GENERAL TECHNICAL APPROACH AND OBJECTIVES

As briefly mentioned earlier, the concept of refanning requires starting with an engine that was conservatively designed in order to extract additional work. This is further explained by P&WA in Reference (2.1-74), "to lower the primary jet noise by reducing the primary jet velocity without losing thrust requires that more of the primary engine's gas stream energy be converted into the low velocity bypass fan stream," (as shown in Figure 2-9). "This conversion can be accomplished by either increasing the fan pressure ratio, or the bypass flow or by increasing both. Increasing the bypass airflow is the more desirable route because it also provides increased total engine thrust and reduced fuel consumption. This route is feasible since both the JT3D and JT8D low pressure turbines have the capability of doing more work to absorb more primary gas stream energy. Furthermore, the gains in fan design technology since the initial design of these engines support the feasibility of new fans that would absorb the additional low turbine work."



JT3D-9 RELATIVE TO JT3D-3B	
DIAMETER (FLOW PATH)	+ 6.4 INCHES
LENGTH	+ 0.7 INCHES
WEIGHT	+ 400 POUNDS

Figure 2-7. JT3D-3B/JT3D-9 Comparison (Reference 2.1-74)



JT8D-109 RELATIVE TO JT8D-9	
DIAMETER	+ 12 INCHES
LENGTH	+ 14.17 INCHES
WEIGHT	+ 562 POUNDS

Figure 2-8. JT8D-9/109 Comparison (Reference 2.1-74)

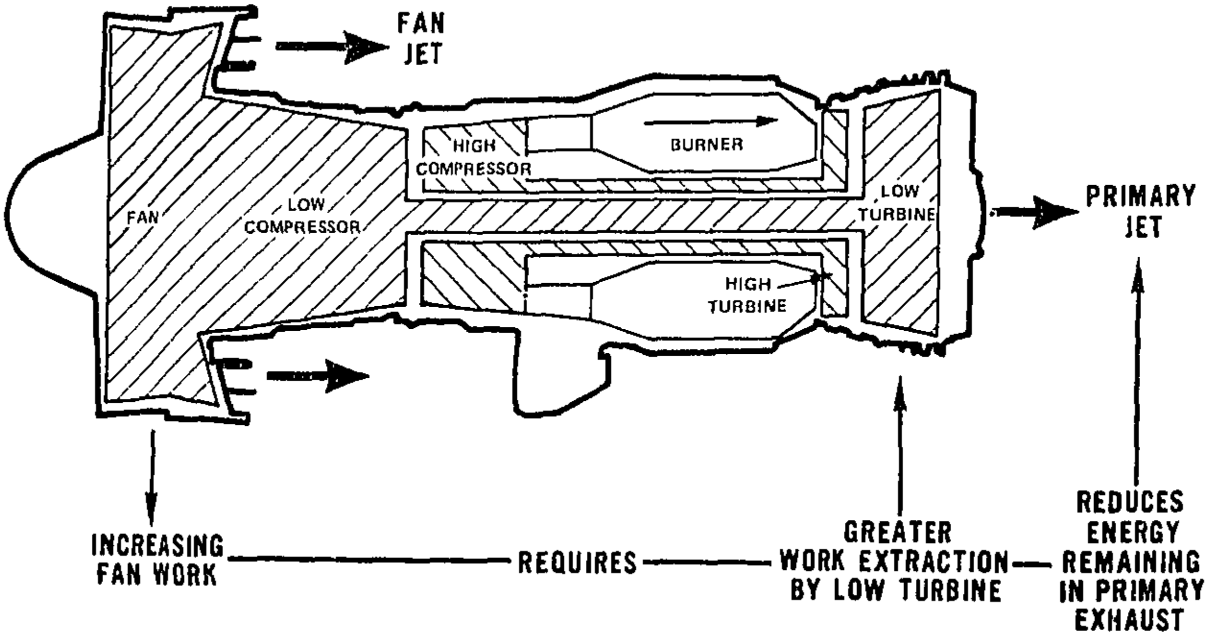


Figure 2-9. Core Jet Noise Reduction (Reference 2.1-74)

While refanning is primarily directed toward reducing the primary jet noise, redesign details, such as number of stages, spacing between the rotating and stationary elements, numbers of rotor blades, and stator vanes, are also studied in order to minimize the turbomachinery noise portion of the spectrum. After this has been accomplished, nacelle modification and treatment with sound absorbing material is added in order to further reduce the noise levels.

The refan Program, as sponsored by the NASA, takes the above described multi-faceted approach to engine and nacelle retrofitting with the following program objectives"... through development of retrofit kits (demonstrate) that the noise produced by narrow-body fleet can be reduced to 5 to 10 EPNdB below FAR-36, while retaining demonstrated engine reliability and maintainability, causing no degrading of aircraft performance or safety and could be accomplished at an acceptable fleet retrofit cost."

ESTIMATED RESULTS; NOISE REDUCTION

The NASA and the two aircraft manufacturers, Boeing and Douglas, have made estimates of the noise levels associated with each of the various aircraft considered to be possible candidates for a refan retrofit. In every case, the estimated noise levels are those for the FAR Part 36 positions and conditions with the aircraft powered by the refanned engine. In some cases, estimated noise levels for more than one nacelle treatment or configuration were developed and reported. A compilation of the estimates from reports* available to the task group is provided in Tables 2-1 and 2. These estimates and those being used in the DOT aircraft retrofit cost effectiveness analysis, (Reference 8.5-355), have been combined to provide a range of estimated noise levels for the five most representative aircraft. The estimates and noise levels normally associated with the baseline aircraft are shown for comparison in

*Figures 2-10 through 2-12 and Tables 2-1 through 2-4 are based on data provided in the references cited in the tables. More recent information (References 3.6-411, 3.7-412, 3.10-456, 2.4-454 and 11.2-398) indicate small differences in acoustic data from those listed in the tables and provided in the figures, as well as some variability of data between the submitting sources. However, the data presented in the figures and tables are considered representative of the noise trends for the refan program. Firmer noise performance figures will be established as the program progresses into ground and flight tests.

AIRCRAFT TYPE AND SERIES	NUMBER OF ACFT IN 1973 FLEET (REF. 2.1.67) U.S.	WORLD	SOURCE OF DATA	DEGREE OF TREATMENT	NOISE LEVELS IN EPNdB SIDELINE BASE-LINE	SIDELINE FAR PART36	SIDELINE REFAN ACFT	TAKEOFF BASE-LINE	TAKEOFF FAR PART36	TAKEOFF REFAN ACFT	TAKEOFF W/CUTBACK BASE-LINE	TAKEOFF W/CUTBACK FAR PART36	TAKEOFF W/CUTBACK REFAN ACFT	APPROACH BASE-LINE	APPROACH FAR PART36	APPROACH REFAN ACFT	DATA REFERENCE
DC 8 61	65	87	NASA	*	103	105.6	94	–	–		117	103.5	95	117	105.5	98	11.1-186
			McD D	Maximum	103	106.2	93	116	103.6	102	116	103.6	98	117	106.2	96	3.4-135
				Intermediate			96			107			102			100	
				Minimum			96			107			103			104	
DC-8-64F	24	51	McD D	Intermediate	104	106.1	97	-	103.4	106	115	103.4	101	118	106.1	100	3.4-135
DC 8 51	40	65	McD-D	Intermediate	104	105.8	97	110	102.4	102	109	102.4	95	117	105.8	99	3.4-135
DC-8-62	17	64	McD-D	Maximum	103	106.3	95	113	103.8	102	112	103.8	97	114	106.3	95	3.4-135
DC-8 63	47	102	McD-D	Maximum	102	106.4	93	115	104.1	103	114	104.1	98	114	106.4	96	3.4-135
				Minimum			95			104			101			100	
707-320B/C	242	437	NASA	*	107.5	106.5	94	–	–	–	113	104.0	95	110.5	106.5	98	11.1-186
			Boeing	Maximum			91.9	115.0	104.0	99.5	114	104.0	94.8	120.5	106.5	102.2	3.3-123
				Intermediate			92.1			99.7			95.1			103.0	
				Minimum			92.7			100.6			96.6			107.6	
707-120B	103	111	Boeing	Intermediate	107.5	–	–	110.0	–	–	108	–	–	118	–	–	3.3-123
720B	59	93	Boeing	Intermediate	107.5	–	–	108.5	–	–	105.5	–	–	117.5	–	–	3.3-123
ΣJT3D Powered ACFT	603	1040															

NOTE: DIFFERENT DEGREES OF TREATMENT ARE NOT PHYSICALLY THE SAME FROM TYPE-TO-TYPE AND MAY NOT BE THE SAME FROM SERIES TO SERIES WITHIN A TYPE.

* NOT SPECIFIED

TABLE 2-1: ESTIMATED NOISE LEVELS FOR JT3D-9 (REFANNED) POWERED AIRCRAFT

AIRCRAFT TYPE AND SERIES	NUMBER OF ACFT IN 1973 FLEET (REF. 2.1-67) U.S.	WORLD	SOURCE OF DATA	DEGREE OF TREATMENT	SIDELINE BASE-LINE	SIDELINE FAR PART36	SIDELINE REFAN ACFT	TAKEOFF BASE-LINE	TAKEOFF FAR PART36	TAKEOFF REFAN ACFT	TAKEOFF W/CUTBACK BASE-LINE	TAKEOFF W/CUTBACK FAR PART36	TAKEOFF W/CUTBACK REFAN ACFT	APPROACH BASE-LINE	APPROACH FAR PART36	APPROACH REFAN ACFT	DATA REFERENCE
NOISE LEVELS IN EPNdB																	
DC-9-30	286	479	NASA	*	101.5	103.5	92	--	--	--	97	96	84	108	103.5	95	11.1-186
DC-9-32			McD D	Maximum	107.0	103.1	92	103	95.6	92	97	96.6	88	108	103.1	97	3.4-136
↓			↓	Intermediate	↓	↓	93	↓	↓	91	↓	↓	87	↓	↓	100	↓
				Minimum			94			91			87			102	
DC-9-10	95	133															
DC-9-20	0	10															
DC-9-40	0	24															
727-200	264	332	NASA	*	102.0	104.5	92	--	--	--	102.0	100	88	109.5	104.5	96	11.1-180
			Boeing	Maximum	99.9	104.4	84.9	107.4	99.0	92.4	100.0	99.0	87.0	108.2	104.4	98.2	3.8-243
			↓	Intermediate	↓	↓	89.9	↓	↓	97.4	↓	↓	89.0	↓	↓	98.2	↓
				Minimum			90.9			97.4			89.0			100.2	
727-100	300	397															
727-100 C/QC	125	161															
737-200	168	248	NASA	*	104	103.6	92	–	--	–	96	96.5	84	108	103.5	95	11.1-186
			Boeing	*	101.1	103.5	92.5	–	–	–	96.7	96.5	85.5	108.9/ 110.9	103.5	100	3.1-1
737-200 C/QC	12	33															
737-100	0	29															
ΣJT8D Powered ACFT	1248	1846															

NOTE: DIFFERENT DEGREES OF TREATMENT ARE NOT PHYSICALLY THE SAME FROM TYPE-TO-TYPE AND MAY NOT BE THE SAME FROM SERIES-TO-SERIES WITHIN A TYPE.

* NOT SPECIFIED

TABLE 2-2: ESTIMATED NOISE LEVELS FOR JT8D-109 (REFANNED) POWERED AIRCRAFT

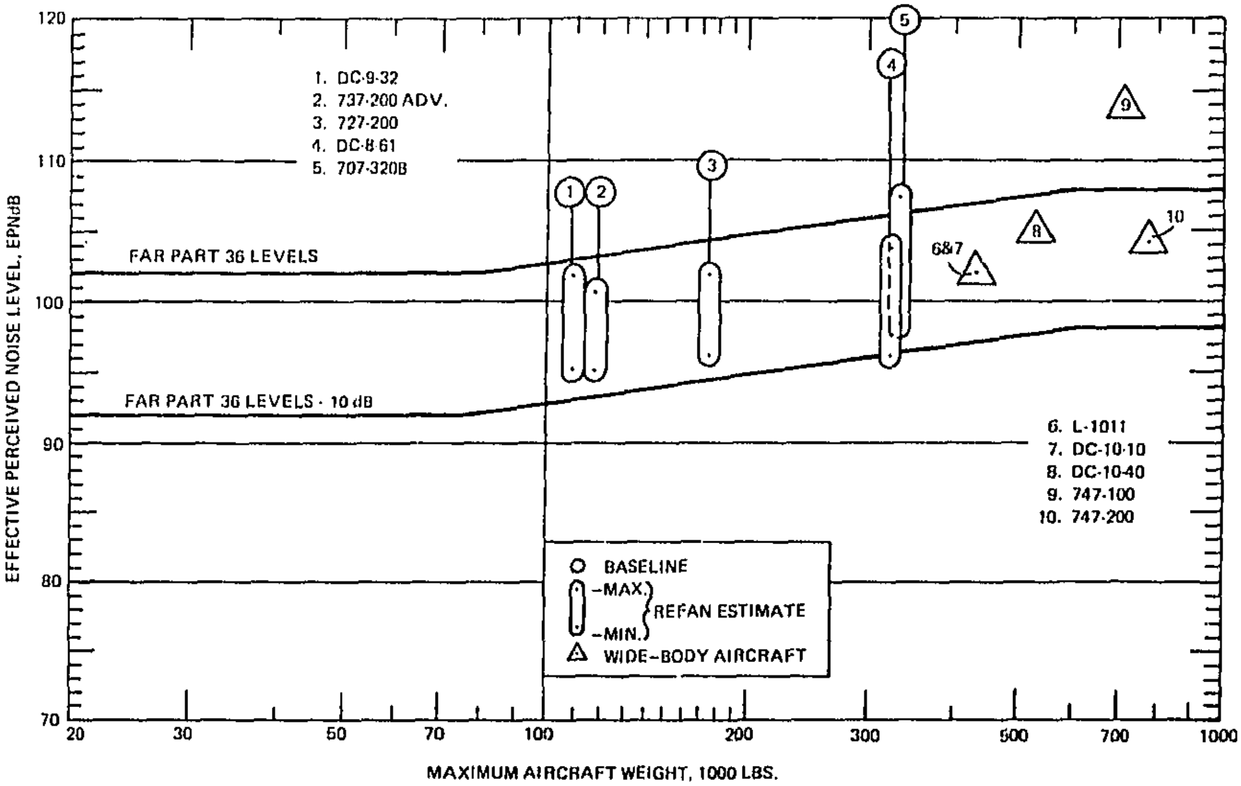


Figure 2-10. Current and Estimated Refan Retrofit Noise Levels - Approach

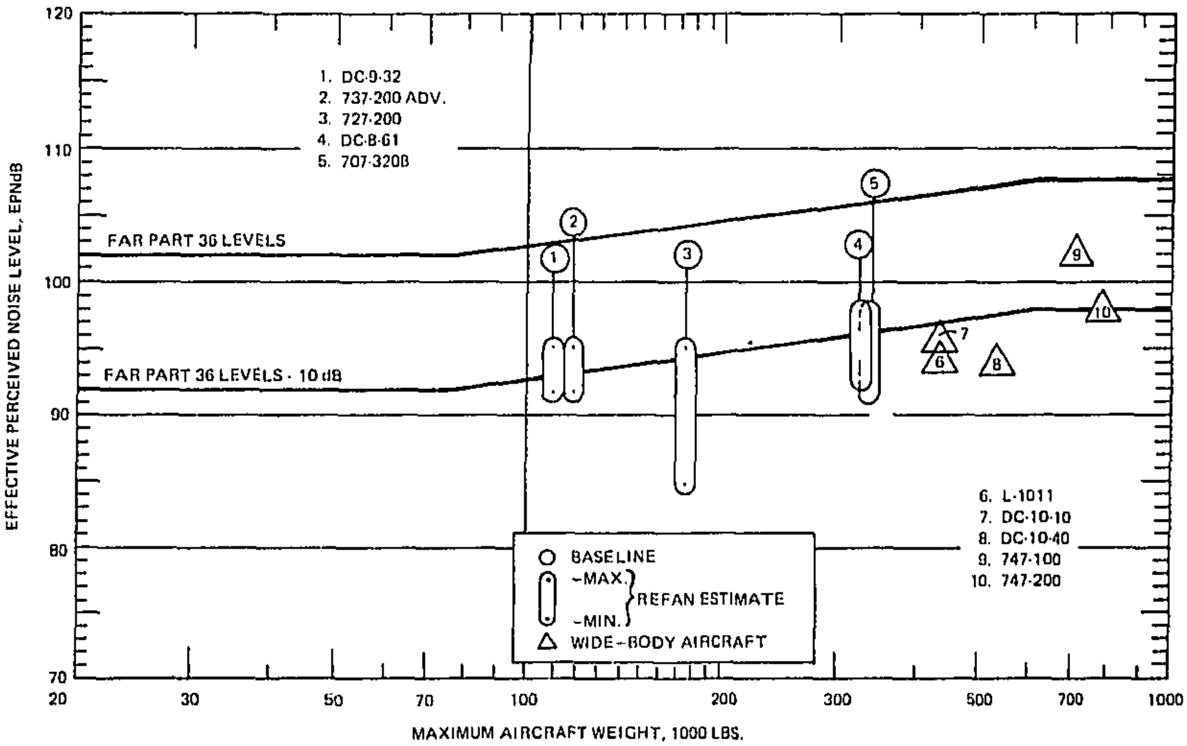


Figure 2-11. Current and Estimated Refan Retrofit Noise Levels - Sideline

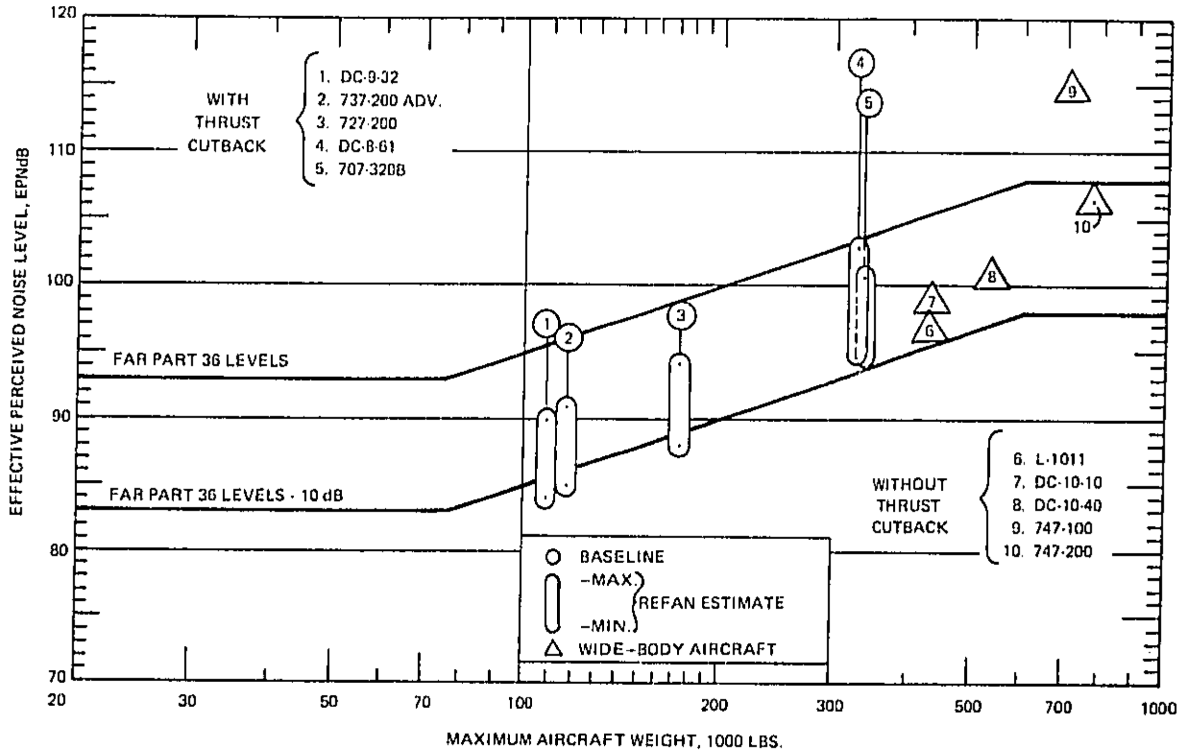


Figure 2-12. Current and Estimated Refan Retrofit Noise Levels - Takeoff

AIRCRAFT TYPE AND SERIES	NUMBER OF ACFT IN 1973 FLEET (REF 7.1.67) U.S.	WORLD	SOURCE OF DATA	DEGREE OF TREATMENT	BASELINE INST TAKEOFF THRUST (lbs.)	REFAN ΔF_n (%)	BASE LINE SFC_{CR} (lb/hr)/lb	REFAN ΔSFC (%)	B/L OPER. EMPTY WEIGHT (klb)	ΔOEW (%)	B/L MAX. TAXI WEIGHT (klb)	ΔMTW (%)	BASELINE FIELD LENGTH (ft)	ΔFL (%)	B/L RANGE (nm)	ΔR (%)	RECERT TAKEOFF WEIGHT (lb)	RECERT ΔR (%)	DATA REFERENCE
DC 8 [illegible]	65	87	McD D	* Maximum Intermediate Minimum	14,120	+4.8 +3.4 +5.8	0.947	-3.1 -1.6 -3.1	103.2	* +2.3 +2.0 +1.6	328.0	* +1.1 +1.0 +0.8	9,980	-0.8 -1.9 -2.9	* 3,500	* +0.3 -1.4 +1.1	* *	*	11.1-186 3.4-129
DC 8 54F	24	51	McD D	Intermediate	14,120	+3.4	0.947	-1.6	136.7	+2.5			9,300	-5.4	3,600	-3.0			3.4-129
DC 8 61	46	05	McD D	Intermediate	14,120	+3.4	0.947	-1.6	128.0	+2.5		*	7,200	-4.7	4,600	-1.2	*	*	3.4-129
DC 8 62	17	64	McD D	Maximum	13,875	+6.7	0.916	-0.7	143.6	+2.3			5,800	-7.2	5,700	-2.3		*	3.4-131
DC 8 63	47	102	McD D	Maximum Minimum	13,875	+6.7 +7.4	0.916	-0.2 -0.7	161.8	+2.1 +1.7	350.0	+1.0 +0.8	11,500	-2.1 -1.3	4,900	-4.1 -3.1		*	3.4-131
707-320B/C	247	437	NASA Boeing	* Maximum Intermediate Minimum	16,720	+8.8 +8.5 +8.6 +8.7	0.85	-3.2 -3.0 -4.4 -1.8	145.0 145.0	+2.7/-3.1 +2.7 +2.6 +1.5	336.0 336.0	0/+1.5 +1.1 +1.0 +0.6	11,350	-0.7/-5.6 -6.1 -7.0 -5.6	4,770	-2.9/0.0 -2.6 -3.6 -4.6	* 3,394 *	* * +2.7 *	11.1-186 3.3-123
707-120B	103	111	Boeing	Intermediate					131.0		258.0								3.3-125
720B	59	93	Boeing	Intermediate					122.0		230.0								3.3-123
ΣJT3D Powered ACFT	603	1040																	

NOTE DIFFERENT DEGREES OF TREATMENT ARE NOT PHYSICALLY THE SAME FROM TYPE TO TYPE AND MAY NOT BE THE SAME FROM SERIES TO SERIES WITHIN A TYPE

*NOT SPECIFIED

TABLE 2-3: ESTIMATED PERFORMANCE PARAMETERS FOR JT3D-9 (REFANNED) POWERED AIRCRAFT

AIRCRAFT TYPE AND SERIES	NUMBER OF ACFT IN 1973 FLEET (REF 2-157) U.S.	WORLD	SOURCE OF DATA	DEGREE OF TREATMENT	TAKEOFF THRUST (lbs)	REFAN ΔF_N (%)	BASE LINE CSFC (lb/hr/lb)	REFAN ΔCSFC (%)	B/L OPER EMPTY WEIGHT (klb)	ΔOEW (%)	B/L MAX. TAXI WEIGHT (%)	ΔMTW (%)	BASE LINE FIELD LENGTH (ft)	ΔFL (%)	BASE LINE RANGE (nm)	ΔR (%)	RECENT TAKEOFF WEIGHT (lb)	RECENT ΔR (%)	DATA REFERENCE
	286	479																	
DC-9-32			McD D	Maximum	12,200	-3.3	0.862	+7.7	58.59	+8.1	109.0	0	7,000	-1.4	1000/2000	-10.0/-16.0		-	3.4-138
				Intermediate	12,200	+1.3	0.862	+3.0	58.59	+6.2	109.0	0	7,000	-13.6	1000/2000	-5.0/-10.0		--	
↓			↓	Minimum	12,200	+6.7	0.862	1.0	58.59	+4.1	109.0	0	7,000	-17.0	1000/2000	0/-2.5		--	↓
DC-9-10	95	133																	
DC-9-20	0	10																	
DC-9-40	0	24																	
727-200	264	332	NASA	*	17,700	6.7/10.0	0.83	-1.4/-2.4	99.0	+2.0-4.1	*		8,370	-3.5/-8.4	1,355	/-20	-	0	11.1-186
			Boeing	Maximum		+5.4		-2.6		+4.9				-12.9	1,015	-7.9	182.5	+14.0	3.8-243
				Intermediate		+5.1		0		+4.5				-12.2		-9.8		+11.4	
			↓	Minimum	↓	+7.7	↓	-1.6	↓	+3.8			↓	-15.0	↓	4.0	↓	+14.0	↓
727-100	300	397																	
727-100C/QC	126	161																	
737-200	160	248	Boeing													-16.0	108.3	+3.1	3.1-1
737-200C/QC	12	33																	
737-100	0	29																	
ΣJT8D Powered ACFT	1248	1846																	

NOTE: DIFFERENT DEGREES OF TREATMENT ARE NOT PHYSICALLY THE SAME FROM TYPE TO TYPE AND MAY NOT BE THE SAME FROM SERIES TO SERIES WITHIN A TYPE

*NOT SPECIFIED

TABLE 2-4: ESTIMATED PERFORMANCE PARAMETERS FOR JT8D-109 (REFANNED) POWERED AIRCRAFT

Figures 2-10 through 12 for the approach, sideline and cutback takeoff operations, respectively. The range of estimates for a "refanned" aircraft includes all levels of nacelle treatments considered from all of the available sources.

ESTIMATED RESULTS; PERFORMANCE PARAMETERS

In conjunction with the noise levels, NASA and the two aircraft manufacturers have also made at least a preliminary assessment of the performance impact of various retrofits associated with refanning for the various aircraft. An attempt to collect and compile data indicative of the effect on various performance parameters has been made and these data are tabulated in Tables 2-3 and 2-4 for the JT3D and JT8D powered aircraft, respectively.

JET ENGINE REPLACEMENT

AIR CARRIER FLEET

Replacing the low bypass fan engines in the air carrier fleet (JT3D, JT8D, Spey MK 511) with characteristically quieter high bypass engines is not a viable current technology option. There are no engines available in the thrust classes required. The NASA Quiet Engine Program (discussed in Section 3) effectively demonstrated the capability for noise reduction in an experimental engine test program at thrust levels comparable to those of the JT3D and JT8D, but, the engine hardware that was utilized was not flightworthy nor was it intended to be.

However, even if a new engine development program were initiated to provide a quieter high-bypass fan engine, the option of replacing the current engines with a new engine would be prohibitive in cost particularly in view of the limited life that would be remaining in these aircraft. (Reference 7.1-25.) The modification program could not begin until late in the decade after the engine development and certification program was completed.

GENERAL AVIATION FLEET

There are currently several small turbofan engines that can be considered for possible retrofit in existing turbojet aircraft. One such program has already been announced, the replacement of the JT12 turbojet engines currently in the Jetstar with the moderate bypass Garrett 731 turbofan. It is estimated that not only will the noise level of the re-engined Jetstar comply with the FAR 36 requirements but the range/payload characteristics will be significantly enhanced.

The Learjet has been test flown with the Garrett 731 engine, providing still another retrofit option possibility. The General Aviation Division, Rockwell Corp. is proceeding with the development of a turbofan-powered Sabreliner with the CF 700 engine (used on the Falcon 20) which could offer a retrofit possibility for the existing Model 60 and 70 Sabreliners.

In addition to the Garrett 731 and the GE CF 700 engine, the Lycoming ALF502D and the UAC-Canada JT15D turbofan engines are available for possible retrofit.

Some of these engines are also being evaluated as possible replacement engines in turboprop installations.

AIRCRAFT REPLACEMENT

In addition to the technical options cited above, accelerated retirement of the noiser aircraft with their equivalent capacity maintained by accelerated procurement of the new technology, quieter widebodies has been suggested as an alternate means of reducing aircraft noise.

However, this too is an extremely costly option. As indicated in Reference 7.1-99, the cost of replacement of the JT3D fleet alone would represent an investment of 6 to 8 billion dollars. This does not take into account any additional procurement that may be required to meet the forecasted growing demand for air service nor does it consider the residual value remaining in both the aircraft and the world wide stock of spare parts inventory which must be scrapped.

In the case of the business jet owner, aircraft replacement may be a viable option. The improved range/payload characteristics of the new turbofan powered aircraft (due primarily to the major reduction in fuel requirements) may provide adequate incentive for the individual or corporate owner to upgrade his aircraft equipment. The aircraft replaced, however, may still require a nacelle modification or engine replacement program if it is sold to another U.S. operator. The cost of a used aircraft with acoustical modifications would still be significantly lower than the cost of a new aircraft, which could lead to a new market for these aircraft.

SECTION 3
FUTURE TECHNOLOGY OPTIONS AND RESTRAINTS

Diminution of aircraft noise will be a continuing objective as new, more advanced vehicles are introduced into the civil aviation fleet. It is anticipated that the standard of noise acceptability will be steadily reduced as the developing technology demonstrates the feasibility of so doing.

This section of the report addresses the current developments in both airplane and engine component technology, as well as advanced engine concepts, which will largely determine the potential for significant reduction in aircraft noise in the years ahead.

COMPONENT TECHNOLOGY

NASA QUIET ENGINE PROGRAM

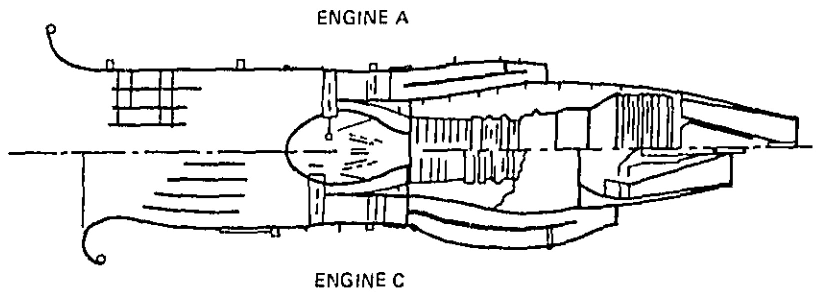
The NASA Quiet Engine Program was initiated about 5 years ago with the objective of developing engine noise reduction technology and demonstrating in engine tests the combined effect that this technology would have on reducing engine noise. An additional objective was to determine the impact on airplane economics resulting from the measures necessary to reduce the noise.

Two "engines" were built and tested during the program, in which two basically different fan designs were evaluated. To obtain a major cost saving, both engines used the CF-6 engine core, and for this application it is oversized; therefore, the engines were not flight weight. A high-bypass ratio engine was chosen to reduce jet velocity and, consequently, jet noise. A number of features were incorporated to reduce fan noise production. A relatively large rotor-stator spacing of two rotor chords was employed to reduce fan discrete frequency noise. A choice of rotor tip speeds was available for the fan design. Low tip speed fans have been found to produce less noise, while high tip speed fans can improve airplane economics by reducing engine weight, but they require additional noise suppression to achieve equally low noise output. Both approaches were evaluated in this program. Finally, a noise governed optimum ratio of number of fan stator to rotor blades was employed (2.25 to 1). In addition to design features aimed at low fan noise production, the fan noise can be reduced further by the addition of sound absorbing liners to the inlet and outlet ducts. This was also investigated on the experimental engines.

A cross section of quiet engines A and C with full fan acoustic treatment applied is shown in Figure 3-1. Also shown are some of the important performance and design characteristics of the engines. Both engines were designed to produce 22,000 pounds of thrust, and this puts them in the thrust class of the JT3D engines used in the DC-8 and 707 type aircraft. Engine C, the high-speed engine, has a single-stage fan with a design fan tip speed of 1550 ft/sec, while engine A, the low-speed engine, has a single-stage fan with a tip speed design point of 1160 ft/sec.

This program has been of great importance in determining the tradeoffs associated with performance and noise reduction. The first results of this highly successful program were reported in 1972. The program goal of a noise level reduction of 15 to 20 EPNdB below the levels of the 707/DC-8 long range transport aircraft was exceeded (Table 3-1). These results clearly indicate that the potential for lower noise levels of future engines, and aircraft, is excellent. It has been estimated that the fan technology demonstrated in the Quiet Engine Program would, in a new engine scaled to the thrust level of the current high bypass engines, yield a 5-to-6-dB reduction in fan generated noise compared with the current engines.

In relating the performance improvements to be expected with the technology developed in these advanced fan concepts, an economic analysis was performed for an assumed new trijet of approximately 200,000 lb. gross weight. The results of the study, using flight type engine designs based upon the experimental data developed for engines A and C, is provided in Figure 3-2. Changes in direct operating cost (DOC) utilizing unsuppressed engine "C" technology as the base, is plotted against aircraft noise level relative to FAR-36 noise regulations for both the high-speed and low-speed engine designs. The curves shown for each engine represent various degrees of fan acoustic treatment starting with an unsuppressed case at the lower end of the curves and ending with wall treatment plus three inlet and two exhaust splitters at the upper end. The higher speed engine is more economical (-2.5 percent DOC) in an unsuppressed condition because the high engine speed allows the number of turbine and compressor stages to be reduced, thereby reducing engine weight. However, it produces more noise, as stated previously. The knee in the curves (where DOC begins to increase rapidly with noise reduction) results from increased engine weight and engine pressure losses that accrue as acoustic splitters are added to the fan inlet and exhaust ducts. As a result,



	ENGINE A	ENGINE C
FAN PRESSURE RATIO	1.5	1.6
BYPASS RATIO	6.1	5.1
THRUST, LB	22,000	22,000
ENGINE CORE	CF-6	CF-6
FAN TIP SPEED, FT/SEC	1160	1550

Figure 3-1. NASA Quiet Engines with Full Suppression

TABLE 3-1

FLYOVER NOISE COMPARISON - FOUR ENGINE AIRCRAFT

	TAKEOFF	APPROACH
	EPNdB	
DC-8	116	118
FAR-36	104	106
Baseline Quiet Engine A	97	98
Quiet Engine A with Acoustic Nacelle	90	89

the low speed engine (A), even though it is a basically less efficient engine, is more economical as lower noise levels are reached. The cost of obtaining a noise level of FAR-36 minus 10 EPNdB, using the A-type engine, is seen to be about 4 percent in DOC for this particular study. These results are not necessarily typical and must be determined for each aircraft/engine installation.

It is obvious, however, that to progress beyond the FAR-36 minus 10 EPNdB noise levels economically, a vigorous noise reduction technology program is required. Advances in noise source reduction and improved suppression efficiency are areas of major importance for future technology programs. The fan and possibly the turbine as well as core engine noise are candidates for source noise reduction programs. In addition, the non-engine aerodynamic noise may preclude the realization of further benefits from engine source noise reduction, particularly in the aircraft approach mode. This noise contribution must be identified and resolved. Additional discussion relative to the technology programs addressing the above limitations are presented in subsequent portions of this section. Improvements in suppression technology are needed to increase acoustic treatment effectiveness so that less treatment will be required for a given noise reduction and also to reduce the weight per unit area of treatment by incorporating new materials or fabrication concepts or both.

SONIC INLETS

The NASA Quiet Engine Program established fan design concepts which indicated that significant reductions in fan-generated noise was achievable in future engines.

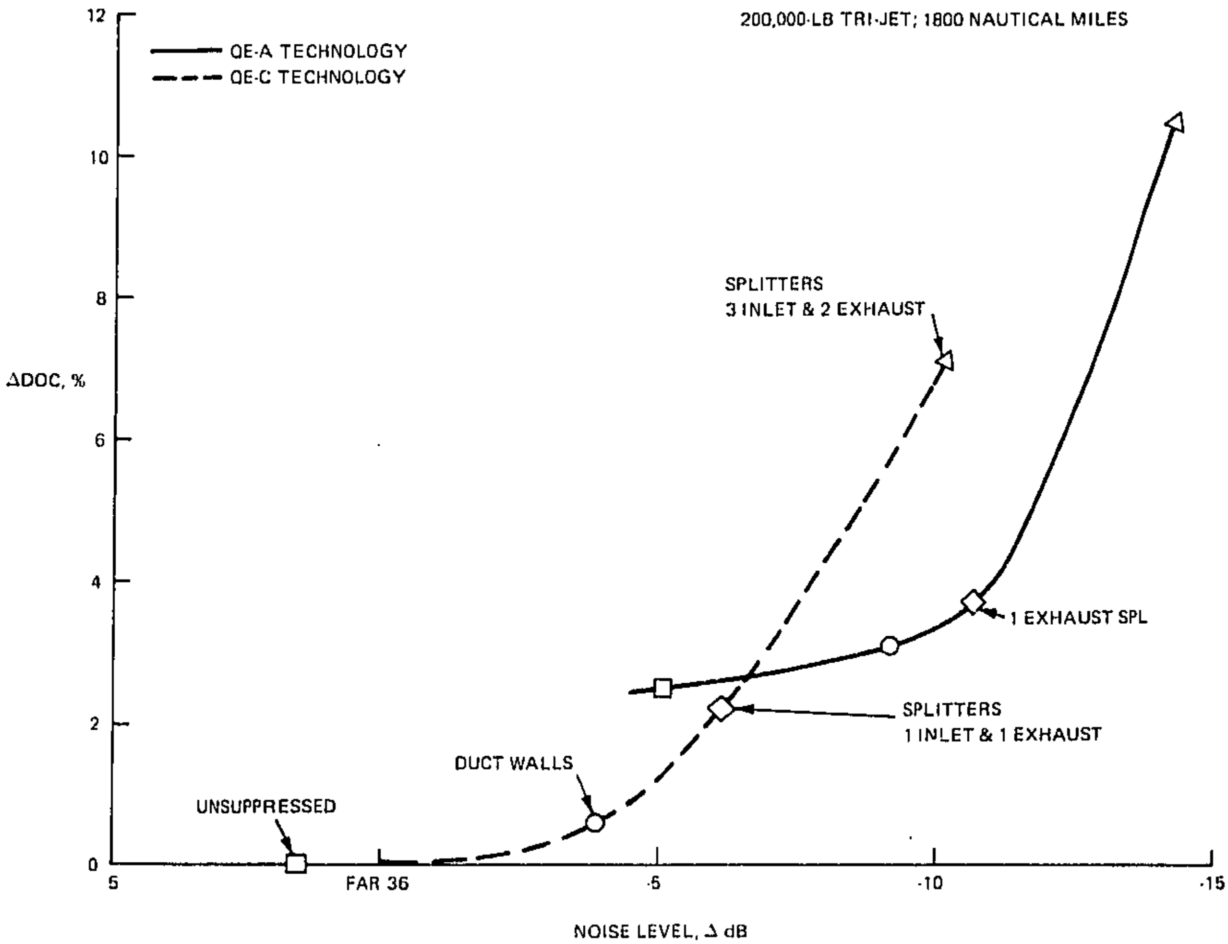


Figure 3-2. Effect of Degree of Fan Suppression on Aircraft Economics

Treating the nacelle inlet with sound absorption materials (SAM) reduces the external propagation of whatever noise is generated.

An additional noise reduction concept that may replace or supplement the use of SAM is the sonic (or choked) inlet which is essentially a reflective type of device.

The simplest explanation of its operation is that if the steady flow within a duct has obtained sonic velocity then a sound wave cannot propagate against this flow. This implies that this principle can be applied only when the sound is propagating against the steady flow. In an actual inlet, however, the mechanism is much more complicated than that implied previously. There will be continuous reflections of the sound wave caused by the varying duct diameter and steady flow Mach number. Radial and transverse velocity gradients also exist which will refract the sound waves away from the axial direction where they can be swept back from the inlet by the steady flow. Experimental data indicates a steady increase in suppression as the average inlet Mach number approaches one.

A collaborative NASA/General Electric Company parametric study on choked inlets is underway. The work involves both acoustic and aerodynamic measurements of a family of 19 different inlet configurations which should provide significant inlet quadrant noise suppression. The tests are being accomplished on a 12-inch diameter fan, and the hardware represents elements of variable geometry cowl and center-body systems. Particular attention is being given to measurements of inlet flow profiles in order to make direct correlations with both the internal and external inlet noise fields.

Figure 3-3 shows two of the choked inlet concepts under study in the current program. The concept is simple but there are difficult practical problems to be solved before adequate technology is available.

The mechanical complexity, structural integrity, and weight of the inlets must be reduced as well as airflow distortions and large losses in total pressure.

In FY 1974, some of the more promising sonic inlets will be tested on a full-scale two-stage fan rig to measure both acoustic and aerodynamic performance. Full scale acoustic tests will be performed with two different sonic inlets added to Quiet Engine C.

CORE ENGINE COMPONENTS

As discussed previously, much progress has been made in commercial jet engine noise reduction since its inception, approximately 15 years ago.

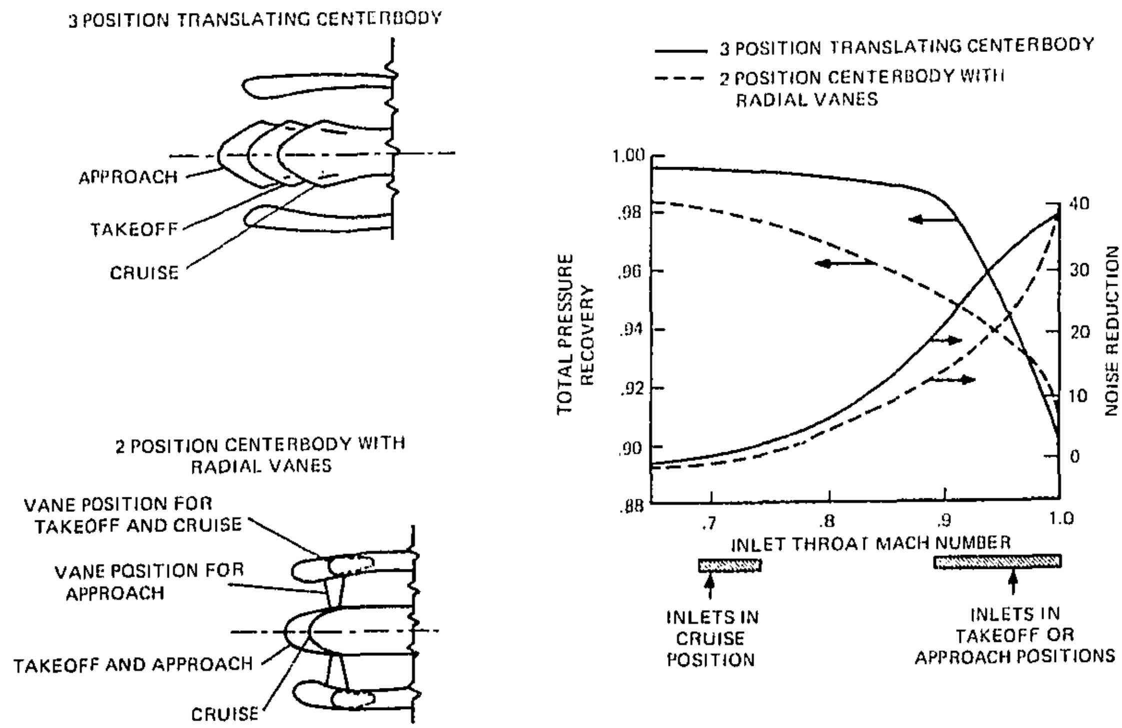


Figure 3-3. Sonic Inlet Research

All of the noise control advancements, from the pure turbojet to the high-bypass-ratio turbofan engines, were the result of technology developments for rotating machinery (fan component) and/or sound absorption materials. No comparable advancements have been experienced for the core engine noise of the high-bypass-ratio engines in current production. Rotating machinery and sound absorption noise control technology have continued to advance to the point where further progress may be ineffective unless the core engine noise is controlled as well. As visualized now, core engine noise is the floor which establishes the limit of effectiveness of the current noise control state of the art as it pertains to aircraft engines.

The FAA is currently sponsoring a Core Engine Noise Control Program, the purpose of which is to provide theoretical and experimental data to assist the designers in developing future technology aircraft capable of conforming to lower noise levels than are now required by FAR Part 36. The effort is directed to identifying, evaluating, and controlling the component noise sources inherent in the core engine (the gas generator).

Core engine noise is defined as the noise produced by the gas generator portion of the gas turbine engine either solely or as influenced or amplified by the fan discharge, tail pipe, and other portion of the exhaust system. Core engine noise is assumed to radiate only in the aft engine quadrant, and its sources may be generated either upstream or downstream of the tail pipe exit plane. Core engine noise does not include compressor generated noise radiating from the engine inlet nor fan generated noise radiating from either the engine inlet or exhaust ducting. It may, however, include compressor generated noise transmitted downstream through the engine flow passages or fan generated noise enhanced by interaction with the core engine noise or gas stream.

The factors under investigation that cause or influence the component noise sources of the core engine include but are not limited to:

- Jet Exhaust Stream. Historically, the jet noise has been defined by the quadrapole concept leading to the classical velocity to the eighth power law, with the absolute level at any given velocity dependent upon various influences upstream of the engine tail pipe such as geometry, roughness, turbulence scale, etc. Are the assumptions valid for subsonic flow? Can the influences upstream of the tail pipe be quantified?

- Turbine. Does the turbine generate noise in a similar manner as the compressor and fan, and can compressor and fan noise reduction techniques be successfully applied to turbines? What are the effects of rotating stall, hot spots, and other flow irregularities on noise generation?
- Compressor. Can the compressor have any significant contribution or influence on the noise transmitted or generated within the core engine?
- Combustor. What contributions do the combustion equipment and process make to the noise field? Are combustion screech and rumble significant?
- Discontinuities in the Flow Passages. Is there significant dipole or monopole noise generation from such discontinuities as linkages, orifices, constrictions, and bends in the core engine flow passages?
- Interaction of the Core Engine Exhaust and Fan Duct Streams. Can the combination of the two exhaust streams generate a significant noise component? Is noise from either the fan or core engine amplified by the other? Is some resonant condition set up in the tail pipe?
- Noise Radiation from the Engine Casing. Are engine casings designed to have adequate sound transmission loss capability? Can significant structure borne sound be transmitted to and radiated from the casing?

In addition to the FAA program on core noise investigations, NASA and DOD are undertaking complementary research efforts relative to their unique requirements. Formal and informal interagency discussions preclude the possibility of redundancy among the various programs.

AERODYNAMICS

The principal source noise abatement activity to date has been concentrated on attempts to reduce engine generated noise for a given size aircraft. Additional source noise control may be possible if the aircraft is treated as a system where each element of the system is designed to provide minimum overall aircraft system noise. Some examples of this concept follow.

Wing Design

Supercritical Wing

Application of supercritical wing technology to the design of new aircraft could result in reduced noise, as a secondary effect.

Conventional airfoils are designed for operational efficiency over a limited performance range. At flight speeds beyond the design capability of the airfoil, generally identified as the critical flight speed, excessive drag and buffeting are experienced. The supercritical wing is configured to operate beyond the normal Mach number limits that have constrained conventional wings. The potential benefits of the application of supercritical wing technology to civil aircraft are:

- More efficient cruise performance when operating at high subsonic Mach numbers, by delaying the onset of transonic drag rise.
- Its use can result in reduced wing structural weight, thereby permitting increased payload or increased fuel capacity for greater range.

For a given range/payload design, the gross weight of the aircraft would be reduced, requiring smaller engines, which for the same state of technology would result in lower noise. Design studies of the effects of supercritical wing technology to the B-1 bomber program showed an 11 percent reduction in gross weight for the specified mission.

The recent Advanced Technology Transport studies utilized supercritical wing technology in developing the efficient performance characteristics of the near sonic commercial transport designs. This technology is equally applicable to the business jet aircraft currently operating in the general aviation fleet. William Lear, developer of the Learjet, is planning to demonstrate a supercritical wing on a Learjet aircraft in 1973.

Asymmetric Wing

Wind tunnel tests at the NASA Ames Research Center of an elliptical, asymmetric (or oblique) wing for efficient low supersonic or high transonic performance has produced some dramatic initial results. Studies and model testing of this unconventional, radical design indicated better noise, performance, and structural characteristics than for the variable swept wing configuration. Tests to date have been limited to experimental wind tunnel and small radio-controlled flying models. Additional development effort is required, particularly full scale demonstration testing, before the preliminary data can be validated.

Study results also indicated that the oblique wing configurations incur less cost for a given level of noise reduction.

High-Lift Devices

As indicated in Section 1, continuing developments in wing flap design have effected significant improvement in aerodynamic lift capability over the years. Current activity is directed at the evaluation of various "powered-lift" concepts in an attempt to meet the requirements of potential future short takeoff and landing aircraft (STOL).

To serve the high-density short haul need, and still prove profitable, these aircraft must also approximate the productivity, cruise speed and economy, and ride comfort of the CTOL transports. The latter considerations dictate relatively high wing loadings (80 to 110 lbs/sq. ft.). Hence, the desired low-speed performance requires maximum lift values well in excess of those achievable with the most effective aerodynamic high lift systems.

To generate these high-lift values, propulsive energy must be applied to augment the aerodynamic wing lift.

The powered lift effort presently is being concentrated on three principal types (See Figure 1-11):

1. The augmentor wing (AW).
2. The externally blown flap (EBF) with engines located under the wing (UTW).
3. The EBF with engines located over the wing (OTW).

Figure 3-4 provides some indication of the performance characteristics of the powered lift jet systems as compared with the typical, present day, turboprop STOL transport aircraft.

The steep ascent and descent flight paths, made possible by these high lift devices, is expected to reduce the extent of the noise impact on the community. However, the effect of the higher engine thrust requirement, combined with the induced noise generated by the exhaust gas and flap interaction (Figure 3-5), needs to be determined by full scale testing in an operationally viable system in order to more completely evaluate the overall system noise.

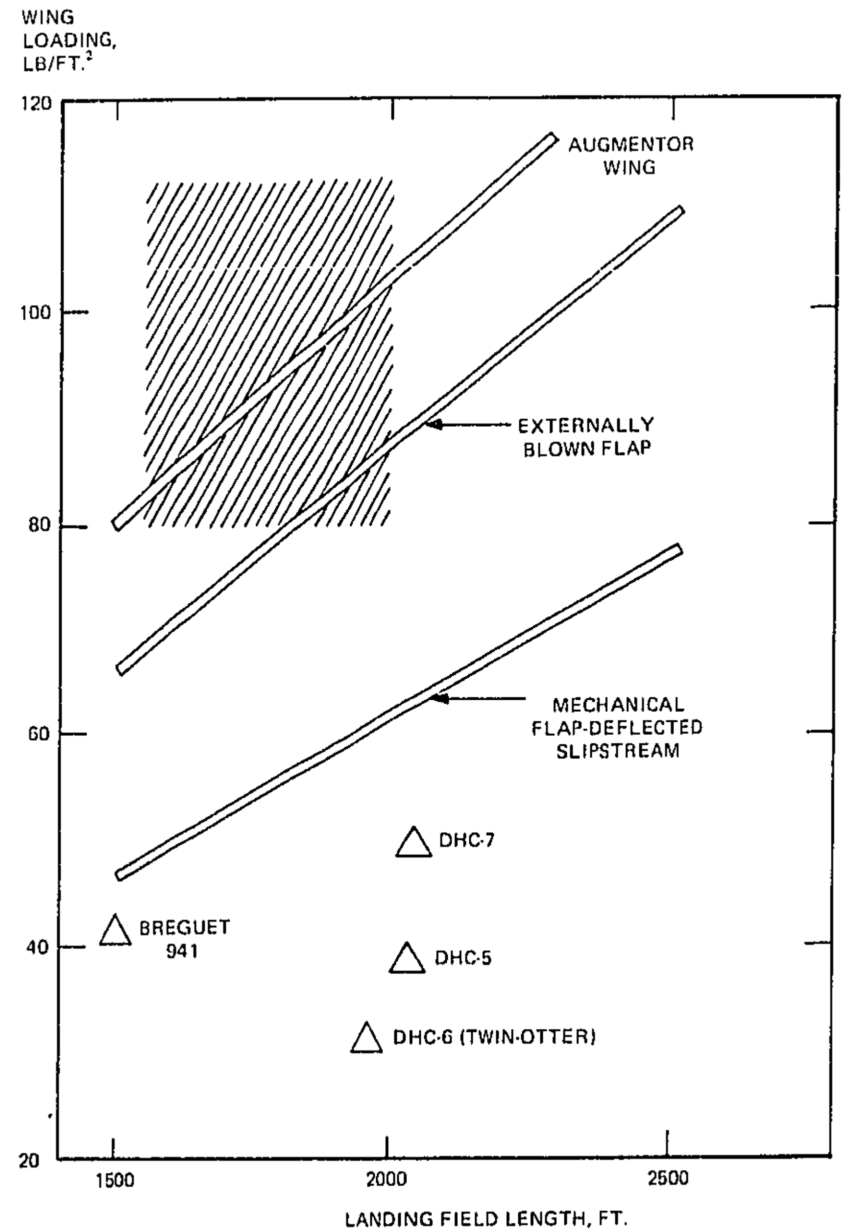


Figure 3-4. Aircraft Wing Loading vs. Short Field Length

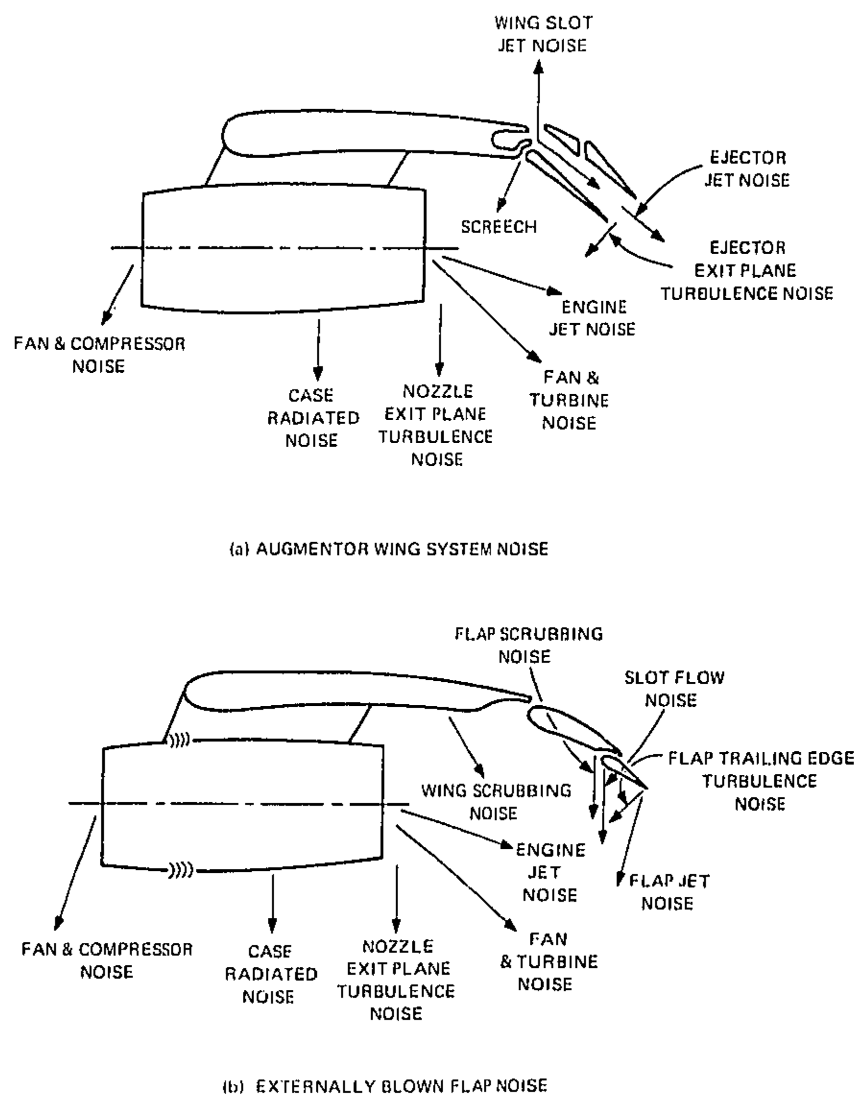


Figure 3-5. High Lift System Noise

As discussed earlier, the development of the high-bypass fan (bypass ratio of 5 or 6:1) provided large reductions in noise for the conventional transport aircraft. In order to meet the anticipated noise limitations for high performance STOL aircraft, much higher bypass engines may be required. The higher the bypass, for a given thrust, the lower the jet velocity. This low exhaust velocity will not only reduce the engine jet noise but will also minimize the flap interaction noise in these high lift systems.

External Flow

The approach noise of an aircraft is currently dominated by the high frequency noise produced by the engines.

Advances have been made in the technologies of quieter engine design and the acoustic treatment of engine installations to attenuate engine-generated noise. Considerable payoff is expected on future aircraft/engine combinations designed from the beginning for very low noise. This has encouraged predictions that noise at the standard FAR 36 noise measuring points can be reduced 10 dB, or more, per decade starting immediately. However, recent studies and flight tests of large commercial airplanes strongly indicate that we now face an airframe noise constraint for at least the approach condition, with flaps extended, below which additional noise reduction would be difficult even if the airplane had no engines.

Airframe noise is defined as the noise generated by an aircraft in flight from sources other than the engine, auxiliary power units, and machine accessories. Airframe noise or aircraft nonpropulsive noise sources, as illustrated in Figure 3-6, thus include noise generated by airflow over the fuselage, wings, nacelles, flap systems, landing gear struts, wheel wells, etc.

Measured and predicted aerodynamic approach noise data are presented in Figure 3-7. The trend of the points has a slightly greater slope than the FAR 36 minus 10 EPNdB curve, which indicates that the aerodynamic noise effect becomes more critical as gross weight is increased.

The most controlling parameters in aerodynamic noise generation are flap angle and aircraft velocity. The turbulence and, therefore, aerodynamic noise, varies with flap angle but depends to a large extent on the flap design. The landing velocity change results in a change in EPNdB proportional to velocity to the fourth power. This

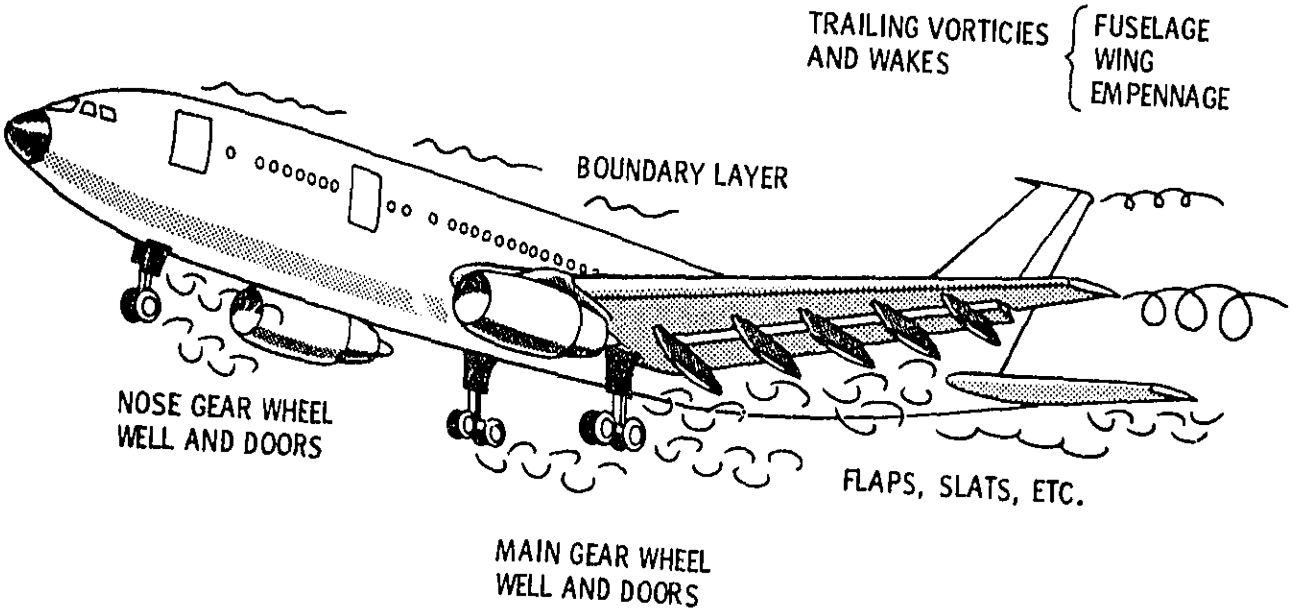


Figure 3-6. Aerodynamic Noise Sources

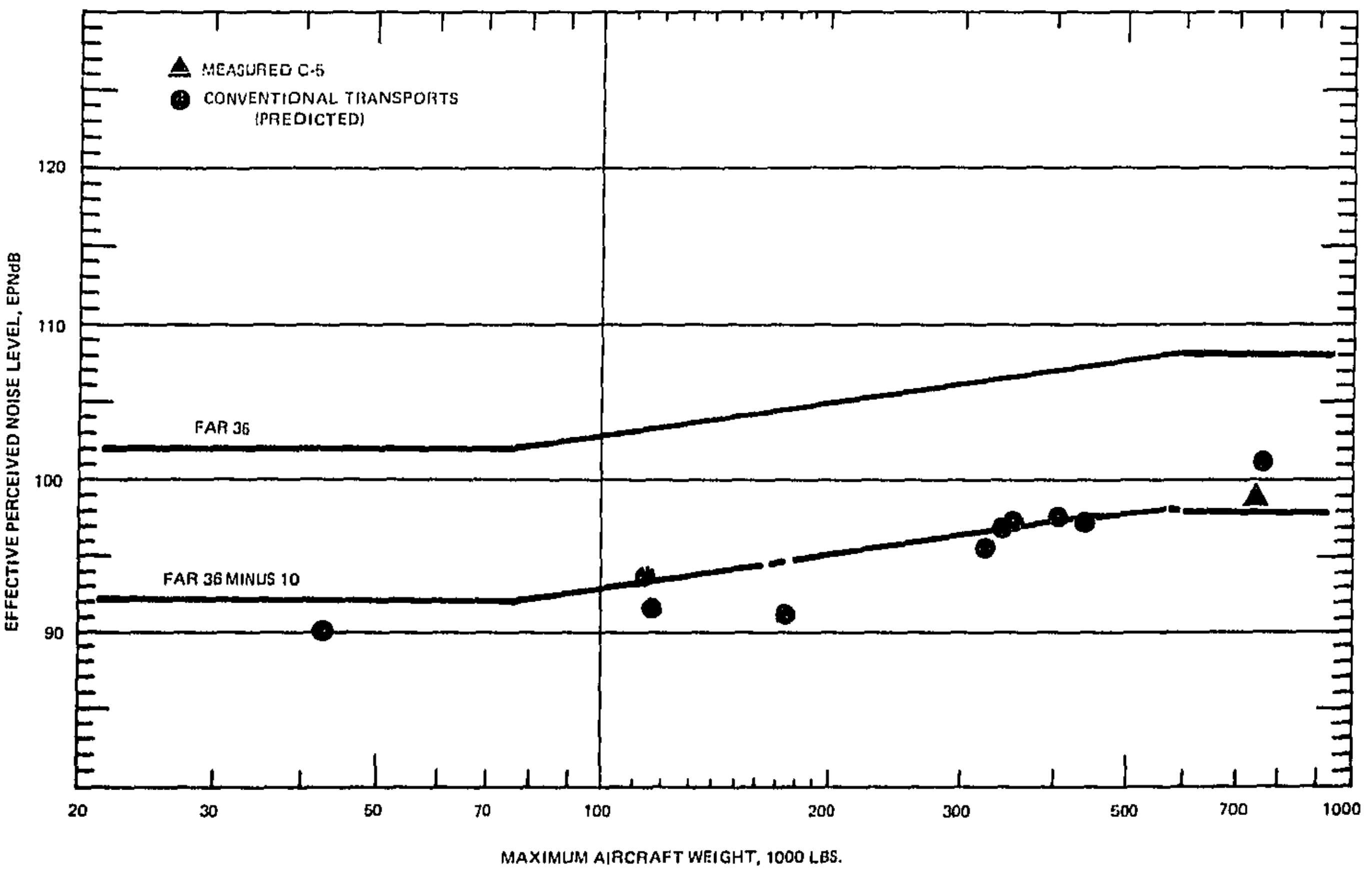


Figure 3-7. Non-Engine Aerodynamic Noise Relative to FAR 36 Approach Noise Limits

characteristic should be considered when appraising the effectiveness of alternative approach and landing procedures. For example, in a decelerating approach the aircraft would not only have low engine noise but would be clean, i.e., have low drag, and therefore low aerodynamic noise until its final deceleration close to touchdown. Just prior to touchdown the aerodynamic noise would be the same as for a constant speed approach. However, during the final deceleration phase the aircraft would have a high flap angle and higher than touchdown velocity and therefore higher than a constant speed approach aerodynamic noise.

Decreasing engine noise to levels near or under the aerodynamic noise level would have essentially no effect on further total aircraft noise reduction, unless the aerodynamic noise itself is reduced.

A program to understand and reduce the nonpropulsive noise is underway at NASA. These studies will provide information relative to the identification and location of airframe noise sources; the manner in which noise varies as a function of angle of attack, local air velocity, turbulence levels, separated flows, etc.; improved prediction methods; and approaches to noise alleviation. A flight test program is planned to better understand the relationship between aerodynamic noise and engine noise and the different types of noise abatement approaches (the steep slope, the two-segment approach, the curved ground track, and decelerating approach).

Helicopter Rotors

It has been generally accepted (Ref. 3.6-195) that for the turbine-powered rotary-wing aircraft, sources of the most annoying sound, are:

1. Rotor blade slap
2. Tail rotor rotational noise
3. Main rotor broadband and rotational noise
4. Turbine engine noise
5. Transmission noise

Blade slap and rotor rotational noise are unique to the helicopter and will be briefly discussed in the following paragraphs along with the potential means for reducing their noise impact.

Blade Slap

With its characteristic acoustic signature, blade slap can occur in many regimes of flight. In high-speed forward flight, blade slap is usually due to the compressibility phenomena occurring on the advancing blade of the helicopter rotor. Studies indicate that in this case, the impulsive noise can be attributed to the rapid drag rise of the advancing blade tip, coupled with Doppler effect. "Banging" in hover, and low-speed regimes of flight, are probably caused by interaction of the tip or rolled-up vorticles from the preceding blades with the oncoming blades.

Reduced tip speeds, which lessen the strength of the interacting trailing vortex and reduce the blade tip Mach number, combined with special blade design characteristics (e.g., blade loadings and tip design), will tend to suppress blade slap. Increasing the number of blades to provide the same lift capability at reduced rotor speeds can also contribute to reduced noise.

Rotational Noise (main and tail rotors)

In a physical sense, rotational noise and blade slap have much in common. In both cases, there is an element of interaction between wake vortices and the blade. Thus, blade slap (in other than high-speed regimes of flight) may be considered as a particular case of strong manifestation of that interaction. For this reason, many of the means suggested for blade slap suppression, especially through modification of the vortex structure and wake geometry (e.g., special blade tips, increase in the number of blades) could also be beneficial for the reduction of rotational noise.

Reduction in rotor tip speed is the primary parameter in reducing helicopter noise. However, in a pure helicopter configuration, a key determinant of the forward flight speed capability of the vehicle is the rotor tip speed. Generally, higher flight speeds are associated with higher tip speeds. This establishes a tradeoff between noise reduction and helicopter performance and economics.

However, if the rotor is not required to provide forward flight capability (as in a compound helicopter configuration), the tip speed for optimum hovering flight tends to be lower, and therefore more compatible with reduced noise.

ENGINE TECHNOLOGY

In Section 2, engine source noise was discussed in the context of available near term options for reducing the noise of current engines and aircraft.

The longer range goal is to reduce the FAR 36 noise limits by 5 to 10 EPNdB. This can be most efficiently accomplished by source noise control in new engines by dedicated attention to this requirement when the inital designs are laid down.

The basic technology that would permit the development of advanced engines and aircraft, with noise levels approximately 10 dB below the FAR 36 standard has been demonstrated, as pointed out earlier in the discussion of the NASA Quiet Engine Program. Unfortunately no engine development program which could apply the lessons learned in the NASA program to an operationally viable system has resulted from this activity. While it may be interesting or comforting, from a purely R&D perspective, to have demonstrated the capability for lower noise, unless this technology results in a practical application, the expenditure of time and money is worthless.

The Air Force Advanced Turbofan Engine (ATE) development program could be the catalyst that would utilize the demonstrated technology of the NASA Quiet Engine Program. Such an engine development program would provide, as it has in the past, the basis for a new, quieter engine for the next generation of commercial aircraft.

Figures 3-8 and -9 indicate the variations in noise levels for comparable military and commercial aircraft utilizing similar technology propulsion systems. It is apparent that significant noise reductions can be achieved in the commercial derivatives, where they are not constrained by the tactical performance requirements associated with a military application. Commercial derivatives of the ATE would conceivably provide similar noise reduction potential.

Since the propulsion system development generally represents the longest lead time requirement in a new aircraft program, any delay in the development of advanced propulsion technology will impact on the eventual operational availability of new, advanced aircraft systems. Figure 3-10 illustrates a typical engine development cycle. If new quiet aircraft are to be operational in the fleet by 1980, an advanced quiet engine development program must be initiated no later than late 1973 or early 1974. On the other hand, a quiet STOL engine technology program is only just being initiated. The technology (as stated earlier) is not yet in hand and a 3-year experimental

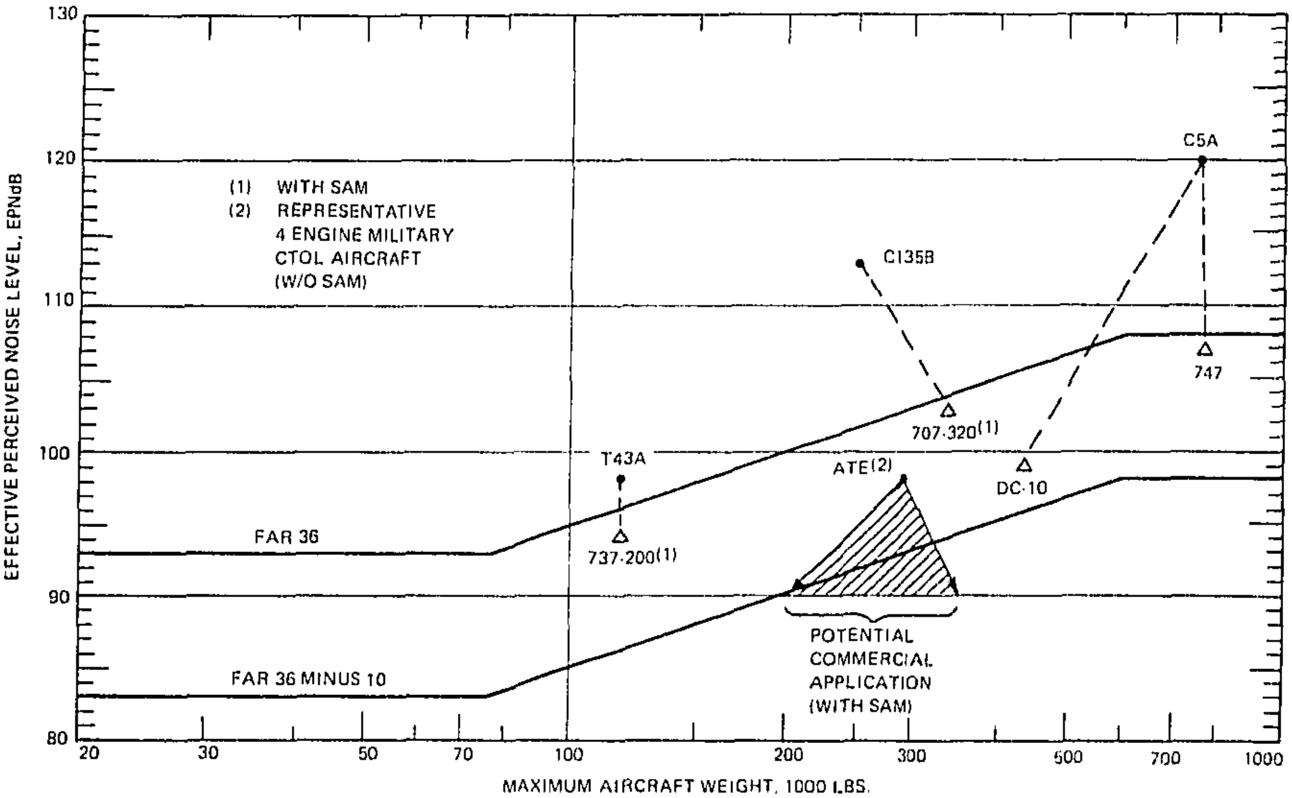


Figure 3-8. Military/Commercial Transport Noise Levels - Takeoff

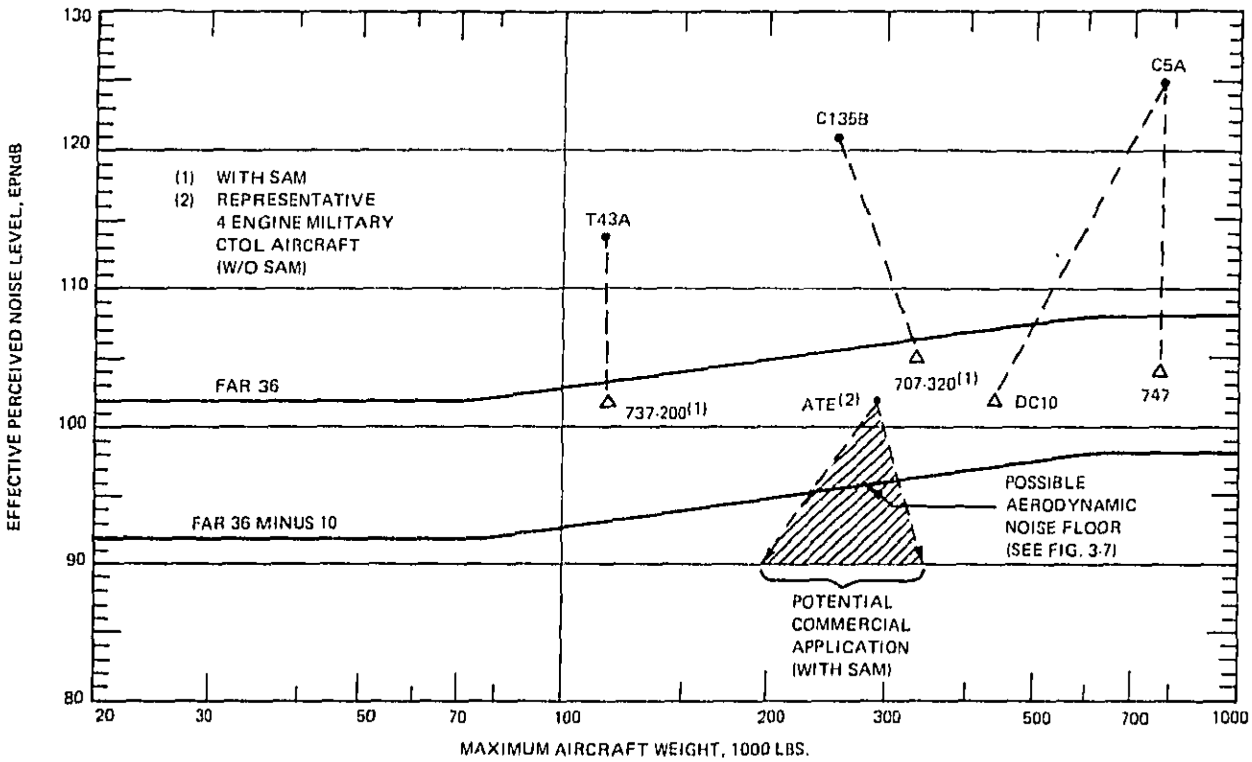


Figure 3-9. Military/Commercial Transport Noise Levels - Approach

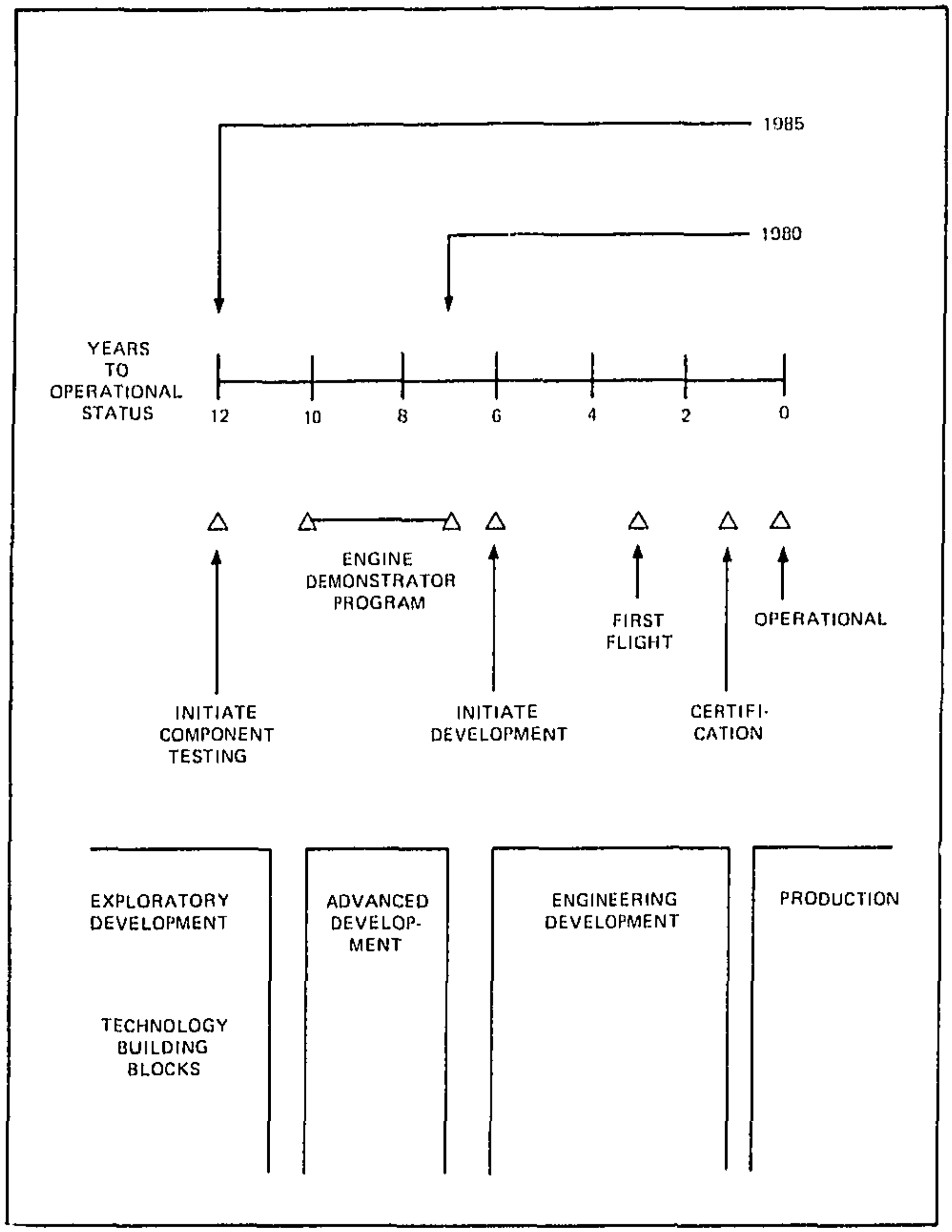


Figure 3-10. Engine Development Cycle

(demonstration) program is being pursued by NASA (see following Section on STOL engines). It is not likely that an advanced technology quiet STOL turbofan engine program can become fully operational before 1983.

The following discussion presents some of the new engine options and their current status.

AIR CARRIER CTOL ENGINES

Industry and Government projections indicate that new, modern technology engine types are needed to power next generation CTOL (conventional takeoff and landing) long haul and intermediate range transport aircraft by the end of this decade. Previous testimony by industry and Government at special aeronautics hearings of the Subcommittee on Advanced Research and Technology, House of Representatives committee on Science and Astronautics, in January 1972 indicated that some kind of government support and encouragement is needed for the development of one or more new engine types within the current "thrust gap" between about 10,000 and 40,000 pound thrust, particularly around the 25,000 pound thrust level.

Both General Electric and Pratt and Whitney have indicated that engines in this class could be available by 1978. The CFM 56 (GE) and the JT10D (P&W) engines when packaged in optimally designed and treated nacelles, would produce noise signatures compatible with the FAR 36 minus 5-10 EPNdB objective. These designs are based on demonstrated hardware developments. The CFM 56 core gas generator utilizes the technology incorporated in the B-1 engine, which is under development for the Air Force. The fan component reflects the results of the NASA Quiet Engine test program and the CF-6 program. The P&W JT10D draws on the technology developed for the JT9D engine.

STOL ENGINES

The Quiet, Clean Short-Haul Experimental Engine (QCSEE) Program is a major element in NASA's quiet powered-lift propulsive technology program. It is being undertaken to establish the technology base for very quiet propulsion systems, designed for installation in powered-lift STOL aircraft. As discussed earlier, the blown flap, powe lift concept will probably require a very high bypass ratio power plant in order to mini mize the flap interaction noise, as well as providing adequate flow for increased lift.

The prop-fan, (Figure 3-11) developed by the Hamilton Standard Division of the United Aircraft Corporation, provides one method for developing this capability. The prop-fan is basically a very high-bypass, low-tip speed fan that can be matched to existing core engines to provide the propulsive requirements (thrust, bypass ratio, etc.) of any subsonic aircraft type. The engine thus conceived will have characteristically low noise levels due primarily to the high-bypass ratios possible (BPR of 15-30) and the low fan tip speeds (600 to [illegible] feet per second).

Prop-fan engines have been included as part of the initial QCSEE preliminary design studies. The QCSEE program is not directed towards the development of an engine for flight and the experimental engine resulting from QCSEE will not be flown. The QCSEE program provides for close cooperation and coordination with the Air Force in their development of the Advanced Turbofan Engine (ATE) demonstrator. The possibility exists for the core gas generator of the ATE to be compatible with both the military requirement as well as for the more stringent potential commercial STOL application.

VTOL ENGINES

For nonrotary wing high speed VTOL aircraft, the propulsion system concepts vary from lift fans (as demonstrated in the Army XV-5 program), deflected thrust engines (as in the Marine Harrier aircraft), to direct lift turbojets or turbofans (the German DO-31).

For commercial applications, the only serious studies to date have been developed utilizing lift fan systems. Demonstration flights of the DO-31 yielded a noise level of 135 EPNdB at 500 feet. Harrier noise levels are reported as 120 PNdB at 500 feet.

Recent studies by Rockwell International, McDonnell, and Boeing indicated that in the 1980 to 85 time period a 100,000 pound gross weight, 100 passenger VTOL transport powered by advanced technology engines and lift fans would be able to meet a 95 EPNdB criterion at 500 feet. Using existing engines and current lift fan technology, a research aircraft could be built by 1978 that would develop a noise level of approximately 99 EPNdB's at 500 feet.

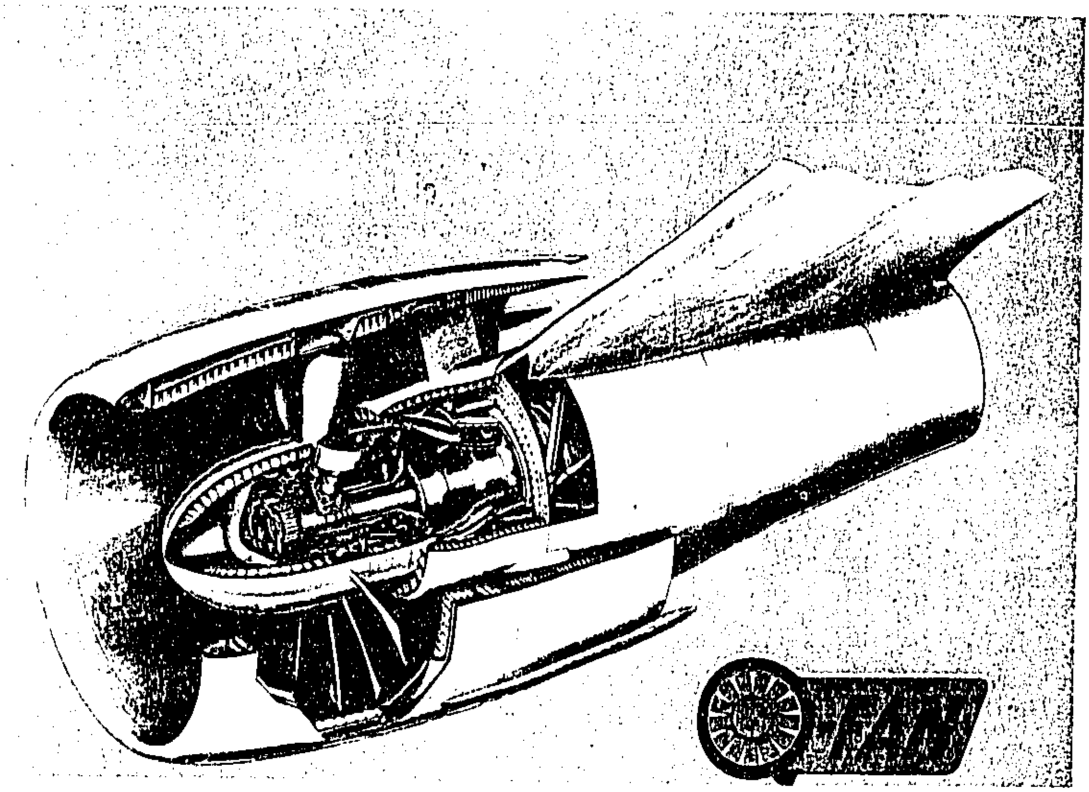


Figure 3-11. Quiet Fan Propulsive System

GENERAL AVIATION ENGINES

There are several new engine, as well as new engine concept, programs currently in development which could find future homes in the high performance business aircraft or helicopter market.

Turbofan Engines

- Garrett ATF 3 at 5000 pounds of thrust is in development for the Air Force. Military qualification is scheduled for the 1974 time period. Commercial availability would follow, if there is a market. The noise levels of this engine would meet the current FAR 36 standard.
- TURBOMECA Astafan IV is a French developed fan engine of 2250 pounds thrust with a bypass ratio of approximately 8.0. Initial engine tests took place in June of 71. Estimated noise levels are well within the FAR 36 requirement.
- TURBOMECA LARZAC at about 3000 pounds thrust is a low-bypass, low pressure ratio fan engine. Studies of the engine in a small (13,500 pound gross weight) business jet indicated noise levels well below the requirements of FAR 36. U.S. license for the engine is held by Teledyne CAE.
- Teledyne - CAE participation in the Air Force ATEGG (Advançed Turbine Engine Gas Generator) program has provided a core gas generator that, when matched with an appropriate fan, could lead to an engine in the 3000-5600 pound thrust class. A certificated fan engine could be available in the 1978-80 time period.

Rotary Engines

Curtiss Wright has been exploring the potential of the Wankel-type rotary engine for light aircraft and helicopter applications. The benefits claimed for this engine are low noise and emissions as well as better maintainability and reduced weight, particularly when compared with the reciprocating engine. Flight tests of the engine in both fixed wing and helicopter installations have been initiated.

Prop-fan Engines

The characteristics of the prop-fan concept discussed earlier are equally applicable to the light aircraft market where the fan can be matched to the power output of the reciprocating engine. Small turboshaft engines and the rotary-type engine discussed above are also core engine possibilities for the prop-fan concept.

SST ENGINES

The cancellation of the U.S. development of a commercial supersonic transport was due to several factors, only one of which was the high noise levels to be expected.

The basic design parameters of the Concorde SST, which will be entering revenue service in 1975, were essentially frozen in the mid-1960's, prior to the need for noise certification of new aircraft. Even then, noise control was of significant concern to the manufacturers. The noise levels of the Concorde, at its service entry date, will be comparable to the contemporary straight jet and low-bypass, long range, subsonic aircraft. It is technologically infeasible to reduce the noise levels of the Concorde to meet the current FAR 36 Appendix C requirement.

A variety of engine cycles can be considered for possible future supersonic transport aircraft. However, the jet exhaust velocities tend to be considerably higher than those for subsonic aircraft. As a consequence, the jet noise for these engines, being a primary function of jet velocity, is much louder than for those used in subsonic CTOL aircraft. Although the fan for supersonic aircraft engines generally operates at low-bypass ratios and high pressure ratios with resultant high noise, the unsuppressed jet due to its high velocity is the dominant noise source. There is, therefore, a need to suppress jet noise in order to render supersonic transport aircraft acceptable to the community. As the jet noise is suppressed, the fan noise and core (internal) noise may become dominant. Noise attenuation means for these noise sources are similar to those applied to the current subsonic engines.

The use of variable-cycle engines has been proposed in order to help reduce the jet noise. NASA has contracted with the General Electric Company and Pratt and Whitney to perform analyses of propulsion systems suitable for a second-generation supersonic transport aircraft. A major goal of the work is to examine systems that can meet severe noise constraints, not only those of today but the possibly more stringent ones of the future. The engine contracts are coordinated with more general studies of the complete airplane design being performed by the Boeing, Lockheed, and Douglas airplane companies under contract to Langley Research Center. The Langley contracts will study the technology problems and design tradeoffs for the integrated airframe/engine combination, including such operational constraints as engine noise limits.

The overall objective of the Advanced Supersonic Technology program is to provide an expanded supersonic technology base in the technical areas critical to:

1. Future advanced military supersonic cruise aircraft.
2. Assessment of the impact of present and future foreign civil supersonic aircraft.
3. Future consideration for an environmentally acceptable and economically viable supersonic transport.

SECTION 4

COST & ECONOMIC ANALYSIS

In recent years, the public's tolerance to aircraft and airport noise has diminished, giving rise to widespread complaints and in some cases legal action. Some recent court decisions possibly have exposed airports to legal liability. If the present noise levels continue, public opinion and concerted action will continue to limit new airport development, extension of existing facilities, commercial flight frequencies, arrival and departure time windows, aircraft types, and runway choices. The effects of such action may seriously impair the financial stability of the airline and aerospace industries.

The general economic question addressed is which combinations of noise impact reduction options are the most economically efficient for achieving various levels of cumulative noise exposure? Of corollary interest is the determination of the financial implications to the affected institutions if no national airport noise reduction program is undertaken.

The set of options of interest in this report are those which reduce source noise; consequently, the issue to be resolved is what economically efficient role can source noise reduction options play in reducing the noise environment around the nation's airports.

The implications and costs associated with some expected legal and administrative actions that might occur if no coordinated federal airport noise reduction program is forthcoming are initially analysed. Subsequently, the financial consequences of achieving several levels of cumulative noise around airports are then developed, assuming no source reduction options are utilized. Using these data, the economic implications of utilizing source noise reduction options are then projected.* Finally, a qualitative sensitivity analysis of the results is undertaken, primarily in recognition

*These investigations are on a cost-effectiveness and not a cost benefits basis. This situation is primarily due to the fact that although the benefits of the air transportation system are known and dollar estimates exist, reliable data on the benefits of noise reduction to the public are not available.

of the fact that the data used herein will most likely become obsolete subsequent to the release of this study. Accordingly, the data presented here should be viewed as only providing a relative measure of the costs and effectiveness associated with the options investigated.

Each of the current technology source treatment options discussed in previous sections can be combined to offer a number of basic strategies. Some of the types of strategic alternatives investigated are discussed in the subsequent text. The first and perhaps least expensive basic approach, although they are not source options, is to change aircraft operating procedures.** At the other end of the expense and schedule spectrum is replacement of the existing narrow body fleet with new aircraft employing advanced jet aircraft noise reduction technology. Adoption of the latter approach would provide markedly quieter aircraft beginning in the early 1980's. The forced obsolescence of the then existing narrow bodied fleet would produce significant airline industry writeoffs on the order of billions, equipment certificate payment default problems, and additional billions of dollars in outlays for new aircraft.

Modification of the engines in existing narrow bodied aircraft with advanced noise technology engines (refan) could possibly be accomplished earlier. Both the write-off and the new outlay requirements should be relatively less and performance gains might further offset some of the cost.

Another approach is to provide new modified low noise nacelles, including engine treatment, for the existing narrow bodied fleet. This approach provides relatively early noise reduction opportunities at relatively low write-off and new outlay requirements.

THE NULL CASE

The null case condition assumes that no source abatement options are utilized. Several situations and their contribution towards alleviating the airport noise environment will be examined under this condition. These situations are;

1. The courts adopting a policy of allowing a recovery of noise damages by any person exposed to high noise environments.

**The costs and effectiveness of these options are discussed in Ref. 10.4-426.

2. The adoption of a national night-time curfew.

3. Increasing the use of capacity limitation agreements between airlines.

4. Implementing land use and receiver treatment alternatives.

In this section, the viewpoint is adopted that although airports are an essential part of the community they serve, and its economic environment, the benefits to the community largely represent redistribution of economic activity rather than the creation of new activity (8.5-103). As such, regional transfers balance out at the national level; consequently, the regional impacts of each situation will not be examined. This is not to say that the regional impacts are insignificant, rather the impacts can be examined on a national level.

The interest group relationships that the subsequent analysis uses as a frame of reference are such that ultimately, the consumer of transportation services will pay, either directly or indirectly, for the cost of resolving the aircraft/airport/community noise environment conflict problem. More specifically, the public affected by high noise levels around airports is the primary interest group whose actions are demanding a solution to the aircraft/airport noise problem. The litigation this group has initiated, their demands for curfews and quotas and their denial of local funding authority at the voting booths all translate into increased costs of delivering the transportation services of the air mode to a community. In the free enterprise pricing system, one of the interest groups must pay these increased costs.......how these costs are passed on will be discussed in the subsequent text.

Litigation awards are costs initially incurred by the airport operators. Depending on the operator's contractual arrangements with the airlines, the operators will attempt to pass these costs on to its customers, the airlines, as soon as possible. Regardless of these contractual arrangements, there will be a lag between the time when the operator must pay out the awards and when the operators can recover the amount of the awards. It should further be recognized that although awards for damages are made, this does not preclude the operator instituting curfews, quotas, etc., in an attempt to defer future litigation or in response to political pressure, the establishment of noise exposure standards, etc.

Not only are litigation costs ultimately passed on to the airlines, when the lease arrangement permits, but the airlines also incur costs associated with the curfews, etc. The costs of delays, diversions, and cancellations which result from curfews, quotas and aircraft type restrictions are directly incurred by the airlines. Off-setting these costs would be a commensurate increase in passengers carried per trip resulting from carrying the same volume of customers over a shorter daily operating time span. In other words, assuming a constant demand level, airport operator initiated schemes to reduce the airport/community noise problem can result in increased profits and productivity of airline activity which are, in turn, offset by costs of delays, diversions, etc.

Within this action/reaction loop the CAB is the determining body as to whether, and when, litigation and these other costs are passed on to the users. Again, there is a perceived time lag between the incurrance of costs and when such costs can be recouped. The CAB in allowing tariff adjustments to pass on the described costs will have taken an action which can theoretically affect user demand for air transportation services. That is, by passing along the increased costs of operator actions to the users, the demand for transportation services will be affected. Such a result tends to have a negative effect on airline profits and productivity.

As superficially discussed, the action/reaction relationships began with the impacted public's legal and/or political reactions to high noise exposures. Such action in turn stimulates airport operators to take administrative actions which affect airline economics. Given such effects the CAB can agree to tariff adjustments which allow the airlines to defray such increased cost. These tariff adjustments can theoretically affect the demand for air travel services. Now, if the public does not perceive a significant change in the noise environment, they could, in turn initiate additional actions which again trigger the reaction chain. As described, this reaction chain is degenerate or self defeating in that only solutions to local airport/community noise problems may result, i.e. there is no national solution. The net result is the allocation of resources in an inefficient manner (e.g., resources to satisfy a particular community as opposed to those necessary to effect a national solution.

It should be expected that the impacted public will increasingly attempt to take actions resulting in increasing costs of delivering air transport services. One should also note that the longer the time between tariff adjustments via CAB actions, the greater will be the pressure on the industry's cash flow. It is conceivable that this pressure will result in further disrupting the delivery of services (e.g., via insufficient operating funds or curtailment of credit lines, where such a situation can lead to curtailment of flights, cancellations, etc., which in turn affects the competitive positions of the airlines as a function of route structure). Therefore, the speed with which costs are passed on is seen to be a key factor in assessing the feasibility of implementing any noise reduction alternative. In the following section, estimates of the magnitudes of costs of the various public and locally legislated actions are developed.

The Cost of a Judicial Alternative*

One incentive to lower noise around airports is the threat of a lawsuit against an airport and an adverse judgment. The policy of allowing a recovery of noise damages by any person exposed to high noise annoyance, if it were to prevail in the courts, would have an economic impact that would depend on when the policy prevailed and what noise abatement policies were in effect at the time. Actions brought to date have had only limited success and awards have usually been small lump sums when awarded. Additional damages in such cases are only awarded if noise levels substantially increase. Therefore, the same amount of noise can continue indefinitely once compensation has been paid. Obviously, there is no incentive to decrease noise levels after compensation.

Compensation payments, then, will not solve the noise environment problem; furthermore, with the setting of public health and welfare criteria, additional actions may have to be taken to protect the public. This suggests that litigation costs are only one element of a total cost to achieve a cumulative noise environment. In addition, dollars for this element are absorbed locally and divert resources from a national solution.

The measure of damages normally is based upon the difference between the property value before and after the high noise levels began. Traditionally, the amount of the damages is ascertained by the use of expert appraisers, with the court often

*In this section only lawsuits against airports are considered. Condemnation proceedings by airports against real estate holders to create clear zones are not discussed. The magnitudes of money involved can also run in the hundred of millions.

splitting the difference or using average values of the evidence introduced. Recently, however, there have been instances of the courts at least considering technical data. In a recent case the Federal Court for the District of Connecticut used a geometric formula derived from an article in the Appraisal Journal (10.4-271).

A California court has gone so far as to consider the Noise Exposure Forecast value for the property in question. Although the amount of the award was not based on the actual NEF exposure, the Court did use the concept to identify which pieces of property were eligible to plead for recovery (10.4-425). In light of these instances it is not unreasonable to anticipate the courts at some future date basing damages on a formula similar in concept to that used in this latter case.

Extending this rationale to past court award history which, incidentally, has only occurred in exposure contours of 40 NEF and above, the formula used to calculate potential damage is \$53 per person per unit change in NEF value.*

Using the demographic data developed by Task Group 3 efforts, Figure 4-1 was developed. Shown in this figure is the estimated national 1972 population within each NEF contour generated by aircraft/airport activity. No attempt will be made to forecast population changes with time for this distribution. Since the award history is relevant for levels of 40 NEF and above, only those people currently exposed to such levels appear to have the best chance of successful suit. Based on the national population by noise exposure level, it is estimated that there are some 1.5 million people exposed to such levels. If one assumes a perfect information transfer to this population, it is reasonable to expect that the total population within such contours will seek legal relief. Assuming further that each person receives legal relief, then the level of potential damage awards in 1973 dollars, is calculated to be approximately 300 million dollars. Court costs should also be added to this potential damage estimate.

It should be recognized that this estimate is based on past court proceedings. Where public health and welfare noise exposure standards as established by the EPA, an entirely new dimension of litigation approaches could envolve and result in even more litigation awards. Since the incidence of this type of litigation is by airport, it then follows that those airports with the most severe noise problems face the highest potential legal costs and social and political pressures.

*This number was developed by dividing the national average of people per household (3.5) into the historical average of court awards per unit change in NEF (10.4-271).

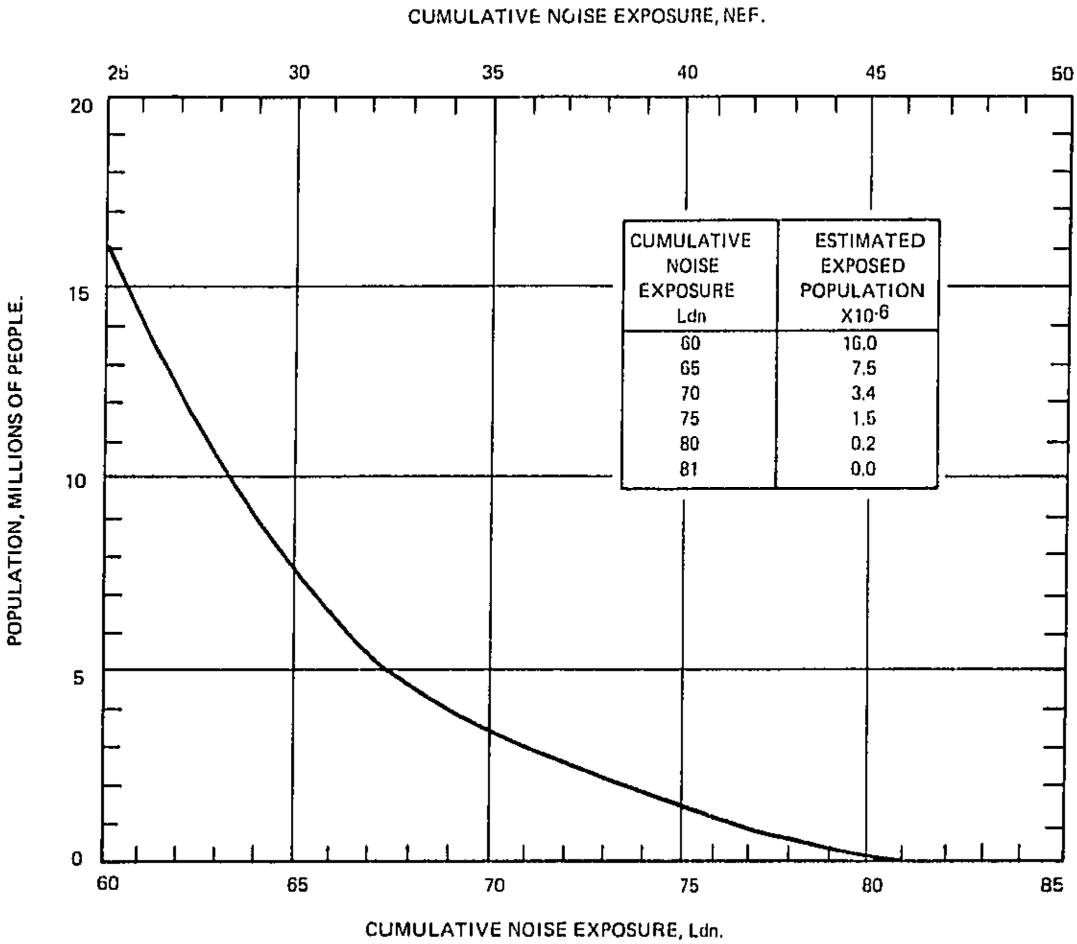


Figure 4-1. Estimated Number of People Impacted by Aircraft Noise-1972 Baseline

If an aggressive, national airport environmental noise abatement policy is followed, there is less chance that the courts will liberalize awards. If any awards are granted, they will be relatively small. If abatement policies are not pursued, it is more likely that the courts will act, that they will act sooner, and that there will be correspondingly higher damage awards. This is just one basis, i.e., the avoidance of perceived potential damage costs, on which the relative attractiveness of other strategy alternatives could be determined.

The Cost of a National 10 P.M.-7 A.M. Curfew

Faced with such magnitudes of potential damage awards, it is possible that if a source noise reduction program is not adopted on a Federal level, airport operators will take independent action to avoid and/or reduce the amounts of potential damage awards. One of the most dramatic actions that can be taken is the imposition of a night-time curfew. As soon as it is apparent that no Federal program will be undertaken, it is assumed that the operators will undertake independent actions resulting in a national curfew and maintain it until effective noise reduction alternatives become available.* The assumption is made that the curfew will be instituted in 1974 and maintained until at least 1980 when quieter aircraft could become available. Because there is little factual data available on the costs of curfews, the implications of this policy alternative requires more detailed analysis than the preceding alternatives to develop at least a minimum cost impact estimate and a perspective as to whether public convenience will be adversely affected.

The impact of a curfew can be broken down into the following areas:

- Impact on passenger service
- Impact on air cargo service
- Impact on mail and express
- Impact on maintenance and repair activities
- Impact on international operations

*Underlying this assumption are the further ones that the operators of the airports are the owners such that the Burbank ruling is satisfied and also that the FAA allows such actions to occur. Further details on the Burbank ruling may be found in Ref. 10.4-425.

Actually, there are some airports where no curfew would be needed or where less restrictive limits could be imposed. The transfer of some maintenance and freight operations to these airports would lessen the economic loss to an area, if, and only if, the noise exposure at these airports does not increase as a result of the activity transfers. The detailed-analysis of the costs incurred by category may be found in an annex at the end of this chapter. (See Page 4-59)

The Noise Reduction Effectiveness of a Curfew

Most techniques for measuring the cumulative effects of aircraft operations over time place a heavier annoyance weighting on nighttime operations than those during the day. The Cumulative Noise Forecast method considers a flight between 10 p.m. and 7 a.m. to be as intrusive as would a higher multiple of daytime flights. As a result, the elimination of these heavily weighted night operations through the imposition of a curfew yields a dramatic reduction in L_{dn} levels with a corresponding decrease in the land area within any given L_{dn} contour.

Applying the mathematics of L_{dn} construction to the assumptions used in determining curfew costs (i.e., 15 percent of the present total operations occur during the proposed curfew period, 1/3 of the cancelled flights could be shifted to non-curfew hours and 1/3 could be rescheduled with new aircraft), calculations show that a 10 p.m. to 7 a.m. curfew would result in a 5 to 6-dB reduction, which in turn would reduce the land area exposed to any L_{dn} level by approximately 60 percent. Since the assumption that 15 percent of the present total operations occur during the curfew period is based on national statistics, a further verification of this estimate was made. The weighted average percentage of night time operations at twelve of the nation's most active and noise impacted airports was found to be 11 percent. Using L_{dn} mathematics, a curfew implementation at these airports would result in an average 3 dB environmental noise reduction at each airport which in turn would reduce the land areas exposed to any L_{dn} level by approximately 35 percent (10.4-441). Such impacted area reductions are significant and it follows that if such a curfew were implemented, potential damage costs would then be reduced proportionally. This reduction would be in addition to any other noise abatement technique employed and would be based on the total land area exposed at the time of the curfew's implementation.

Summary of Curfew Costs and Institutional Effects

The curfew investigation found that a national curfew implementation would affect maintenance, mail and express, air cargo and passenger operations. The major impacts on the national airline system are the costs associated with the additional delay times. Airline operating costs can also be affected through the purchase of additional aircraft, and the hiring of crews to fly them, so as to make up the capacity lost by the inability to move or pre-position aircraft at night. The effects on cargo, assuming the shippers can adjust their schedules, are the relatively small loss of business. The effects on mail and express may be such that public convenience would be affected if the peak volume periods for mail processing cannot be shifted to meet the departure and delivery requirements of a national curfew. A summary of the estimated curfew induced costs are shown in Table 4-1. Finally, by implementing a national curfew, the airport operators are able to avoid a significant portion of the estimated potential damage awards and the costs required to protect public health and welfare once such standards are promulgated.

In retrospect, it does not appear that litigation awards will provide sufficient market incentive to trigger a national curfew. This follows from the very low success rate to date in such litigation. The real incentive to implement curfews will stem from the execution of the Noise Control Act provisions and the share of land use costs that airport operators must incur if no source abatement technology is transferred to the active civil fleet.

Capacity Limitation Agreements

In recent years, the CAB has approved several agreements between airlines competing on the same route whereby each airline reduces its flight frequency along the subject route. Under such agreements the amount of equipment necessary to service the route and its user volume is less, as are the airlines' costs. The financial results of these agreements have been dramatic in that significantly higher profits have been realized, by each participating airline, relative to the same user traffic levels which existed before the agreements.

Understandably, the question then arises as to what extent can the frequency of flights within the national network be reduced so as to provide some national noise

TABLE 4-1. SUMMARY OF CURFEW COSTS

MILLIONS OF 1973 DOLLARS

YEAR	DELAY TIMES (000 MINUTES)	AIRLINE OPS. COST INCREASE (1)	AIRLINE LOST CARGO REVS. (2)	AIRLINE DELAY COSTS (3)	USER DELAY COSTS (4)	TOTAL (5)
1974	5139.8	7.30	3.77	39.06	36.06	86.19
1975	5353.4	7.83	4.13	40.68	37.56	90.20
1976	5567.4	8.40	4.51	42.31	39.06	94.28
1977	5781.2	9.06	4.92	43.93	40.56	98.47
1978	5995.1	9.73	5.37	45.56	42.06	102.72
1979	6208.9	10.54	5.87	47.18	43.56	107.45
1980	6422.7	11.37	6.22	48.81	45.06	111.46
	TOTALS	64.23	34.79	307.53	283.92	690.77

SOURCE: REF 8.4-182

relief around airports? The answer to this question is little or none at all! This follows from the apparent industry viewpoint of a conservative system in operation.* Given a national level of capacity, then if less capacity is carrying more users in one portion of the system, the remaining capacity can be re-allocated among the other routes. Therefore, if the same frequency of flights to maintain this capacity occurs, then the national noise problem is not changed significantly. What may change are the levels around some airports where some might decline while at others, receiving greater numbers of flights, the levels may increase.

Where such agreements may be of utility to the airlines is in offsetting the 5 percent additional capacity requirement created by the implementation of a nation curfew. If this could be offset, then the operating costs shown in column (1) of Table 4-1 may be avoided by the airlines. There would also be some reduction in this industry's demand for fuel. To date, there are not sufficient data to analyze this possibility.

Implementation of Land Use and Receiver Treatment Alternatives

Only one of the legal and administrative response areas (i.e., a national curfew) so far investigated will result in a reduction of the general noise environment around the nation's airports.** Given the promulgation and enforcement of a national noise exposure standard, and the situation where no source abatement technology is transferred to the exposure civil aviation fleet, the only completely effective alternatives to public protection are noise compatible land use control options.***

The responsibility for exercising land use control options are shared by the airport operators and the Federal, State and local governments depending upon the size

*This is the essence of competing airline responses in CAB hearings, where the assertions are made that excess capacity taken off one route is dumped on another.

**It is acknowledged that aircraft operational procedures, when implemented, will reduce the NEF contours and the amount of population exposed to aircraft activity generated high noise environments. However, these procedures will not completely protect the nationally impacted public. It is in this sense that the term completely effective is used.

***In setting the noise exposure standard, it has been assumed that technological practicability, safety and economic reasonableness relative to all of the options available to achieve the desired levels, have been considered. Thus the discussion here is in the context that land use and receiver treatment options are feasible under the considerations discussed.

of the noise impacted areas and the political jurisdictions that control its welfare. Implementation of this type of alternative can require the removal of population from areas of noise exposure greater than the public health standard, the noise reduction treatment of private and public structures in the areas where noise affects public welfare, and the denial via zoning restrictions of any current and future land use developments that are not compatible with the noise environment.

New airport development shall be assumed to occur only if noise compatible land uses occur concurrently. For airports already in existence, the costs of zoning restrictions precluding already planned development will not be estimated. The estimate to be developed is the cost of protecting people in areas where the noise environment exceeds the public health and welfare standards. The type of protection employed must result in an environment that is not in violation of these standards.

The Unit Cost Curves

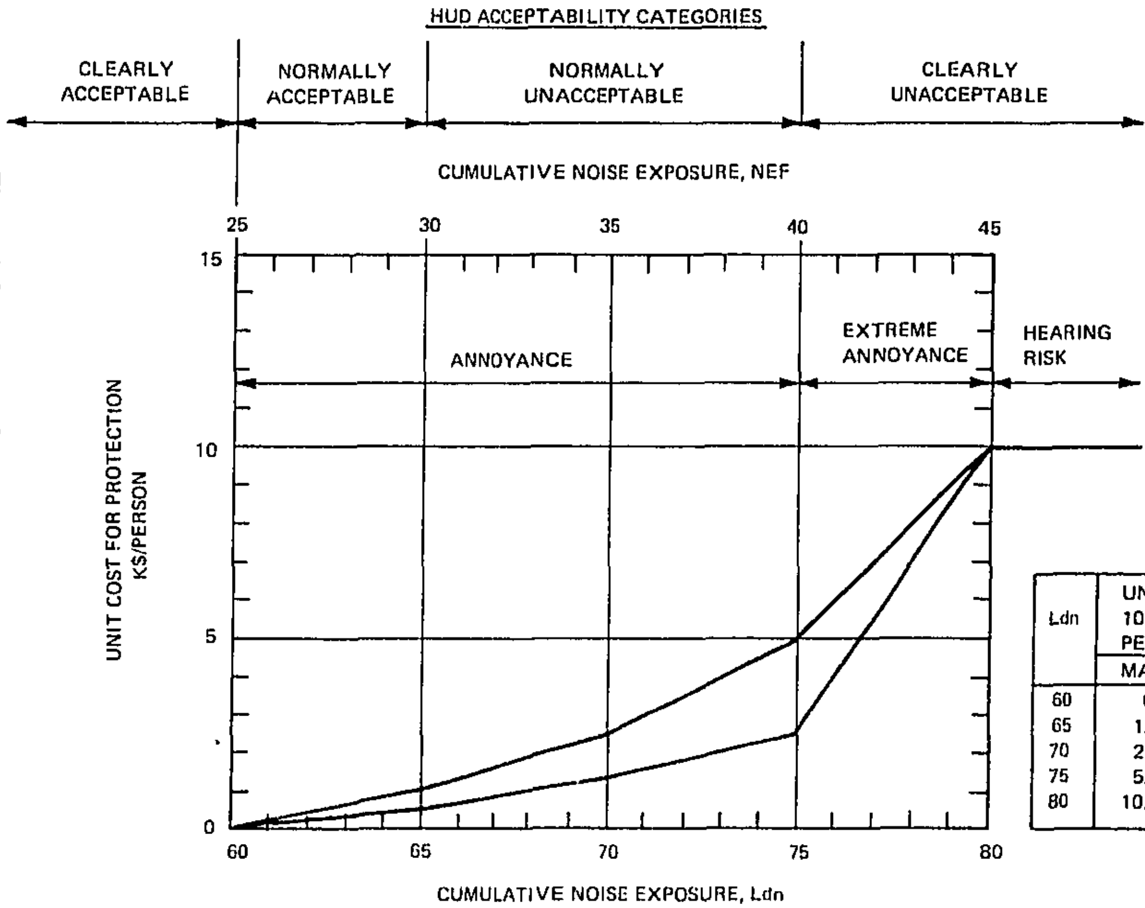
The Task Group 3 report (10.4-427) indicates that persons exposed to exterior cumulative noise levels (L_{dn}) of 80 dB or above are exposed to a significant risk of a decrease in hearing acuity. Persons exposed to exterior L_{dn} levels of 75 through 80 dB are subject to extreme annoyance from the intrusion of noise and the effects such intrusion has on their daily activities. The degree of annoyance decreases with corresponding decreases in L_{dn}. An exterior L_{dn} of 60 dB is apparently the threshold where activity interruption is not significant enough to generate substantial numbers of complaints.

Using these levels as a guideline, the rule of public protection employed in the cost calculations is that every person exposed to L_{dn} = 60 dB or greater must be protected. Actions taken to reduce a person's environment to this level, or less, range from relocation to insulating structures.

For levels of L_{dn} of 80 dB or greater, no structures treatment technologies are feasible (12.2-291). The only feasible land use alternative is the conversion of the existing land uses to those which are noise compatible. In a study for the Aviation Advisory Commission (Reference 7.1-99) just such an estimate was developed for the costs of converting incompatible land uses within L_{dn} = 80 dB around 11 airports. The estimate, developed in 1972 dollars, was $16,000 per person relocated. The cost consisted of acquiring all incompatible land uses, relocating the people at no expense to them, razing the structures and packaging the land into noise compatible land use parcels. Consequently, most of the infrastructure costs of neighborhoods were captured in this effort. There are, however, several shortcomings in using this estimate. First, the 80 L_{dn} contours under which this estimate was developed were for the year 1985. The current 80 L_{dn} contours are larger and contain more people and incompatible land uses. Secondly, no allowance was made in the development of this estimate for the recovery of the conversion investment. This was primarily due to the lack of information on the timing and sales rates that could reasonably be expected. Assuming that the same infrastructure relationships more or less obtain, then although larger land areas are currently involved the conversion costs per person will remain relatively stable. Making an allowance for investment recovery, it is assumed that 50 percent of the property acquisition costs (1/3 of the total conversion costs) can be recovered during the time period of interest. These assumptions result in a 1973 dollar estimate of $10,000 per person relocated and will be used in this analysis.

For levels of L_{dn} less than 80 dB there exist structure treatment technologies which, if implemented, will insure that noise intrusion will not affect the daily activities of the public inside the treated structures (12.2-291). It should be noted that implementating structure treatment technologies makes no provisions for the effect of noise on the outdoor environment, i.e., it requires the impacted public to remain inside acoustically treated homes to avoid the annoyance caused by aircraft operations. Consequently, estimates developed from the structure technologies approach are conservative in the welfare sense that <u>all</u> public activities should not be affected by noise intrusion. The average treatment cost utilized has been put on a per capita basis to facilitate computations. In 1973 dollars the levels per person used were $2500 per person for 13-17 dB reductions, $1400 per person for 8 to 12 dB reductions and $500 per person for 3 to 7 dB reductions.

Using the data presented above, the lower curve shown in Figure 4-2 has been constructed. It represents the minimum land use and receiver treatment costs per person per unit (dB) of cumulative noise exposure. Use of this curve does not allow for public choice, when it is applicable, of having one's structure soundproofed or



Ldn	UNIT COST 1000 $ PER PERSON	
	MAX	MIN
60	0	0
65	1.0	0.5
70	2.5	1.4
75	5.0	2.5
80	10.0	10.0

Figure 4-2. Estimated Unit Cost for Noise Compatible Land Use Control

choosing to leave the high noise environment at no cost.* The upper curve has been developed to present a more probable outcome of having the public choose its protection techniques. Its construction assumed that all persons severely annoyed in the population exposed to L_{dn} levels of 75-80 dB would choose to relocate at a cost of $10,000, the rest of the exposed population will choose to remain in the area and have their dwellings soundproofed. Between the L_{dn} range of 65-75 dB only one half of the annoyed population will choose to relocate. Finally, at L_{dn} = 30 dB, none of the people annoyed will choose to relocate. Included on this figure are the HUD acceptability categories. A fuller explanation of these may be found in Table 4-2.

Baseline Land Use and Receiver Treatment Costs

Supplied with a set of unit cost curves, the estimated national distribution of population exposed to various levels of noise in 1972, and the percentages of exposed populations that are annoyed,** one can develop a national estimate of the costs to protect the public from noise pollution using only land use and receiver treatment options. Exercising these data, the total cost of this option is estimated to be in the range of 21 to 31.5 billions of 1973 dollars. How these costs cumulate by cumulative exposure level are shown in Figure 4-3.

Summary of the Null Findings and Implications

Several possible implications of a strategy of not implementing source noise reduction technologies have been examined. It has been estimated that potential litigation awards could total $300 million 1973 dollars. However, the realization of such an award level would require some fundamental changes in the law currently utilized in such litigation. As this likelihood is small, then the expected actual awards should also be small. In addition, the incidence of such awards first falls on the airport operator who may or may not be able to pass these costs on to the airlines. The

*It should be noted that not all persons exposed to high noise environments are annoyed. In general, the higher the noise environment, the greater will be the percentage of exposed population annoyed. For a complete discussion see the report of Task Group 3 (10.4-427).

**See summary table in section 4-G of the Task Group 3 Report. (Ref. 10.4-427)

TABLE 4-2. HUD ACCEPTABILITY CATEGORIES FOR PROPOSED HOUSING SITES

Clearly Acceptable:	the noise exposure is such that both the indoor and outdoor environments are pleasant.
Normally Acceptable:	the noise exposure is great enough to be of some concern but common building construction will make the indoor environment acceptable, even for sleeping quarters, and the outdoor environment will be reasonably pleasant for recreation and play.
Normally Unacceptable:	the noise exposure is significantly more severe so that unusual and costly building constructions are necessary to ensure some tranquility indoors, and barriers must be erected between the site and prominent noise sources to make the outdoor environment tolerable.
Clearly Unacceptable:	the noise exposure at the site is so severe that the construction costs to make the indoor environment acceptable would be prohibitive and the outdoor environment would still be intolerable.

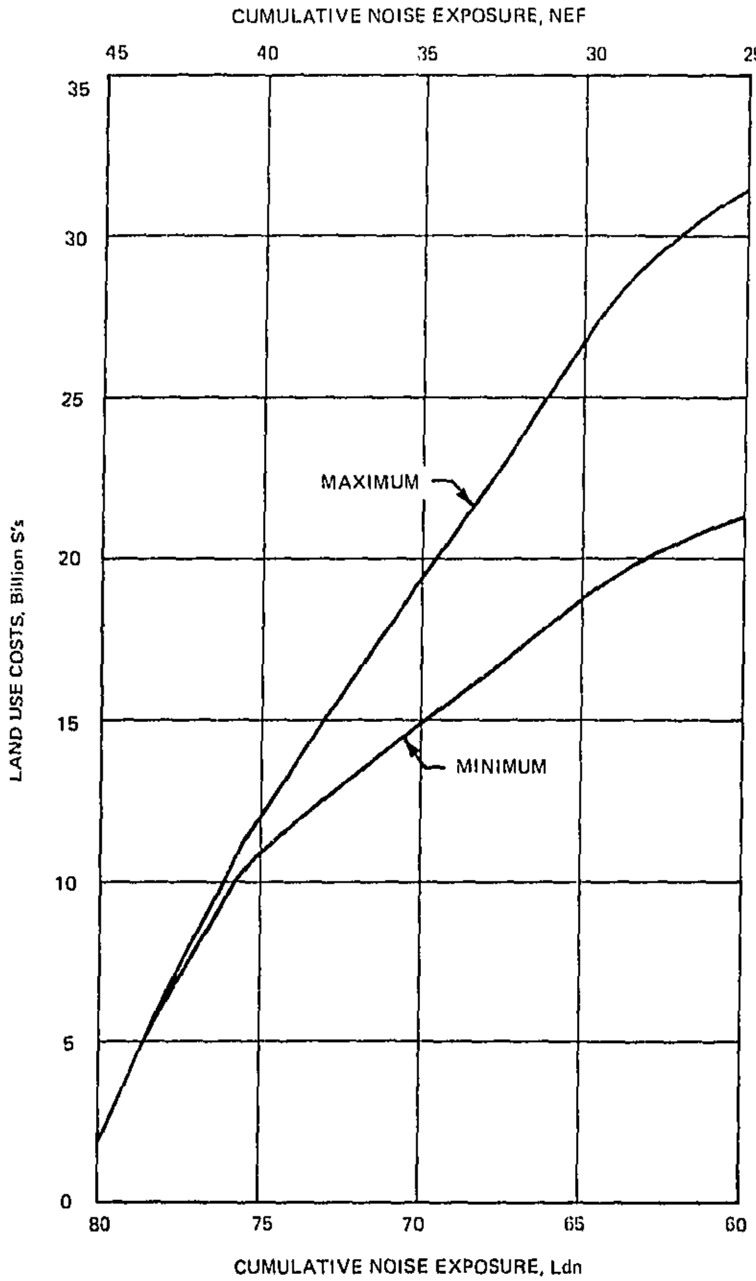


Figure 4-3. Cumulative Land Use Costs

ability to pass through such costs is a function of the type of lease each airport operator has with the airlines.

This litigation spectre is only one of the pressures that an airport operator would be under. Perhaps, just as important are the local, political, and social pressures currently being exerted. In addition, the 1972 Noise Control Act, as its provisions are being implemented will establish environmental noise exposure standards which the operator will at some point in time be required to comply with. Under such a set of pressures and circumstances, it is reasonable to expect the airport operator, knowing that source reduction technology will not be implemented, to take independent actions to reduce the extent of the airport/community noise environment problem.

One of the actions an operator may take is to institute a night-time curfew. The implications of such independent actions when they amount to a national 10:00 p.m. to 7:00 a.m. curfew on aircraft flights have also been examined. Although the cost estimate developed is admittedly conservative, the estimated total six year cost of such a curfew is approximately $700 million. Slightly over half of this cost is initially incurred by the airlines, the remainder is incurred by the users. This estimate was developed under the assumption that airline users could adjust their transportation requirements to schedules that comply with the curfews. Where this structural response is not valid, the costs of the curfew are understated. However, the effectiveness of a national curfew is estimated to result in a 35 to 60 percent reduction in the land areas exposed to high noise environments.

A cursory examination of whether increasing approval of capacity limitation agreements would help alleviate the noise environment problem around airports revealed that this trend would not be very effective for this problem. It could, however, aid airlines to earn higher profits and reduce the operating fuel requirements of this industry.

Since the airport operator can also be a paying partner in the land use options to alleviate the subject problem, estimates of these options were also developed. The total cost range of a land use and receiver treatment option to achieve a L_{dn} = 60 dB environment has been estimated to be $21 to 31.5 billion. Although the extent of the operator's participation in this option has yet to be determined, it should be expected that it will be significant and provide the real incentives for the operators to take actions to reduce the noise environments around their respective airports.

Given the magnitude of the costs associated with some of the possible responses to a decision not to implement source noise reduction technology into the current civil aviation fleet, a more rational solution to this conflict problem must be identified.

CURRENT TECHNOLOGY OPTIONS

The objective of the following analysis is to investigate whether transferring current noise reduction technology into the civil fleet of this nation would have more desirable financial and economic results in achieving various cumulative noise levels, than those developed in the previous discussion. Initially, commercial and general aviation fleet modification strategies, resulting in reduced noise impacts around airports, are developed from the available options. Estimation of the costs and noise impact effectiveness associated with each strategy are then generated. From these data the economics of achieving various cumulative noise levels are developed for each fleet modification strategy. *

The Relationship of the Options to Fleet Modification Strategies

The four basic technology options available during the time period of interest (1973-1985) are the nacelle retrofit, engine refan retrofit, engine replacement and aircraft replacement. These latter two options are not investigated here for the commercial fleet because of the scarcity of effectiveness data and their high program costs. The remaining options, nacelle and engine refan retrofits, may be used individually or in combination on various types of aircraft in the commercial airline fleet. They may also be used in conjunction with aircraft operational procedures.

Time plays an important role because of the dynamics of change both with respect to fleet mix and numbers of operations. Given the fact that the new high-bypass ratio engine aircraft are quieter than existing narrow-body aircraft, and that presumably future aircraft will be even quieter, the expected long run trend is for reduction in

*The data and findings of Ref. 8.5-355 are used extensively in this study.

airport noise. This trend has not been reflected in the null case just discussed as it was examined from the viewpoint of short term potential public reactions in the previous section.

Understandably, the timing of the commercial aviation retrofit programs will have a significant impact on the overall effectiveness of the program relative to the public protection requirements. Schedules developed in Ref. S.5-355 for retrofit implementation were based upon current and proposed regulatory actions and the status of the ongoing FAA and NASA research programs. These schedules are realistic but do not represent a commitment on the part of the Government to any specific regulatory or program action. For this analysis the schedules are:

- Nacelle retrofit on all JT8D engine aircraft starting in early 1975 and JT3D engine aircraft starting in late 1975, all airplanes completed by July 1, 1978.
- Refanned engine retrofit on all JT8D engined aircraft starting near the end of 1976, complete by December 31, 1979.
- Refanned engine retrofit on all JT3D engine aircraft starting near the end of 1977, complete by December 31, 1980 (included for comparative purposes only. Program support discontinued by the Government in January, 1973).
- Operational change in 1973, 3000 foot approach altitude until intercept of a 3^{o} glide slope.
- Operational change starting in mid-1974 and completed by the end of 1978, 3000 foot approach altitude until intercept of a 6^{o} glide slope to 1,200 foot transition to a 3^{o} glide slope by 800 foot altitude.

Seven combinations of the commercial aviation SAM and REFAN retrofit options were analyzed. They were:

1. SAM 8D — Retrofit all JT8D engined airplanes with acoustically treated nacelles.
2. SAM 3D — Retrofit all JT3D engined airplanes with acoustically treated nacelles.
3. SAM 8D/3D — Retrofit all JT3D and JT8D engined airplanes with acoustically treated nacelles.

4. RFN 727/ SAM rest — Retrofit the B-727 with refanned engines and the other JT3D and JT8D engined airplanes with acoustically treated ancelles.

5. RFN 8D — Retrofit the JT8D engined airplanes with refanned engines; including aircraft produced with "quiet" nacelles prior to start of refan retrofit.

6. RFN 8D/ SAM 3D — Retrofit the JT8D engined airplanes with refanned engines and the JT3D engined airplanes with acoustically treated nacelles.

7. RFN 8D/3D — Retrofit all JT3D and JT8D engined airplanes with refanned engines.

It was further assumed that all aircraft produced after the start of the retrofit program would be produced with the appropriate engine/nacelle configuration to keep newly produced airplanes at the same level as the retrofit airplanes. Figure 4-4 depicts the schedule start and completion times for each option during the time period of interest.

As discussed in Sections IV-1 and 2 of this report, the jet powered aircraft in the general aviation fleet are expected to increase in number at a much more rapid rate than those in the air carrier fleet. New aircraft introduced into this fleet will, in general, probably take advantage of the operating economics associated with the turbofan engines and, therefore, also produce less noise. However, a major portion of the existing fleet is powered by turbojet or very low bypass turbofan engines. Noise suppression kits, including modified exhaust nozzles and sound absorbing materials, and/or engine replacements for the existing aircraft are being considered. Specific considerations are detailed in Section IV-2 of this report. For the purposes of this study, it is assumed that each type of general aviation aircraft will have the appropriate retrofit option implemented by 1978 such that it complies with the current FAR-36 requirements.

Retrofit Effectiveness Measure

Retrofit effectiveness can be measured in a number of different ways: noise reduction at a given set of points on the ground; reduction in the size of the noise footprint for a single takeoff and landing; reduction in the noise impacted population around airports using some criterion measure which incorporates the noise effect

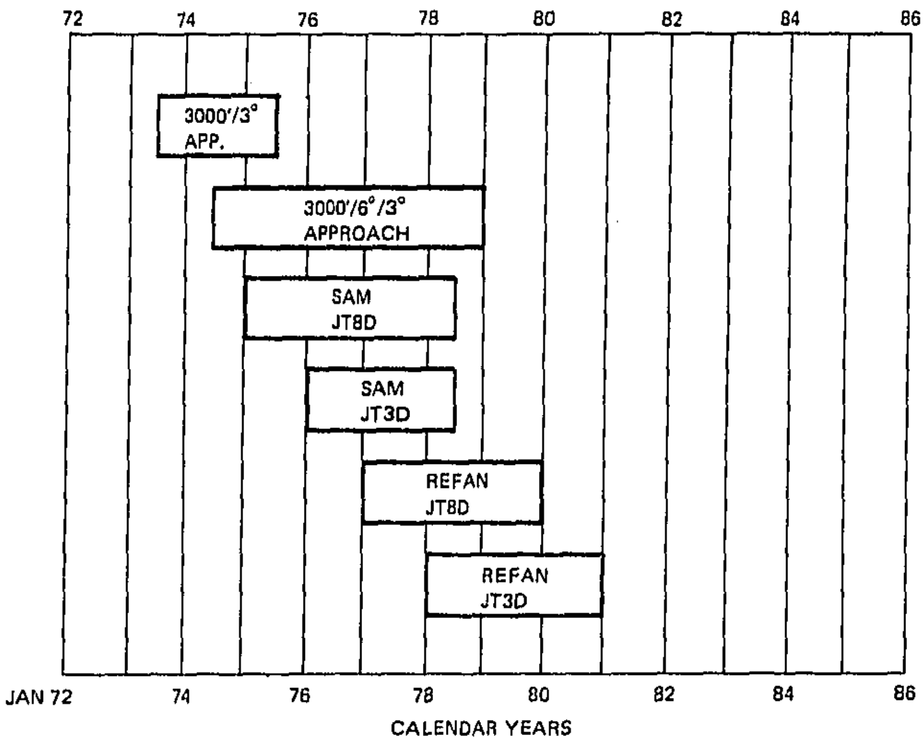


Figure 4-4. Estimated Schedules for Approach Procedures and Retrofit Implementation

of all aircraft operating at that airport. This latter criterion measure (reduction in impacted population) is used to judge program effectiveness.

Data Inputs

The baseline aircraft noise levels, the FAR 36 limits and the retrofitted aircraft noise levels used in this analysis are summarized in Figures 4-5 through 4-7 for the JT3D and JT8D powered aircraft under study by the FAA and NASA contractors. The FAR 36 data are for aircraft flying at maximum gross takeoff weights. The data for the FAA nacelles with sound absorption material (SAM) are based upon flight tests (B-707, B-727, B-737, DC-9) or analytical studies (DC-8). Recent flight test data for the Boeing 707 with acoustically treated nacelles have not been fully analyzed, but give high confidence to ground test estimates. A range of data has been presented for the NASA Refan Program since the effort to date is basically analytical and has not progressed to the point where a final configuration (engine and nacelle) can be selected.

The refanned JT3D aircraft (707 & DC-8) are included, although Government funding for this program has been terminated. At the present time the maximum refan treatment used in this analysis has been dropped by the NASA program and the more probable configuration is the minimum refan. The maximum and minimum refan reductions are also depicted in the above cited figures.

Analysis Approach

Given these various sets of noise output data, the important question then is how noisy will the airport environments be under relatively realistic operating conditions; i.e., a mix of takeoff profiles and aircraft types. Six airports were analyzed in considerable detail with respect to forecasted operations by aircraft type, aircraft flight procedures and airport runway/flight track utilization. The analysis of the six airports assumed maximum acoustical treatment for refan.

The analysis for each airport included the establishment of the present airport configuration, including land area (and boundaries), the heading, length and layout of usable runways, a summary of operational facilities pertinent to the airport's current and future operations and capacity including NAVAIDS and taxiways.

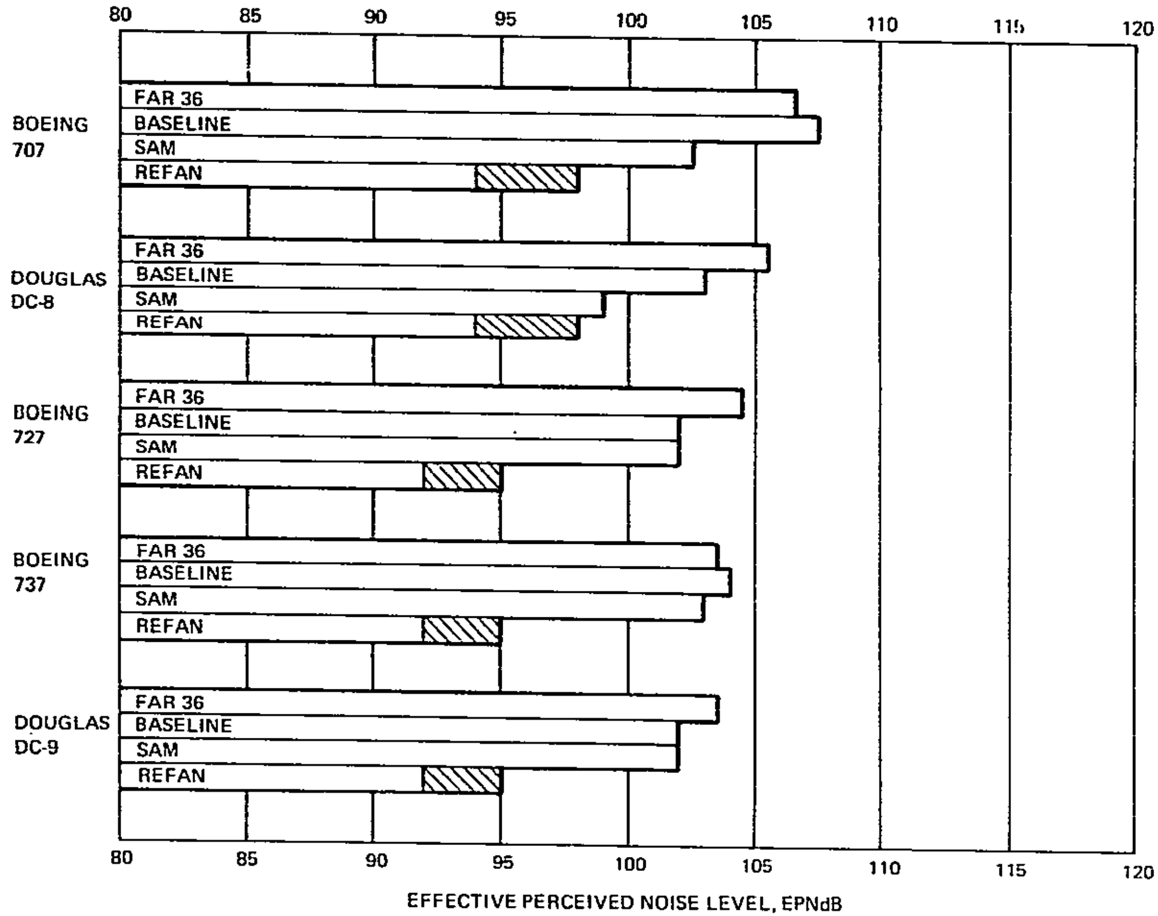


Figure 4-5. Estimated Noise Levels at FAR 36 Measuring Points.
(a) Sideline.

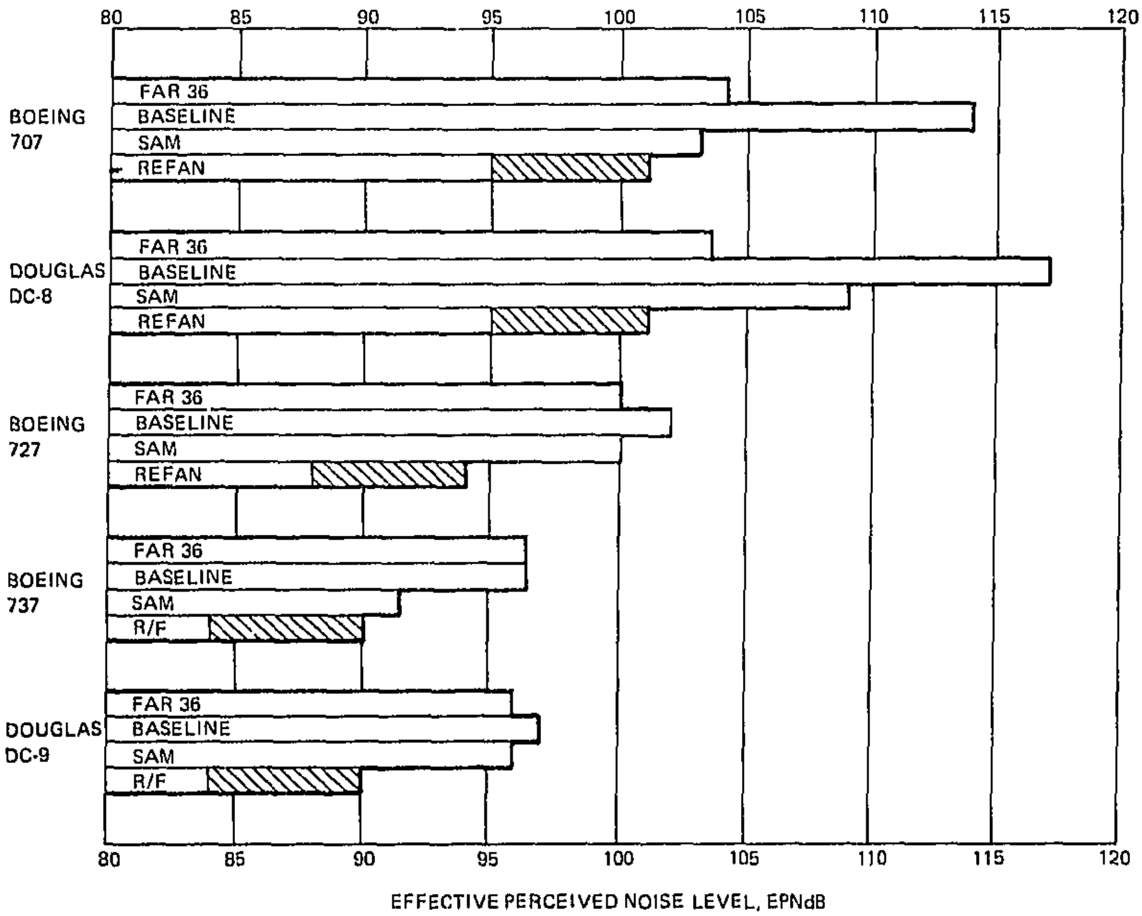


Figure 4-6. Estimated Noise Levels at FAR 36 Measuring Points.
(b) Takeoff with Cutback.

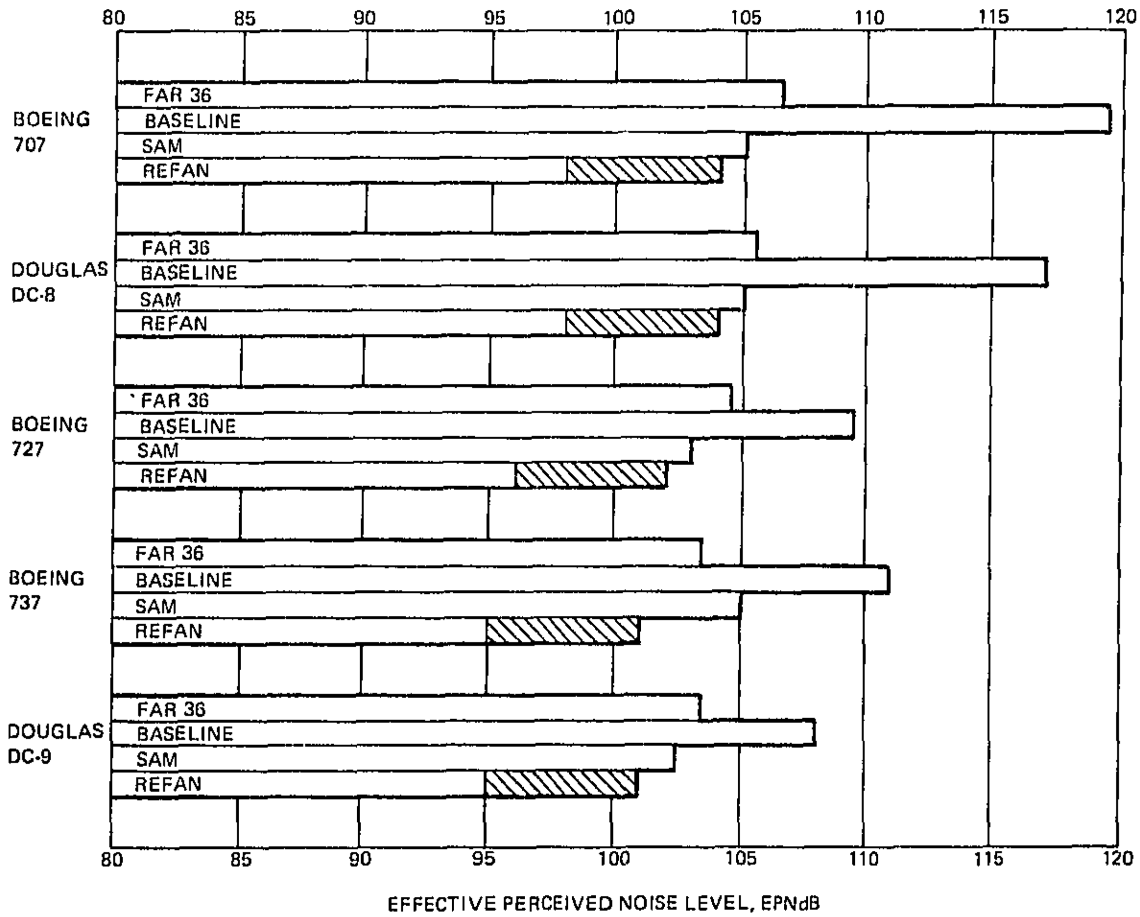


Figure 4-7. Estimated Noise Levels at FAR 36 Measuring Points.
(c) Approach.

The statistic used to describe noise exposure around an airport is the Noise Exposure Forecast (NEF). NEF is determined by the noise levels of the individual airplanes and the total number of movements into and out of the airport. For this analysis, the number of aircraft movements representative of an average day based on an annual estimate have been established for each airport. The annual average day has been used because:

- NEF contours are not absolute measurements but are intended for comparative purposes. Therefore, the operational information utilized in developing the contours is correctly based on averaged conditions. Noise measurements made at any one time (say, over a period of a few days) may be thought of as representing a "snapshot" of the situation at that time rather than the long-term average of the NEF contours.
- NEF contours are relatively insensitive to small changes in traffic volumes.
- Total airport activity is relatively stable over periods lasting several months.

Assuming that a major portion of business jets flights are into or out of large airports, then the noise reduction impacts of these craft will be masked by commercial airline activity. However, if no modifications were made to these aircraft which now exceed the current FAR-36 levels, then regardless of what alternative is implemented for the commercial fleet, the business jet fleet would contribute more significantly to the noise impacted environment. Consequently, modification of each element of the civil aviation fleet not in compliance with the existing FAR-36 levels is assumed in this analysis since it is not only equitable but the most efficient way to reduce the noise environments around all classes of airports.

The estimated average daily operations used for the year 1972, 1978 and 1985 by major airplane categories at the six analysis airports (Atlanta, LaGuardia, Kennedy, San Francisco, Los Angeles and O'Hare) are summarized in Figures 4-8 through 13.

To reiterate, aircraft retrofits with either acoustically treated nacelles or refanned engines are intended, primarily, to alleviate the problems associated with noise around existing airports and not future airports. Future airports are expected to be built with

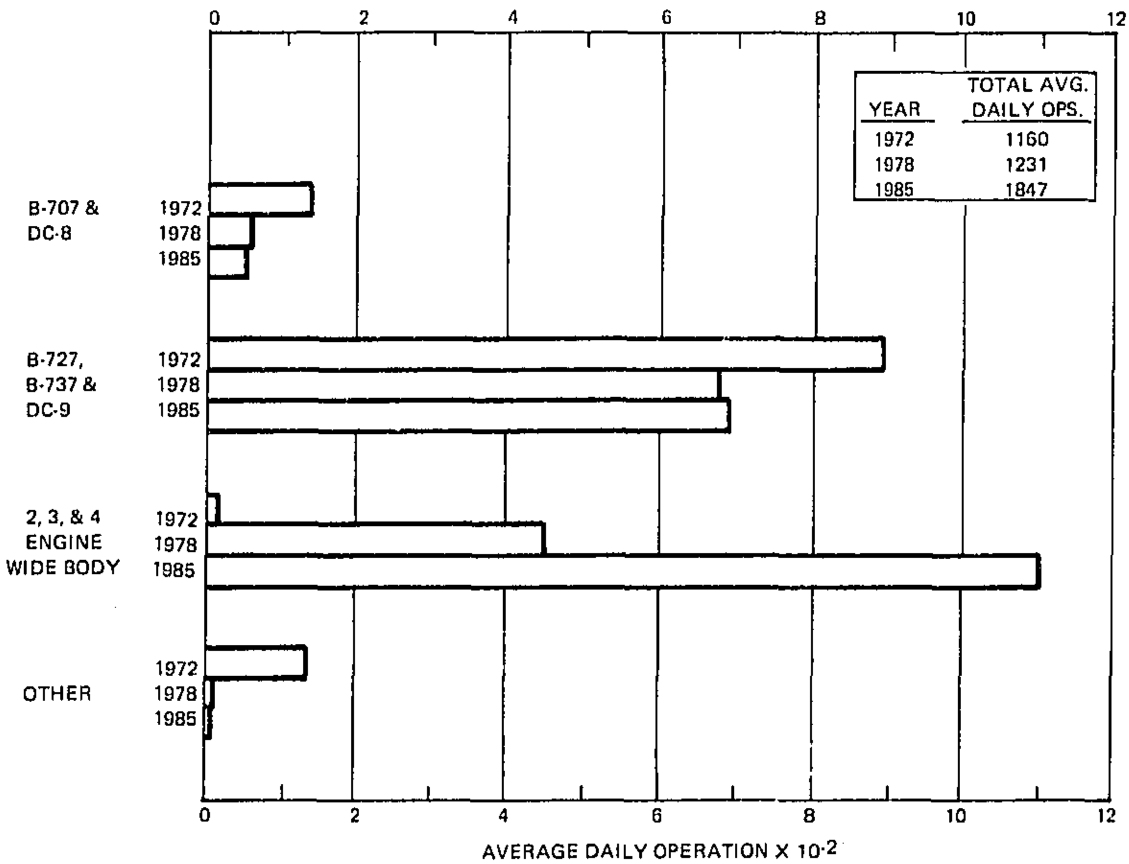


Figure 4-8. Average Daily Air Carrier Fleet Operations for 1972, 1978 & 1985—Atlanta

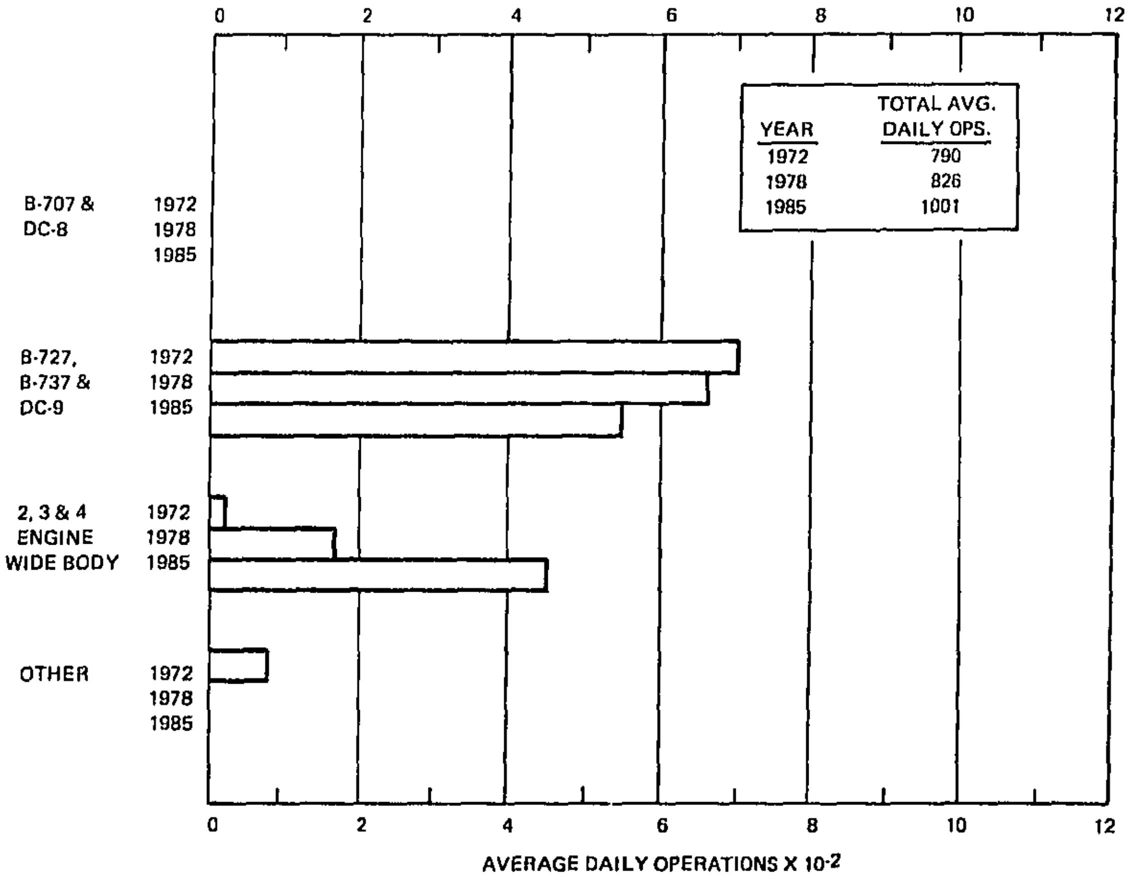


Figure 4-9. Average Daily Air Carrier Fleet Operations for 1972, 1978 & 1985—LaGuardia

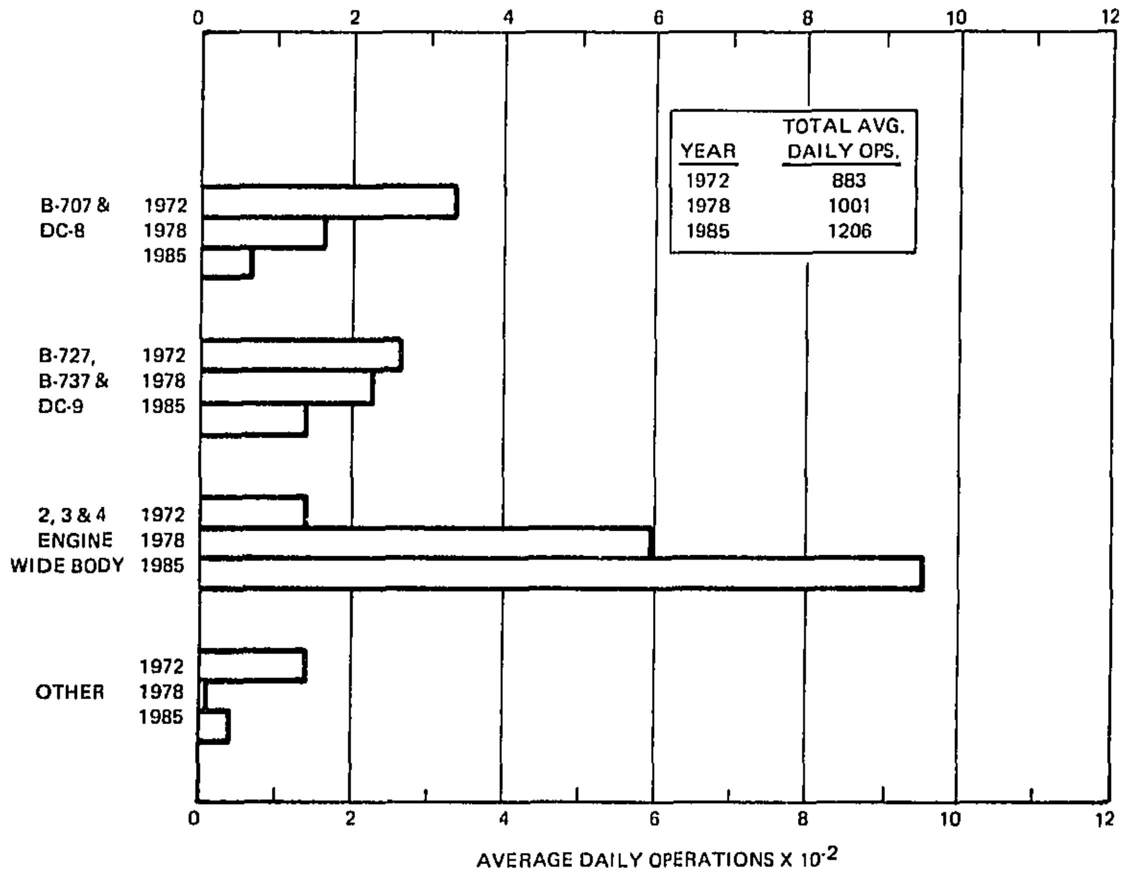


Figure 4-10. Average Daily Air Carrier Fleet Operations for 1972, 1978 & 1985—Kennedy International

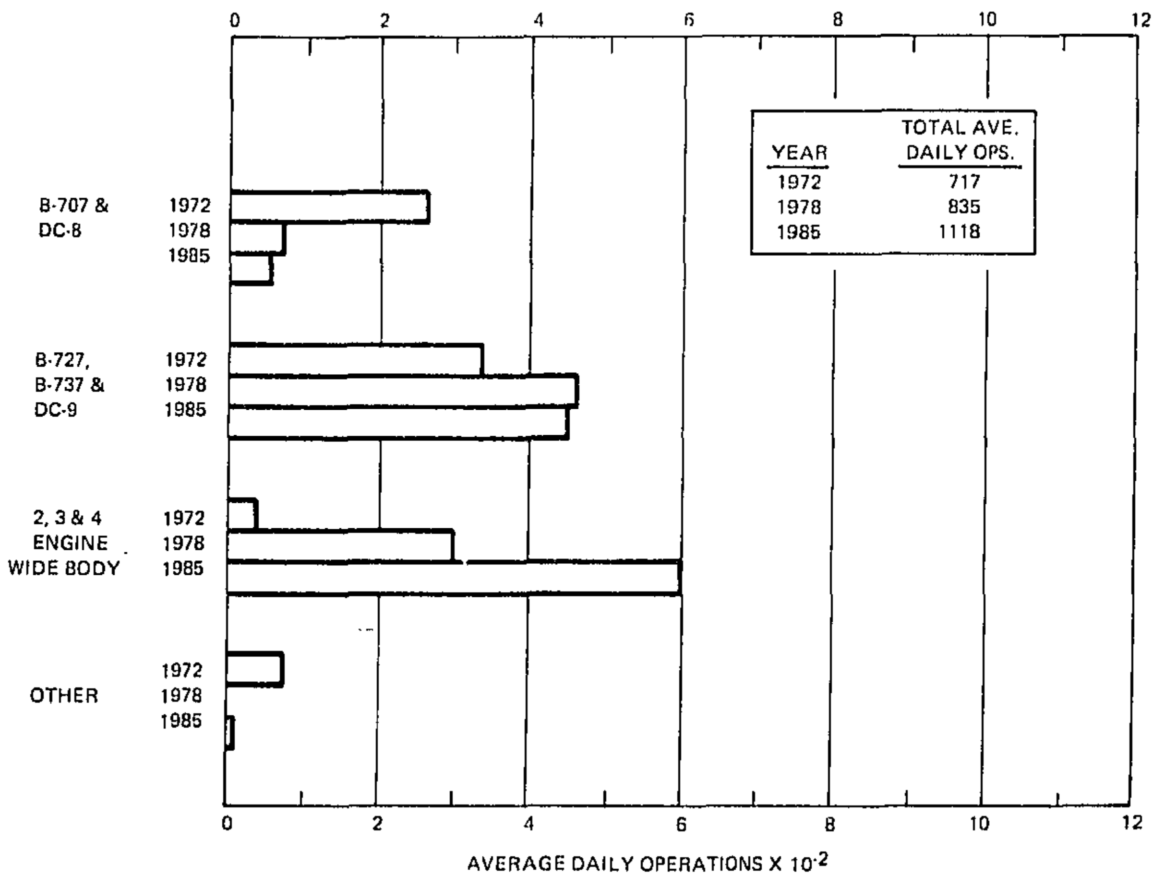


Figure 4-11. Average Daily Air Carrier Fleet Operations for 1972, 1978 & 1985—San Francisco International

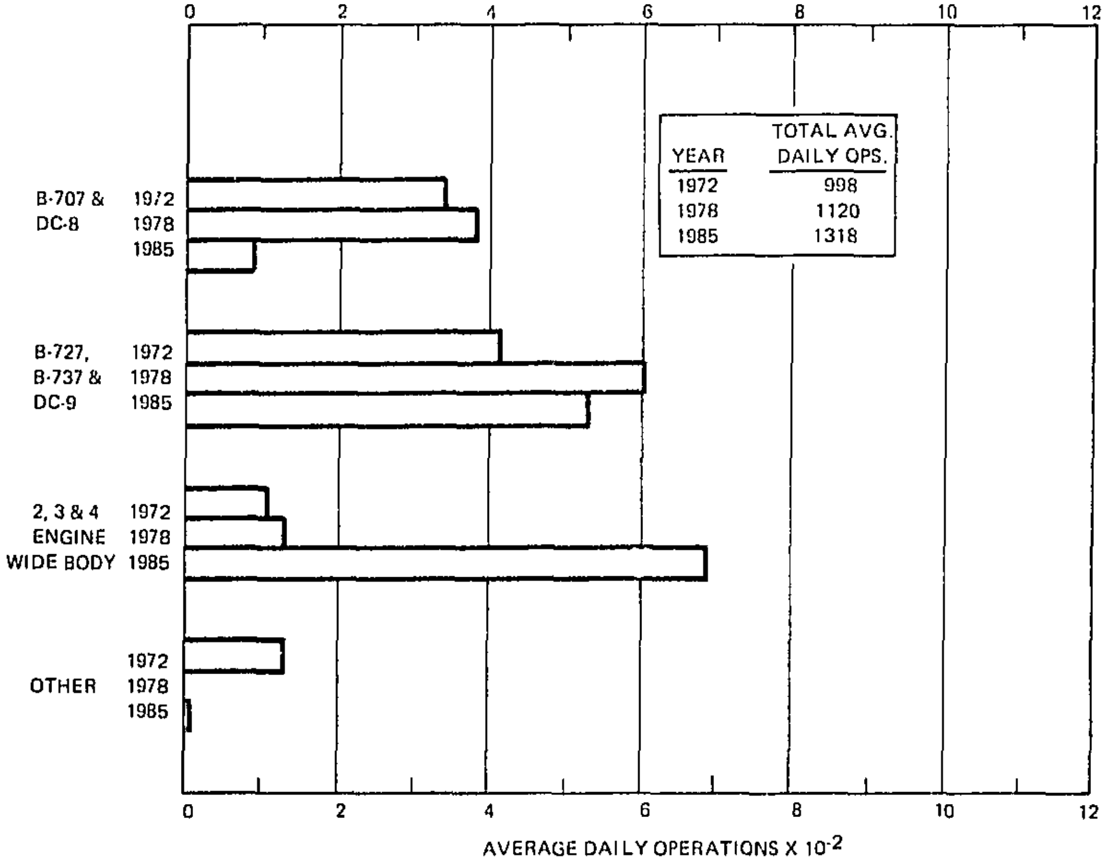


Figure 4-12. Average Daily Air Carrier Fleet Operations for 1972, 1978 & 1985—Los Angeles International

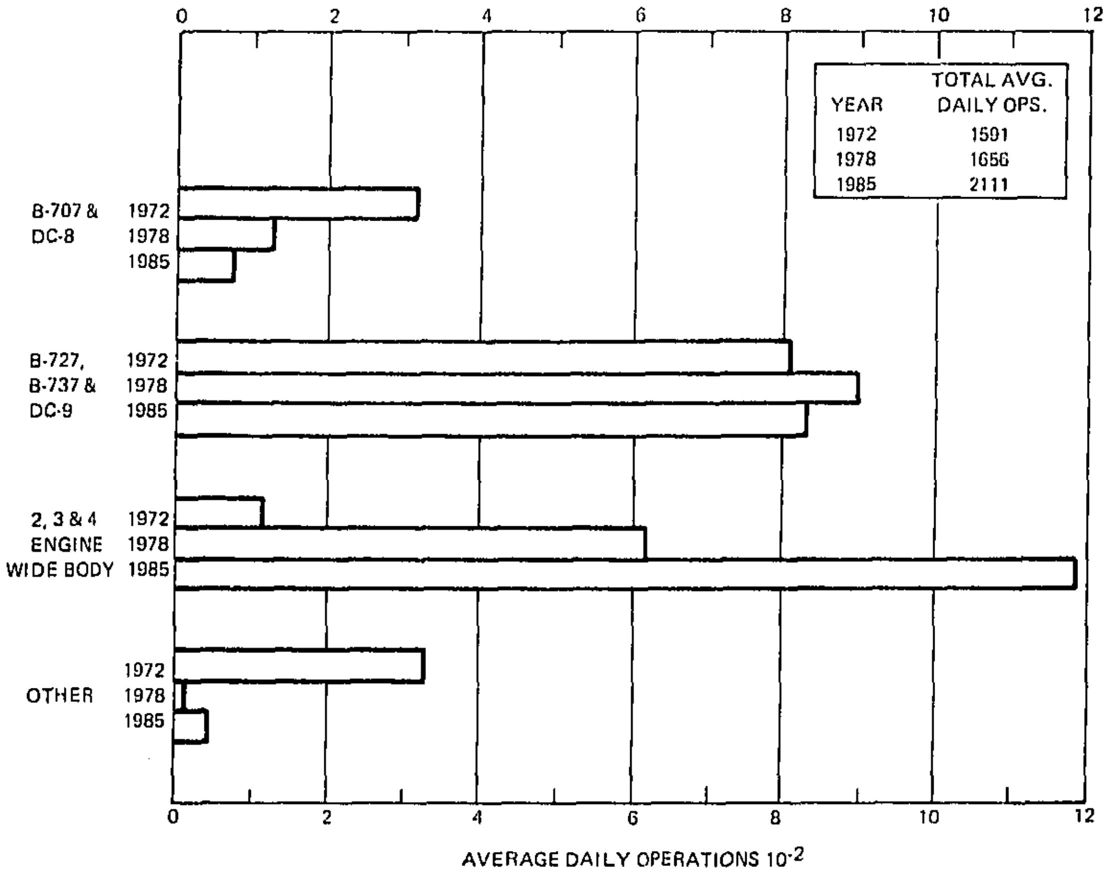


Figure 4-13. Average Daily Air Carrier Fleet Operations for 1972, 1978 & 1985—O'Hare

noise as one of the design criteria taking into account the noise levels of aircraft expected to be in use when the airport is operational. One objective of this study is to determine if source abatement technology, if applied, will reduce the total cost of achieving various cumulative noise levels. The major impact of aircraft noise has been on the people residing under or adjacent to the various flight tracks; therefore, reduction in the number of people living in noise impacted areas is the major criterion for assessing the effectiveness of any noise abatement effort. A major sub-objective of this analysis effort has been to estimate the number of people currently residing in noise impacted areas, the expected number adversely impacted in the future if there were no retrofit or change in operational procedures, and the change in the number of people impacted if a retrofit program and/or operational changes are implemented. Population estimates are based on the 1970 census. No attempt was made to forecast population changes for future years.

Analysis Results

Estimates of the population residing within the noise impacted areas for each of the airports in the analysis have been generated for the two operational alternatives and the seven retrofit options. These estimates are for 1972 (the baseline year) and the year the modification option was completed, assuming no change in population from the 1970 census estimates.

The curves of Figures 4-14 and 15 show the population effects of the baseline "do nothing" case, plus the effects of two retrofit options and modified landing procedures on population impacted by noise for the six airports studied. The relative effectiveness of the noise reduction alternatives is highly sensitive to the airport being analyzed. Some general tendencies, however, can be derived from the figures. When combined with two-segment approach, either the SAM or the Refan 8D/SAM3D retrofit will reduce the population exposed in the L_{dn} = 65 dB and 75 dB contours. With the JT8D refan/SAM3D option, the reduction in population exposed to L_{dn} = 65 dB region is significantly greater than that achieved by SAM. The extent to which this tendency will be modified by shifting to the minimum refan acoustical treatment should be determined by further analysis. One other factor should be reiterated: the SAM nacelle is currently in production or has been flight-tested on the B-707, B-727, B-737, and DC-9; the JT8D refanned engine and modified nacelle data is based upon engineering

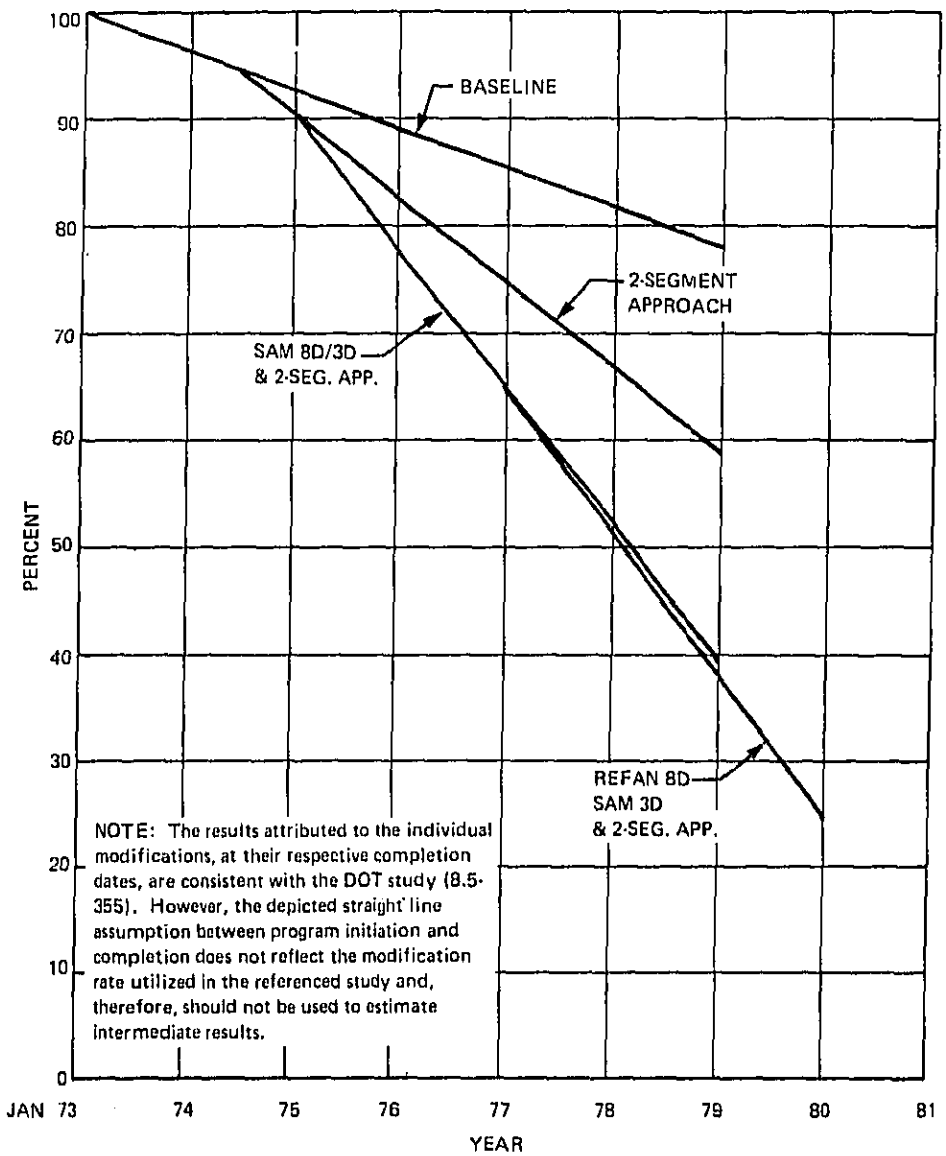


Figure 4-14. Estimated Percent Reduction in Population Impacted by Aircraft Noise—75 L_{dn} Contour (40 NEF)

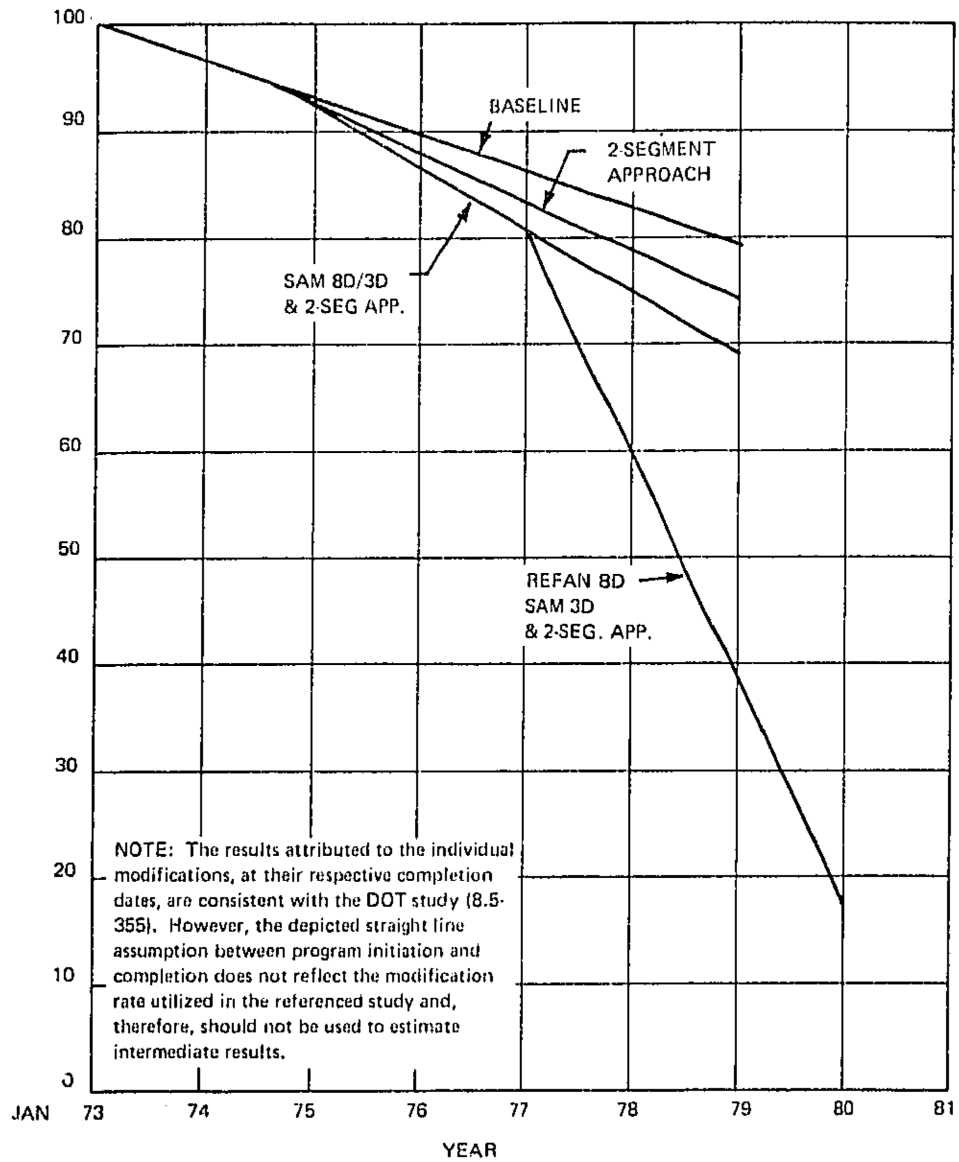


Figure 4-15. Estimated Percent Reduction in Population Impacted by Aircraft Noise—65 L_{dn} Contour (30 NEF)

analyses; and the exact configuration and degree of acoustical treatment is yet to be decided; therefore, data presented are subject to significant variation until further work is accomplished.

The difference in program timing will have an effect as to when the noise reduction can be achieved. As can be seen in the baseline case of Figures 4-14 and 15 there will be a reduction in the number of people in the L_{dn} = 65 dB and 75 dB contours between 1972 and 1978 with normal attrition and replacement of the current fleet of JT3D aircraft and new production of JT8D engined aircraft which meet FAR 36 (the Boeing 727 and 737 airplanes have been certificated in compliance with the FAR 36 noise requirements). The assumption has also been made that the population density around the airports will not change between the 1970 census data and 1978. This latter assumption depends upon proper land use planning to prevent continued encroachment in the vicinity of the airports. Such an influence is currently beyond the control of the airport operator.

There will be further reductions if the two-segment approach is implemented starting in mid-1974.

COST ANALYSIS OF RETROFIT ALTERNATIVES

The Commercial Airlines

To determine the impacts of these various fleet modification strategies on airline industry economics, several assumptions must be made on how the economy is expected to perform and whether the industry will become more efficient during the time period of interest. In general, the DOT studies from which this analysis has been performed assumed that the economy would continue to grow at a rate of 4 percent real growth per annum. In addition, an industry average flight load factor of 55 percent was assumed to be reached by 1978.

From these assumptions, existing FAA, CAB and ATA traffic demand estimates were used as bases for estimating passenger and cargo traffic growth on an annual or specific future year basis. Given the productivity of each type of aircraft, their respective numbers in the current fleet and individual airline equipment retirement and acquisition plans, estimates of the fleet mix at points in time are made. Given these data, the candidate fleets which would be affected by each retrofit alternative are then identified. Note should be taken here that fleet mix estimates developed as described above will necessarily be different than that which would obtain if industry economics were such as to preclude early retirement due to the high cost of capacity replacement or the cost of capital in the private market. This situation of delayed retirement of the noisier aircraft in the fleet was not investigated in this analysis.

Evaluation of the cost of proposed noise reduction programs is based on specific data derived from the FAA and NASA studies. Because these studies are at different stages of completion, the accuracy of the cost estimates will vary between programs. For this reason the costs discussed here, particularly with respect to the Refan Program, are preliminary and are subject to change as the research programs near completion. Nevertheless, the relative order-of-magnitude estimates of the retrofit costs can be used at this point to compare the cost effectiveness of the various program alternatives.

Alternative programs for noise reduction have been evaluated in terms of total cost of the investment required to develop, certificate and install these selected modifications on all candidate aircraft, plus the marginal operating costs associated with the modification over the time period, and for the varying number of candidate aircraft subject to the program.

Analysis of future costs must also take into account all likely losses incurred by virtue of the retrofitting program. Among these are opportunity costs resulting from loss of revenue due to forced idleness of the equipment during installation and maintenance of noise reduction kits, and lost productivity from changes in performance, weight or fuel consumption. The impact of any potential lost productivity of retrofit aircraft which could result from changes in performance, weight, or fuel consumption have been considered by assuming that the available-ton-miles produced in any given time period will be unchanged either by increasing the number of airplanes flown per day or the utilization rate of each airplane for each retrofit alternative. Therefore, no revenue will be "lost;" however, the cost of providing the fixed level of productivity may be significantly altered by retrofit. An approximate measure of the cost impact of lower productivity has been developed by applying the changes in unit direct operating costs over the additional flight hours, additional aircraft miles or additional trips necessary to produce the original level of available ton miles. Shown in Table 4-3 are the retrofit unit costs per aircraft.

Table 4-4 summarizes the retrofit program costs by element, both in current dollars and present value discounted to 1973 at a 10 percent discount rate. Figures 4-16 and 17 show the total program cost in both current and present value. Minimum and maximum estimates have been derived based upon a range of refan retrofit cost and performance changes. Uncertainty in the estimate of number of aircraft to be retrofitted and the unit cost per aircraft is bounded by a plus and minus in these estimates. As has been previously noted, NASA has dropped the maximum refan treatment from its JT8D refan research program. In addition, funding for the JT3D refan program has been dropped. To this extent one should expect the performance effects estimated here to diminish and/or program costs to increase.

The Business Jet Portion of the General Aviation Fleet

Since the current business jet fleet will still be operating during the time period of interest, those aircraft which currently cannot satisfy FAR 36 requirements are the candidate set of aircraft for the nacelle, modified nozzle or re-engine alternative. For those aircraft yet to be manufactured, the assumption is made that these aircraft will conform to the current FAR 36 requirements. Given this set of conditions, then the retrofit or re-engine investment per aircraft type would be as shown in Table 4-5. Shown in this Table are the total investment requirements by aircraft type and for the total fleet.

It should be noted that the total business jet fleet investment requirements are significant. In the case of the Re-engine option however performance and operational benefits will be realized and, under a ceteris paribus activity level assumption, these business jet operators will realize a savings.

ECONOMICS OF ACHIEVING VARIOUS LEVELS OF CUMULATIVE NOISE EXPOSURE

The objective of the following analysis is to utilize the cost and effectiveness results of the previous discussion to determine if a mix of source noise reduction techniques and land use alternatives can result in a more equitable and less costly program of achieving various levels of cumulative noise.

TABLE 4-3. UNIT COSTS FOR NOISE RETROFIT PROGRAMS*

Aircraft	S.A.M. Sound Absorption Material	REFAN New Front Fan with S.A.M.
JT3D Engines		
B-707's	$ 930,000	$ 1,900,000
DC-8's	$ 770,000	$ 2,300,000
JT8D Engines		
B-727's	$ 169,000	$ 1,400,000
B-737's	$ 202,000	$ 1,000,000
DC-9's	$ 175,000	$ 1,100,000

* Installed cost per aircraft, including spares (1973 dollars).

Source: Reference 8.5-355

TABLE 4-4. RETROFIT PROGRAM COSTS ($M)

Program	Minimum Estimate: Investment	Change in Cash D.O.C.	Lost Time	Lost Productivity	Total Retrofit Cost	Maximum Estimate: Investment	Change in Cash D.O.C.	Lost Time	Lost Productivity	Total Retrofit Cost
Current Dollars										
SAM 8D	164.4	25.0	25.4	7.4	222.2	222.5	25.0	25.4	7.4	280.3
SAM 3D	290.7	58.0	11.8	55.9	416.4	393.4	58.0	11.8	55.9	519.1
SAM 8D/3D	455.1	83.1	37.2	63.3	638.7	615.9	83.1	37.2	63.3	799.5
REFAN 727/ SAM Others	1,065.0	249.9	36.6	111.7	1,463.2	1,440.8	493.1	36.6	587.7	2,558.2
REFAN 8D	1,121.0	339.0	24.4	189.3	1,673.7	1,516.7	756.7	24.4	1,004.4	3,302.2
REFAN 8D/ SAM 3D	1,411.8	397.1	36.2	245.2	2,090.3	1,910.0	814.8	36.2	1,060.3	3,821.3
REFAN 8D/3D	1,652.7	456.3	33.3	205.3	2,347.6	2,236.1	945.7	33.3	1,126.7	4,341.8
Present Value, $1973 (10% Discount Rate)										
SAM 8D	112.5	10.9	17.4	3.2	144.0	152.2	10.9	17.4	3.2	183.7
SAM 3D	193.2	25.4	7.9	24.8	251.3	261.4	25.4	7.9	24.8	319.5
SAM 8D/3D	305.7	36.3	25.3	28.0	395.3	413.6	36.3	25.3	28.0	503.2
REFAN 727/ SAM Others	673.5	101.4	23.4	46.9	845.2	911.3	197.2	23.4	234.3	1,366.2
REFAN 8D	687.1	132.5	15.0	73.5	906.1	929.7	295.9	15.0	392.2	1,632.8
REFAN 8D/ SAM 3D	880.3	157.9	22.9	98.3	1,159.4	1,191.0	321.4	22.9	417.0	1,952.3
REFAN 8D/3D	1,015.0	180.4	20.5	80.0	1,295.9	1,373.2	373.7	20.5	443.1	2,210.5

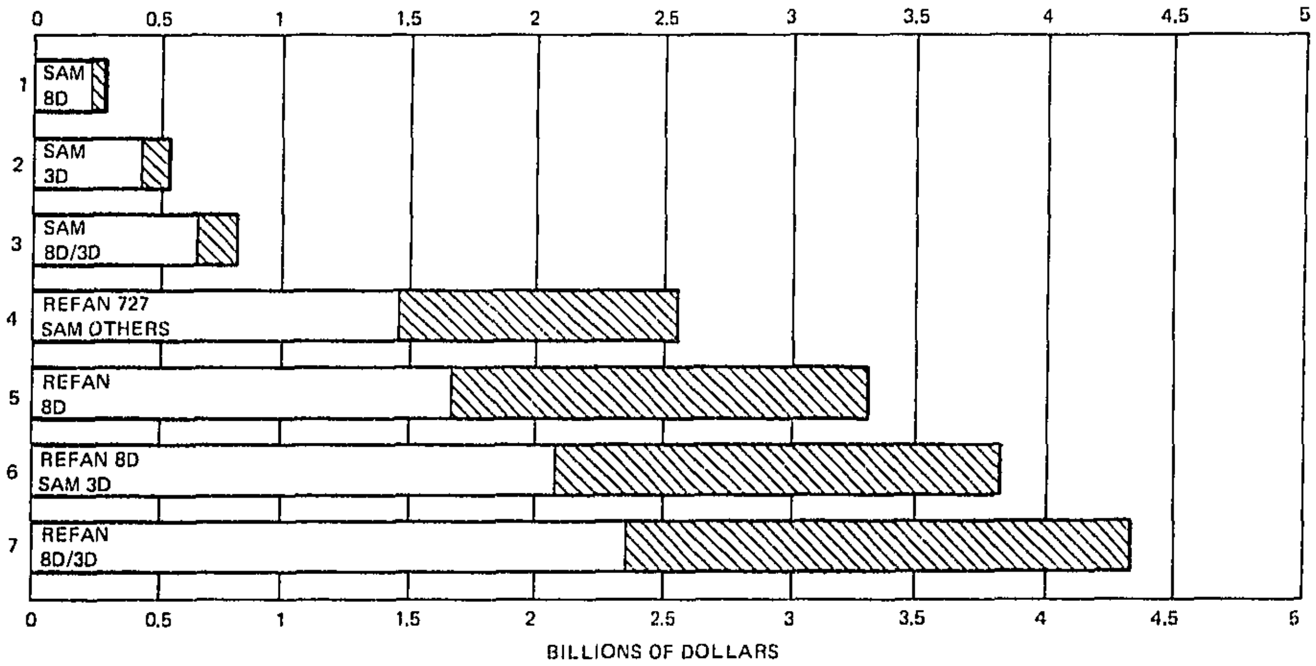


Figure 4-16. Estimated Total Costs for Seven Retrofit Options
(a) Current Dollars

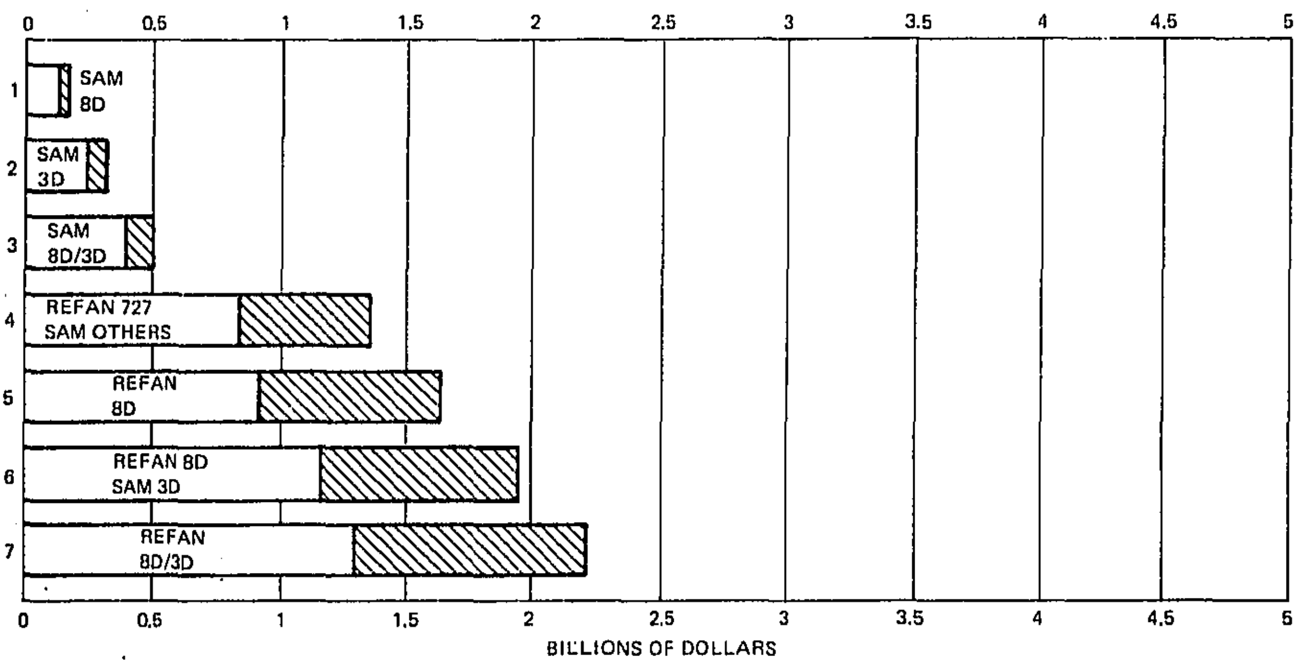


Figure 4-17. Estimated Total Costs for Seven Retrofit Options
(b) Present Value 1973 (10% Discount Rate)

TABLE 4-5. INVESTMENT COSTS FOR NOISE SOURCE TREATMENT OF DOMESTIC BUSINESS JETS

Aircraft Type	INVESTMENTS (1973 Dollars x 10^6)							
	Est. Costs/Aircraft					Costs/U.S. Fleet		
	U.S. Fleet Qty	Engine Set Costs	Installation Costs*	Re-engine Costs	Re-trofit Costs	Re-engine Costs	Re-trofit Costs	Fleet Costs
BH125-400	142	-	-	-	0.100	-	14.2	14.2
-600		-	-	-	0.100	-		
Commodore 1121	134	.210	.150	0.360	-	48.3		48.3
1123		.210	.150	0.360	-			
Gates-Lear 24D		-	-	-	-			
25B/C	81	.210	.150	0.360	-	29.2		29.2
26		-	-	-	-			
Grumman II	113	-	-	-	.150**	-	17.0	17.0
Jet Star 1329	124	-	-	1.350	-	167.4	-	167.4
Sabreliner 60	63	.340	.150	.490	-	30.8	-	30.8
70		-	-	-	-		-	
				TOTALS		275.7	31.2	306.9

* Assumed $75,000/engine installation (Ref. 7.1-54)
** Cost estimate based upon BAC-111 and F-28 Data (Ref. 3.8-367)

It has been found that the introduction of source abatement technology will reduce the noise impacted population around airports due to the shrinkage of NEF contours. However, the impacted population or noise reduction effectiveness of any of the alternatives varies as a function of time. This is due to the different time periods for the start and completion of a specific program, and the varying effect of changes in the fleet mix between retrofitted airplanes, unmodified airplanes and new airplanes. As a measure of effectiveness the maximum impacted reduction achieved by retrofit has been selected. Implicit in this selection is the assumption that public policy would not permit the noise problem to grow once noise reduction had been attained. Various policy alternatives to attain this objective are currently being explored in the DOT.

The results of the six airports analyzed in these effectiveness terms may be generalized from Figures 4-14 and 15. The "no change" alternative has an effectiveness of about 20 percent; i.e., changes in the fleet mix alone will result in an average 20 percent reduction in the population within the 30 or 40 NEF at no additional cost for noise abatement. Implementing the two-segment approach would increase the effectiveness to about 25 percent in the 30 NEF area, and to about 40 percent in the 40 NEF area. Retrofitting all of the JT3D and JT8D engined airplanes with acoustically treated nacelles and using a two-segment approach will increase this effectiveness further to about 30 percent in the 30 NEF area and about 60 percent in the 40 NEF area and, as shown in Figure 4-16 and 17, at a current dollar total program cost of some \$600 to 800 million (present value of \$400 to 500 million in 1973 dollars). Similarly, retrofitting all JT8D engined aircraft with refanned engines, and all JT3D engined aircraft with acoustically treated nacelles and flying a two-segment approach will have an efficiency of over 80 percent in the 30 NEF area, and about 75 percent in the 40 NEF area, at a current dollar total program cost of \$2.1 to 3.8 billion (present value of \$1.2 to 2.0 billion in 1973 dollars). These effectiveness levels indicate that the 31.5 billion dollar maximum estimate to protect the 1972 impacted public to $L_{dn} = 60$ dB using land use options only, can be significantly reduced as shown subsequently in Figures 4-18 through 22. However, one should recall that the numbers cited in the Refan cases are optimistic both from a performance and cost standpoint, and some adjustment may be required as firm figures are developed.

Translation of the Six Airport Effectiveness Results

To translate the general findings to the national impacted population distribution, the following procedure was followed. By assuming that the six airport effectiveness results reasonably reflect what can be expected on a national basis and normalizing the six airport results to a percentage reduction of the baseline population, one can develop an annual relationship between effectiveness per option and calendar year. Shown in Figures 4-14 and 15 are the percent population impacted variations by year, for two of the options, for the L_{dn} = 65 and 75 dB levels. Basically, because of the static population aspect of the baseline case, population shrinkage in any contour is the result of that contour itself shrinking. Assuming that all other L_{dn} contours also shrink proportionately as the L_{dn} = 65 and 75 dB contours vary by option, by year, then these results become transferrable to any impacted population distribution.

For this analysis, a static national estimate of the impacted population distribution by L_{dn} level (see Figure 4-1) has been assumed and this distribution is utilized to estimate the remaining population impacted in the following manner. The two data points indicating baseline percentage population reductions for an option, also represent two points on the resulting national population distribution curve. To construct an entire option curve, the assumption was made that the original curve shape represented the relationship between population impacted and cumulative noise exposure. Therefore, a symmetric shift of the original curve form was performed and the population impacted per L_{dn} level was tabulated. This process was performed for every option investigated.

Retrofit Influence on Total Achievement Costs

Recall that the rule employed in the cost calculations is that every person exposed to L_{dn} = 60 or greater must be protected to that level. On this basis a land use and structure treatment unit cost curve (Figure 4-2) was applied to the baseline national impacted population curve to develop the estimate range of 21 to 31.5 billions of 1973 dollars to achieve an L_{dn} = 60 dB environment in 1973.

Since, with the passage of time and/or the implementation of an operational or source abatement option, the impacted population decreases, then it also follows that the 1973 dollar cost of achieving this or any other level will diminish. However, the operational and/or retrofit program costs must be added to the land use and treatment costs to accurately reflect the total costs of achieving a desired cumulative noise environment. Shown in Figures 4-18 through 22 are such total costs for each five unit increment of L_{dn} or NEF level. The top bar in each figure portrays the 1973 land use only option, the reduction of these costs as the baseline situation occurs, and the effects on achievement costs of also implementing $6^o/3^o$ approach procedures.* One should also note that the retrofit program completion dates are included to illustrate that there do exist differences in the duration, or waiting period, before the impacted public could expect relief via the transfer of source abatement technology to the operating civil aviation fleet.

One will find, upon inspection of these figures, that the implementation of any source abatement technology will exclude the national population around airports from being exposed to 80 L_{dn} levels and above. One will also find that the implementation of any source abatement technology will reduce the total L_{dn} = 60 dB achievement costs by at least 13 billions of 1973 dollars. Again, in reviewing these figures, one is cautioned that the Refan total protection costs are subject to revision upwards as more refined data on expected performance and unit costs are developed.

On the basis of the rational use of resources, it is apparent that source abatement technology should be implemented into the active civil aviation fleet.

Sensitivity Analyses

As previously mentioned, the assumptions and basic data supporting this analysis are subject to variations and revisions. To determine if the conclusions of the analysis would change if such actions took place, a sensitivity analyses of some of the key variables must be undertaken.

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*Recall that the procedure for determining population reductions was a symmetric shift of the population distribution curve such that the new curve passes through the L_{dn} = 65 and 75 dB point estimates. However, operational procedure effectiveness in high noise environments ($L_{dn} \geq 80$ dB) is non-existent or small, primarily because these procedures only redistribute energy. Consequently, on Page 4-49, no population reduction credit is given to the two-segment approach.

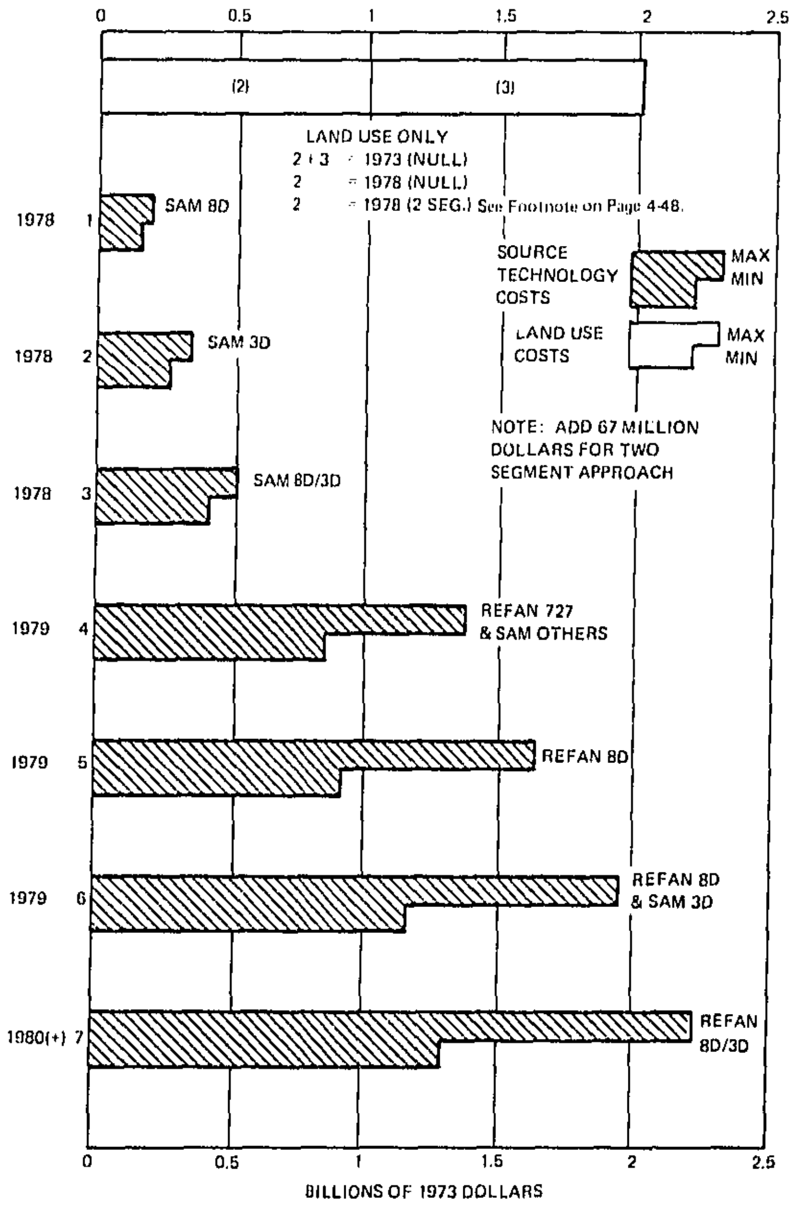

Figure 4-18. Estimated Total Costs for Noise Protection—
80 L_{dn} Contour (45 NEF)

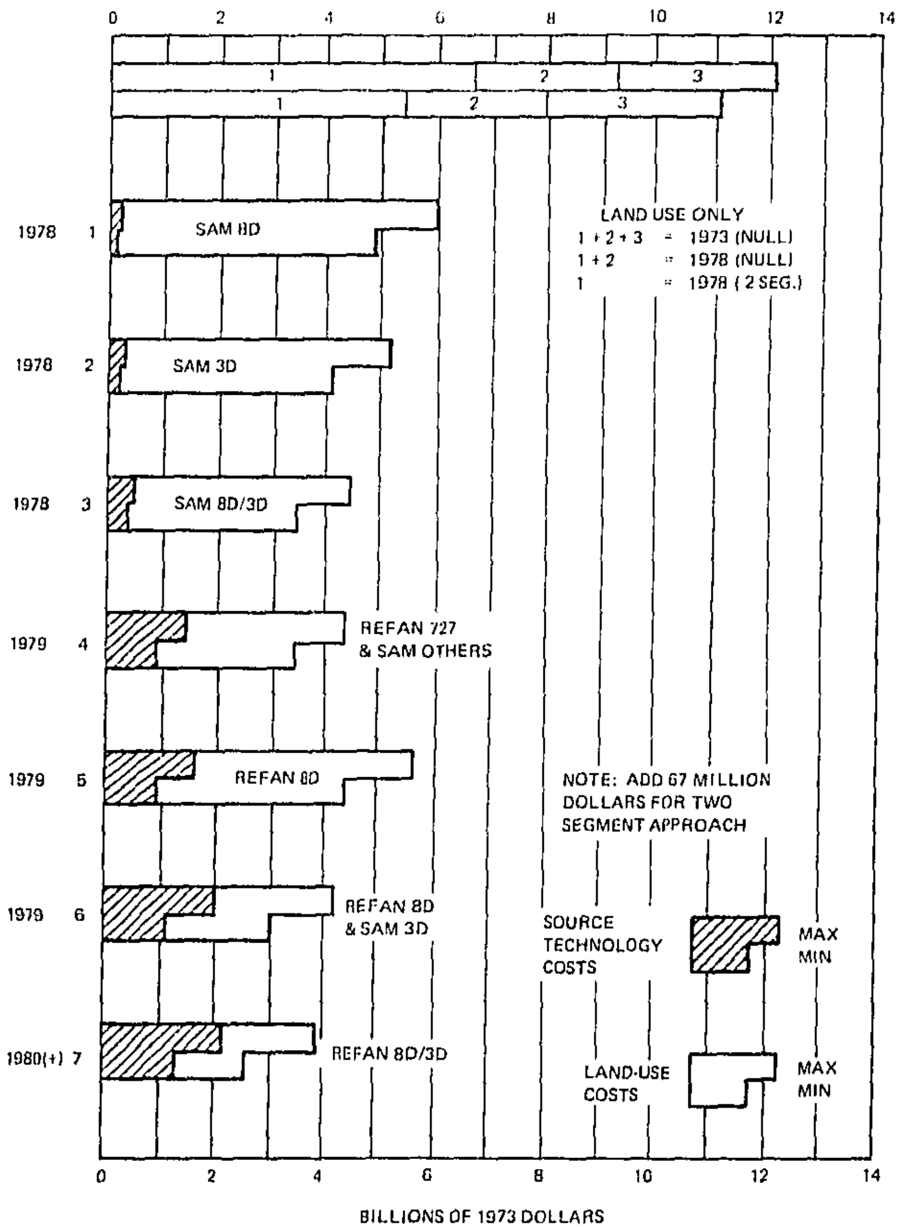

Figure 4-19. Estimated Total Costs for Noise Protection—
75 L_{dn} Contour (40NEF)

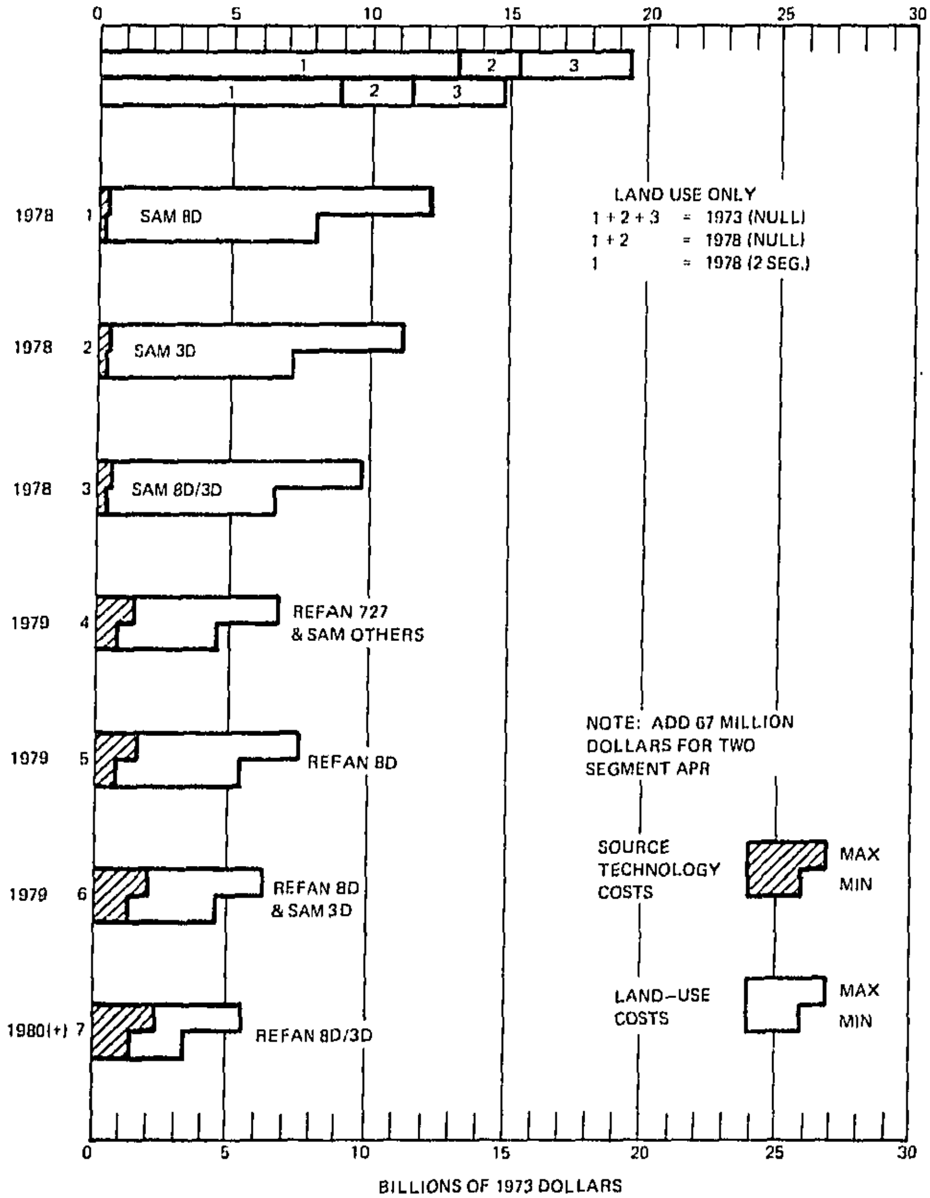

Figure 4-20. Estimated Total Costs for Noise Protection—
70 L_{dn} Contour (35 NEF)

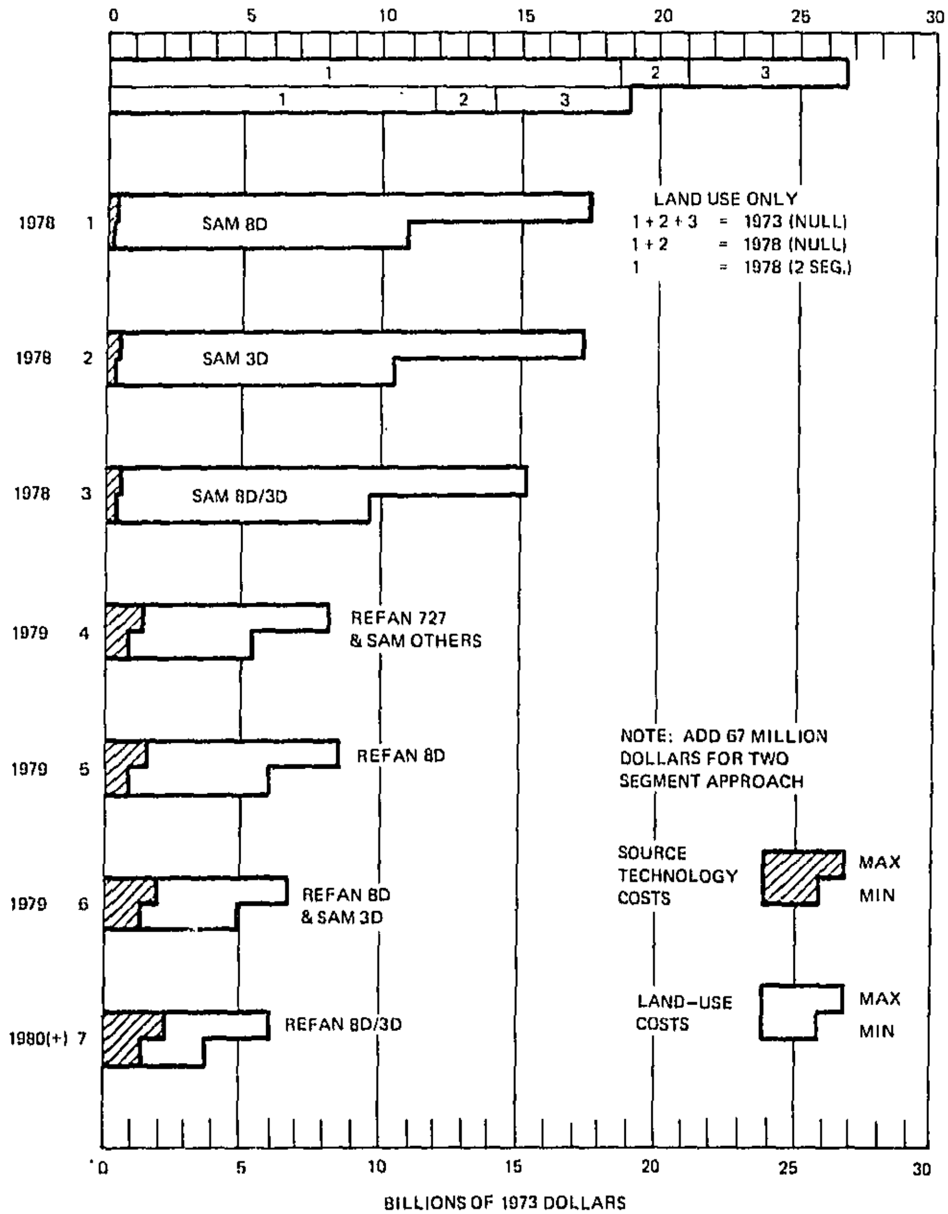

Figure 4-21. Estimated Total Costs for Noise Protection— 65 L_{dn} Contour (30 NEF)

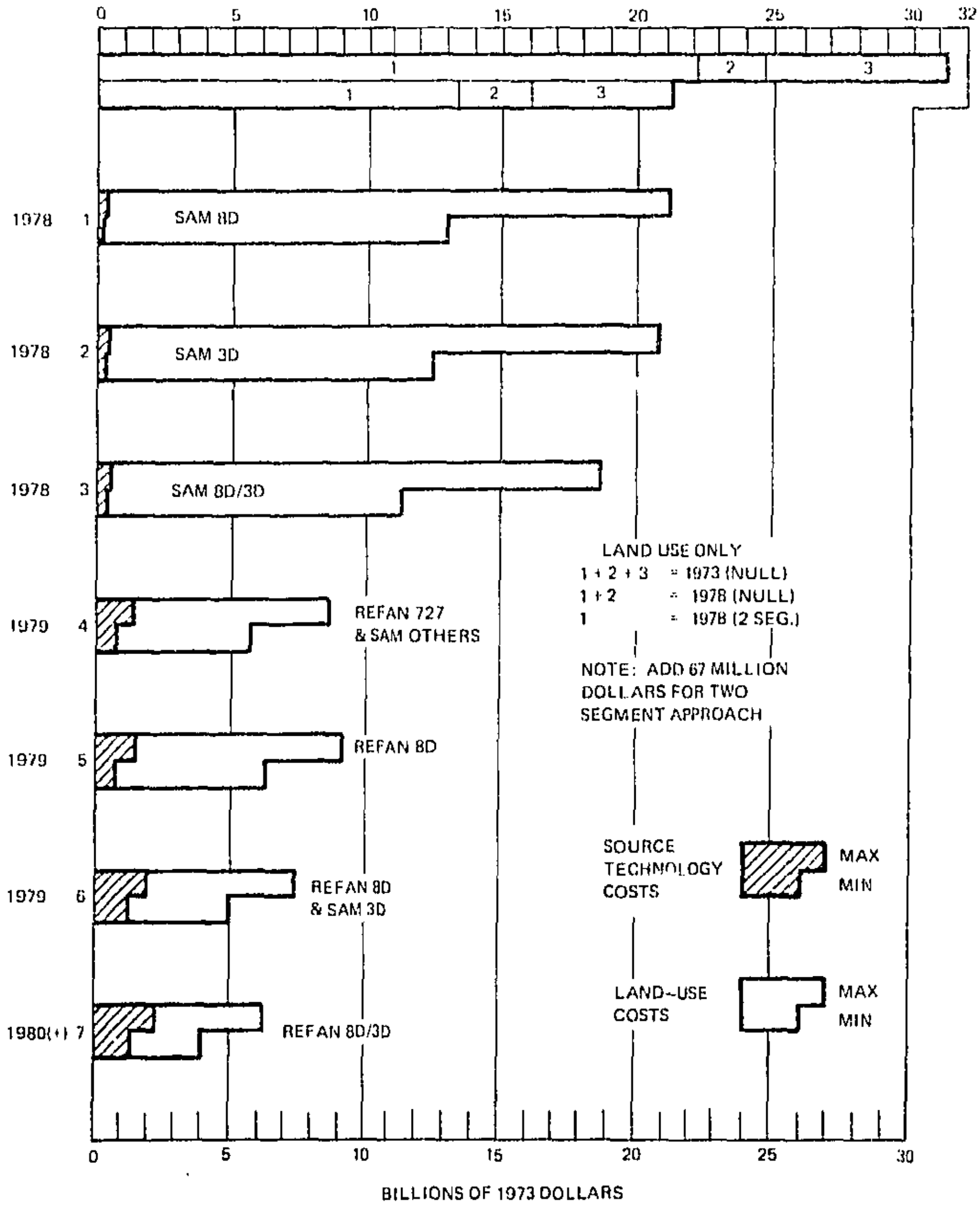

Figure 4-22. Estimated Total Costs for Noise Protection—
60 L_{dn} Contour (25 NEF)

One of the basic assumptions made was that no further population encroachment occurred in currently noise impacted areas around the nation's airports. In reality, one should expect that such encroachment will occur until local governments actually come to grips with the noise pollution problem and implement effective land use controls. The effects of such encroachment are increases in noise impacted populations and increases in the costs of achieving any desired level of cumulative noise exposure. This is one argument for a timely adoption of an integrated environmental noise reduction program if the costs of achievement are to be reasonable.

If the impacted population distribution curve were changed, then the effectiveness and costs of the various options examined would change. If the change were symmetric, the land use cost component would change accordingly. The relative results would still obtain; however, a stopping point may be created. If the change were non-symmetric then a re-evaluation of each option may be required.

The other key variables, which can influence this study's findings are the following:

- the number of aircraft to be retrofit;
- the availability dates of the retrofit kits;
- the estimated source noise reductions resulting from the retrofit; and
- the cost of the kits.

The number of aircraft to be retrofit has both program cost and effectiveness implications. Total retrofit program costs would increase if the number of aircraft to be retrofit were greater than that used in this study. The effectiveness of an expanded fleet retrofit for either technology would be approximately that estimated in this study if not greater. This follows from the fact that when the narrow bodied portion of the commercial fleet is retrofit with SAM technology, their resulting noise output levels are reduced to those comparable to the 747, DC-10, and L-1011. The activity levels at airports, under a constant capacity offered assumption, may increase slightly due to the requisite capacity substitution from wide bodies to narrow bodies. However, the resulting cumulative noise levels around airports would not change proportionally, but logarithmically. Retrofit of narrow bodies with Refan technology would make these retrofit aircraft quieter than the wide bodies. It therefore follows that the Refan retrofit fleet would have relatively quieter aircraft operating than that used in this study; consequently, the effectiveness of this type of retrofit program would be greater than that employed in this analysis.

The remaining variables of availability, noise reduction performance and costs of the retrofit kits have little uncertainty associated with them for the SAM technology. This situation is primarily due to the fact that this technology is flying in current production aircraft and flight demonstration tests have been made of a kit for one type of aircraft not currently in production. The chance of a slip in the availability schedule of more than six months, from that used in this study, is felt to be rather small. If such a slip occurred, the result would be that there would be a delay in the achievement of any given cumulative noise level.* Significant changes in the levels of noise reduction performance of SAM retrofit kits are not expected essentially for the same reasons cited previously. The costs of SAM retrofit kits can change as a result of production decisions. Such cost changes will vary total retrofit program costs accordingly.

The uncertainty associated with kit availability, noise reduction performance, and kit costs for the Refan technology are relatively greater than that associated with SAM retrofit. The reason being that this technology is now in the engineering design phase where the design has yet to be fixed, fabricated, and flown. If there is a slip in the availability of Refan kits the general result would again be a delay in the achievement of cumulative noise levels around the nation's airports and the attendant inflation of achievement costs. If there were to be a reduction in Refan noise reduction performance from that used in this study, there would be an increase in the land use component of achievement costs. Essentially, in this situation the relative attractiveness of Refan vis-a-vis SAM would decrease and the achievement costs of Refan would tend towards those of SAM. Changes in the Refan kit costs would have the same general effect as those sited for SAM.

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*It should be noted here that the longer it takes to achieve reductions in L_{dn} = 75 dB and above, the greater could be the frequency of local litigation for damages. As previously discussed this could result in a diversion of resources from those necessary to achieve national airport cumulative noise levels.

Considering the differences in the key program variables between the SAM and Refan retrofit alternatives it is apparent that there is a significant risk in a singular decision to key an airport noise reduction program to the Refan program. The more prudent approach appears to be to initiate such a program with the SAM retrofit and have Refan retrofits when the kits become available. Under this mixed strategy, source reduction relief will occur at the earliest possible dates and the maximum costs of the program are known.

Summary of the Economies of Achievement

In terms of the economic question of which combinations of options are the most efficient to achieve a desired cumulative outdoor noise environment level, the following findings can be stated.

- The costs of transferring aircraft source noise abatement technology into the civil aviation fleet are always less than the costs of achieving cumulative noise without such transfers.
- Transferring the aircraft source noise reduction technology into the civil aviation fleet alone cannot eliminate the outdoor noise environment problem around the nation's airports.
- Source technology cannot be <u>fully</u> implemented into the civil aviation fleet until 1977 at the earliest, and path technology by 1978; however, intermediate relief can occur before this period by the effective exercising of fleet operational procedures, airport operator options and local government land use options. Such intermediate relief <u>must</u> occur, especially the curtailment of further encroachment of population around airports, if the costs of achievement are to be kept at a minimum.
- The problem of equitable treatment of populations residing near large military airports although not addressed here cannot be ignored and appropriate remedies and costs will have to be developed.

<u>The Alternative Impacts on the General Economy</u>

Given the situation that the alternative of not changing current aircraft/airport activity procedures will ultimately cost the airport operators, airlines, and users billions of dollars, it is then reasonable to assume that an economically rational solution to the aircraft/airport noise impact problem will evolve. This solution will most likely consist of a mixed strategy of retrofitting, airport operations optimization, land use programs and possibly some removal of impacted populations. Necessarily, retrofitting will create an additional demand for capital goods, labor and materials. Also the costs of retrofitting will ultimately have to be borne by the users of the air transportation system. Since the air network system is not now reflecting the economic and social costs of noise in its tariffs, the resulting rise in tariffs or business cost pass through to recover the costs of an integrated noise reduction program will have demand effects of the revenue of the airlines and the activity levels of general aviation. In addition, if fewer people fly because of higher tariffs, then it follows that relatively less money is spent in the regional destination economy.

In essence, the implementation of the rational noise abatement alternatives will have demand creating and diminution effects. What these effects are on a national basis as well as on a regional impact basis must be investigated to insure that the selected program is also one which creates the least undesirable economic impacts.

Finally, the achievement of cumulative noise levels around the nation's airports will require international cooperation due to the high level of foreign flag air carrier activity at a number of domestic airports. Questions as to whether, and how, these nations can comply with the domestically developed schedule of achievement, how requisite investment and operating expenses enter into their cost functions, and whether such increased achievement costs will be passed through or used as a competitive advantage, must and will be addressed in the subsequent rulemaking study effort.

FUTURE TECHNOLOGY OPTIONS

Although the component and engine technologies discussed in Section III have high potential for significant noise reductions, their associated production costs are not really understood at this time. Consequently, the costs associated with these options are primarily research and development costs. When more definitive development plans are provided, order of magnitude estimates of their cost implications can be developed.

ANNEX TO CHAPTER 4

THE IMPLICATIONS OF A NATIONAL CURFEW

Introduction

During the course of the task group meetings on which this report is based, one airport noise reduction option continually created controversy. This was the implementation of curfews by airport operators. The basic question was to what extent the curtailment of night time flights would effect the operations and users of the national air transportation system.

What is reported here is a basic analysis of all elements of the problem. The key assumption made, primarily due to the lack of valid data, was that the users of the air transportation network could re-arrange their schedule requirements to those offered after the curfew implementation at little cost. Necessarily, this assumption is optimistic; consequently, the results of the analysis as reported here should be viewed as the minimum which would obtain if a national curfew were implemented.

The Cost of a National 10 P.M.-7 A.M. Curfew

Faced with significant magnitudes of potential damage awards and/or land use costs, it is possible that if a source noise reduction program is not adopted on a Federal level, airport operators will take independent action to avoid and/or reduce the amounts of potential damage awards. One of the most dramatic actions that can be taken is the imposition of a night-time curfew. As soon as it is apparent that no Federal program will be undertaken, it is assumed that the operators will undertake a national curfew and maintain it until effective noise reduction alternatives become available. The assumption is made that the curfew will be instituted in 1974 and maintained until at lease 1980 when quieter aircraft could become available. Because there is little factual data available on the costs of curfews, the implications of this policy alternative requires more detailed analysis than the preceding alternatives to develop at least a minimum cost impact estimate.

The impact of a curfew can be broken down into the following areas:

- Impact on passenger service
- Impact on air cargo service
- Impact on mail and express
- Impact on maintenance and repair activities
- Impact on international operations

Actually, there are some airports where no curfew would be needed or where less restrictive limits could be imposed. The transfer of some maintenance and freight operations to these airports would lessen the economic loss to an area, if, and only if, the noise exposure at these airports does not increase as a result of the activity transfers.

Impact on Passenger Service

Using the Official Airline Guide, a survey was made of the arrival patterns of passenger aircraft at several airports across the country, including Los Angeles International. Only about 15 percent of passenger aircraft movements occur between 10 P.M. and 7 A.M. and, of that number, about half are within an hour of the curfew limits i.e. 11 P.M. and 6 A.M. The assumption is made that at least one-third of the curfew affected flights could be rescheduled to arrive or depart during noncurfew hours. This rescheduling of flights will lead to increased congestion and delays in the national aviation system. The remainder of the flights affected cannot effectively be rescheduled; therefore, this would represent an overall decrease in airline industry flight activity of about 10%. An assumption is made that half of this activity will not be replaced and that the passengers will travel on noncurfew flights. This will result in an increase in the noncurfew flight load factor. Such a situation would tend to increase airline profits while at the same time expose these additional passengers to the additonal airport congestion and delays previously mentioned. To replace the remaining 5% of affected aircraft movements, the airlines would have to buy new equipment to compensate for decreased aircraft utility and scheduling flexibility, (e.g. pre-positioning for next day flights). The corresponding increase in fleet size would not only add to airport delay and congestion but also raise airline annual depreciation costs over presently planned industry expenditures by 5 percent. Since depreciation represents about 10 percent of the total industry operating costs, the change in overall industry operating cost because of the additional aircraft would be 0.5 percent.

Additional flight crews would be needed to operate these new aircraft. Since crew costs represent about 13 percent of the total operating costs, the required increase in crews (corresponding to the 5 percent increase in the number of aircraft) would raise the overall operating costs 0.65 percent (13 percent of 5 percent). Based on these figures, the total increase in fleet operating costs, due to this compensating activity caused by a 10 p.m. to 7 a.m. curfew would then be the sum of the 0.5 percent depreciation increase and the 0.65 percent crew cost penalty for which there is no offsetting profit!

To estimate the costs of congestion and delays the viewpoint was taken that although 95 percent of the original capacity is maintained, this capacity is offered over a much shorter operational period due to the imposition of a daily 9-hour curfew. To maintain this capacity over a shorter time period, a "virtual" 10 percent increase in operations per hour will occur. This increase will result in additional aircraft, passenger and cargo delays. Since delays are inherent in the airline system, this will represent an increase over and above what the system would consider normal. Shown in Table 4-6 are airport capacity or operations estimates for a sample of airports for which delay data were available. The historical operations data shown in column 2 were taken from Reference 7.1-175. The estimated 1985 capacities of the

TABLE 4-6. SAMPLE AIRPORT CAPACITY ESTIMATES

AIRPORTS	1971 CAPACITY (000 OPERATIONS/YEAR)	EST. 1985 CAPACITY (000 OPERATIONS/YEAR)	PERCENT ANNUAL GROWTH	PERCENT OF TOTAL DELAYS IN 1969
O'HARE	617	700	1.0	13.7
JFK	344	395	1.0	10.6
LAGUARDIA	258	300	1.0	6.9
ATLANTA	385	530	2.4	5.9
LOS ANGELES	413	471	1.0	3.7
NEWARK	184	237	1.9	3.7
MIAMI	250	323	1.9	4.1
SAN FRANCISCO	297	383	1.9	2.8
PHILADELPHIA	186	240	1.9	3.1
WASHINGTON NAT'L	215	277	1.9	2.9
ST. LOUIS	187	241	1.9	1.7
			TOTAL:	59.1

sample airports were either taken directly from Reference 7.1-99 or estimated by assuming the same capacity growth rate for those airports in the cited reference similar to the sample airports. The delay data were taken from Reference 8.5-103. From these data, estimates of the curfew induced incremental delays were developed. Shown in Table 4-7 are these estimates for the year 1974. The basic approach to developing these estimates was to estimate the normal capacity of each sample airport by compounding the annual capacity growth rate from the year of interest (1974). A "virtual" 10 percent increase in capacity was then applied to develop the curfew induced flight activity level at each airport. Using an annual delay versus annual airport activity figure from Reference 8.5-103, delay times were estimated for each airport. Assuming that the relative shares of percentage of total delays remain constant for each airport, the net curfew induced delays were extrapolated to a national number. Shown in Table 4-8 are the delay estimates for the year 1980. From these two tables, the delay times associated with each intervening year can be estimated under a uniform growth assumption. Multiplying these delay times by the respective airline and passenger delay costs from Reference 8.4-182, yields the airline and user cost impacts shown in Table 4-1. (See Page 4-11)

Impact on Air Cargo Service*

Since approximately 50 percent of air cargo moves in passenger aircraft, the impact of a curfew on this portion of the business would be included in the passenger service calculations. The remaining 50 percent moves in all-cargo aircraft which fly almost exclusively at night.

It is difficult to estimate the impact on system economics if a curfew required a rescheduling of these aircraft since the combination carriers themselves (other than exclusive air cargo carriers) have little feel for the value of cargo business.

The traditional service pattern of overnight delivery is such that there is a large influx of shipments into the freight terminals after the close of business of shipper firms. The resulting congestion often exceeds the ability of the freight facility to handle the shipments. Additional people must be employed (at evening rates) for these peaks and must be paid a full day's wage even if they are needed only for a few hours. (This reduces the productivity of employees in the air cargo industry to about

* The major portion of this discussion has been taken from Reference 10-271.

TABLE 4-7. ESTIMATES OF CURFEW INDUCED INCREMENTAL DELAYS
(a) 1974

AIRPORTS	1974 CAPACITY (000 OPS./YR.)	CURFEW INDUCED 1974 CAPACITY (000 OPS./YR.)	NORMAL DELAY TIME (000 MINUTES)	CURFEW INDUCED TOTAL DELAY TIME (000 MINUTES)	NET CURFEW INDUCED DELAY (000 MINUTES)
O'HARE	636	700	960	1600	640
JFK	355	391	550	820	270
LAGUARDIA	266	293	410	600	190
ATLANTA	410	451	625	960	335
LOS ANGELES	426	469	660	1200	540
NEWARK	195	215	295	395	100
MIAMI	265	292	410	600	190
SAN FRANCISCO	307	338	470	680	210
PHILADELPHIA	197	217	295	395	100
WASHINGTON NAT'L	228	251	350	520	170
ST. LOUIS	198	218	300	400	100
				TOTAL:	2845

TABLE 4-8. ESTIMATES OF CURFEW INDUCED INCREMENTAL DELAYS (b) 1980

AIRPORTS	1980 CAPACITY (000 OPS./YR.)	CURFEW INDUCED 1980 CAPACITY (000 OPS./YR.)	NORMAL DELAY TIME (000 MINUTES)	CURFEW INDUCED TOTAL DELAY TIME (000 MINUTES)	NET CURFEW INDUCED DELAY (000 MINUTES)
O'HARE	676	743	1100	1750	650
JFK	376	414	580	910	330
LAGUARDIA	283	311	420	680	260
ATLANTA	474	522	710	1300	590
LOS ANGELES	452	497	700	1250	550
NEWARK	218	240	330	495	165
MIAMI	296	326	460	690	230
SAN FRANCISCO	352	387	525	810	285
PHILADELPHIA	220	244	330	495	165
WASHINGTON NAT'L	255	281	390	580	190
ST. LOUIS	222	244	335	500	165
				TOTAL:	3580

1/10th of that in the trucking industry.) After the peak, the facilities stand nearly idle until the next evening. As a result of this cyclic peaking, then idle, capacity at least one-half of the costs of moving air freight are for ground handling. Because of such activity cycles, night-time operations are at least part of the reason for this loss.

Thus, the carriers themselves would prefer to transfer a large part of their cargo activities to day hours to spread the traffic flow and make better use of manpower and facilities. With the advent of the widebodied jets with their large cargo compartments, the airlines are now able to move more freight during the day on scheduled passenger flights. In fact, the use of such "belly" capacity can greatly improve the profitability of passenger flight and offset the low-load factors often experienced on widebodied aircraft.

For all these reasons, the elimination of all-cargo flights at night might actually improve the financial performance of the air system rather than create additional costs. However, the airlines contend that all-cargo service cannot be evaluated apart from overall system cargo service because the existence of freighters, properly marketed, generates traffic for the total fleet. Often more traffic will be delivered for a freighter flight than can be accommodated so the overflow moves as belly freight on passenger flights. Also, once a shipper has stopped to make one delivery, he may use the same airline to ship additional goods to other places rather than go to other terminals. On the other hand, airlines argue that night-time capacity will be required in the future because of the rapid expansion of the air cargo business (as indicated by the 400 percent increase in the overall volume of domestic air freight from 1960 to 1970 and the even greater growth rate for all-cargo aircraft traffic).

It is impossible to evaluate the importance of these factors or to predict how they might change if all-freight aircraft were still available but required to fly by day. Rather than attempt to quantify the effects of a curfew on shipments by examining the carrier's performance, it may be useful to examine the needs of the shipper.

Air cargo shipments can be placed in three distinct categories:

1. routine non perishable planned traffic;
2. routine perishable traffic that is time-sensitive, but its movement planned in advance; and
3. emergency traffic which is unplanned and highly time-sensitive.

A curfew would have little effect on the first two, since day freighter service could be planned as an alternative. Also, since these types of shipments can be anticipated and containerized more easily than unplanned emergency traffic, they represent lower cost to the airlines. Thus, a marketing thrust can be anticipated in the direction of high-density, high-volume regular movements with a corresponding de-emphasis on emergency cargo.

The real impact of a curfew on air cargo movements is on the emergency shipments. It is assumed that 50 percent of all air freight is emergency traffic or at least perceived to require emergency shipment by the shipper. It can further be assumed that most of these shipments are not perishable, since a shipper of perishable goods would normally anticipate and plan his shipments in advance. Therefore, under these assumptions a few hours' delay in most "emergency" traffic will result primarily in inconvenience, not spoilage.

The emergency market can be divided into two geographic markets—one where alternate service by truck exists, and one where it does not. If truck service is a viable alternative, then most emergency shipments probably already move by truck because the cost is about half that of air service. Assuming an average speed of 50 miles per hour for trucking, a pick-up made at 5 p.m. could be delivered anywhere within a 750-mile radius by 8 a.m. the next morning. Assuming a 500-mph speed for aircraft, a jet could also provide overnight service in this market if it could depart before 8:30 p.m. (in order to arrive before the 10 p.m. curfew is enforced). If the plane could not depart until 7 a.m. the next morning, it still would provide faster service than the truck for distances beyond 850 miles (the distance of an overnight truck drive plus the additional distance the truck could travel in the two hours necessary for the plane to overtake it). Over greater distances, aircraft would have a clear speed advantage. Therefore, much of the emergency traffic that moves by air today would still go by air since there is little alternative. The difference would be that shipments would not arrive as quickly as they do today.

The major problem would be for emergency shipments moving east since time zone changes decrease the apparent speed of aircraft. To arrive on the east coast before 10 p.m. a flight would have to leave the west coast before 2 p.m. (5-hour flight plus 3-hour time zone change). This would essentially preclude any shipments that could not be picked up from the shipper before 10 or 11 a.m. Alternatively, it would be possible for a plane to depart the west coast at 10 p.m., delay one hour in flight and arrive on the east coast at 7 a.m. (5-hour flight plus 1-hour in-flight delay plus 3-hour time zone change). This would increase the cost of such a flight by 20 percent because of the hour delay, but the cost could be passed along to the shipper if he really desired next-day delivery.

Failing either of these two options, the shipper would have to wait for a 7 a.m. departure the next morning, arriving on the east coast at 3 p.m. with little likelihood of delivery until the following morning. With these alternatives in mind, the shipper would probably become more conscious of which shipments were really emergency and which were not, paying the premium for overnight service only when it was justified.

Summarizing these effects:

1. The 50 percent of air cargo that presently moves in passenger aircraft would not be affected by a 10 p.m. to 7 a.m. curfew.

2. Assuming 50 percent of the remaining air cargo is perceived as "emergency" traffic then 50 percent of the freighter traffic presently moving at night is non-emergency and could be diverted to day flight.

3. The 50 percent emergency traffic moving at night is 25 percent of the total air cargo traffic. In most cases, next day delivery could still be achieved by either getting the goods to the airport in time for a precurfew departure or by settling for a mid-day delivery the next day, based on a post-curfew departure. Since the shipper has little alternative, he would still use air service for most of these shipments although it would not be as convenient as without the curfew.

4. The greatest impact on traffic is on shipments moving from the west coast to the east coast. Assuming that half the total air cargo moves north-south and half moves east-west, then only half of the 25 percent (or 12.5 percent) of the total traffic that represents emergency shipments moves in the cross-country direction. The half of this that moves east to west is much less sensitive to curfew effects. Of the remaining traffic moving west to east, perhaps only half is transcontinental. The rest is distributed at lesser distances and therefore capable of mid-day delivery on the next day after shipment. Therefore, only 3.125 percent of the total air cargo traffic (transcontinental eastbound emergency traffic presently moving in night freighters) could be severely restricted by a curfew.

5. However, this 3.125 percent of the traffic could still move on an overnight freighter by paying a 20 percent premium. Assuming the -0.7 elasticity used for passenger traffic (which is not unreasonable since "emergency" traffic is relatively insensitive to price changes), 14 percent (-0.7 x 20 percent rate premium) of 3.125 percent would be lost. Thus the total air cargo traffic loss attributable to a curfew would be 0.4375 percent.

6. Since domestic air cargo shipments provide about 6.5 percent of total air system revenues, this traffic loss would decrease revenues by .028 percent (6.5 percent x .004375). Based on total system revenues estimated in Reference 8.4-214, these lost revenues are estimated as shown in Table 4-1.

Impact on Mail and Express

Mail traffic represents about 3.3 percent and express about 0.4 percent of total system revenues, approximately half that of cargo. Following a similar type of analysis, the impact of a curfew on air system costs and revenues due to changes in the carriage of mail are very small.* Here, however, public convenience may be more important.

Most of the country could still receive one-day delivery from other areas if the postal service were to shift its delivery service to afternoon, allowing most north, south and westbound flights to leave at 7 a.m. and arrive in time to distribute the mail. In lieu of this, a change in postal pickups could allow earlier sorting and delivery to planes in time to depart early evening and still arrive in time for night sorting and next-morning distribution of mail. In short, a great deal of the inconvenience could be minimized by revised pickup and delivery services.

The worst case, as with cargo, is overnight service from the west coast to the east coast. But again, premium service could be available on departures just prior to the start of the curfew.

Banks would perhaps be hurt most by delayed express deliveries. It has been estimated that a curfew would cost New York banks $34.8 million per year in lost interest because of delays in handling transactions between banks, the Federal Reserve and the bank clearing houses. It can be assumed, however, that much

*Note that an implicit assumption has been made that the peak volume periods for mail processing can be shifted to coincide with the curfew restrictions.

of this loss could be regained by earlier processing by using computers or hiring additional personnel, so that shipments could be made on earlier flights. The cost of these measures would be considerably less than the potential loss of interest and actually benefit the regions involved by higher employment.

Impact on Maintenance and Repair Activities

In a recent airport curfew case in California, the district court opinion spent some time discussing the potential impact of a curfew on maintenance and repair activities, concluding that considerable cost increases would result. * However, it is doubtful whether this would really occur. About 2 percent of all present flights are non-revenue operations connected with maintenance, training or movements to reposition equipment. Most of these are planned well in advance, however, so those influenced by a curfew could be eliminated by schedule changes. In addition, because of the high reliability of present jet aircraft, most maintenance is done on an as-needed basis. Many airports are already equipped to do various minor repairs and backup aircraft are available if major repairs require an empty flight to a repair base. Thus the unnecessary duplicate facilities feared by the court either already exist or are really not needed. In either case, the additional aircraft purchases required as a result of rescheduling passenger service would provide enough flexibility to alleviate many of the scheduling and planning problems associated with maintenance activities.

Impact on International Operations

Many major foreign airports have instituted nighttime curfews on aircraft operations. Typically, these curfews are in effect during 11 p.m. through 6 a.m., local time. Due to these curfews, the departure and arrival windows of flights to and from these foreign airports, and U.S. airports, have shrunken to approximately 17 hours a day. However, public convenience; i.e., the ability of a traveling public to travel when it wishes, apparently has not been diminished significantly by the imposition of these curfews.

What must now be determined are the effects on the aircraft activity windows and the attendant impacts on public convenience of instituting a U.S. curfew between

* 318 F. Supp. 914 (C.D. Cal. 1970)

10 p.m. and 7 a.m. Flights to and from JFK and SFO to Paris, France and Tokyo, Japan were analyzed for the curfew effects on both passenger and cargo freighter operations.

On passenger flights from JFK to Paris, the departure window shrinks from 17 hours to approximately 8 hours. However, on checking the flight schedules of two domestic airlines on this route, not one daily scheduled passenger flight would be eliminated! The departure window on flights from the West Coast to Paris shrinks similarly from 17 hours to 8 hours. Again, for these same airlines, no currently scheduled daily flight would eliminated.

If a U.S. curfew were implemented, then for flights from Paris to JFK, the window shrinks from 17 hours to approximately 15 hours. Understandably, not one currently scheduled passenger flight would be affected by this curfew. For flights from Paris to the West Coast of the U.S. the window shrinks to 11 hours. Again, no currently scheduled flights would be affected.

Flights from JFK and the West Coast to Tokyo currently have 16 and 17 hour departure windows, respectively. The adoption of a U.S. nighttime curfew will decrease these departure windows by no more than two hours. Daily flight schedules for a domestic and foreign flag carrier were analyzed to ascertain whether any currently scheduled daily flights would be cancelled. Again it was found that no currently scheduled flights of these two airlines would be cancelled or re-scheduled as a result of implementing a U.S. night curfew on airport activity. With the implementation of a national curfew the windows on flights from Tokyo to the West Coast and JFK will decrease, respectively, to approximately 12 and 10 hours. However, no flights of the airlines investigated would be cancelled.

Assuming that daily flight schedules reasonably reflect the public's travel requirements, it appears that international passenger traffic between the U.S. and the two foreign airports considered would not be affected by the implementation of a national curfew. If one further assumes that these foreign airports are gateways for a major portion of European and Far Eastern travel, it would appear that a significant share of the currently scheduled international traffic would not be affected by the implementation of a U.S. nighttime curfew. With the advent of the tourist season, this finding may change somewhat.

The passenger arrival and departure windows stated above also obtain for the pure cargo freighter activity. On reviewing the U.S. freighter departure schedules of the subject airlines it was found that every flight would be affected. Each flight was found to be in violation of the U.S. curfew by roughly 2 hours. It would not be unreasonable to expect that such flights could be rescheduled to depart earlier, thereby reducing the impact of the curfew. However, due to the recent devaluations of the dollar, export cargo traffic or volume should be expected to increase.*

The increase in this export volume may be such that additional freighter flights are necessary. Given this situation and the advent of the tourist season, it then follows that more daily international flights will occur. Such increased activity in turn will result in departure and arrival delays and flight diversions. As no international delays and diversion data are available and also that the extent of the tourist and export/import cargo effects of the devaluation has yet to be determined, then the effects of a national curfew on international traffic cannot be monetized at this time. However, from the currently scheduled flight activities, if they represent travel and/or shipping desires, it appears that implementation of a national curfew will not cause catastrophic structural dislocations in international patterns of air transport user requirements.

<u>The Noise Reduction Effectiveness of a Curfew</u>

Most techniques for measuring the cumulative effects of aircraft operations over time place a heavier annoyance weighting on nighttime operations than those during the day. The Cumulative Noise Forecast method considers a flight between 10 p.m. and 7 a.m. to be as intrusive as would a higher multiple of daytime flights. As a result, the elimination of these heavily weighted night operations through the imposition of a curfew yields a dramatic reduction in L_{dn} levels with a corresponding decrease in the land area within any given L_{dn} contour.

Applying the mathematics of L_{dn} calculations to the assumptions used in determining curfew costs (i.e., 15 percent of the present total operations occur during the proposed curfew period, 1/3 of the cancelled flights could be shifted to non-curfew hours and 1/3 could be rescheduled with new aircraft), calculations show that a 10 p.m.

* Conversely, import cargo volume should at least stabilize if not decrease.

to 7 a.m. curfew would result in a 5 to 6-db reduction, which in turn would reduce the land area exposed to any L_{dn} level by approximately 60 percent.* Potential damage costs would then be reduced proportionally. This reduction would be in addition to any other noise abatement technique employed and would be based on the total land area exposed at the time of the curfew's implementation. It should be mentioned here that the exposed population distribution (Fig. 4-1) upon which the damage award costs were calculated shifts downward with the passage of time due to the natural retirement of the noisier aircraft and the introduction of relatively quieter aircraft into the fleet.

Summary of Curfew Costs

As shown, a national curfew implementation would affect maintenance, mail and express, air cargo and passenger operations. The major impacts on the national airline system are the costs associated with the additional delay times. Airline operating costs are also affected through the purchase of additional aircraft, and the hiring of crews to fly them, to make up the capacity lost by the inability to move aircraft at night. The effects on cargo are the relatively small loss of business. A summary of these costs is shown in Table 4-1. Finally, by implementing a national curfew, the airport operators are able to avoid a significant portion of the estimated potential damage awards and the costs required to protect public health and welfare once such standards are promulgated. In retrospect, it does not appear that litigation awards will provide sufficient market incentive to trigger a national curfew. This follows from the very low success rate to date in such litigation. The real incentive to implement curfews will stem from the execution of the Noise Control Act provisions and the share of land use costs that airport operators must incur if no source abatement technology is transferred to the active civil fleet.

*Ref. 10.4-441 found that for twelve of the nation's most severly noise impact airports, the areas for any L_{dn} level would decrease approximately 35 percent.

SECTION 5
SUMMARY AND CONCLUSIONS

The degree of aircraft source noise reduction is time-dependent and based upon an effective program of technological development and demonstration.

The current state-of-the-art has progressed to the point where there are technology options available, which can be initiated immediately, to reduce the noise generated by the civil jet aircraft fleet. Other development programs indicate the potential for greater noise benefits at some later date at greater cost.

An optimum solution to the aircraft noise problem is a comprehensive, dedicated program taking advantage of current techniques and technologies for near term noise relief and providing assurance that future generations of transport aircraft will be less obtrusive to the airport neighbor.

In the context of achieving a goal of a certain level of cumulative noise exposure, it has been found that the cost of introducing currently available noise reduction technology into the civil aviation fleet is always less than the cost of achieving such levels not utilizing this technology. Therefore, on a rational use of resource basis, retrofit of state-of-the-art technology into the civil aviation fleet must be an integral part of any comprehensive program of cumulative noise reduction around airports.

CURRENT TECHNOLOGY STATUS

The present FAA noise standard, FAR 36, Appendix C, essentially put an upper limit on the generation of noise for newly certificated aircraft. However, the major portion of both the commercial air carrier fleet and the jet powered segment of the general aviation fleet exceed those limits. These aircraft are expected to continue to represent a dominant part of the inventory into the 1980's, thus masking the noise improvements being realized by the newer, quieter widebodied jets.

Demonstrated current technology can provide the means to bring all of these aircraft under the noise "umbrella" of FAR 36. This could be accomplished by the 1977 to '78 time period if an enforced noise abatement program is initiated immediately.

Meeting the present requirements of FAR 36 should not be interpreted as being the ultimate in noise reduction. The noise levels identified therein were based upon the technology available at the time of issuance of the rule. Present and future technological developments will permit a lowering of the allowable source noise level (See Task Group 5 Report).

FUTURE TECHNOLOGY STATUS

The NASA Experimental Quiet Engine Program successfully demonstrated the feasibility of realizing significant reductions in source noise in future engine developments. The capability now exists within industry to produce advanced-technology engines and transport aircraft with source noise levels approximately 5 to 10 EPNdB below the current FAR 36 requirement. With appropriate incentives and funding, these vehicles could be operational by 1980.

The same degree of noise reduction has not been demonstrated for the smaller engines that are compatible with the business jet aircraft requirement. Comparable research and development in noise abatement concepts for this class of engines and aircraft has not been accomplished.

Further reductions in engine-generated noise may have limited effectiveness, since it appears that a noise floor, due to external aerodynamic flow, is present during the approach and landing pattern. This is due to the relatively dirty, flaps down, wheels down, configuration in which the flow over these appurtenances has been estimated to generate a noise level of approximately FAR 36 levels minus 5 to 10 EPNdB.

New propulsion system concepts, particularly for RTOL and STOL-type aircraft, are in the early stages of development. Very high-bypass fans, such as the prop-fan concept, are currently being evaluated for future air carrier and general aviation type aircraft. Aircraft component developments, such as blown flaps, quieter helicopter rotor systems, while requiring additional development and demonstration testing, are all designed to provide a reduced future noise environment.

A continuing, but accelerated, technology research and demonstration program is imperative to provide early implementation of advanced concepts in source noise abatement.

SECTION 6
RESEARCH AND DEVELOPMENT RECOMMENDATIONS

The discussions in Sections 2 and 3 illustrate that extensive noise source research and development work has been and continues to be conducted by Government and industry. It is clear that considerable state-of-the-art technology is available for immediate application and that significant R&D effort is in progress for near-future utilization. Most of the R&D costs to date have been borne by the Federal Government, but not all. Industry has recognized that noise is an inhibiting factor to the promotion, encouragement, and development of civil aeronautics and has contributed substantial in-house funding to noise control. If the current and near-future source noise abatement technology were fully exploited, the noise exposure would drastically decrease, and a great deal of the noise impacted airport neighborhoods would experience welcome relief.

The R&D conducted to date, however, is by no means complete. New and more efficient aviation systems are needed and are under consideration. These systems may introduce noise characteristics and special problems that have not yet been adequately investigated. More R&D is required if civil aviation is to continue to grow and at the same time drastically reduce its noise emissions. The costs of the necessary R&D probably cannot be borne by the aviation community alone. The Federal Government, in order to ensure that civil aviation continues to be a viable national asset without jeopardizing the public health and welfare, must assume the R&D leadership, both in funding and technical direction, to the extent necessary for industry to continue on its own.

Research and development recommendations for aircraft noise control are well documented in a Society of Automotive Engineers Aerospace Information Report (SAE AIR 1079), and those relevant to this report are included in the following paragraphs.

COMPONENT TECHNOLOGY

The following research areas relating to components or systems have general application to a wide variety of aircraft and engine types.

POWER SOURCES

Engine and auxiliary power unit (APU) noise is generated by:

- Rotating components such as fans, compressors, turbines, propellers, rotors, and gears.
- Airflow interactions with such internal components as struts, vanes, surfaces, and burners.
- Accessories
- Mixing of exhaust jets with the ambient air.

Investigation is required to identify the mechanisms of noise generation in each case, to relate the noise of the various sources parametrically to operational variables, to establish reliable procedures for determining the relative strengths of the various sources, and to develop effective and practical methods of noise reduction.

DUCT TREATMENT MATERIALS AND TECHNOLOGY

This technology relates to the application of sound absorbing materials to the interior passages of the airflow ducts of all types of jet engines, to reduce the noise propagating in the ducts and thus minimize the noise radiated from the nacelles.

Additional work is needed to optimize the acoustical, mechanical, and aerodynamic properties of the sound absorptive materials and the duct lining configurations. Of particular importance is the development of general methods for predicting the acoustical performance of duct treatment for specific applications and the limit of effectiveness governed by self noise (aerodynamic flow).

CABIN NOISE

It has become customary to specify the airplane cabin noise environment in terms of overall sound pressure level (OASPL) and a speech interference level (SIL). The OASPL normally represents the low frequency end of the spectrum, and the SIL represents the medium to high frequency end. The use of OASPL and SIL has, in some cases, been shown to be an unsatisfactory means for indicating cabin acoustical acceptability. Investigation into more satisfactory forms of passenger cabin and crew compartment noise criteria is needed to provide a basis for guiding fuselage wall and interior acoustical design.

NOISE MEASUREMENT AND ANALYSIS

Continuing review and improvement of noise measurement and analysis instrumentation and procedures is needed to keep pace with regulatory and monitoring requirements. Among items that should receive immediate attention are analyzer characteristics and procedures for defining tones in aircraft noise, integration times for analyses of flyby noise measurements, specification of test sites, and method of correction for ground plane effects.

ENGINE AND AIRCRAFT TECHNOLOGY

The following research areas are pertinent to particular types of aircraft and their propulsion systems.

SUBSONIC AIRCRAFT

- Engine compressor and fan noise generation, prediction, and reduction.
- Engine duct treatment technology.
- Development of prediction and reduction techniques for medium (1000 to 2000 ft./sec.) and low velocity (below 1000 ft./sec.) jet exhaust noise including flight (relative velocity) effects.
- APU noise prediction and control.
- Aircraft interior noise criteria and evaluation.
- Subjective response to flyby, ramp, and interior noise.

SUPERSONIC AIRCRAFT

- Development of prediction and reduction techniques for high velocity (above 2000 ft./sec.) jet exhaust noise including afterburner operations and flight (relative velocity) effects.
- Sonic boom generation, propagation, and effects.
- Sonic boom abatement operational techniques.
- Subjective reaction, particularly related to low frequency noise and sonic booms and to associated vibrations.
- Cabin noise prediction and evaluation for supersonic cruise.

V/STOL AIRCRAFT

- Prediction of noise characteristics of integrated lift-propulsion systems.
- Prediction of noise characteristics of variable camber, including shrouded, propellers.
- Prediction of noise characteristics of deflected jet streams.
- Subjective reaction, particularly relating to low frequency noise and long-time exposures.
- Cabin noise reduction.

HELICOPTERS

- Main-rotor noise generation, prediction, and reduction.
- Rotor/rotor and rotor/propeller interaction effects.
- Cabin noise reduction.

GENERAL AVIATION AIRCRAFT

- Engine exhaust muffler technology.
- Noise reduction for slow-turning multiblade propellers.
- Engine mechanical and intake noise reduction.
- Cabin noise reduction.

AIRCRAFT DESIGN

The development of new structural design concepts to lower aircraft gross weight for a given mission, improve aerodynamic efficiency for better aircraft performance, and optimize engine placement should be investigated for beneficial effects on noise exposure.

In future aircraft designs, consideration should be given, in the preliminary design stage, to those components and design parameters that would permit more extensive use of preferential runways under high crosswind and gust conditions.

Airframe noise, defined as the noise generated by an aircraft in flight from sources other than the engine, auxiliary power units, and machine accessories, is the floor that establishes the limit of effectiveness of the current noise control state-of-the-art for aircraft during approach operations. Additional research and development is needed on noise generated by airflow over fuselage, wings, nacelles, flap systems, landing gear struts, wheel wells, etc., in order to provide data to assist designers in developing future technology aircraft capable of conforming to lower noise levels than are now achievable.

NEW ENGINE DEVELOPMENT

The NASA Quiet Engine Program provided the technology to permit the development of quieter engines for the next generation of commercial transports. Since the propulsion system is the longest lead time component for a new aircraft system, its development must be initiated now if new quieter aircraft are to be introduced into the fleet by 1980. Direct support of a new commercial engine development program or, as an alternative, accelerated development of the Air Force ATE program, from which commercial derivatives will be developed, is strongly recommended as a tool for future aircraft noise control.

OPERATIONAL PROCEDURES

Study of the optimization of takeoff and landing operations for noise minimization should continue, with attention given to such items as takeoff cutback procedures, optimum flap settings, optimum speeds, and approach path alternatives. In parallel, it is necessary to develop specialized instrumentation for use on board aircraft or on the ground to enhance the noise abatement procedures. A detailed discussion of the noise reduction benefits associated with the use of modified operational procedures is covered in the Task Group 2 report.

GENERAL

The DOT/NASA Joint Office of Noise Abatement (JONA) has begun the development of an integrated long-range plan for aircraft noise abatement research and development which covers the following subject matter:

1. Community Acceptance

2. Existing CTOL Aircraft

3. Advanced CTOL Aircraft (Including SST)

4. General Aviation Aircraft

5. Powered Lift Aircraft (STOL, RTOL, and VTOL)

6. Basic Noise Research

7. Aircraft Systems Analysis

The plan, while still in the formative stage, appears to be sufficiently comprehensive to cover all important aspects of aircraft noise control for the foreseeable future.

Complementary to the long range plan, NASA has created a new Aircraft Noise Prediction (ANOP) Office, initiated an Aircraft Noise Prediction Program (ANOPP), and established a technical advisory group of Government personnel from DOD, DOT, EPA, HUD, and NASA. The purpose of these actions is the development of accurate prediction techniques for noise generated by aircraft. This is essential in evaluating community impact of new modified aircraft systems as well as for screening aircraft and engine component and system concepts to guide research efforts aimed at noise reduction. Predictions will be developed in such forms as peak noise levels and spectra, noise time histories, noise "footprint" contours and as various measures of community impact.

The most effective use of technology to achieve maximum noise control is in the design and development of new aircraft systems. Consequently, noise abatement research and development (both for source control and flight procedures) must continue to be adequately funded to insure that these new aircraft systems evolve with the capability for substantially less noise impact than exists for current aircraft. The JONA Long Range Plan and the NASA ANOP Office, if adequately funded and staffed, has the potential for accomplishing this objective.

REFERENCES AND BIBLIOGRAPHY

TABLE OF CONTENTS

1.0 AIRPORT OPERATORS/OWNERS

MASTER FILE NO.	BIBLIOGRAPHIC CITATION
58	J. D. Reilly, Ltr: "Noise Rules for Supersonic Transport," AOCI, 6 March 1973.
60	C. A. Moore, "Presentation to the Board of Airport Commissioners of Management's Recommendation for Airport Regulations and Policies Designed to Reduce the Noise Contours at Los Angeles International Airport," Los Angeles Department of Airports, 20 December 1972.
61	N. Ewers et al, "Results of an Area Wide Noise Monitoring System," Presented to the Acoustical Society of America, Date unknown.
87	J. D. Reilly, Ltr: "Response to ANPRM 73-3 Docket No. 12534," Airport Operators Council International, 7 March 1973.
187	R. J. Bresnahan, "Effectiveness of the ECOLOG I Noise Monitoring System Installed at Orange County Airport as a Noise Abatement Tool," Orange County Airport, 16 March 1973.
191	G. J. Bender, Jr., Ltr: "Two Segment Approach Procedure and Wake Turbulence," Boston-Logan International Airport, 16 March 1973.
278	Resolution No. 7483, Los Angeles International Airport Board of Airport Commissioners, Subject: "Aircraft Sound Description System (ASDS)," 20 Dec. 1972.
352	Pamphlet: "What is Massport Doing about Airport Noise," Mass. Port Authority, Date Unknown.
287	Press Release: Five-Point Program to Alleviate Airport Noise; Los Angeles Department of Airports, 20 Dec 1972.
288	Resolution No. 7467: Resolution Adopted Five-Point Program to Alleviate Airport Noise; Board of Airport Commissioners, Los Angeles International Airport, 20 Dec 1972.

MASTER FILE NO.	BIBLIOGRAPHIC CITATION
289	Resolution No.7484: Resolution Affirming Support of Parts of Joint Policy Statement Issued by Airport Communities; Board of Airport Commissioners, Los Angeles International Airport, 20 Dec 1972.
290	Resolution No.7484-A: Resolution Recommending the Adoption of Appropriate Legislation to Effect Stronger Methods of Compatible Land Use in the Surrounding Communities; Board of Airport Commissioners, Los Angeles International Airport, 20 Dec 1972.
392	"Los Angeles International Airport-Environmental Impact Study" Phase I Report. Northrop Corporation for the Los Angeles Department of Airports, Jan 12, 1973.
417	Clifton A. Moore, Ltr. with Enclosure, "Comments on Draft Reports by Task Groups on Airport Noise", Department of Airports, City of Los Angeles, 29 June 1973.
418	Louis Achitoff, Ltr. with Enclosure, "Comments with Respect to Task Group 4 and 5 Reports", The Port Authority of New York and New Jersey, 29 June 1973.
421	"Ontario International Airport Environmental Impact Study" Volume 1-Executive Summary; Volume 2-Air Pollution and Related Studies; Volume 3- Aircraft Noise Studies; Volume 4-Biological and Related Studies; Volume 5-Economic Studies. Northrop Corporation for the Los Angeles Department of Airports, June 1973.
422	"Ontario International Airport: Draft Environmental Impact Statement; Pursuant to Section 102(2)(c), Public Law 91-190" Northrop Corporation for the Los Angeles Department of Airports, June 1973.
434	"Draft Environmental Impact Statement Pursuant to Section 102(2)(c) Public Law 91-190" Submitted by Board of County Road Commissioners Wayne County, Michigan to Department of Transportation, Federal Aviation Administration, April 1973.

AIRCRAFT ENGINE MANUFACTURERS

MASTER FILE NO.	BIBLIOGRAPHIC CITATION
2	"Noise Reduction Programs at Pratt and Whitney Aircraft," Presented to the Environmental Protection Agency Aircraft/Airport Noise Study Task Group 4, 28 February 1973, (Rev) 14 Mar '73.
15	W. G. Cornell, "Selective Bibliography of General Electric Reports on Aircraft Noise Research and Development," Submitted to EPA Aircraft/Airport Noise Study Task Group 4, 27 February 1973.
67	U. S. and International Commercial Jet Transport Fleets, Pratt and Whitney Aircraft, February 15, 1973
74	W. E. Helfrich, "Noise Reduction Program at Pratt & Whitney Aircraft," Presented to the Environmental Protection Agency, Pratt & Whitney Aircraft, February 28, 1973.
81	W. G. Cornell, "Supplementary Bibliography of General Electric Reports and Papers," General Electric, 15 Mar'73.
82	W. G. Cornell, Ltr: "ANPRM 73-3," General Electric, 15 March 1973.
93	"Supersonic Transport Noise Reduction Technology Program--Phase II," Report No. DOT-FA72WA-2890, Aircraft Engine Group, General Electric Quarterly Progress Report, 1 December thru 28 February 1973.
124	"Preliminary Engine Definition and Characteristics of the JT3D Quiet Engine," Pratt and Whitney, September 14, 1972.
125	"Preliminary Engine Definition and Characteristics of the JT8D Quiet Engine," Pratt and Whitney, October 14, 1972.
126	"Final Phase I Engine Definition and Characteristics of the JT3D--9 Engine," Pratt and Whitney, 14 Dec '72.
387	W. E. Helfrich, Ltr. "Core Engine Noise Levels for JT8D Refan Engine," Pratt and Whitney Aircraft, 6 June 1973.
410	L.G. Dawson and T. D. Sills, "The Changing Environment and Propulsion", Presented to the 13th Anglo-American Aeronautical Conference, London (4-8 June 1973), Rolls-Royce (1971) Limited.

MASTER FILE NO.	BIBLIOGRAPHIC CITATION
127	"Supplement 1 to Preliminary Engine Definition and Characteristics of the JT8D Quiet Engine," Pratt and Whitney, December 22, 1972.
134	"Preliminary Engine Definition and Characteristics of the JT8D-100 Quiet Engine," PWA 4671, Pratt and Whitney, February 12, 1973.
306	M. C. Steele, "Viewgraphs and Reference Material Used in Presentation to EPA/ONAC Aircraft Noise Task Group 4," Garrett-Airesearch 4 April 1973.
170	"JT8D-100 Series: Current Performance Data," Pratt and Whitney Aircraft, 8 February 1973.
174	W. G. Cornell, Ltr: "Comments on Various FAA Regulatory Notices on Aircraft Noise," General Electric, 2 April 1973.
197	"Visuals in Support of Presentation on Small Quiet Engine-Nacelle-Airplane Program," Airesearch Division of Garrett Corporation, 18 April 1973.
198	"Visuals in Support of Presentation on Airesearch Propulsion Engines," Airesearch Division of Garrett Corp, 18 April 1973.
199	"Visuals in Support of Presentation on Effect of Noise Regulations Program Schedule," Airesearch Division of Garrett Corp., 18 April 1973.
200	"Visuals in Support of Presentation on Combustion Noise and Emissions," Airesearch Division of Garrett Corp., 18 April 1973.
201	"Visuals in Support of Presentation on Turbine Noise Control," Airesearch Division of Garrett Corp., 18 April 1973.
202	"Visuals in Support of Presentation on Mechanical Noise," Airesearch Division of Garrett Corp., 18 April 1973.
419	J. N. Krebs, Ltr. "Views on Aircraft Noise Regulations", General Electric Co., 22 May 1973.

MASTER FILE NO.	BIBLIOGRAPHIC CITATION
203	"Visuals in Support of Presentation on V/STOL Rotary Propulsion Study, "Airesearch Division of Garrett Corp., 18 April 1973.
204	"Visuals in Support of Presentation on Dual Bypass Turbofan Engine Concept," Airesearch Division of Garrett Corp., 18 April 1973.
220	"Aircraft Engine Noise Reduction at Airesearch," Airesearch Division of the Garrett Corp., April 1973.
261	Comments On FAA Project Report, "Noise Certification Rule for Quiet Short Haul Category Aircraft," Hamilton Standard, 27 April 1973.
264	Comments On FAA Project Report, "Propeller Driven Aircraft Noise Type Certification Standards," Hamilton Standard, 27 April 1973.
258	F. B. Metzger et al, "Noise Characteristics Of Quiet Propellers For STOL Aircraft, Purdue Noise Conference, 15 July 1971.
259	F. B. Metzger et al, "New Low-Pressure-Ratio Fans for Quiet Business Aircraft Propulsion, SAE Business Aircraft Meeting, Wichita, 3-6 April 1973.
260	F. B. Metzger et al, "Low-Pressure-Ratio Fan Noise Equipment and Theory," Journal for Engineering and Power, January 1973.
356	W. E. Helfrich, Ltr. with Position Paper Related to Task Group 4 Efforts, Pratt & Whitney Aircraft, 15 May 1973.
357	W. E. Helfrich, Ltr. with Position Paper Related to Task Group 5 Efforts, Pratt & Whitney Aircraft, 11 May 1973.
365	"Q-FAN"; Report No.SP06A72, Hamilton Standard Division of United Aircraft Corp, Sept 1972.
375	E. G. Ratering and C. L. Walker, "General Motors Statement Before the Environmental Protection Agency Task Force on the Aircraft/Airport Noise Study," Detroit Diesel Allison Division of General Motors, 21 June 1973.

2.0 AIRCRAFT ENGINE MANUFACTURERS (CONT'D)

MASTER FILE NO.	BIBLIOGRAPHIC CITATION
454	"Visual Aids in Support of Oral Report on JT8D Refan Program" Pratt and Whitney Aircraft, 25 July 1973.

3.0 AIRCRAFT MANUFACTURERS

MASTER FILE NO.	BIBLIOGRAPHIC CITATION
1	V. L. Blumenthal, W. S. Huntington, J. M. Streckenbach, "Noise-Reduction Research and Development - 1972 Progress," Boeing Document D6-60199, March 1973.
13	V. L. Blumenthal, R.E. Russell, J. M. Streckenbach, "Summary Noise Reduction Research and Development," Boeing Document D6-60146, November 1971.
14	V. L. Blumenthal, J. M. Streckenbach, R. B. Tate, "Aircraft Environmental Problems," AIAA Paper No. 73-5 AIAA 9th Annual Meeting and Technical Display, Washington, D.C., 8-10 January 1973.
4	R. E. Pendley, "Noise Retrofit of DC-8 and DC-9 Airplanes," Presented to Subcommittee on Advanced Research and Technology, House of Representatives Committee on Science and Astronautics, Douglas Aircraft Co., 19 January 1972.
7	"DC-9 Engine Noise Reduction Programs," Douglas Aircraft Co. Report MDC-J4358, 5 January 1973.
8	A. L. McPike, "The Generation and Suppression of Aircraft Noise," Douglas Aircraft Co. Report 710304, No Date.
9	R. E. Pendley, "Review of Programs Dealing with Reduction of Subsonic Transport Noise at the Source," Douglas Aircraft Co. Paper 5799, Presented to Air Transport Association of America, Chicago, Illinois, 26 May 1970.
10	A. L. McPike, "Evaluation of Advances in Engine Noise Technology," Douglas Paper 5631, Presented to Eleventh Anglo-American Aeronautical Conference, Royal Aeronautical Society, London, England, 8-12 September 1969.

MASTER FILE NO.	BIBLIOGRAPHIC CITATION
11	P. F. Pendley, "Technical and Economic Feasibility of Developing Nacelle Modifications to Reduce Fly-over Noise of DC-8 and DC- 9 Airplanes," Douglas Aircraft Co. Paper 5834, August 1970.
32	A. L. McPike, "Community Noise Levels of the DC-10 Aircraft," J. Aircraft Vol.9, No. 8, August 1972.
5	J. S. Gibson, "Non-Engine Aerodynamic Noise Technology and Impact," Lockheed-Georgia Co. Information Brief, 21 February 1972.
6	J. S. Gibson, "V/STOL Noise Technology and Design Considerations," Lockheed-Georgia Co. Information Brief, 22 February 1972.
17	N. Shapiro, J. F. Schulert, "Improved Airport/Community Noise Environment with the New L-1011 Trijets," AIAA Paper No. 69-801, AIAA Aircraft Design and Operations Meetings, Los Angeles, California, 14-16 July 1969.
18	N. Shapiro, "Community Noise Levels of the L-1011 Tristar Jet Transport," Acoustical Society of America, Buffalo, N. Y., 18-21 April 1972.
19	H. Drell, "Impact of Noise on Subsonic Transport Design," Society of Automotive Engineers Paper 700806, Los Angeles, California, 5 -9 October 1970.
20	J. R. Thompson, M. J. T. Smith, "Minimum Noise Pod Design," Society of Automotive Engineers Paper 700805, Los Angeles, California, 5-9 October 1970.
21	N. Shapiro, G. J. Healy, "A Realistic Assessment of the Vertiport/Community Noise Problem," J. Aircraft, Vol. 5, No. 4, July-August 1968.
22	N. Shapiro, J. W. Vogel, "Noise Certification of a Transport Airplane," Inter-Noise 72 Proceedings, Washington, D.C., 4-6 October 1972

3.0 AIRCRAFT MANUFACTURES (CONT'D)

MASTER FILE NO.	BIBLIOGRAPHIC CITATION
23	J. R. Thompson, N. Shapiro, "The Effect of Temperature Inversions of Flyover Noise Measurements," Symposium on Atmospheric Acoustic and Noise Propagation, National Bureau of Standards, Gaithersburg, Md., 27-29 September 1972.
28	"Concorde: Airport Noise and Silencing Programme, Annex 1, Test Facilities," SNIA, SNECMA, BAC and Rolls Royce Limited, October 1972.
78	J. S. Gibson, "The Ultimate Noise Barrier--Far Field Radiated Aerodynamic Noise," Lockheed-Georgia, 4 October 1972.
88	H. W. Withington, "Response to ANPRM 73-3, Docket No. 12534," Boeing Commercial Airplane Company, 28 February 1973.
89	A. L. McPike, "Response to ANPRM 73-3, Docket No. 12534," McDonnell-Douglas, 1 March 1973.
90	A. L. McPike, "Copies of View Graphs Used in Presenting A New Aircraft Noise Rating Concept," McDonnell-Douglas, 22 March 1973.
91	A. L. McPike, "The Relative Importance of Take-Off, Sideline and Approach Noise," McDonnell-Douglas, 22 March 1973.
96	A. L. McPike, " A Suggested Alternative Approach to Controlling the Noise of the Fleet," McDonnell-Douglas, 22 March 1973.
122	"707/JT3D -9 Refan Nacelle and Airplane Integration Definition," D3-9039-1, Boeing, November 10, 1972.
123	"707/JT3D-9 Refan Nacelle and Airplane Integration Definition, D3-9039-1, Boeing, Second Submittal January 15, 1973.
128	"DC-8 Series 61 Engine and Nacelle/Airframe Integration Definition," Report MDC J5731, McDonnell-Douglas , November 10, 1972.

MASTER FILE NO.	BIBLIOGRAPHIC CITATION
129	"DC-8 Series 61 Engine and Nacelle/Airframe Inte - gration," Report MDC J5731A, McDonnell-Douglas, January 8, 1973.
130	"DC-8 Series 63 Engine and Nacelle/Airframe Inte - gration Definition," Report MDC J5732, McDonnell-Douglas, November 10, 1972.
131	"DC-8 Series 63 Engine and Nacelle/Airframe Inte - gration Definition," Report MDC J5732A, McDonnell-Douglas, January 8, 1973.
132	"Preliminary Retrofit and Economic Analysis," Volume I Economic Analysis, Report MDC J5734-1 McDonnell-Douglas, January 8, 1973.
133	"Preliminary Retrofit and Economic Analysis," Volume II Retrofit (Trade Study) Analysis, Report MDC J5734-2, McDonnell-Douglas, January 8, 1973.
135	"JT3D Final Engine and Nacelle/Airframe Integration Definition," Report MDC J5735, McDonnell-Douglas, March 15, 1973.
136	"DC-9-32 Engine and Nacelle/Airframe Integration Definition," Report MDC J5733, McDonnell-Douglas, March 15, 1973.
140	R. A. Fuhrman, Ltr: "Response on Docket No. 12534, Notice No. 73-3," Lockheed - California Co., 27 February 1973.
142	H. Drell, Ltr: "Comments on Information Brief on Aircraft Noise Control Options and Methods of Exploiting Technology," Lockheed -California Co., 30 March 1973.
151	W. R. Dunbar, "DC-8 Noise Reduction Studies" Mc Donnell-Douglas , 2 April 1973.
152	"DC-9 Engine Noise Reduction Programs" McDonnell Douglas, 5 January 1973.
153	"The Integration of Quiet Engines with Subsonic Transport Aircraft," McDonnell-Douglas, 1 August 1969.

MASTER FILE NO.	BIBLIOGRAPHIC CITATION
159	V. L. Blumenthal, Ltr: Some General Comments and Recommendations Pertaining to Task Group 4 Activities, Boeing, 2 April 1973.
161	D. R. Hawes, C. R. Cox, "Noise Reduction Possibilities for a Light Helicopter," Bell Helicopter Co., Date Unknown.
162	C. R. Cox, "Subcommitte Chairman's Report to Membership on Aerodynamic Sources of Rotor Noise," Presented to the 28th Annual National Forum of the American Helicopter Society, Wash., May 1972.
163	C. R. Cox, "Flying Neighborly - How to Operate the Light Helicopter More Quietly," Bell Helicopter, Date Unknown.
164	C. R. Cox, "VTOL Noise," Presented at EPA.ONAC Aircraft, Airport Noise Task Group 4 Meeting, 3 April 1973.
178	V. L. Blumenthal, Ltr: (w/Attachments) "Thoughts on the Existing Aircraft Noise Regulation and Planned Regulatory Actions," Boeing, 2 April 1973.
184	G. I. Martin, Ltr: (with enclosures) "AIAA Response to FAA Noise Rule Making Dockets," AIAA, 9 April 1973.
190	J. S. Gibson, "Technical Brief: Status of the Aircraft Non-Engine Aerodynamic Noise Problem," Lockheed-Georgia Co., 5 February 1973.
193	H. Sternfeld, Jr.; E. Hinterkeuser, "Effects of Noise on Commercial V/STOL Aircraft Design and Operation," Presented at AIAA 5th Annual Meeting and Display, Vertol Division of the Boeing Co., October 1968.
395	Ronald G. Schlegel, Ltr: "Position Paper Related to VTOL Aircraft Noise Rules", Sikorsky Aircraft, Division of United Aircraft Corp., 2 July 1973.

MASTER FILE NO.	BIBLIOGRAPHIC CITATION
194	F. H. Duke, W.E. Hooper, "The Boeing Model 347 Advanced Technology Helicopter Program," Presented at the 27th Annual National V/STOL Forum of the Helicopter Society, Vertol Division of the Boeing Company, May 1971.
195	W. E. Stepniewski, F. H. Schmitz, "Possibilities and Problems of Achieving Community Noise Acceptance of VTOL," Presented to 8th Congress of the International Council of the Aeronautical Sciences, Vertol Division of the Boeing Company and the Army Air Mobility Lab., August 1972.
196	N. B. Hirsh, H. W. Ferris, "Design Requirements for a Quiet Helicopter," Presented at the 28th Annual National Forum of the American Helicopter Society, Aircraft Division of the Hughes Tool Co., May 1972.
212	"Summary: 707-727-737-747 Noise-Reduction Activities," Report D6- 40613-B, The Boeing Commercial Airplane Company, March 1973.
211	N. B. Hirsh, H. W.Ferris, "The Hughes OH-6A Quiet Helicopter Program," Hughes Helicopter, A Division of Summa Corp., Undated.
208	W. H. Barlow et.al., "OH-6A Phase II Quiet Helicopter Program," USAAMRDL Report 72-29, Prepared for Eustis Directorate of U. S. Army Air Mobility Research and Development Laboratory, Hughes Tool Company, Sept. 1972.
206	E. G. Hinterkeuser, H. Sternfeld Jr., "Subjective Response to Synthesized Flight Noise Signatures of Several Types of V/STOL Aircraft," Vertol Division of the Boeing Co. NASA CR Report CR-1118, Undated.
205	"Visuals in Support of Presentation on 737/T-43A Noise Reduction Program," The Boeing Company, 30 March 1973.
400	E. J. Whitehead, "Program on Ground Test of Modified Quiet Clean JT3D and JT8D Engines in Their Respective Nacelles: DC-9 Series 32, Engine and Nacelle/Airframe Integration Definition", Report MDC J5733A, Douglas Aircraft Company, 23 May 1973 (Second Submittal).
411	A. L. McPike, Ltr: "Additional Comments on Task Group 4 Report of an Editorial Nature", Douglas Aircraft Company, 29 June 1973.

MASTER FILE NO.	BIBLIOGRAPHIC CITATION
221	"Noise Abatement Takeoff Procedure Recommended for Commodore Jet 1123, Israel CAA Approved Flight Manual, 26 Nov. 1971.
226	C. R. Cox, Ltr: (including enclosures), Corrected Visual of Air Speed vs Sideline Noise and "Fly Neighborly-How to Operate the Medium Helicopter More Quietly," Bell Helicopter, 12 April 1973.
227	J. S. Gibson, "Information Brief - V/STOL Noise Technology and Design Considerations," IB 7302, Lockheed-Georgia Company, 9 March 1973 (Rev.).
228	J. S. Gibson, "Information Brief-Non-Engine Aerodynamic Noise Technology and Impact," IB7301, Lockheed-Georgia Company, 6 April 1973 (Rev.).
219	H. Sternfeld, Jr., E. G. Hinterkeuser, "Acceptability of VTOL Aircraft Noise Determined by Absolute Subjective Testing," NASA CR-2043, Vertol Division of the Boeing Company, 10 Jan. 1972.
217	"An Investigation of Noise Generation on a Hovering Rotor: PartII," Vertol Division of the Boeing Company, Nov. 1972.
216	F. H. Schmitz et.al., "A Comparison of Optimal and Noise Abatement Trajectories of a Tilt-Rotor Aircraft," Vertol Division of the Boeing Company, Jan. 1972.
230	"FAA 727 Quiet Nacelle Retrofit Feasibility Study - Contract DOT-FA71WA-2637," Wichita Division of the Boeing Company, Date unknown.
231	"Feasibility and Initial Model Studies of a Coanda/Refraction Type Noise Suppressor System," Report D3-9068, Wichita Division of the Boeing Company, January 1973.
412	A. L. McPike, Ltr: "Comments on Draft Report and Operations of EPA Task Group 4", Douglas Aircraft Company, 29 June 1973
413	A. L. McPike, Ltr: "Comments on Draft Report and Operations of EPA Task Group 5", Douglas Aircraft Company, 29 June 1973.

AIRCRAFT MANUFACTURERS (CONT'D)

MASTER FILE NO.	BIBLIOGRAPHIC CITATION
286	H. Drell, Ltr: (with enclosure),"Lockheed-California Company/Rolls-Royce Position Related to the Potential for further Engine Noise Reduction, Lockheed-Calif. Company, 25 April 1973.
304	J. Vogel, Ltr:(with enclosures), "Sideline Noise Measurements," Lockheed-California Company, 1 May 1973.
[illegible]	J.L. Blumenthal, Ltr. "Additional Comments on Draft Reports" Boeing Commercial Airplane Company, 20 June 1973.
330	"Contract DOT-FA71WA-2628, FAA JT3D-707 Quiet Nacelle Program Summary," Boeing-Wichita, 7 May 1973.
246	R. E. Russell, Ltr. w/attachments, "Data on Operational Procedures as Requested in EPA Letter of 12 April 1973," Boeing Commercial Airplane Group, 20 April 1973.
338	"Concorde: Airport Noise and Silencing Programme," SNIA, SNECMA, BAC and Rolls Royce Limited, Oct. 1972.
339	"Concorde: Airport Noise and Silencing Programme; Annex 3, The Economic Aspects of Silencing Concorde," SNIA, SNECMA, BAC and Rolls Royce Limited, Oct. 1972.
340	"Concorde; Airport Noise and Silencing Programme; Annex 2, Manufacturers Further Studies of Noise Reduction," SNIA, SNECMA, BAC and Rolls Royce Limited, Oct. 1972.
367	"BAC - 111 Noise Reduction Programs," British Aircraft, Corp. (USA), 29 May 1973.
354	M. G. Wilde, Ltr. with "Recommendations of the Concorde Manufacturers to the EPA Relating to the Regulation of Concorde Noise," BAC, 17 May 1973.
243	"[illegible] JT8D-109 Refan Nacelle and Airplane Integration Definition", Preliminary Submittal D-640822, Boeing Commercial Airplane Company, [illegible] April 1973.

MASTER FILE NO.	BIBLIOGRAPHIC CITATION
401	K. P. Rice, "Program on Ground Test of Modified, Quiet, Clean JT3D and JT8D Engines in Their Respective Nacelles; JT3D/JT8D REFAN Preliminary Economic Study" Report No. D6-40982, Boeing Commericial Airplane Company, April 1973.
402	K. P. Rice, "Program on Ground Test of Modified, Quiet, Clean JT3D and JT8D Engines in Their Respective Nacelles; 707/JT3D-9 REFAN Nacelle, Engineering Summary Report" Report No. D3-9107, Boeing Commercial Airplane Company, April 10, 1973.
403	K. P. Rice, "Program on Ground Test of Modified, Quiet, Clean JT3D and JT8D Engines in Their Respective Nacelles; Phase I, 737, JT8D-109 REFAN Nacelle and Airplane Integration Definition" Report No. D6-32569, Boeing Commercial Airplane Company, June 22, 1973.
404	K. P. Rice, "Program on Ground Test of Modified, Quiet, Clean JT3D and JT8D Engines in Their Respective Nacelles; Phase I, 727, JT8D-109 REFAN Nacelle and Airplane Integration Definition" Report No. D6-41170, Boeing Commercial Airplane Company 1 June 1973.
405	Bernard D. Brown, Ltr. "Confirming Currency of Documentation Supplied to the Task Group", British Aircraft Corporation (U.S.A.) Inc., 2 July '73.
406	Bernard D. Brown, Ltr. "Position Paper Related to EPA Aircraft/Airport Noise Study Report", British Aircraft Corporation (U.S.A.) Inc. for Concorde Project Director, BAC-CAD on behalf of the four Concorde Manufacturers, 2 July 1973.
408	V. L. Blumenthal, Ltr. w/Attachments: "Boeing Commercial Airplane Company Position on Task Group 4, Noise Source Technology and Cost Analysis Including Retrofitting", Boeing Commercial Airplane Company Letter 6-7270-1-444, 29, June 1973.
409	V. L. Blumenthal, Ltr.: "Boeing Commercial Airplane Company Position on Task Group 5, Review and Analysis of Present and Planned FAA Noise Regulatory Actions and Their Consequences Regarding Aircraft and Airport Operations" Boeing Company Letter No. 6-7270-1-455, 29 June 1973.

MASTER FILE NO.	BIBLIOGRAPHIC CITATION
445	Ronald G. Schlegel, "Position on VTOL Noise Certification", Sikorsly Aircraft, 20 July 1973.
449	D. L. Hiatt, M. B. McKaig, et.al., "727 Noise Retrofit Feasibility; Vol. III: Upper Goal Flight Testing and Program Summary" FAA-RD-72-40, III, Boeing Commercial Airplane Co., June 1973.
450	"Visual Aids in Support of an Oral Report on Contract DOT-FA71WA-2628, FAA JT3D-707 Quiet Nacelle Program", Boeing Commercial Airplane Company, 25 July 1973.
451	"Visual Aids in Support of an Oral Report on Contract DOT-FA71WA-2637, FAA 727 Quiet Nacelle Retrofit Feasibility Study", Boeing Commercial Airplane Company, 25 July 1973.
452	"Program on Ground Test of Modified Quiet Clean JT3D and JT8D Engines in Their Respective Nacelles: Visual Aids in Support of an Oral Report on Phase I Results", Douglas Aircraft Company, 25 July 1973.
453	"Visual Aids in Support of Oral Report on a Retrofit Feasibility Program", Federal Aviation Administration, 25 July 1973.
455	"Visual Aids in Support of Oral Report on Long Range Noise Measurements" Boeing Commercial Airplane Company, 25 July 1973.
456	"Visual Aids in Support of Oral Report on Refan Retrofit Program Status" Boeing Commercial Airplane Company, 25 July 1973.

4.0

AIRLINES

MASTER FILE NO.	BIBLIOGRAPHIC CITATION
56	J. T. Davis, Ltr: "Comments on FAA Rules and Proposals," Delta Airlines, 9 March 1973.
73	P. A. Soderlind, Ltr: "Northwest Airlines Noise Abatement Procedures," Northwest Airlines, 24 November 1970.
270	"Flight Standard Bulletin No. 3-70: Revised Standard NWA Takeoff," Northwest Airlines, Inc., 5 October 1970.
267	R. E. L. Carmichael, Ltr: (with enclosures) "Regarding PSA Policies Involving Noise Abatement During Arrivals and Departures," Pacific Southwest Airlines, 28 March 1973.
268	J. R. Tucker, "Takeoff Flight Path Studies," Air California, 1 March 1973.
269	"Special DCA Noise Abatement Procedure," Flight Operations Manual, United Air Lines, 25 Feb. 1972.
333	J. T. Davis, Ltr: "Comments on Draft Report Task Group 5, 5 May 1973," Delta Air Lines, 16 May 1973.
334	J. T. Davis, "Visuals in Support of Comments on Draft Report Task Group 5, 5 May 1973," Delta Air Lines, 16 May 1973.
384	R. W. Rummel, Ltr. with Enclosure titled "Airlines and the Energy Crisis", Trans World Airlines, 23 May 1973.

5.0 INDIVIDUALS

MASTER FILE NO.	BIBLIOGRAPHIC CITATION
41	M. P. Kelly; Ltr: "Nosie Problems at Opa-Locka Airport," 12 February 1973.
47	R. Gegauff; Ltr: "Noise Problems at Logan Airport," 2 March 1973.
372	J. C. Bohonis; Ltr: "Suggestions for Aircraft/Airport Noise Study Report," 17 April 1973.
373	E. E. Farman; Ltr: "Aircraft Noise" 12 May 1973.
381	W. H. Rodgers, Jr. Ltr with Copy of Chapter from Author's Book Titled "Corporate Country", 8 June 1973.

ENVIRONMENTAL GROUPS

MASTER FILE NO.	BIBLIOGRAPHIC CITATION
12	Lloyd Hinton, "Aircraft Noise as a Continuing National Problem," Proceedings of International Conference on Transportation and the Environment, No Date.
16	J. Tyler, "Source Abatement Technology," Submitted to EPA Aircraft/Airport Noise Study Task Group 4, 28 February 1973.
27	J. Hellegers, L. Hinton, N. McBride, C. Lerza, J. Conroy, Environmental Defense Fund Letter to John Schettino, 23 February 1973.
30	J. Hellegers, Raelynn Janssen, L. Hinton, J. Tyler, N. McBride, M. Moore, P. Borrelli, M. Evans, Ltr: "Docket No. 12534; ANPRM on Civilian Airplane Fleet Noise (FNL) Requirements," EDF, NOISE, ACAP, CAN, Sierra Club, 2 March 1973.
46	J. Hellegers; Ltr: "Advice on Requesting Info from the FAA," 26 February 1973.
57	L. Hinton et al; Ltr: "Aircraft and Airport Instrumentation," 13 March 1973.
77	T. Berland, "Response to ANPRM on FNL, Docket No. 12534, Notice 73-3," Citizens Against Noise, 14 March 1973.
85	L. Hinton, J. Tyler, "Response to ANPRM 73-3, Docket No. 12534," N.O.I.S.E.," 2 March 1973.
94	"Comments Related to FAR Part 36: Aircraft Noise Certification Procedures," N.O.I.S.E., 22 March 1973.
95	"Comments Related to Airport Certification," N.O.I.S.E., 22 March 1973.
168	"Control of Aircraft Noise in the Basic Engine Aircraft Design," NOISE, J. Tyler, 3 April 1973.
169	"Airport Design" NOISE, J. Tyler, 3 April 1973.
173	L. V. Hinton, J. M. Tyler, Ltr: "Recommended Regulations," N.O.I.S.E., 5 April 1973.

ENVIRONMENTAL GROUPS (CONT'D)

MASTER FILE NO.	BIBLIOGRPAHIC CITATION
294	L. Hinton; Ltr: "Questions Related to FAA's Understanding of Authority to Regulate Airport Noise," N.O.I.S.E., 4 May 1973.
293	L. Hinton; Ltr: "To Mr. Phillip T. Cummings, Asst. Counsel, Committee on Public Works, United States Senate, N.O.I.S.E., 4 May 1973.
295	J. Tyler, L. Hinton; Press Release Related to Aircraft Noise Reduction Demonstration at Dulles Airport on 7 May 1973, N.O.I.S.E., 7 May 1973.
325	J. Scaffetta; Ltr: "Concern over SST Noise Pollution, Member of Friends of the Earth, 15 March 1973.
345	J. M. Tyler, L. Hinton, "Comments on Draft Reports of Task Group 4 and 5," NOISE, 15 May 1973.
346	L. Hinton, Ltr: "Findings and Recommendations Related to "Adequacy of FAA Flight and Operational Noise Controls," NOISE, 27 April 1973.
358	L. Hinton, J. Tyler, Ltr: "Comments and Recommendations for Draft No. 1, Chapter 3 of the Report to the Congress," NOISE, 18 May 1973.
389	J. F. Hellegers, Ltr. "Capacity Limitation Agreements," Environmental Defense Fund, 31 May 1973.
393	Lloyd Hinton and John Tyler, Ltr: "Position Paper Related to Task Group 5 Report", N.O.I.S.E, 30 June 1973.
394	Lloyd Hinton and John Tyler, Ltr: "Position Paper Related to Task Group 4 Report", N.O.I.S.E, 30 June 1973.

FEDERAL GOV'T; AVIATION ADVISORY COMMISSION

MASTER FILE NO.	BIBLIOGRAPHIC CITATION
25	"The Long Range Needs of Aviation, "Report of the Aviation Advisory Commission, 1 January 1973.
52	The Long Range Needs of Aviation: "Technical Annex to the Report of the Aviation Advisory Commission," Vol I, January 1973.
53	The Long Range Needs of Aviation: "Technical Annex to the Report of the Aviation Advisory Commission," Vol II, January 1973.
99	"Aircraft Noise Analysis for the Existing Air Carrier System," Report No. 2218, Contract No. CON-AAC-72-12, Bolt, Beranek and Newman for the Aviation Advisory Commission, 1 September 1972.
54	"Impact of Business Jets on Community Noise Exposure," Proj. Report No. 2222, Bolt, Beranek and Newman for the Aviation Advisory Commission 21 August 1972.
117	"Classification of Airport Environs by Airport/Community Land Use Compatibility," Back & Sterling, Inc. for Aviation Advisory Commission, 28 Jan '72.
118	"Cost Estimates for Removal of Residental and Related Land Use Near Selected Airports," Back & Sterling, Inc. for Aviation Advisory Commission, 25 August 1971.
175	"A Model and Methodology for Estimating National Land Use Removal Costs," The Decision Information Group, Inc., For the Aviation Advisory Commission, 4 August 1972.

MASTER FILE NO.	BIBLIOGRAPHIC CITATION
29	L. Simpson, R. C. Knowles, J. B. Feir, "Airline Industry Financial Analysis with Respect to Aircraft Noise Retrofit Programs ," R. Dixon Speas Associates, N. Y., January 1973.
24	D. C. Gray, "Results of Noise Surveys of Seventeen General Aviation Type Aircraft," Federal Aviation Administration Report No. FAA-EQ-73-1, Dec '72.
37	"Draft: Environmental Impact Statement for Policy Changes on the Role of Washington National Airport and Dulles International Airport," Prepared by the Federal Aviation Administration, 31 January 1973.
70	Working Paper No. 10: "Aviation Cost Allocation Study; Allocation of Airport and Airway System Costs," Office of Policy Review, Department of Transportation, December 1972.
48	"Noise Abatement Procedures," Federal Aviation Agency, November 1960.
49	R. L. Paullin, :The Status of International Noise Certification Standards for Business Aircraft," Department of Transportation, 6 April 1973, NBAA Meeting.
50	"Noise Abatement Rules: Amendment 91-46 to FAR," Federal Aviation Administration, 4 Dec'67.
68	J. D. Wells et al, "An Analysis of the Financial and Institutional Framework for Urban Transportation Planning and Investment," Study S-355, Contract No. DAHC15-67-C-0011, Department of Transportation, June 1970.
69	Working Paper No. 8: "Aviation Cost Allocation Study, Design Rationale for a General Aviation National Airspace System," Office of Policy Review, Department of Transportation, July 1972.

MASTER FILE NO.	BIBLIOGRAPHIC CITATION
71	Working Paper No. 18: "Aviation Cost Allocation Study, The Price Elasticity of Demand for General Aviation," Office of Policy Review, Department of Transportation, December, 1972.
72	D. L. Hiatt et. al., "727 Noise Retrofit Feasibility; Vol. III: Upper Goal Flight Testing and Summary," Report No. FAA-RD-72-40, III., Federal Aviation Administration, January, 1973. (PRELIMINARY).
100	"Project Report: Noise Certification Rule for STOL Category Aircraft," FAA, 18 January 1971.
101	"Aviation Cost Allocation Study: Overview of Cost Allocation Methodologies; Working Paper No. 1," Office of Policy Review; Dept. of Transportation, January 1972.
102	"Aviation Cost Allocation Study: Working Paper No. 15; Socio - Economic Approach to Benefits of the Airport and Airway System," Office of Policy Review, Dept. of Transportation, Dec '72.
104	W. C. Sperry, "Information Brief on Bibliography on Aircraft Certificated Noise Levels," Preliminary Data Compiled by FAA/AEQ-20, 21 December 1972.
105	W. C. Sperry, "Information Brief on Bibliography of FAA Aircraft Noise Reports," 18 August 1972.
107	W. C. Sperry "Information Brief on Current and Estimated Noise Levels for Major U. S. Aircraft Series," FAA, 2 December 1972.
108	W. C. Sperry. L. A. Ronk "Information Brief on Boeing 707-320B Aircraft Noise," FAA, 25 January 1972.
109	L. A. Ronk, T. N. Cokenais, W. C. Sperry, "Information Brief of EPNL Contour (Footprint) Comparison of Noise Abatement Retrofit Options for 707-320B Aircraft," FAA, 11 January 1973.
110	L. A. Ronk, T. N. Cokenais, W.C. Sperry, "Information Brief of EPNL Contour (Footprint) Comparison of Noise Abatement Retrofit Options for 727-200 Aircraft," FAA 22 December 1972.

MASTER FILE NO.	BIBLIOGRAPHIC CITATION
111	T. N. Cokenais, "Information Brief on Computer Programs for the Evaluation of EPNL Contours for Approach Operations," FAA, 19 September 1972.
112	L. A. Ronk, "Information Brief on Computer Programs for the Evaluation of EPNL Contours for Takeoff Operations," FAA, 11 September 1972.
113	L. A. Ronk, T. N. Cokenais, W. C. Sperry," Information Brief on EPNL Contours and Enclosed Areas for 727, DC-9, and 707 Aircraft," FAA, 1 May 1972.
114	L. A. Ronk, W.C. Sperry, T. N. Cokenais, "Information Brief on Takeoff and Approach Noise for Boeing 727 Aircraft," FAA, 8 January 1973.
116	W. C. Sperry, L. A. Ronk, T. N. Cokenais, "Information Brief on Prediction of Aircraft Noise Levels for Planning Purposes," FAA, 7 September 1971.
119	"Part 91: General Operating Flight Rules; Civil Aircraft Sonic Boom," Federal Register Vol. 38, No. 59, 28 March 1973.
120	W. C. Sperry, "Information Brief on Current and Estimated Noise Levels for Major U.S. Aircraft Series,' FAA, 2 December 1972.
147	W. C. Sperry, "Information Brief on Federal Aviation Administration Noise Abatement Research and Development," FAA, 22 December 1972.
148	W. C. Sperry, "Information Brief on FAA Aircraft Noise Research," FAA, 6 December 1972.
149	W. C. Sperry, "Information Brief on Analysis of Aircraft Sound Description System (ASDS)," EPA, 2 April 1973.
307	"A Study of the Magnitude of Transportation Noise Generation and Potential Abatement: Vol. I - Summary," OST-ONAC-71-1, Department of Transportation, Nov'70.
364	"A Study of the Magnitude of Transportation Noise Generation and Potential Abatement: Vol. VII - Abatement Responsibility," OST-ONA-71--1, Dept. of Transportation, November 1970.

MASTER FILE NO.	BIBLIOGRAPHIC CITATION
213	"Airline Economic Impact Computer Model: Vol. I - Detailed Discussion," FAA-EQ-72-4, I, Federal Aviation Administration, Department of Transportation, June 1972.
182	"Airline Economic Impact Computer Model. Vol II - Appendix, Detailed Data Tables," FAA-EQ-72-4,II, Rohr Industries, Inc. and Mitchell Research Associates for the Department of Transportation, June 1972.
286	J. E. Cruz, "Aircraft Sound Description System - Background and Application" Final Report FAA-EQ-73-3, Office of Environmental Quality, FAA, March 1973.
424	DRAFT "Noise Standards for Newly Produced Airplanes of Older Type Designs" Federal Aviation Administration, Draft Regulation, July 1973.
185	C. R. Foster, Memo and Enclosure; "Report of the U. S. Delegation to the ICAO Committee on Aircraft Noise, Third Meeting," 5 March 1973.
207	"Arrival and Departure Handling of High Performance Aircraft," DOT/FAA Advisory Circular No. AC 90-59, 28 February 1972.
222	News Article: "FAA Uncertain of Authority in Regulating SST Noise," Aviation Daily, 18 April 1973.
165	H. Safeer, "Visuals on Airport Noise Reduction Forecast," Presented to EPA/ONAC Aircraft/Airport Noise Study Task Group 4, Meeting No. 4, 3 April 1973.
251	"Proposed FAA Maximum Allowable Noise Levels to be Required for Certification of Future Aircraft," Enclosed with Ltr. by Joseph D. Blatt, 1 September 1966.
263	H. B. Safeer Ltr: (with enclosures) "Summary of Effects of Retrofit on Population for Six Airports and Program Costs," 30 April 1973.

MASTER FILE NO.	BIBLIOGRAPHIC CITATION
233	"Economic Impact of Implementing Acoustically Treated Nacelle and Duct Configurations Applicable to Low-By-Pass Turbofan Engines," Report FAA-NO-70-11, Prepared for Dept. of Transportation, Federal Aviation Administration by Rohr Corporation, July 1970.
234	Claude S. Brinegar, Ltr: "Regarding the Assignment of DOT Personnel to Work with EPA in Meeting EPA Responsibilities under Sections 7, 17, and 18 of the Noise Control Act of 1972," Department of Transportation, 5 April 1973.
252	J. F. Woodall and Advisors, "Aircraft Development Service Proposal for FAA Noise Certification Criteria," 1 February 1968.
254	I. H. Hoover, "Aircraft Noise Certification Alternatives," Ltr: Aircraft Industry Manufacturers, Operators, and Consultants, 3 October 1967.
103	"Aviation Cost Allocation Study: Working Paper No.9; Benefits," Office of Policy Review, Department of Transportation, October. 1972.
348	"Aviation Forecasts Fiscal Years 1973-1984," Dept. of Transportation, Federal Aviation Administration, Sept. 1972.
355	H. B. Safeer, Tech. Memo. "Aircraft Retrofit - A Cost Effectiveness Analysis," Dept. of Transportation, 18 May 1973.
391	"Land Use Control Strategies for Airport Impacted Areas", Report No. DOT-FA71WA-2579, Urban Systems Research and Engineering, Inc for the Federal Aviation Administration, Oct. 1972.
436	"The New Aviation Taxes", E. C. Bulletin No. 70-2, Office of Aviation Economics, Federal Aviation Administration, July 1970.

MASTER FILE NO.	BIBLIOGRAPHIC CITATION
439	Project Report: "Newly Produced Airplanes of Older Type Designs - Proposed Application of FAR 36 Noise Standards (NPRM 72-19, Docket No.12064), Before July 1972.
440	Project Report: "Aircraft Noise Certification Rule for Transport Category Aircraft" 24 Sept. 1968.
154	"A Study of the Magnitude of Transportation Noise Generation and Potential Abatement: Vol.III-Airport/Aircraft System Noise," OST-ONA-71-1, Dept. of Transportation, Nov '70.
443	Carole S. Tanner, Roy E. Glass, "Analysis of Operational Noise Measurements in Terms of Selected Human Response Noise Evaluation Measures", FAA-RD-71-112, December 1971.
457	"Visual Aids in Support of Oral Report on Retrofit Study" R. Dixon Speas, 25 July 1973.
458	"Visual Aids in Support of Oral Report on the Airport Noise Reduction Forecast Program", Wyle Laboratories, 25 July 1973.

9.0 FEDERAL GOV'T; DOD

MASTER FILE NO.	BIBLIOGRAPHIC CITATION
75	P. A. Shahady, "Department of Defense Noise Research Programs Source Noise Abatement Technology," Department of Defense, Air Force Aero Propulsion Labs, 21 March 1973.
192	N. J. Asher et.al., "The Demand for Intercity Passenger Transportation by VTOL Aircraft," Institute for Defense Analysis, Aug. 1968.
335	P. A. Shahady, "U. S. Air Force Noise Research," Presented to EPA Aircraft/Airport Noise Study Task Group 4, 16 May 1973.
336	W. S. Blazowski et al, "The Aircraft Engine and the Environment," Air Force Aero Propulsion Laboratory, 16 May 1973.
337	R. P. Burns, "Noise Pollution Control in the U.S. Navy," Naval Air Propulsion Test Center, 16 May 1973.
363	F. H. Schmitz, "Rotary Wing Acoustic Research," Ames Directorate, U. S. Army Air Mobility R & D Laboratory, 16 May 1973.
350	R. W. Young, "Material for Report on Aircraft/Airport Noise," Submitted to EPA Task Group 3, Department of the Navy, 3 May 1973.

MASTER FILE NO.	BIBLIOGRAPHIC CITATION
26	W. C. Sperry, "Three Point Measurement Concept for STOL Noise Certification," Information Brief, 2 October 1972.
31	W. C. Sperry, "Aircraft/Airport Noise Report Study: Meeting No. 1 of Task Groups 4 and 5 - Summary," EPA/ONAC, 27 February 1973.
40	L. A. Plumlee, (EPA) M.D.; Ltr: "Police Helicopters," Noise and Utilization, 22 February 1973.
45	J. C. Schettino, Ltr: "DOT Participation in Aircraft/Airport Noise Report Study," EPA/ONAC, 7 Mar'73.
59	W. C. Sperry, "Minutes of Meeting No. 2, Aircraft/Airport Noise Report Study - Task Groups 4 and 5," EPA/ONAC, 14 March 1973.
84	A. F. Meyer, Jr., Memo: "Comments on ANPRM on FNL," 19 Mar'73.
86	W. C. Sperry, "Information Brief on Fleet Noise Level Methodology," EPA, 19 March 1973.
97	W. C. Sperry, "Summary Minutes of Aircraft/Airport Noise Report Study; Meeting No. 3 for Task Groups 4 and 5 with Enclosure," EPA/ONAC, 26 March 1973.
98	W. C. Sperry, "Information Brief on Aircraft Noise Control Options and Methods of Exploiting Technology," EPA/ONAC, 24 March 1973. (Rev. 23 April 1973)
115	W. C. Sperry, "Aircraft Noise Exposure: Background, Methodology and Comparisons," FAA, 24 September '71.
121	"Information Brief on Aircraft Equipment Growth and Future Trends," Aviation Week and Space Technology, 19 March 1973.
139	"Information Brief on Aircraft and Engine Specifications," Aviation Week and Space Teahnology, 19 March 1973.

MASTER FILE NO.	BIBLIOGRAPHIC CITATION
141	Betsy Amin-Arsala, Memo: "Concept of Airport Certification, G.W.U./EPA, 30 March 1973.
146	"REFAN: Promising Technology, Uncertain Future," Article from Aerospace Daily, 23 March 1973.
179	W. C. Sperry, "Summary Minutes of Aircraft/Airport Noise Report Study; Meeting No. 4 for Task Groups 4 and 5 with Enclosures," EPA/ONAC, 10 April 1973.
180	R. S. Bennin, "Information Brief on Framework for Airport/Aircraft Regulations," EPA/ONAC Task Group 5, 5 April 1973.
224	W. D. Ruckelshaus; Ltr: (with enclosures), "Indicating Response to Concern Expressed by Ms. K. W. Hemer, Constituent of Hon. W. G. Magnuson," EPA, 2 April 1973.
308	J. C. Schettino; Ltr: "In Reply to Mr. William M. Cooper, Jr., Citizens for Conservation," EPA, 19 April 1973.
377	H. J. Nozick, Information Brief on Noise Exposure Forecast (NEF) Areas and Land Clearance Costs at Twelve Air Carrier Airports for Six Fleet Configurations (985 Operations), EPA, 9 April 1973.
241	W. C. Sperry, Memo: "ICAO Activity, can/3," EPA, 20 Mar 1973.
285	Draft #1: Chapter 3: Operations Analysis, Environmental Protection Agency Aircraft/Airport Noise Report of Task Group 2, 5 May 1973.
39	A. Meyer, Jr., Memo: "Information Regarding Department of Transportation Consultations and Participation in the Aircraft and Airport Noise Study - Noise Control Act of 1972," EPA/ONAC, 6 March 1973.
376	H. J. Nozick, Information Brief on Business Jet Identification and Estimated Noise Levels, EPA, 6 April 1973.

MASTER FILE NO.	BIBLIOGRAPHIC CITATION
271	"An Evaluation of Policy Alternatives for Airport Noise Abatement," Joseph Vittek Jr., March 14, 1973, A supporting document for George Washington University Legal and Institutional Analysis of the Noise Control Act of 1972.
299	DRAFT: "Impact Characterization" Report of Task Group 3 of the Aircraft/Airport Noise Study, 10 May 1973.
300	DRAFT: "Report on Aircraft Noise Source Technology for Environmental Protection Agency Aircraft/Airport Noise Report Study," EPA Task Group 4, 5 May 1973.
301	DRAFT: "Report on Noise Regulatory Actions by the Federal Aviation Administration for Environmental Protection Agency Aircraft/Airport Noise Report Study," EPA Task Group 5, 5 May 1973.
302	DRAFT: "Section VII. Bibliography and References for Task Group 4 Draft Report and Task Group 5 Draft Report," EPA Aircraft/Airport Noise Report Study, 5 May 1973.
257	"The Economic Impact of Noise," NTID 300.14, U.S. Environmental Protection Agency, 31 December 1971
327	J. C. Schettino, Ltr: Reply to Mr. Jerry Scaffetta's letter of 15 March 1973, EPA, Undated
347	A. Meyer, Jr., Ltr: to FAA "EPA Comments ANPRM 73-3, Civil Airplane Fleet Noise (FNL) Requirements," EPA, 2 February 1973.
349	R. Amin-Arsala, "Relevant Data on Starrett City Development Project, Brooklyn, New York," Submitted to Task Group 5 on 16 May 1973, G.W.U., 18 April 1973.
366	P.P. Back, "Information Brief on Relationships and Data Requirements for Analysis of Aircraft Source Noise Abatement Options," EPA, 11 April 1973.
379	R. L. Randall, "Information Brief on the U. S. Supreme Court's Decision in the Burbank Case," EPA, 31 May 1973.

MASTER FILE NO.	BIBLIOGRAPHIC CITATION
425	"Legal and Institutional Analysis of Aircraft and Airport Noise and Apportionment of Authority Between Federal, State and Local Governments", NTID 73.2, Environmental Protection Agency, July 1973.
426	"Operations Analysis Including Monitoring, Enforcement, Safety, and Cost" NTID 73.3, Environmental Protection Agency, July 1973.
427	"Impact Characterization of Noise Including Implications of Identifying and Achieving Levels of Cumulative Noise Exposure" NTID 73.4, Environmental Protection Agency, July 1973.
428	"Noise Source Abatement Technology and Cost Analysis Including Retrofitting" NTID 73.5, Environmental Protection Agency, July 1973.
429	"Review and Analysis of Present and Planned FAA Noise Regulatory Actions and Their Consequences Regarding Aircraft and Airport Operations" NTID 73.6, Environmental Protection Agency, July 1973.
430	"Military Aircraft and Airport Noise and Opportunities for Reduction Without Inhibition of Military Missions" NTID 73.7, Environmental Protection Agency, July 1973.
431	"Report to Congress on Aircraft/Airport Noise" Report of the Administrator of the Environmental Protection Agency in Compliance with the Noise Control Act of 1972, Public Law 92-574" NRC 73.1, Environmental Protection Agency, July 1973.
433	Larry A Ronk, "Information Brief on Land Use Costs to Provide Noise Impact Protection at Various Noise Exposure Levels for Various Retrofit Options" Environmental Protection Agency, 15 June 1973.
432	Randall L. Hurlburt, "Information Brief on Noise Problems at 19 Large Hub Airports", Environmental Protection Agency, 30 June 1973.
438	W. C. Sperry & D. C. Gray; "Information Brief on Project Reports" EPA, 19 July 1973.
441	Randall L. Hurlburt: "Information Brief on Night Operations at Airports", EPA, 19 July 1973.

MASTER FILE NO.	BIBLIOGRAPHIC CITATION
459	"Public Health and Welfare Criteria for Noise" NCD 73.1, Environmental Protection Agency, 27 July 1973.

MASTER FILE NO.	BIBLIOGRAPHIC CITATION
3	"Aircraft Noise Reduction Technology," A Preliminary NASA Report to the Environmental Protection Agency for the Aircraft/Airport Noise Study," W. H. Roudebush, 28 February 1973.
44	J. J. Kramer, Ltr: "Footprint Calculation Procedures in REFAN Program," NASA, 5 March 1973.
51	"NASA REFAN Program" Presented to Task Group 4 of A/A Noise Report Study by J.J. Kramer, 28 Feb'73.
79	C. Ciepluch, "Visuals Presented by Carl Ciepluch, NASA's Quiet Engine Program," 21 Mar'73.
167	"Viewgraphs for Review of NASA Quiet Engine Program" Presented to EPA/ONAC Aircraft/Airport Noise Report Study Task Group 4, Meeting No.3, 21 March 1973.
186	"Aircraft Noise Reduction Technology," Presented to the EPA for the Aircraft/Airport Noise Study, NASA, 30 March 1973.
209	G. C. Smith, "Publications and Presentations of the Acoustics Branch, Loads Division, NASA-Langley Research Center," NASA, 31 Dec. 1972.
210	"Human Response to Noise-Publications and Presentation," Acoustics Branch, Langley Research Center, NASA, 15 Dec. 1972.
229	"Statement of R. P. Jackson, Associate Administrator for Aeronautics and Space Technology, NASA before the Subcommittee on Aeronautics and Space Technology, Committee on Sciences and Astronautics, House of Representatives," April 1973.
262	F. B. Metzger, et al, "Analytical Parametric Investigation Of Low Pressure Ratio Fan Noise," NASA CR-2188, March 1973.

MASTER FILE NO.	BIBLIOGRAPHIC CITATION
237	"Statement of Roy P. Jackson, Associate Adm. for Aeronautics and Space Technology, NASA before the Committee on Aeronautics and Space Science," United States Senate, April 1973.
277	M. H. Waters et al. "Shrouded Fan Propulsors for Light Aircraft, SAE Business Aircraft Meeting, Wichita, 3-6 April 1973.
378	B. J. Clark, Ltr. with Enclosure; "FAR 36 and CTOL Engine Noise Levels Extrapolated to 500 - Foot Sideline for 150,000-Pound G. W. Aircraft", NASA Lewis Research Center, 23 May 1973.
380	J. J. Kramer; Ltr. with Enclosures, "Data Related to Refan Program and Fleet Sizes", NASA Hqs., 24 May 1973.
341	W. H. Roudebush, Ltr. "Task Group 4 Draft Report, Aircraft Noise Source Technology," NASA, 15 May 1973.
342	W. H. Roudebush, Ltr. "Task Group 5 Draft Report, Envrionmental Noise Regulatory Actions by the FAA," NASA, 15 May 1973.
398	William H. Roudebush, Ltr with Enclosures: "Comments On and Corrections to the Task Group 4 Draft Report", NASA, 28 June 1973.

MASTER FILE NO.	BIBLIOGRAPHIC CITATION
106	"Status of the Federal Aircraft Noise Alleviation Program as of July 1, 1967 and Recommendation for Updating and Improving the Program," Report of the Program Evaluation and Development Committee (PEDC), 1 July 1967.
183	M. R. Segal, "Aircraft Noise: The Retrofitting Approach," 72-78 SP, Congressional Research Service, Library of Congress, 28 March 1972.
189	J. H. Ogonji, S. Loo, "Noise Effects and Problems of Control; Selected, Annotated References 1966-1972," Congressional Research Service, Library of Congress, 15 Jan. 1973.
223	S. N. Goldstein, "Environmental Noise Quality-A Proposed Standard and Index," The Mitre Corp. for the Council on Environmental Quality, Mar '71.
225	J. V. Tunney, Ltr: "Concern Over EPA Effort under Noise Control Act of 1972 and Interest in Public Hearings," U.S. Senate, 14 February 1973.
249	"Alleviation of Jet Aircraft Noise Near Airports, a Report of the Jet Aircraft Noise Panel," Office of Science and Technology, March 1966.
250	International Conference on the Reduction of Noise and Disturbance Caused by Civil Aircraft, London, November 1966.
253	Fifth Air Navigation Conference, International Civil Aviation Organization, Montreal, Canada, November-December 1967.

MASTER FILE NO.	BIBLIOGRPAHIC CITATION
329	"Action Against Aircraft Noise: Progress Report 1973," A Department of Trade and Industry Publication, 1973.
291	"Aircraft Noise Impact - Planning Guidelines for Local Agencies" Prepared for Department of Housing and Urban Development by Bolt, Beranek and Newman and Wilsey and Ham. Nov. 1972.
247	Federal Aviation Act of 1958 (Public Law 85-726) 23 August 1958.
248	"Title IV - Noise Pollution of the Clean Air Act (Public Law 91-604).
343	"Social and Economic Impact of Aircraft Noise," OECE, 13 April 1973.
385	C. W. Graves, Ltr; Review and Position on Task Group 5 Report, Assistant Secretary for Community Planning and Management, Department of Housing and Urban Development, 1 June 1973.
423	Clifford W. Graves, Ltr. with Enclosure "HUD Comments on Recommendations on the EPA Task Force on Aircraft/ Airport Noise Problems", Dept. of Housing and Urban Development, 29 June 1973.
442	"Noise Assessment Guidelines; Technical Background", Report No. TE/NA 172, Dept. of Housing and Urban Development, 1972.
446	"Views of the Department of Commerce Concerning EPA's Aircraft/Airport Noise Report Study", General Counsel of the Department of Commerce, 19 July 1973.

13.0 PROFESSIONAL AND TRADE GROUPS

MASTER FILE NO.	BIBLIOGRAPHIC CITATION
42	K. D. Kryter, Ltr: "Participation in Aircraft/ Airport Noise Report Study," Acoustical Society of America, 12 February 1973.
43	W. W. Lang, Ltr: "Participation in Aircraft/ Airport Noise Report Study," Institute of Noise Control Engineering, No Date.
62	J. A. Nammack, Ltr: "State Laws as Related to Land Use Control," National Association of State Aviation Officials, 16 March 1973.
150	L. P. Bedore, Ltr: "NBAA Noise Abatement Programs," National Business Aircraft Association, Inc., 26 March 1973.
171	C. P. Miller; Ltr: "Statement on Proposed Noise Standards for Propeller-Driven Aircraft," AOPA, 29 March 1973.
188	L. P. Bedore, Ltr.: "Recommended Changes to NBAA Noise Abatement Program," National Business Aircraft Assoc., Inc., 10 Nov. 1972.
255	K. G. Harr, Ltr: "To FAA (McKee), with "Aerospace Industries Report on Aircraft Noise Certification," 5 December 1967.
266	W. A. Jenson, "ATA Flight Operations Committee Recommended Takeoff Procedures-Effective Date: 1 Aug. 1972," Operations Memorandum No. 72-64, Air Transport Association of America, 12 June 1972.
332	W. B. Becker: Ltr. with Attachments "Comments Upon Review of Task Group 3 Draft Report," ATA, 10 May 1973.
344	R. G. Flynn: Ltr. with Attachments "Comments on Draft Report of Task Group 2," 11 May 1973.
253	Report of the Third Meeting of the Committee on Aircraft Noise (CAN), Montreal, 5 to 23 March 1973, International Civil Aviation Organization (ICAO), 23 March 1973.
359	L. Bedore, Memo: "Definition of General Aviation," NBAA, 17 May 1973.

MASTER FILE NO.	BIBLIOGRAPHIC CITATION
160	"Retrofit Costs," Compiled by Allen Dallas, ATA 31 March 1973.
166	W. B. Becker, "In the Matter of Noise Standards, Aircraft Type Certification; Docket No. 9337, Notice 69-1," ATA, 4 June 1969.
172	A. W. Dallas, Ltr: "Fleet Mix," ATA, 28 March 1973.
176	"Compilation of ATA's Original Responses to Various Noise Regulation Proposals," Compiled by A. Dallas, Presented to Aircraft/Airport Noise Report Study, Task Group 5, 5 April 1973.
177	C. F. VonKann, "Statement before the Senate Aviation Subcommittee on Aircraft Noise, Los Angeles," ATA, 30 March 1973.
236	"Standard Method of Estimating Comparative Direct Operating Costs of Turbine Powered Transport Airplanes," Air Transport Association of America, Dec. 1967.
235	R. R. Shaw, Ltr: "Declining Invitation to Participate in Aircraft/Airport Noise Study Task Force," International Air Transport Association, 10 April '73.
238	G. Fromm, "Value of Aviation Activity," Prepared for the Air Transport Association by Data Resources, Inc., January 1973.
239	"Comments on Aviation Cost Allocation Study Working Paper No.4-An Airport and Airway System Cost Base: FAA,DOD,NASA and DOT-OST," ATA Staff, Undated.
240	"ATA Comments on Public Benefits Portion of Aviation Cost Allocation Study, Working Paper #9, Benefits," ATA Staff, Undated.
371	Working Papers from the Third Meeting of the Committee on Aircraft Noise (CAN), Montreal, 5 to 23 March 1973, International Civil Aviation Organization (ICAO), 23 March 1973.
396	Roger G. Flynn, Ltr. with 3 enclosures: "Principal Positions Related to Task Group 5 Report dated 1 June 1973", Air Transport Association, 2 July '73.

13.0 PROFESSIONAL AND TRADE GROUPS (CONT'D)

MASTER FILE NO.	BIBLIOGRAPHIC CITATION
33	"Noise Retrofit - Existing Airplanes Powered by JT3D and JT8D Engines," ATA Staff Study, March 1972.
55	C. F. VonKann, Ltr: "Response to Docket No. 12534: Notice No. 73-3," Air Transport Association, 2 March 1973.
359	L. Bedore, Memo: "Definition of General Aviation," NBAA, 17 May 1973.
326	"Aircraft Noise Research Needs", AIR No. 1079, Society of Automotive Engineers, Inc., May 1972.
92	"Estimated Number of Jet (Non-Propeller) Aircraft in the Scheduled U. S. Airplane Fleet (ATA Members) as of 30 June 1972, ATA, 1 Sept '72.
360	"The Magnitude and Economic Impact of General Aviation, 1968-1980," A Report Prepared for the General Aviation Manufacturers' Association (GAMA) by R. Dixon Speas Associates, February 1970.
155	"NPRM 69-1, Economic Impact Study," Airplane Performace and Operating Economics, Vol. I," AIA/ATA, May 1969.
156	"NPRM 69-1, Economic Impact Study, Airline System Economic Impact, Vol. II," AIA/ATA, May 1969.
157	"NPRM 69-1, Economic Impact Study, Exhibit II, Legal Considerations," AIA/ATA, May 1969.
158	"NPRM 69-1, Economic Impact Study, Exhibit III, Detail Comments on Proposed Noise Standards; Aircraft Type Certification," AIA/ATA, May 1969.
390	G. I. Martin, Ltr. "Concern Over Conduct of EPA Aircraft/Airport Noise Study" Aerospace Industries Association of America, Inc., 25 May 1973.

MASTER FILE NO.	BIBLIOGRAPHIC CITATION
399	J. Donald Reilly, Ltr with Enclosure: "Comments on Task Group IV and V Draft Reports", Airport Operators Council International, Inc, 2 July 1973.
407	A. W. Dallas, Ltr. "Principal Positions Related to Task Group 4 Report dated 1 June 1973", Air Transport Association, 2 July 1973.
414	"General Aviation Manufacturers Association Comments on the Draft Report on Noise Source Abatement Technology and Cost Analysis Including Retrofitting for Environmental Protection Agency Aircraft/Airport Noise Report Study-Task Group 4" General Aviation Manufacturers Association (GAMA), 20 June 1973.
415	"General Aviation Manufacturers Association Comments on the Draft Report on Review and Analysis of Present and Planned FAA Noise Regulatory Actions and Their Consequences Regarding Aircraft and Airport Operations for EPA-Task Group 5" General Aviation Manufacturers Association (GAMA), 20 June 1973.
416	Gene I. Martin, Ltr. with Enclosure, "Comments on the Conduct of the Aircraft/Airport Noise Study", Aerospace Industries Association of America, Inc., 2 July 1973.
420	Clifton F. von Kann, Ltr. "Expression of ATA's Interest in EPA's Aircraft/Airport Noise Studies", Air Transport Association, 3 July 1973.
437	"Statement of William B. Becker, Assistant Vice President for Operations, Air Transport Association at the Environmental Protection Agency Conference, June 21, 1973" ATA, 21 June 1973.
448	"Positions on the Issues Contained in the Report on Review and Analysis of Present and Planned FAA Noise Regulatory Actions and Their Consequences Regarding Aircraft and Airport Operations" Submitted to the Environmental Protection Agency by the General Aviation Manufacturers Association, 20 June 1973.

MASTER FILE NO.	BIBLIOGRAPHIC CITATION
447	"Positions on the Issues Contained in the Report on Noise Source Abatement Technology and Cost Analysis including Retrofitting" Submitted to the Environmental Protection Agency by the General Aviation Manufacturers Association, 20 June 1973.

14.0 ## REGULATORY CONSIDERATIONS

MASTER FILE NO.	TITLE	IDENTIF.	DATE
310	Control & Abatement of Aircraft Noise & Sonic Boom	PL 90-411	21 Jul 68
311	Noise Standards: Aircraft Type Certification	FAR PART 36	21 Nov 69
312	Civil Aircraft Sonic Boom	NPRM 70-16	10 Apr 70
313	Civil Supersonic Aircraft Noise Type Certification Standards	ANPRM 70-33	4 Aug 70
314	Civil Airplane Noise Reduction Retrofit Requirements	ANPRM 70-44	30 Oct 70
315	Noise Type Certification & Acoustical Change Approvals	NPRM 71-26	13 Sep 71
316	ATA Flight Operations Committee Recommended Takeoff Procedures	ATA ops. Memo. 72-64	12 Jun 72
317	Newly Produced Airplanes of Older Type Designs	NPRM 72-19	7 Jul 72
318	Three Point Measurement Concept For STOL Noise Certification	Information Brief	2 Oct 72
319	Civil Aircraft Fleet Noise Level (FNL) & Retrofit Requirements	Draft NPRM	8 Nov 72
320	Amendment To Federal Aviation Regulations To Provide For A Takeoff Noise Control Operating Rule	Project Report	21 Nov 72
321	Civil Airplane Fleet Noise (FNL) Requirements	ANPRM 73-3	24 Jan 73
322	Propeller Driven Aircraft Noise Type Certification Standards	Project Report	22 Jan 73

REGULATORY CONSIDERATIONS (CONT'D)

MASTER FILE NO.	TITLE	IDENTIF.	DATE
323	Noise Certification Rule for Quiet Short Haul	Project Report	29 Dec 72
324	Part 91: General Operating and Flight Rules; Civil Aircraft Sonic Boom	Part 91	28 Mar 73
242	Criteria for Implementation of Jet Noise Abatement Take-off Profile	Final Draft Advisory Circular	20 Mar 68
256	Noise Standards: Aircraft Type Certification	NPRM 69-1	3 Jan 69
281	Federal Aviation Act of 1958	PL 85-726	23 Aug 58
282	National Environmental Policy Act of 1969	PL 91-190	1 Jan 70
283	Noise Pollution and Abatement Act of 1970	Title IV PL 91-604	
284	Noise Control Act of 1972	PL 92-574	27 Oct 72
279	Code of Federal Regulations, Aeronautics and Space, Parts 1 to 59, 60 to 199, 200- , Revised		1 Jan 72
280	Aeronautical Status and Related Material, Civil Aeronautics Board, Revised		1 Jun 70
353	"Airport and Airway Development Act of 1970 and Airport and Airway Revenue Act of 1970,"		21 May 70

15.0 STATE AND LOCAL GOV'TS

MASTER FILE NO.	BIBLIOGRAPHIC CITATION
34	"Title 4: Subchapter 6: Noise Standards," Department of Aeronautics, State of California.
35	"Section 21669.5: Construction; Application; Duration," Public Utilities Code, State of California.
36	"Preamble: The City of New York Noise Control Code (Local Law 57)," 12 October 1972.
63	Resolution No. 6598: A Resolution of the City Council of the City of Inglewood, California, Regarding Civil Airplane Fleet Noise Requirement, 27 February 1973.
64	Press Release: Related to Restrictions of Use at Oakland International Airport, 9 March 1973.
66	California Laws Relating to Aeronautics, Calif. Department of Aeronautics, Rev. 2 (6-72).
65	N. C. Yost, Deputy Attorney General, Ltr: "Airport/Aircraft Noise Report Task Force Effort, State of California.
38	R. T. Weston, "Congressional Intent: Re. Section 7(b) of the Noise Control Act of 1972; Comparison of Criteria Established in the 1968 and 1972 Acts for the Promulgation of Federal Aircraft Noise Regulations," March 1973.
76	C. Gaulding, R. T. Weston, "Comments on the ANPRM on FNL, Docket No. 12534, Notice No. 73-3," Commonwealth of Pennsylvania, 27 February 1973.
80	"Resolution Related to ANPRM on FNL, Docket No. 12534, Notice 73-3," City of Los Angeles, 27 February 1973.
388	"A Report of the Ad Hoc Committee Studying the Impact of Aircraft Noise from Dulles International Airport on Fairfax County," Dept. of County Development, Fairfax County, Va., Feb 1972.

MASTER FILE NO.	BIBLIOGRAPHIC CITATION
83	R. H. Quinn, "Comments Re: Proposed Fleet Noise Requirements for Civil Airplanes (14 CFR 121)," Department of the Attorney General, Mass., 2 March 1973.
143	R. Hurlburt, "A Complete Analysis of the Costs and Benefits of a Quiet Engine Retrofit Program," City of Inglewood, 15 January 1971.
144	A. H. Colman, "Aircraft Noise Abatement Alternatives," City of Inglewood, September 1971.
232	"Testimony of Mayor Merle Megell, Inglewood, California," Presented to the Aviation Subcommittee of the United States Senate Commerce Committee, 30 March 1973.
265	"Resolution No. 7467- A Five Point Plan for Airport Noise Abatement," Board of Airport Commissions, Los Angeles International Airport, 20 Dec. 1972.
344	"Supporting Information for the Adopted Noise Regulations for California Airports," Final Report to the California Department of Aeronautics, Report No. WCR 70-3(R), Wyle Laboratories, 29 Jan '71.
397	John S. Moore, Ltr: "Comments on Aircraft/Airport Noise Study Task Force", Illinois Environmental Protection Agency, 20 June 1973.
351	B. J. Lockheed, Ltr: "Comments on Chapter 3: Operations Analysis Task Group 2," City of Los Angeles, Dept. of Airports, 8 May 1973.
245	M. Mergell; Ltr: "City of Inglewood's Support of EPA Aircraft/Airport Noise Study Task Force," City of Inglewood, 26 March 1973.
382	M. S. Spelman, Ltr. "Comments on Possible Aircraft Jet Engine Noise Research," Malcolm S. Spelman Associates, Aviation Consultants to Nassau County, N.Y., 4 May '73.
383	H. L. Diamond, Ltr. "Participation in EPA Task Force", Department of Environmental Conservation, State of New York, 25 April 1973.

MASTER FILE NO.	BIBLIOGRAPHIC CITATION
444	John S. Moore; "Position Statement for Illinois Environmental Protection Agency", State of Illinois, July 1973.

APPENDIX A

POSITION PAPERS

OF

TASK GROUP MEMBERS

Note: Throughout the development of this report, and especially during the review of the two published drafts, the chairman and staff continually solicited two types of information from the task group membership. First, written comments and critiques, as well as additional data, were requested of all and submitted by most active participants. This information has been helpful in the refinement of this final report. All of the submissions, comments and critiques are contained in the list of references and bibliography, and a copy of each is preserved and maintained, available to the public, in the task group master file. Second, position papers in which the members, representing their various interests, would state their position relative to the issues, independent of the conclusions and recommendations stated in this report, were solicited. Those position papers are included in this appendix.

AEROSPACE INDUSTRIES ASSOCIATION OF AMERICA, INC.

1725 DE SALES STREET, N.W. WASHINGTON D.C. 20036 TEL. 347-2315

July 2, 1973

Dr. Alvin F. Meyer
Deputy Assistant Administrator for
Noise Control Program
Environmental Protection Agency
1921 Jefferson Davis Highway
Room 1115
Arlington, Virginia 20460

Dear Dr. Meyer:

At the invitation of the Administrator, Environmental Protection Agency, several AIA member companies participated in your Aircraft/Airport Noise Study. A study task force, divided into six study groups, has assisted in developing respective parts of the report required by the Noise Control Act of 1972. Because of the pace of task group activities and broad scope of information and data being assembled, it was not possible for AIA to develop and submit positions as the study progressed.

We are deeply concerned over the conduct of the study and desire to provide the following comments on this matter:

a. The total subject of aircraft noise control, including standards, retrofit or phaseout of existing aircraft, cumulative noise exposure, operating procedures and definition of health and welfare is exceedingly complex and involved. We are concerned that the five month period available did not allow sufficient time for EPA to assemble a team, let contracts, and accomplish the work necessary to complete the study in a entirely satisfactory manner. Furthermore, this short time made it impossible for the task group members to adequately analyze the findings of the contractors or comment on the work to date in any detail.

b. Because of the diverse backgrounds, expertise and interests of the task group members, little attempt was made to determine consensus or majority opinions on the multitude of questions discussed in the meetings. Many of the conclusions and recommendations developed by Task Group Chairmen were in fact not even covered in the meetings. Consequently, the final reports should not be represented as the conclusions and recommendations of the task groups. They are, more realistically, the opinions and individual views of the Task Group Chairmen which in some important instances do not reflect the arguments and facts presented by the members.

c. The AIA supports efforts to review the existing noise standards for new aircraft designs and to strengthen them. The successful introduction of resulting quieter aircraft into the fleet is critically dependent on Federal action to insure that these aircraft once certificated as complying with the applicable standards shall have the right to operate at all airports, where they meet airworthiness requirements. It is essential that airport operators be preempted from prescribing restrictions which would prevent such certificated aircraft from operating at their airports. The necessity for federal preemptions does not conflict with the use of noise abatement operating procedures. However, it is essential that the operational procedures and required aircraft equipment be FAA prescribed for reasons of safety of operation, pilot training and equipment interchangeability. Any other course which permits individual airport authorities to specify unique requirements will lead to chaos and will be counterproductive to the intent of Public Law 92-574.

d. In general, we find that the cost analysis approach taken by EPA was inadequate. For example, the cost analysis on curfews would suggest that night time curfews offer a very efficient means of reducing noise exposure areas on per dollar cost basis. In fact, the adverse economic impact resulting from disruption to overseas travel and from aircraft being other than where needed for the following day's flights would be severe and was not properly considered. Another example is in the case of land use studies where more factual data is needed in place of oversimplified extrapolations. We are convinced that the economic analyses must be completely re-examined before any meaningful conclusions can be drawn.

e. While AIA is not in a position to disagree with the general approach taken to rate noise exposure using the dBA unit, we strongly question the selection of the specific values of 80 for hearing damage and 60 as the ultimate goal for annoyance or disturbance criteria in the L_{dn} scale. The data presented does not adequately substantiate the selection of these levels. The implication and impact of these limits is far reaching. Such limits require substantiation prior to their selection.

f. The FAA noise regulatory actions recommended by the Task Group Chairmen contai a number of elements with which AIA is not in agreem it. These disagreements will be discussed at the time issue of subsequent regulatory notices.

The AIA recognizes the extent of the noise problem and the need for progress in alleviating it impact on the environment. We agree that regulations and proce ires relating to operations and compatible land use are necessary to assist in reducing noise exposure. We also agree with the need for continued research to reduce noise at the source and provide operating procedures to reduce noise exposure for airport neighbors. We concur with the need to provide financing for research, equipment development, implementation of noise control measures, and land acquisition.

In closing, we do want to commend the EPA Task Group Chairmen for their diligent efforts under difficult circumstances. We urge your consideration of our concerns discussed above.

This letter revises AIA letter of May 25, 1973 to you. It is submitted in request to your appeal at the EPA hearings on June 20, 1973 at the Department of Commerce Auditorium, Washington, D. C. for all previous submittals made to EPA on the study subject be reviewed and revised not later than July 2, 1973. As reflected in our statement at the hearing on June 20, 1973, it is requested that this statement be included in the record of all study groups.

Very truly yours,

AEROSPACE TECHNICAL COUNCIL

Gene I. Martin

Gene I. Martin
Associate Director
Civil Aircraft Technical Requirements

GIM:ssf

cc: John Schettino - EPA
EPA Task Group Chairmen (6)

COMMERCIAL AIRPLANE COMPANY
P.O. Box 3707 Seattle, Washington 98124

June 29, 1973
6-7270-1-444

Mr. W. C. Sperry
Office of Noise Abatement and Control
Environmental Protection Agency
Washington, D. C. 20460

Subject: Boeing Commercial Airplane Company Position on Task Group 4, "Noise Source Abatement Technology and Cost Analysis Including Retrofitting"

References:
1) Boeing Letter 6-7270-1-442, V. L. Blumenthal to R. L. Hurlburt.

2) Boeing Letter 6-7270-1-443, V. L. Blumenthal to H. E. von Gierke.

3) Boeing Letter 6-7270-1-445, V. L. Blumenthal to W. C. Sperry.

Dear Bill:

In response to the request made by Mr. John Schettino in his letter of June 25, 1973, the Boeing Commercial Airplane Company wishes to include only this letter (with attachments) in the final report of Task Group 4. References 1, 2 and 3 contain our position letters for Task Groups 2, 3 and 5.

In some of the Task Group draft reports it clearly states that the conclusions and recommendations are the responsibility of the chairman. We endorse this position and agree with it completely as being the only reasonable and fair manner in which such reports could be written. Because of the variety of opinions espoused in the Group discussions, and because generally no formal attempt was made to obtain a consensus, we would suggest that any inference of unanimity of opinion be expurgated.

Attachment 1 contains our letter to you dated April 2, 1973, but revised to include later information. Note that we have now included our latest estimate of 707 Quiet Nacelle availability date, delivery rate, and approximate pricing.

The comments that follow pertain to the 1 June 1973 Task Group 4 Report, but are written in general terms rather than specific comments to that document.

Mr. W. C. Sperry 6-7270-1-444

1. In numerous instances airplane noise values are presented. Please note that the 747-100 airplane type is shown at its pre-December 1971 levels. The correct 747-100 noise levels for airplanes currently being delivered should be presented as

	747-100 (Post-December 1971)
Takeoff (No Cutback)	107
Approach	107/105
Sideline	99

2. Attachment 2 is one chart and three graphs to update Boeing airplane fleet projections from those provided on June 22. These data include aircraft sold plus firm options only. However, we anticipate continued sales of all our present product lines into the 1980 to 1985 period.

3. Options for nacelle retrofit are discussed in the Task Group 4 Report. The report describes the FAA Quiet Nacelle contract and states that two or more nacelle retrofit options have been developed under FAA contract for each airplane. This is not completely correct. For example, the 737 quiet nacelle option, developed on Boeing funds, will enable the 737 to meet FAR 36. We know of no additional quiet nacelle option for this airplane. Likewise, mention is made of a SAM + JNR treatment option for the 707 that will eventually be available. We are not aware of work currently in progress on such a configuration.

4. The general philosophy is expressed that, ultimately, the consumer of transportation services will pay the total cost of noise reduction. It is not clear why only the air transport consumer must bear this burden. It is broadly acknowledged that at least part of the growth of the noise problem is due to encroachment around airports of new residential areas. It seems that perhaps consideration should be given to having the interest groups who will receive the benefits of noise reduction share in its cost, as well as all the benefactors of air transportation, including the air traveler.

5. We encourage the EPA to conduct studies such as is outlined in the Task Group 4 report under the heading of Cost and Economic Analysis. The endorsement of this approach stems from our belief that the magnitude of the consequences of a recommendation for a compatible land usage criterion (e.g., 80 or 60 L_{dn}) must be thoroughly understood before a recommendation can be made, or adopted, as a national standard.

Although we endorse the general approach and methodology used in the study, we do have extreme concern with the study as reported to date. As we have stated in our comments on the Task 3 effort (reference 2), we do not believe that sufficient data are available to establish definitive maximum values of community noise exposure. Notwithstanding this weakness, and assuming that the data used in the study are correct, the Task 4 report establishes a national noise problem extent of between 2 and 31 billion dollars. Not only is the magnitude of this problem specification staggering, but the variation of cost liability between the selection of L_{dn} 80 and 60 (roughly 29 billion dollars) shows the leverage associated with the selection of community criteria. We believe this magnitude and variability of dollar exposure clearly points out the need for an accurate and comprehensive study.

The implication of retrofit hardware selection, depending upon the criterion used, is also worthy of comment. For L_{dn} 80, the study results show JT8D SAM retrofit as the minimum cost solution. Using L_{dn} 60 as the criterion, refan for both JT3D and JT8D fleets results in lowest system cost. More realistically, SAM JT3D and JT8D retrofit (technology that is currently being developed) still results in an 11 to 18 billion dollar national liability based on the unsupported Task 3 goal of 60 L_{dn}. Task Group 5 further implies that the residual problem should be solved by restricting operations and land purchase. It is our opinion that more study is required to investigate how this is to be accomplished, and the associated consequences.

In addition, the results of the study present questions that we are unable to resolve. For example, SAM retrofit of only the JT8D fleet (in conjunction with two-segment approach) appears as effective as nacelle retrofit of the JT3D fleet. The dollar reduction shown for JT8D retrofit implies perhaps a 30 to 50 percent reduction in NEF area. Our studies do not reflect anything like this. From a recent Boeing study, for a domestic short haul airport with no JT3D powered airplanes, SAM retrofit of all JT8D powered airplanes resulted in a NEF 25 area reduction of about 3 percent, with a NEF 45 area reduction of about 15 percent. For any airport with JT3D airplanes mixed in, it would seem that even less effect would be observed due to nacelle retrofit of only the JT8D powered airplanes.

We are also concerned with the data upon which much of this study is based. Although we appreciate that every effort was made to obtain the best data available, within the study time constraints, this need not imply that the data were valid enough to base decisions of the magnitude implied in the Task Group 4 report. We believe that noise data are now becoming available, through the FAA Noise Definition and NASA Contracts, that will hopefully contain reasonably consistent information upon which to base such a study. Further, the selection of only six airports, several of which are dominated by surrounding water, may understate the scope of the problem. It could well be that the extent of the problem is far greater than 31 billion dollars if the airports selected were more typical of inland airports. If the information in Task Group 4's report is to be used as the basis to make major decisions such as retrofit configuration selection, and to establish community acceptability criterion, we strongly recommend the following:

* That the details of the study methodology and data used be completely reviewed so that a thorough understanding and endorsement of its contents can be obtained.

* If required, a re-run of the study should be conducted when a more consistent and solid data base is available.

Finally, there is the question of who pays. The range of retrofit costs quoted is from 280 million to over 4 billion dollars. It is probably conceivable that a fare increase could pay part of this cost, thereby passing part of the expense to the air traveler. There is no way that the air transportation industry can pay the total system costs ranging to 31 billion dollars or more. We urge that this aspect be thoroughly considered before final recommendations are drafted.

It has been our pleasure to participate in the Task Force effort. In these meetings we have attempted to present our knowledge of the present state of the art in the various facets of aircraft noise reduction. In addition we have attempted to identify those areas where adequate decision-making knowledge was lacking. We hope that the EPA will carefully review the various inputs received from the Task Force participants, separate fact from fantasy and desire, and establish its recommendations for future rule making on technically proven concepts. Only in this manner can progressive steps be taken to reduce aircraft noise and, at the same time, avoid costly mistakes which this nation can ill afford.

The EPA is to be congratulated for its success in completing a Study of this magnitude in the short time available.

Very truly yours,

BOEING COMMERCIAL
AIRPLANE COMPANY

Vaughn Blumenthal

V. L. Blumenthal
Director, Noise and Emission
Abatement Programs

Attachments:

Letter 6-7270-1-361 dated April 2, 1973 (Revised June 29, 1973)

Chart and (3) curves revised June 28, 1973

COMMERCIAL AIRPLANE GROUP

April 2, 1973

6-7270-1-361
Revised 29 June 1973

Mr. W. C. Sperry
Environmental Protection Agency
Washington, D. C. 20460

Dear Bill:

The following are some general comments and recommendations pertaining to Task Group 4 activities.

As part of the effort to attain a compatible airport/aircraft community noise environment The Boeing Company has recognized the need to control aircraft noise at the source. To this end the Company has developed, and is providing, production configurations that fully comply with FAR 36, Appendix C, noise criteria for all models of the 727, 737 and 747 airplanes.

Information related to the pricing and scheduling of retrofit kits for these airplanes is shown on Attachment 1. Details on noise reductions and weight and range penalties associated with the modifications are presented in the report, D6-60199 "Noise-Reduction Research and Development 1972 Progress," already provided to the Task Group. That paper also includes a detailed discussion of our noise reduction activities and provides the major portion of our comments.

We are currently in the final stages of an FAA/Boeing co-funded program to design, develop, fabricate, and flight test a quiet nacelle for model 707 aircraft. The flight test program, now complete, was necessary to substantiate the estimated acoustic and airplane performance of this installation and to assist in identifying design changes needed to achieve an acceptable configuration. Continued coordination with the airlines to ensure a reliable, maintainable design is a prerequisite to firm pricing and scheduling of kit availability. We currently estimate completion of this work in the third quarter of this year, but have included current estimates of availability and price on an attachment to this letter.

Attachment 1 to 6-7270-1-444

Mr. W. C. Sperry

6-7270-1-361
Page Two

Alternate means of noise reduction, by modifying those engines powering 707, 727 and 737 aircraft, have recently received considerable attention. Studies started by Boeing, and subsequently sponsored by NASA in August 1972, were aimed at determining the feasibility of noise reduction on JT3D and JT8D powered airplanes by replacing the two-stage fans with larger diameter single-stage fans. Work accomplished to date indicates that these refan concepts are potentially very attractive.

We would recommend that the recently cancelled JT3D program be re-instated and that adequate funding be provided to both JT3D and JT8D programs to ensure technical viability.

Source noise reduction must be complemented by other methods of reducing community noise if a "noise compatible" airport environment is to be achieved. In order to fully exploit available options for shrinking noise affected land area in the vicinity of airports, it is recommended that the government take immediate steps to increase the ILS glide slopes to the maximum extent practical. In addition, it is recommended that the government, after appropriate and successful review of the two-segment approach as outlined in the comments submitted for Task Group 2, initiate and promulgate plans to install the necessary compatible ground equipment associated with the two-segment approach concept selected. No ground equipment installation can be undertaken by industry and the door will generally remain closed to these two options unless and/or until the government responsibility is discharged.

It is hoped the information provided in our "Noise Reduction R&D Progress" report and the above comments provide constructive and useful assistance to Task Group 4.

Sincerely,

BOEING COMMERCIAL
AIRPLANE COMPANY

Vaughn L. Blumenthal
Director, Noise and Emission
Abatement Programs

Attachment

Attachment to
6-7270-1-361
Revised 29 June 1973

AVAILABILITY AND PRICING OF RETROFIT SHIPSETS (1)

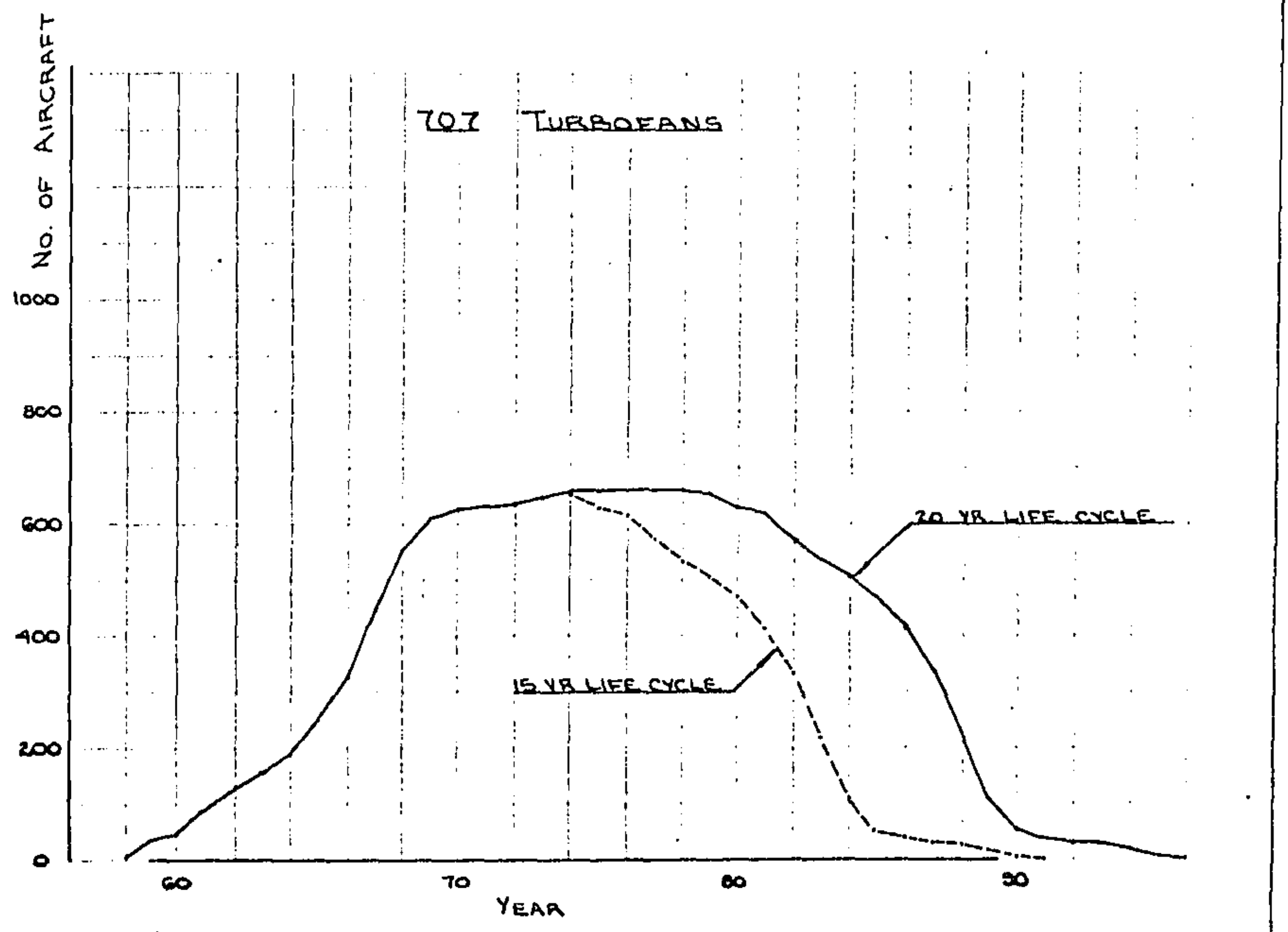
	AIRCRAFT TYPE 707	727	737	747
INITIAL DELIVERY DATE				
Boeing	1st Qtr. 1975 (2)	10 Mo. After Go-Ahead (3)	10 Mo. After Go-Ahead (3)	9 Mo. After Go-Ahead
P&W		15 Mo. After Go-Ahead (4)		
AVAILABILITY				
Possible Delivery Rates				
Boeing	10/Mo., 2nd Qtr. 1976 (2)	33/Mo., 11 Mo. After Go-Ahead (3)	14/Mo., 11 Mo. After Go-Ahead (3)	5/Mo., 9 Mo. After Go-Ahead
P&W		130 Engine Treatments/ Mo., 21 Mo. After Go-Ahead (2)		
APPROXIMATE PRICING				
Boeing Nacelle, $	720,000	80,000	135,000	250,000
Spares (5)	43,000	4,800	8,000	-
P&W	-	65,600	43,800	-
Spares (5)	-	16,800	11,200	-
Installation	40,000	7,200	3,500	1,200

NOTES:
(1) All information is per shipset except where otherwise specified.
(2) Assuming continuous funding.
(3) Assumes material availability. An additional 9 months flow time may be required for material procurement.
(4) May be required for DC-9 also.
(5) Boeing estimate of additional spare parts required.

NUMBER OF BOEING LBPR FAN JETS (SALES AND OPTIONS 5/9/73)

YEAR	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75
TOTAL WORLD (Cumulative)																		
707	5	31	43	87	127	155	189	248	328	444	551	609	623	629	632	642	656	658
727						6	99	206	336	490	649	764	819	849	892	978	1030	1052
737										2	107	219	255	285	307	323	340	343
TOTAL U.S. (Cumulative)																		
707	5	25	31	48	80	97	125	158	208	287	341	379	381	381	381			
727						6	88	184	279	385	526	622	656	662	682	739	755	759
737										1	69	143	144	146				

Revised June 28, 1973



CALC NAP/MLC 6/28/73
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THE BOEING COMPANY

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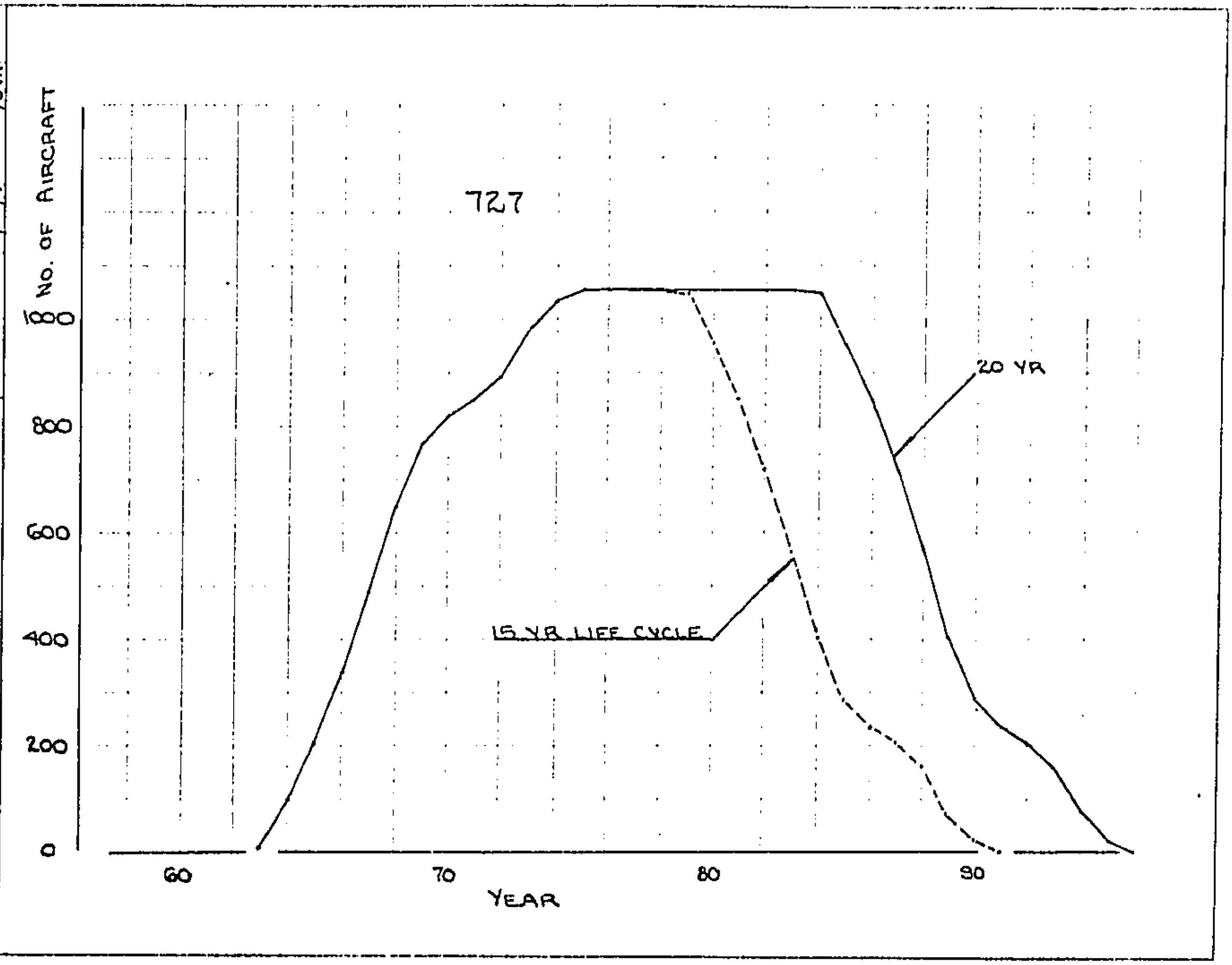

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THE BOEING COMPANY

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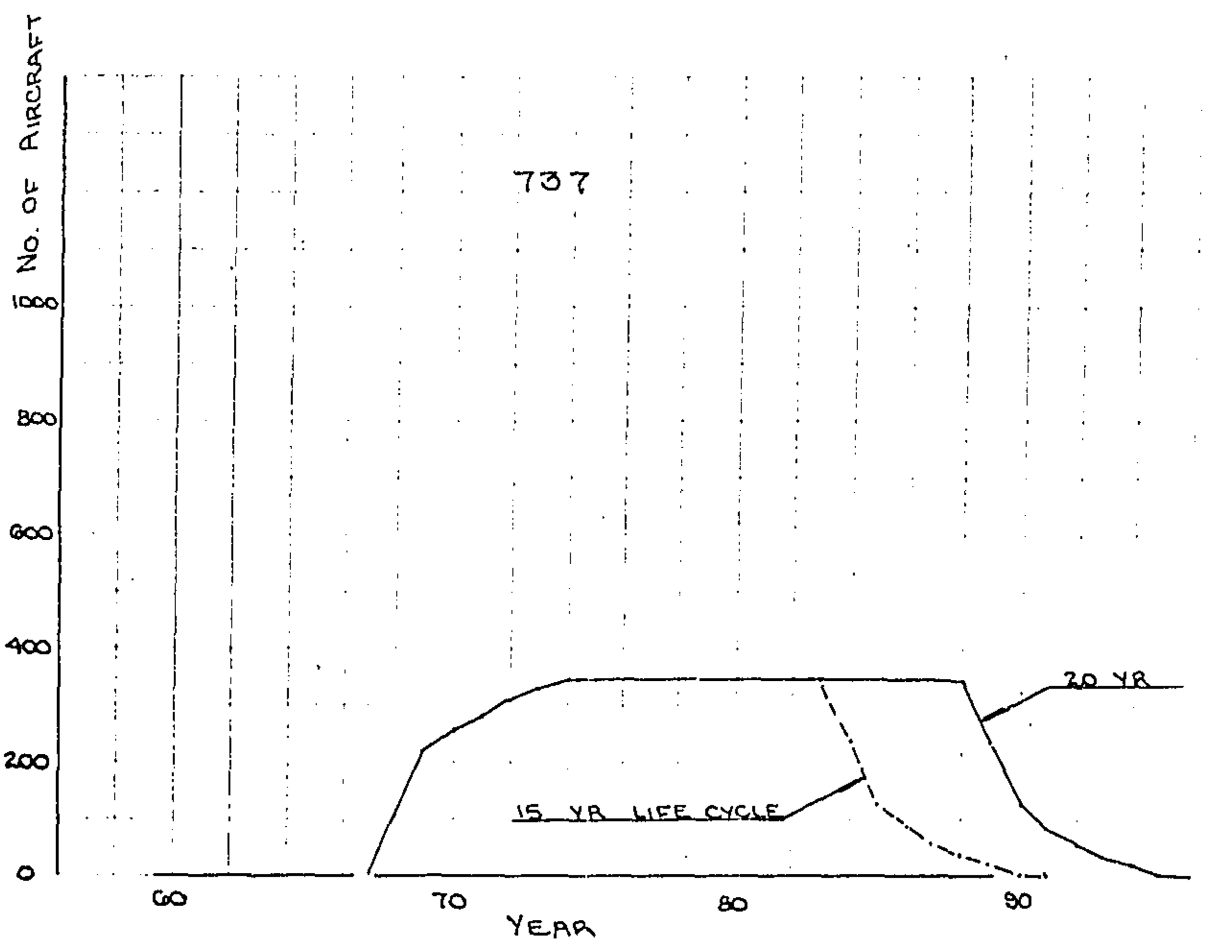


General Aviation
Manufacturers Association

Suite 1215
1025 Connecticut Ave., N.W.
Washington, D. C. 20036
(202) 296-8848

GENERAL AVIATION MANUFACTURERS ASSOCIATION

POSITIONS ON THE ISSUES
CONTAINED IN THE REPORT

ON

NOISE SOURCE ABATEMENT TECHNOLOGY AND
COST ANALYSIS INCLUDING RETROFITTING

FOR

ENVIRONMENTAL PROTECTION AGENCY
AIRCRAFT/AIRPORT NOISE REPORT STUDY

TASK GROUP 4

June 20, 1973

The General Aviation Manufacturers Association has been pleased to contribute to the work of Task Group 4. Specific comments on the report are as follows:

1. The unit L_{dn} and allowable magnitude to protect public health and welfare is described by Task Group 3. It is assumed that Task Group 4 should orient itself to this new measure and base its recommendations on the feasibility of industry to comply. It is not clear to GAMA what relationship the new measure has to existing regulations (FAR Part 36 or the pending ICAO/FAA regulations) and, indeed, how the new measure could be utilized by a regulatory body. Since L_{dn} encompasses all noise sources, what preferences will be given in controlling cumulative noise exposures in the vicinity of an airport? Will the airport be closed if other noise sources reach or exceed the allowable daily quota? GAMA respectfully requests a clarification by the EPA on how they intend to use L_{dn} for regulation and enforcement.

2. Effort has been expended by the task group on noise abatement technology and the economic impact of various noise reduction options. This effort has understandably centered around the transport category aircraft. Neither technology nor the economic impact of noise reduction options is available for general aviation aircraft, as pointed out in the task group's recommendations. GAMA is concerned that lack of this type of data may impose an unknown burden on the general aviation industry, and it requests clarification from the EPA that transport category data will not be applied directly to the general aviation aircraft. A paper, originally submitted to NASA, is presented as an attachment to this communication with the belief that it may be of assistance to the EPA in their consideration of the general aviation industry's requirements.

3. A considerable amount of work has been expended by GAMA, other industry associations, and U.S. and foreign governments, to formulate new ICAO/FAA regulations for general aviation aircraft. These pending regulations represent a sincere challenge in noise reduction and, indeed, tax the capabilities of the general aviation industry. GAMA requests clarification from the EPA on the specific relationship between its recommendations and the pending ICAO/FAA regulations.

GAMA endorses the goal to control noise for the benefit of public health and welfare, and will cooperate fully in establishing responsible recommendations, consistent with the health of the general aviation industry.

NOISE CONSIDERATIONS IN THE DESIGN OF
TURBOPROPULSION ENGINES FOR
GENERAL AVIATION

73-210222 May 10, 1973

1.0 INTRODUCTION

Small turbopropulsion engines, such as those used in general aviation aircraft, typically produce little noise that is significantly different from that produced by larger engines. Thus, often the techniques used to mitigate or attenuate the sounds from the large commercial aircraft engines are thought to be applicable also to small engines. The smaller size of the engines used by business and general aviation aircraft, however, imposes unique constraints on performance, weight, and cost that preclude the direct application of these methods and materials without considerable adaptation. In some instances, weight or volume limitations may be so severe that radically new approaches are required if the engines and their installations are to meet acceptable low-noise emission standards.

This document discusses the significant design and operational features of small turbopropulsion aircraft engines as they are related to the acoustical qualities of these engines. Several specific acoustical problems unique to small engines and their installations are discussed, and four areas requiring further research are identified.

2.0 MECHANICAL AND AEROTHERMODYNAMIC DESIGN

Unquestionably, every aircraft engine design represents a compromise among the various technical disciplines involved. Aerodynamic elegance may be sacrificed for producibility and cost; mechanical ruggedness may be derated to achieve acceptable weight; and each of these factors, as well as others, may be compromised for a lower engine noise level. However, among those features of greatest concern to turbopropulsion engine manufacturers are those that directly influence performance and integrity since those factors also influence aircraft costs and safety.

The basic performance cycles for turboprop, turboshaft, turbojet, and turbofan engines are the same regardless of engine size. However, small aircraft, as a class, operate over broad ranges of cruise speeds and altitudes, as shown in Figure 1. Small engine designs include a corresponding broad range of cycle variations to meet the aircraft flight requirements. Thus, the large variety of business and general aviation aircraft types, coupled with the broad range of operating conditions, requires that the small engine manufacturer be prepared to analyze and respond to a much larger number of engine/aircraft cycle optimization problem statements than manufacturers of the larger commercial engines. Therefore, to provide engines optimized for each operational requirement, the small engine manufacturer must be prepared to introduce a larger number of engine configurations into the time-consuming and expensive design-development-certification-production cycle.

Figure 2 shows the AiResearch TFE731-2 Engine that was designed for a sea-level thrust of 3500 pounds and compares it to a typical larger turbofan engine. Although such small turbopropulsion aircraft engines are generally less complex, their small size can impose problems that can ultimately result in aircraft performance, weight, and cost penalties.

The factors that influence the integrity of an engine include the choice of materials, predetermination of failure modes, redundancy of functions, etc. In this regard, while the smaller engines are generally less complex in their operation and installations than engines used on commercial aircraft, they must still meet, for example, the same regulations regarding bird ingestion as the large engines. A 4-pound bird entering the inlet of a 5000-pound thrust turbofan engine imposes a relatively much greater potential for damage to that engine than to a 40,000-pound-thrust engine. As a result, the mechanical strength of small engines required to pass bird-ingestion tests must inevitably exceed the minimum performance and life requirements.

Because small engines are less tolerant of disturbances to the cycle, the effects of blade clearances and other leakage paths are more critical. This fact requires that extra attention be given to manufacturing tolerances, thermal growth and distortion effects, and internal air distribution passages.

Compromising designs to accommodate extra structural integrity, manufacturing with extra precision to minimize the effects of leakages, designing aerothermodynamic components to achieve higher cycle efficiencies, and anticipating and responding to the broad operating requirements of a multiplicity of aircraft types are extraordinary requirements that have been accepted and met by small engine manufacturers while still producing engines of competitive cost and efficiency. To these requirements, low noise must now be added.

3.0 ACOUSTIC IMPLICATIONS OF ENGINE SIZE

From the above discussion, it will be noted that there are both similarities and dissimilarities between large and small turbofan engines. However, even the similarities in engine design and operation often lead to differences in approach to acoustical suppression. For instance, most modern turbofan engines for subsonic applications (regardless of size) operate within the same general regimes of fan tip speed and exhaust velocity. Thus, much of the radiated acoustical power from any size engine falls within the same part of the audible frequency spectrum. Unfortunately, this range (1000-4000 Hz) generally overlaps both the critical speech interference frequencies and those associated with maximum annoyance. Thus, the manufacturers of small engines are faced with eliminating or attenuating sounds within much the same frequency ranges as the manufacturers of the large engines. However, much of the technology developed (a great deal of it at government expense) for attenuating large turbofan engine noise employs material constructions whose thickness, weight, and cost are wavelength (and thus frequency) dependent. Figure 3 shows a typical quieted aircraft propulsion engine utilizing resonative attenuation in a concentric splitter ring within the inlet and longitudinal splitters in the fan exhaust duct. If treatment tuned to 2000 Hertz were applied to both sides of each splitter, the splitters would be about 3 inches thick. Therefore, a ring designed for use in a 6-foot-diameter turbofan engine inlet might take up only about 6 percent of the inlet area (an important consideration in calculating the drag and performance of the engine), while the identical splitter construction designed for the same frequency when employed on a small turbofan would block 23 percent of the area. The weight and cost penalties are also proportionally larger for the same treatment.

There are other acoustic problems in quieting small-sized engines. Combination-tone ("buzz-saw) noise, for instance, is the result of the interaction of shock waves from the supersonic portion of each fan blade. This interaction is the result of inlet flow distortions and nonuniformity of the repetitive blades. Both are easier to control in the design and manufacture of the larger engines and components.

Product safety and integrity also play an important part in limiting the direct application of the large engine acoustic technology. Anti-icing and foreign-object-damage criteria become more critical constraints within small turbopropulsion engines because of the thinner blades and higher rotational speeds employed. The FAA-required 4-pound-bird ingestion test mentioned above would also uniquely influence the design of splitters and their installation hardware in small engines, since there is physically less structure available for support without assuming a disproportionate weight penalty. It is also necessary to ensure that foreign objects cannot become lodged in the smaller passages.

While commercial transport category aircraft certainly make more noise individually than business and general aviation planes, the latter fleets are roughly 20 times the size of the transport category. Further, they are dispersed more widely across the country and often employ suburban airfields that do not have the industrial and commercial buffer zones often possessed by the larger metropolitan fields. Therefore, the continued use of small, unquieted aircraft has the potential to create a more widespread adverse community reaction.

It should also be recalled that a very large percentage of the general aviation fleet consists of propeller-driven aircraft. In all likelihood, barring government restriction or intervention, these classes of aircraft will continue to grow in number and, as the commercial fleets are quieted, will grow in acoustic importance at an even faster rate.

What is therefore necessary to solve these and other related acoustical problems of small aircraft is a definitive program to incorporate the applicable portions of previous (large engine) noise-reduction studies and to develop new and more appropriate solutions to the unique general aviation problems. In each case, it will be necessary to observe practical limits of weight, space, and cost.

4.0 RESEARCH REQUIREMENTS

According to the Joint DOT/NASA Civil Aviation Research and Development Policy Study, between $20 and $25 million were spent

Some work was performed on sonic inlets for large quiet-engine applications, but they did not find general use because of the bulk required to control such a device on a large engine. However, some version of the sonic inlet may be practical for small engine installations.

Attenuating devices that do not depend upon the resonance of air columns, but rather upon mechanical or electrical resonances, might be more practical for eliminating low frequencies in small engines.

4.3 Research Is Required into Effective Regulatory Practices and Their Interaction with Cost and Performance Tradeoffs

Many NASA, DOT, and FAA studies have been funded for investigating the effect that various proposed noise rules, units, etc., would have upon the economics of the commercial airline industry. Some additional similar efforts are needed to assess the cost and performance impacts of various rule-making activities. For instance, a small engine that was designed to make a high blade-passage frequency would benefit from a FAR Part-36-type rule where the measuring points are at relatively large distances from the aircraft during takeoff, since the higher frequencies attenuate at an exponentially higher rate than low frequencies. However, some of the schemes being discussed for bringing the measuring points closer in would negate that advantage and might force the manufacturer to adopt some other engineering feature. Obviously, the goal should be the definition of a fair and consistent rule that would protect the public interest without artificially penalizing anyone.

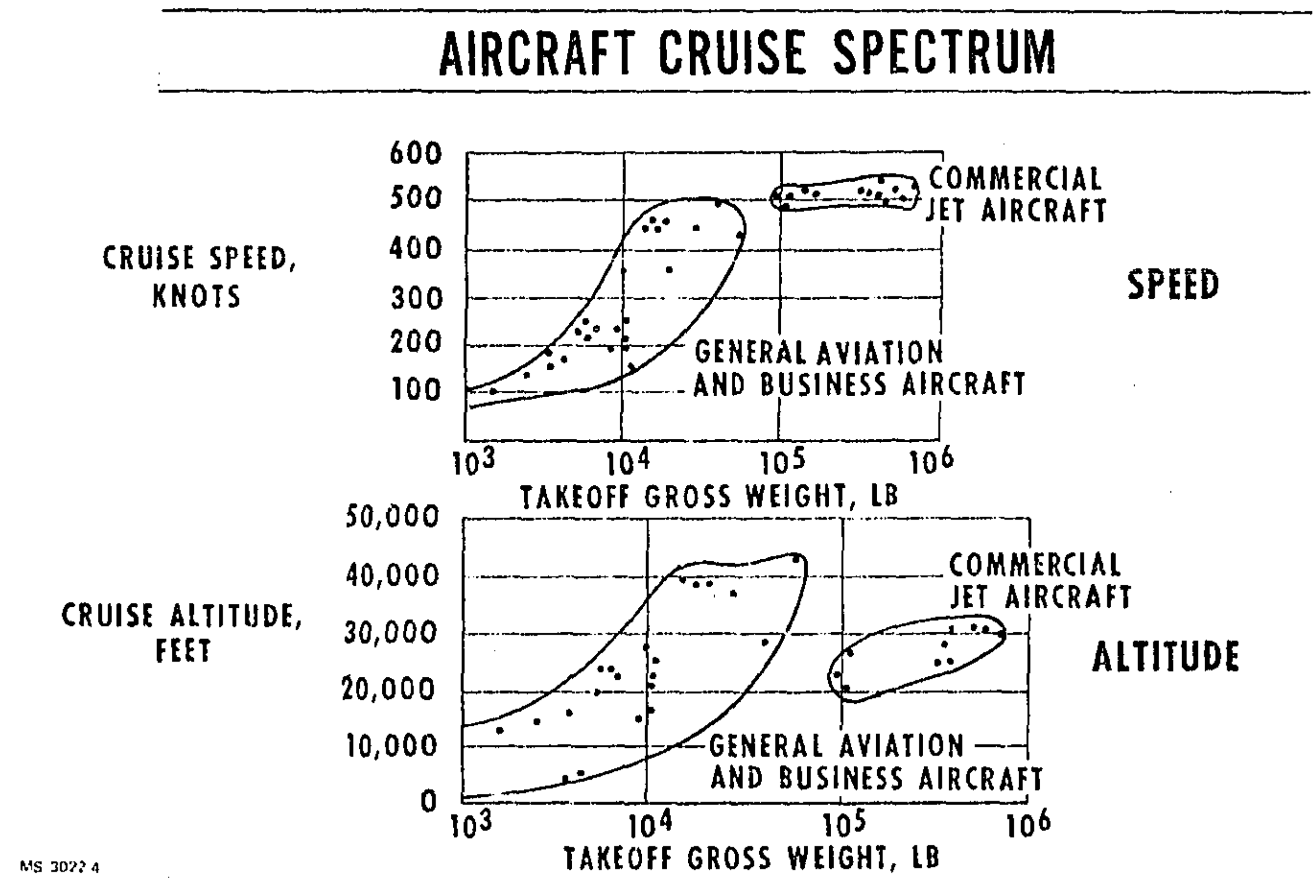
4.4 Research Is Required into Means for Reducing Noise Emissions from Propeller-Driven Aircraft

NASA has conducted research in this area for several years; however, more definitive noise and performance tradeoff studies are required for general aviation-type propellers and engines. Again, the type of noise rule that is to be promulgated will affect the types of solutions to be recommended.

Most current general aviation propellers are manufactured with use of the same materials, designs, and processes employed 20 to 50 years ago. The advent of composites and other space-age technologies offers the promise of constructions that are less controlled by material strengths and yield points and more by aerodynamic and acoustic considerations. Scalloped, notched, and slotted blades that a few years ago were only laboratory curiosities because of cost and/or strength limitations are now more practically within the reach of most general aviation operators. However, specific programs are required to clearly set down the design and performance guidelines, as well as to identify the potential benefits.

4.5 Research Results Should Be Substantiated in an Engine-Nacelle Test Bed

The separate and combined results of the above research efforts should be adequately demonstrated in a nacelle-engine environment.


AIRCRAFT CRUISE SPECTRUM
CRUISE SPEED, KNOTS
600
500
400
300
200
100
COMMERCIAL JET AIRCRAFT
GENERAL AVIATION AND BUSINESS AIRCRAFT
SPEED
10^3
10^4
10^5
10^6
TAKEOFF GROSS WEIGHT, LB
CRUISE ALTITUDE, FEET
50,000
40,000
30,000
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COMMERCIAL JET AIRCRAFT
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FIGURE 1

SMALL ENGINES ARE DIFFERENT

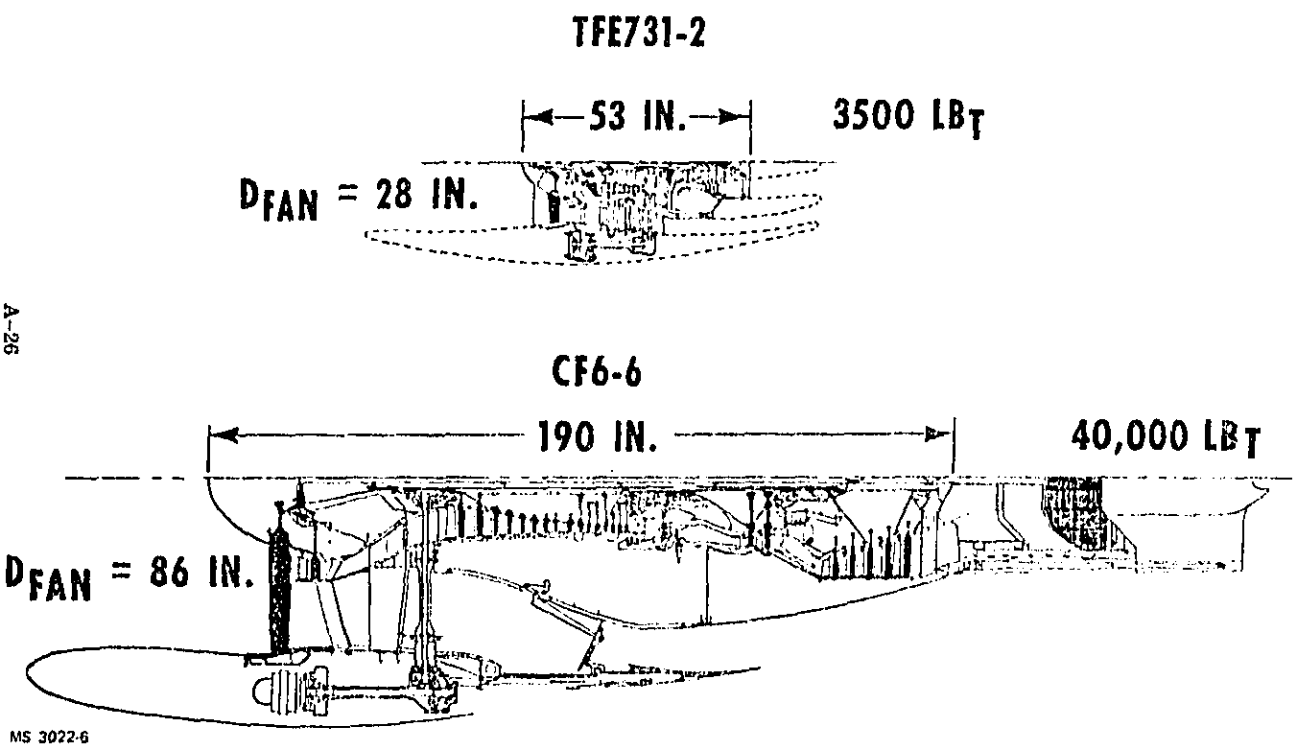


FIGURE 2

TURBOFAN ENGINE NOISE CONSIDERATIONS

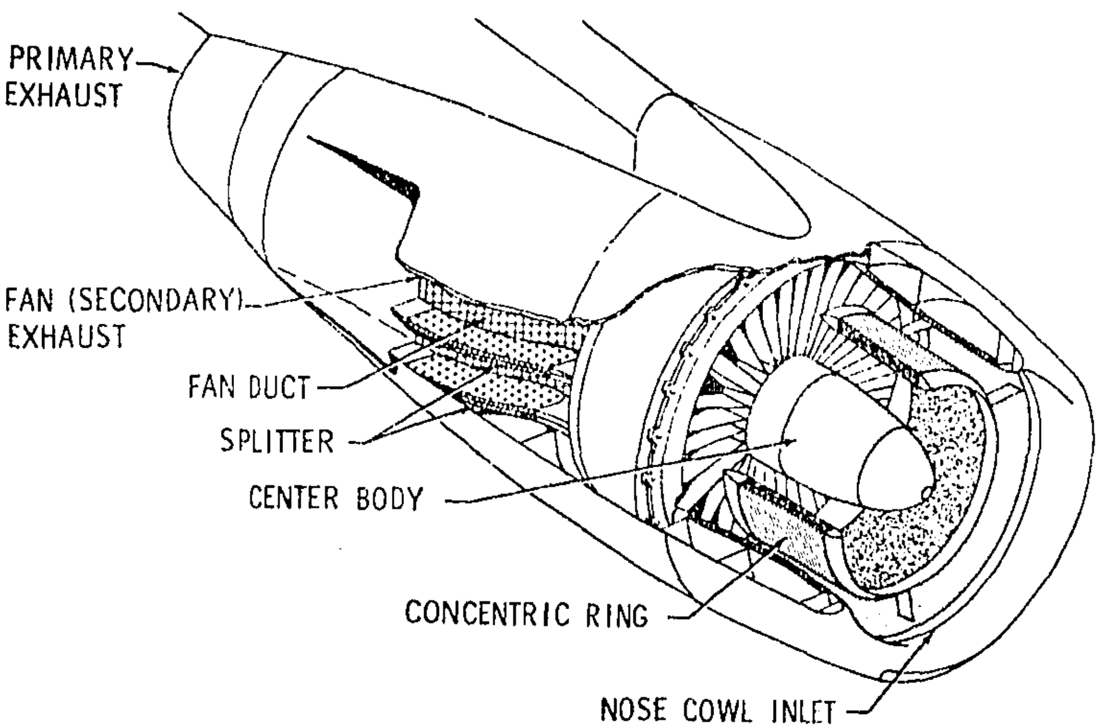


FIGURE 3

GENERAL ELECTRIC
COMPANY
CINCINNATI, OHIO 45215

AIRCRAFT ENGINE GROUP

22 May 1973

Dr. Alvin Meyer
Environmental Protection Agency
401 M Street, N. W.
Washington, D. C.

Dear Dr. Meyer:

In reference to discussions at the meetings of the EPA Aircraft/Airport Noise Study Task Force, the views of the Aircraft Engine Group of General Electric on aircraft noise regulations can be briefly summarized as follows:

1. FAR 36 (as issued on 23 November 1969) has been effective in stimulating noise reductions. For example, new wide-bodied aircraft have been certified at or below Appendix C levels.

2. We suggest the promulgation of the subsonic CTOL Fleet Noise Rule we proposed in our comments on ANPRM 73-3, sent to the FAA Rules Docket on 12 March 1973, rather than a series of separate, incomplete and possibly conflicting regulations. For example, we favor regulations which would require all newly-produced aircraft to comply with FAR 36 at reasonable dates, depending on the aircraft type. The suggested Fleet Noise Rule would accomplish this. We do not favor regulations which would require all of the current fleet of older types of aircraft now in service to be retrofitted with nacelle acoustic treatment or refanned engines. The suggested Fleet Noise Rule would promote some retrofit of some aircraft types, depending on the particular airline operator's constraints.

   A proper Fleet Noise Rule would allow an airline a decreasing "noise quota" with time, out into the 1980 period. We believe that such a method would offer the airline operators maximum flexibility to control noise through a combination of off-loading, operating procedures, retrofit and fleet replacement in the most economic and practical way for each airline and aircraft type. It is important to note in this connection that most airline fleets use a mixture of two, three, and four engine aircraft across a wide range of different stage lengths and numbers of operations.

We suggest promulgation of an FAA regulation of the generic type of the Fleet Noise Level (FNL) proposed by FAA in ANPRM 73-3, but with important modifications proposed by General Electric, as follows:

a. The noise measure in such a rule should be weighted to give considerable incentive to airlines to acquire aircraft having noise levels significantly below Appendix C levels. This was not the case with the noise measure proposed in ANPRM 73-3.

b. Rather than the interim nature of the FNL rule of ANPRM 73-3, which would terminate in 1978, we suggest a rule with a number of "gates" at specified times, requiring aircraft "on-the-average" to get half-way-down to FAR 36 by some date, down to FAR 36 by a later date, and down to levels below FAR 36 by some still later date. The noise levels shown on the attached figure are suggested as typical certification levels for new aircraft in the late 1970's, based on our views of possible noise reduction, available technology and economic reasonableness, over the wide range of aircraft types covered. The suggested approach noise levels are for the flap settings used in normal operating practice, rather than the maximum flap settings as required currently in FAR 36. The use of normal flap settings is a worthwhile noise abatement operating procedure in itself.

It should be noted that separate certification rules will be required for supersonic transport aircraft and for quiet short-haul aircraft, due to the different characteristics of these aircraft types.

It is also suggested that FAR 36 be modified to encourage the use of two-segment approach procedures, by specification of an additional special reference point, such as a 3 1/2nm approach point, and maximum allowable noise levels at this point. If this method were used, the FAR 36 tradeoff provisions should be maintained at the normal three reference points only.

3. EPA has proposed airport regulations as such. The cognizant authority for such regulations should be a Federal agency, in order to assure that this vital and integral part of the national transportation system is not adversely compromised by local piece-meal actions. Therefore, such definitive Federal pre-emption of airport noise

regulations should be a part of the proposed action in order to afford equitable treatment for all airport users, including airlines. Appropriate FAA noise source control and aircraft path control regulations should separately provide final "design requirements" for manufacturers, as FAR 36 has done in the past.

4. An increased level of aircraft noise reduction research and development is needed in the following areas:

   a. Development of noise technology for advanced CTOL engine/aircraft systems which emphasize reduction of the economic penalties of lower noise, i.e., lower cost, weight and performance losses.

   b. Identification of improved measures of airport community noise annoyance for aircraft operations making noise equal to or less than required by FAR 36.

   c. Determination of aircraft-alone noise levels and identification of means to control this noise source.

General Electric has been active in aircraft noise reduction since the middle 1950's, in both the civil and military aircraft areas. Substantial progress has been made, as evinced by the civil fleet introduction of the new wide-bodied aircraft, which are much quieter than their predecessors. We believe that Federal aircraft noise regulations and additional research and development of the types suggested above will achieve further reductions in airport community noise exposure.

Very truly yours,

J N Krebs

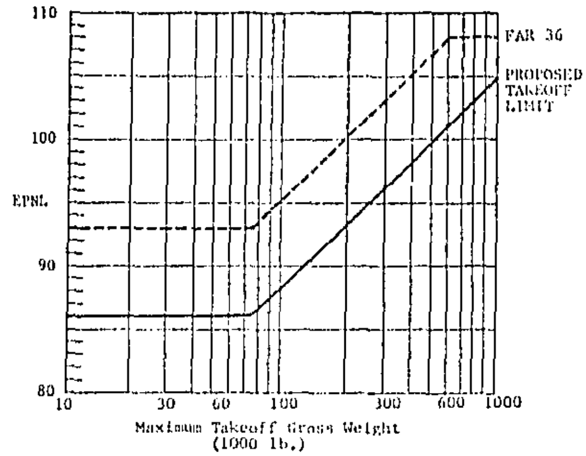
J. N. Krebs

attach.

CERTIFICATION LEVELS FOR NEW AIRCRAFT IN THE LATE 1970's TIME PERIOD

TAKEOFF

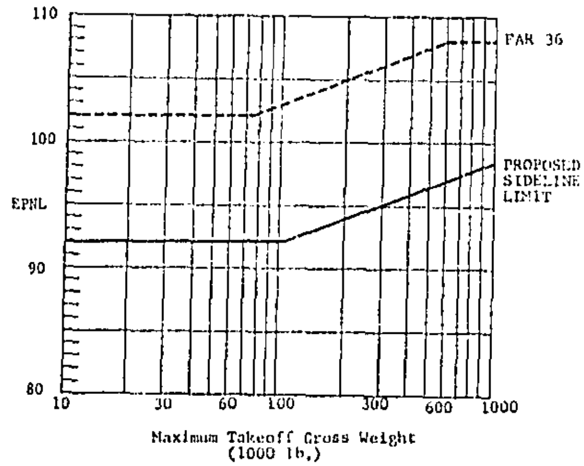
3.5 N. Mi. from Brake Release



SIDELINE

0.35 N. Mi. (4 Engine A/C)

0.25 N. Mi (Less than 4 Engines)

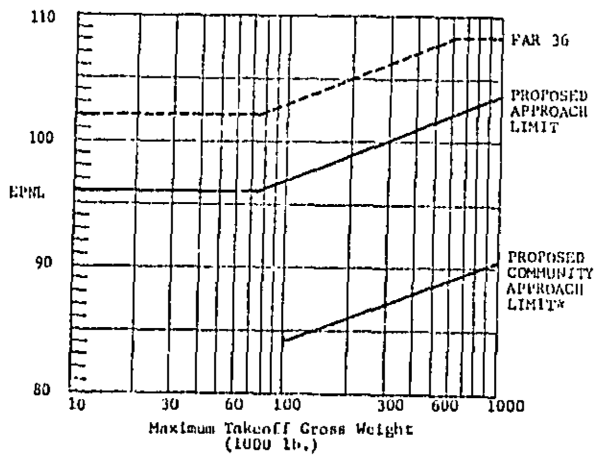


APPROACH

1.0 N. Mi. from Threshold

COMMUNITY APPROACH

3.5 N. Mi. from Threshold



*Based on 6°/3° Two-Segment Approach with 600 ft. Intercept

Environmental Activities Staff
General Motors Corporation
General Motors Technical Center
Warren, Michigan 48090

July 25, 1973

Mr. William Sperry, Chairman
Task Group 4
Aircraft/Airport Noise Study
Environmental Protection Agency
Room 1102F
Crystal Mall Building
1921 Jefferson Davis Highway
Arlington, Virginia 20460

Dear Mr. Sperry:

In a discussion with Mr. Curt Walker we agreed to change page 2 of this submission to reflect an emphasis on our position relative to the issues rather than to the Task Group Report.

Attached is our revised submission. Thank you very much for the opportunity to comment on this important area of environmental noise control.

Sincerely,

E. G. Ratering, Director
Vehicular Noise Control

Attachment

cc: Mr. C. L. Walker
Detroit Diesel Allison Division, GMC

General Motors Statement
Before the

Environmental Protection Agency Task Force

on

The Aircraft/Airport Noise Study

Submitted By

Edwin G. Rotering
Director, Vehicular Noise Control
Environmental Activities Staff
General Motors Corporation

and

Curtis L. Walker
Section Chief, Noise Reduction
Detroit Diesel Allison Division
General Motors Corporation

June 21, 1973

General Motors Statement

Mr. Chairman, my name is Curtis L. Walker, Section Chief, Noise Reduction Research, Detroit Diesel Allison Division, General Motors. We appreciate the opportunity to comment upon the problems we see in the study of aircraft noise reduction.

Detroit Diesel Allison manufactures the commercial aircraft engine, Model 501 turboprop, for use in Electras and Convair conversions. Consequently we are concerned with the noise reduction objectives being considered for aircraft engines.

We appreciate the problem that faces the Task Groups, due to the short time which Congress allotted to the Environmental Protection Agency to carry out the Aircraft/Airport Noise Study. Therefore, we will submit brief comments on those areas under Task Group consideration wherein our experience and testing has given us competence.

As a preface to our comments, may I establish for the Group two facts:

(1) Our Model 501 turboprop engine is a significantly quieter engine than a contemporary turbofan engine used in an aircraft of the same gross weight, viz., the Electra compared with the DC9-30. A noise footprint making this comparison between the Electra and DC9-30 is attached as Figure 1. We believe that the Electra will meet any reasonable noise emission requirement.

(2) If, as a result of the EPA studies, reduction of general aviation aircraft noise is required, then there are several turboshaft engines which are available which are quieter than comparable reciprocating engines. One of these turboshaft engines is the Allison 400-horsepower Model 250, which is currently in widespread helicopter use.

During the past seven years at Detroit Diesel Allison, we have been doing research in the aeroacoustics of advanced high-bypass engines. This effort has made it necessary for us to construct a unique test facility which is devoted to fan noise research. As a result of this effort, we believe that technology does exist for further noise reduction below that currently specified in FAR 36. Moreover, our studies of commercial derivatives of our current advanced technology core engines indicate that some noise reduction below current regulatory limits would involve a relatively straightforward engineering and development effort. We would like to caution, however, that reductions in the range of 10 EPNdB or more below those levels currently specified in FAR 36 will be difficult to achieve. Indeed, such reduction may require significant technological advancements in order to avoid appreciable aircraft performance penalties.

The exact degree of improvement which may be available without such performance penalties is impossible to predict at this time. However, the possibilities for noise reduction through currently available technology are indicated by the calculated footprint for a commercial derivative of the Advanced Medium STOL Transport (AMST), which is shown at two typical bypass ratios in Figure 2 (also attached).

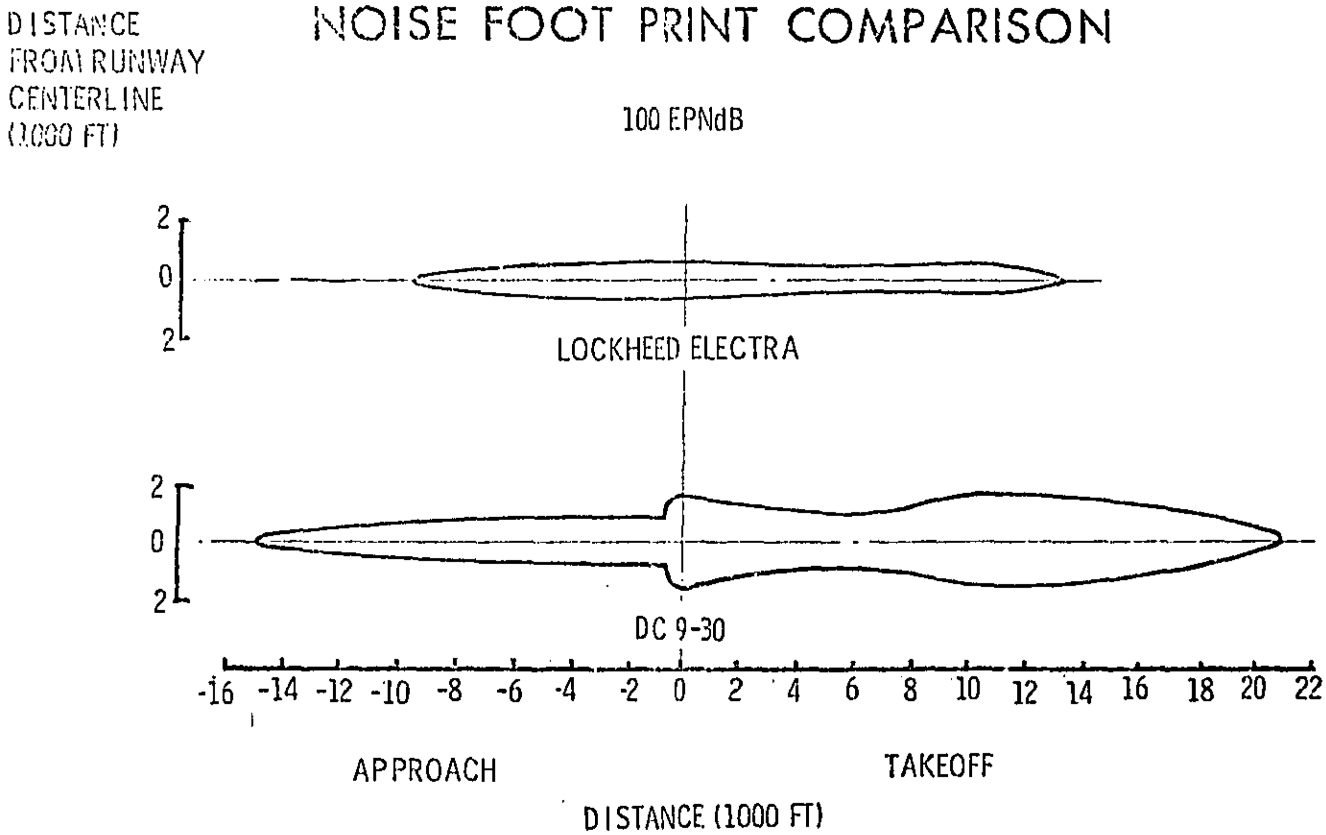
Finally, Detroit Diesel Allison Division is greatly concerned that an adequate amount of lead time be allowed in developing engine improvements of the type we are discussing today.

Our experience in the development of aircraft engines leads us to the conclusions we have depicted on the chart attached as Figure 3. As you can see, it is our judgment that even when the technology is at hand to accomplish a specific objective, it is likely to take several years of further development and qualification before such technolgoy has been incorporated into the final aircraft so that it can enter the market as a production aircraft. In other words, the phrase "immediately available solutions" in the aircraft field means that several years of additional testing are still required before translation to flying hardware is likely to be completed.

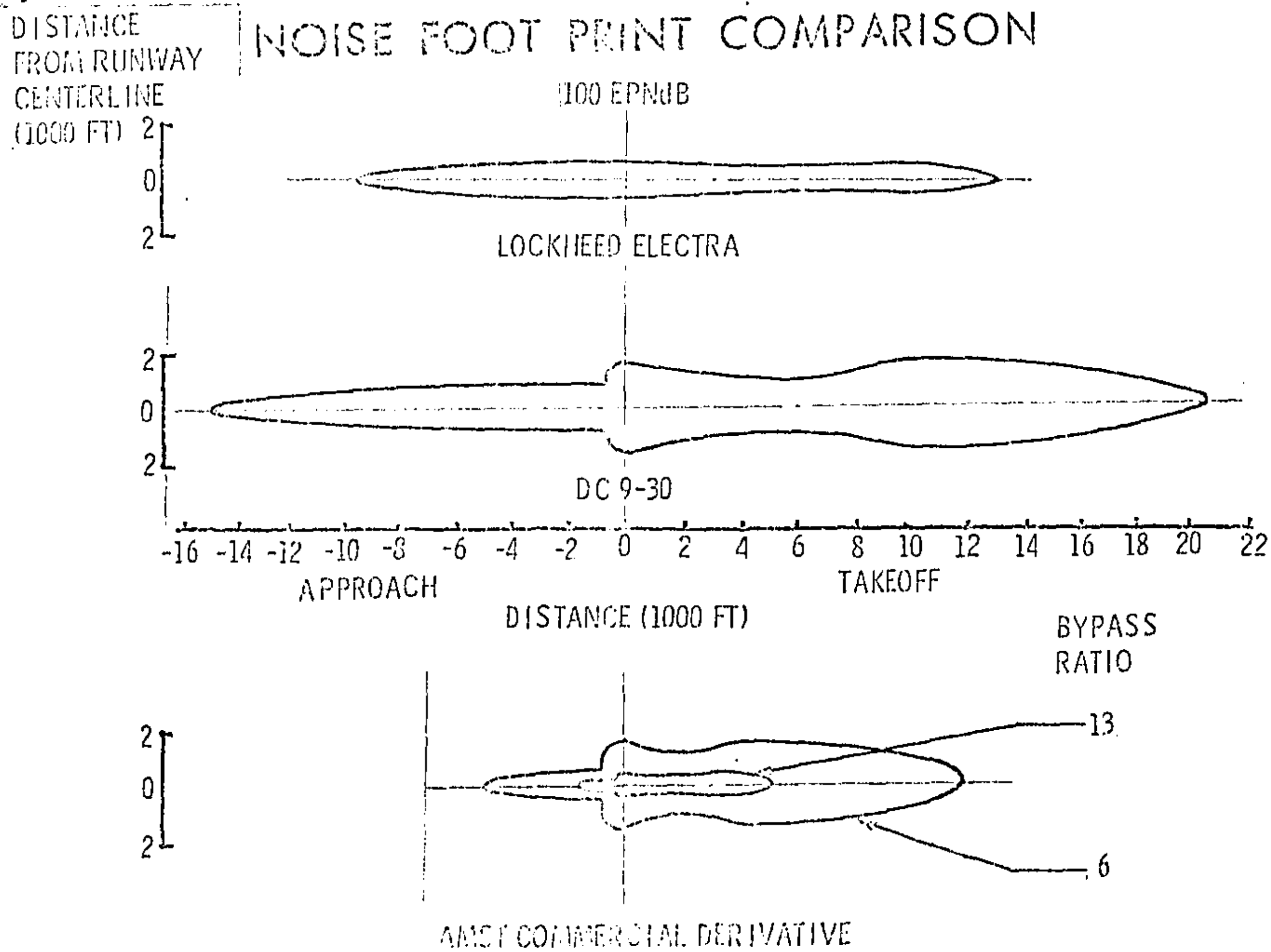
This concludes my prepared statement. At this time, we will attempt to answer satisfactorily any questions that you may wish to ask.

Thank you.

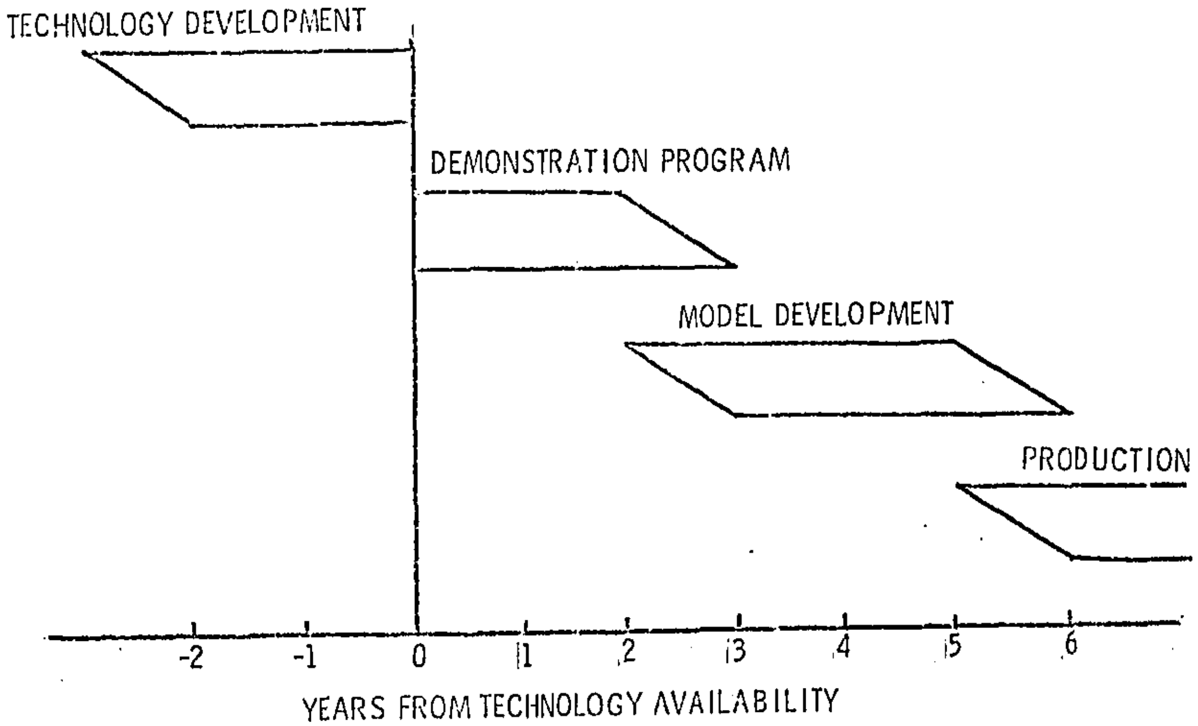
NOISE FOOT PRINT COMPARISON



NOISE FOOT PRINT COMPARISON



ENGINE DEVELOPMENT CYCLE



DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT
WASHINGTON, D. C. 20410

ASSISTANT SECRETARY FOR
COMMUNITY PLANNING AND MANAGEMENT

JUN 29 1973

Mr. John C. Schettino
Director, Aircraft/Airport Noise Study
Office of Noise Abatement and Control
Environmental Protection Agency
Washington, D. C. 20460

Dear Mr. Schettino:

We would like to take this opportunity to express our general satisfaction with the work of EPA Task Force which was organized to provide recommendations for dealing with the aircraft/airport noise problems. Unfortunately, we were able to provide only limited assistance to three of the Task Groups due to staff shortages and other pressing assignments; however, I am enclosing our general observations and position on many of the preliminary recommendations of the Task Force.

We will continue to support the activities of the Environmental Protection Agency in the aircraft/airport noise program, and will be happy to provide whatever assistance we can to the EPA in this effort.

Sincerely,

Clifford W. Graves
Acting Assistant Secretary

Enclosure

Department of Housing and Urban Development

Comments on

RECOMMENDATIONS ON THE EPA TASK FORCE ON AIRCRAFT/AIRPORT NOISE PROBLEMS

A. HUD's ROLE IN NOISE ABATEMENT

It has long been HUD's policy to encourage the creation and maintenance of a quiet environment. To further this goal, HUD issued, on August 4, 1971, a policy Circular on "Noise Abatement and Control: Departmental Policy, Implementation Responsibilities and Standards." This policy was promulgated after several years of development, in an effort to fulfill the Department's mandate to "provide a decent home and a suitable living environment for every American family". With the issuance of this policy, HUD stated its conviction that "noise is a major source of environmental pollution which represents a threat to the serenity and quality of life in population centers." The policy formalized and expanded existing FHA noise regulations which had been in effect for many years, and drew upon the work of several other agencies and groups and on a long standing and developing body of knowledge in the area.

The policy establishes noise exposure policies and standards to be observed in the approval or disapproval of all HUD projects; it supersedes those portions of existing program regulations and guidance documents which have less demanding noise exposure requirements. Further, it is HUD's general policy to foster the creation of controls and standards for community noise abatement and control by general purpose agencies of State and local governments. HUD also requires that noise exposures and sources of noise be given adequate consideration as an integral part of urban environments in connection with all HUD programs which provide financial support to planning. The policy emphasizes the importance of compatible land use planning in relation to airports, other general modes of transportation, and other sources of high noise, and supports the use of planning funds to explore ways of reducing environmental noise to acceptable exposures by use of appropriate methods. Reconnaissance studies, and, where justifiable, studies in depth for noise control and abatement will be considered allowable costs.

Because HUD's noise standards are technically specific in nature, the Department has published "Noise Assessment Guidelines", a manual to provide HUD's personnel and the general public with a practical methodology for preliminary evaluation of noise levels at given project sites. An important facet of the Department's noise control activities is a continuing program of sponsored research into various aspects of the cause and effects of environmental noise. Typical of these is a series of Metropolitan Aircraft Noise Abatement Policy Studies, funded jointly by HUD and the Department of Transportation. This work was summarized and extended in the form of a guideline manual, to help localities plan community growth in the vicinity of airports. The manual discusses the costs, benefits and limitations of alternative methods of noise alleviation such as compatible land use development, zoning, and noise attenuation measures in building construction. Applicable to all type of airports, it will be used to develop procedures for dealing with a variety of local airport noise situations. It also contains relevant information on Federal and State programs to assist in achieving compatible airport-community development. The manual entitled "Aircraft Noise Impact: Planning Guidelines for Local Agencies," is now in printing by the Government Printing Office and will be given wide distribution.

B. HUD's POSITION ON ISSUES RELATED TO THE WORK OF THE TASK FORCE

1. Cumulative Noise Exposure

We believe that there is an urgent need to standardize a measure of noise exposure as a prerequisite to promulgating a national set of noise exposure standards and implementing procedures. We, therefore, strongly support the activities of Task Group 3. The lack of what might be called a "perfect" index of measure is no excuse for inaction on the growing problems of noise abatement and control. Our major concern is that any proposed aircraft noise assessment method be compatible with those now in use by this Department in implementing the HUD noise policy, i.e., Composite Noise Rating (CNR) or Noise Exposure Forecast (NEF).

We are in agreement with the long term goal of Ldn of 60 (NEF 25) recommended in the Task Group report, though we feel that further clarification is needed. Current HUD policy is to discourage residential development beyond 30 NEF (though some discretion is applied in certain cases where noise exposures lie between NEF 30 and 40). The NEF 30 value corresponds roughly to an Ldn of 65. Thus, the current allowable noise exposure for HUD assisted new residential construction is marginally higher than the long term goal recommended by the Task Group. However, we fully hope and anticipate that the EPA, with the cooperation of other Federal agencies and industry groups, will be successful in reducing noise through source and operational controls, so that noise reduction from these activities will bring current residential construction satisfying existing HUD criteria well within the long term objective (Ldn of 60). It is important to emphasize that since new construction represents the long term establishment of a given land use to a particular area, implementation of long term goals requires immediate action of the type HUD has been actively pursuing in the last two years.

We assume that the immediate goal of Ldn (45 NEF) of 80 is to be implemented through source and operations controls, building modifications, and where necessary, condemnation and relocation, and is to be applied to existing residential units. We fully support such a recommendation providing adequate relocation resources are available at a price the displacees can afford (pursuant to provisions of the Uniform Relocation Act).

We are concerned, however, that noise levels less than Ldn 80 may also constitute risks to health resulting from sleep interference, unless airports have stringent restrictions on night-time operations. The problem is exacerbated with windows open, as they must be in the summer months in many areas when adequate alternative ventilation is not available.

We support recommendation concerning a standardized computer program for calculating cumulative noise exposure. Further, there should be a standardized definition of data input requirements and a central data center which can generate contours of cumulative noise exposure for use by Federal, State and local agencies in making land use decisions.

2. Airport Noise Regulation

We would endorse the recommendationsthat airport operators exercise their authority to regulate aircraft operations to reduce noise in residential areas. The requirement that airport operators predict operations and noise exposure to determine compatibility of airport operations with the adjacent land uses and then take actions to achieve a larger measure of compatibility through reduction in the noise effective size of the airport is an important element in the total program to reduce airport-community conflicts. Decisions on runway alignment, airport expansion and volume and type of aircraft use are as essential to ameliorating and preventing noise conflicts as are the control of noise at the source and the control and guidance of land use development in the airport environs.

It is understood that the FAA has the authority for requiring airport certification under existing legislation. That agency should therefore be encouraged to take the necessary action to meet the EPA compliance schedule.

3. Continuing Program for Noise Abatement

We would concur in the need for a continuing Federal Program to assist in implementing a comprehensive national aircraft/airport noise abatement program. We would be happy to participate in those aspects of the program which are of interest and concern to the Department.

C. OTHER RELATED ISSUES

There are other problems that need to addressed to further goals of the aircraft/airport noise abatement program; some of these are:

1. National Airport System Planning

A National Airport System Plan appears to offer a key to the problem of location and expansion of airports in the Nation, and a meaningful document can lessen the potentially adverse impacts of such development. The long range plan could identify the projected kinds and volume of operations at specific classes of airports so that there would not continue to be the many surprises which appear to develop fairly regularly following the creation of an airport or changes in operations at existing airports. Communities in the airport environs would then have an explicit idea of the kinds of airport development expected and could plan accordingly. The National Airports System Plan should have a rational national focus and not be only a compilation of airport projects conceived solely by state and local authorities.

2. Modification of Airport and Airway Development Act (AADA)

We believe that the AADA can be strengthened to insure a greater measure of compatibility between airports and their surrounding areas, as follows:

a) Aircraft noise is not specifically addressed in the law. In view of the growing concern with environmental quality and the impact of the airport development program, noise merits specific recognition. The law does not now support the acquisition of land to be exposed to severe levels of noise;consideration should therefore be given to modifying the statute to allow the acquisition of such land, by easement or fee simple, as part of the airport development project costs. Inclusion of such a provision to cover areas of very severe noise exposure is both desirable and necessary to any meaningful solution to the noise problem.

b) The rules promulgated by the FAA for implementing the Planning Grant Program under the AADA are not consistent with Section 11 of the Act. Airport systems planning should be an integral part of multi-modal transportation planning for the metropolitan area, and should be handled by the appropriate public comprehensive planning agency. Environmental considerations and airport location should be a significant part of the systems planning process rather than a token after-the-fact issue in airport master planning.

MCE
6/21/73

LOCKHEED-CALIFORNIA COMPANY
A DIVISION OF LOCKHEED AIRCRAFT CORPORATION
BURBANK, CALIFORNIA 91503

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April 25, 1973

Mr. W. C. Sperry
Chairman, Task Groups 4 & 5
Aircraft/Airport Noise Study Task Force
Office of Noise Abatement and Control
Washington, D.C. 20460

Dear Bill:

As part of the Lockheed effort in support of the EPA Aircraft/Airport Noise Task Force, we some time ago asked Rolls-Royce to provide their evaluation of the potential for further engine noise reduction. I feel that consideration of the Rolls-Royce input by EPA is appropriate both because of the pre-eminence of Rolls-Royce in aircraft engine noise technology and because Rolls-Royce engines power a growing proportion of the U.S. air transport fleet.

The attached statement was prepared by Mike Smith, Manager of the Rolls-Royce Noise Department, and approved for submission to EPA by Mr. E. M. Eltis, Director of Engineering, RB.211 Programme. I hope you will find it useful.

Sincerely,

H. Drell

H. Drell
Flight Sciences Division
Commercial Engineering

HD:JRT:jg
Attach.

16 April 1973

CONSIDERATIONS RELEVANT TO QUIETENING OF AIRCRAFT NOISE IN THE IMMEDIATE FUTURE

The noise environment around airports is governed almost entirely by aircraft powered by engines designed about a decade ago. With less than 5% of world fleets currently comprising the newer more quiet Trijets, the L-1011 and DC.10, this situation is likely to prevail until at least 1978, when the FAA propose that all types comply with FAR Part 36 Standards. Even then the improved standard of the high bypass engines over modified earlier counterparts will ensure that newer types cannot be cited as the main offenders. There would therefore appear to be little justification for demanding unduly improved standard from new equipment, for the effect would not be reflected in the overall environmental picture.

However, some improvement in noise standard for new types entering service in the second half of this decade is desirable, to ensure that the problem is largely solved during the 1980's. Having said this, two important problems to be addressed are how much the improvement should be and when new regulations should be enacted. The following paragraphs express our view and are offered to the EPA for their consideration.

The RB.211 is a prime example of the new breed of quiet engines. Its main features were designed in 1966, development commenced in 1967, and the first production engines entered service in early 1972. Any radically new engine can be expected to follow approximately the same cycle of events, and therefore it would be unrealistic to apply stringent new regulations before the end of this decade, since the technology to meet such standards is not developed today.

What is available today is the technology to make limited, but nevertheless, worthwhile improvements. The improvements possible are limited by the new problems that have been revealed in the developments of the newer engines, a prime example being the noise floor created by the core engine. This fact has already been recognised by U.S. Government Agencies in the Research and Development Contracts offered to Industry in the recent past, and clearly the answers will not appear without considerable research, involving in some cases new test facilities.

We therefore see two clearly defined stages in improving the noise environment, viz:

a) limited improvements possible with todays technology, for implementation on engines entering service in the second half of this decade.

b) further improvements made possible by ongoing research, over the next three to five years, for implementation on engines entering service during the early to mid 1980's.

Let us consider each category in turn.

a) Improvements possible using todays technology

On an engine of the RB.211 type there are two important flight conditions to be considered in defining the improvement afforded by engineering action. These are the high power case for lateral and Take-off noise, and part power for Approach.

The RB.211 noise source distribution has been defined as shown in Figure 1. Without resorting to major changes to the rotating machinery improvements are possible by virtue of better aerodynamic standards and improved liner performance. The latter may result from improved design of the liner structure, or the introduction of extra surfaces in the main air-flow passages.

Already we are proposing modest improvements for developed versions of the RB.211, and estimate that such action will improve the standard by about 2 EPNL. Even these improvements are not, however, without penalty. The weight change alone would cost the Tristar the equivalent of five passengers (unless the aircraft weight can be increased by an equivalent amount). On an aircraft already bettering Part 36 standards by 10 EPNL at full power and 4 EPNL at approach it is difficult to see the extra cost being readily borne by the operator.

Further improvements are possible, at an increased operating penalty. The Company entered a partnership with the U.K. Government nine months ago to produce a quiet engine demonstrator based on the RB.211. This programme is directed at improving the noise standard by 5 PNdB, but the modifications are not in any way designed for the production powerplant. Some of the modifications could eventually be incorporated in a saleable powerplant, but others like the full length bypass duct splitters, would involve major redesign, performance penalties and mechanical complication. For example the whole thrust reverser system would need replacing. To integrate all the improvements in a powerplant would cost around 350 lbs weight per engine, and the cruise sfc penalty would probably be of the order of 1/2%. Furthermore if significant modification were required to the inlet system, for example by the introduction of a splitter ring, the full effect would be a further increase of sfc of at least 1/2% and 200 lb in weight per engine. Moreover such devices would require careful consideration of the vibration problems of the fan assembly and may necessitate changes to the fan design.

We would estimate that a 5 PNdB package would take not less than four years to develop and apply to a production standard engine. Assuming a go-ahead early in 1974, quieted production engines could be available in the late 1970's.

The overall result, taking installed performance into account, would probably be a Trijet some 3 - 4 EPNL better than the standard of the TriStar today.

b) Further improvements in newly designed engines

Our research programmes are indicating that basic improvements, other than the extensive use of sound absorbing materials, will only come from more extensive redesign.

Even so the potential for such further basic improvement does not, at the present time, appear to be more than about 3 PNdB, and it is our belief that the contribution of the powerplant alone cannot be regarded as the ultimate solution to the noise problem. It will be necessary for the airframe design to be even more closely integrated with the powerplant to ensure full benefit from shielding by wing and fuselage structures, and such constraints may well dictate the design of future airplanes. Another factor clearly affecting potential noise reduction is the noise generated by the airframe itself, and unless this can be reduced it is unprofitable to demand an improved standard from the engines alone.

CONCLUSIONS

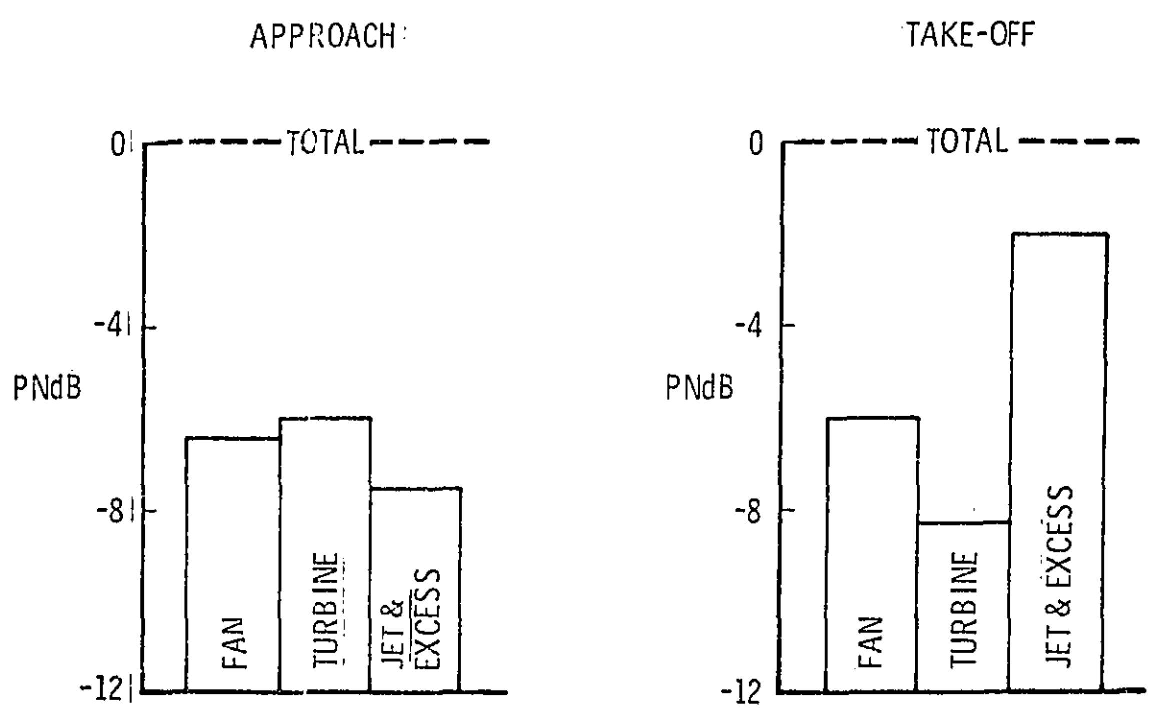
We see two distinct stages relating to future noise legislation;

1. A reduction in Part 36 standards during the latter part of this decade, probably of the order of 4 - 8 EPNL with the provision that the measuring points are modified to remove the current inequality between the landing and take-off measuring distance. Such reduced levels could be demanded from all new aircraft, including developed versions of existing types. The relationship between the two, three and four engined aircraft would however need careful consideration.

2. A further reduction of the order of 5 EPNL during the early part of the 1980's, to be applicable to completely new types only. The practicality of this reduction, of course, depends upon the level to which airframe noise can be reduced.

Beyond that point it is necessary to define both the technically feasible noise floor and the noise level beyond which community exposure is not longer a problem. Assuming that these two criteria are not coincident, it will be necessary to carefully balance technical feasibility and economic impact against any long term legislation proposals.

RB.211-22C IN FLIGHT NOISE SOURCE DISTRIBUTION



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203 - 633-2835

National Organization to Insure a Sound-controlled Environment

June 30, 1973

Mr. William Sperry
Chairman Task Group 4
Aircraft/Airport Noise Study Task Force
U.S. Environmental Protection Agency
Building 2, Crystal Mall
Arlington, Virginia 20460

Dear Mr. Sperry:

We have participated in the meetings of Task Group 4, working on "Noise Source Abatement Technology and Cost Analysis Including Retrofit" for the Environmental Protection Agency Aircraft/Airport Noise Report Study and submit the following as the position of the National Organization to Insure a Sound Controlled Environment.

Aircraft Powerplant Noise Abatement

We find that aircraft powerplant noise abatement technology has advanced rapidly since the introduction of the high by-pass turbo-fan engine which produces less noise in the jet wake and where the internal noise can be abated by acoustic treatment of the inlet and discharge ducts. While continued R&D is necessary for the further noise abatement of powerplants to be used in future designs of aircraft it is important that the benefits of the present state of the art be used to provide relief to airport neighbors as soon as possible.

It should be noted that aircraft models are expected to remain in production for 10 years or more and that the airlines operate these aircraft for 10 years or more after delivery. This fact together with the fact that a few noisy aircraft in the fleet keeps the noise exposure level high shows that the noise in areas in the airport environs may reflect the noise abatement technology of a period 20 years or more earlier. For this reason, during periods of rapid technological development in noise abatement, two means for shortening the period of excessive noise must be utilized to the fullest. They are:

(a) Retrofits of noisy powerplants with quieter ones taking advantage of improvements in powerplant performance where possible.

(b) Updating the powerplant being used on the aircraft which is in production as the state of the art advances or changing to a quieter powerplant during the production period.

An analysis of the aircraft in the airline fleet in the future indicates that if a retrofit is made which extends the life of aircraft into a period when the presently delivered aircraft are being retired it should be as quiet or quieter than the presently delivered aircraft otherwise it will stand out as a noisy and therefore undesirable aircraft.

It is anticipated that airport operators will, in the future, be required to permit only a specified noise exposure in the environs of the airport. In that case the aircraft which can provide the maximum service per unit of noise exposure will be welcome and the noisy aircraft may be barred. For these reasons We recommend that:

(a) Any retrofit which extends the life of an aircraft be designed to reduce the noise of the aircraft to levels as low as or lower than the noise levels of new aircraft in production.

(b) Aircraft powerplants in production be updated every 3 to 5 years to incorporate advances in the state of the art in aircraft noise abatement.

Noise Abatement Operating Procedures

While operating procedures is the subject of the Task Group 2 Study, technology is involved in providing equipment to facilitate noise abatement operating procedures. There are two areas where technology can contribute significantly to aircraft noise abatement. They are:

1. Aircraft automatic control equipment to facilitate the use of 2 segment, decel~~l~~erating approaches where engine thrust is kept to a minimum and flaps are used to bring the aircraft to touchdown speed just prior to touchdown. This gives a minimum of both engine noise and flap turbulence prior to reaching the airport boundary.

2. The improvement of aircraft performance in crosswind and tailwind operation on preferential runways. It has been found, for example, that an increase in the permissible crosswind from 10 to 20 or 25 knots will in some cases permit the use of a preferential runway 90% or more of the time as compared with 20 or 30%. This may make it possible to shrink a noise sensitive residential area exposed to unacceptable noise to a small fraction of its previous size.

Noise Abatement By Improved Aircraft Performance

It is well known that two engine aircraft have steeper climbout capability than three and four engine aircraft because of their higher power loading. This steeper climb and larger percentage thrust cutback which is possible with high power loading aircraft makes possible large reductions in the areas enclosed within specified noise exposure contours on takeoff.

In the competition to carry the most passengers ~~/~~ per unit of noise exposure on takeoff under the airport noise certification procedure, airlines will want to exploit all possible procedures for getting aircraft into the air with a minimum contribution of noise exposure. This competition may be the incentive for new developments in the aircraft/airport system for noise reduction.

Cost of Aircraft Noise Reduction

The cost of aircraft noise reduction becomes reasonable after the size of the area of incompatible land use has been reduced by the introduction of quiet aircraft and noise abatement operating procedures. As discussed in detail in our position paper presented to Task Group 1, we recommend that the cost of aircraft noise reduction and the cost of land use change required as a result of excessive aircraft noise be paid for by the users of the air transport system.

Sincerely yours,

John M Tyler Lloyd V. Hinton

John M. Tyler and Lloyd V. Hinton, Executive Directors

Pratt & Whitney Aircraft DIVISION OF UNITED AIRCRAFT CORPORATION

May 15, 1973

Mr. William C. Sperry
Office of Noise Abatement and Control
Aircraft/Airport Task Force
Environmental Protection Agency
Washington, DC 20460

Dear Bill:

During the meetings of your Environmental Protection Agency Task Group 4, you requested position papers from the members commenting on the various possible source control options for reducing aircraft noise.

The attached comments from Pratt & Whitney Aircraft are divided into two sections. The first section covers the various options for noise retrofit of the narrow-body commercial transport fleet. We do not believe that sufficient data is yet available to make a decision on the feasibility of retrofit. Our comments are based on the technical information available. The second section provides comments on the development of new quieter engines, including a comparison of the JT9D and NASA Quiet Engine.

These comments along with the previously provided report, "Noise Reduction Programs at Pratt & Whitney Aircraft," comprise the information we wish to provide to Task Group 4. We hope this information will be of assistance to you.

Sincerely,

PRATT & WHITNEY AIRCRAFT

W. E. Helfrich

W. E. Helfrich
Project Engineer - Noise Reduction

WEH:caz

Enclosure

EAST HARTFORD, CONNECTICUT 06108

NOISE RETROFIT OF THE NARROW-BODY COMMERCIAL TRANSPORT FLEET

The Environmental Protection Agency Task Group 4 is considering the various possible options for retrofit of the current narrow-body commercial transport fleet to reduce aircraft noise. Because the JT3D and JT8D powered aircraft comprise a large part of the current U.S. fleet, and have many more years of useful life, a decision on how to best provide noise reduction for these airplanes involves a complex array of economic and technical factors.

The FAA treated nacelle programs have not yet been completed and the NASA refan programs are still in the design stage. Results of these programs will provide comparative data on economics, performance and noise reduction. These results will determine whether a noise retrofit program is feasible which meets the requirements of Public Law 90-411. The following are Pratt & Whitney Aircraft's comments based on the technical information available.

General

Noise levels of the current narrow-body airplanes along with various retrofit schemes are shown in Figures 1, 2 and 3 at approach, takeoff and sideline conditions. Noise levels of the wide body aircraft are shown for comparison.

Summaries of the various retrofit schemes for a 727-200 and a 707-320B are given in Boeing reports, references 2 and 3, showing the estimated tradeoffs between noise footprint area, airplane range and retrofit cost.

Nacelle Treatment

Treated nacelles which will meet FAR 36 noise levels have been developed and certified by Boeing for the 727 and 737 and are being developed by Douglas for the DC-9. As may be seen in Figures 1, 2 and 3, the untreated JT8D powered aircraft are close to FAR 36 noise levels, and consequently these treated nacelles will only provide small noise reductions. A typical case for the 727 shown in the reference 2 Boeing report indicates a modest retrofit cost and a small change in airplane range, but the noise footprint area for a 90 EPNdB contour is only reduced from 29.4 to 26.4 square miles. This comparison implies that treated nacelles for JT8D powered aircraft will not provide meaningful noise reduction to the airport communities in a retrofit program.

Treated nacelles are being developed for the 707 in a Boeing/FAA program. Flight tests to demonstrate performance and noise levels are currently in progress. Predicted flyover noise levels would provide significant noise reduction, as shown in Figures 1, 2 and 3. This would be equivalent to a reduction in noise footprint area from 54 to 21 square miles. The estimated retrofit cost is approximately 0.75 million dollars and the estimated reduction in range is 2.7% as shown in reference 2.

Nacelle Treatment and Jet Suppressor

A Boeing/FAA program to develop an ejector-suppressor and treated nacelle for the 727 was completed. As shown in reference 2, this configuration gave a siginficant reduction in the 90 EPNdB noise footprint area from 29.4 to 6.6 square miles but the range penalties were not considered reasonable for airline operation.

Boeing developed a plug nozzle suppressor for the 707, but the final configuration did not give any significant noise reduction.

Based on the adverse results of these extensive programs, it does not appear that the nacelle treatment and jet suppressor concept is currently a satisfactory candidate for retrofit.

Refan Engines and Nacelle Treatment

A detailed description of the JT8D and JT3D refan engines was given in reference 1.

The JT8D refan engine is expected to provide a 13% increase in static takeoff thrust, a 5% increase in max cruise thrust and a 3% reduction in cruise fuel consumption compared to the present JT8D engine. Primary jet velocity is reduced by 16%, giving a 9 dB reduction in jet noise. Predicted noise levels for JT8D refan engines with treated nacelles in 727, 737 and DC-9 airplanes are shown in Figures 1, 2 and 3 for approach, takeoff and sideline. These are NASA predicted noise levels, based on input from the aircraft companies, and are well below FAR 36 levels. As shown in reference 2, the 90 EPNdB noise footprint area for a 727-200 would be reduced from 29.4 to 3.9 square miles with refan engines, which would place the noise footprint almost within the boundary of many airports. This would provide significant noise reduction to airport communities.

The JT8D refan engine development program is in progress and a demonstration ground test is scheduled in early 1974.

The JT3D refan engine is estimated to provide a 17% increase in static takeoff thrust, a 7% increase in max cruise thrust and a 7% decrease in cruise fuel consumption compared to the present JT3D engine. Primary jet velocity is decreased by 14% resulting in a 7 dB reduction in jet noise. NASA predicted noise levels for JT3D refan engines with treated nacelles in the 707 are shown in Figures 1, 2 and 3. Where the FAA treated nacelles for the 707 are predicted at FAR 36 noise levels for approach and takeoff, the refan predictions are 6-7 EPNdB below FAR 36 at approach and takeoff, and sideline is 12 below FAR 36. The refan engines would reduce the 90 EPNdB footprint area from the baseline of 54 to 8 square miles and would provide a small improvement in maximum range as shown in reference 3.

The JT3D refan engine development has been terminated by NASA due to lack of funds. This refan program could still be completed in a reasonable time if it were reinstated in the near future, since the engine redesign has already been completed.

Re-engine

Retrofit of the JT3D and JT8D powered commercial transport fleets with new quiet engines is not feasible. There are no high bypass ratio replacement engines available in the 20,000 lb. thrust class, and engines of this type will not be available during the next few years which is the critical period for retrofit. Even if new engines were available, the retrofit cost of new engines and new treated nacelles would be considerably higher than the other retrofit options.

Fleet Replacement

There are no suitable aircraft available to replace the JT3D and JT8D powered fleet. The current large wide-body aircraft with high bypass ratio engines would not be efficient replacements for the many short range and long range airline routes where smaller passenger capacity is required. It is anticipated that a new 100-200 passenger aircraft with new technology engines may be introduced in the late 1970's which will gradually replace the current 707, DC-8 and 727 aircraft during the following decade.

DEVELOPMENT OF NEW QUIETER ENGINES

Pratt & Whitney Aircraft has been conducting noise reduction research and development programs for jet engines since the beginning of the jet era. Programs at P&WA in this field currently include basic noise research, development of noise reduction hardware for current engines, and development of new quieter engines. The current P&WA noise research programs along with retrofit programs for current engines were covered in reference 1. Some comments on the development of new quieter engines are included here.

JT9D Engine Noise Reduction Features

The JT9D high bypass ratio turbofan engine which powers the 747 and DC10-40 wide-bodied transports was designed in 1965, well before Federal aircraft noise standards were established. Because public concern over airplane noise was recognized at that time, noise suppression was included among the design objectives for the JT9D engine. Significant reductions in jet noise were achieved because the high bypass cycle chosen for the JT9D had lower jet velocities than earlier engines. Discrete tone noise from the single stage fan of the JT9D was minimized by reduction in fan tip speed, the omission of inlet guide vanes, providing ample spacing between the fan rotor blades and exit guide vanes, and the selection of the optimum number of fan blades and exit vanes. Acoustical treatment was incorporated in the fan exhaust cases. The low noise design features of the JT9D were selected based on prior P&WA fan noise research work. In addition to the low noise features of the engine, acoustical treatment is incorporated in the nacelles of both the 747 and the DC10-40 to provide aircraft noise levels below the requirements of FAR Part 36.

Comparison of the JT9D and NASA Quiet Engine

The NASA Quiet Engine Program has utilized the core from a current high bypass ratio engine as a vehicle to ground test the effects of fan tip speed on noise. One of the demonstrator engines, known as "Quiet Engine A", incorporated similar noise reduction features to the JT9D high bypass ratio engine and went one step further by lowering the tip speed of the fan. Whereas the fan RPM of the JT9D and the other high bypass ratio production engines was selected to ensure subsonic tip speed at approach thrust and hence the absence of combination tone noise from the inlet, the tip speed of the Quiet Engine A fan was selected to be subsonic at takeoff as well as approach. Because of the lower fan speed, the Quiet Engine A demonstrator has fan noise about 5 PNdB quieter than an engine such as the JT9D when both are installed in a nacelle that does not incorporate acoustical treatment. Comparisons between the takeoff noise level of Quiet Engine A and the JT9D scaled to the same size are shown in the following table at ground test conditions:

	Quiet Engine "A"	(De-Rated) Scaled JT9D	Scaled JT9D
Fan Pressure Ratio	1.4	1.4	1.50
200 Ft. Sideline Peak PNdB	121	121.5	125
Fan Tip Speed, Ft/Sec.	1040	1225	1370

Two columns are shown for the JT9D; one when the fan is operated derated at the same pressure ratio as the Quiet Engine A, and one for operation at the rated JT9D takeoff condition that reflects the higher design pressure ratio of the JT9D. As shown by the table, the "derated" scaled JT9D produces similar noise to the Quiet Engine A but the scaled engine is about 4 PNdB louder because of the higher tip speed and fan pressure ratio.

Noise levels of the scaled JT9D and the Quiet Engine A at approach thrust conditions are compared below:

	Quiet Engine A	Scaled JT9D
Fan Pressure Ratio	1.15	1.15
Fan Tip Speed, Ft/Sec.	695	850
200 Foot Sideline, Peak PNdB	107.5	112.5

At this part power condition, the lower fan tip speed of Quiet Engine A provides a noise level about 5 PNdB lower than the scaled JT9D with an untreated configuration.

P&WA/FAA Fan Research Program

The effects of fan tip speed on noise generation were also measured in an FAA sponsored research program at P&WA. High, medium and low tip speed fans were tested in a large scale outdoor fan noise rig. These results also showed that the lower fan tip speeds could reduce aft arc fan noise by about 5 PNdB. Noise levels from the low tip speed fan were very close to those measured on NASA Quiet Engine A, when scaled to the same size, as shown below:

	Takeoff		Approach	
	Quiet Engine A	Scaled FAA Fan	Quiet Engine A	Scaled FAA Fan
Fan Pressure Ratio	1.4	1.4	1.15	1.15
Fan Tip Speed, Ft/Sec.	1040	910	695	585
200 Ft. Sideline, Peak PNdB	121	118.5	107.5	106.5

Future Engine Technology

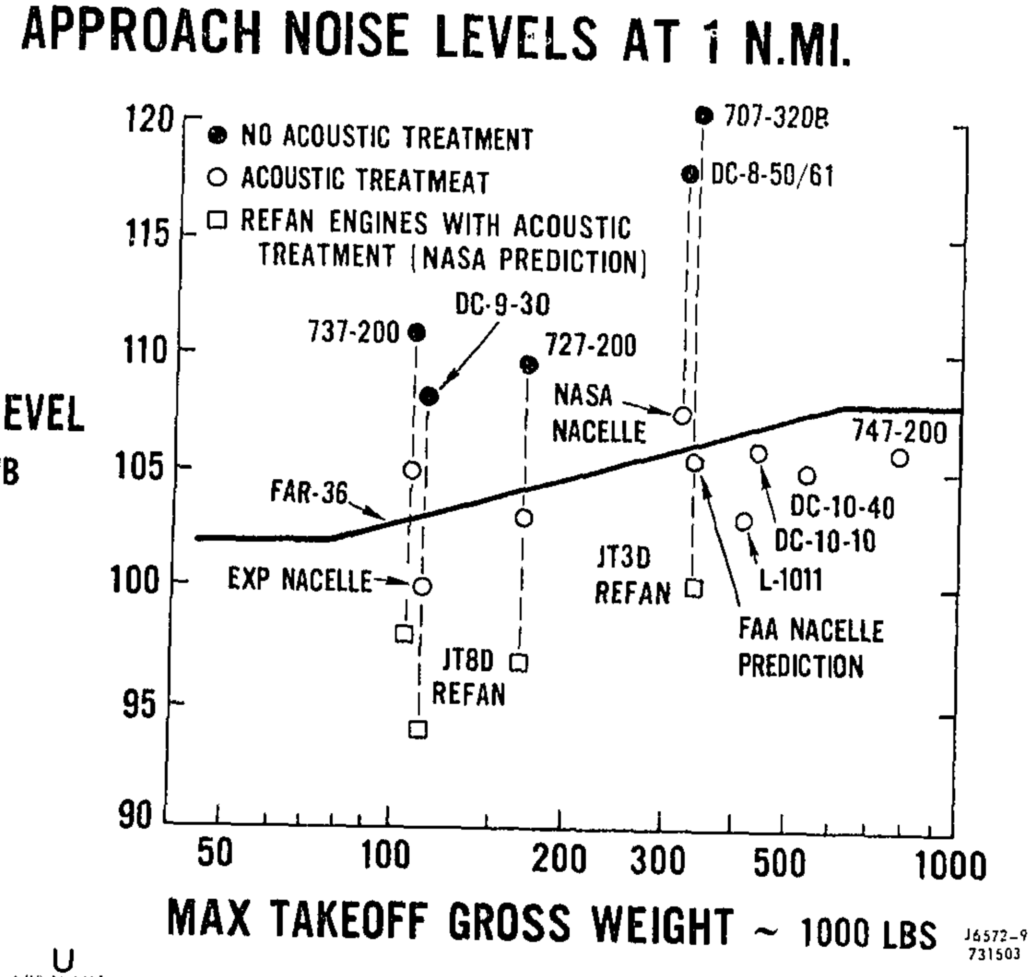
Both the NASA Quiet Engine Program and the P&WA/FAA Fan Research Program demonstrated that source noise reductions could be achieved by lower speed fans. However, this technology cannot be arbitrarily applied to all new engine designs. The low speed fan gives a heavier, larger and more expensive engine design with present technology because of the larger low turbine required. This leads to a larger, less efficient aircraft for the same mission. Conversely, a high speed fan gives a lighter, less expensive engine and a more efficient aircraft. The amount of acoustic treatment required and the associated performance losses are significant in determining the optimum engine cycle. An airplane/engine system trade study is essential to determine the best economics for a given set of requirements.

Each airplane/engine installation presents unique problems and specific design requirements. The type of engine installation has a significant effect on the aircraft noise level. Choice of the optimum engine design for a particular installation requires a thorough study of all approaches to obtaining a given noise objective. As noise research programs provide new techniques for reducing engine noise generation, these will be included in the engine cycle trade studies.

Reference 1: "Noise Reduction Programs at Pratt & Whitney Aircraft", Presented to the EPA Aircraft/Airport Noise Study Task Force, Task Group 4, February 28, 1973 by W. E. Helfrich.

Reference 2: Boeing Report D6-60199, "Noise Reduction Research and Development 1972 Progress", March 1973.

Reference 3: Boeing Report D6-40982, "JT3D/JT8D Refan Preliminary Economic Study", April 1973.



Pratt & Whitney Aircraft

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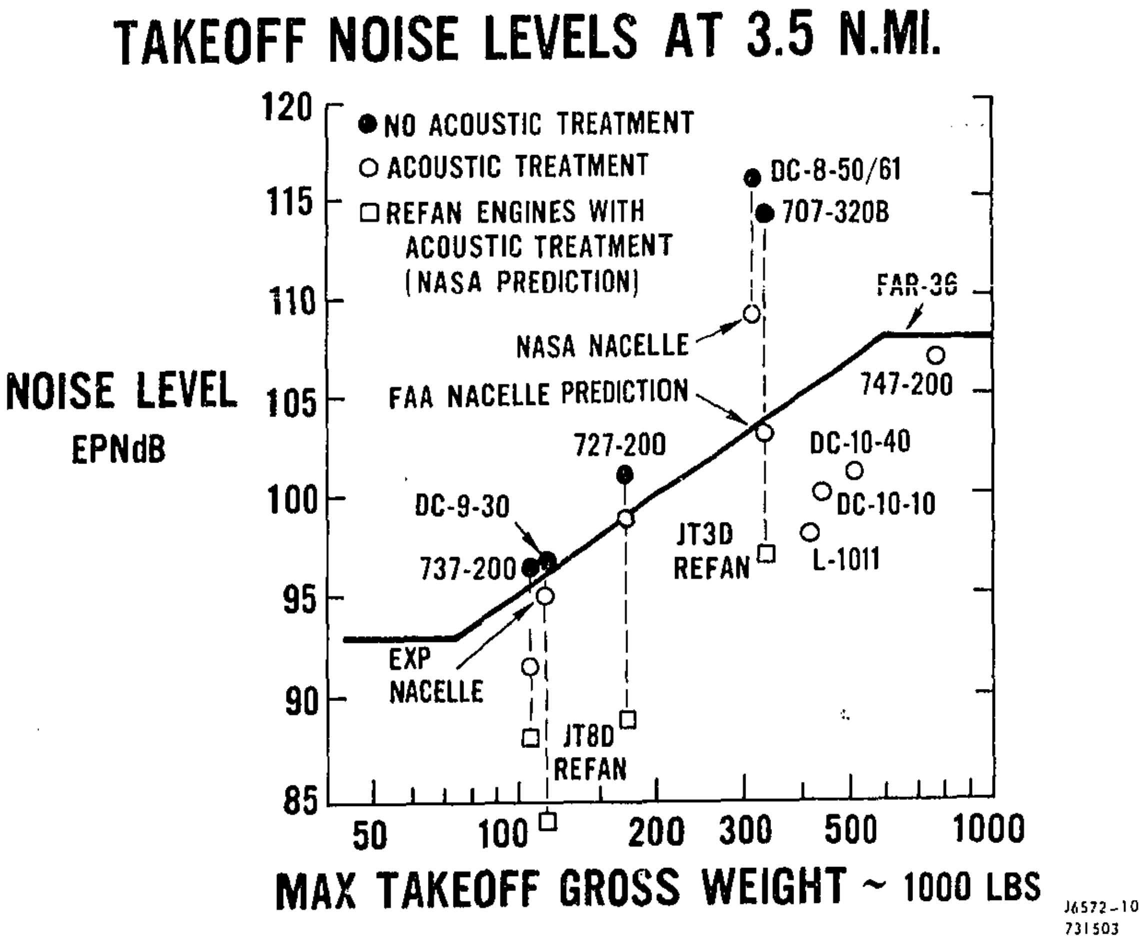
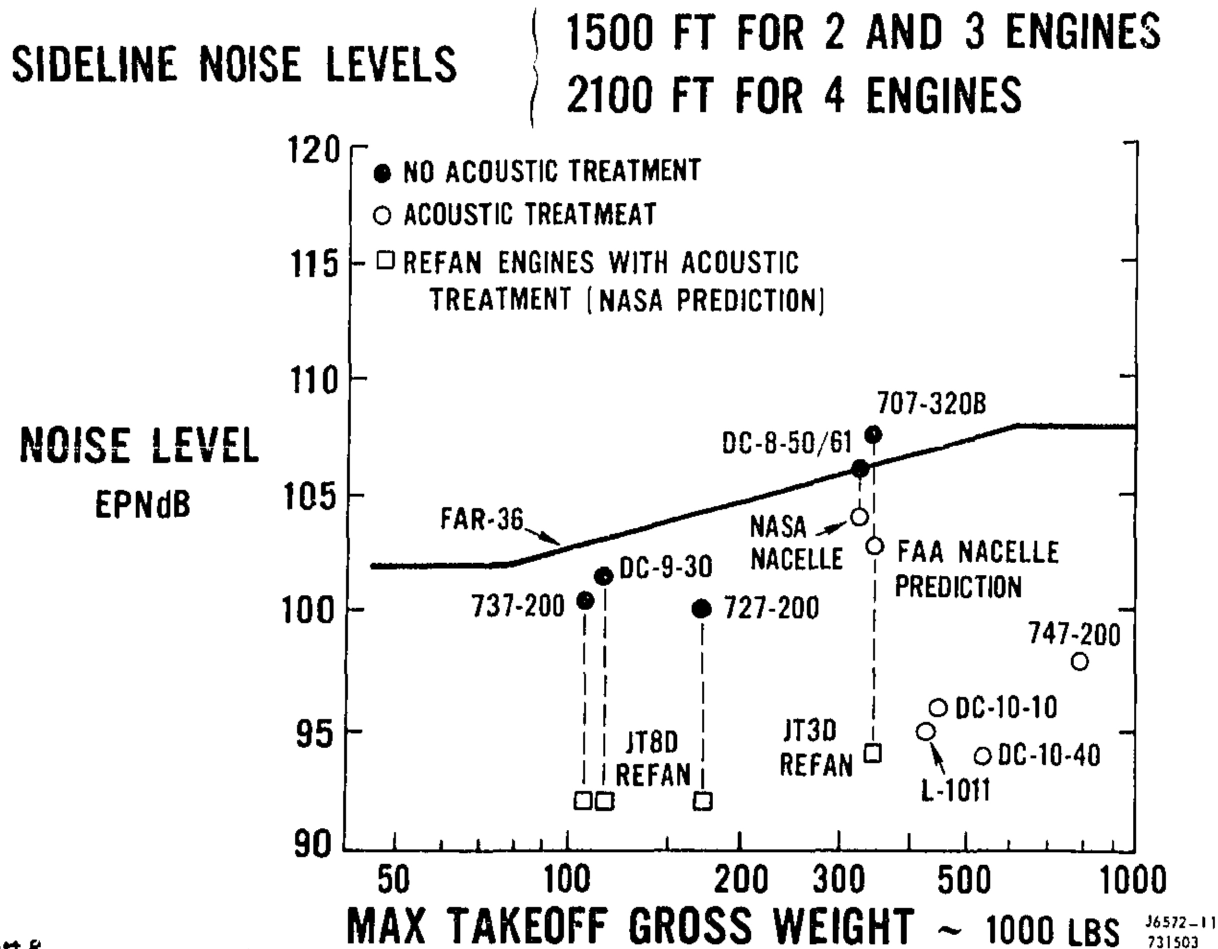
FIGURE 1



Pratt & Whitney Aircraft

FIGURE 2



Pratt & Whitney Aircraft

FIGURE 3

Sikorsky Aircraft DIVISION OF UNITED AIRCRAFT CORPORATION

STRATFORD, CONNECTICUT 06602

PHONE (203) 378-6361

July 20, 1973

SEL-4095

Mr. William Sperry
Environmental Protection Agency
Crystal Mall, Building #2
1921 Jefferson Davis Highway
Arlington, Virginia 20460

Dear Mr. Sperry:

During the last meetings of the Environmental Protection Agency Task Groups on June 21 and 22, 1973, it was indicated that written positions from concerned groups would be considered and incorporated into the task group reports. The following remarks summarize the position of Sikorsky Aircraft on VTOL noise certification. It is requested that these remarks be incorporated into the Task Group 4 and 5 Reports.

In establishing the categories into which to place the various classes of aircraft for noise certification purposes, it is strongly recommended that VTOL be considered separately from STOL and RTOL. Placement of VTOL in a separate category would free it from the operational limitations necessary to accommodate the flight profiles of the other two classes if grouped in a combined category. Significant reductions in noise footprint by flight trajectory control are available and should be allowed to be developed in keeping with the intent of the Noise Control Act of 1972, to make aircraft inherently quieter and to have them flown as quietly as possible.

The issuance of a noise rule for the VTOL category of aircraft is premature at this time because of the following reasons:

a) There is insufficient data available on VTOLs in the unit most likely to be used in the rule to properly assess the state of the art. Measurement programs must be carried out to rectify this lack of information.

b) Relevant research is due to be completed by NASA within a year on VTOL noise to establish the state of the art on the applicability of noise reduction technology to current helicopter designs.

c) Operational procedures have not yet been adequately explored to assure that the noise certification concept will take full advantage of the low noise capabilities of the helicopter.

d) Current rating schemes do not appear to rate the annoyance of "blade slap" noise accurately. "Blade slap" is the impulsive type of noise that can be produced by some helicopter rotor systems under certain operating conditions.

No penalty should be levied against helicopters as a class for the occurrence of blade slap, as it occurs only on certain types of helicopters under a limited number of operating conditions.

An initial noise rule should allow all current generation helicopters to become certificated. De-escalation should not be considered until sufficient information has been generated to allow an accurate assessment of its economic impact and requirements for technological advances which may result.

Caution should be observed in attempting to relate the existing hover PNL data for helicopters to EPNL. The large variation in noise levels between the hover and the takeoff, landing, and cruise conditions coupled with the wide available operational range for these vehicles makes the conversion highly variable.

Economic considerations dictate flight paths below 3000 feet altitude for VTOLs in typical operations. Enroute noise controls which may force the cruise altitude to be significantly higher can have a significant impact on the operating economics of this type of aircraft, and therefore should not be considered until the consequences have been evaluated. A more viable solution to the regulation of enroute noise by certification appears to be the use of a measure of cumulative noise exposure impact, such as the Noise Exposure Forecast footprints, to dictate flight paths and operational procedures. This approach allows control of the environmental impact on areas of the community located between ports of operation in a manner which fully accounts for the environmental protection requirements of the community while not imposing unnecessary economic penalties on the helicopter operator.

Ambient noise should be considered when evaluating the impact of noise on the community. In V-port areas where higher than average background noise levels are likely to exist, the masking effect of these ambients should be factored into the allowable noise from aircraft.

We hope the preceeding comments have identified in a constructive manner, some of the potential pitfalls associated with VTOL noise regulation. It is our feeling that a workable VTOL noise certification rule can be developed in a reasonable period of time and that the rule can fully satisfy the environmental requirements intended by the Congress while stimulating the growth of this important facet of air transport. We hope to work further with you in this endeavor.

Yours truly,

SIKORSKY AIRCRAFT

Ronald G. Schlegel

Ronald G. Schlegel
Supervisor - Acoustics

APPENDIX B

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