Military Aircraft Noise

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Opportunities to reduce military aircraft noise without inhibiting mission capability are considered. Emphasis is placed on the need for a comprehensive military aircraft noise abatement program involving compatible land use in the vicinity of military airports, operational constraints, and procedures to reduce noise impact and source noise reduction. The military to civil transfer of aircraft and engine technology is discussed together with the effect of increasing civil noise constraints on this evolutionary practice. Research and development activities to reduce military aircraft noise at the source are highlighted and plans to incorporate noise reduction technology early in the development cycle of military engines are outlined. Recommended noise goals for military aircraft are presented.

Introduction

NOISE is not a new problem to the military services. They recognized many years ago that high noise levels were detrimental to personnel, contributed to structural failures, and degraded the general community environment. Comprehensive bioacoustic research efforts were conducted to assess the effect of high noise levels on personnel. As a result of these programs, allowable noise exposure limits were developed. Ear protection devices were issued to all personnel exposed to excessive noise, and hearing conservation programs were initiated throughout the military services. These early bioacoustic research efforts formed the basis for much of the current work on subjective response to aircraft noise.

With the advent of the jet engine, the problem of acoustically induced fatigue in aircraft structures became more predominant. In response to this problem, extensive in-house research facilities were established. Sonic fatigue and interior noise control techniques were developed and comprehensive standards were formulated. However, very little effort was directed toward the real culprit—the propulsion system, since at that time all engine noise reduction techniques were accompanied by intolerable performance and weight penalties.

The most elusive problem to face was community annoyance. To partially overcome this problem, the military services expended considerable manpower and funding to develop effective ground runup suppression equipment. This effort, together with a limited use of operational constraints and land use planning, represented the military's principal weapons against noise pollution. These efforts are now being expanded and, in addition, new efforts are being initiated to reduce aircraft propulsion system noise at the source. This paper emphasizes the community annoyance aspects of military aircraft noise and explores what opportunities exist to reduce the impact of military aircraft noise without inhibiting mission capability.

Military Aircraft Noise Control

The impact of noise emanating from military aircraft operations can be significantly reduced by a comprehensive noise abatement program involving compatible land use in the vicinity of military airports, operational constraints, and procedures, and source noise reduction, Fig. 1. Since a large majority of military aircraft are high performance aircraft not presently amenable to source noise reduction techniques, land use control is the single most important method to lessen the impact of military aircraft noise on communities adjacent to military flying installations.[1] The Department of Defense recognized this to be the case and recently published an environmental impact statement of the policy necessary to implement land use control in the vicinity of military airports.[2]

Operational constraints and procedures can be employed to reduce noise. However, military flight operations are somewhat unique and, therefore, noise abatement procedures which are applicable to civil aircraft operations may not be appropriate for military aircraft. The fact remains, however, that the potential for effective military aircraft noise abatement constraints and procedures does exist. Comprehensive studies should be conducted to fully evaluate this potential. This need was pointed out in a recently drafted Department of Defense Area Coordinating Paper on Environmental Quality.[3]

The potential for large source noise reductions for strategic and tactical military aircraft does not exist at the present time. These high performance aircraft cannot accept the performance degradations associated with current source noise reduction techniques. However, source noise reduction techniques can be successfully applied to selected military aircraft classes that operate in the civilian as well as the military domain, such as helicopters, transports, tankers, and patrol aircraft, without imposing excessive performance and weight penalties. The Department of Defense and other agencies of the Federal Government are conducting comprehensive research and development programs to develop source noise reduction techniques that can be applied to both military and civil aircraft.[4-6]

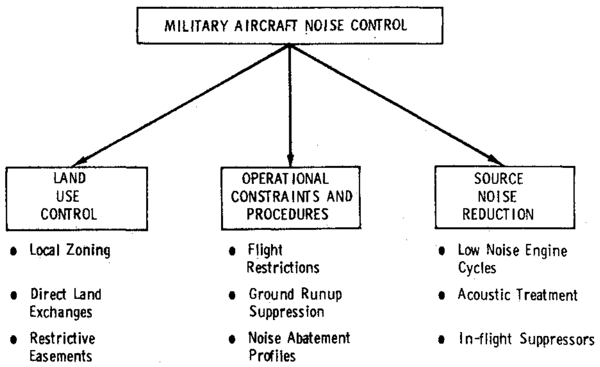

Fig. 1 Essential components for a comprehensive military aircraft noise abatement program.

Presented as Paper 73-1291 at the AIAA/SAE 9th Propulsion Conference, Las Vegas Nevada, November 5-7, 1973; submitted November 30, 1973; revision received November 14, 1974. The author sincerely appreciates the efforts of 1st Lt. G.D. Vest and the members of the Randolph Airport Environs Study Group whose publications were used extensively in the development of the land use planning sections of this paper.

Index categories: Aircraft Noise, Powerplant; Aircraft Powerplant Design and Installation; Airbreathing Propulsion, Subsonic and Supersonic.

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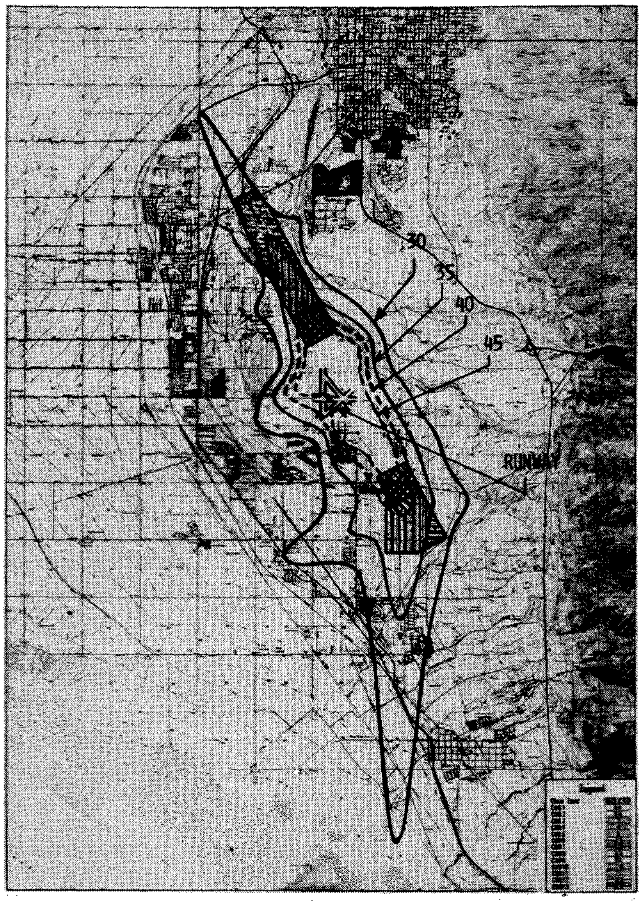

Fig. 2 Representative sample of an airport environs compatibility land use plan.

Land Use Control

Military and civilian airfields attract activity in their immediate surroundings. New cities grow up near bases and existing cities grow outward toward the airfield. Since the military airfield structure has remained largely static the past fifteen years, this encroachment process has endangered the potential freedom of these bases to support flight operations. This trend can be combated by halting the encroachment process at existing bases or by constructing new bases at locations and with land procurement policies which would prohibit adjacent encroachment.[7] Given the anticipated limits of future military construction budgets, it seems very unlikely that the Department of Defense will be able to build many new military airfields. Therefore, the military services must strive to halt the encroachment caused by urbanization. In most cases this goal can be supported by the adjacent communities.

The incentive for an adjacent community to cooperate with the military services to establish compatible land use does have practical limitations. Large areas of land cannot be sterilized by unrealistic land use assumptions; this is contrary to laws which protect a property owner's right to profitable use.

Air Installation Compatible Use Zone (AICUZ)

The principal causes of concern relative to airbase encroachment are complaints against noise and fear of aircraft accidents. The military services have had procedures to evaluate noise and assess its effect on surrounding areas since the early 1960's.[8] Also, accident investigation and strong public information programs have been practiced to minimize the ill-effects of either noise or accident hazard. However, until recently, the Department of Defense did not have a policy that was designed to protect its operational capability from off-base intrusion. In May 1972, Headquarters, U. S. Air Force issued the draft of a Real Property Management Regulation (AFR 87-14) under the title, "Air Installation Compatible Use Zone' (AICUZ) Protection of Air Force Bases Against Urban Encroachment."[9] The concept established by this draft is designed to encourage compatible land use in nongovernment areas around military airbases. It does not require that the land remain open space, but that uses be compatible with the noise and occassional hazard which exist from aircraft operations. Three basic techniques are provided to insure compatible land uses: a) Encourage adoption of local zoning for compatible land use; b) Exchange excess or surplus Government land for land of equivalent value within the compatible use area; and c) Purchase restrictive easements or fee title.

Purchase of restrictive easements or fee title is considered a last resort method in view of the likelihood of budget restrictions. Land exchanges are limited by the availability of excess Government land. Therefore, it is clear that the principal technique of general use will be the adoption of local zoning.

Application of the AICUZ concept results in an airport environs land use compatibility plan which includes: 1) land areas upon which certain land uses could obstruct the airspace or otherwise be hazardous to aircraft operations, and 2) land areas which are exposed to the health and safety hazards of aircraft operations. The plan results from overlaying noise and accident zone maps and establishing compatible use districts from the overlays. The actual delineation of the accident zones for a given installation will, to a large degree, be the result of professional judgment by planners and aviation experts. The noise zones are generally formed by using four or five contour lines from NEF 30 to 50. The NEF prediction procedure utilizes an EPNdB source noise data base combined with a description of flight paths and their utilization to produce NEF contours using a sophisticated computer program. Overlays of the noise and accident zones produce a number of compatible use districts. This information serves as the basis for final districting decisions together with other land use determinants to form a comprehensive land use plan. Figure 2 shows a typical NEF and accident zone map.

In most cases it is not practical to simply overlay the Compatible Use Districts on a vicinity map and adopt a corresponding ordinance. These districts serve as the basis for final districting decisions together with other land use determinants to form the comprehensive land use plane. Land use planning experts point out that the airport environs compatibility use plan should not be considered an end in itself. It is only one of many inputs into a comprehensive environmental land use planning process. References 1 and 7 provide specific details concerning the land use planning process.

Operational Constraints and Procedures

Operational constraints and procedures for both flight and ground operations can reduce the impact of military aircraft noise on local communities. Operational constraints include such items as: a) Restricting hours of operation; b) Prescribing the number of operations permitted per unit of time; c) Limiting operations on weekends and holidays; d) Limiting areas in which operations may be performed; e) Prohibiting certain operations.

Operational procedures include such items as: a) Use of nonstandard techniques; e.g., high gliding, low power approaches, fast no flap approaches, etc.; b) Minimum power takeoffs, power reductions; c) Nonstandard departures and arrivals; d) Adjustment of flight patterns.

All of these constraints and procedures should be carefully reviewed to determine their applicability to the military aircraft noise problem. However, there are unique aspects of military aircraft operations that must be carefully assessed before adopting any operational constraints or procedures.

The training evolution of individual pilots and units

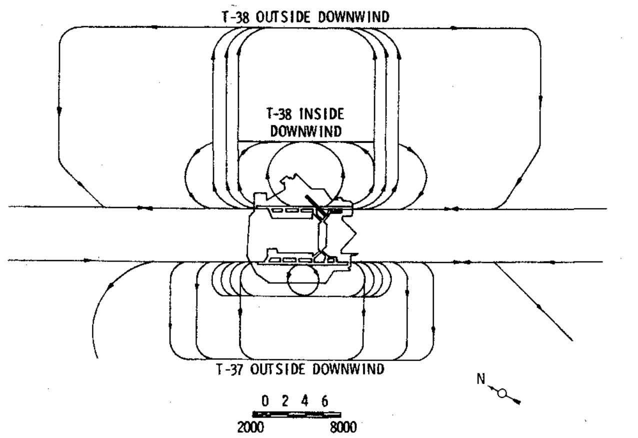

Fig. 3 Typical military aircraft flight patterns at a pilot training base.

requires the capability for flexible planning. The level of experience of assigned pilots, weather, target availability, hours of darkness, etc. require continuous adjustments in planning to achieve a proper readiness stature. Restrictions on the frequency or time of operations could be detrimental to the training process. Commanders must have the option, implemented wisely, to conduct the training they consider necessary to maintain readiness.

Aircraft traffic patterns must be evaluated in the light of mission requirements. Some adjustment may be made to alleviate noise; however, many of the apparent changes are not feasible. An example of the complexity of the problem is shown in Figure 3.

The figure shows five basic patterns used at military bases: straight out takeoff, straight in landing, overhead landing, closed pattern to the inside downwind, and closed pattern to the outside downwind. Similar patterns can be found at civil airports with National Guard or Reserve units; however most civil aviation patterns are essentially straight-in and straight-out. The complexity of the military patterns pose quite a problem to the development of effective military aircraft noise abatement procedures. Another significant point in establishing noise abatement procedures is that the current flight techniques developed for each aircraft are optimized for maximum performance in any particular mode of operation. These standard operating procedures are directly related to flight safety. Burdening pilots with a number of aircraft operating techniques for various air installations and aircraft operating conditions to reduce noise must be approached very carefully to avoid derogation of safety.

Source Noise Reduction

Extensive industry and Government efforts have been conducted over the past decade to reduce aircraft noise at the source. Some of the current noise abatement techniques that can be applied to reduce aircraft/engine noise include: a) New quieter engine designs with components and engine cycles selected for lower noise; b) Acoustically treated nacelles and ducts; c) Vehicle aerodynamics to allow for steeper ascent and descent, and reduction in time required for ascent/decent; d) In-flight suppressors to reduce jet noise.

However, because the performance, weight, and cost penalties involved, most military aircraft and engines do not include source noise reduction technology. Figures 4 and 5 show a comparison of the noise levels from selected military aircraft with the levels allowed by current Federal Aviation Regulation, Pt. 36 for subsonic commercial aircraft.

The data plotted in these figures were taken from a variety of sources. Noise levels for the F100, F4, KC135, B52, C5A, C135B, and the C141 were based on actual measurements conducted by the 6570th Aerospace Medical Research Lab. C9A and T43A levels were based on published FAA data on

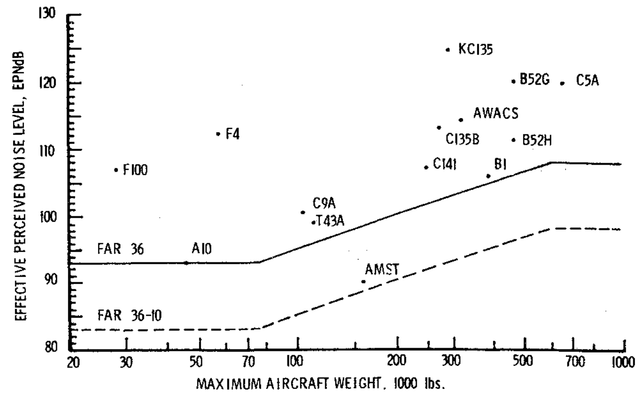

Fig. 4 Military aircraft noise at takeoff compared with the federal aviation administration's civil aircraft noise regulations (FAR PART 36).

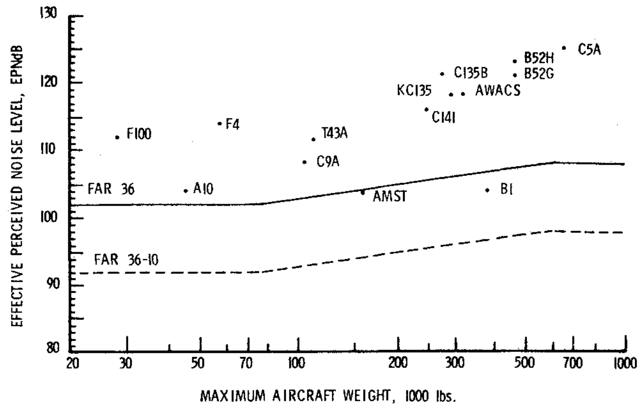

Fig. 5 Military aircraft noise at approach compared with the federal aviation administration's civil aircraft noise regulations FAR PART 36).

the DC9 and 737 aircraft, commercial versions of the C9A and T43A, respectively. The B1 and A10 data were predicted, based on aircraft/engine design and operational characteristics, and the AMST levels were obtained from Ref. 10. The major noise source for all of these aircraft is the propulsion system.

Military to Civil Technology Transfer

Figures 6 and 7 explore the commercial compatibility of some military aircraft with respect to FAR 36 requirements. The C9A, T43A, and C135B are all military versions of operational commercial aircraft (DC9, 737, and 707, respectively). By employing new nacelles with sound absorption material, these aircraft can be retrofitted to meet current FAR 36 noise requirements. The technology developed under the C5A program is compatible with current commercial noise constraints. The high bypass technology reduced the jet noise floor of the propulsion system and allowed the industry to concentrate on developing effective means to reduce fan inlet noise. By employing these noise reduction features in certain classes of future military aircraft, commercial compatibility with current and proposed FAA noise regulations can be assured.

Predicted noise characteristics for the Boeing version of USAF's Advanced Medium STOL Transport are shown. The General Electric CF6 engines powering this aircraft are identical to those used by the McDonnell Douglas DC10 wide bodied commercial transport. Many desirable noise reduction characteristics are incorporated into the propulsion system. In addition, the aircraft employs advanced vehicle aerodynamic techniques to allow for steeper ascent and descent. Therefore, the noise levels of the basic military configuration are sufficiently low to insure that commercial versions of the air-

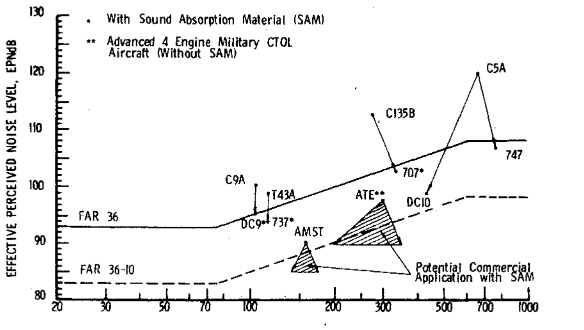

Fig. 6 Commercial compatibility of military transport aircraft with respect to current and proposed FAA noise regulations—Takeoff.

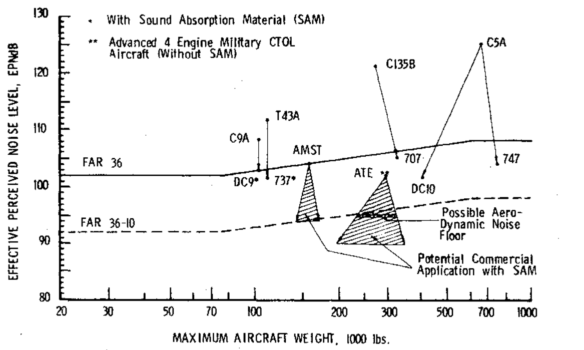

Fig. 7 Commercial compatibility of military transport aircraft with respect to current and proposed FAA noise regulations—approach.

craft, employing advanced acoustic treatment, will meet future FAA noise regulations.

The second example is a preliminary design four engine military transport/tanker. The aircraft employs advanced turbine engines in the 20,000 lb thrust class incorporating second generation noise reduction features based on advanced quiet engine technology development programs. Incorporation of noise reduction technology early in the development cycle of the engine and aircraft system insures that stringent commercial noise regulations of the future can be met by civil derivatives of this aircraft.

Current Research and Development

The Army, Navy, and Air Force are conducting a number of aircraft noise control research and development programs. Army efforts emphasize helicopter noise generation, propagation, and reduction. The Navy is concentrating on the development of new ground runup suppression techniques and assessments of the noise environments of aircraft carriers. The most extensive research and development efforts within the Department of Defense to control aircraft noise are being conducted by the Air Force. These efforts include the areas of bio and psycho acoustics, propulsion, and aircraft acoustics and aircraft noise measurement. Specific details concerning the Defense Department's aircraft noise research programs are presented in Refs. 11-13. Much of the technology developed under these programs is applicable to the solution of both military and civil noise problems. Therefore, the Department of Defense is conducting several noise research efforts jointly with other agencies of the Federal Government including the Department of Transportation (DOT), the National Aeronautics and Space Administration (NASA), and the Environmental Protection Agency (EPA). These joint programs include a DOT/USAF program to investigate the fundamental mechanisms of supersonic jet exhaust noise, a NASA/Army cooperative effort to study helicopter noise generation characteristics, and an EPA/USAF program to provide technical guidance relative to

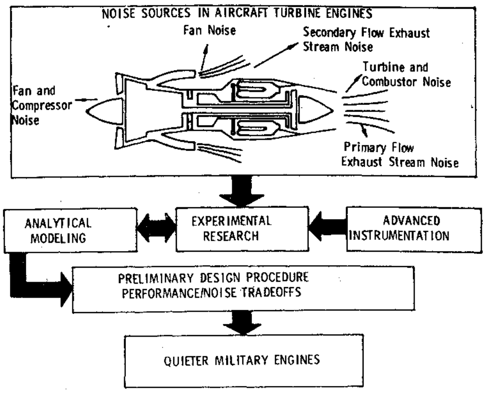

Fig. 8 Department of defense program to reduce propulsion system noise.

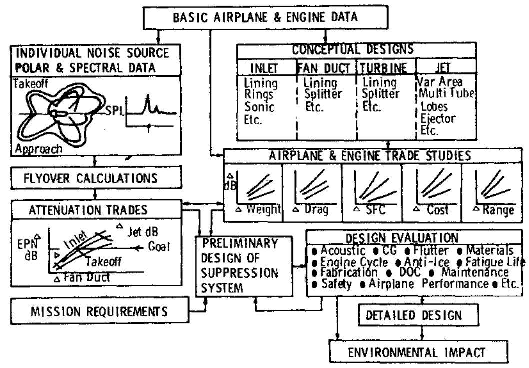

Fig. 9 Comprehensive procedure to assess noise/performance cost trades.

a wide variety of noise control activities. Figure 8 shows the structure of the Department of Defense's research program to reduce propulsion system noise.

The impact of source noise reduction techniques on system performance must be carefully and comprehensively assessed before any of these techniques can be applied to military aircraft. To achieve maximum noise reduction for minimum penalty, performance/noise/cost trade studies must be conducted early in the development of each new aircraft and engine system. These studies, coupled with expected technology advances, will aid in the practical application of noise control techniques to future military aircraft. Figure 9 indicates the complexity of a typical noise/performance/cost trade procedure.

Technology Implementation

The initiation of comprehensive research programs to develop noise reduction techniques is really only a first step. The technology developed under these programs must be incorporated into the hardware phases of the military engine development cycle. Figure 10 shows a typical aircraft engine development cycle from basic research to final production.

Most of the military's source noise reduction efforts have been limited to basic and exploratory research. Severe funding limitations have for the most part prevented the incorporation of noise control technology into the hardware phases of the military engine development cycle. The transition from the research to the development phases must be made to insure that available source noise reduction technology is properly implemented. This problem emphasized the need for a definitive Department of Defense policy on source noise abatement for military aircraft.

Recommended Noise Goals for Military Aircraft

Recently, the Department of Defense conducted an intraagency study on environmental quality. One of the major ob-

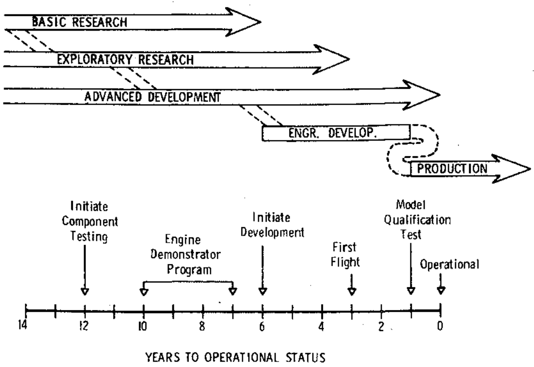

Fig. 10 Representative aircraft engine development cycle.

Table 1 Military aircraft noise goals

Strategic/tactical aircraft

Operational aircraft: Rely on land use planning, operational constraints/procedures, ground runup suppression

Future aircraft

1) Conduct noise/performance/cost trades early in the development cycle of each system

2) Implement noise reduction techniques only if they do not inhibit the military mission

3) Utilize land use planning, operational constraints/procedures, and ground runup suppression

Transport/other selected aircraft

Operational aircraft

1) Conduct source noise reduction community impact studies

2) Conduct noise retrofit/performance/cost trades

3) Where feasible, retrofit to meet FAR 36 based on tradeoff analyses

4) Utilize land use planning operational constraints/procedures, and ground runup suppression

Future aircraft

1) Conduct noise/performance/cost trades early in the development cycle of each system

2) Meet current FAR 36 noise requirements as a minimum

3) Employ state-of-the-art noise control technology to the greatest extent possible

4) Approach future commercial noise regulations to the greatest extent possible

5) Utilize and use planning operational constraints/procedures and ground runup suppression

jectives of this study was to develop a coordinated long range plane for environmental quality research. The study included a discussion of the feasibility of developing source noise reduction goals for future military aircraft.

The Air Force Aero Propulsion Laboratory has formulated source noise reduction goals for current and future military aircraft and has recommended that these goals be adopted by the Air Force and the Department of Defense. The goals were developed under the premise that source noise reduction techniques can be applied to certain classes of military aircraft without inhibiting military missions. The goals address two separate classes of aircraft—strategic/tactical aircraft and transport/other selected aircraft. Strategic and tactical aircraft include fighters, bombers, interceptors, tactical helicopters, etc. Transport and other selected aircraft include CTOL and STOL transports, tankers, navigator trainers, cargo aircraft, certain reconnaissance and long range patrol aircraft, etc. These goals are summarized in Table 1.

As a result of these recommendations, Air Force Headquarters modified Air Force Regulation 80-36 entitled "Civil Airworthiness Standards for U.S. Air Force Transport Aircraft." The modified regulation states that where military requirements permit, transport aircraft must be designed to comply with civil airworthiness standards including the FAA noise standard.

Summary

It is clear that the impact of noise from military aircraft operations can be significantly reduced by a comprehensive noise abatement program involving compatible land use in the vicinity of military airports, operational constraints and procedures, and source noise reduction. In the area of compatible land use, good community relations provide the key to success. The military services must work closely with local governments and community groups to provide protection for military flight operations within a framework of land use which the cities can afford. Operational constraints and procedures can be employed. However, specific research programs are required to develop realistic constraints and procedures and to evaluate their effect on mission performance and safety. Finally, source noise reduction is feasible for certain classes of military aircraft that operate in the civilian as well as the military domain. The techniques exist and have been demonstrated on operational commercial aircraft such as the DC10 and 747 and in technology programs such as the JT3D and JT8D and retrofit programs conducted by the FAA. The cost of such techniques, however, is relatively large. High performance aircraft (fighters, bombers, tactical helicopters, etc.), whose mission requirements are demanding, would incur significant penalties if they were subjected to current noise suppression techniques. Therefore, the Department of Defense is continuing to search for techniques that can be applied to high performance aircraft without adversely affecting their mission capabilities.

References

[1] "Military Aircraft and Airport Noise and Opportunities for Reduction Without Inhibition of Military Missions." EPA Aircraft/Airport Noise Rept. Study—Task Group 6, June 1973 (revised draft), Environmental Protection Agency, Washington, D.C.

[2] "DoD Impact Statement on Air Installation Compatible Use Zone," Dept. of Defense, Washington, D. C., March 1973.

[3] "Area Coordinating Paper on Environmental Quality," Dept. of Defense, Washington, D.C.

[4] Shahady, P. A., "Department of Defense Noise Research Programs—Source Noise Abatement Technology," Air Force Aero Propulsion Lab., March 1973, Wright-Patterson Air Force Base, Ohio.

[5] Roudebush, W. H. et al., "Aircraft Noise Reduction Technology," March 1973, NASA.

[6] Sperry, W. C., "Noise Source Abatement Technology and Cost Analysis Including Retrofiting (Draft)," EPA Aircraft/Airport Noise Rept. Study-Task Group 4, June 1973, Agency, Washington D.C., Environmental Protection Agency, Washington D.C.

[7] "Randolph Airport Environs Study," A Report to the Randolph Subregion Community Council, March 1973, Randolph AFB, Texas.

[8] "Land Use Planning with Respect to Aircraft Noise," Dept. of the Air Force, AFM 86-5; Dept. of the Army, TM 5-365; Dept. of the Navy, NAVDOCKS P-98, Washington, D.C., Oct. 1964.

[9] "Air Installation Compatible Use Zone (AICUZ)," Letter, Dept. of the Air Force (PRERD), May 1972 to Major Air Commands with Atch Draft AFR 87-14, "Air Installation Compatible Use Zone: (AICUZ) Protection of Air Force Base Against Urban Encroachment.

[10] Foody, J. J., "The Air Force/Boeing Advanced Medium STOL Transport Prototype," Air Transportation Meeting, Miami, Fla., April 1973.

[11] Schmitz, F. H., "Rotary Wing Acoustic Research," Ames Directorate, U.S. Army Air Mobility R&D Lab., Moffett Field, Calif., May 1973.

[12] Burns, R.P., "Noise Pollution Control in the U.S. Navy," May 1973, Naval Air Propulsion Test Center, Trenton, N.J.

[13] Shahady, P. A., "U. S. Air Force Noise Research," Presented to EPA Aircraft/Airport Noise Study—Task Group 4, May 1973, Environmental Protection Agency, Washington, D. C.