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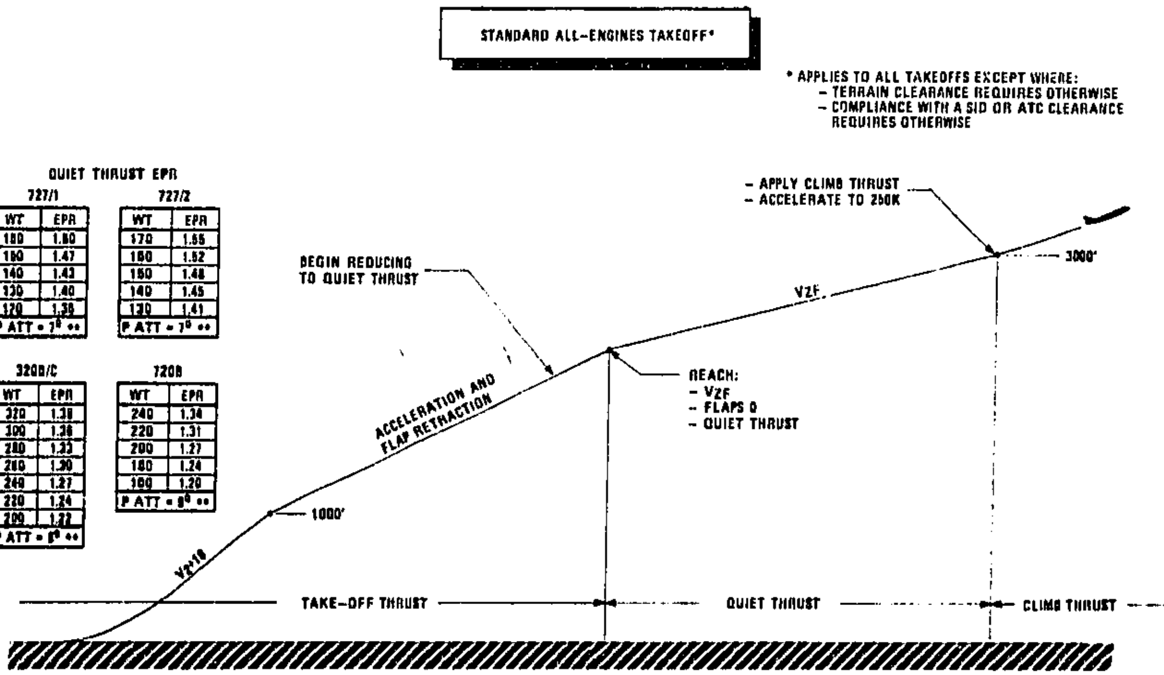
REPORT ON OPERATIONS ANALYSIS INCLUDING MONITORING, ENFORCEMENT, SAFETY AND COSTS

ENVIRONMENTAL PROTECTION AGENCY
AIRCRAFT/AIRPORT NOISE STUDY REPORT

27 JULY 1973



QUIET THRUST EPR

727/1

WT	EPR
180	1.50
160	1.47
140	1.43
130	1.40
120	1.38
P ATT = 7° **	

727/2

WT	EPR
170	1.55
160	1.52
150	1.48
140	1.45
130	1.41
P ATT = 7° **	

320B/C

WT	EPR
320	1.38
300	1.36
280	1.33
260	1.30
240	1.27
220	1.24
200	1.22
P ATT = 8° **	

720B

WT	EPR
240	1.34
220	1.31
200	1.27
180	1.24
160	1.20
P ATT = 8° **	

ALTITUDE VALUES SHOWN ARE ABOVE AIRPORT ELEVATION

** NOMINAL PITCH ATTITUDE FOR THE QUIET EPR CLIMB SEGMENT

Northwest Airlines Noise Abatement Takeoff

N-96-01
II-A-224

REPORT ON OPERATIONS ANALYSIS INCLUDING MONITORING, ENFORCEMENT, SAFETY AND COSTS

ENVIRONMENTAL PROTECTION AGENCY
AIRCRAFT/AIRPORT NOISE STUDY REPORT

27 JULY 1973

RANDALL L. HURLBURT, TASK GROUP CHAIRMAN

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 2 effort devoted to the analysis of aircraft and airport operations. The membership of Task Group 2 was made up of representatives of the federal government, local government, airport operators, airlines, pilots, airframe manufacturers, general and business 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 received are listed in the "References" section and are available for inspection in the Airport/Aircraft Study files. Throughout this report, numbers in parentheses indicate the number of the reference document as listed under "References." Excerpts from many of the technical documents are included in Appendix A. Specific positions of individual task group members are included in Appendix B.

This report summarizes the information assembled by Task Group 2 so as to inform the Congress and the public about the existing state-of-the-art in aircraft/airport operational procedures. At the same time, it provides a basis for proposing regulations as required by Public Law 92-574.

The conclusions of this report are the conclusions of the task group chairman based on the information supplied by task group members and on consideration of the public health and welfare. The difficult and controversial subjects of the task group assignment precluded complete agreement among or preparation of a consensus report by the task group members. The chairman sincerely appreciates the wholehearted efforts that the task group members have put forth; without their assistance this report could not have been prepared in the time available.

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SECTION 1

INTRODUCTION

GENERAL

This report analyzes a number of noise abatement flight and operational procedures which are presently in use in one form or another in scattered parts of the air transportation system. For the most part the use of these procedures is not required by the FAA. The discussion in this report concentrates on the noise reduction potential, the costs, and other advantages and disadvantages of these noise abatement procedures. The attractiveness of procedural methods of noise reduction is that they can be accomplished in a short time (0 to 5 years) and at low cost (often no cost). This is in contrast to aircraft or engine modifications or land use conversion which can provide more substantial long term benefits (3 to 15 years) but at greater cost.

It is important to recognize that flight noise controls usually apply to a single aircraft, and airport operational noise controls usually apply to a single airport. But the single aircraft and the single airport are merely single parts of a total system that, while providing air transportation to the nation, causes people to be exposed to high levels of noise. Each individual aircraft engine makes noise; the way in which the aircraft is flown can increase or reduce the level of noise at a point on the ground; but it is the total effect of many different aircraft operating from many different specific airports in such a manner as to adversely affect people that creates the aircraft/airport noise "problem." For example, regardless of the procedures used, a severe noise problem is not likely to result from a single flight over populated areas or from numerous flights over unpopulated areas. Furthermore, some procedures may reduce the noise impact at one airport but increase the noise impact at another. The implication here is that flight or airport procedures alone cannot be expected to totally solve the noise problem. At best they must be considered as only two elements of what must be a more comprehensive plan which also includes controls on the source of the noise and the location of people exposed to noise.

In addition, one should keep in mind that flight safety is of paramount importance in developing flight and operational noise controls. It is the FAA's legal responsibility to ensure that flight and operational regulations are consistent with the highest degree of safety, and EPA, therefore, cannot categorically state that certain flight and operational noise controls are either adequate or inadequate from a safety standpoint. This report does, however, identify a number of noise abatement flight procedures which it appears may be consistent with the highest degree of safety and which therefore merit consideration for rulemaking or implementation by the FAA.

NOISE TERMINOLOGY

There are a vast number of scales used for measuring noise. For the purpose of this report two scales will be used to describe single event noise: Effective Perceived Noise Decibels (EPNdB) and Decibels, A-Weighted (dBA). Both are logarithmic scales such that each decrease of 10 EPNdB or 10 dBA represents approximately a halving of perceived noisiness.

Most of the aircraft noise data used as background for this report are in units of EPNdB, therefore this will be the primary scale used; dBA units will be shown as a secondary (approximate) scale to relate to noise sources of other types and to the cumulative noise standard recommended in the EPA Aircraft/Airport Noise Study Task Group 3 Report. The numerical value of EPNdB is approximately 13 units higher than the numerical value of dBA for the same noise level (the relationship actually varies with frequency spectrum and time duration, so this relationship is valid only to ± approximately 3 dB).

The impact of noise depends on the cumulative effect of many overflights; so the public health and welfare is measured by a scale which accumulates, logarithmically, the total noise from a series of successive flights. When EPNdB is the basic single event unit, the cumulative scale is termed Noise Exposure Forecast (NEF). When dBA is the basic single event unit, the cumulative scale is termed Day/Night Average Sound Level (L_{dn}). Both scales include a weighting factor for the increased annoyance of nighttime (10 PM to 7 AM) flights. The numerical value of L_{dn} is approximately 35 units higher than the numerical value of NEF for the same noise environment (± 3dB).

A more complete discussion of the various units of noise measurement is contained in the EPA Aircraft Airport Noise Study Task Group 3 Report (512). That report recommends L_{dn} as the basic measure of cumulative noise exposure. That report further recommends that an outdoor L_{dn} value of 80 (NEF 45) be adopted as a national standard for protection of the public from possible hearing damage and an outdoor L_{dn} value of 60 (NEF 25) be adopted as a long range goal for the full protection of the public health and welfare from excessive noise.

This report is concerned first with the flight procedures conducted by individual airplanes. Therefore the effectiveness of any given procedure will be measured in terms of single event noise, and, in particular, by the percentage reduction in the area exposed to 90 EPNdB or above. For medium sized airports (250 operations per 24 hours, 10% at night) this area often corresponds to the area exposed to an outdoor L_{dn} of 65 (NEF 30) and higher. Later, when considering the nationwide effects of various combinations of procedures, the area exposed to cumulative noise above an L_{dn} of 65 (NEF 30) will be the effectiveness measure. L_{dn} = 65 was chosen rather than L_{dn} = 60 because most of the available data concerns NEF 30 (L_{dn} = 65) and this may be a more realistic medium range noise goal. Throughout the report it may be useful to know the reduction in exposed area that accompanies an average reduction in noise level (or vice-versa). This may be estimated approximately by reference to Figure 1-1.

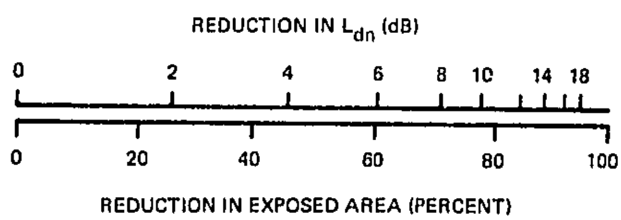

Figure 1-1. Relationship Between Cumulative Noise Reduction and Area Reduction (Reference 503).

It should be remembered that noise level predictions are not precise, but are subject to errors of approximately ±5 dB. Nevertheless, comparisons of relative noise levels are still meaningful.

EXISTING FAA FLIGHT AND OPERATIONAL NOISE CONTROLS

The FAA has adopted two Federal Aviation Regulations (FAR's) and two Advisory Circulars (AC's) related to flight and operational noise controls. (Advisory Circulars inform the aviation public of nonregulatory material of interest. They are not binding on the public.)

These are:

FAR 91.55 prohibits flight at speeds in excess of Mach 1 and thereby prevents the occurrence of sonic booms unless a specific authorization is given.

FAR 91.87 regulates operation at airports with operating control towers. FAR 91.87(d) and (f) specify that the minimum altitude for turbine powered or large aircraft is 1500 feet above the surface of the airport except when lower altitudes are necessary for takeoff or landing. FAR 91.87(d) further requires that such aircraft when approaching to land remain on or above the Instrument Landing System (ILS) or Visual Approach Slope Indicator (VASI) glide slopes if available until a lower altitude is necessary for a safe landing (normal bracketing maneuvers above or below the glide slope are permitted for the purpose of remaining on the glide slope). In addition FAR 91.87 (g) requires pilots of these aircraft to use, whenever possible, the preferential noise abatement runway assigned by Air Traffic Control (ATC).

AC 90-59 describes the FAA "Keep-Em'High" program wherein controllers issue clearances to keep high performance aircraft as high as possible as long as possible (112). This program was initially introduced for the purpose of collision avoidance, but it also provides some noise relief by preventing unnecessary low altitude flight. There is nothing in the Keep-Em-High program that requires the use of any specific noise abatement takeoff or approach procedure.

AC 91-36 encourages pilots operating fixed or rotary wing aircraft under Visual Flight Rules (VFR) to fly at not less than 2000 feet above the surface over noise sensitive areas (27).

In addition to the above system-wide controls, there are specific noise abatement procedures in effect at Washington National Airport which is operated by the FAA. There the airlines use a thrust reduction during climbout from a point 3 nautical miles northbound or 4 nautical miles southbound until reaching an altitude of 6,000 feet or a distance of 10 nautical miles, whichever occurs first. Aircraft on approach must follow the Potomac River. A jet curfew is in effect from 10 p.m. to 7 a.m. Only certain types of aircraft are permitted to use the airport (the largest being Boeing 727's), and trip lengths are limited to 650 miles with exceptions for nonstop flights to 7 cities within 1,000 miles (153, 154, 155).

A complete analysis of FAA regulatory actions is contained in the EPA Aircraft/ Airport Noise Study Task Group 5 Report (514).

Subsequent sections of this report discuss additional procedures which may be useful in controlling aircraft and airport noise. First, flight and operational noise controls are discussed, followed by a section on airport noise controls. Then a nationwide analysis of the noise benefits and the cost of these procedures is made. Finally, there is a section on conclusions and recommendations. The most important recommendations are that there be regulations establishing:

1. Takeoff Noise Abatement Procedures

2. Approach and Landing Noise Abatement Procedures

3. Higher Minimum Altitudes

4. Airport Noise Certification

SECTION 2

FLIGHT AND OPERATIONAL NOISE CONTROLS

Most of the aircraft/airport noise problem results from the operation of jet aircraft in the vicinity of airports. Therefore the bulk of this section will concentrate on the procedures available to reduce jet aircraft noise during departure and during approach and landing. However, at the end of this section brief consideration is given to the noise from propeller driven aircraft and helicopters.

DEPARTURE PROCEDURES (JET AIRCRAFT)

There are two types of departure noise problems: sideline noise and climbout noise. The sideline noise problem occurs along the sides of the runway while the aircraft is still on or close to the ground. It is dominated by the noise from the aircraft engines themselves and by shielding of noise by intervening buildings. This noise shielding no longer exists after the aircraft has reached an altitude of several hundred feet. The climbout noise problem occurs as the aircraft passes over or near noise sensitive areas* after departing the immediate vicinity of the runway and the airport. This problem is dominated by the engine noise and by the climb performance of the aircraft. The following sections discuss flight procedures appropriate for reducing sideline or climbout noise.

The FAA has not adopted any regulations or other controls related to noise abatement departure procedures except at the Washington, D. C. (National) Airport, which it operates, where it requires a power cutback on climbout.

SIDELINE

For runways having sideline noise as the critical departure problem, a procedure of reduced thrust takeoff will create less noise than a full power takeoff. This benefit is of course a tradeoff for greater noise along the flight track because the resulting climbout altitudes will be lower. The actual power required for takeoff depends on

*As used in this report, "noise sensitive area" means a residential area exposed to aircraft noise above the critical L_{dn} level for a given airport.

aircraft type, flap configuration, runway length, wind, altitude, temperature, and many other factors. As an illustration, Figure 2-1 shows the thrust required for a Boeing 707 to take off from a 10,000 foot level runway on a standard day with no wind. Figure 2-2 shows the 90 EPNdB sideline noise contours for full power and reduced power takeoffs, indicating that the noise exposed area to the side of the runway can be reduced by 20% through the use of reduced thrust takeoffs.

Many airlines currently use reduced thrust takeoffs for the purpose of reducing engine maintenance costs. Many aircraft flight manuals prescribe procedures to be used by pilots for making reduced thrust takeoffs. These procedures are approved by both the aircraft manufacturer and the FAA. FAA policy generally limits the amount of thrust reduction to no more than 10 percent.

The Air Line Pilots Association (ALPA) cautions that care must be exercised in using reduced thrust takeoffs since the procedure does result in a lengthened takeoff roll (90).

Conclusion: reduced thrust takeoffs are a technically feasible way of reducing sideline noise when performed in accordance with manufacturers' recommendations and FAA limitations.

CLIMBOUT

For runways where noise along the flight track is the critical problem, there are two procedures most often considered: a full power (maximum angle) climbout or a power cutback during climbout. The two factors of distance and acoustic energy tend to work against each other during climbout, lower power settings being associated with lower altitudes. The optimum procedure for reducing climbout noise therefore depends on the location of the noise sensitive area(s). Furthermore, with respect to the power cutback climbout, there are disagreements regarding the amount of thrust reduction, the point at which it should take place, and the appropriate flap configurations and airspeeds.

Therefore it may be appropriate to briefly discuss a few aspects of aircraft climb performance before discussing the noise benefits of various procedures. First, the effect of airspeed and flap setting on takeoff climb gradient (slope of aircraft climbout

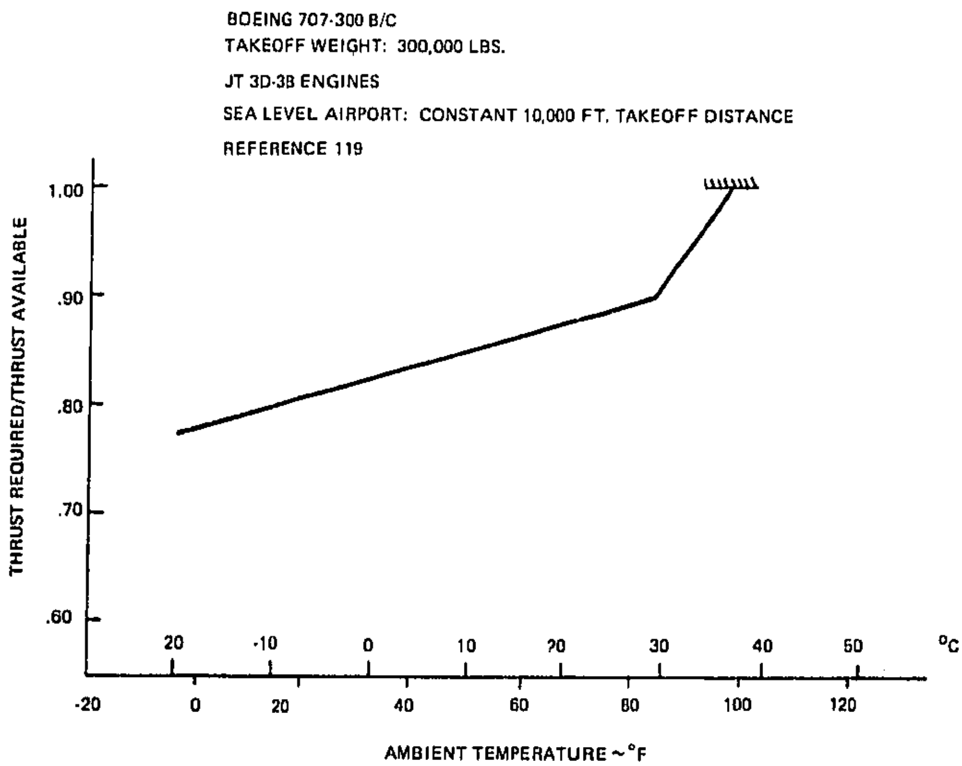

Figure 2-1. Thrust Required for Takeoff

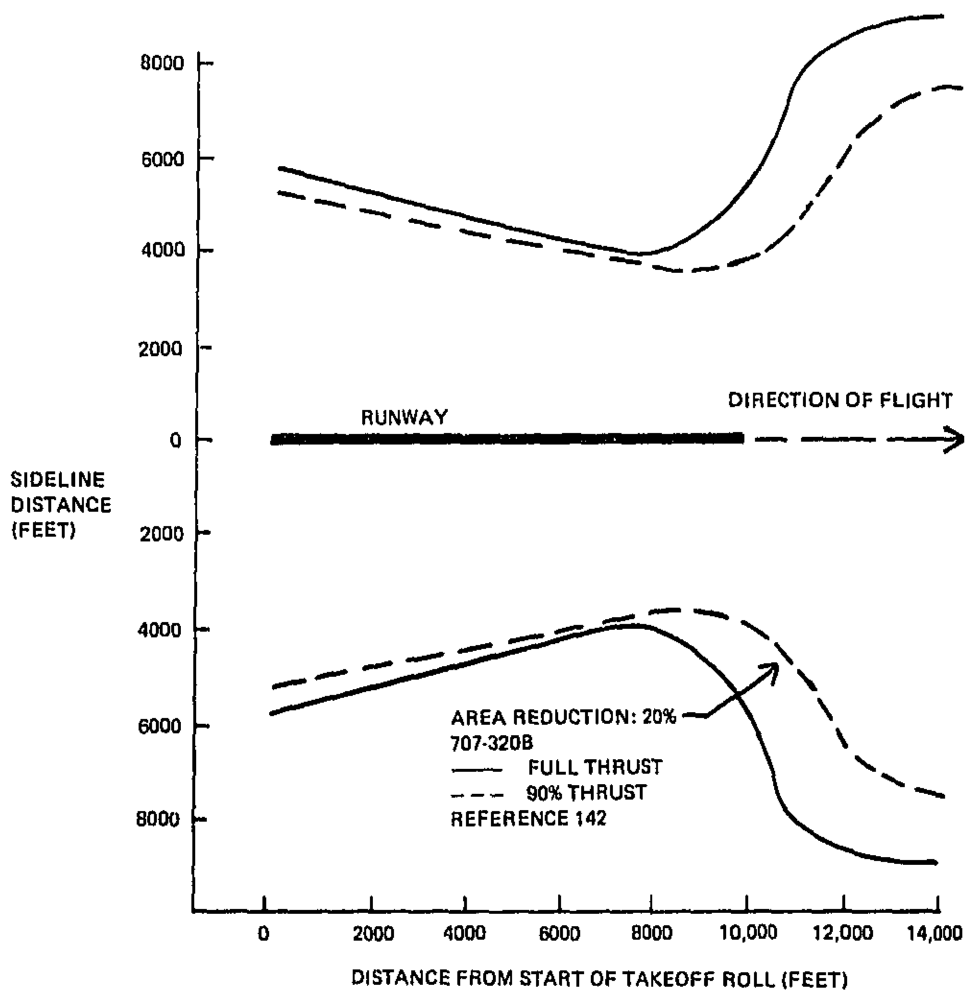

Figure 2-2. 90 EPNdB Noise Contours for Maximum Thrust and Reduced Thrust Takeoffs

path) is illustrated in Figure 2-3. For the Boeing 707 aircraft, the maximum climb gradient can be seen to occur with zero flaps at the airspeed V_x (maximum angle of climb airspeed). In the takeoff flap configuration the maximum climb gradient occurs at or near the speed V_2 + 10 knots (V_2 is the safety speed in the takeoff configuration), but this maximum gradient is lower than the maximum gradient in the clean (zero flap) configuration.

Secondly, the effect of aircraft weight and thrust setting is shown in Figure 2-4. Higher weights and lower thrust settings can be seen to give lower climb gradients.

Another factor in obtaining maximum initial climb gradient is aircraft body angle limitation. Such limitations may make it impossible to achieve the optimum climb gradient. The only jet transport aircraft with a manufacturer's body angle limitation is the DC-9 (16° limit).

Various organizations have proposed different noise abatement climbout procedures. The Air Transport Association (ATA) recommends a maximum angle climbout as quoted below (54):

I. First Segment - Takeoff to 1500 Feet

1. Takeoff power
2. V_2 + 10 (+)
3. Takeoff flaps

II. Second Segment - at 1500 Feet to 3000 Feet

1. V_2 + 10 (+)
2. Optimum flap setting speed permitting*
3. Reduce to not less than climb power

*Retract or retain flap setting as required

III. Third Segment - at 3000 Feet

1. Retract flaps on schedule
2. Normal enroute climb

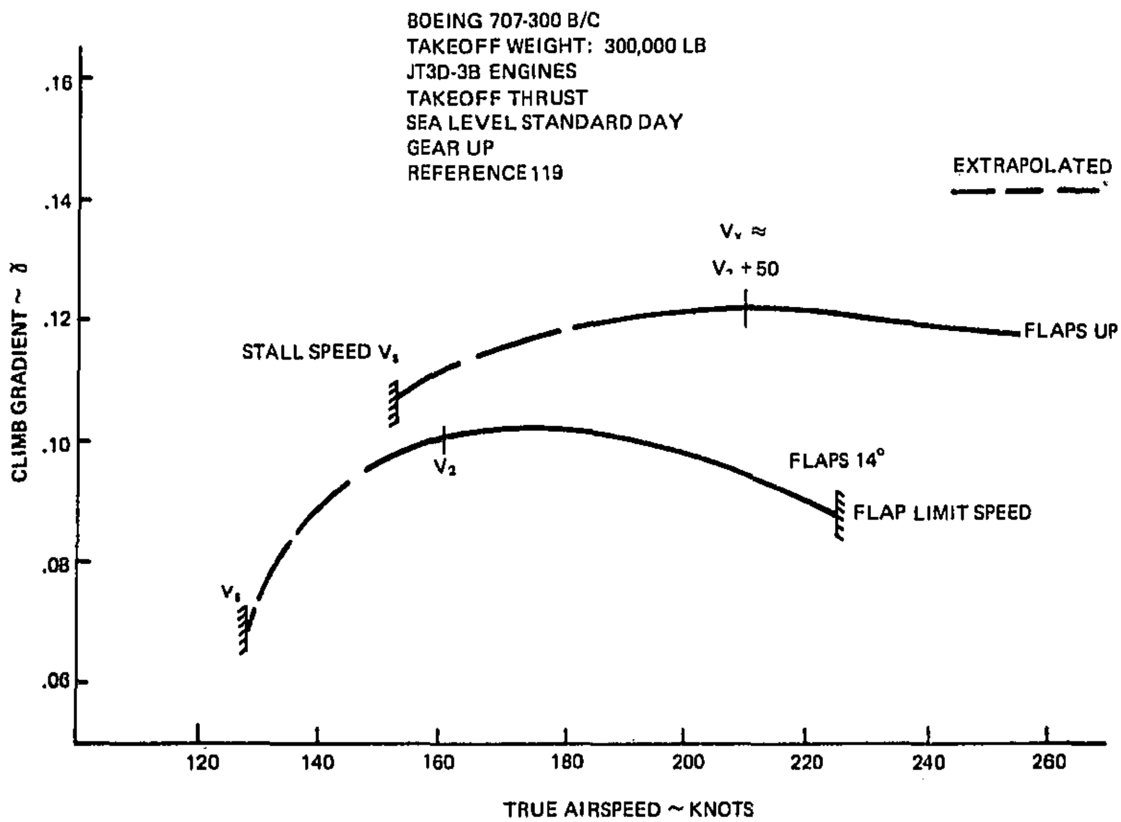

Figure 2-3. Effect of Flaps on Climb Gradient

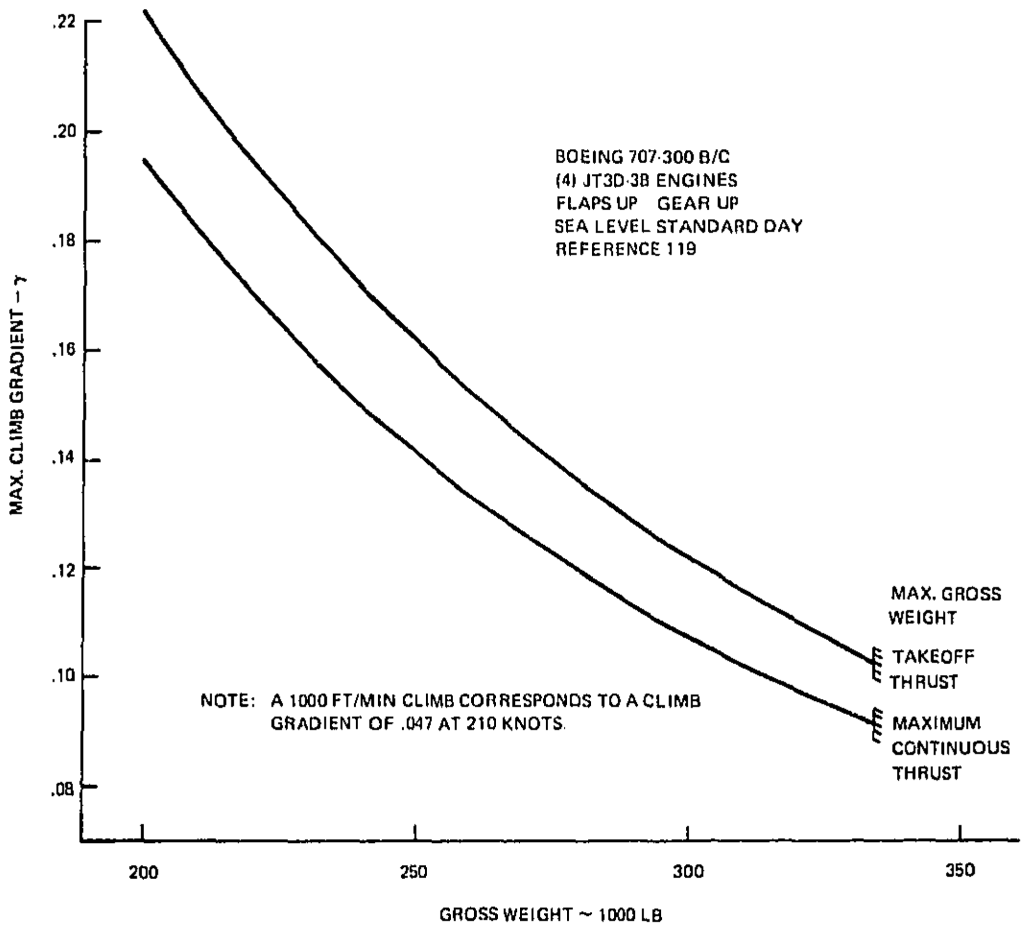

Figure 2-4. Effect of Weight and Thrust Setting on Climb Gradient

The ALPA recommends a power cutback procedure as quoted next (14):

> "A normal takeoff with normal rotation is made ideally to a pre-computed pitch attitude. The aircraft is climbed at V_2 + 10 to 20 until at least 400' altitude is reached. The pitch angle is then reduced to begin acceleration to reach flaps reduction schedules that will bring the aircraft to approximately 1500' above the airport elevation in a clean configuration and at maneuvering speed. Thrust is then reduced to that thrust required to produce the engine out climb gradient for that particular aircraft. (This thrust setting is also precomputed.) This thrust is maintained until the aircraft reaches 4000' at which time enroute climb thrust is resumed.
>
> It should be emphasized that 400' is a minimum altitude for the start of flap retraction and for most aircraft the flap retraction should be started appreciably above this altitude."

The National Business Aircraft Association (NBAA) recommends procedures similar to the ATA maximum angle climbout (26):

1. Standard Procedure

   a. Maintain maximum power and takeoff flap setting to 1,500' AFL (above field level) for a maximum rate-of-climb subject to items in paragraph b following (immediately below).

   b. Maintain V_2 + 10 (+) knots.

   c. Flight path outbound from takeoff should not require any turn below 300' AFL, and not more than a 15^o bank.

   d. At or before 1,500' AFL, retract flaps (if possible) and set power at desired climb EPR (engine pressure ratio) or RPM (revolutions per minute).

   e. Above 3,000' AFL normal climb schedule.

2. Close-In Procedure (*)

   (*) For communities less than 10,000' from brake release point.

   a. Accelerate to V_2 + 10 (+) knots.

   b. After crossing airport boundary and after reaching 300' AFL reduce to desired climb EPR or RPM.

   c. Flight path outbound from takeoff shall not require any turn below 300' AFL and not more than a 15^o bank.

d. At or before 1,500' AFL, retract flaps (if possible).

e. Above 3,000' AFL, normal climb schedule.

The ATA climb procedure is presently in use by Pacific Southwest Airlines (PSA), United, American, and possibly other airlines. Procedures similar to the ALPA procedure are in use by Northwest Airlines and Air California. All airlines at Washington (National) Airport make a power cutback from a point 3 nautical miles northbound or 4 nautical miles southbound until reaching an altitude of 6000 feet or a distance of 10 nautical miles, whichever occurs first (153).

The noise effect of these procedures is depicted in Figures 2-5 and 2-6 (curves are not shown for the NBAA procedure since it closely resembles the ATA procedure). The reference procedure shown is a continuous acceleration to 250 knots and then a climb at 250 knots, typical of a departure unconstrained by noise abatement considerations.

As can be seen from the figures, the maximum angle climbout (ATA) procedure reduces noise approximately 1 EPNdB at distances from 3 to 12 miles from brake release and increases noise approximately 1 dB farther out. The total area exposed to 90 EPNdB or greater is not significantly changed as compared to the reference procedure. The power cutback climbout (ALPA) procedure reduces noise approximately 2 EPNdB at distances from 4 to 14 miles from brake release and increases noise approximately 2 EPNdB farther out. The area exposed to 90 EPNdB or greater is reduced by approximately 6 percent as compared to the reference procedure. Which procedure is better under specific conditions depends on the location of the noise sensitive areas. If the noise sensitive area is located under the reduced power segments, then a power cutback procedure such as ALPA recommends is better. If the noise sensitive area is at some distance from the airport then a maximum angle climbout such as ATA recommends is better.

The effectiveness of a power cutback climbout is dependent on a number of factors. First, it is dependent on the type of aircraft, being most effective for those aircraft powered by JT8D engines (727, 737, DC-9) because of their high power to weight ratios and high levels of exhaust noise relative to fan noise. This effect is shown in Figure 2-7. Figure 2-7 also shows that the noise exposed area is dependent on the altitude

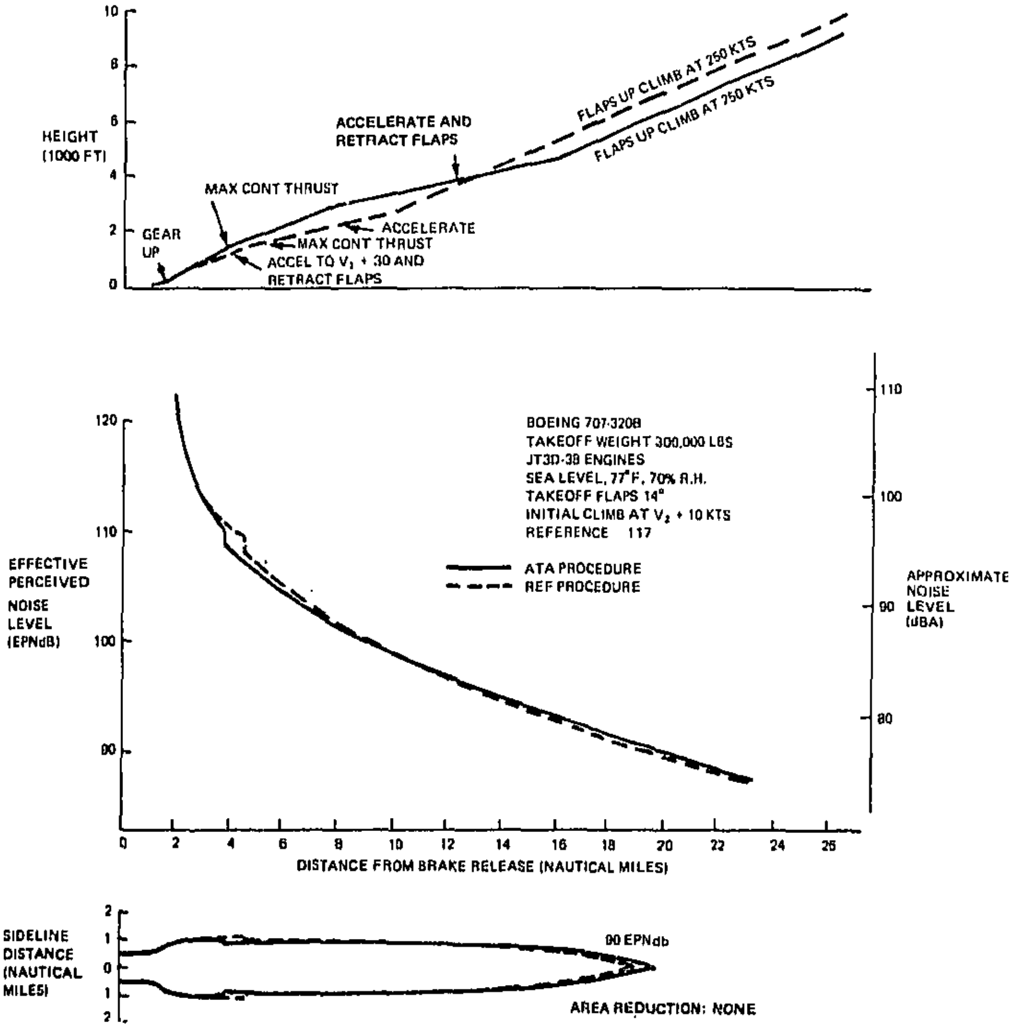

Figure 2-5. Noise Data for Maximum Angle (ATA) Climbout

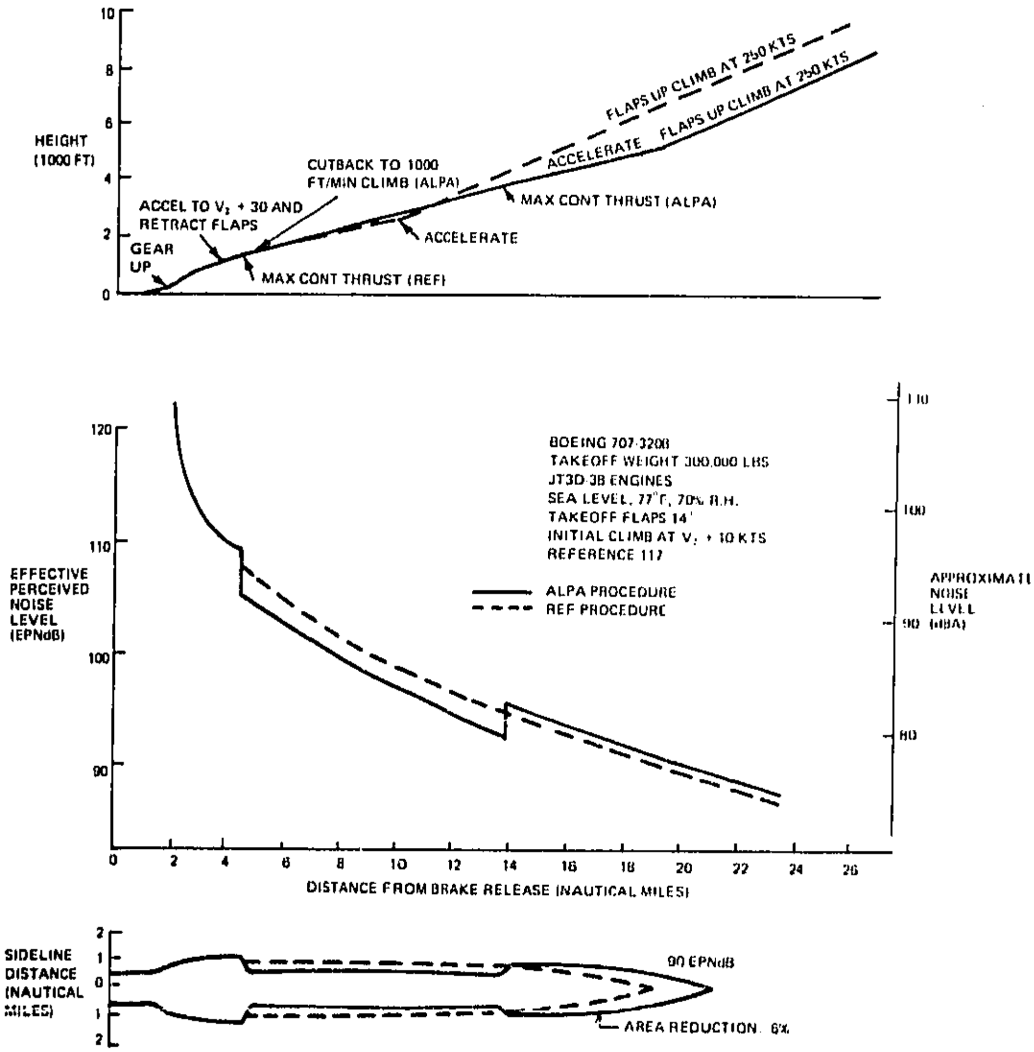

Figure 2-6. Noise Data for Power Cutback (ALPA) Climbout

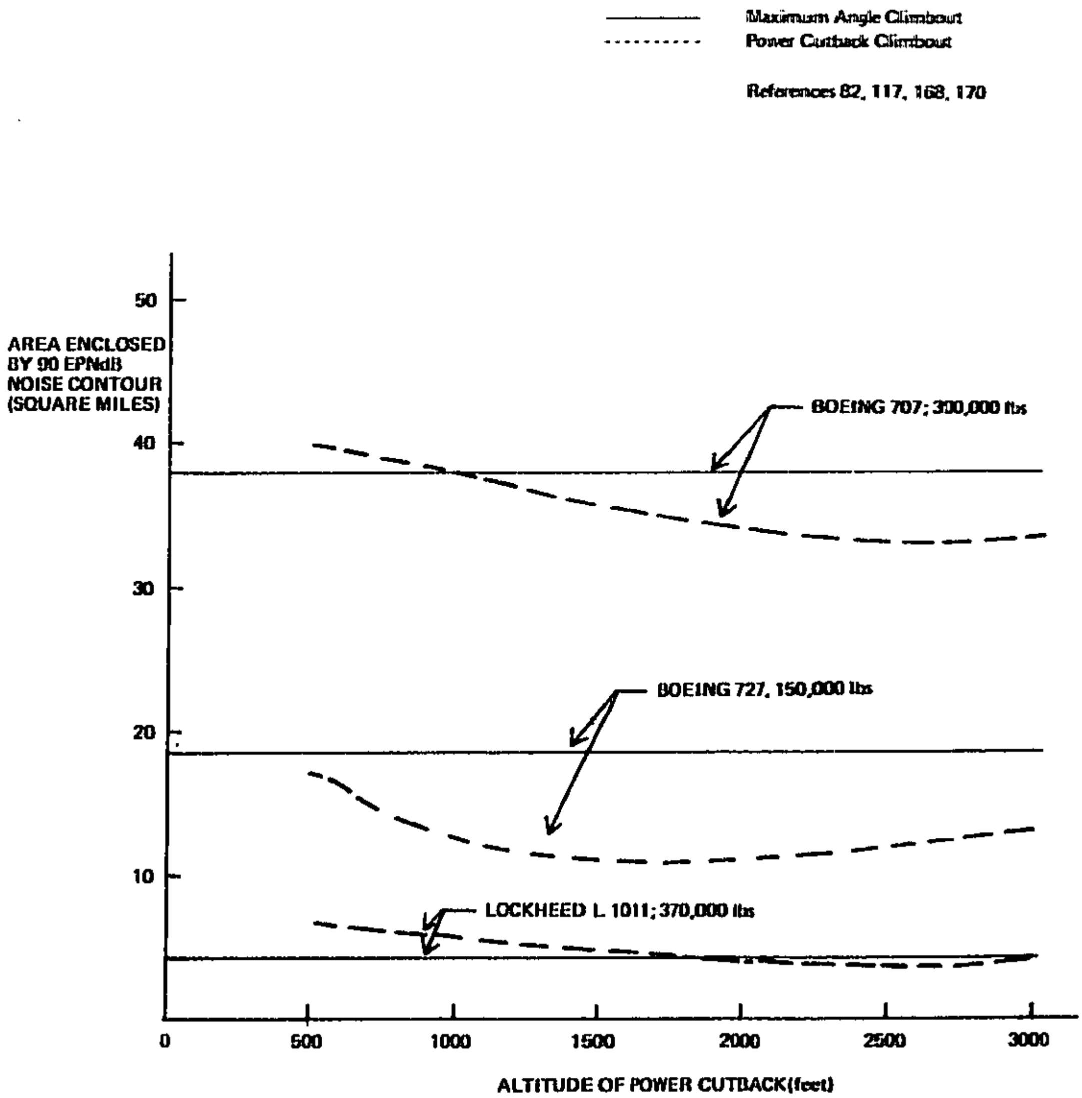

Figure 2-7. Effect of Aircraft Type and Cutback Altitude on 90 EPNdB Enclosed Area

of cutback: for the 707, the 90 EPNdB area can be reduced most by making the cutback at approximately 2500 feet above the surface. This altitude, however, must be weighed against the actual location of noise sensitive areas and the value of reducing areas exposed to levels of noise above 90 EPNdB. Figure 2-8 illustrates the latter point further, showing that the later the cutback is made, the more it reduces the noise level directly below, but the length of effectiveness is decreased and the exposure to noise levels above approximately 95 EPNdB (for the 727 aircraft) is increased.

In addition, one should note that power cutbacks are most effective for the moderately high (but not extremely high) noise levels. Figure 2-9 shows that for the 727 aircraft, the maximum effectivity is for the 90 EPNdB contour. The area exposed to 100 EPNdB or greater is actually increased slightly as a result of the power carried during acceleration and flap retraction. This increase in exposure to high noise levels could perhaps be overcome by making the thrust reduction before retracting flaps; this would reduce the subsequent effectiveness of the procedure, however, as indicated by the following quotation from a NASA Report (115).

> ". . . the optimum profiles. . . can be characterized by a period of acceleration as soon as possible after take-off, followed by a steep climb, which in turn is followed by thrust reduction when the noise-sensitive area or a specified altitude is reached. Before the transition from accelerating to climbing, the optimum profiles achieved an airspeed that permitted full retraction of flaps. This acceleration caused some altitude loss at the beginning of the noise-sensitive area, but the disadvantage of a slightly lower altitude can be outweighed by the advantage of greater thrust reduction that is possible in the clean airplane configuration. Thus, in the trade off between airspeed and altitude, gaining airspeed until it is permissible to retract flaps can be more important than gaining altitude, if the objective is to minimize the average perceived noise along the noise-sensitive ground track."

For the larger, noisier 707 type aircraft, the power cutback is effective for the 100 EPNdB contour as well as the 90 EPNdB contour but may increase the size of the 110 EPNdB contour because of the flap retraction distance (refer again to Figures 2-5 and 2-6). The overall effectiveness of the power cutback procedure can be improved by having an automated flap retraction system, but this concept is still in the early research stage (111).

Finally, even for a given aircraft type, the takeoff weight can effect the benefits to be gained by a power cutback. As illustrated in Figure 2-10, the amount of benefit and the optimum cutback altitude for the L-1011 aircraft is very weight dependent.

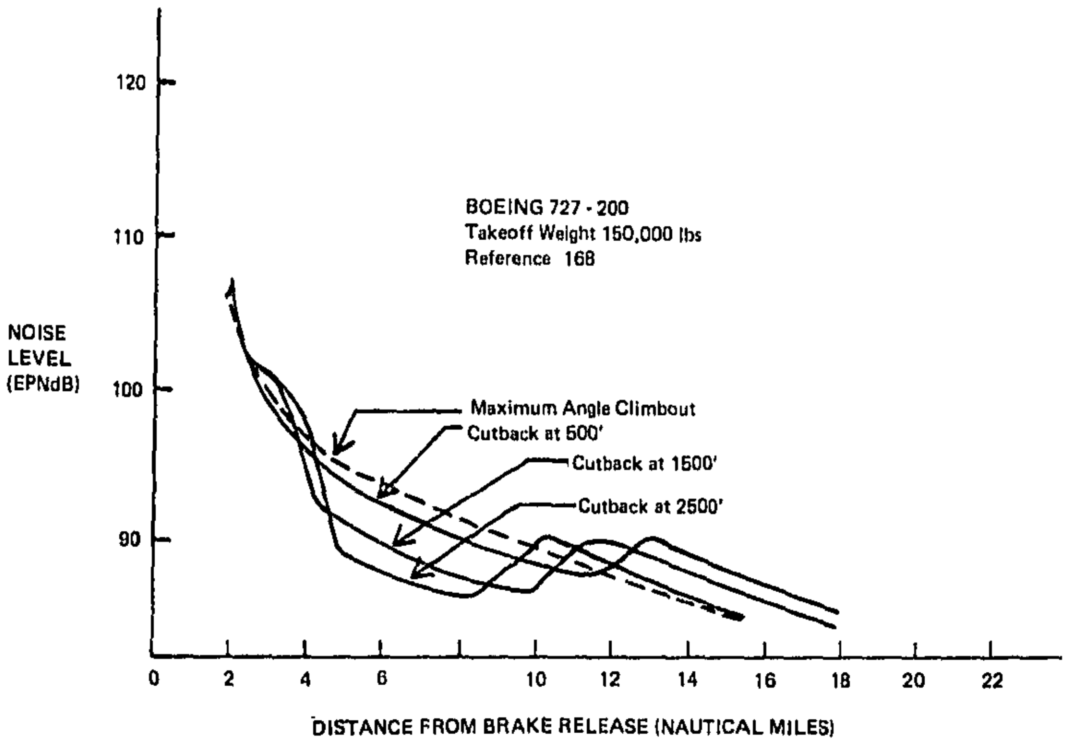

Figure 2-8. Centerline Noise Data for Various Power Cutback Altitudes

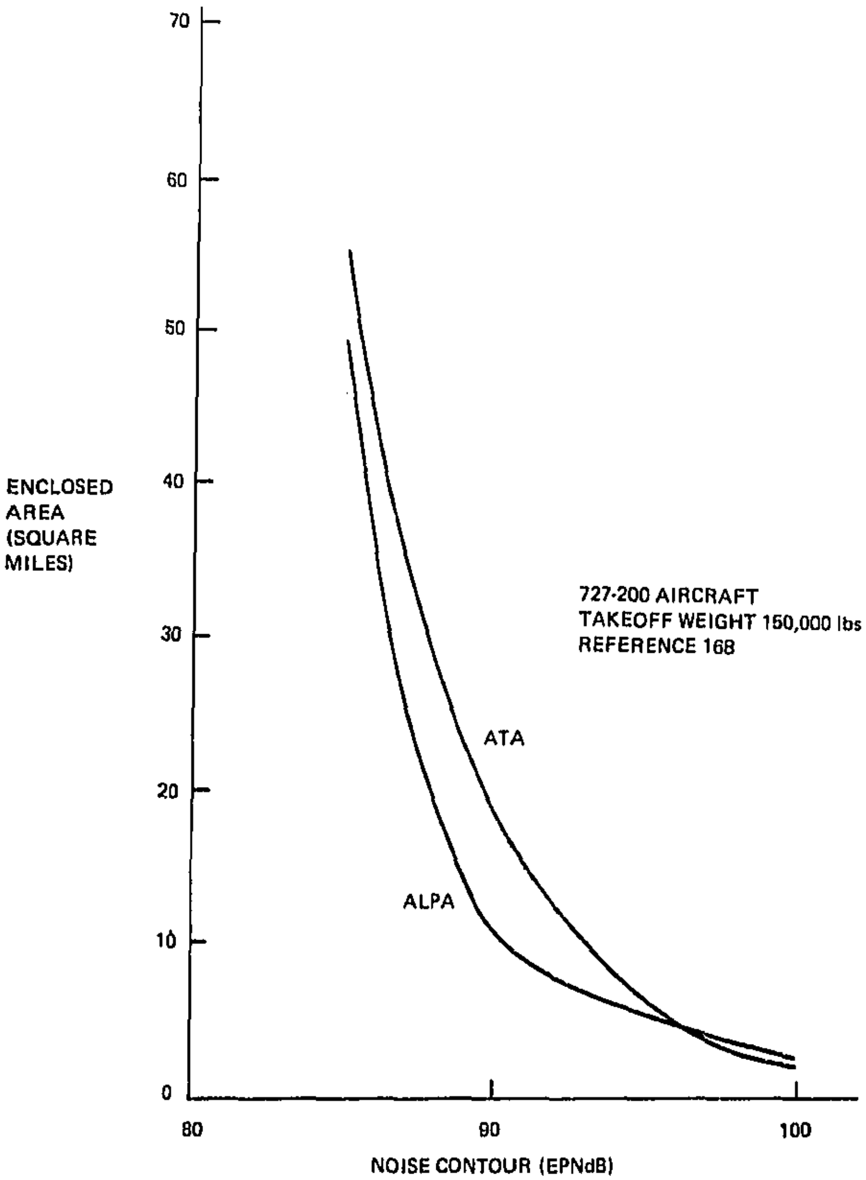

Figure 2-9. Enclosed Area as a Function of EPNL Contour for ATA and ALPA Takeoff Profiles

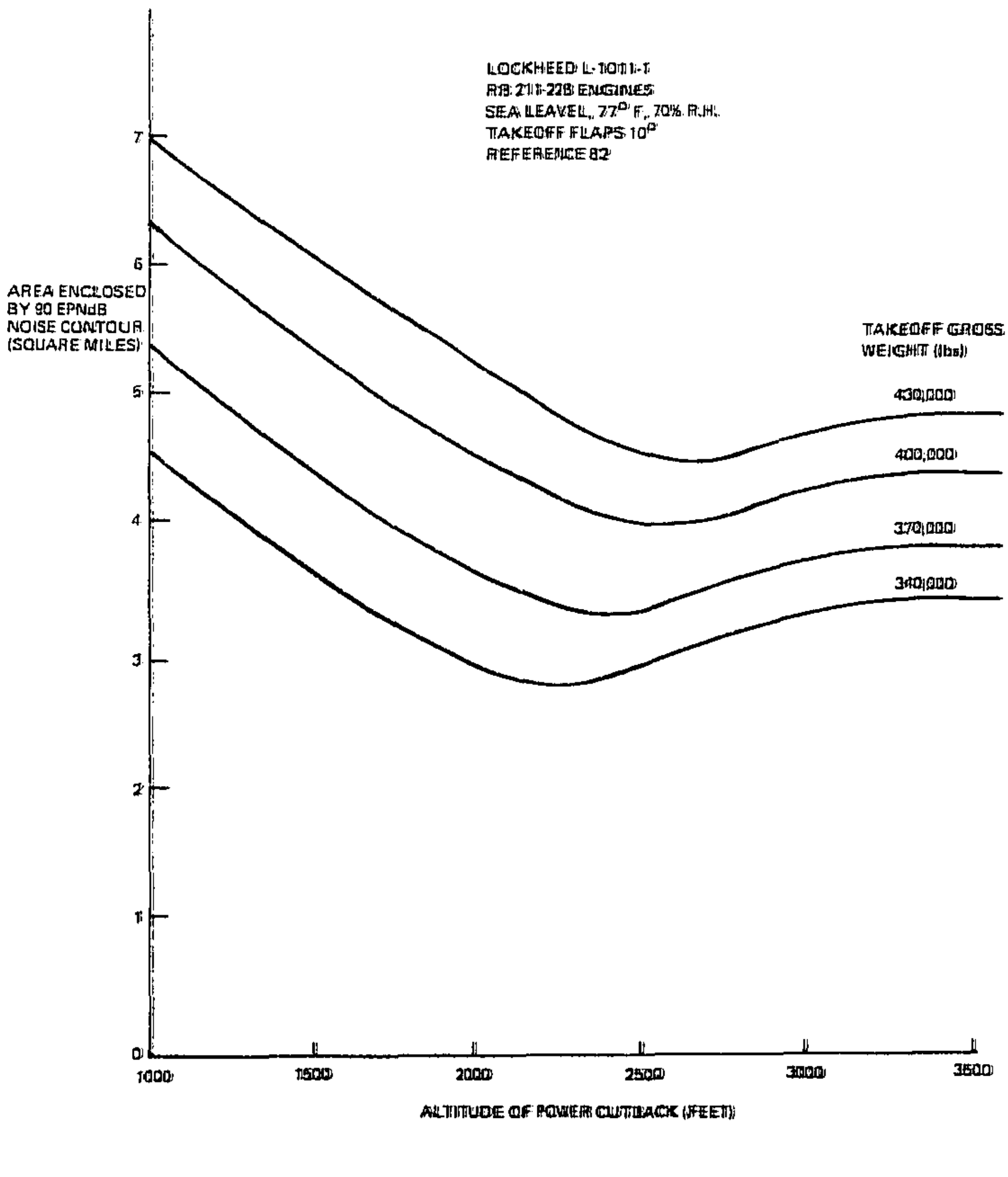

Figure 2-10. Effect of Aircraft Weight and Cutback Altitude on 90 EPNdB Enclosed Area

In general, if the location of the noise sensitive area is known, the takeoff profile can be optimized to reduce noise there. In fact, the noise impact on people may in some cases be reduced even if the area within the 90 EPNdB contour is increased. such as in the case of an early cutback over residential areas followed by an expanded contour over water or other sparsely populated areas.

In the extreme, optimization of the takeoff profile would mean different procedures for every combination of runway, aircraft type, aircraft weight, and weather conditions. Less variability could be achieved by having only the point of power cutback vary depending on the location of the noise sensitive community with respect to the runway. Even less variability could be achieved by having two or three "standard" noise abatement procedures which, while not necessarily optimum for any specific situation, would provide a selection from which one could choose a profile that would probably be better than no noise abatement procedures at all or only one standard procedure.

Airline pilots, however, argue for a single standard procedure, asserting that if a pilot always flies the same way he will react in the usual (and safe) way if an emergency occurs. The countering argument asserts that no two takeoffs are alike anyway because of differences in runway, weather, weight, obstacles, Air Traffic Control (ATC) requirements, etc., therefore use of optimum climb procedures would not in fact degrade standardization.

A spinoff advantage of a power cutback takeoff is that it consumes less fuel than a full power (maximum angle) climbout. For a 300,000 lb. Boeing 707, the difference is approximately 250 pounds of fuel (167). This is also a cost savings of approximately \$3.75 per takeoff (based on a fuel cost of 1.5¢ per pound). The reduced power settings would probably result in increased air emissions of carbon monoxide and hydrocarbons but decreased emissions of nitrogen oxides (128). These air emission effects are expected to be small, especially since the aircraft will be at altitudes of 1500 feet and above when the power cutback takes place.

Conclusions: maximum angle (full power) climbouts and power cutback climbouts are two technically feasible noise abatement procedures in current use. The choice of which procedure is better (or which cutback altitude is best) depends on the location of noise sensitive areas with respect to the departure runway. The maximum angle climbout is most beneficial for far downrange (more than approximately 10 miles from the airport) noise problems. The power cutback climbout is most beneficial for near downrange (approximately 4 to 10 miles from brake release) noise problems.

APPROACH AND LANDING PROCEDURES (JET AIRCRAFT

Several procedures have been proposed to reduce approach and landing noise. The most important of these are:

1. Use of lower flap settings for approach and landing
2. Raising initial approach altitudes above 1500'
3. Raising all ILS glide slopes to 3^{0}
4. Raising all ILS glide slopes to 3.5^{0}
5. Use of two-segment approaches in VFR conditions
6. Use of two-segment approaches in IFR conditions
7. Use of decelerating approaches
8. Limitations on use of thrust reversers.

Each of these procedures will be discussed individually in the following sections.

REDUCED FLAP SETTINGS

Approaches made with less than full landing flaps reduce noise as compared to a full flap approach because the airframe drag is less and thereby the power required is lower.

Many aircraft (707, 727, 737, 747, DC-10, L-1011) have more than one certificated flap setting for landing. Certain airlines, including American, Northwest, and United use the reduced landing flap when conditions permit and also use an even lower flap setting during the approach phase. The United Airlines procedure, for example, calls for using one "notch" less than landing flaps for the approach, with landing flaps (which may be one notch less than full flaps) lowered so that the aircraft can be completely stabilized in the landing configuration prior to reaching an altitude of 500 feet above the runway elevation (approximately 200 to 300 feet are required to stabilize an aircraft following a configuration, airspeed, power, or attitude change).

Figure 2-11 shows that this type of flap management approach can reduce the area exposed to 90 EPNdB or greater by approximately 30 percent.

The ATA endorses such a flap management approach and ALPA endorses it for VFR flight subject to pilot discretion.

The reduced power settings result in lower rates of fuel consumption and also reduced costs. The fuel savings is estimated to be approximately 380 pounds per landing (or $5.70 based on a fuel cost of 1.5¢ per pound) for a Boeing 727 aircraft (167).

Conclusion: reduced flap settings provide meaningful noise relief and are technically feasible. In succeeding sections the flap management approach will be used as the reference for comparing other procedures.

INCREASED INITIAL APPROACH ALTITUDES

Increasing the altitude at which the glide slope is intercepted can reduce approach noise. The regulatory minimum altitude for turbine powered or large aircraft is 1500 feet above the runway elevation (FAR 91.87 (d) (1)). For straight-in approaches the area exposed to 90 EPNdB or greater can be reduced by 25% if the glide slope intercept altitude is increased to 3000 feet (Figure 2-12). This noise reduction is one of the purposes of the FAA "keep-em-high" program described in AC 90-59 (112).

In some cases it may be argued that an increased intercept altitude increases total noise exposure by causing the aircraft to fly a longer ground track (when making a curved approach). However, at least in VFR conditions, the experience at San Jose Airport (see Technical Annex) indicates that in fact, rather than traveling a long distance to intercept the glide slope from below, most pilots will actually choose to make an approach steeper than 3° in order to shorten the distance. In IFR conditions the requirement for a long stabilized final approach would require glide slope intercept far from the airport anyway. To the extent that curved approaches might be lengthened, additional fuel would be consumed (approximately 60 pounds per mile for a Boeing 727) (167).

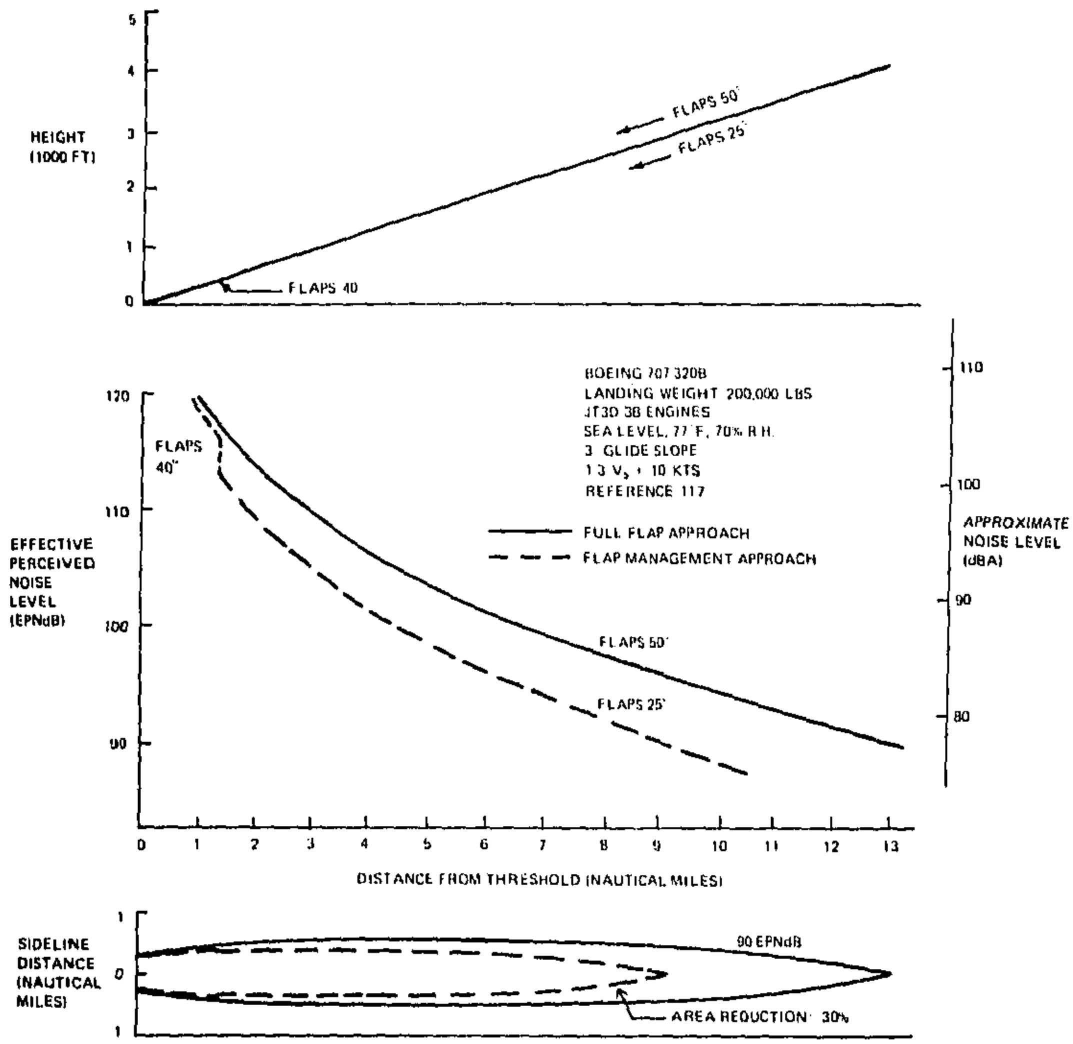

Figure 2-11. Noise Data for Flap Management Approach

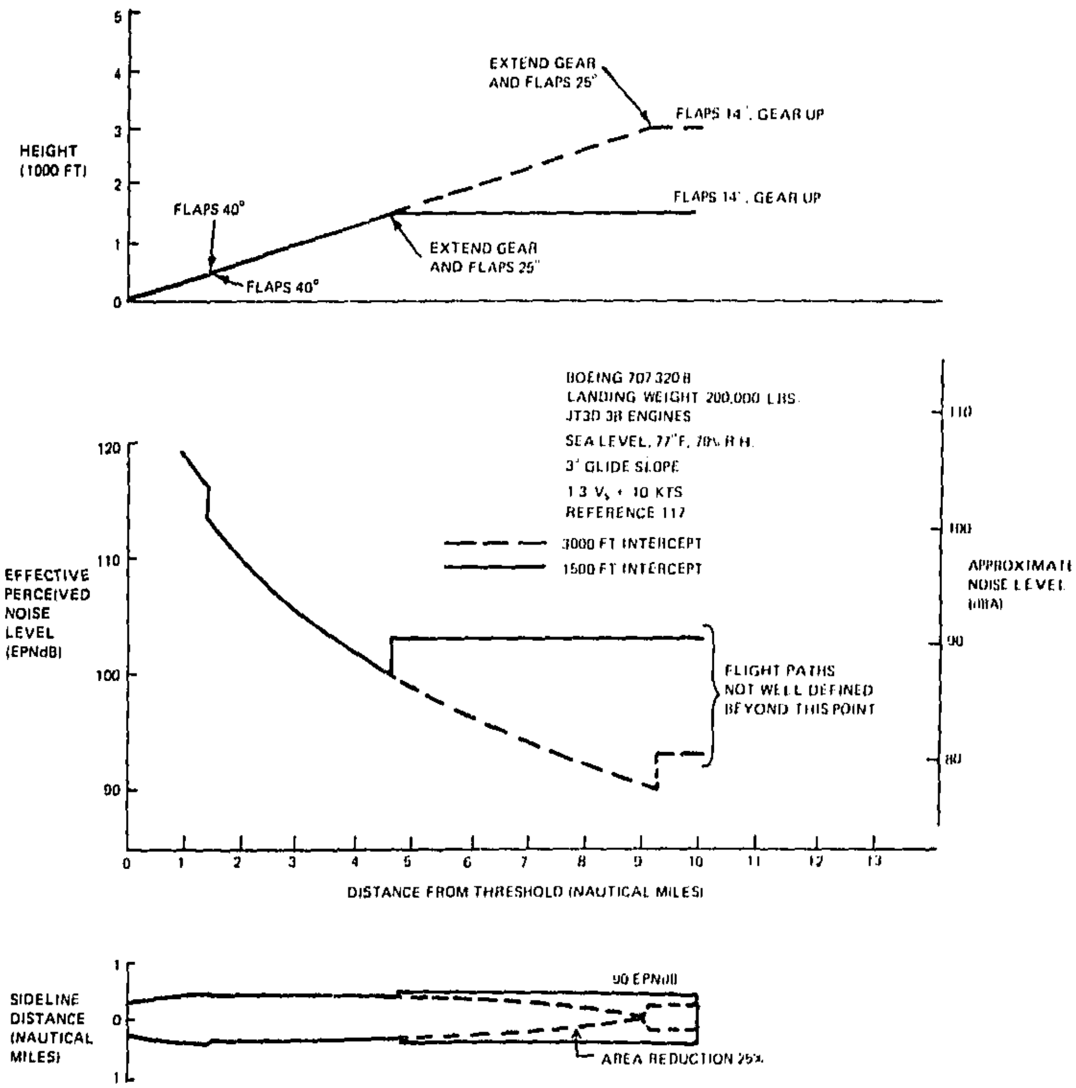

Figure 2-12. Noise Data for 1500 and 3000 Ft Intercept Altitudes

Conclusion: the "keep-em-high" philosophy provides meaningful noise relief and is technically feasible. Obviously such procedures must be closely coordinated with other air traffic control requirements.

HIGHER GLIDE SLOPES

Higher approach angles result in reduced power settings and higher altitudes which combine to reduce noise. Although the present FAA standard for new ILS glide slope installations is 3^{o} and a few older ILS glide slopes have been raised to 3^{o}, there still remain 190 installations (out of a total of 293 reported in a tentative FAA list) with glide slope angles of less than 2.9^{o} (many as low as 2.5^{o}). (71)

A few air carrier airports have glide slope angles significantly in excess of 3^{o} (see Table 2-1). Some additional (mostly military) airports with glide slopes in excess of 3^{o} are reported in reference 75. In all cases these glide slope angles were instituted to clear high terrain. The San Diego airport accommodates nearly all types of aircraft using a 3.22^{o} ILS or a 4.5^{o} VASI even though the runway is quite short (7,590 feet available for landing on runway 27). The ILS glide slope at Berlin (Tempelhof) Airport was 4^{o} prior to being lowered to 3.5^{o} in 1968 (143). There is no evidence to indicate that any of these higher glide slopes are unsafe.

Table 2-1

AIR CARRIER AIRPORTS WITH GLIDE SLOPES ABOVE 3^{o}

Airport	Glide Slope Angle	Weather Minimums Ceiling (feet) / Visibility (miles)
San Diego, Calif. (Lindbergh, Runway 09)	3.22° ILS	350/1
San Diego, Calif. (Lindbergh, Runway 27)	4.5° VASI	800/2
Annette Island, Alaska	3.27° ILS	250/ 1/2
Ft Worth, Texas (Meacham)	3.33° ILS	300/1
Berlin, Free Republic of Germany (Tempelhof)	3.5° ILS	250/ 3/4

FAR 91.87 (d) (2 and 3) require that all turbine powered or large aircraft properly equipped remain at or above the glide slope except for normal maneuvering above and below the glide slope conducted for the purpose of remaining on the glide slope.

The noise reduction effect of raising the glide slope angle is approximately 2 to 3 EPNdB per one-half degree increase in glide slope angle as shown in Figure 2-13. The considerable scatter in the data is evident in Figure 2-13 and again it should be remembered that all noise predictions in this report are subject to similar uncertainties. Figure 2-14 shows that a 0.5 degree increase in glide slope angle will reduce the area exposed to 90 EPNdB or above by approximately 25 percent. This procedure has the advantage of reducing noise almost uniformly from the start of approach to touchdown.

Several members of the task group raised a safety issue regarding 3.5^{o} ILS glide slopes. Their argument is that increasing the glide slope angle increases the descent rate, reducing the pilot's decision time while simultaneously causing a more abrupt flare-out maneuver at the point of touchdown. The descent rate for various airspeeds and approach angles is shown in Figure 2-15. The position of ALPA, ATA, NBAA, the Aircraft Owners and Pilots Association (AOPA), and others is that descent rates for angles above 3^{o} are excessive (600 to 800 feet per minute). On the other hand, several NASA reports, (9, 10, 116) indicate that descent rates of more than 900 to 1000 feet per minute near the ground are excessive. PSA procedures (95) require that the copilot make a verbal call to the pilot if the descent rate exceeds 1000 feet per minute.

Several task group members, San Jose Airport, NASA, Air California and others indicated that they considered 3.5^{o} approach angles to be safe and recommended their adoption if the minimum weather conditions for landing did not have to be raised (85), (100).

A monitoring study by the City of Inglewood, California (75) showed that when the electronic glide slope was inoperative, pilots tended to fly at about a 3.5^{o} angle in visual weather conditions.

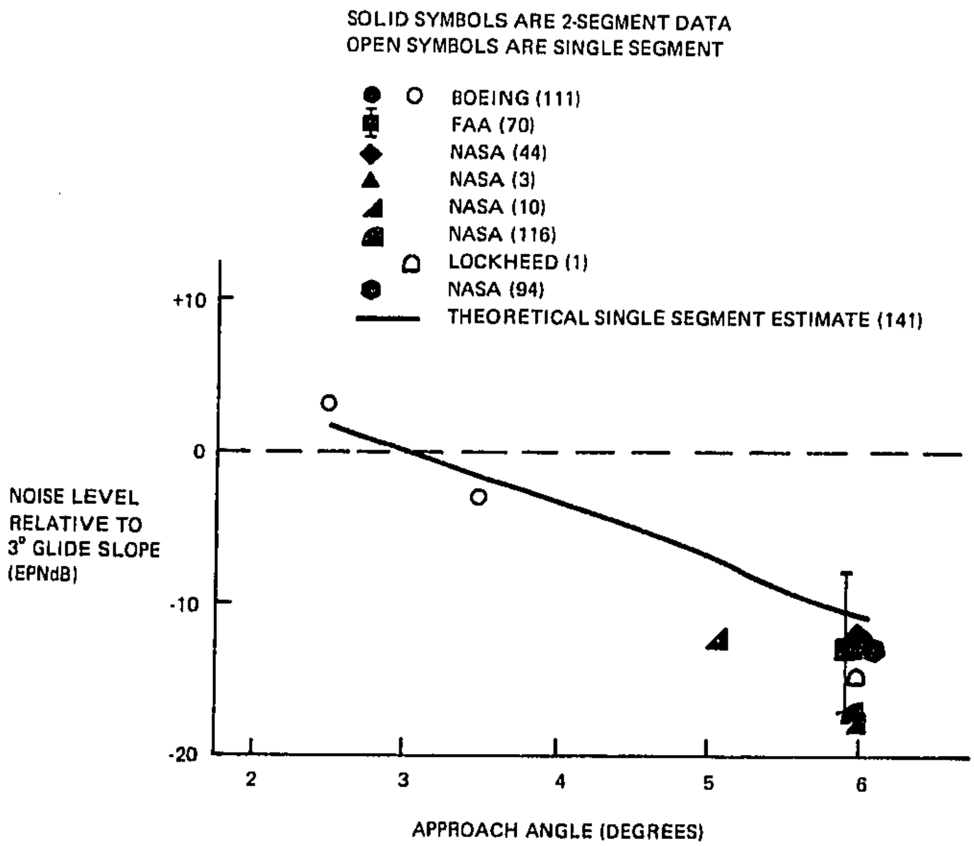

Figure 2-13. Effect of Approach Angle on Noise

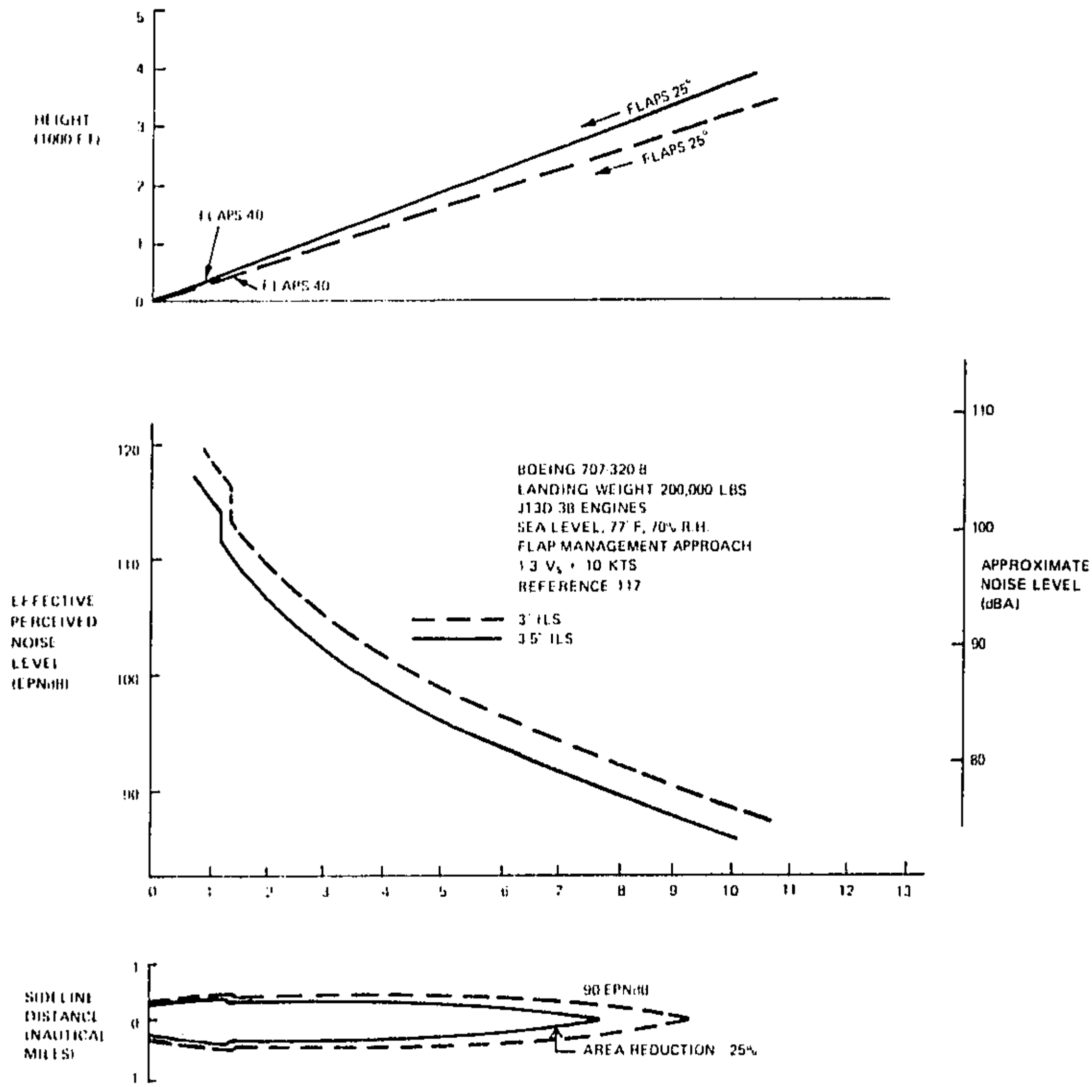

Figure 2-14. Noise Data for 3.5° ILS Approach

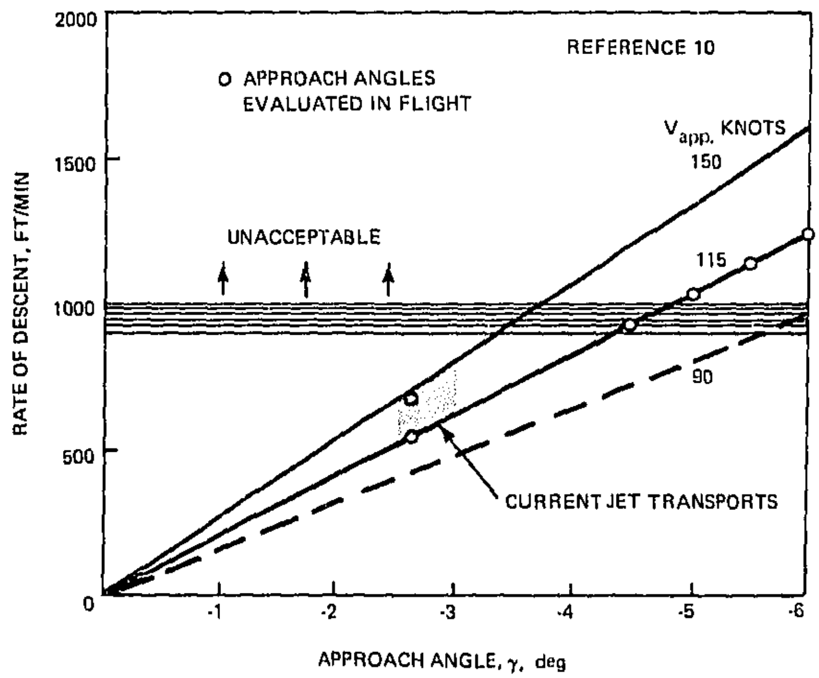

Figure 2-15. Variation of Rate of Descent with Approach Angle

Current ILS weather minimums (Category I, approximate) are: 200 foot ceiling and 0.5 mile visibility. Twenty four runways are equipped for Category II landings with approximate weather minimums: 100 foot ceiling and 1/4 mile visibility. Table 2-1 suggests that the Category I weather minimums for a 3.5^{0} ILS might have to be raised to 250 foot ceiling and 3/4 mile visibility in order to preserve the decision time available to the pilot after making visual contact with the runway. As shown in Table 2-2, the weather conditions are likely to be between 200 ft/ 1/2 mile and 250 ft/ 3/4 mile approximately 0.7% of the time.

Table 2-2

FREQUENCY DISTRIBUTION OF WEATHER CONDITIONS
(Reference 120)

Percentage of time ceiling and visibility are above levels indicated

Airport (years considered)	200 feet 1/2 mile	250 feet 3/4 mile	1000 feet 3 miles	3000 feet 5 miles
Atlanta (1946-1967)	98.3	97.6	88.7	77.5
Chicago (1946-1965)	98.9	98.2	86.2	69.1
Los Angeles (1949-1965)	97.7	96.9	78.9	57.6
New York (1949-1965)	98.4	97.7	87.2	73.1
Average	98.3	97.6	85.3	69.3

The costs associated with raising the ILS glide slope are estimated by the FAA to be (146):

- Relocate glide slope antenna, middle marker, and outer marker: $56,000 per runway
- Flight check glide slope: $6,000 per runway

If the timing were such that the adjustment coincided with a regular flight check of the glide slope, only the equipment relocation costs would apply.

If the angle were raised to 3.5° and it was necessary to raise weather minimums also, there might be an additional cost associated with the delay or diversion of 0.7 percent of all landings. This is estimated to be approximately 20 minutes or $200 per delayed flight plus passenger inconvenience. Assuming approximately 5 million air carrier landings annually (there were 4.7 million in 1969 (500)) this amounts to approximately $7 million annually (plus passenger inconvenience) if all glide slopes were raised to 3.5° and weather minimums had to be raised also.

Conclusion: glide slope angles of 3° are standard for new installations and result in less noise than lower glide slope angles, yet a majority of existing glide slopes are lower than 3°. Glide slope angles of up to 3.5° reduce noise even further and are in use at a few locations to provide terrain clearance.

TWO-SEGMENT APPROACHES

Like the higher glide slope angles, two-segment approaches reduce noise through the combined effect of reduced power settings and higher altitudes. In the two segment approach the initial descent is accomplished at a fairly steep angle (nominally 6°) and then a transition is made to a normal glide slope (nominally 3°) at an altitude sufficient to safely reduce the initial high descent rates. Considerable noise reduction is possible beneath the 6° segment, but no noise benefit occurs between the point where transition is complete and the runway.

Figure 2-16 shows the noise reductions possible for the 707 aircraft and indicates that the area exposed to 90 EPNdB or greater is reduced by 75 percent compared to a flap management approach. This is a very significant reduction, especially since the 707 is one of the noisiest aircraft in the current fleet. The noise reductions provided by two segment approaches for aircraft which already include noise suppression may not be as great, but are still significant. For example, a two segment approach for a 707 equipped with an acoustically treated nacelle reduces the 90 EPNdB area by 77 percent (to 9 percent of the untreated 707) (117); a two segment approach for the L-1011 reduces the 90 EPNdB area by 62 percent (to 8 percent of an untreated 707) (1).

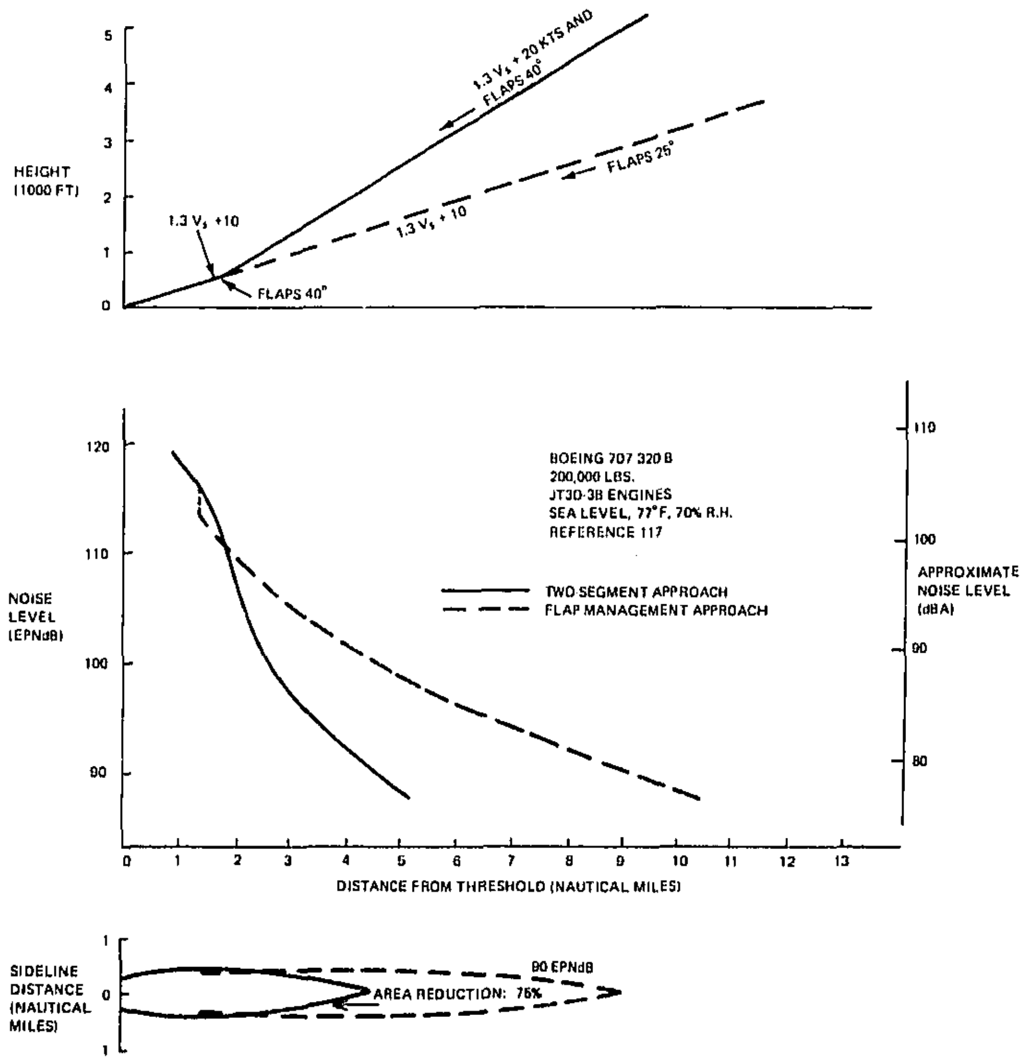

Figure 2-16. Noise Data for 2-Segment Approach

From a noise standpoint, the most effective procedure would be a very steep initial angle with transition occurring very close to the runway. The initial angle is limited, however, by the power and drag characteristics of the aircraft: under certain conditions initial angles of more than 6° would not permit speed stabilization or might allow ice to build up in the engines (if icing conditions exist). Furthermore, high descent rates (1600 feet per minute, instead of a normal 800 feet per minute, see Figure 2-15) coupled with low power and long engine response times (7 seconds instead of a normal 4 seconds, see Figure 2-17) make low altitude, close in transition hazardous. NASA tests using transition altitudes of 250 feet and 400 feet showed that pilots felt slightly rushed using the 250 foot transition and therefore preferred a 400 foot transition (116, 186). ALPA and ATA have established positions favoring having the aircraft completely stabilized on the glide slope by 500 foot altitude; this requires a geometric point of transition at approximately a 700 foot altitude (the aircraft actually begins the transition at a higher altitude and completes it at a lower altitude, the complete maneuver taking 200 to 300 feet). Current NASA tests are therefore using approximately a 700 foot transition altitude (60).

The various tests of two segment approaches which have been completed or are in progress are summarized briefly in Appendix A. The National Aeronautics and Space Administration (NASA) has conducted many tests and has demonstrated the technical feasibility of this procedure including the use of automatic guidance for all weather operation. Currently, tests are in progress under a NASA contract to United Air Lines to demonstrate the feasibility of the two-segment approach in routine airline operations. In addition, two segment approaches are already being conducted on a regular basis in visual weather by PSA using 727 and 737 aircraft at all airports it serves and by National Airlines using 727 aircraft at Miami (75). Furthermore, Air California utilizes a VFR procedure which is a combination two-segment and decelerating approach in their 737 aircraft (122). Approaches to the San Diego airport are regularly flown at a 5° angle by all airlines serving that airport (aircraft types as large as DC-8s) (79). The National Business Aircraft Association recommends the use of two segment approaches in VFR conditions (26).

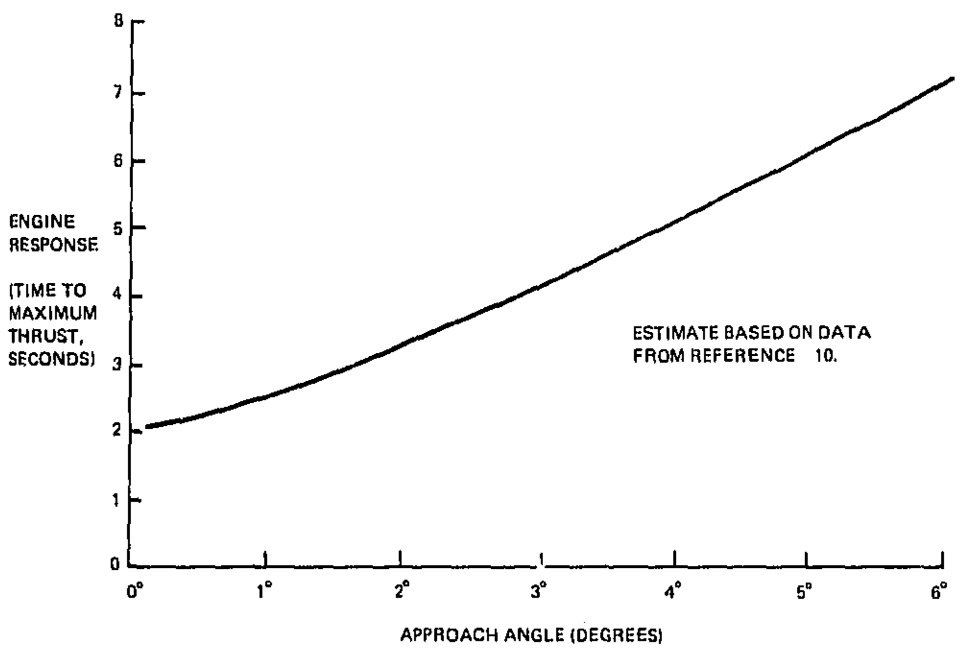

Figure 2-17. Relation of Engine Response Time to Approach Angle

There are numerous items of equipment available to provide guidance during two-segment approaches. The most pertinent items of equipment are listed below along with estimates of the investment costs (in 1973 dollars).

- Distance Measuring Equipment (DME) – All air carrier aircraft have at least one DME receiver. When a DME transmitter is located on an airport, the pilot has information in the cockpit regarding the distance from touchdown. When electronically combined with a glide slope computer, two segment approaches can be made with full flight director guidance. Currently only 16 airports have DME installed or on order. Present FAA programming calls for 5 more in Fiscal Year 1975, 20 in FY 76, 20 in FY 77, and 40 in FY 78-82 (507). This is a significant slowdown from plans of a year ago which indicated 100 new installations by FY 75 (506). Based on information from Collins Radio, NASA estimates that a dual DME transmitter installation costs approximately $26,400 and delivery of 50 units could take place in 10 months under current specifications (86). FAA cost estimates range from $45,000 to $60,000 per installation (507, 146).

- Glide Slope Computer – One way of providing guidance on the upper segment of a two segment approach is to install a special glide slope computer in the aircraft. In conjunction with the DME on the airport, complete flight director guidance is provided for the approach. Based on estimates from Collins Radio and United Air Lines, NASA estimates the cost of a dual glide slope computer installation to be $31,400 per aircraft (60). Deliveries could begin one year after receipt of order.

- Vertical Navigation Equipment (V-Nav) – This is an extension of Area Navigation (R-Nav) into three dimensions. It is an airborne system which can compute aircraft position in space using the existing network of VORTAC radio navigation stations. No airport DME or ILS is required (for non-precision approaches). Cost estimates for such a system range from $65,000 to $200,000 per aircraft if it is not already R-Nav equipped (179).

NASA estimates a cost of approximately $9,000 for aircraft already R-Nav equipped, based on data from Collins Radio, with a delivery time of approximately 1 year (60). Few aircraft have R-Nav equipment at present, but their numbers are expected to increase as new aircraft enter the fleet and R-Nav routes are adopted by the FAA.

- Visual Approach Slope Indicator (VASI) — This is a set of lights near the runway which provide a visual glide slope. They are generally set for 3°, but at San Diego, for example, they are set at 4 $1/2^{\circ}$ for terrain clearance. VASI's provide a convenient visual check on the aircraft's approach profile. They cost approximately $30,000 (installed) each and are available off the shelf (507).
- Visual Approach Monitor (VAM) — This is an electronic visual display in the cockpit wherein the pilot controls the aircraft so as to keep a command bar positioned across his view of the runway. This display will guide him from a low or high altitude through a smooth transition to a normal 3° glide path. The cost is approximately $16,000 per aircraft including installation and first deliveries could begin within 90 days from date of order (109).
- Microwave Landing System (MLS) — This is a future replacement for the current ILS. Its noise abatement advantage is that multiple flight paths or glide paths may be selected by the pilot. Present FAA planning calls for initial installation of 10 units in FY 77, an additional 407 units in FY 78-82. The present cost estimate is approximately $200,000 each. (507).

According to NASA the time required for airline installation of guidance equipment concurrent with scheduled aircraft downtime is 3 to 4 years for a normal schedule, 2 1/2 to 3 years for a "crash" schedule. More rapid installation could be accomplished but only by using unscheduled aircraft downtime with resultant additional cost or reduced service (86). (An estimate for the downtime is approximately 4 days per aircraft at an out of service cost of $7,000 per day (156, 516).)

The fuel burned on a two-segment approach is not significantly different than the fuel burned on a flap management approach. This is, however, substantially less than the fuel burned on a full flap approach (167). The data from Reference

167 was based on an initial intercept altitude of 3000 feet, and the two segment fuel comparison might be even more favorable if a higher intercept altitude were used.

Air pollution emissions of carbon monoxide and hydrocarbons may be increased slightly by the lower power settings but the emissions of nitrogen oxides should be reduced (128). All emissions would of course take place at flight altitudes.

An important issue concerns the use of "VFR only" two-segment approaches such as those employed by PSA, National, Air California, at the San Diego airport, and recommended by NBAA. The advantage of such a procedure is that it can be implemented almost immediately, without waiting for tests and installation of all-weather guidance equipment (visual contact with the ground provides the necessary guidance). Although the noise benefit might not be as great as a precisely guided approach, a "VFR only" procedure would still provide significant noise benefits and would be useful most of the time. (Referring again to Table 2-2, weather conditions are likely to be "VFR" (1000 foot ceiling and 3 mile visibility) or better approximately 85 percent of the time and better than a 3000 foot ceiling and 5 mile visibility approximately 69 percent of the time.)

The ALPA and ATA hold positions opposing introduction of any "VFR only" procedures. Their argument is that standardization is essential for safety and therefore all approaches should be made in the same manner, whether IFR or VFR. The ALPA contends that the reason PSA and Air California can use VFR procedures is that they operate into only a small number of airports and the routes are short; therefore the pilots are thoroughly familiar with each runway and also make many more landings per month than a pilot who flies only transcontinental or international routes. Others argue oppositely, saying that even under present circumstances VFR procedures are often much different from IFR procedures, so the "standardization" called for does not now exist.

Furthermore, ALPA contends that steep VFR approaches are likely to result in landing accidents because of the high sink rates involved. One analysis of visual approach accidents available to the task group did not bear this out, however. Reference 97 analyzed 44 air carrier visual approach accidents by extracting data from Civil Aeronautics Board, National Transportation Safety Board, International Civil Aviation Organization, and individual state reports. Accidents considered visual were those with ceilings greater than 500 feet and visibility such that the runway approach lights or lights in the airport area were visible. Accidents were not considered where structural integrity, fire, loss of control, thrust or power, icing, or pilot incapacitation were involved or suspected.

The major common factor appeared to be that the accidents occurred at night (37) or in degraded daytime visual conditions (7). With regard to approach slopes, low approaches were the most common problem. In general, from distances of 5 miles to 1 mile from touchdown, 23 approaches were more than 100 feet below a 3° slope, 11 approaches were more than 100 feet above a 3° slope, and 10 approaches were within 100 feet of a 3° slope.

The most frequently referenced steep approach accident is the crash of a United Airlines 727 at Salt Lake City in 1965. The facts, as reported by the National Transportation Safety Board, were that the pilot had a history of poor judgement during landing, he was not following any recommended procedure, the final approach angle was as high as 9°, and the landing could have been saved if the pilot had taken any action prior to an altitude of 148 feet (122). Therefore this accident does not appear to justify non-use of properly developed VFR two-segment approaches.

The AOPA is concerned about possible wake turbulence hazards to light aircraft landing on the same runway where heavy aircraft are making two-segment approaches. Light aircraft have occasionally been forced out of control when flying behind and below heavy aircraft. Since instrumentation for two-segment approaches may be too expensive for light aircraft operators, a safety problem may exist. The FAA is conducting experiments to define this problem more accurately. In visual weather conditions light aircraft can maintain a flight path above the heavy aircraft by visual reference. In IFR weather, light aircraft not equipped with two-segment guidance equipment would probably have to be spaced farther behind when following a heavy aircraft conducting a two-segment approach. At several major airports either separate runways are provided for light aircraft or a non-interfering runway use plan is in effect to minimize the problem of wake turbulence.

Conclusion: Two-segment approaches provide significant noise reductions, are technically feasible, and are already in use in some segments of the air transportation system during VFR weather conditions. Some type of guidance equipment appears to be necessary and is available for VFR conditions (DME, VASI, or VAM). Completion and evaluation of the current NASA test program should result in equipment suitable for IFR two-segment approaches.

DECELERATING APPROACH

In a decelerating approach, the aircraft starts at a high speed and then thrust is reduced to nearly flight idle. The aircraft then slows down during the approach because of aerodynamic drag. The approach airspeeds can be controlled by progressively lowering flaps and landing gear as necessary. Figure 2-18 shows the resulting noise levels assuming a 3° decelerating approach.

The ALPA position is that the decelerating approach is never "stabilized," therefore it adds to the pilot's workload and detracts from his ability to properly judge the progress of the approach. As pointed out by Lockheed, the decelerating approach is best suited to aircraft with programmable automatic landing systems (1).

The Air California VFR procedure (127) is essentially a decelerating, two segment approach. To the task group's knowledge, however, this is the only routine use of this procedure and there have been relatively few flight tests of it. Very few aircraft are properly equipped to conduct IFR automatic decelerating approaches.

Conclusion: the decelerating approach is technically feasible but has not been proven adequate for widespread routine use. The decelerating approach does offer the potential for meaningful noise relief, however, so research and development work to make it acceptable for routine use should be intensified.

THRUST REVERSE LIMITATIONS

Communities located along the side of operational runways find thrust reverse noise to be objectionable, especially at night (74). Its sharp application makes it easily distinguishable from takeoff noise even though the level may be approximately 10 EPNdB lower.

Transport Aircraft have a certificated runway length in which they can safely land and stop. This distance is calculated <u>without</u> the use of thrust reversers and includes necessary safety factors. Figure 2-19 shows that in many cases these distances are considerably shorter than the runway length available. Using thrust reversers shortens these distances even further.

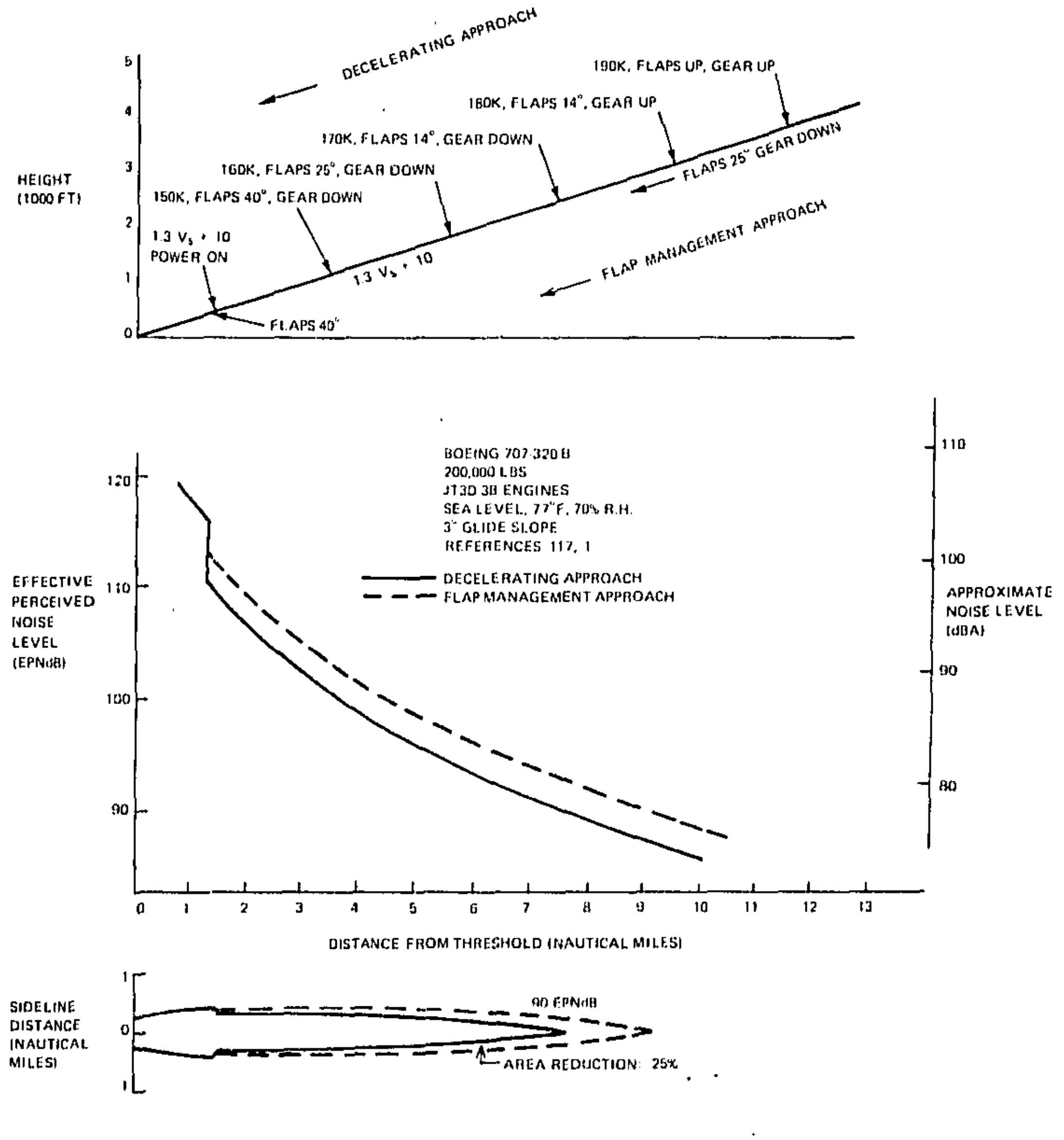

Figure 2-18. Noise Data for Decelerating Approach

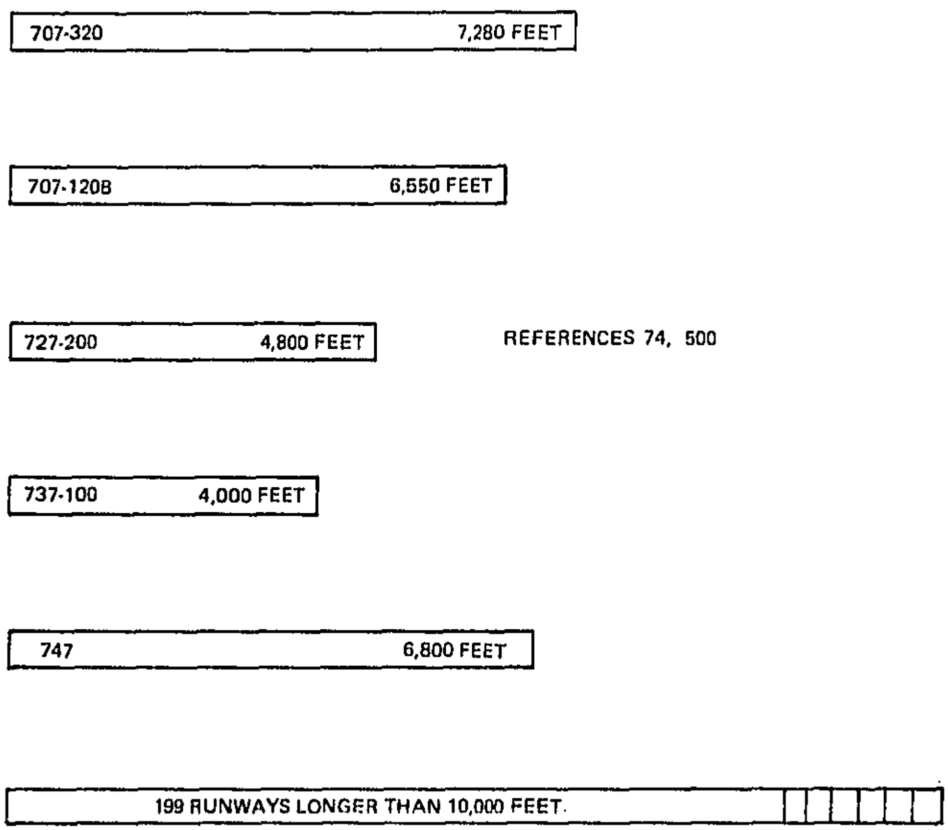

Figure 2-19. FAA Runway Lengths for Typical Aircraft Types
(Landing without thrust reversers)

ALPA and others contend, however, that in order for the pilot to use thrust reversers properly when required he should use them on every landing. Boeing points out (136) that it has been FAA policy to require that some effective additional retarding devi :: be available before they will allow credit for all the wheel brakes and spoile; s. Furthermore, some members of the task group argued that in many cases it is necessary to use thrust reverse in order to turn off the runway quickly so that another aircraft may land or depart. On the other hand, the Massachusetts Port Authority points out that runway and taxiway construction plans are based on certificated runway length and cannot be used as an excuse to require thrust reversal. Others have suggested that using a minimum amount of power during thrust reversal is of value in stopping the aircraft and creates less noise than full power thrust reversal.

It has also been pointed out that not using thrust reverse generally increases the taxi time and resultant noise and air pollution (128).

Two foreign airports (Zurich, Switzerland and Stuttgart, Germany) have established nighttime prohibitions against the use of thrust reverse (77).

There seems to be merit in the ALPA position that pilots maintain their proficiency by consistently deploying the thrust reversers. However, the extensive high power use of thrust reversers for landings on long, dry runways where there is a sideline noise problem and no air traffic control urgency appears to be unnecessary and undesirable. The tradeoff between sideline thrust reverse noise and aircraft taxi induced air pollution is one which can only be made at the local level and should be a consideration included in the airport certification process (see Section 3).

PROPELLER DRIVEN AIRCRAFT AND HELICOPTER OPERATIONS

Inasmuch as the vast majority of the aircraft noise problem occurs near airports with jet aircraft operations, almost all of the time in the task group was occupied with the jet noise problem. Nevertheless, people frequently report annoyance from propeller driven aircraft and helicopters. The complaints come most often from the vicinity of airports or heliports, but also frequently from instances of low altitude flight away from the airport (39, 66).

FAA AC 91-36 deals with this problem by recommending that pilots of fixed and rotary wing aircraft flying VFR maintain at least 2000 feet above noise sensitive areas whenever possible (27).

A comparison of noise from jet aircraft, propeller driven aircraft, and helicopters is given in Figure 2-20. It can be seen that jet aircraft are typically at least 10 EPNdB louder than (twice as loud as) the other types of aircraft; therefore it is natural that they have received the most attention.

In concept, the operational procedures for reduction of noise from propeller driven aircraft and helicopters are much the same as for jet aircraft: keep them as high as possible and at the lowest power settings possible. There are certain different constraints, however, as enumerated below:

1. In many cases the operators of general aviation propeller driven aircraft and helicopters are not financially able to install special electronic guidance equipment.
2. In most cases the operators of general aviation aircraft and helicopters do not have access to computer aided flight planning.
3. The training and proficiency requirements for pilots are not as high in general aviation operations as in air carrier operations.

For the reasons stated, operators of general aviation propeller driven aircraft cannot be expected to fly sophisticated two-segment approaches in IFR conditions or to compute the best climbout procedure for minimizing noise over a specified area. On the other hand, most of their operations are VFR, the aircraft are capable of descending at a steeper angle than jet aircraft, and noise levels are not so great that power cutbacks on climbout are as essential.

Helicopters are a special case in that a good deal of their noise annoyance comes from the "slap" of the large rotor blades. This generally occurs within a narrow range of airspeeds and descent rates, as shown in Figure 2-21. As indicated, a noise abatement approach, slightly steeper than a normal approach, can be made without entering the blade slap regime.

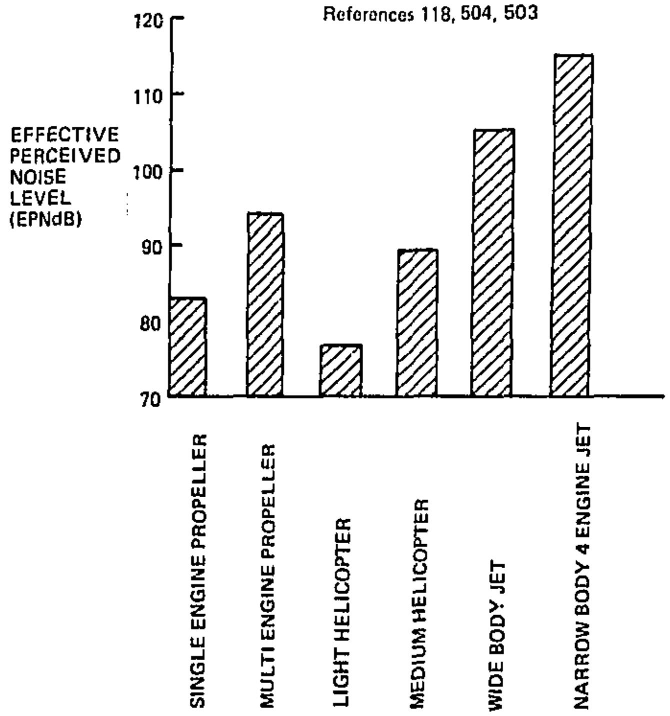

Figure 2-20. Typical Noise Levels at 1000 feet, Maximum Continuous Power

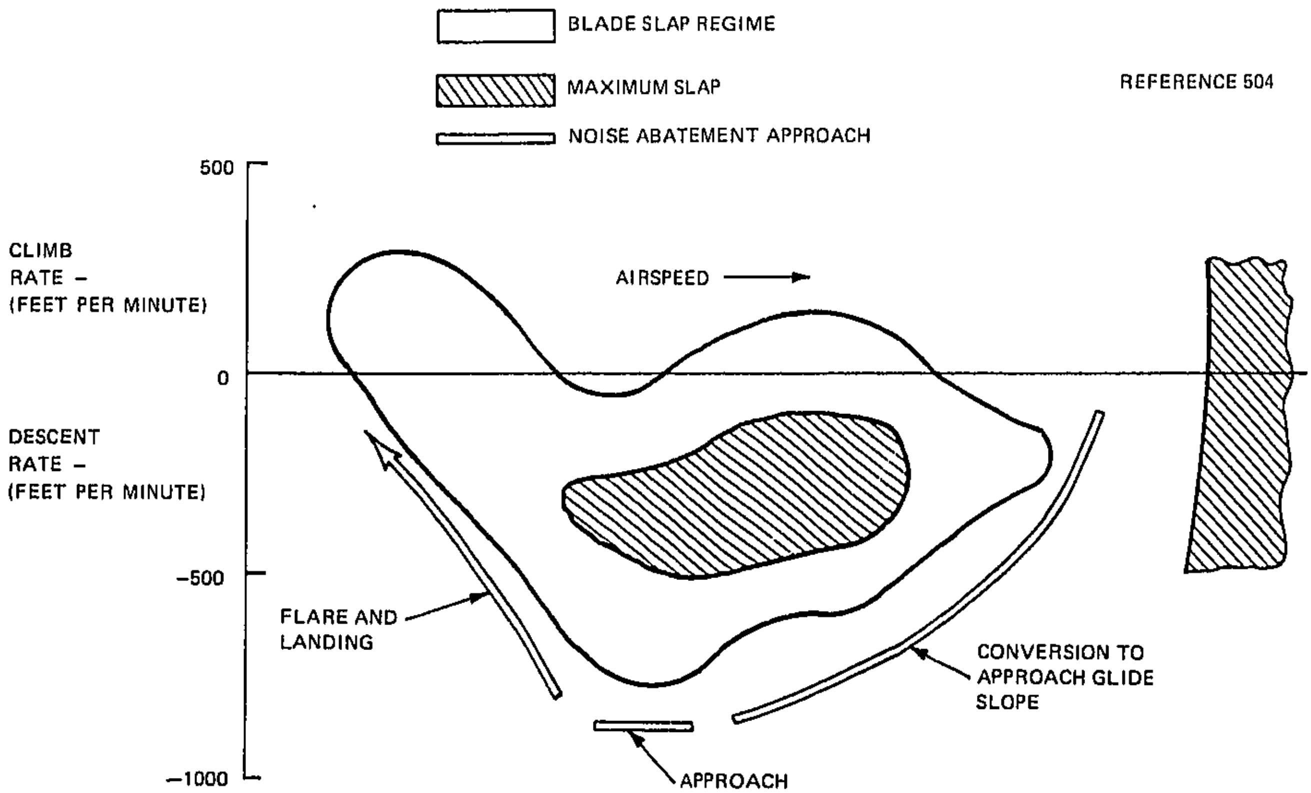

Figure 2-21. Helicopter Blade Slap Regime

Because of the near vertical nature of helicopter takeoffs, power cutbacks are not practical as a noise abatement measure. Noise reduction is achieved by a steep climb profile as shown in Figure 2-22.

In summary, then:

1. Noise from general aviation propeller aircraft and helicopters is not as extensive as noise from jet aircraft.

2. Departure procedures involving the steepest possible climbout angles provide the best possible noise relief for general aviation and helicopter takeoffs.

3. Approach procedures using the steepest possible angle will provide the maximum noise relief on landing (helicopters should avoid the blade slap regime). Visual Approach Slope Indicators (VASIs) set for an angle of 4° to 5° could be helpful for general aviation landing runways.

4. Enroute altitudes as high as possible will minimize noise away from airports and heliports.

5. Further study of this problem may be warranted as noise from air carrier and business jet operations diminishes.

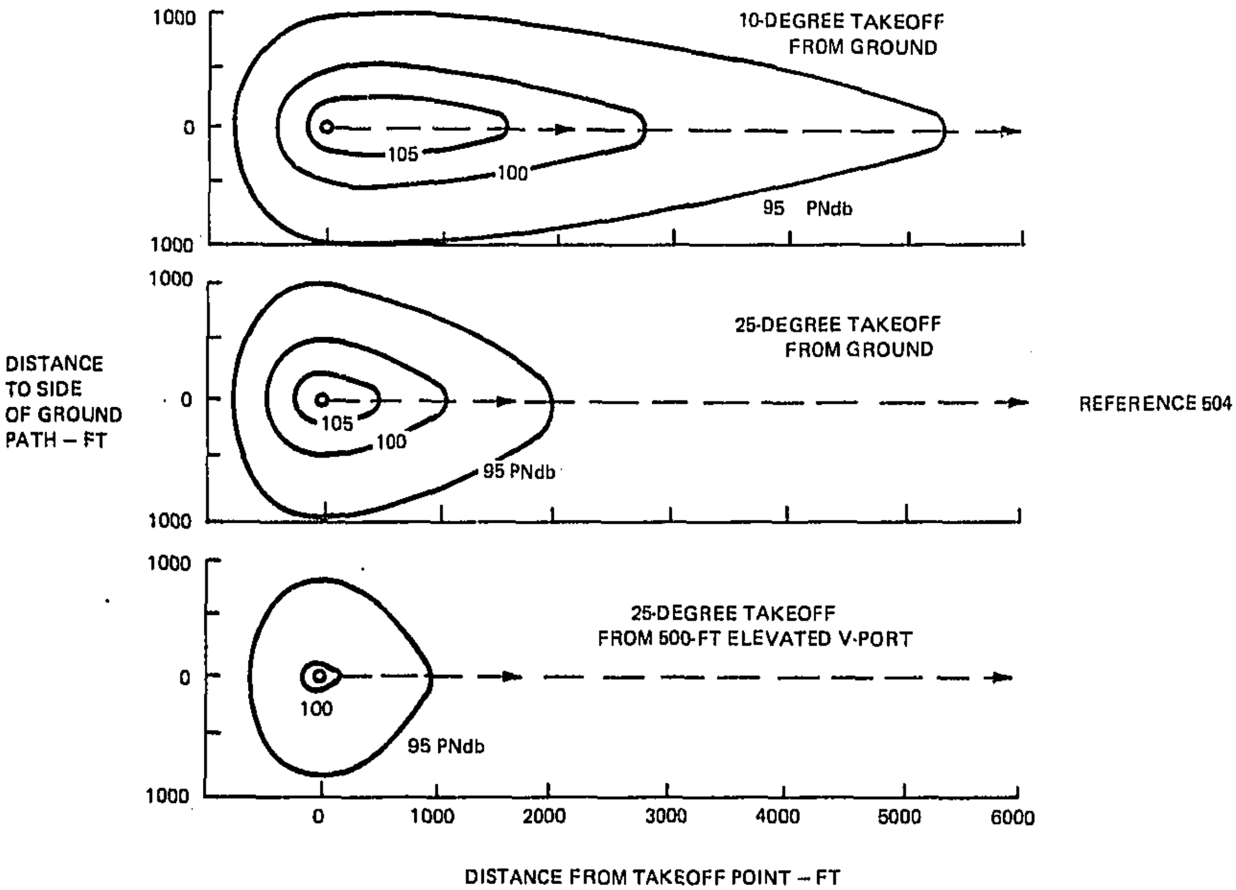

Figure 2-22. Noise Exposure Contours for Transport Proprotor VTOL

SECTION 3

AIRPORT NOISE CONTROLS

As was mentioned in previous sections, the majority of the aircraft noise problem is associated with jet airplanes. Similarly, most of the concern centers around airports that have jet operations. This study will therefore be most applicable to the 151 Air Traffic Hubs (175 airports) identified in Figure 3-1 and Appendix A. These hubs accommodated approximately 96% of the 160 million passenger enplanements in Fiscal Year 1971 (169). This does not mean that noise problems do not exist elsewhere: there are 798 points served by air carriers, 3,240 airports in the National Airport System, and more than 12,000 airports on record with the FAA (506). Many of the non-air carrier airports have business jet operations which can be very noisy. Nevertheless, the number of enplaned passengers is related to the population served by an airport, the number of operations, and probably is also related to the population density near the airport. Therefore the 175 airports in the "hub" network probably account for, if not 96%, at least a vast majority of the aircraft noise problem.

This section discusses the noise reduction potential of various measures available at the airport level. The EPA Aircraft/Airport Noise Study – Task Group 1 Report discusses the legal basis of these measures more fully (511). In general, that report indicates that the airport proprietor can legally institute any non-discriminatory and safe noise abatement controls on the use of his property. Furthermore, the Federal Government (but not the state or local governments) can prescribe noise standards (in terms of cumulative noise exposure) which must be met or bettered by the airport proprietor. Finally, the optimum combination of procedures for a local airport situation can only be determined by balancing the local and national needs for air transportation with the local and national needs for a quiet environment.

The FAA, airlines, and airport proprietors have instituted some of the controls listed below, but except in the case of the 1971 State of California Airport Noise Standards, there has not been any comprehensive long range noise planning.

Figure 3-1. Air Traffic Hubs, June 30, 1971

SCHEDULE LIMITATIONS

Limiting the number of operations each day is one means of reducing the cumulative noise exposure to communities. The FAA has established hourly quotas on IFR operations at John F. Kennedy, La Guardia, Newark, O'Hare, and Washington National Airports but these were for the purpose of alleviating congestion, not noise (501). The only airport known to be limiting schedules on its own authority and for noise abatement is Orange County, California where the limit is 38.3 average daily departures (based on an annual average) (140).

Schedule limitations are obviously capable of reducing the cumulative noise exposure (from aircraft) to any extent desired (in the extreme case-closing the airport). But it is equally obvious that closing airports would not be desirable from the standpoint of providing air service to the public. The value of L_{dn} for a single flyover is shown in Figure 3-2, and the variation of L_{dn} with number of operations is shown in Figure 3-3. It requires a halving of the number of flights to reduce L_{dn} by 3 dB (or the exposed area by 37 percent).

AIRCRAFT TYPE LIMITATIONS

Another tool available to airport proprietors is to restrict aircraft which create noise above a specified level from using any particular runway. The Port of New York Authority, for example, has a noise limit of 112 PNdB as measured at any of its monitoring stations. The Los Angeles International Airport has a policy which by December 31, 1974 will permit only aircraft which comply with FAR Part 36 Appendix C noise levels (51).

The takeoff, sideline, and approach noise levels of various aircraft types are shown in Figure 3-4 (see Reference 513 for the basis of these noise level estimates). Aircraft type limitations can achieve single event noise reductions of up to 18 EPNdB (comparing the approach noise levels of the 707-320B with the L-1011). The reduction of cumulative noise exposure (L_{dn}) depends on the proportions of noisy and quiet aircraft. Because of its logarithmic nature, the value of L_{dn} is dominated by the noisiest aircraft. As an illustration, Figure 3-5 shows that L_{dn} can increase by 10 dB or more if there is a wide range of aircraft noise levels, even though the average noise level remains the same.

The effect of aircraft type limitations at specific airports would be to generate a competition for the quietest aircraft types. A redistribution of aircraft types would most likely occur in the nationwide effort to achieve noise levels consistent with

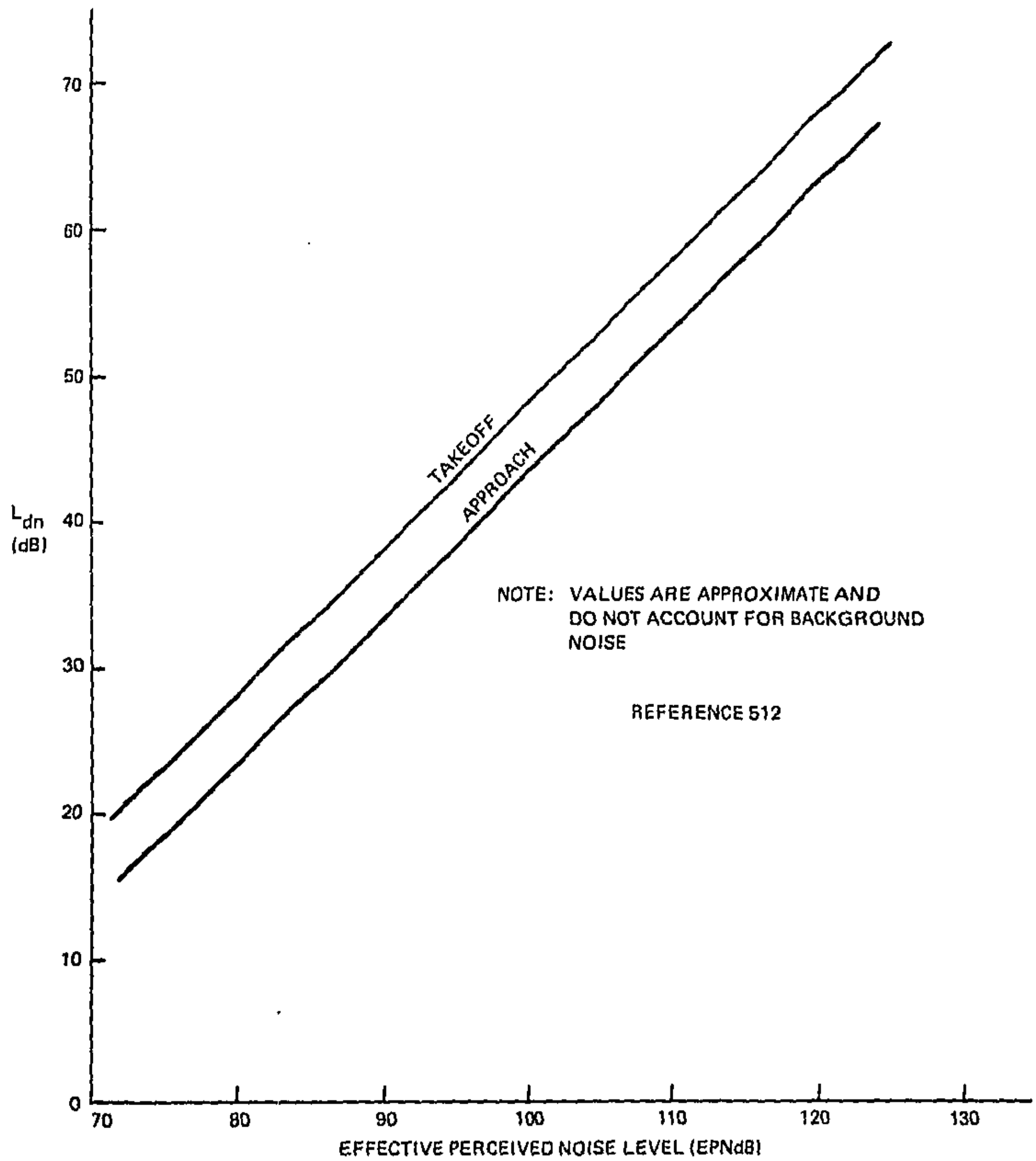

Figure 3-2. Cumulative Noise Exposure for a Single Flyover

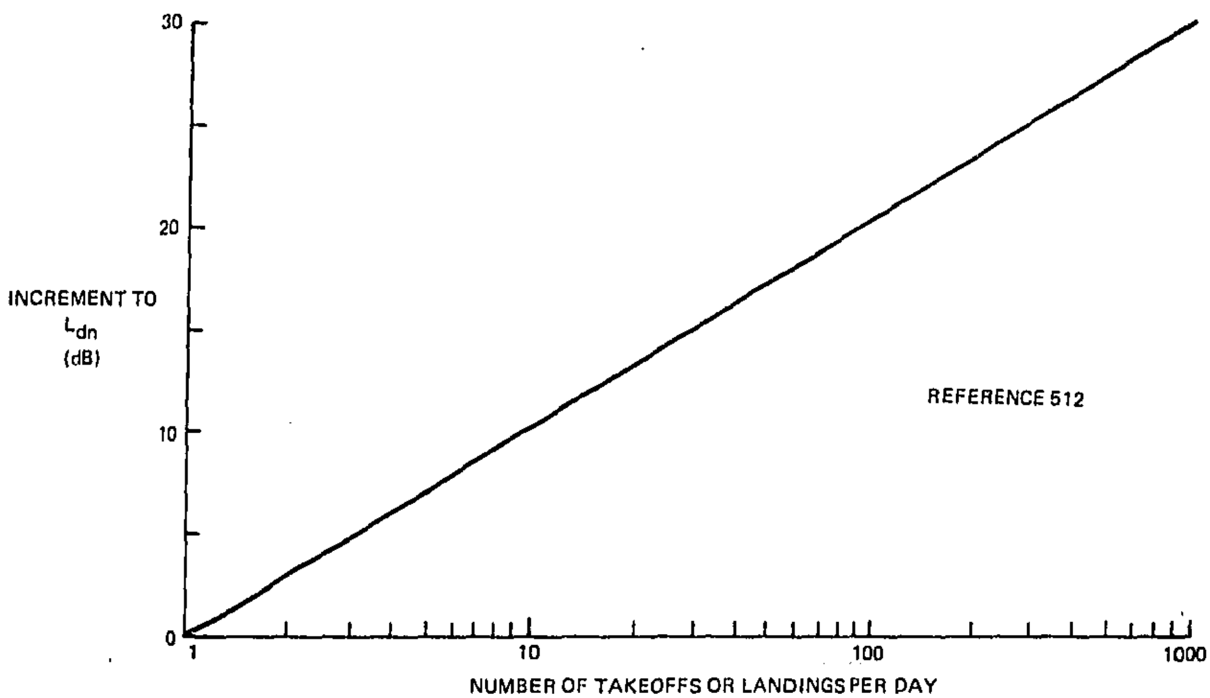

Figure 3-3. Effect of Number of Flights on Cumulative Noise Exposure

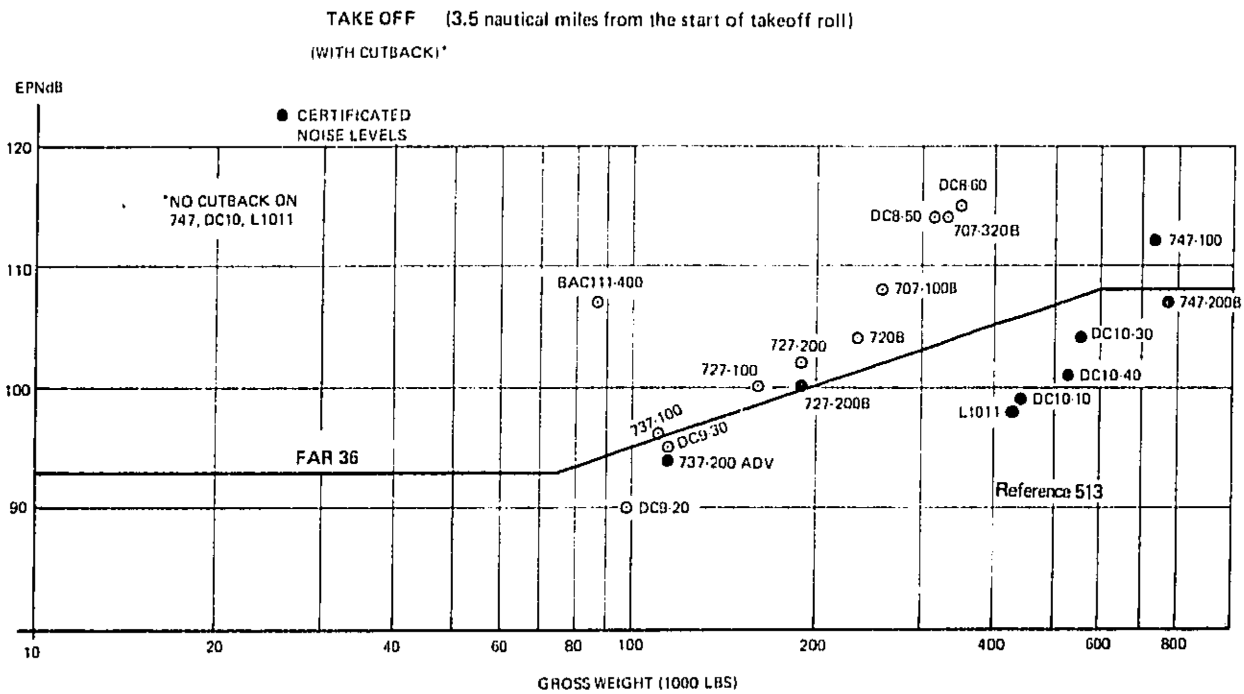

Figure 3-4. U. S. Air Carrier Fleet - Takeoff Noise Levels (Sheet 1 of 3)

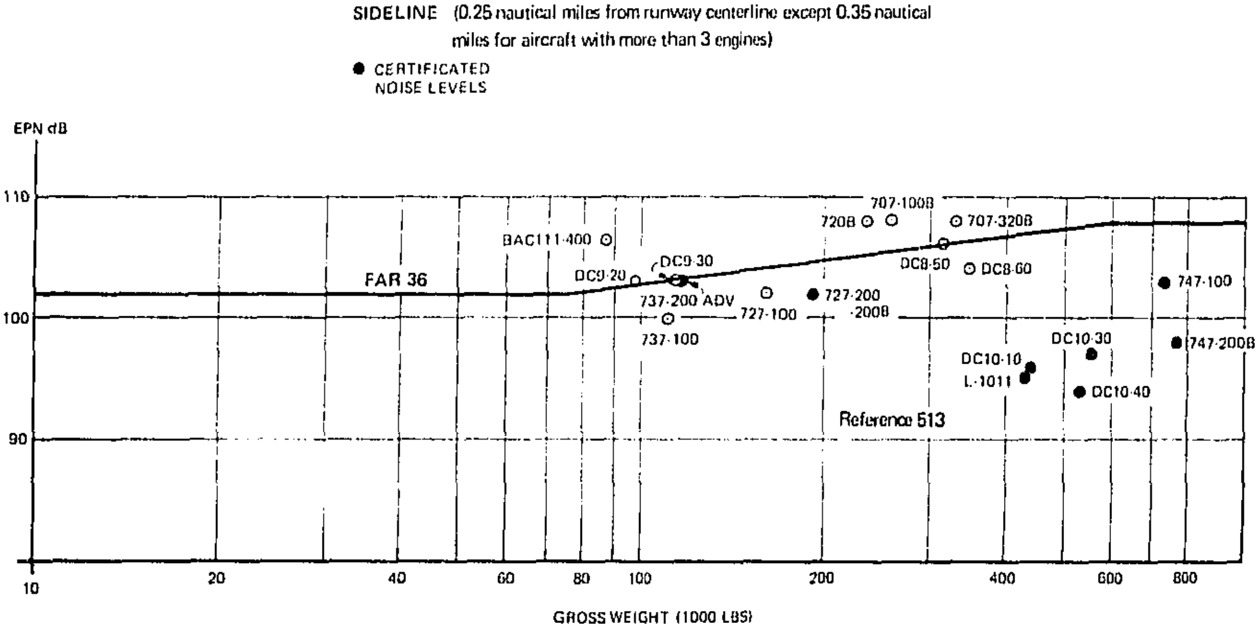

Figure 3-4. U. S. Air Carrier Fleet - Sideline Noise Levels
(Sheet 2 of 3)

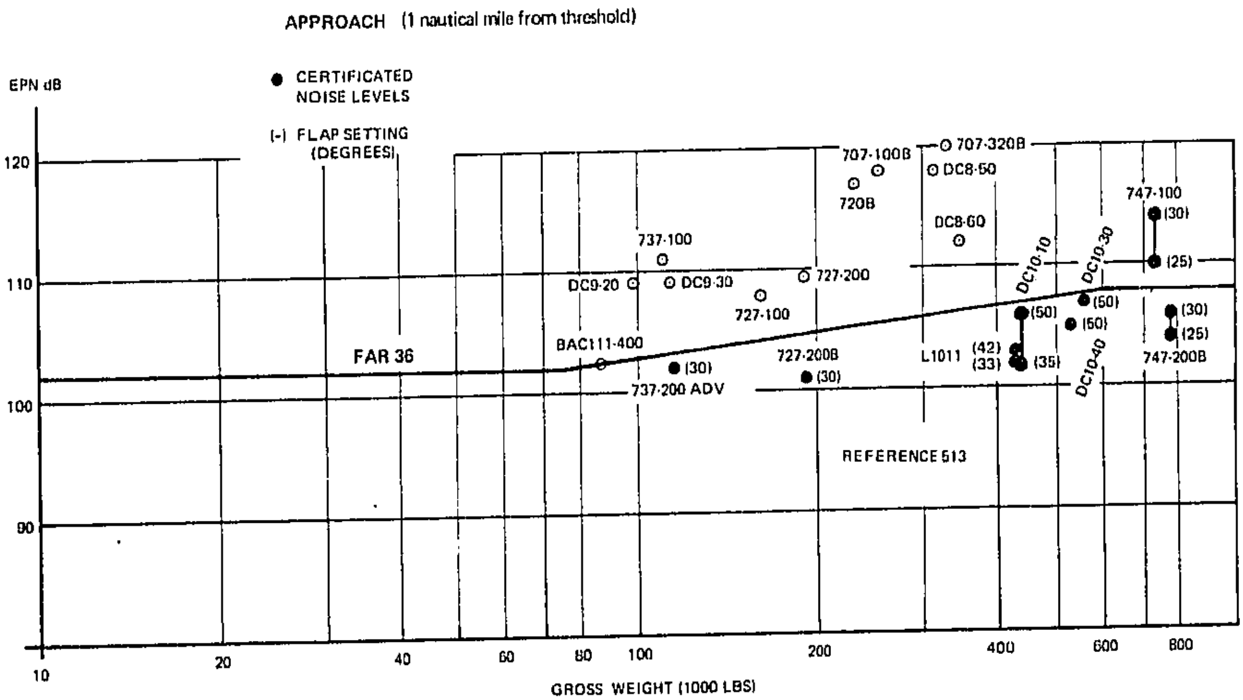

Figure 3-4. U. S. Air Carrier Fleet - Approach Noise Levels
(Sheet 3 of 3)

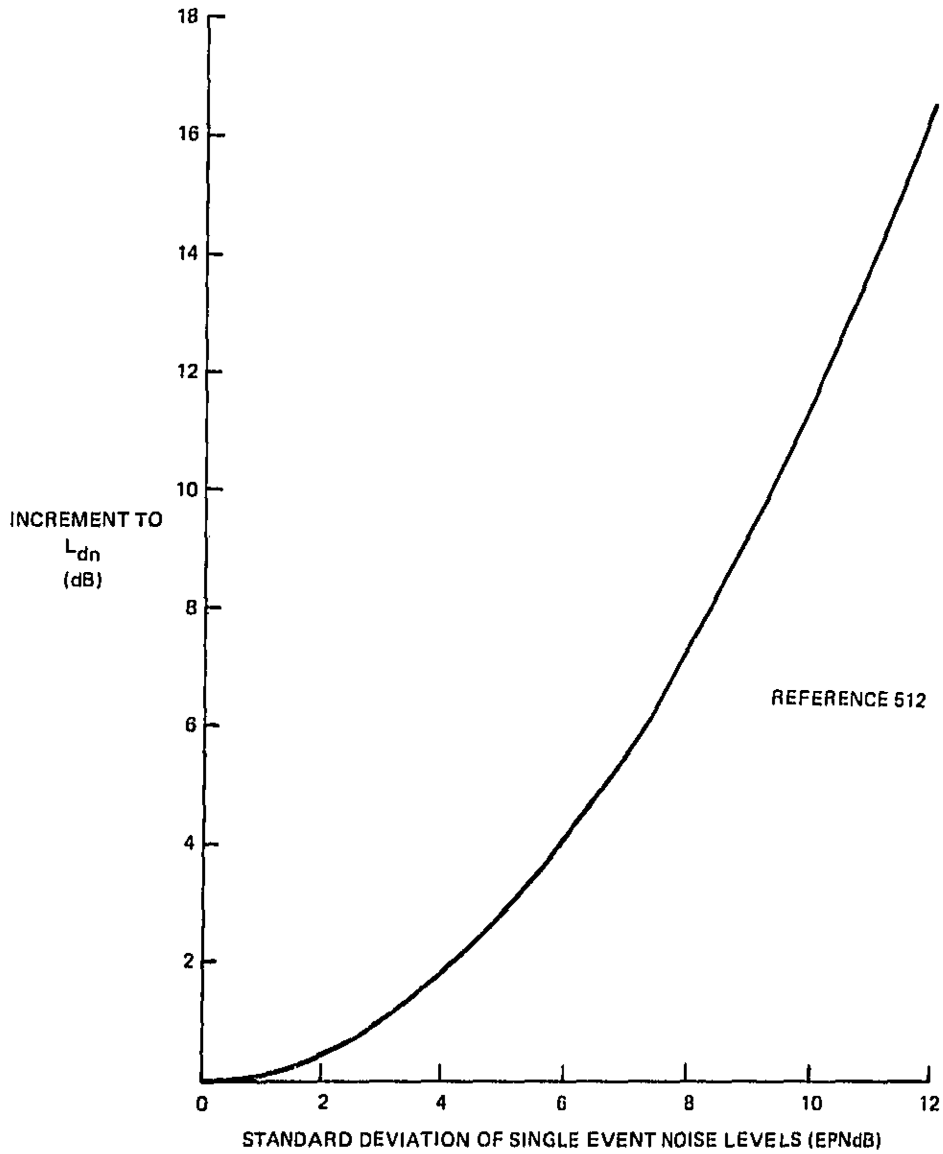

Figure 3-5. Effect of Standard Deviation of Noise Levels on Cumulative Noise Exposure (Normal Distribution)

Federal standards. Airports with the greatest noise problems would demand service by only the quietest types. Airlines ordering new aircraft would certainly include noise as a criterion, perhaps even pressuring the aircraft manufacturers to do better than Federal noise emission standards require.

NIGHT CURFEWS

The subject of nighttime curfews is a very controversial one. Obviously, a curfew would reduce airline service to the extent that passengers and freight could not arrive or depart during the curfew hours. Furthermore, even during the noncurfew hours it would not always be possible to depart at any hour for a non-stop flight to another airport with a similar curfew. The difficulties of rescheduling flights to avoid curfew hours, possible resultant less efficient utilization of aircraft, and the desire for a national system of airports open to all users at all times are other reasons put forth in opposition to curfews.

Nevertheless, even if every airport in the world had curfews for 8 hours each night, there would always be from 8 to 16 hours each day that one could fly nonstop from any one to any other. A more complete analysis of the costs associated with a nationwide curfew is contained in the EPA Aircraft/Airport Noise Study Task Group 4 Report (513). The legal authority for the airport proprietor to establish a curfew is discussed in the EPA Aircraft/Airport Noise Study Task Group 1 Report (511).

Figure 3-6 shows the noise reduction effectiveness of a complete curfew between 10 PM and 7 AM. For an airport with (initially) 11 percent nighttime operations the reduction in L_{dn} is approximately 3 dB (an area reduction of approximately 37 percent). (The 12 airports analyzed in Reference 503 had an average of 11% nighttime operations, ranging from 7% to 19%. (189).)

Two U. S. air carrier airports and five foreign air carrier airports are known to have some form of total or partial nighttime curfews. These are (77):

- Washington, D. C. (National)
- Orange County, California
- Stuttgart, Germany

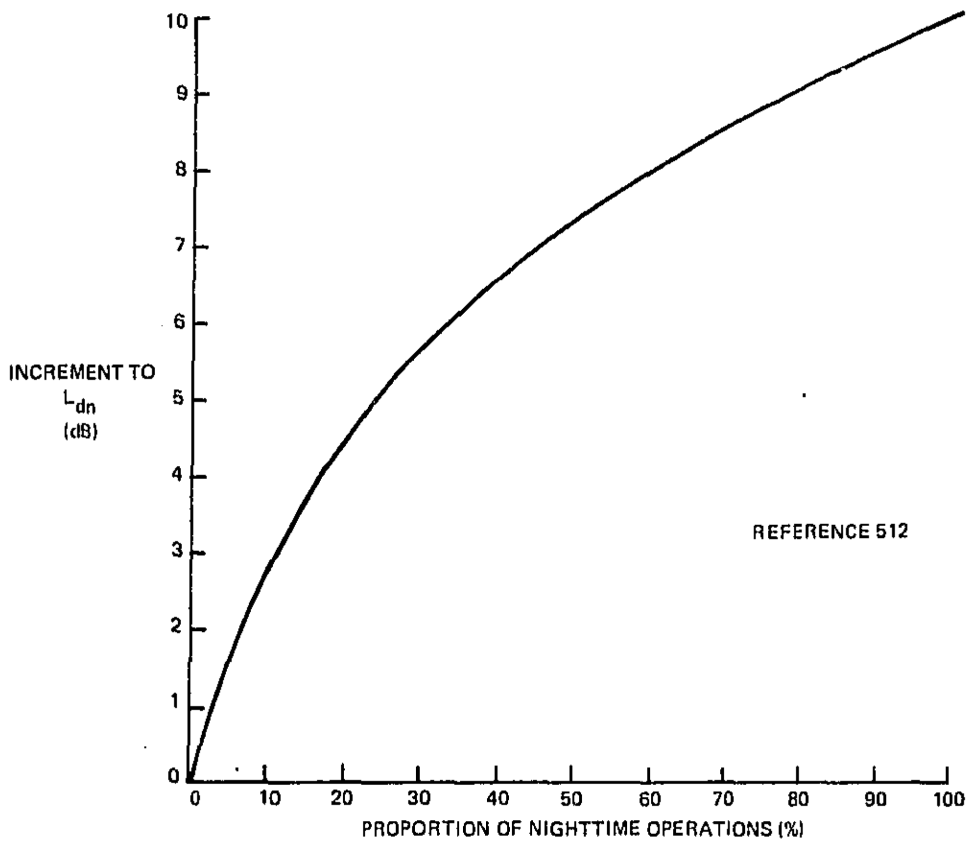

Figure 3-6. Effect of Night Operations on Cumulative Noise Exposure

- Paris, France (Orly)
- Osaka, Japan
- Tokyo, Japan
- London, England (Heathrow)

The Los Angeles International Airport's "over-ocean" preferential runway program is also a form of night curfew (see page 3-15).

There does not appear to be any widespread desire on the part of major airports to close at night, so in the absence of a Federal requirement, curfews will probably not proliferate at a rate too fast for airline schedules to adjust in a gradual way. As new aircraft noise abatement technology is introduced, the need for extensive curfews or other restrictions will be reduced, thereby encouraging the introduction of quieter aircraft at the earliest possible date.

AIRCRAFT WEIGHT OR TRIP LENGTH LIMITATIONS

The purpose of restricting aircraft to a maximum weight or a maximum trip length would be to reduce noise by allowing only flights which can climb rapidly (or, conversely, can cut back power the most). As can be seen from Table 3-1 and Figure 3-7, limiting 707-320 trip lengths from 4500+ to 2500 miles (or a corresponding weight limitation) would reduce noise by approximately 13 EPNdB at a distance of 20,000 feet from brake release.

One argument against such limitations is that more stops or more flights might be required and this would increase the cumulative exposure. But since doubling the number of flights increases the value of L_{dn} by only 3 dB, it can be seen that weight or trip length limitations may provide a noise benefit in some cases.

It should be pointed out that setting single event noise limits might accomplish the same purpose as weight or trip length limitations.

Table 3-1.

TAKEOFF PROFILES FOR VARIOUS TRIP LENGTHS
(Reference 503)

Aircraft Type	Examples	TAKEOFF PROFILE* Trip Length in N. Miles 0-500	500-1000	1000-1500	1500-2500	2500-3500	3500-4500	4500+
Large 4-engine turbojet transports	Boeing 707-120, and 720 Douglas DC-8-10, -20, -30, -40 Convair 880	B	B	B	C	D	E	E
Large 4-engine turbofan transports (standard and stretched)	Boeing 707-320 B, C Douglas DC-8-50, -8F, -60 series	B	B	B	B	C	D	E
Three-engine turbofan transports (standard)	Boeing 727-100	B	C	C	D	D		
Three-engine turbofan transports (stretched)	Boeing 727-200	B	C	D	D	D		
Two-engine turbofan transports	Boeing 737 Douglas DC-9 BAC 111	B	B	B	B			
Large "new generation" 4-engine turbofan transports	Boeing 747	B	B	B	B	C	D	E
Large "new generation" 3-engine turbofan transports	Douglas DC-10 Lockheed 1011	B	C	C	D	D		

*See Figure 3-7.

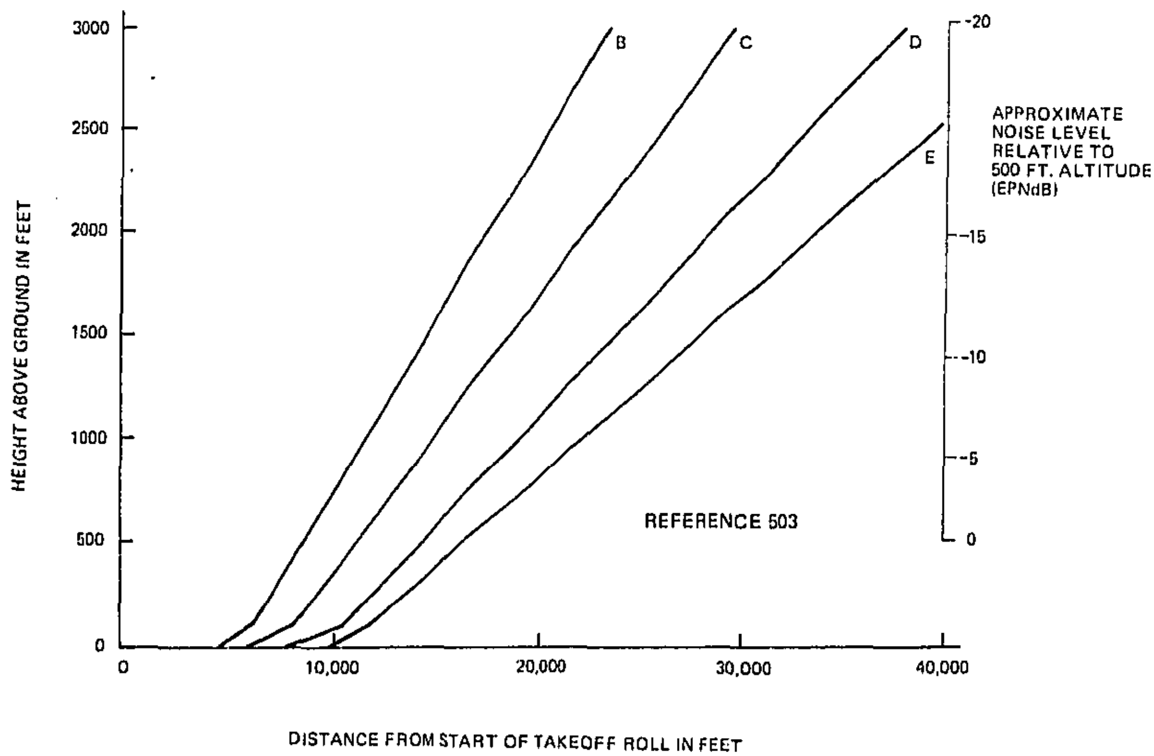

Figure 3-7. Generalized Takeoff Profiles for Jet Aircraft

PREFERENTIAL RUNWAYS

It is presently common practice for the FAA, after consultation with airport proprietors and airlines, to designate preferential runways. Use of these runways reduces the number of flights which take place over noise sensitive areas. Pilots are required by FAR 91.87(g) to use these runways whenever possible.

At the Los Angeles International Airport, for example, the proprietor has designated that during the hours of 11 PM to 6 AM all takeoffs and landings must take place on runways which place the airborne operations over water (51). This rule is effective whenever tailwind conditions are less than 10 knots, and can only be complied with by using opposing direction traffic over the Pacific Ocean. The program was instituted after an experimental program showed that during these hours the air traffic frequency was low enough to permit the over-ocean approaches and departures to be conducted safely. When the wind exceeds 10 knots, only aircraft which comply with the noise emission levels of FAR Part 36 Appendix C may take off or land over the populated areas to the east of the airport.

Obviously, the noise benefit of establishing preferential runways can vary greatly depending on the runway configurations and the configuration of noise sensitive areas in the vicinity of the airport. If runways can be designated which route air traffic entirely away from populated areas, the noise reduction can be almost complete (an L_{dn} reduction of up to 30 dB). In other cases, the best that can be done is to choose a runway which is slightly farther from populated areas or which affects fewer people.

All task group members concurred that preferential runways were a beneficial noise abatement measure. No generalizations concerning their use can be made other than that designation of preferential runways should take place after a careful analysis of the local noise (and air pollution) situation.

PREFERENTIAL FLIGHT PATHS

As with preferential runways, preferential flight paths can minimize noise impact by routings which avoid noise sensitive areas as much as possible. For example, at the Washington, D. C. (National) airport which is operated by the FAA, pilots making VFR approaches are required to follow the Potomac River to minimize noise.

As is the case with preferential runways, the noise benefit of preferential flight paths is greatly dependent on the local airport and land use configurations, making generalizations regarding the amount of benefit impossible. It can be said, however, that once preferential flight paths are designated, their use should be enforced to the maximum possible extent.

One question that often arises is whether it is preferable to concentrate flights in one corridor or to spread them out in many directions (98). From an analysis of the governing equations for Figures 1-1 and 3-3, it can be shown that as the number of different flight paths is increased, the total area enclosed within any L_{dn} contour goes up approximately as $n^{1/3}$ where n is the number of distinct routes. Therefore, the "least area" procedure is to concentrate the flights in one corridor. This will be the most beneficial from a noise standpoint if the population is uniformly distributed. However, if the population is sufficiently far from the runway, route dispersion may be advantageous in that it shrinks the length of the contours even though the total area is increased. Figure 3-8 shows a simplified airport situation where a single flight route, even though directed towards the most distant population, still causes noise exposure that could be eliminated by using multiple flight routes.

ENGINE RUNUP RESTRICTIONS

Restrictions on engine maintenance runups, especially at night, are in effect at many airports. They have usually been worked out cooperatively between the airports and the airlines. They are a useful tool for reducing noise exposure around airports.

The cumulative effect of engine runup restrictions depends on the type and number of runups and the type of restrictions.

NOISE BARRIERS

A wall or earth berm of sufficient height can reduce sideline noise from aircraft operating on the ground. On takeoff, the noise barrier has its major effect when the aircraft is on the ground and still not airborne when passing a point approximately 45° beyond a given location. On landing, the beneficial effect of a barrier extends both forward and backward from the point of thrust reverse application.

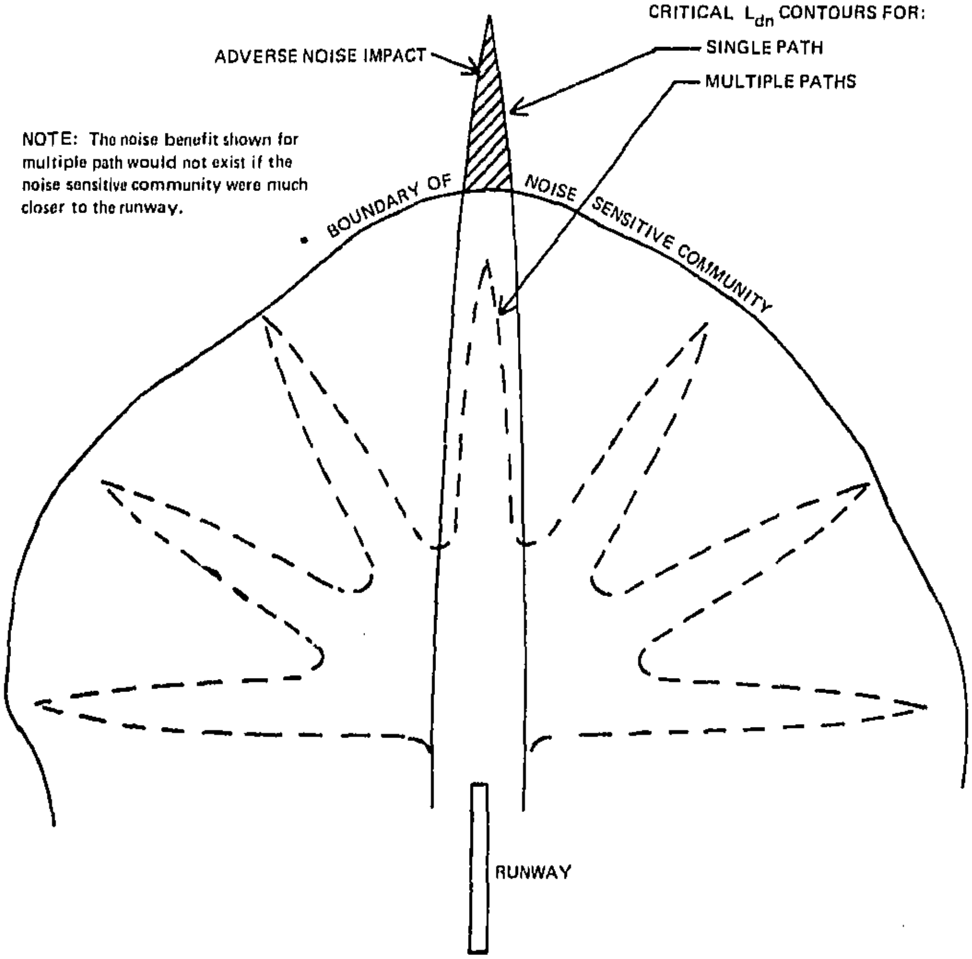

Figure 3-8. Effect of Route Dispersion on Noise Impact

Areas which potentially could be helped by a noise barrier at Los Angeles International Airport are shown in Appendix A (Reference 22). The Minneapolis St. Paul Airport Authority reports a 5 to 15 PNdB noise reduction from a "green barrier" consisting of a 15 foot high earth berm and 25 foot high trees planted 60 to 100 feet deep. The cost for this mile long green barrier was approximately $225,000. (163, 166).

ECONOMIC INCENTIVES

Airport use fees based on noise (rather than on aircraft weight as at present) have been proposed as an incentive measure to encourage use of the airport by quieter aircraft. A scheme such as this is being implemented at the Los Angeles International Airport (51). The use of economic incentives may be contingent upon the lease arrangements between the airport and the airlines.

The exact noise benefit of such measures is difficult to predict. However, it is likely that if the rate schedules are steep enough for the noisiest aircraft, they can be made as effective as desired. The greatest effect would probably be gained by having the schedules get steeper every year.

MONITORING AND ENFORCEMENT

If a regulation is established for maximum permissible noise exposure around airports, there should be an enforcement mechanism developed to insure compliance. Communities and airports (Orange County, Port of New York Authority, Los Angeles) are of the opinion that 24 hour monitoring is necessary to apprehend violators. On the other hand, ALPA contends that pilots are a professional group and will adhere as closely as possible to any regulations established.

Inasmuch as noise may also come from sources other than aircraft, monitoring is also necessary to determine accountability for an adverse noise environment. It would make no sense, for example, to ask that airport operations be reduced significantly if the L_{dn} values are dominated by truck noise.

Two kinds of monitoring were discussed in the Task Group: operations monitoring and noise monitoring. For direct enforcement of operational procedures, operations monitoring is most appropriate. This can be done by observation in the normal course of air traffic control. To actually provide a photograph of a radar display or other record of a procedural violation would be expensive. The ATA contends that the best operational noise monitors are the affected public. Proposals to paint the aircraft number on the bottom of the wings may merit attention in this regard (502, 509).

Noise monitoring is not entirely useful for enforcing operational regulations. This is because variations in weather conditions, aircraft weight, and many other factors affect noise levels even if a prescribed procedure is flown exactly. Noise monitoring is, however, the appropriate tool for enforcing noise level regulations or for gathering noise data for planning purposes.

Quite a number of foreign airports operate noise monitoring systems. Most have established single event noise level standards, some have lower noise standards for night operations. Only Frankfurt, Germany assesses any penalty against violators. The airports with monitoring systems are (77):

- London, England (Heathrow)
- Zurich, Switzerland
- Stuttgart, Free Republic of Germany
- Paris, France (Orly)
- Osaka, Japan
- Tokyo, Japan

The State of California requires that airports which have a noise problem monitor for both single event and cumulative noise. The single event monitors must be directly under the approach and departure paths and the cumulative monitors (at least 12) must be located approximately 1.5 miles apart on the noise impact boundary. Continuous monitoring is required where more than 1000 homes fall within the 70 CNEL (Community Noise Exposure Level, similar to L_{dn}) boundary. At least 4 weeks per year of continuous monitoring is required for other airports (38).

The costs of airport noise monitoring and enforcement as indicated by cost estimates where monitoring is being done are shown in Table 3-2. The large variances in the operating cost figures are primarily the result of differing philosophies regarding the enforcement staff necessary (i.e. around-the-clock or merely spot check).

The Orange County Airport management is of the opinion that monitoring has reduced noise by approximately 20 percent and monitoring any less extensive would be ineffective (99).

The Los Angeles International Airport management thinks that the monitoring required by California law is too extensive and too complex. They feel that fewer stations and less sophisticated equipment would be adequate (81).

It appears that a monitoring program which consists of one 24 hour monitoring period with one fixed or portable measuring station for every 1000 annual operations might be adequate. Such a measuring station, capable of recording L_{dn} and single event dBA is estimated to cost approximately $10,000. This is $22 per monitoring day assuming a useful life of 3 years and 150 days per year utilization. Further assuming that each day of monitoring requires 1 man-day for set up, 1 man-day for data reduction, one man-day for analysis, and the equivalent of 1 man-day for maintenance, supplies, and support services, monitoring costs (1973 dollars) for each 1000 annual operations would be $422 (based on $100 per man-day). Using a rounded figure of $500 per 1000 annual operations, total annual monitoring and noise planning costs for the airports listed in Table 3-2 would be (including equipment amortization or lease):

- Los Angeles $221,000
- Orange County 11,500
- Port of New York and New Jersey 350,000

Individual airports could obviously perform more extensive monitoring if they so desired.

Based on 5 million air carrier departures (10 million operations), the nationwide annual cost of such monitoring under this logic would be approximately $5 million.

Table 3-2

COSTS OF NOISE MONITORING

Airport	Annual Operations	Number of Stations	Equipment Costs	Estimated Annual Oper-ating Cost
Los Angeles, Calif.	443,000	15	$220,000	$100,000
City of Inglewood, Calif. (adjacent to Los Angeles)		5	50,000	60,000
Orange County, Calif.	23,000	5	58,000	85,000
Port of New York and New Jersey (Kennedy, La Guardia, Newark).	700,000	10	175,000	750,000

Conclusion: Cumulative noise exposure monitoring seems to be necessary to ascertain whether public health and welfare standards are being met. Single event monitoring may be desirable where an airport operator wishes to restrict the type of aircraft by noise level or discriminate between airport and non-airport noise sources. However, extensive monitoring systems or around the clock enforcement do not seem necessary. The best way to assure correct use of flight procedures is to have proper pilot training and pilot flight checks. FAA should include demonstration of noise abatement procedures as a part of pilot flight checks.

AIRPORT CERTIFICATION

It is the total effect of noise from many flights that creates the airport noise "problem". Therefore neither flight procedures nor engine noise reduction can by themselves assure that the problem will be solved. What is needed is a comprehensive plan for controlling all aspects of aircraft and airport noise. No such plans are known to exist except at the Orange County (California) Airport (19). Nowhere is there a requirement for such plans except in the state of California (510).

Part 139 of the Federal Air Regulations (FARs) requires that all air carrier airports be certificated by the FAA (502). At present this certification is in regard to aircraft and airport safety only although authority exists to include noise control. The EPA Aircraft/Airport Noise Study Task Group 1 Report (511) discusses the legal basis of airport noise certification more fully.

The advantage of airport certification with respect to noise is that it could provide the needed orderly planning process to ensure that noise standards are achieved in the most effective and safe manner. It also would provide a framework within which the optimum combination of procedures could be selected to solve the local noise problem. The airport authority would specify in an application for certification and then in an airport operating manual the procedures and limitations which are in effect or planned and the cumulative noise levels that are expected to result from airport operations. Public hearings would assure that local needs are considered. Final FAA approval would insure that safety and the integrity of the air transportation system are preserved.

Since the health and welfare of airport neighbors is an important aspect of air transportation, airport related noise should be included in the airport certification process.

SECTION 4

NATIONWIDE BENEFIT-COST ANALYSIS

CUMULATIVE NOISE BENEFITS AND COSTS

The noise abatement benefits and costs discussed in the previous two sections are summarized in Table 4-1. The table shows the range of single event noise reductions possible and also the range of reductions in the 90 EPNdB enclosed area for single flyovers.

Table 4-1 also shows the estimated nationwide reduction in the $L_{dn} \geq 65$ and 75 (NEF 30 and 40) areas (the symbol $\geq$ means "equal to or greater than"). For the airport related procedures (curfews, schedule limitations, etc.), no attempt has been made to estimate the nationwide effect of each one, since it cannot be known in advance which combinations will be selected as most beneficial at each airport. The combined effect of these procedures is estimated to be an area reduction of 30%, although it could be as high as 50% (or even higher at specific airports). The estimate is based on reducing the percentage of night flights from 11% to 6% (reduces L_{dn} by 1 dB), reducing the total number of flights by 20% (reduces L_{dn} by 1 dB and could increase load factors assuming a constant level of demand), and using the other airport options to achieve an additional 1 dB reduction in L_{dn}. (The total of 3 dB reduction in L_{dn} actually corresponds to more than a 35% area reduction; other combinations of airport options could also have been used.) For the flight procedures, the nationwide estimates are based on a hypothetical "average airport" having a 2.75° ILS glide slope and 250 departures (or landings) per day. At specific airports, the effectiveness may be greater or smaller as shown in Figure 4-1.

The "Area Coefficient" in Figure 4-1 is the fraction of the L_{dn} area that remains after implementation of the specific noise abatement procedure (it is the difference between 100 percent and the area reduction). The effectiveness of flight procedures on L_{dn} areas can be seen to be dependent on the number of operations. For example, the two segment approach procedure is most effective at the busiest airports because the $L_{dn} \geq 65$ and 75 areas extend well beyond the point of transition from 6° to 3° approach angle. Power cutback departure procedures become effective for higher values of L_{dn} at the busier airports as these contours extend beyond the power cutback point.

Table 4-1

SUMMARY OF NOISE BENEFITS AND COSTS

Procedure	Single event noise reduction*	Single event area reduction (90 EPNdB)*	Estimated nationwide $L_{dn} \geq 65$ takeoff or landing area reduction*	Estimated nationwide $L_{dn} \geq 75$ takeoff or landing area reduction*	Unit Costs**	Units	Nationwide Costs**
Reduced Thrust Takeoffs	0-2 dB	0-20% sideline only	1%	-	possible engine wear savings	-	-
Power Cutback Departure	0-7 dB	0-15%	10%	6%	probable fuel savings***	-	-
Reduced Flap Settings on approach	0-5 dB	0-30%	20%	6%	probable fuel savings	-	-
Increased Initial Approach Altitudes	0-10 dB	0-25%	10%	-	-	-	-
3° ILS Glide Slopes	0-3 dB	0-25%	15%	15%	$50,000 per runway for system change	100 runways	$5 million
					$6,000 per runway for flight check	100 runways	$1 million
					probable fuel savings		
3.5° ILS Glide Slopes	3-6 dB	25-44%	35%	35%	$50,000 per runway for system change	200 runways	$10 million
					$6,000 per runway for flight check	200 runways	$1 million
					or		
					$200 per delayed flight	3500 delayed flights per year	$7 million per year
					probable fuel savings		
6°/3° Two Segment Approaches	0-17 dB	50-75%	64%	25%	$60,000 per runway for DME	200 runways	$12 million
					$31,400 per aircraft for glide slope computer (IFR only)	1200 aircraft	$38 million
					$9,000 per aircraft for V-Nav as addition to R-Nav (IFR only)	1200 aircraft	$11 million
					probable fuel savings	-	-
Decelerating Approaches	0-3 dB	10-25%	15%	5%	Undetermined	-	-
Thrust Reverse Limitations	0-10 dB	0-75% sideline only	-	-	possible brake wear cost	-	-
Preferential Runways	0-30 dB	0-100%					
Preferential Flight Paths	0-30 dB	0-100%					
Night Curfews	-	-	30%	30%			
Aircraft Type Limitations	0-18 dB	0-84%					
Schedule Limitations	0-30 dB	0-100%					
Trip Length Limitations	0-13 dB	0-65%					
Airport Certification					$500 per 1000 operations	10 million operations per year	$5 million per year

* Noise reductions or area reductions are not necessarily additive: see text. The symbol ≥ means "equal to or greater than"

** All costs (savings) in 1973 dollars.

*** See text for discussion of fuel savings.

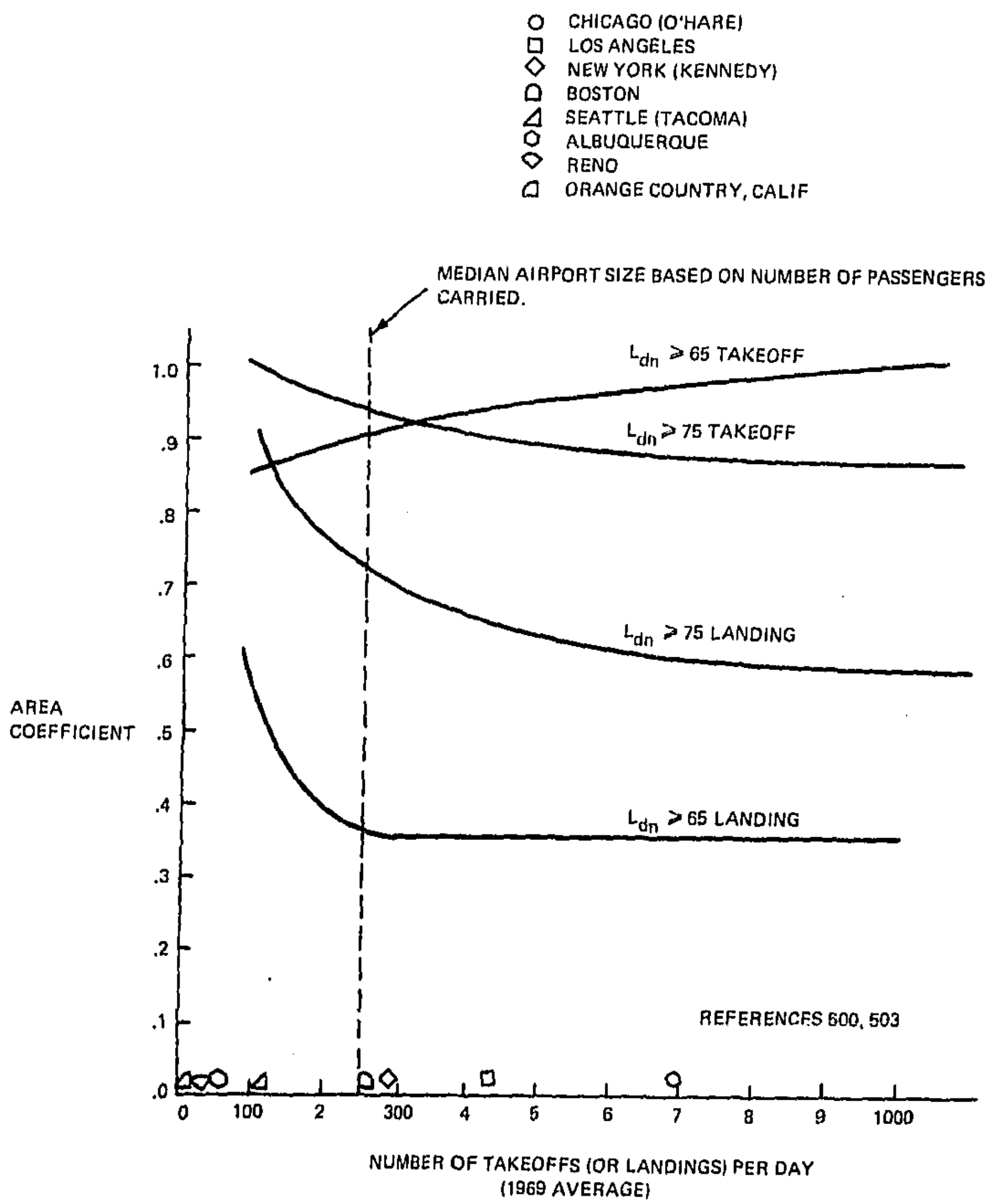

Figure 4-1. Procedural Effectiveness Related to Airport Activity

It should be pointed out that area reductions through combined procedural techniques are not additive. In some cases procedures are not independent. For example: increased initial approach altitudes are assumed as a part of two segment approaches, reduced flap settings and higher glide slopes are not as effective if two segment approaches are used, and reduced thrust takeoffs are not consistent with power cutback climbouts.

The proper method for determining the effectiveness of combined independent procedures is to multiply the corresponding area coefficients together. Takeoff and landing coefficients cannot be directly combined, however, because the takeoff areas are about three times as large as the landing areas. At airports where takeoff and landing directions are variable because of variable wind conditions (the majority of airports), takeoff noise dominates the L_{dn} areas, and a 64 percent reduction in landing $L_{dn} \geq 65$ area reduces the total $L_{dn} \geq 65$ area by only about 13 percent (based on equal distribution of takeoffs and landings) (144). This is computed by adding on an energy basis the "area average" noise levels as determined from Figure 1-1.

The noise benefits shown in Table 4-1 are considered to be conservative and to underestimate the actual potential nationwide area reductions. This is so for two primary reasons. First, the effectiveness of takeoff and landing procedures shown in Figure 4-1 is based on Reference 503, which made no attempt to optimize the procedures for each airport. Secondly, the area reduction estimates are dominated by the less effective takeoff procedures as discussed in the previous paragraph. Although this takeoff domination may be theoretically correct, it does not necessarily reflect the real world situation. In fact, there appears to be evidence that approach noise is the greater problem by a ratio of two to one at the largest airports (171).

The conclusions to be drawn from the foregoing analysis are that noise abatement procedures are more effective for the $L_{dn} \geq 65$ area than for the $L_{dn} \geq 75$ area. The most important procedures are power cutback climbouts and two segment approaches, which, when combined, reduce the $L_{dn} \geq 65$ area by approximately 21 percent and the $L_{dn} \geq 75$ area by approximately 9 percent. The 3.5° ILS glide slope is the most effective flight procedure for reducing $L_{dn} \geq 75$ areas, but for the most part significant reductions in the number of people exposed to $L_{dn} \geq 75$ will be dependent upon quieter aircraft and land use changes.

ANALYSIS OF ALTERNATIVES

To assess the overall implications of any of the proposed noise abatement solutions discussed above, an analysis of total costs, both economic and social, must be accomplished. This analysis must include the effects of a time-phased implementation plan. Such an analysis is accomplished below for four alternative procedural options. The options considered are:

1. Null Case (Do Nothing)

   This alternative is characterized by normal attrition and replacement of aircraft. There would be no regulations adopted. Research on operational procedures and source noise abatement would continue but implementation would be left to the discretion of the airlines.

2. Normal Effort Case

   This alternative is similar to alternative number 1 except that there is more emphasis placed on rapid research, pilot education is emphasized harder, and regulations are adopted as they become accepted standard operating practice for most airlines.

3. Accelerated Effort Case

   This alternative is similar to alternative number 4 below except that the time of implementation is stretched out. Many of the same regulations would be adopted, but the effective dates would be made later to allow more time for research, experience, technology, and economics to overcome any presently unresolved problems.

4. Maximum Effort Case

   This alternative is characterized by the attitude that money is no object. Strict regulations would be adopted and made effective immediately or as soon as production would allow. The regulations would include departure and steep approach procedures immediately in VFR conditions, immediate glide slope increases to 3.5^{o}, rapid installation of equipment to permit IFR two segment approaches, thrust reverse restrictions, initial approach altitude restrictions, and airport certification requiring rapid reduction of the area exposed to L_{dn} levels above the Federal standard.

Figures 4-2 through 5 indicate the schedules that would be associated with instituting the procedures associated with each option.

Figure 4-6 shows the expected reduction in the area enclosed within the $L_{dn} = 65$ contour as a result of each option.

For each of these procedural options, some assessment is required of the costs of implementation as well as the "public costs of noise." The viewpoint is taken that with the presence of noise a cost appears in either the utility or production functions of those exposed for which they are not recompensed; i. e., costs fall on economic activities other than those which produce the cost. The presence of aircraft noise is a cost because it either reduces the utility or values of services that individuals receive from properties exposed to this noise or it reduces the quality and delivery of public services, e. g., educational and medical services, and other production functions. In economic terms, aircraft noise is a technological externality. Economic welfare and efficiency principles suggest that the social costs created by such noise be internalized into the production functions for air transportation services, and that the users of these services will then make rational decisions that translate into new demands for transportation services based on the full costs of providing such services.

At this point in time, there do not exist sufficient data to estimate the demand curve for a quiet environment. Consequently, no attempts are made here to equate the demand for quiet with that amount of quiet which can be supplied by operational procedures. What is investigated is the amount of public costs of noise that will not be incurred if various operational procedures are implemented.

Several different means of estimating the cost of noise are employed in the following analyses. In addition, two different techniques of estimating the acoustical benefits are used: these benefits may be measured by the number of people no longer exposed to $L_{dn} > 65$ after implementation of the operational procedures (without regard to how much their environment has improved) or by the average noise reduction felt by all people within the $L_{dn} = 65$ contour.

First, the "avoidances of public costs" (or "social benefits") are developed using hypothetical unit values of the costs of noise to people of \$1/person/year, \$10/person/year, \$100/person/year and \$1000/person/year. Note that no provision is made for variable costs with differences in L_{dn} levels. For this analysis, the avoidance costs

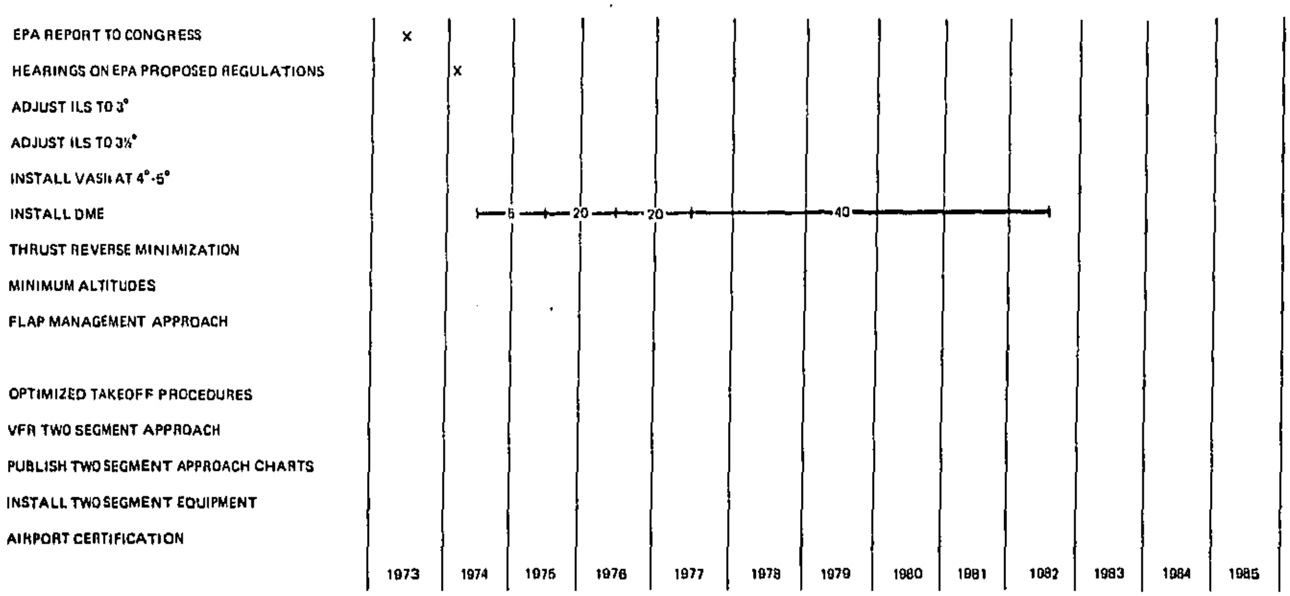

Figure 4-2. Null Case Schedule

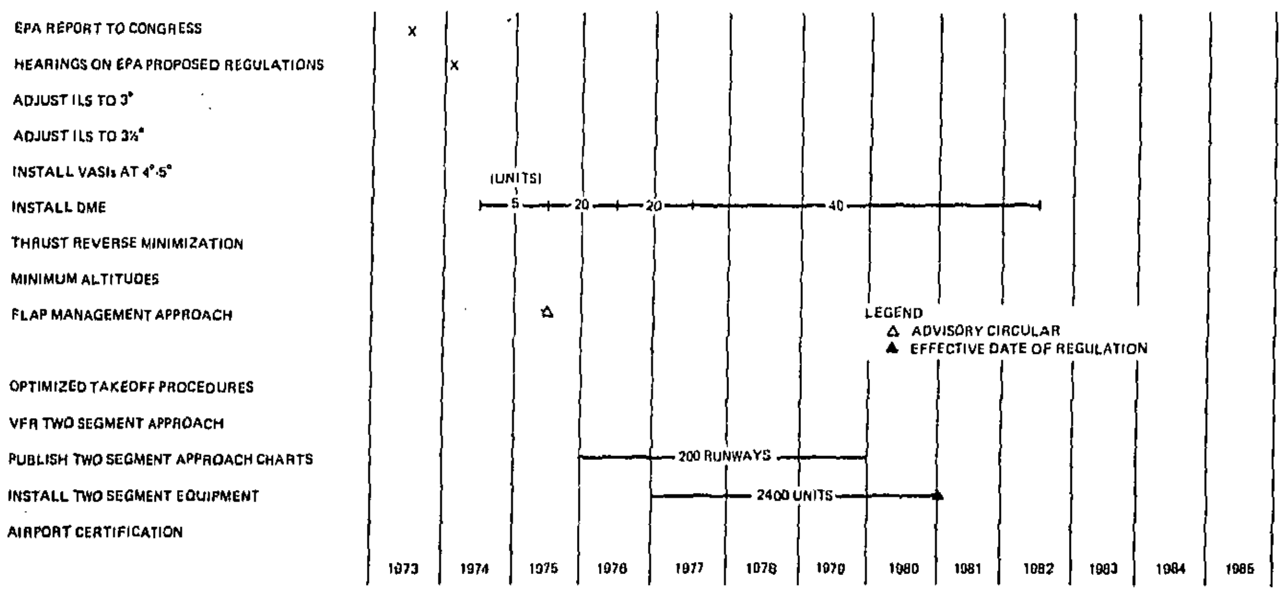

Figure 4-3. Normal Effort Schedule

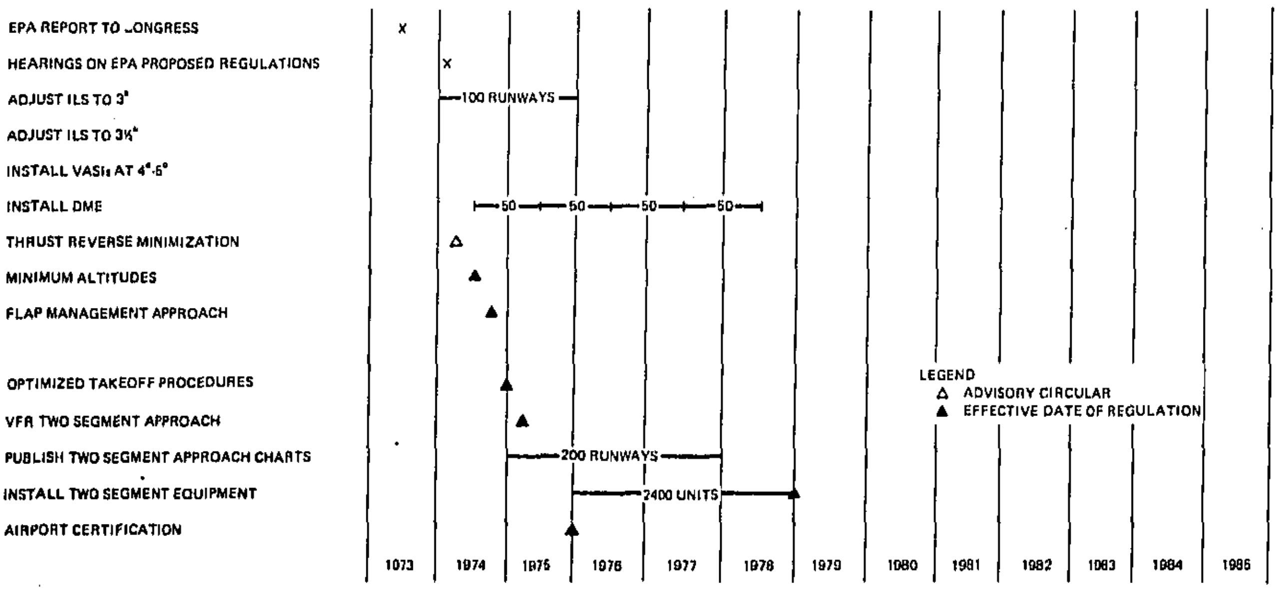

Figure 4-4. Accelerated Effort Schedule

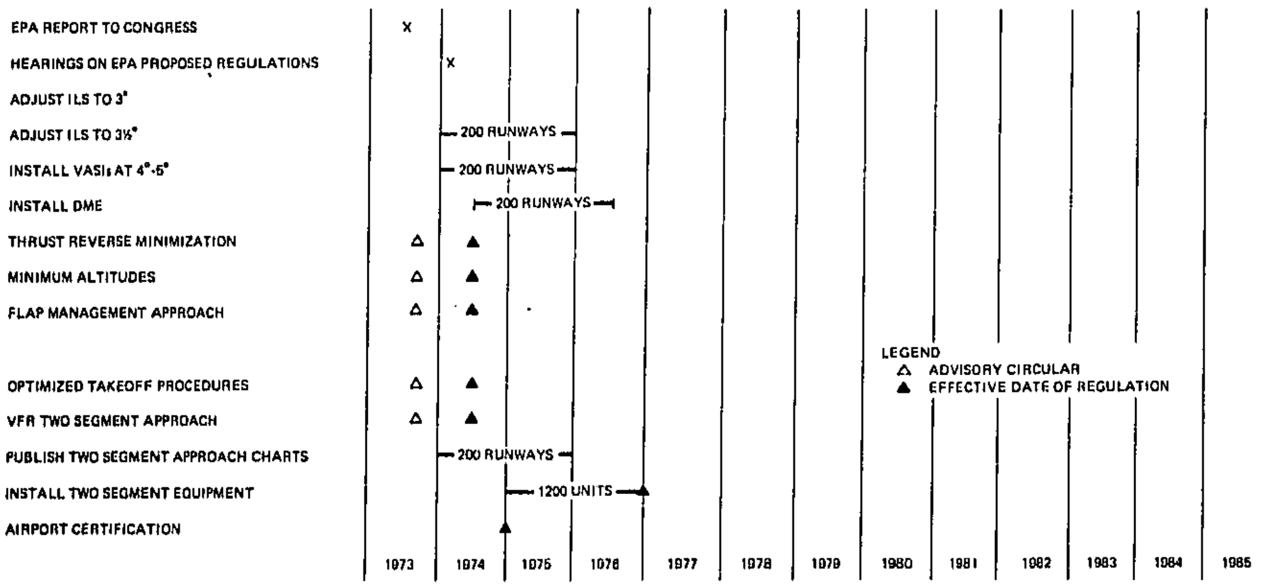

Figure 4-5. Maximum Effort Schedule

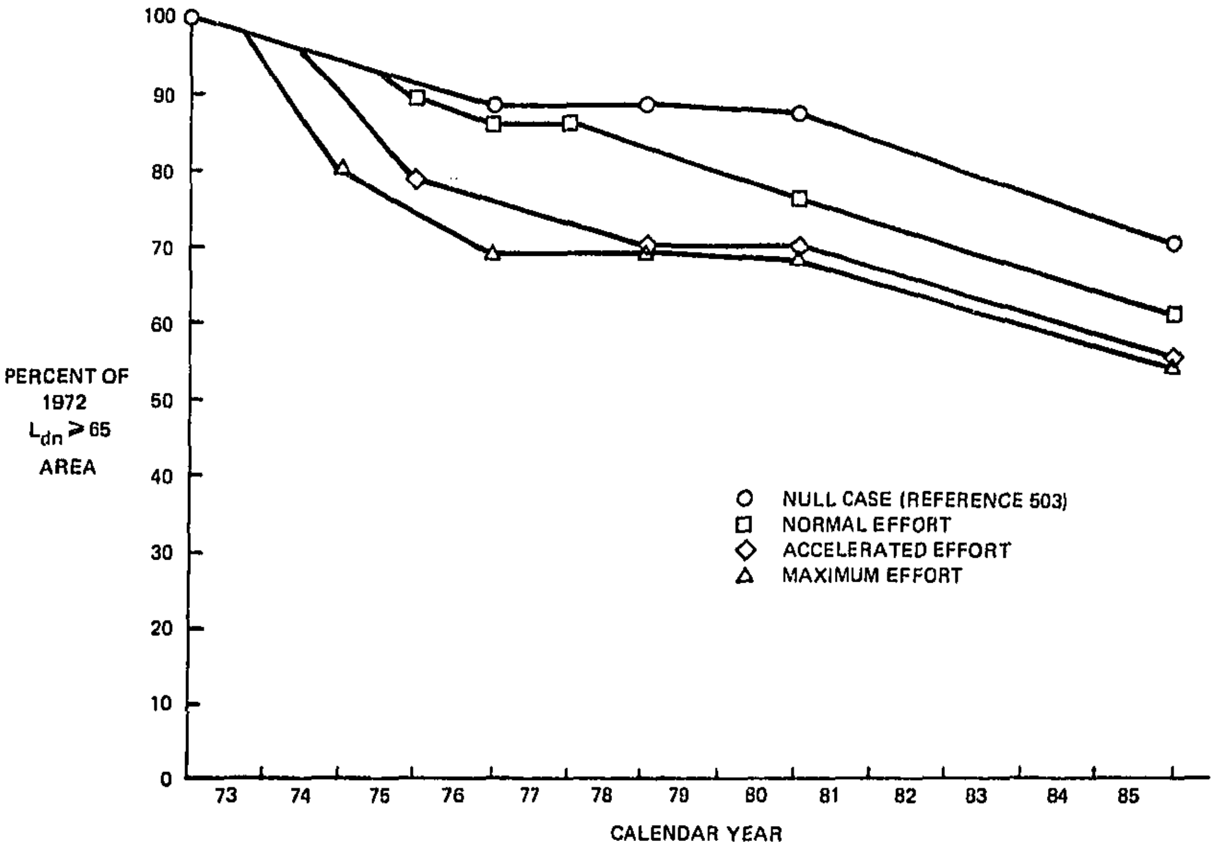

Figure 4-6. Procedural Reductions in Cumulative Noise Exposure

are based upon the number of people no longer exposed to environments of $L_{dn} \geq 65$.* For the purposes of this investigation, the Reference 512 estimate of 7.5 million people exposed to aircraft noise above $L_{dn} = 65$ dB in 1972 will be used.** In developing the population protection estimates, a static 1972 population is assumed and, further, it is assumed that the number of people no longer exposed to the $L_{dn} \geq 65$ dB environment is proportional to the area removed from this environment due to the implementation of operational procedures.

Tables 4-2 through 5 list the basic cost and benefit data for each of the four options. In Table 4-5 an additional assumption is made that to accomplish two-segment equipment installation in two years would increase the costs by $34 million. This estimate is based on unscheduled downtime for 1200 aircraft, out of service costs of $7000 per day, and installation time of 4 days per aircraft (516, 156).

A further assumption in Table 4-5 (Maximum Effort) is that a 3.5° ILS either (a) does not result in increased weather minimums, or (b) if it does result in increased weather minimums it is only installed in a few critical locations, in which case the estimated additional aircraft delay cost of $7 million per year accounts for both passenger inconvenience and aircraft operating costs. (All other procedures are to be instituted on a "non-interfering" basis so that there are no hidden passenger inconvenience costs in any procedures except possibly the 3.5° ILS.)

To compare costs and public "benefits" which are incurred and realized at different times, the technique employed was that of discounting to present values the future streams of these two elements. A rate of inflation of 3% per annum was assumed for each element. Implementation costs were discounted at an 8% per annum rate and the public benefits discount rate assumed was 10%.

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*Recall that this is the cumulative noise level at which operational procedures have their relatively greatest effect.

**It is recognized that aircraft may not always be the dominant source of noise. A later sensitivity analysis will examine this point.

Table 4-2

NULL CASE BENEFITS AND COSTS
(all figures except lines 1 and 2 are in millions of 1973 dollars)

	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	Totals 1985
Benefits (% 1972 $L_{dn} \geq 65$ area)*	0	0	0	0	0	0	0	0	0	0	0	0	0
Benefits (People no longer exposed to $L_{dn} \geq 65$)													
Benefits at $1/person/yr													
Benefits at $10/person/yr													
Benefits at $100/person/yr													
Benefits at $1000/person/yr													
Install DME			1	1	1	1	1						5
Total Costs			1	1	1	1	1						5

* The symbol ≥ means "equal to or greater than"

Table 4-3

NORMAL EFFORT BENEFITS AND COSTS

(all figures except lines 1 and 2 in millions of 1973 dollars)

	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	Totals
Benefits (% 1972 $L_{dn} \geq 65$ area)*	0	0	0	2%	2%	3%	7%	10%	11%	11%	11%	10%	9%	
Benefits (People no longer exposed to $L_{dn} \geq 65$				150,000	150,000	225,000	525,000	750,000	825,000	825,000	825,000	750,000	675,000	5,710,000**
Benefits at $1/person/yr								1	1	1	1	1	1	6
Benefits at $10/person				2	2	2	5	8	8	8	8	8	7	57
Benefits at $100/person/yr				15	15	23	53	75	83	83	83	75	68	570
Benefits at $1000/person/yr				150	150	225	525	750	825	825	825	750	675	5,700
Install DME			1	1	1	1	1							5
Flap Management Approach			PROBABLE	FUEL SA	VINGS									
IFR Two Segment Approach					12	12	13	12	PROBA	BLE FUEL	SAVINGS			49
Total Costs			1	1	13	13	14	12						54

* The symbol ≥ means "equal to or greater than"

** This number may be interpreted as "people-years of noise reduction"

Table 4-4

ACCELERATED EFFORT BENEFITS AND COSTS
(all figures except lines 1 and 2 are in millions of 1973 dollars)

	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	Totals
Benefits (% 1972 $L_{dn} \geq 65$ area)*	0	0	9%	13%	14%	18%	18%	18%	18%	16%	15%	15%	15%	
Benefits (People no longer exposed to $L_{dn} \geq 65$)			675,000	975,000	1,050,000	1,350,000	1,350,000	1,350,000	1,350,000	1,200,000	1,120,000	1,120,000	1,120,000	12,710,000**
Benefits at $1/person/year			1	1	1	2	2	1	1	1	1	1	1	13
Benefits at $10/person/yr			7	10	11	14	14	14	14	12	11	11	11	127
Benefits at $100/person/yr			68	98	105	135	135	135	135	120	112	112	112	1,266
Benefits at $1000/person/yr			675	975	1,050	1,350	1,350	1,350	1,350	1,200	1,120	1,120	1,120	12,660
Adjust ILS to 3°		3	3											6
Install DME		2	3	3	3	1								12
Flap Management Approach		PROBABLE FUEL SAVINGS												
Optimized Takeoff Procedures		PROBABLE FUEL SAVINGS												
VFR Two Segment Approach			PROBABLE FUEL SAVINGS											
IFR Two Segment Approach				17	16	16	PROBABLE FUEL SAVINGS							49
Airport Certification & Monitoring				5	5	5	5	5	5	5	5	5	5	50
Total Costs		5	6	25	24	22	5	5	5	5	5	5	5	117

* The symbol ≥ means "equal to or greater than"

** This number may be intrepreted as "people years of noise reduction"

Table 4-5

MAXIMUM EFFORT BENEFITS AND COSTS

(all figures except lines 1 and 2 are in millions of 1973 dollars)

	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	Totals
Benefits (% 1972 $L_{dn} \geq 65$ area)*	0	9%	16%	18%	19%	19%	19%	19%	19%	17%	16%	16%	16%	
Benefits (People no longer exposed to $L_{dn} \geq 65$)		675,000	1,200,000	1,350,000	1,430,000	1,430,000	1,430,000	1,430,000	1,430,000	1,280,000	1,200,000	1,200,000	1,200,000	15,255,000**
Benefits at $1/person/yr		1	1	1	1	2	2	2	1	1	1	1	1	15
Benefits at $10/person/yr		7	12	14	14	14	14	14	14	13	12	12	12	153
Benefits at $100/person/yr		68	120	135	143	143	143	143	143	128	120	120	120	1,526
Benefits at $1000/person/yr		675	1,200	1,350	1,430	1,430	1,430	1,430	1,430	1,280	1,200	1,200	1,200	15,255
Adjust ILS to 3 1/2°		10	12	7	7	7	7	7	7	7	7	7	7	92
Install DME		3	6	3										12
Flap Management Approach		PROBABLE FUEL SAVINGS												
OPTIMIZED TAKEOFF PROCEDURES		PROBABLE FUEL SAVINGS												
VFR Two Segment Approach		PROBABLE FUEL SAVINGS												
IFR Two Segment Approach			42	41										83
Airport Certification & Monitoring			5	5	5	5	5	5	5	5	5	5	5	55
Total Costs		13	65	56	12	12	12	12	12	12	12	12	12	242

* The symbol ≥ means "equal to or greater than"

** This number may be interpreted as "people years of noise reduction"

Table 4-6 summarizes the present value computation results by option. Using a criteria that an option is feasible for implementation if the present value of the public benefit equals or exceeds the present value of the implementation costs, the central question is: at what unit values per annum of the cost of noise to the public are each of the options feasible? Calculations from Table 4-6 indicate that under the assumptions described, a unit value of $12/person/year justifies implementation of the normal effort option, a value of $11/person/year would justify the accelerated effort option, and a unit cost of noise of $19/person/year would justify the maximum effort case. (Note that if the unit cost of noise is sufficient to justify "normal effort," it is also sufficient to justify "accelerated effort.")

It can be argued that after approximately 1980, the numbers of people exposed to noise are more significantly reduced by the implementation of source noise control options than by operational options and that, therefore, the public benefits of flight procedures are overestimated in the above analysis. If the time period of this analysis were shortened to 1974 through 1980, the respective unit values per person per year would change to $38, $15, and $22 to justify the normal, accelerated and maximum effort options respectively.

The above results are directly sensitive to the estimated number of people exposed to noise above L_{dn} = 65. If the estimate of 7.5 million were to be too high by a factor of two, then the unit public cost of noise required to justify any option would double. In summary, if the public valuated noise costs at greater than approximately $11 to $30/person/year, a program of at least "accelerated effort" would be justifiable.

Another approach to balancing costs and benefits is to compare the costs of alternative means of noise reduction. Recall that implementation of operational procedures is only one set of options that is part of what must be a more comprehensive program to reduce the noise environment to levels that are consistent with public health and welfare considerations. The EPA Aircraft/Airport Noise Study-Task Group 4 Report (Reference 513) found that the most expensive environmental noise reduction options are those of land use, e.g., soundproofing of residences, redevelopment, etc. Since operational procedures reduce the number of people exposed to cumulative noise environments, then by implementing these procedures,

Table 4-6

Present Value Economic Cost and Social Benefit for Various "Costs of Noise" Assumptions
(all figures in millions of dollars, present value)

Option	Relative Economic Cost	Cost of Noise $1/person/yr Social Benefit	Cost of Noise $10/person/yr Social Benefit	Cost of Noise $100/person/yr Social Benefit	Cost of Noise $1000/person/yr Social Benefit
Do Nothing	0	0	0	0	0
Normal Effort	38	3	35	349	3,494
Accelerated Effort	88	8	81	805	8,052
Maximum Effort	100	10	101	1,012	10,116

there should result a reduction in land use costs vis a vis the costs if the procedures were not implemented. This reduction is a "savings" that can be compared to operational procedure implementation costs to determine whether implementation of a particular set of procedures is justified.*

The reductions in land areas within specific cumulative noise level contours translate into reduced noise levels perceived by the receiver. Depending on the operational procedure options implemented, the reduction in cumulative noise levels can be as high as 17 dB. However, the conservative estimate of an "average" noise reduction developed earlier in this section considering both takeoffs and landings as well as all sizes of airports and averaged over the entire area within the L_{dn} = 65 contour (including those areas for which operational procedures and not effective) results in average noise reductions of 0 to 1.7 dB depending on the option chosen. On the average, this is the noise reduction felt by all people within the L_{dn} = 65 contour. Reference 513 estimates that the cost of noise protection by land use (in this case soundproofing) is $100 to $200 per person per dB for the environment of L_{dn} = 65 (where flight procedures are most effective). Table 4-7 delineates the land use cost reductions, based on the lowest land use cost estimate, that can be expected from the implementation of various operational options.

It can be seen from the table that the reductions in land use costs exceed the implementation costs of each option. The absolute magnitude of this savings is greatest for "maximum effort". Again, if the population estimate is too high by a factor of two, then the reduction in land use costs would be only half as great. The absolute magnitude of the "savings" would then be greatest for "accelerated effort."

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*There is a methodological problem with this notion of "savings" that should be recognized. Primarily it is one of cost incidence or "savings" to whom. This is an allocation problem and the answer derives from the allocation scheme adopted. For a more detailed discussion the reader is referred to Reference 511.

Table 4-7

Reductions in Land Use Cost Resulting from Implementation of Operational Procedures

(1) Procedure Option	(2) Implementation Costs (millions of 1973 dollars)	(3) Number of People within 1980 L_{dn} = 65 contour before implementation of operational procedures (millions)	(4) Average Reduction in Cumulative Noise Level due to Operational Procedures (dB)	(5) Minimum Land Use Cost per person per dB at L_{dn} = 65 (1973 dollars)*	(3)x(4)x(5) Reduction in Land Use Costs due to operational procedures (millions of 1973 dollars)
Do Nothing	0	6.6	0	100	0
Normal Effort	49	6.6	.9	100	594
Accelerated Effort	112	6.6	1.5	100	991
Maximum Effort	237	6.6	1.7	100	1122

*Reference 513

Based on these findings, it is concluded that operational procedures result in reduced noise impacts and, when they satisfy FAA regulatory constraints, are justified on the basis of reduced costs to achieve a given level of cumulative environmental noise.

So far, in this analysis, no attempt has been made to assign a specific numerical value to the public cost of noise. Doing so is fraught with many difficulties and uncertainties, especially since individual responses to noise vary widely. However, this report would fall short if it did not suggest at least one scheme for making such a determination. For example, one might attempt to find some form of compensation that an individual would accept as balancing the adverse effects of the noise. Reference 517 suggests that perhaps a paid vacation away from the noise might be considered partial compensation. It hypothesizes a one week vacation each year at a cost of \$100 per person (\$300 per family). If this is assumed to be applicable for those that are exposed to cumulative noise levels 10 dB above some critical level (for example, above L_{dn} = 65), then it follows that the cost of noise may be valued at at least \$10/person/dB/year. At this rate, "accelerated effort" noise abatement flight procedures are justified if they are effective for 1.1 years or more (based on columns 2, 3, and 4 of Table 4-7).

Still another way of looking at the cost-benefit equation is to place costs in the perspective of how much they would increase the cost of a passenger ticket. Based on 160 million passengers per year (Reference 169) and a 10 year amortization of costs, the required fare increase per passenger would be 3¢ for normal effort, 7.5¢ for accelerated effort, and 15¢ for maximum effort.

It should be pointed out that all of the above computations have included only flight procedures, not airport procedures. The reason for this is that flight procedures can be instituted without changing the level of service to the traveling public. Airport related procedures (curfews, schedule restrictions, etc.) may reduce the level of air service and therefore introduce another variable "public cost" which must be considered. The basic thesis of this report is that the most advantageous combination of airport procedures should be determined by a public process involving all affected parties, both local and national. This would occur in the context of airport noise certification, and it is there that the balancing of transportation needs, environmental needs, and economic costs should take place. Nevertheless, an estimate was made earlier in this section that airport procedures might reasonably result in a 3 dB reduction in cumulative noise exposure nationwide. An estimate of the "public cost" of a national curfew (one way of achieving a 3 dB noise reduction) was made in Reference 513. The estimated nationwide cost averaged approximately $100 million per year (other combinations of airport procedures may have a lower public cost). For the year 1980, and assuming "accelerated effort" flight procedures, an estimated 5,250,000 people would be within the $L_{dn} = 65$ contour near airports. Calculations based on these estimates would then indicate that a national curfew would be justified if the public cost of noise were greater than $6/person/dB/year.

All of the above considerations seem to indicate that noise abatement flight procedures corresponding to at least "accelerated effort" would be desirable. Over the period 1973 to 1985, implementation of such a program would result in a reduction of 13 million people-years of noise exposure at an economic cost of $112 million or 7.5¢ per passenger. Additional noise reduction may be achieved through implementation of airport related procedures, with economic and social costs dependent on the combination of procedures selected for each airport.

SECTION 5

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

A study of aircraft and airport operational noise abatement procedures has been conducted in partial compliance with the Noise Control Act of 1972. All of the procedures analyzed are presently in use in one form or another in scattered parts of the air transportation system.

The data supplied by members of the EPA Aircraft Airport Noise Study Task Group 2 lead the chairman to conclude that airport and flight procedures can significantly reduce aircraft noise impact on communities in a short time and at relatively low cost. They need to be appropriately implemented, however, at airports throughout the air transportation system. Pilots should always be authorized to deviate from established noise abatement procedures whenever, in their opinion, the safety of flight requires it.

The chairman's specific recommendations, and the conclusions on which they are based, follow:

REGULATORY ACTIONS

REGULATIONS SHOULD BE ADOPTED ESTABLISHING STANDARD NOISE ABATEMENT TAKEOFF PROCEDURES

A small set of standard noise abatement takeoff procedures should be developed from which one could be selected for use as appropriate to any departure noise situation. At least three distinct procedures should be considered:

Far Downrange—a maximum angle climbout, such as the one recommended by the Air Transport Association (ATA) and in use by American and United Air Lines (among others), is especially beneficial for areas that are far from the airport (more than approximately 10 miles).

Near Downrange—a power cutback during climbout, such as the procedure recommended by the Air Line Pilots Association or in use by Northwest Air Lines, Air California, North Central Air Lines, or at the Washington National Airport, is especially beneficial for areas closer to the airport (a noise reduction of 2 to 7 EPNdB, depending on aircraft type and weight, approximately 4 to 10 miles from the start of takeoff). This procedure results in increased noise levels for approximately one mile prior to the cutback (while flaps are being retracted) and again after power is reapplied.

Sideline—use of reduced thrust from the start of takeoff roll (to the extent permitted in the FAA approved aircraft flight manual considering takeoff weight, runway length, and other conditions) is especially beneficial for areas alongside the departure runway (a noise reduction of up to 2 EPNdB). This procedure should not be used if near downrange noise is more critical because the reduced thrust takeoff results in lower climbout altitudes.

REGULATIONS SHOULD BE ADOPTED ESTABLISHING STANDARD NOISE ABATEMENT APPROACH PROCEDURES

A small set of standard noise abatement approach procedures should be developed from which one could be selected for use as appropriate to any landing noise situation. At least the following procedures (not necessarily independent) should be considered:

Two Segment Approach—Initially, visual two segment approaches similar to those in use by National Airlines, Pacific Southwest Airlines, Air California, all airlines using San Diego International Airport, and recommended by the National Business Aircraft Association appear feasible. Subsequently, with the use of instrumentation similar to that which has been flight tested over the last 10 years by the Federal Aviation Administration (FAA), the National Aeronautics and Space Administration (NASA), and the airline industry, this noise benefit could be extended to all weather operations. This instrumentation is currently undergoing flight test in scheduled airline passenger service by United Air Lines under contract to NASA. The noise benefit from two segment approaches is approximately 0 to 17 EPNdB depending on the distance from the runway (from approximately 2 to 10 miles). The total air carrier fleet costs for airborne instrumentation (required for all weather operations) are estimated to be $49 million.

Flap Management Approach-procedures which use a reduced flap setting (and consequently less power) during approach and landing are recommended by the Air Transport Association and are employed by American Airlines, United Airlines, and Northwest Airlines, among others. These procedures provide approximately a 3 to 5 EPNdB noise reduction compared to a full flap approach.

REGULATIONS SHOULD BE ADOPTED RAISING MINIMUM FLIGHT ALTITUDES

Level flight maneuvering at the present minimum altitude of 1500 feet above the airport for turbine powered or large aircraft can create approximately 10 EPNdB more noise than maneuvering at 3000 feet. A similar noise reduction could occur if the minimum altitudes for other aircraft were raised from the present 1000 feet to 2000 feet. In developing regulations, care should be taken to avoid causing excessive air traffic congestion and to avoid causing excessively long ground tracks where they would result in increased noise exposure.

AN AIRPORT NOISE CERTIFICATION REGULATION SHOULD BE ADOPTED

Inasmuch as neither flight procedures alone nor noise source controls alone can be expected to totally solve the noise problem, airport noise certification seems to be the most logical way to assure that noise exposure to people is controlled and reduced. The certification process envisioned would be a public partnership among the Federal Government, the Airport Operator, the Airlines, and the affected communities whereby all work together to achieve a meaningful, safe, and reasonable solution to the noise problem. Federal Aviation Administration (FAA) inputs would ensure that safety and national air transportation system needs are considered. Environmental Protection Agency (EPA) inputs would assure that national environmental goals are considered. Airport and community inputs would assure that local needs are considered. Airline inputs would assure that industry needs are considered. Final approval authority would rest with the FAA.

The output of the certification process would be an [illegible] implementation plan wherein all the competing goals are addressed and a timetable for noi[illegible]tion is set forth along with specific plans for meeting this timetable. The noise reduction should be in accordance with public health and welfare requirements and should be expressed in terms of cumulative noise exposure. Noise monitoring should be required where substantial noise problems exist. Federal funding assistance should be made available for the noise certification process (estimated to cost approximately $5 million per year).

The FAA approved implementation plan for any airport might include designation of preferential or restricted runways, preferential flight paths, preferential takeoff procedures, preferential approach procedures, curfew hours or quotas, single event noise limits, aircraft weight or trip length limitations, maintenance runup restrictions, or economic incentives for noise abatement. The cumulative noise exposure benefit of these procedures may total only 1 or 2 dB or may total more than 10 dB, depending on the extent to which they are implemented.

NON-REGULATORY ACTION

WHEREVER TECHNICALLY FEASIBLE, ALL INSTRUMENT LANDING SYSTEM (ILS) GLIDE SLOPES SHOULD BE RAISED TO AT LEAST 3 DEGREES

Approximately 65% of existing ILS glide slopes are at angles lower than the standard for new installations (2.5 degrees to 2.9 degrees instead of 3 degrees). A one-half degree increase in approach angle reduces noise by 2 to 3 EPNdB from the start of approach to touchdown. It should be possible to raise all appropriate glide slopes within two years. In addition, FAA and NASA should evaluate the use of 3.5 degree ILS glide slopes (such as the one at the Berlin (Tempelhof) airport) for airports with critical approach noise problems and adjust such glide slopes to 3.5 degrees as soon as these can be determined to be safe. The use of 4 or 5 degree Visual Approach Slope Indicators (VASI's) for visual noise abatement guidance at general aviation airports also appears worthy of evaluation.

INSTALLATION OF DISTANCE MEASURING EQUIPMENT (DME) CO-LOCATED WITH THE GLIDE SLOPE AT AIRPORTS SHOULD BE EXPEDITED

This equipment is a probable prerequisite for visual and all weather two segment approaches. It should be possible to commission 200 installations within 4 years at a cost of approximately $12 million.

AN ADVISORY CIRCULAR SHOULD BE ISSUED DISCUSSING THE NOISE EFFECTS OF THRUST REVERSE

In some cases use of maximum thrust reversal on landing creates disturbing noise and may not be necessary in order to stop safely. The appropriate use of thrust reversers considering sideline noise problems, runway conditions, air traffic control urgency, and air pollution could result in reduced noise.

ADDITIONAL RESEARCH ON IMPROVED FLIGHT PROCEDURES SHOULD BE ACCELERATED

Decelerating approaches, two-segment approaches with lower transition altitudes, and automatic takeoff procedures have potential for further noise reduction once safety and technical feasibility have been proven by FAA and/or NASA evaluations.

ALL AIR TRAFFIC CONTROLLERS SHOULD BE MADE FAMILIAR WITH NOISE ABATEMENT REGULATIONS AND PURPOSES

Controllers should be instructed to make use of noise abatement procedures, flight paths, and altitudes to the maximum extent possible.

REFERENCES

REFERENCES

1. Drell, H., Submittal to EPA, Aircraft/Airport Noise Study Task Force, Task Group 2, Operations Analysis, The Lockheed - California Company, March 2, 1973.

2. NASA, A Preliminary NASA Report to the Environmental Protection Agency for the Aircraft/Airport Noise Study (Chapter 3 - Operating Procedures), Feb 28, 1973.

3. Denery, D. G. et. al., Flight Evaluation of Three-Dimensional Area Navigation for Jet Transport Noise Abatement, NASA, AIAA Paper 72-814, Aug 7-9, 1972.

4. Denery, D. G. et. al., Preliminary Results on Two-Segment Noise Abatement Studies, NASA TM X - 62,098, Sept 22, 1971.

5. Photograph, "Two-Segment Approach System Components for Noise Abatement Flight Procedures Program," NASA, Jan 30, 1973.

6. Copeland, W. L. and Clark, L. R., Noise Measurement for a Three-Engine Turbofan Transport Airplane During Climbout and Landing Approach Operations, NASA TN D-6137, May, 1971.

7. Ollerhead, J. B., An Evaluation of Methods for Scaling Aircraft Noise Perception, NASA CR - 1883, Oct, 1971.

8. Glass, Ray E., Noise Reductions Achieved on a 720-023 B Aircraft using a Two-Segment Approach, NASA CR - 114417, Dec, 1971.

9. Peery, H. R., and Erzberger, H., Noise Measurement Evaluation of Take-off and Approach, Profiles Optimized for Noise Abatement, NASA TN D-6246, March, 1971.

10. Quigley, H. C., et. al., Flight and Simulation Investigation of Methods for Implementing Noise Abatement Landing Approaches, NASA TN D - 5781, May, 1970.

11. ALPA, "Policy on Noise Abatement," received Mar 6, 1973.

12. Rockwell, R. N., Airport Noise and Aircraft Operations, ALPA paper presented at FAA National Aviation System Planning Review Conference, April 29, 1971.

13. FAA, "Criteria for Implementation of Jet Noise Abatement Take-off Profile," final draft Advisory Circular, March 20, 1968.

14. Rockwell, R. N., and Stefanki, J. X., Letter "To All Members," ALPA, Jan 27, 1970.

15. Ruby, C. H., "Operational Procedures," ALPA, received Mar 6, 1973.

16. ALPA, "Statement of the Air Line Pilots Association in Regard to Community Noise and Aircraft Operations," presented at N.O.I.S.E. meeting in Washington, D. C., Oct 9 1969.

17. Clark, H. E., and Mathinsen, H. F., "Committee No. 3, Operational Noise Abatement Procedures Designed to Limit the Amount of Disturbance Caused by Aircraft Taking Off, In Flight, or Landing," ALPA, International Conference on the Reduction of Noise and Disturbance Caused by Civil Aircraft, Nov, 1966.

18. Ewers, N. G., and Bresnahan, R. J., Preferential Runway Program at Orange County Airport, County of Orange, California, Dec 18, 1972.

19. Bresnahan, R. J., Letter to Orange County Board of Supervisors, Subject: "Report on Implementation of the Adopted Noise Regulations for California (District 5)," County of Orange, Jan 26, 1973.

20. Ewers, N.; Bricken, G.; and Hilliard, J., Results of an Area Wide Noise Monitoring System, County of Orange, prepared for Acoustical Society of America, received Mar 6, 1973.

21. Hartranft, J. B. Jr., Letter to FAA Administrator John H. Shaffer, AOPA, Nov 27, 1972.

22. City of New York, Department of Air Resources, paper regarding provisions of New York Code requiring setting of airport/aircraft regulations, received Mar 6, 1973.

23. Muncy, D. E., Letter, subject: "Revised Route, Oakland to San Jose Airports, West Traffic Flow and San Jose "Keep-em-High" Procedures," FAA Oakland Bay TRACON, Nov 10, 1972.

24. Nissen, J. M., "Program for Improving San Jose Municipal Airport Environmental Quality as Affected by Aircraft," San Jose Municipal Airport, received Mar 6, 1973.

25. Flynn, Roger, paper containing recommended steps for noise abatement approach, received Mar 6, 1973.

26. National Business Aircraft Association, NBAA Noise Abatement Program, report SR 67-12, June, 1967.

27. Department of Transportation, Federal Aviation Administration Advisory Circular Subject: VFR Flight Near Noise Sensitive Areas AC No. 91-36, August 7, 1972.

28. Department of Transportation, Federal Aviation Administration, Advance Notice of Proposed Rule Making, "Civil Airplane Fleet Noise (FNL), Requirements," Docket No. 12534; Notice No. 73-3, Federal Register, January 30, 1973.

29. Department of Transportation, FAA, Proposed Application of Noise Standards, "Newly Produced Airplanes of Older Type Designs," Docket No. 12064, Notice 72-19, Federal Register, July 25, 1972.

30. Department of Transportation, FAA, Notice of Proposed Rule Making, "Noise Type Certification and Acoustical Change Approvals," Docket No. 11412; Notice 71-26, Federal Register, September 17, 1971.

31. Department of Transportation, FAA, Advance Notice of Proposed Rule Making, "Civil Airplane Noise Reduction Retrofit Requirements," Docket No. 10664; Notice No. 70-44, Federal Register, November 4, 1970.

32. Department of Transportation, FAA, Advance Notice of Proposed Rule Making, "Civil Supersonic Aircraft Noise Type Certification Standards," Docket No. 10494, Notice No. 70-33, Federal Register, August 6, 1970.

33. Department of Transportation, FAA, Notice of Proposed Rule Making, "Civil Aircraft Sonic Boom," Docket No. 10261, Notice No. 70-16, Federal Register, April 16, 1970.

34. U.S. Congress, Public Law 90-411, "Control and Abatement of Aircraft Noise and Sonic Boom," July 21, 1968.

35. Sellman, E. W., Propeller Driven Aircraft Noise Type Certification Standards (Notice of Proposed Rulemaking), FAA Project Report, Report No. 5 prepared January 22, 1973.

36. Fontaine, R. B., Letter to FAA, Subject: "Advance Notice of Proposed Rule Making - Civil Airplane Fleet Noise (FNL) Requirements," Martin Aviation Inc., March 6, 1973.

37. Schettino, J. C., Letter to Robin Gegauff, March 12, 1973.

38. Wyle Laboratories, Supporting Information for the Adopted Noise Regulations for California Airports, Final Report to the California Department of Aeronautics, Report No. WCR 70-3(R), January 29, 1971.

39. Cuadra, Elizabeth, Letter to Lawrence Plumlee (EPA) regarding Police Helicopters, EPA, March 10, 1973.

40. Airport Operators Council International, Policy Handbook, September 8, 1972.

41. Sperry, W. C., Ronk, L. A., and Cokenias, T. N., Information Brief on Prediction of Aircraft Noise Levels for Planning Purposes, September 7, 1972.

42. Ronk, L. A., Sperry, W. C., and Cokenias, T. N., Information Brief on Takeoff and Approach Noise for Boeing 727 Aircraft, January 8, 1973.

43. Meyersburg, R. B., and Williams, C. H., Committee No. 3: Operational Noise Abatement Procedures Designed to Limit the Amount of Disturbance Caused by Aircraft Taking Off, In Flight, or Landing, FAA, International Conference on the Reduction of Noise and Disturbance Caused by Civil Aircraft, London, November, 1966.

44. Zalovcik, J. A., Note on Effect of Thrust and Altitude on Noise in Steep Approaches, NASA, LWP-283, September 16, 1966.

45. Copeland, W. L. et. al., Noise Measurement Evaluations of Various Take-Off-Climbout Profiles of a Jet Transport Airplane, NASA, LWP-206, April 6, 1966.

46. Hilton, D. A. et. al., Measurements of Noise Produced by a BAC-111-400 Series Turbofan Transport Airplane During Take-Off-Climbout Operations, NASA, LWP-211, April 13, 1966.

47. Hilton, D. A. et. al., Measurements of Noise Produced by a Boeing 727 Turbofan Airplane During Take-Off-Climbout Operations, NASA, LWP-214, April 20, 1966.

48. Noise - Making the Airport a Good Neighbor, submitted by R. B. Meyersburg, received March 16, 1973.

49. Hilton, D. A., Ground Noise Measurements During Landing and Take-Off Operations of the McMonnell-Douglas 188 (Brequet 941) STOL Airplane, NASA, LWP-741, April 18, 1969.

50. Power, Joseph K., Bibliography of Federal Aviation Administration Noise Reports, Department of Transportation, FAA, received, March 16, 1973.

51. Lockwood, Bert J., Letter enclosing data available on the LAX 5 point program for noise abatement, City of Los Angeles, Department of Airports, March 13, 1973.

52. Bender, George J., Letter to EPA, subject: "Noise Abatement Segmented Approach Procedure," March 16, 1973.

53. Bender, George J., Letter to EPA, subject: "Two Segment Approach Procedure and Wake Turbulence," March 16, 1973.

54. Flynn, Roger, paper presenting views on aircraft and airport operational procedures, received March 19, 1973.

55. Meyersburg, R. B., Some Thoughts on Reducing Approach Noise, March 19, 1973.

56. Bedore, Lawrence P., Letter to EPA transmitting information, NBAA, March 14, 1973.

57. NBAA, NBAA Noise Abatement Program, received March 19, 1973.

58. Bedore, Lawrence P., Letter to all NBAA representatives subject: "Recommended Changes to NBAA Noise Abatement Program," NBAA, November 10, 1972.

59. Women's Advisory Committee on Aviation, Aviation and the Environment, Department of Transportation, FAA, November 1971.

60. NASA, Chapter 3. Operating Procedures for Aircraft Noise Reduction, received March 19, 1973.

61. Bresnahan, Robert J., "Effectiveness of the ECOLOG I Noise Monitoring System Installed at Orange County Airport as a Noise Abatement Tool," Orange County Airport, March 16, 1973.

62. Treece, Lloyd L., Noise Abatement In Flight, United Air Lines, received March 19, 1973.

63. FAA, Operational Evaluation of a Selectable Glide Slope Computer, Experimental Special Instrument Approach Procedure Charts, April, 1970.

64. Tucker, John R., Take-off Flight Path Studies, Air California, March 1, 1973.

65. "Organization of Treatments and Levels for Analysis of Variance for Aviation Advisory Commission Noise Tradeoff Study," received March 22, 1973.

66. Schettino, John C., Letter to M. P. Kelly regarding Opa Locka Airport, United States Environmental Protection Agency, received March 22, 1973.

67. Tanner, Carole S. and Glass, Ray E., Noise Measurements Obtained During Visual Approach Monitor Evaluation in 747 Aircraft, Hydrospace Research Corporation for NASA, May 1972.

68. Hurlburt, R. L., Memorandum to the file subject: "Major Noise Airports," U. S. Environmental Protection Agency, April 3, 1973.

69. Tanner, Carole S., Measurement and Analysis of Noise From Four Aircraft in Level Flight (727, KC-135, 707-3203 and DC-9), FAA Report FAA-RD-71-83, September, 1971.

70. Tanner, Carole S., Measurement and Analysis of Noise From Four Aircraft During Approach and Departure Operations (727, KC-135, 707-320B, and DC-9), FAA Report FAA-RD-71-84, September, 1971.

71. FAA, "Glide Slope Angles at Airports," December, 1971.

72. FAA, "Airports Where 2-Segment Approaches will Afford Noise Relief," received March 29, 1973.

73. Mergell, Merle, Letter to John Schettino regarding aircraft noise study, City of Inglewood, California, March 26, 1973.

74. The communities of El Segundo, Inglewood, Lennox, Playa Del Rey, and Westchester, California, Joint Policy Statement on Airport Noise, Supporting Technical Data, December, 1972.

75. Hurlburt, Randall L., Steep Approaches for Aircraft Noise Abatement-A Collection of Research Studies, City of Inglewood, California, July, 1972.

76. City of Inglewood, California, "Aircraft Noise Abatement Alternatives," Environmental Standards Circular, September, 1971.

77. Boettger, Wolfgang A., A Survey of Aircraft Noise Standards and Monitoring Systems At International Airports, City of Inglewood, California, Report Summary, July, 1972.

78. Boettger, Wolfgang A., A Study of Steep Approaches for Noise Abatement Flown by Pacific Southwest Airlines, City of Inglewood, California, November, 1972.

79. Boettger, Wolfgang A., A Comparison of Aircraft Approach Angles at Los Angeles and San Diego International Airports, City of Inglewood, California, June, 1972.

80. Lockwood, Bert J., Memorandum to Randall L. Hurlburt, Subject: "Task Group 2--Position Report," City of Los Angeles, Department of Airports, March 22, 1973.

81. Lockwood, Bert J., Memorandum to Randall L. Hurlburt, Subject: "Monitoring System-Los Angeles International Airport," City of Los Angeles, Department of Airports, March 30, 1973.

82. Lockheed-California Company, submittal to EPA Aircraft/Airport Noise Study Task Force, Task Group 2, Operations Analysis, March 26, 1973.

83. Lockheed-California Company, Submittal to EPA Aircraft/Airport Noise Study Task Force, Task Group 2, Operations Analysis, March 28, 1973.

84. United Airlines, Flight Operations Manual, "Special DCA Noise Abatement Procedure," February 25, 1972.

85. NASA, Response to Task Group 2 Questionnaire, received April 4, 1973.

86. NASA, "Implementation of VFR/IFR 2-Segment Approach Capability for Noise Abatement," received April 2, 1973.

87. Blumenthal, V. L., letter to R. L. Hurlburt, Subject: "Boeing Comments for EPA Task Group 2," The Boeing Co., March 30, 1973.

88. Rockwell International, Position Questionnaire Comments, Task Group 2, received April 2, 1973.

89. Hinton, Lloyd, Memorandum to Randall L. Hurlburt, Subject: "Response to Position Questionnaire dated 3/19/73," National Organization to Insure a Sound-Controlled Environment, April 2, 1973.

90. Air Line Pilots Association, Comments on Position Questionnaire-Task Group 2, March 19, 1973.

91. Bennin, Robert, Memorandum to Task Group 2, Subject: "Response to Position Questionnaire," City of New York, March 27, 1973.

92. Bedore, Lawrence P., Letter to R. L. Hurlburt regarding responses to questionnaire dated March 19, 1973, National Business Aircraft Assoc., Inc., April 4, 1973.

93. Aircraft Owners and Pilots Association, Position Questionnaire Comments, Task Group 2, received April 9, 1973.

94. Bourquin, Kent, et. al., Initial Flight and Simulator Evaluation of a Head Up Display for Standard and Noise Abatement Visual Approaches, NASA, TM X-62, 187, February, 1973.

95. Carmichael, Robert E. L., Letter to Randall Hurlburt regarding policies involving noise abatement during arrivals and departures, Pacific Southwest Airlines, March 28, 1973.

96. ALPA, Take-off Thrust Chart, Sea-Level, STD Day (707-320B), received April 9, 1973.

97. Sundstrand Data Control, Inc., Visual Approach Monitor, received April 9, 1973.

98. Hart, P. E., Population Densities and Optimal Aircraft Flight Paths, University of Reading, October, 1972.

99. Bresnahan, Robert J., Cost Benefit Analysis of the Ecolog I Noise Monitoring System, Orange County Airport, March 28, 1973.

100. Tucker, John R., memorandum to EPA, subject: "Response to Task Group 2 Questionnaire," Air California, March 29, 1973.

101. Bresnahan, Robert J., response to Task Group 2 Questionnaire, Orange County Airport, April 4, 1973.

102. Bender, George J., Draft "Submittal to Environmental Protection Agency Aircraft/Airport Noise Study Task Force Task Group 2 - Operations Analysis," Boston-Logan Airport, April 4, 1973.

103. Soderlind, Paul A., Letter to Administrator of FAA regarding takeoff and approach noise, Northwest Airlines, Nov. 24, 1970.

104. Amin-Arsala, Betsy, Memorandum to Task Group 4, Subject: Concept of Airport Certification, Washington University, April 2, 1973.

105. N.O.I.S.E., "Airport Certification," received April 18, 1973.

106. Flynn, Roger G., Answers to Position Questionnaire-Task Group 2, March 19, 1973.

107. Regan, John M., Comments on aircraft and airport noise problems to ONAC & FAA, March 22, 1973.

108. FAA, excerpt from National Aviation System Plan, 1972, April 18, 1973.

109. Christiansen, Roy, Letter to Randy Hurlburt regarding enquiry on the Visual Approach Monitor, Sundstrand Data Control, Inc., April 10, 1973.

110. Flynn, Roger, "Take-off Procedure - 707 & 727," received April 18, 1973.

111. Gregoire, M. C. & Streckenbach, J. M., Effects of Aircraft Operation on Community Noise, Boeing Report-June 1971.

112. FAA, Advisory Circular-subject: "Arrival and Departure Handling of High Performance Aircraft," February 28, 1973.

113. Nissen, James M., Letter to R. L. Hurlburt containing responses to position questionnaire, City of San Jose, California, Airport Department, April 6, 1973.

114. Randall, Robert L., Memorandum Re: "Legal Authority available for ce tain actions discussed in Position Question-for Task Group 2, dated 3/ 9/73," received April 19, 1973.

115. Erzberger, Heinz, et. al., "Technique for Calculating Optimum Abatement Take-Off Profiles," Progress of NASA Research Relating to Noise Alleviation of Large Subsonic Jet Aircraft, NASA SP-189, October 8-10, 1968.

116. Quigley, Hervey C., et. al., "Flight Investigations of Methods for Implementing Noise Abatement Landing Approaches," Progress of NASA Research Relating to Noise Alleviation of Large Subsonic Jet Aircraft, NASA SP - 189, October 8-10, 1968.

117. Russell, R. E., Letter to R. L. Hurlburt transm... 707-300, The Boeing Company, April 20, 1973. ... noise data for the

118. Gray, Damon C., Results of Noise Surveys of Seventeen Genera... Type Aircraft, Hydrospace - Challenger Inc., FAA report FAA - EQ ...n 1, December, 1972.

119. Schelp, D. A., Letter to R. L. Hurlburt transmitting performance data for the 707-320B airplane, The Boeing Company, April 13, 1973.

120. Haggard, William H., Letter to Randy Hurlburt transmitting "Revised Uniform Summary of Surface Weather Observations," U. S. Department of Commerce, National Climatic Center, April 25, 1973.

121. Illston, F. E., Letter to Randy Hurlburt submitting noise data, American Airlines, April 26, 1973.

122. Civil Aeronautics Board, United Air Lines, Inc. Boeing 727, N7030U, Salt Lake City, Utah, Nov. 11, 1965, Aircraft Accident Report, June 7, 1966.

123. FAA, Amendment to FAR Part 91-General Operating and Flight to Rules to add Section 91.55 "Civil Aircraft Sonic Boom," Federal Register, March 28, 1973.

124. Nissen, James M., Testimony to Senator John V. Tunney regarding aircraft retrofit, City of San Jose, California, September 14, 1972.

125. Bedore, Lawrence P., Letter to R. L. Hurlburt regarding NBAA responses to questionnaire dated March 19, 1973, NBAA, May 14, 1973.

126. Nissen, James M., Letter to R. L. Hurlburt regarding answers to Position Questionnaire of 3/19/73, San Jose, California, April 4, 1973.

127. Tucker, John R., Letter to R. L. Hurlburt regarding initial draft of Task Group 2 report to Congress, Air California, May 11, 1973.

128. Sanjour, W., Memorandum to R. Hurlburt, Subject: "Air Pollution Implications of Some of the Measures Proposed in the Task Group 2 Draft Report," Environmental Protection Agency, May 17, 1973.

129. Marthinsen, Harold F., Letter to R. Hurlburt regarding EPA's Report-Draft No. 1 of Chapter 3, Air Line Pilots Association, May 18, 1973.

130. Bennin, Robert S., Letter to R. Hurlburt regarding Task Group 2 draft report, Environmental Protection Agency, May 16, 1973.

131. Belles, R. E., Letter to R. L. Hurlburt, regarding Draft #1, Chapter 3, Airport/Aircraft Noise Study Report, Rockwell International, May 14, 1973.

132. Bedore, Lawrence P., Letter to R. L. Hurlburt regarding EPA report Chapter 3 (Operations Analysis), National Business Aircraft Assoc., May 14, 1973.

133. Droll, H., Letter to R. L. Hurlburt regarding Task Group 2 Report Chapter 1, Lockheed-California Co., received May 14, 1973.

134. Lockwood, Bert J., Memorandum to R. Hurlburt, Subject: "Comments-Chapter 3: Operations Analysis-Task Group 2," Department of Airports, City of Los Angeles, California, May 8, 1973.

135. Blumenthal, V. L., Letter to R. L. Hurlburt, regarding Draft #1 of Chapter 3, Boeing Commercial Airplane Group, May 11, 1973.

136. Linnert, T. G., and Kayne, V. J., Letter to Federal Aviation Administration regarding High Performance Aircraft Corridors, ALPA and AOPA, April 13, 1970.

137. Kayne, Victor J., Memorandum to Mr. Miller, Subject: Draft Report of EPA Task Group 2, AOPA, May 9, 1973.

138. Bresnahan, Robert J., Letter to R. L. Hurlburt regarding draft of Chapter 3: Operations Analysis of Task Group 2 Report to Congress, Orange County, California, May 10, 1973.

139. FAA, Charts on Unmodified airplane noise values for May 7, 1973 demonstration flights at Dulles Airport, received May 11, 1973.

140. Flynn, Roger, Letter to R. L. Hurlburt regarding Draft Report of Task Group 2, Air Transport Association, May 11, 1973.

141. Bolt, Beranek and Newman - Noise Reduction Charts, received May 11, 1973.

142. Bishop, Dwight E., Letter to Randall Hurlburt regarding the 100 and 90 EPNdB noise contours for takeoff of a Boeing 707-320B, Bolt, Beranek and Newman, May 17, 1973.

143. Wertenbaker, George L., Letter to Randall L. Hurlburt regarding ILS glide slope angle for runway 27L (Tempelhof), May 14, 1973.

144. Hurlburt, Randall L., Landing Procedure Correction to AAC, 30 NEF impact area, EPA, May 11, 1973.

145. Meyersburg, R., Draft Advisory Circular regarding Reduction of noise during approach and landing, May 22, 1973.

146. Skully, R. P., Letter to Alvin Meyer regarding the draft EPA report (Operational Procedures), FAA, May 21, 1973.

147. Treece, L. L., Letter to R. Hurlburt regarding the draft report to Congress, United Air Lines, May 18, 1973.

148. Bresnahan, Robert J., Letter to R. Hurlburt regarding draft report to Congress, Orange County, Calif., May 17, 1973.

149. Hinton, Lloyd, and Tyler, John, Memorandum to R. Hurlburt Subject: "Comments and Recommendations for draft No. 1, Chapter 3 of the Report to the Congress, "N.O.I.S.E. May 18, 1973.

150. Bender, George J., Letter to R. Hurlburt regarding draft report to Congress, Boston Logan Airport, May 7, 1973.

151. Flynn, Roger G., letter to Randall Hurlburt related to Northwest Airlines "high flight director" approach, Air Transport Association, June 19, 1973.

152. Massport, What is Massport doing about Aircraft Noise, Boston Logan Airport, May 18, 1973.

153. FAA, "Notices to Airmen," Airman's Information Manual, page 3A-2 (District of Columbia), April 12, 1973.

154. FAA, "Washington National Airport Noise Abatement Procedures," Effective June 1, 1970.

155. Air Transport Association, "Takeoff Procedures for Washington National Airport," August 21, 1972.

156. Hurlburt, R., Memo to the Files Subject: "Two Segment Equipment Installment Time," EPA, May 24, 1973.

157. Spencer, Jonathan A., Letter enclosing draft noise data for 707-320 B; Bolt, Beranek, and Newman, 25 May 1973.

158. Schettino, John C., Memo to Deputy Assistant Administrator for Noise Control Programs, Subject: "Aerospace Industries Association of America, Inc. (AIA) Letter Dated May, 1973" (letter attached), EPA, May 31, 1973.

159. Schettino, John C., Letter to Mr. Bohonis regarding his letter of April 17 (letter attached), EPA, June 4, 1973.

160. Tyler, John and Hinton, Lloyd, Letter to Randall L. Hurlburt Re: "Comments and Recommendations for the report to the Congress," N.O.I.S.E., June 6, 1973.

161. Lockwood, Bert J., Memorandum to Randall L. Hurlburt Subject: "Comments--Operations Analysis--Task Group 2," City of Los Angeles Department of Airports, June 5, 1973.

162. Schmidt, Claude C., Letter to Randy Hurlburt forwarding data related to Minneapolis Green Barrier, Minneapolis-St. Paul Metropolitan Airports Commission, June 8, 1973.

163. Midwest Planning and Research Inc., "Plans for Green Belt Construction at World Chamberlain Field for Minneapolis-St. Paul Metropolitan Airports Commission," May 1, 1972.

164. Toltz, King, Duvall, Anderson, and Assoc., Inc., "Specifications for Greenbelt Construction at World-Chamberlain Field for Minneapolis-St. Paul Metropolitan Airports Commission, M.A.C. Contract No. 59.292, Federal Project No. 8-27-0059-03," May 1, 1972.

165. Minnesota, State of, Amendment to Minnesota Statutes 1969, Section 360.107 relating to construction of an acoustical barrier at Minneapolis-St. Paul International Airport, Approved July 22, 1971.

166. Eldred, Kenneth M., Letter to Raymond G. Glumack regarding acoustical performance of tree-covered earth berm at World-Chamberlain Field, Wyle Labs, June 6, 1972.

167. Schelp, Don A., Letter to R. L. Hurlburt regarding fuel usage for approach and takeoff procedures, Boeing, June 18, 1973.

168. Spencer, J.A., and Myer, T.H., A Computer Simulation Study of Noise Abatement Procedures; Bolt, Beranek, and Newman, Inc., Draft BBN Report No. 2567, 29 June 1973.

169. Civil Aeronautics Board and Department of Transportation, excerpts from Airport Activity Statistics of Certificated Route Air Carriers, June 30, 1971.

170. Belles, R. E., Letter to Randall L. Hurlburt regarding comments on Task Group 2 draft reports, North American Rockwell, June 28, 1973.

171. Hurlburt, R. L., "A Survey of Noise Problems as perceived by the Airport Administration at 19 Large Hub Airports," EPA, June 30, 1973.

172. Blumenthal, V. L., Letter to R. L. Hurlburt
Subject: "Boeing Commercial Airplane Company Position on Task Group 2, 'Operations Analysis Including Monitoring, Enforcement, Safety, and Costs,' " Boeing, June 29, 1973.

173. Linnert, Ted G., Letter to Randy Hurlburt enclosing comments and a position paper relating to Task Group 2, ALPA, June 29, 1973.

174. Flynn, Roger G., Letter to John Schettino including comments on Task Group 2 Draft Report of June 1, 1973, July 2, 1973.

175. Hinton, Lloyd V., Letter to Randall Hurlburt including positions related to Task Group 2, N.O.I.S.E., Received July 2, 1973.

176. Reilly, J. Donald, Letter to Randall Hurlburt enclosing comments on Task Group II draft report, AOCI, July 2, 1973.

177. Informatics, Inc., Information Brief on Select Bibliography of Acquired Documents for Aircraft/Airport Noise Report Study, EPA, Received June 26, 1973.

178. Hinton, Lloyd V., Letter to Randall Hurlburt including positions related to Abatement Flight Procedures Demonstration with Sound Measurements," N.O.I.S.E., June 6, 1973.

179. Hurlburt, R.L., Memorandum to File Subject: "Telephone Conversations with Lee Goolsby, NASA," EPA, April 3, 1973.

180. McPike, A.L., Letter to Randall Hurlburt transmitting comments on June 1, 1973 draft report of Task Group 2, Douglas Aircraft Company, June 29, 1973.

181. General Aviation Manufacturers Association, General Aviation Manufacturers Association Comments on the Draft Report on Operations Analysis Including Monitoring, Enforcement, Safety, and Costs for Environmental Protection Agency Aircraft/Airport Noise Report Study, Task Group 2, Received July 9, 1973.

182. Moore, Clifton A., Letter to John C. Schettino transmitting comments on Airport Noise Task Group Draft Reports, June 29, 1973.

183. Blumenthal, V.L., Letter to John C. Schettino transmitting position letters, Boeing, June 29, 1973.

184. Bresnahan, Robert J., Letter to Randall Hurlburt concerning comments on Task Group 2 Draft report dated June 1, 1973, Orange County Airport June 27, 1973.

185. von Kann, Clifton F., Letter to Dr. Meyer regarding EPA Task Groups, Air Transport Association, July 3, 1973.

186. Rogers, Robert A., Wohl, Bernard; and Gale, C.M., Flight Evaluation of Two-Segment Approaches for Jet Transport Noise Abatement, American Airlines, Inc. For NASA, June, 1973.

187. Duffelmeyer, H. James, letter to Randall L. Hurlburt enclosing statement regarding PSA two-segment approach, City of Foster City, California, July 11, 1973.

188. Hurlburt, Randall L., memo to Mark Dees subject: "Historical Intent of FAR 91.87 (d)," City of Inglewood, California, September 9, 1971.

189. Hurlburt, Randall L., Information Brief on "Night Operations at Airports," EPA, July 19, 1973

190. Blumenthal, V. L, letter to William C. Sperry attaching tabulation of landing thrust and velocity versus flap setting, Boeing, July 6, 1973.

191. Skully, R. P., letter to Dr. Alvin F. Meyer, Jr. transmitting project report Amendment to Federal Aviation Regulations to Provide for a Takeoff Noise Control Operating Rule, FAA, 5 February, 1973.

192. Schlegel, Ronald G., Letter to John Schettino summarizing position of Sikorsky Aircraft, Sikorsky Aircraft, July 2, 1973.

193. U.S. Department of Commerce, Letter to John C. Schettino submitting views concerning EPA Aircraft/Airport Noise Report Study, July 19, 1973.

The following references are not a part of the Task Group 2 master file:

500. FAA, FAA Statistical Handbook of Aviation, 1970 edition.

501. FAA, Federal Air Regulations, Part 93, "Special Air Traffic Rules and Airport Traffic Patterns."

502. FAA, Federal Air Regulations, Part 139, "Certification and Operations: Land Airports Serving CAB - Certificated Scheduled Air Carriers Operating Large Aircraft other than Helicopters."

503. Bolt, Beranek, and Newman, Inc., Aircraft Noise Analysis for the Existing Air Carrier System, Report to Aviation Advisory Commission, September 1, 1972.

504. Cox, C. R., VTOL Noise, Bell Helicopter Company, April, 1973.

505. NASA, Aircraft Noise Reduction Technology, March 30, 1973.

506. FAA, The National Aviation System Plan, Ten Year Plan 1973-1982, March 1972.

507. FAA, The National Aviation System Plan, Ten Year Plan 1973-1982, March 1973.

508. Portola Valley Noise Abatement Committee, Letter regarding need for larger, visible aircraft identification numbers, for ground based aircraft identification in communities, Portola Valley, Calif., March 26, 1973 (in Task Group 1 Master File).

509. Evans, M., Letter to E. Cuadra summarizing her remarks at March 30 meeting of Task Group 1, April 2, 1973 (in Task Group 1 Master File).

510. California, State of, "Title 4: Subchapter 6: Noise Standards," California Department of Aeronautics (in Task Group 4 Master File).

511. Cuadra, Elizabeth, Legal and Institutional Analysis of Aircraft and Airport Noise and Apportionment of Authority Between Federal, State, and Local Governments, Report of EPA Aircraft/Airport Noise Study Task Group 1, NTID 73.2, July, 1973.

512. Von Gierke, Henning, Impact Characterization of Noise Including Implications of Identifying and Achieving Levels of Cumulative Noise Exposure, Report of EPA Aircraft/Airport Noise Study Task Group 3, NTID 73.4, July, 1973.

513. Sperry, William C., Noise Source Abatement Technology and Cost Analysis Including Retrofitting, Report of EPA Aircraft/Airport Noise Study Task Group 4, NTID 73.5, July, 1973.

514. Sperry, William C., Review and Analysis of Present and Planned FAA Noise Regulatory Actions and Their Consequences Regarding Aircraft and Airport Operations, Report of EPA Aircraft/Airport Noise Study Task Group 5, NTID 73.6, July, 1973.

515. Nethery, Sidney, Military Aircraft and Airport Noise and Opportunities for Reduction Without Inhibition of Military Missions, Report of EPA Aircraft/Airport Noise Study Task Group 6, NTID 73.7, July, 1973.

516. FAA, "Airline Economic Computer Model: Volume I-Detailed Discussion," FAA-EQ-72-4, June, 1972.

517. Hurlburt, Randall L., A Complete Analysis of the Costs and Benefits of a Quiet Engine Retrofit Program, City of Inglewood, California, January 15, 1971.

Appendix A

TECHNICAL ANNEX

This technical annex contains excerpts or summaries of certain research programs or analyses which have been submitted to the Aircraft/Airport file. It is not a complete record of these documents but is simply intended to provide a more in-depth understanding of the background material submitted to Task Group 2 and considered in the writing of this report. A complete bibliography is included in the REFERENCES section of this report and a complete file of documents is maintained by EPA.

Wherever possible, summaries, conclusions or summary figures are reprinted verbatim from the original report. Where this was not possible summary information is given based on data in the original report.

Technical Annex

Contents

(Excerpts from the following documents)

27. TECHNIQUE FOR CALCULATING OPTIMUM NOISE-ABATEMENT TAKE-OFF PROFILES

By Heinz Erzberger, Homer Q. Lee, H. Rodney Peery, and Fred J. Drinkwater III

NASA Ames Research Center

SUMMARY

An analytical technique has been developed for determining take-off and climbout profiles of jet aircraft that minimize the noise in a noise-sensitive area near an airport. Because the technique is analytical, it is especially suited to the study of the effect of such factors as engine noise characteristics, location of noise-sensitive area, and operational constraints on the optimum profile for noise abatement.

Two important elements of the technique are the division of the ground track of the profile into a section near the airport having low sensitivity to noise, followed by one that is noise sensitive, and the formulation of a criterion for comparing the noisiness of different profiles. The criterion used in this study was the average perceived noise along the noise-sensitive section of the ground track. Any other criterion could be used instead.

The technique was applied to the calculation of optimum profiles for a typical currently inservice jet transport. Although the complete specification of the profiles generally depends on the noise characteristics of the engines and on other factors, the optimum profiles calculated herein can be characterized by a period of acceleration as soon as possible after take-off, followed by a steep climb, which in turn is followed by thrust reduction when the noise-sensitive area or a specified altitude is reached. Before the transition from accelerating to climbing, the optimum profiles achieved an airspeed that permitted full retraction of flaps. This acceleration caused some altitude loss at the beginning of the noise-sensitive area, but the disadvantage of a slightly lower altitude can be outweighed by the advantage of greater thrust reduction that is possible in the clean airplane configuration. Thus, in the trade off between airspeed and altitude, gaining airspeed until it is permissible to retract flaps can be more important than gaining altitude, if the objective is to minimize the average perceived noise along the noise-sensitive ground track.

A piloted fixed-base simulation of take-off profiles demonstrated the reduction in average perceived noise that is possible with the optimum climbout profile. No unusual difficulties in flying this profile on the simulator were encountered by the pilot.

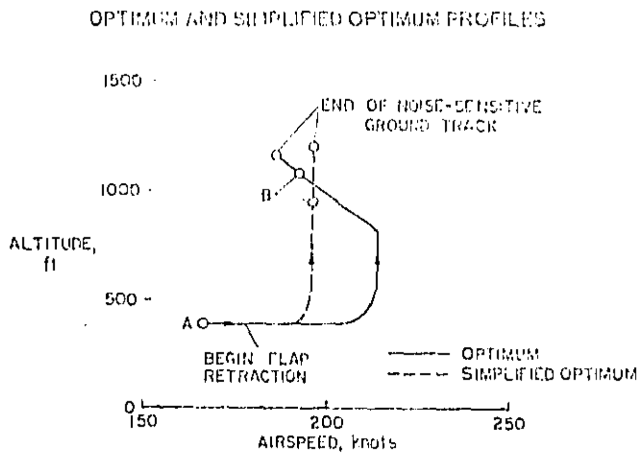


Figure 3

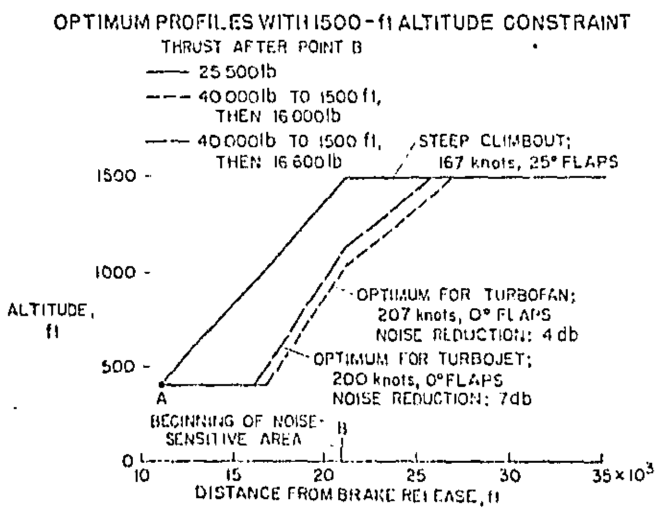


Figure 4

NOISE MEASUREMENT EVALUATIONS OF VARIOUS TAKE-OFF-CLIMBOUT PROFILES OF A JET TRANSPORT AIRPLANE

By W. L. Copeland, D. A. Hilton, V. Huckel,
A. C. Dibble, Jr., and D. J. Maglieri

SUMMARY

Noise measurement evaluations have been conducted on a Boeing 720 turbojet-powered aircraft for several climbout profiles involving various climb speeds, flap settings, and engine pressure ratios, and these data were correlated with airplane operations and position data.

The main result of these studies is that power reductions generally result in reduced noise levels on the ground compared to those associated with a full-power take-off-climbout. Further, the amount of noise reduction attained depends upon the amount of power reduction and the noise level profile on the ground is related directly to the engine power schedule.

MEASUREMENTS OF NOISE PRODUCED BY A

BAC-111-400 SERIES TURBOFAN TRANSPORT AIRPLANE DURING

TAKE-OFF-CLIMBOUT OPERATIONS

By D. A. Hilton, W. L. Copeland, and A. C. Dibble, Jr.

CONCLUDING REMARKS

Noise measurement evaluations have been conducted on a BAC-111-400 series turbofan powered airplane for three climbout profiles involving various engine power settings and flap settings during two segment climb, and these data were correlated with airplane operations and position data.

The main results of these studies are that power reduction during the second segment of climb generally result in reduced noise levels on the ground. Further, the amount of noise reduction attained depends upon the amount of power reduction, and the noise level profile on the ground is related directly to engine power schedule.

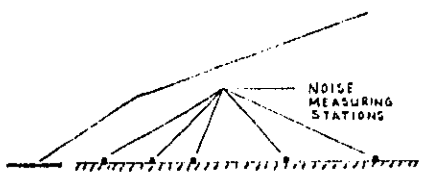
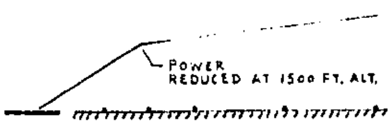
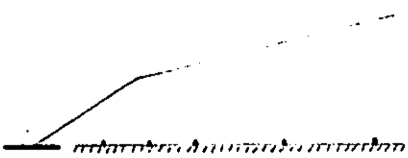
Schematic	Profile	Description of Procedure
	1	Full take-off power at V_2 + 20 kts. with 18° flaps. After 400 ft. altitude retract flaps to 8° and accelerate to 170 kts. At 1500 ft. altitude reduce power from full take-off power to 89% rpm with 8° flaps and maintain until reaching 3000 ft. altitude. Then proceed SOP climb not to exceed 210 KIAS.
	2	Full take-off power at V_2 + 20 kts. with 18° flaps. After 400 ft. altitude retract flaps to 8° and accelerate to 170 kts. At 1500 ft. altitude reduce power from take-off power to 87% rpm with 8° flaps and maintain until reaching 3000 ft. altitude. Then proceed SOP climb not to exceed 210 KIAS.
	3	Full take-off power at V_2 + 20 kts. with 18° flaps. After 400 ft. altitude retract flaps to 8° and accelerate to 170 kts. At 1500 ft. altitude reduce power from take-off power to 87% rpm, retract flaps to 0° holding 87% rpm until 3000 ft. altitude. Then proceed SOP climb not to exceed 210 KIAS.

Figure 5.- Schematics and descriptions of various flight profiles used for take-off-climbout noise tests.

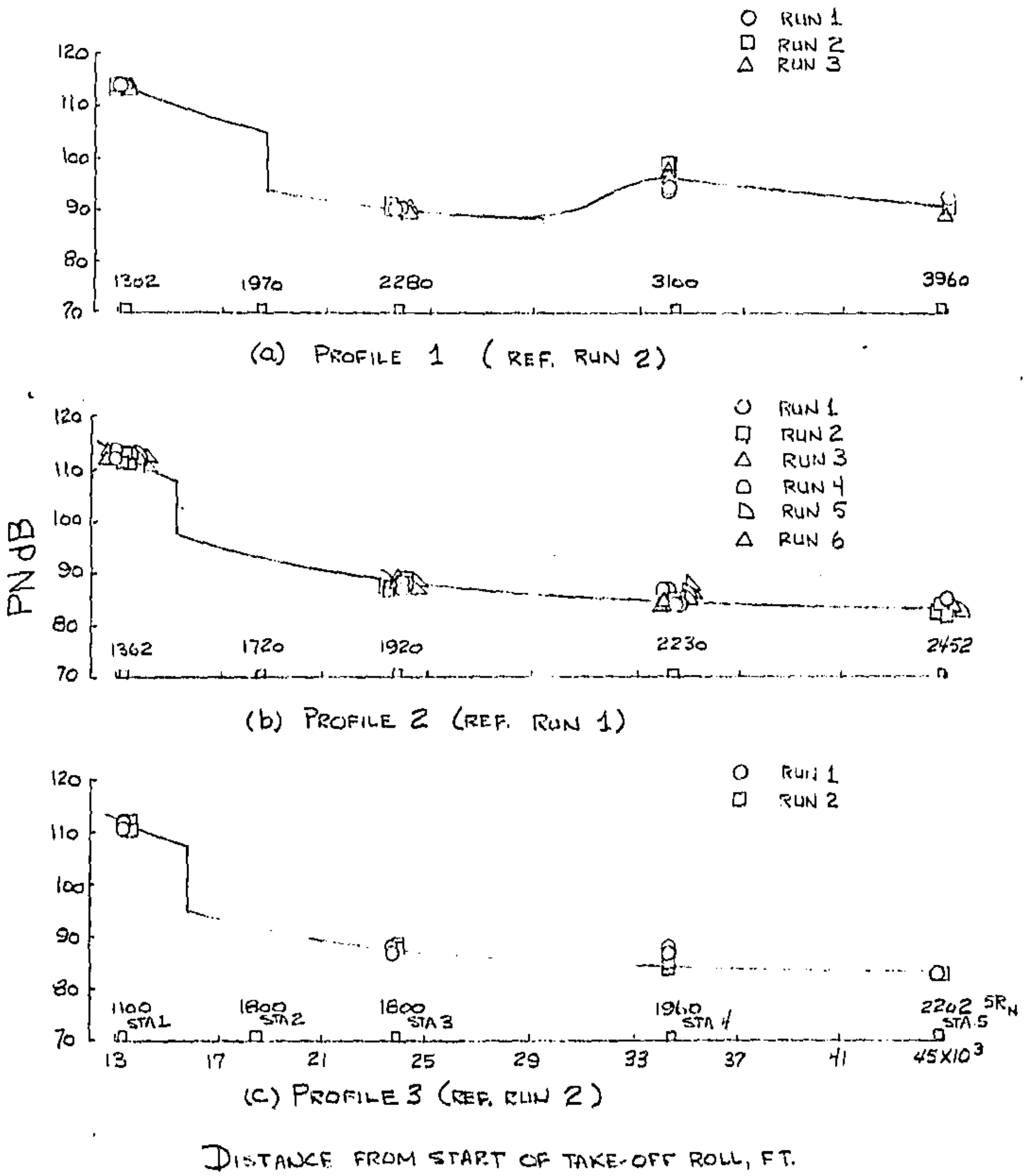


Figure 13.- Normalized perceived noise levels along ground track of airplane for Profiles 1, 2, and 3.

MEASUREMENTS OF NOISE PRODUCED BY A

BOEING 727 TURBOFAN TRANSPORT AIRPLANE DURING

TAKE-OFF-CLIMBOUT OPERATIONS

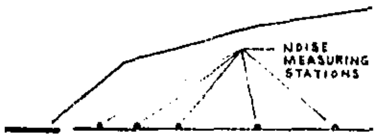
By D. A. Hilton, A. C. Dibble, Jr., and W. L. Copeland

CONCLUDING REMARKS

Noise measurement evaluations have been conducted on a Boeing 727 turbofan powered airplane for three climbout profiles involving various engine power settings and flap settings during two segment climb, and these data were correlated with airplane operations and position data.

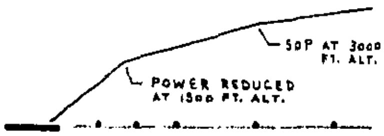
The main result of these studies is that power reductions during the second segment of climb generally result in reduced noise levels on the ground compared to those associated with a full-power take-off climbout. Further, the amount of noise reduction attained depends upon the amount of power reduction and the noise level profile on the ground is related directly to the engine power schedule.

Schematic | Profile | Description of Procedure



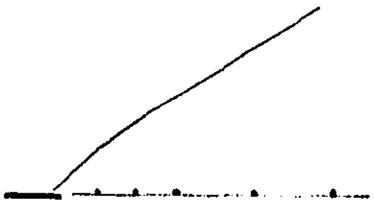
1

Full take-off power at V_2 + (10 or 20 kts) with 15° flaps. After 400 ft. altitude retract flaps to 5° and add 10 kts to climb speed. At 1500 ft. altitude reduce power from take-off power to power required for 500 fpm rate of climb holding V_2 + (10 or 20 kts) and 5° flaps. Maintain these conditions until reaching 3000 ft. altitude then proceed SOP climb not to exceed 210 KIAS (Deck angle limitation 15°).



2

Full take-off power at V_2 + (10 or 20 kts) with 15° flaps. After 400 ft. altitude retract flaps to 5° and then to 2° prior to reaching 1500 ft. altitude. At 1500 ft. altitude reduce power from take-off power to power required for 500 fpm rate of climb holding airspeed and 2° flaps. Upon reaching 3000 ft. altitude proceed SOP not to exceed 210 KIAS (Deck angle limitation 15°).



3

Full take-off power at V_2 + 10 kts with 15° flaps. At 1000 ft. altitude reduce power from take-off power to maximum continuous power holding V_2 + 10 kts and 15° flaps. After reaching 2000 feet altitude retract flaps and accelerate as per schedule (Deck angle limitation 15°)

Figure 5.- Schematics and descriptions of various flight profiles used for take-off-climbout noise tests.

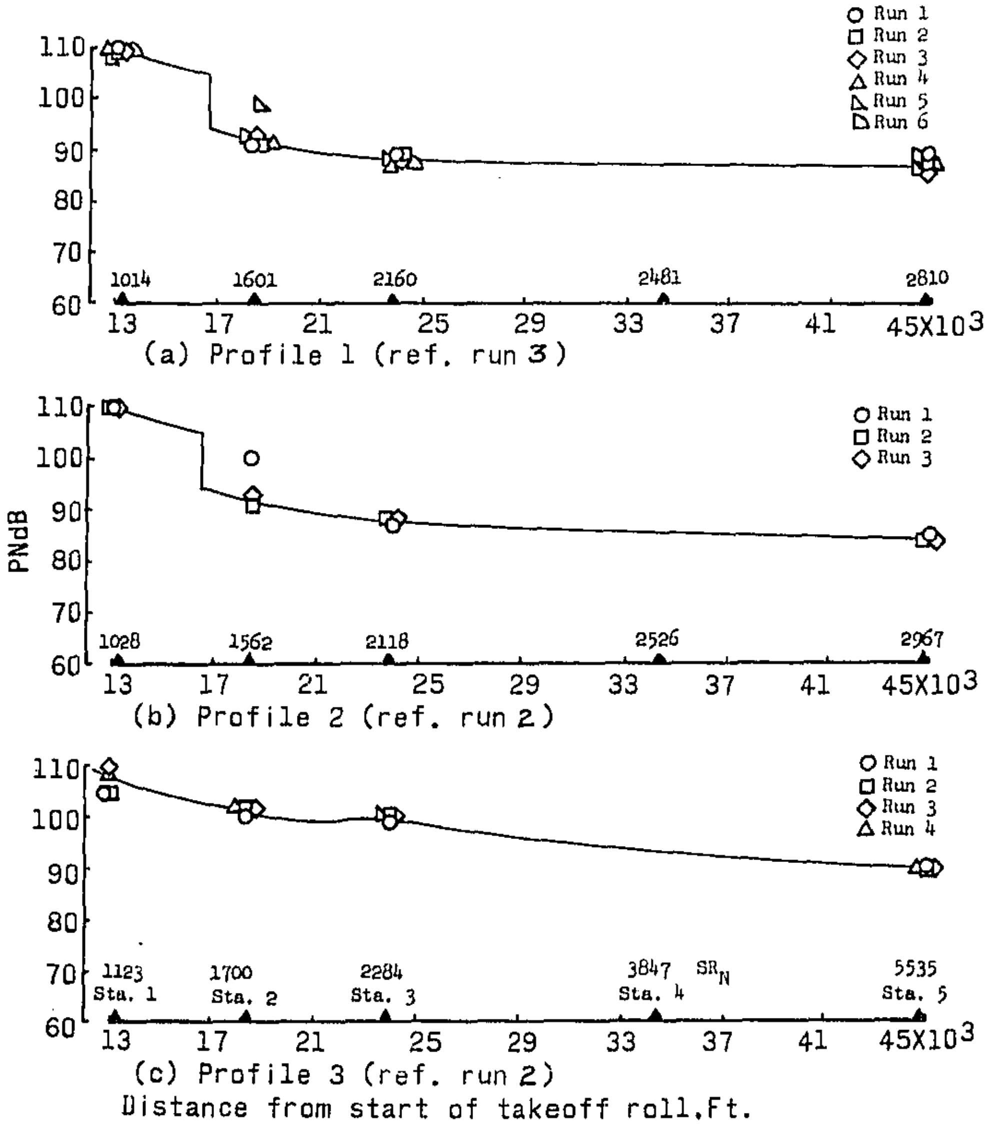


Figure 13.- Normalized perceived noise levels along ground track of Boeing 727 airplane for Profiles 1, 2, and 3.

March 1, 1973

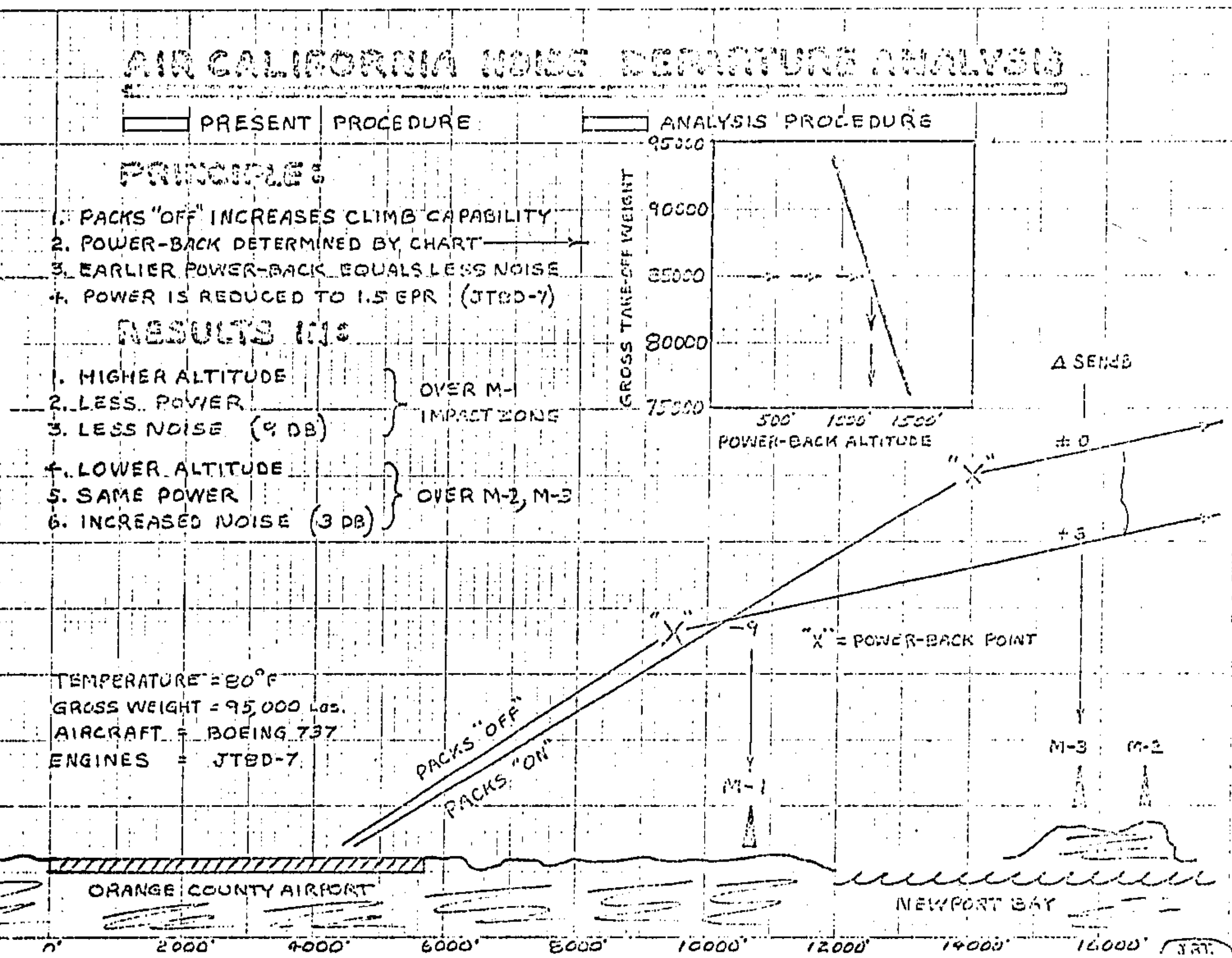
SUBJECT: Take-off Flight Path Studies

1. In addition to our constant surviellance of fuel load and gross take-off weight studies, Air California has been an active leader in the industry in the development of inflight techniques to minimize the noise impact on our airport neighbors. This has been accomplished by introducing specific procedures during take-off and approach to landing at each noise sensitive airport. Additional tests have been conducted to minimize the ground run-up noise on the airport's surface, by location and positioning of aircraft.

2. Since the beginning of our operations at the Orange County Airport in 1966, we have rigidly followed a noise abatement departure which has proven very effective. Subsequent to the installation of the "ECOLOG" Noise Monitoring stations at this airport, we have been able to update our existing procedures as well as flight-test new concepts in our goal to minimize noise.

7. Through the excellent cooperation of the airport noise abatement staff and the ECOLOG Monitor stations, and valuable assistance from the Boeing Company Noise and Aerodynamics staff, computor data indicated we did indeed have a means of further modifying our departure profile and predicting the benefits of such changes.

8. Figure 3 illustrates the comparison of the new analysis procedure with the present procedure. In order to minimize the noise at the critical location, noise monitor M-1, the airplane must attain the highest possible altitude and then reduce thrust to the lowest practical value prior to overflying M-1. In the new procedures, additional altitude is gained by NOT USING engine bleed air for cabin air conditioning (this function is assumed by the airborne APU) thus providing additional take-off and climb thrust from the engines. At 95,000 lbs. this extra performance would result in approximately 50' additional altitude over M-1, however the noise improvement from this altitude increment alone would be small. By reducing thrust just before the airplane overflies M-1, significant noise reduction is obtained. Relative to the present procedures, a reduction of 9 db is estimated at M-1. Because thrust was reduced at about 900 ft. altitude instead of climbing to 1500 ft., the airplane overflies M-2/M-3 with 350 ft. less altitude. This altitude loss will increase noise at M-2/M-3 by an estimated 3 db.

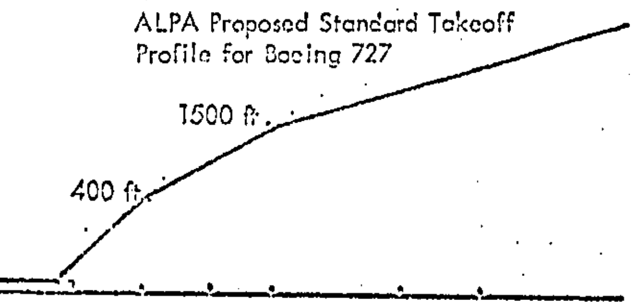
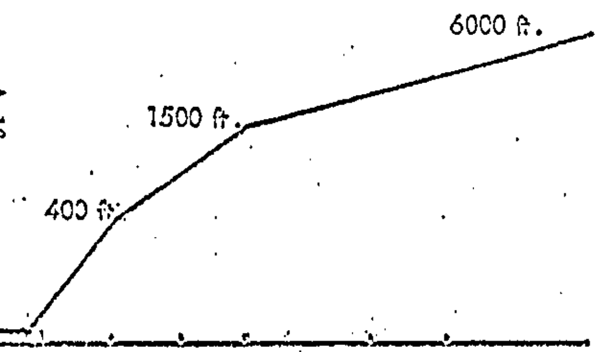
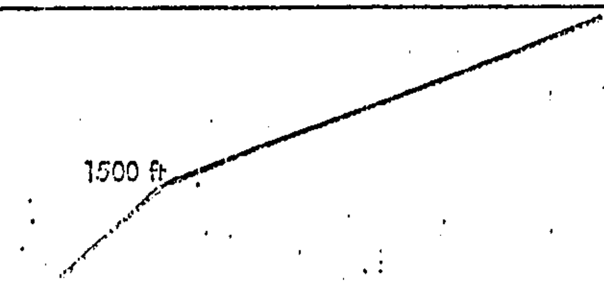

AIR CALIFORNIA NOISE DEPARTURE ANALYSIS
PRESENT PROCEDURE
ANALYSIS PROCEDURE
PRINCIPLES:
1. PACKS "OFF" INCREASES CLIMB CAPABILITY
2. POWER-BACK DETERMINED BY CHART
3. EARLIER POWER-BACK EQUALS LESS NOISE
4. POWER IS REDUCED TO 1.5 EPR (JT8D-7)
RESULTS IN:
1. HIGHER ALTITUDE
2. LESS POWER
3. LESS NOISE (9 DB)
OVER M-1 IMPACT ZONE
4. LOWER ALTITUDE
5. SAME POWER
6. INCREASED NOISE (3 DB)
OVER M-2, M-3
GROSS TAKE-OFF WEIGHT
95000
90000
85000
80000
75000
500'
1000'
1500'
POWER-BACK ALTITUDE
Δ SENDS
±0
+3
-9
"X"
"X" = POWER-BACK POINT
TEMPERATURE = 80°F
GROSS WEIGHT = 95,000 LBS.
AIRCRAFT = BOEING 737
ENGINES = JT8D-7
PACKS "OFF"
PACKS "ON"
M-1
M-3
M-2
ORANGE COUNTY AIRPORT
NEWPORT BAY
0'
2000'
4000'
6000'
8000'
10000'
12000'
14000'
16000'

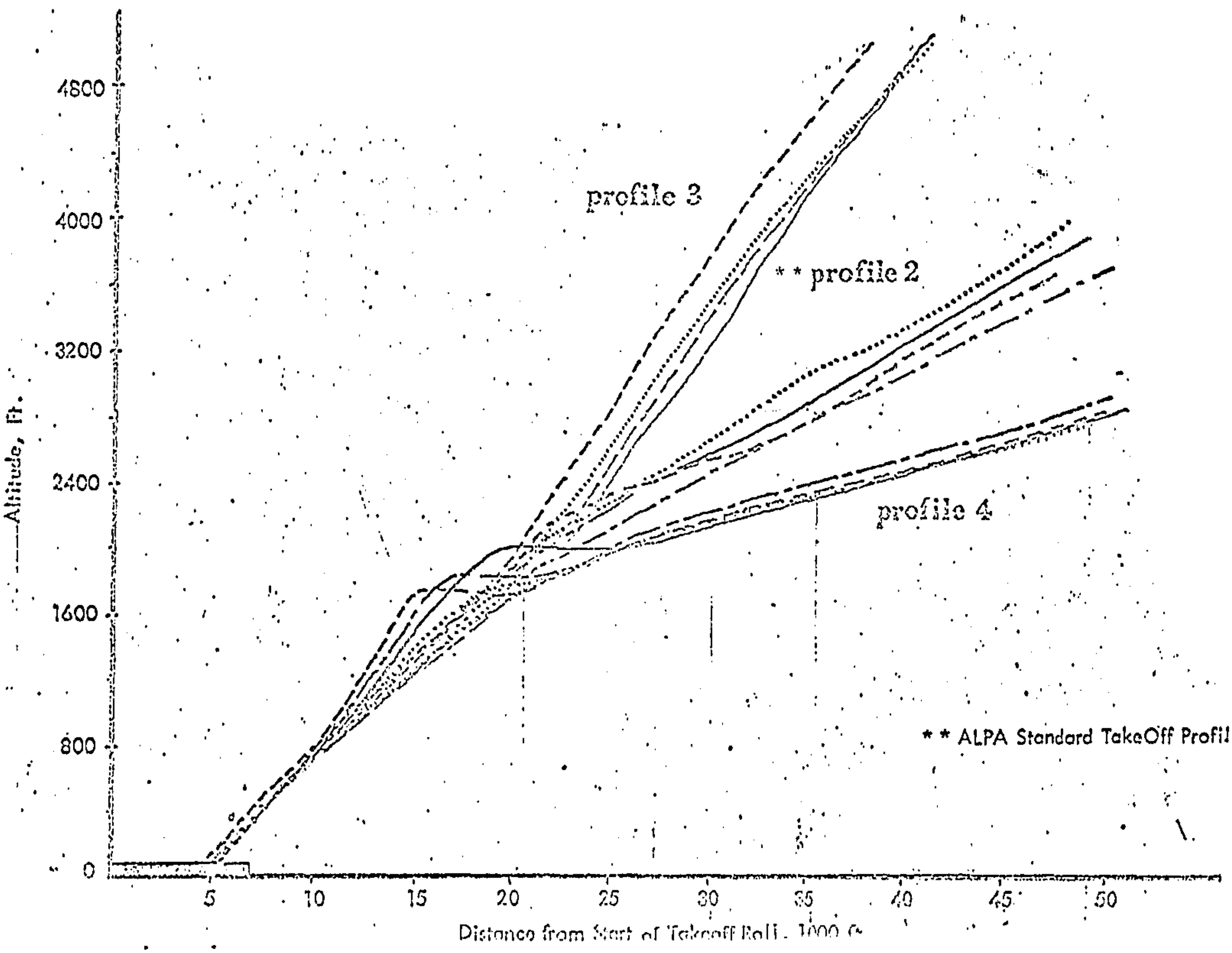
ALPA Standard Take Off Profile

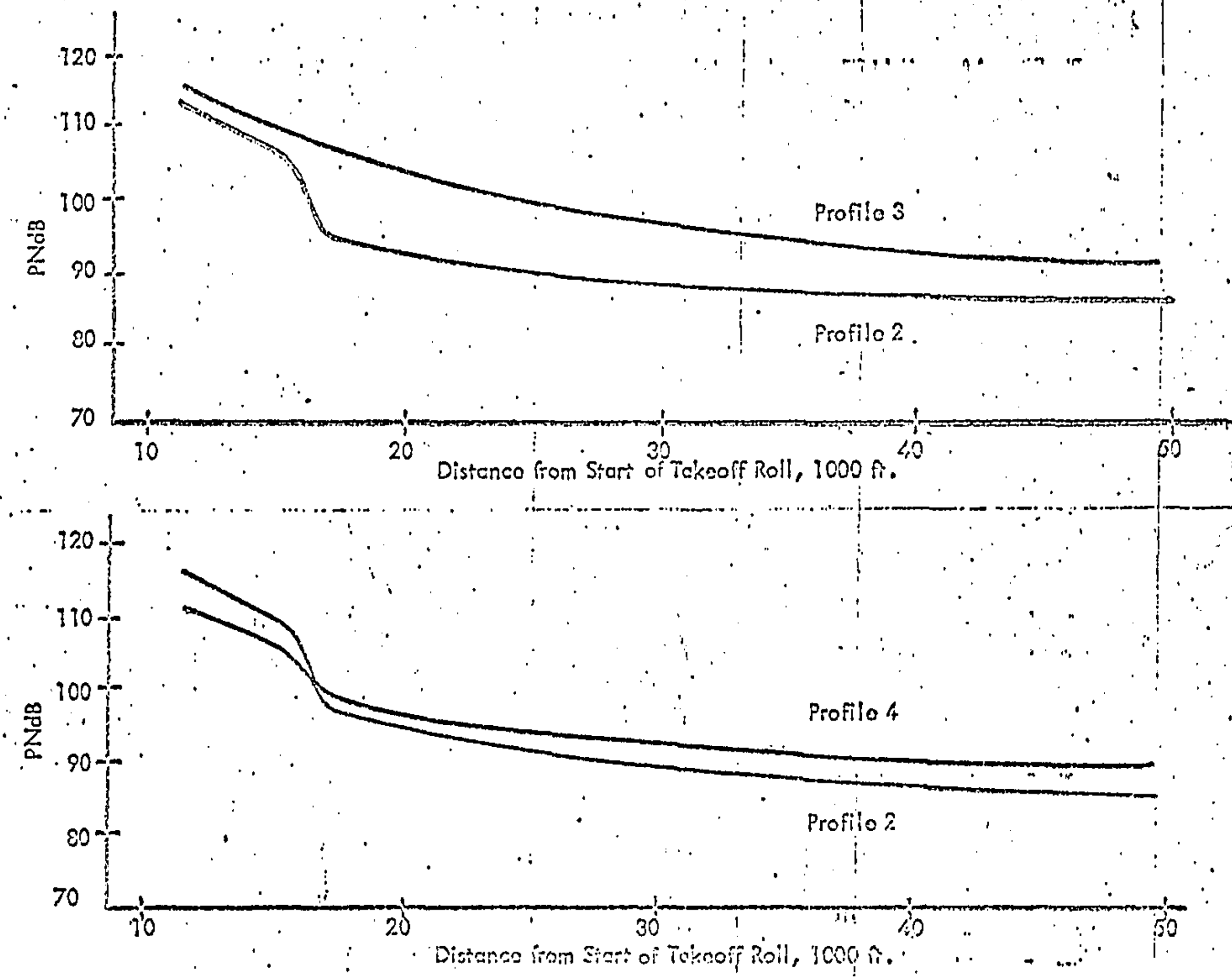
Experimental noise abatement flight tests, in which ALPA participated, were conducted at Wallops Island, Virginia in 1967 by NASA using various airline aircraft. The noise produced was carefully measured at designated points and several different flight procedures and configurations were used to endeavor to find the best takeoff profile consistent with safety and which produced the least amount of overall noise exposure to a community. (See Attachment A-1 through A-3.)

A Standard TakeOff Profile (STOP) was agreed upon by the Air Transport Association, FAA, and ALPA in May, 1968. It was to have been put into operation in the summer of 1968 by issuance of an Advisory Circular by the FAA. However, for unknown reasons, this Advisory Circular was never issued. Since that time, ALPA has actively attempted to have a standard takeoff program revived by the FAA and the airlines.

The ALPA Noise Abatement Committee therefore proposes that all pilots use the standard takeoff profile as outlined in Attachment B. The Committee also proposes that the pilots of each airline work out the procedures to be followed with their individual airline operations managers because there are possible slight variations in the procedure, dependent on aircraft type and airline preference.

SCHEMATIC	PROFILE	DESCRIPTION OF PROCEDURE
	2	Takeoff power at V_2 + 10 knots with 15° fla At 400' altitude begin retracting flaps per s and accelerate to 210 knots. Flaps to be at to 1500' altitude. At 1500' altitude reduce to that required to maintain 1.5% positive g with one engine inoperative (approximately rate of climb at 210 knots with one engine i Maintain at 210 knots.
	3	Takeoff power at V_2 + 10 knots with 15° fla 400' altitude begin reducing to 0° flaps as p schedule and accelerate to 210 knots. At 1. altitude reduce to maximum continuous powe accelerate to 220 knots. At 6000' altitude smooth acceleration to 250 knots and mainta stabilized power.
	4	Takeoff power at V_2 + 10 knots with 15° fla not exceed 15° deck angle. At 1500' altitu power to that required for 500 fpm rate of cl 15° flaps and speed required for holding 15° angle. Maintain this speed and configuratio


4800
4000
3200
2400
1600
800
0
Altitude, Ft.
profile 3
* * profile 2
profile 4
* * ALPA Standard TakeOff Profil
5
10
15
20
25
30
35
40
45
50
Distance from Start of Takeoff Roll - 1000 ft



120
110
100
90
80
70
PNdB
Profile 3
Profile 2
10
20
30
40
50
Distance from Start of Takeoff Roll, 1000 ft.
120
110
100
90
80
70
PNdB
Profile 4
Profile 2
10
20
30
40
50
Distance from Start of Takeoff Roll, 1000 ft.

AIRCRAFT/AIRPORT NOISE STUDY TASK FORCE March 26, 1973

TASK GROUP 2, OPERATIONS ANALYSIS

LOCKHEED-CALIFORNIA COMPANY

BURBANK, CALIFORNIA

The material submitted is a study of the effect of variations of weight, flap angle, and other parameters on noise contour footprints. The numerical data are for the Lockheed L-1011-1 TriStar widebody transport; they are believed to be generally representative of any transport of the same class powered by high-bypass, quieted engines. The principal results are that the contour areas are much smaller than those of older narrow body aircraft and that cutback procedures are much less effective.

In summary -

- o Iso-noise contour footprints provide a more useful evaluation of an airplane's noise impact on a community than do the three FAR Part 36 conditions.

- o The 90 EPNdB contour exposure area is used as an evaluation reference. The 90 PNdB or 80 dBA contours would give similar results.

- o Use of the RB.211-22B engine in place of the -22C will reduce takeoff noise exposure area about 15% at and above the FAR Part 36 reference day temperature of 77°F. Below the -22C flat rating point at 66°F, areas for the two engines are approximately the same.

- o Variation of takeoff or landing weight changes exposed area by about 0.015 sq. mi. (10 acres) per 1000 pounds, or less than 1% of the total exposed area.

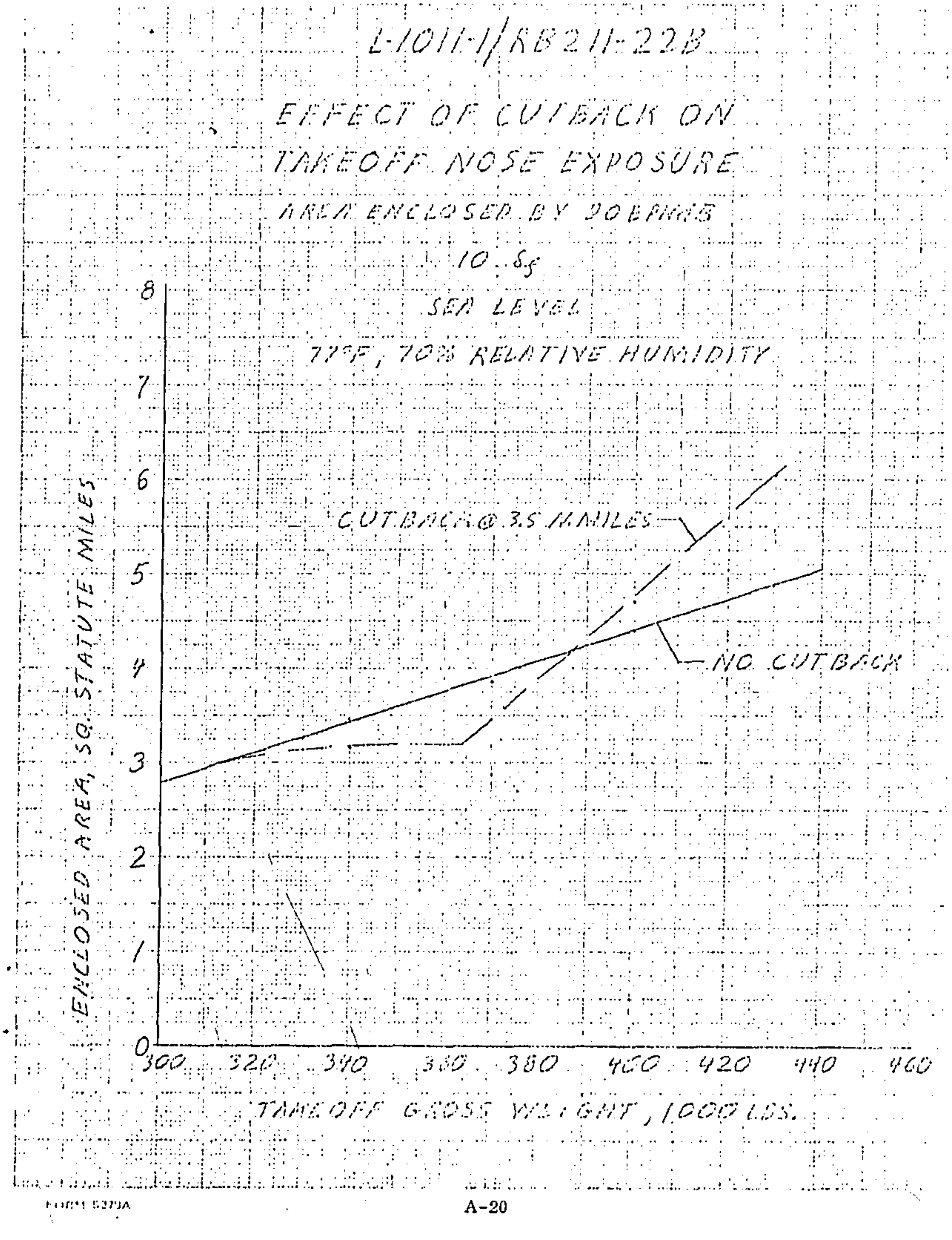
- o Lower flap angles for takeoff expose slightly smaller areas, particularly at heavier weights.

- o Takeoff thrust-cutback at 3.5 n.mi. increases exposed area above 390,000 pound TOGW. For maximum TOGW, minimum exposed area is achieved by cutback about 5 n.mi. from brake release, for lighter takeoff weights at smaller distances, down to 3 n.mi. for 340,000 pound TOGW.

- o Use of DLC increases noise exposure about 10% at maximum design landing weights. At this same weight, flap angle reduction is worth about 0.09 sq. mi. (55 acres) per degree. For 33° flaps there is a 23% reduction in exposed area from the maximum 42° flaps; and if 25° flaps were to be used, there would be a reduction of about 50% from the 42° operation.

- o The combined approach/takeoff operation of a 707/DC-8 type aircraft exposes ten times the area that an L-1011-1 does, and a 727 type about five times the area.

It should be remembered that noise footprints should be considered as broad brush lines. Noise varies quite slowly with distance and, considering a 90 EPNdB contour, for instance, there is a significant area between the 89.5 and 90.5 EPNdB lines; yet subjectively the difference in noise would be insignificant. The areas within a contour should not be read with excessive precision.


L-1011-1/RB211-22B
EFFECT OF CUTBACK ON
TAKEOFF NOISE EXPOSURE
AREA ENCLOSED BY 90 EPNdB
10 δf
SEA LEVEL
77°F, 70% RELATIVE HUMIDITY
CUTBACK @ 3.5 N.MILES
NO CUTBACK
ENCLOSED AREA, SQ. STATUTE MILES
TAKEOFF GROSS WEIGHT, 1000 LBS.
0
1
2
3
4
5
6
7
8
300
320
340
360
380
400
420
440
460

FORM 5279A

PREPARED BY: [signature]
DATE: 7-24-72
CHECKED BY:

LOCKHEED-CALIFORNIA COMPANY
A DIVISION OF LOCKHEED AIRCRAFT CORPORATION

PAGE
MODEL
REPORT NO.

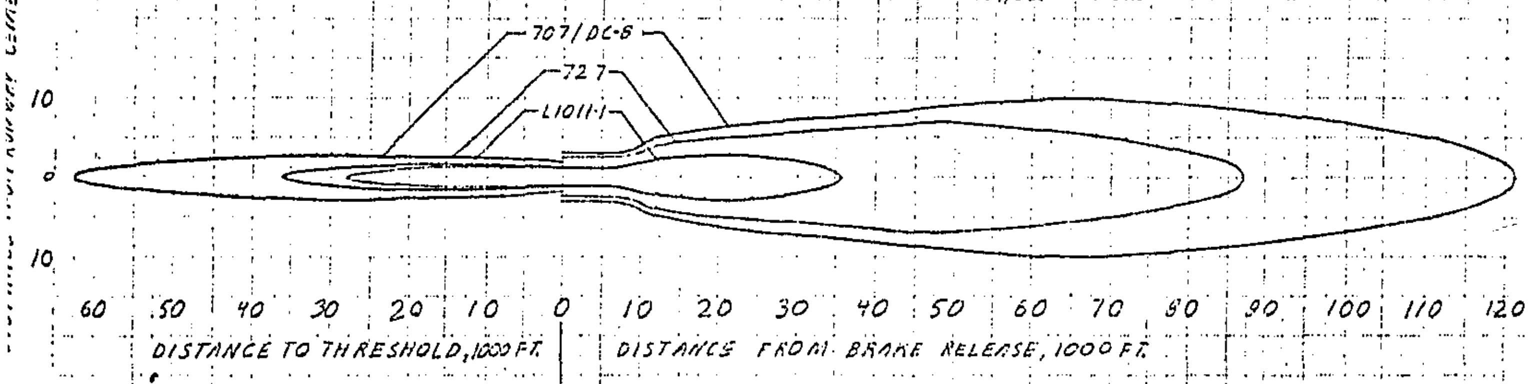
L-1011-1/727/707/DC-8 FOOT PRINT COMPARISON

90 EPNdB

MAXIMUM DESIGN WEIGHTS

ENCLOSED AREAS (SQUARE STATUTE MILES):

	TAKEOFF	APPROACH	TOTAL
L-1011	5.0	2.1	7.1
727	30.8	3.5	34.3
707/DC8	61.8	10.1	71.9



NOISE MEASUREMENT EVALUATION OF TAKEOFF AND APPROACH

PROFILES OPTIMIZED FOR NOISE ABATEMENT

H. Rodney Peery and Heinz Erzberger

Ames Research Center

SUMMARY

A flight investigation to determine the effective perceived noise level associated with certain takeoff and landing profiles has been conducted using the Ames CV-990 aircraft. The tests were designed to evaluate noise-optimum takeoff profiles, previously obtained in an analytical study, and to investigate the potential for noise abatement of nonstandard approach procedures.

During the takeoff tests, the flaps were set at either 27° or 10° and the climb airspeeds varied from V_2+15 to V_2+50 knots (V_2 refers to the takeoff safety speed of the aircraft). Power was reduced to yield either 500 or 750 ft/min rate of climb when the aircraft reached 1500 ft altitude. The assumed noise sensitive ground track extended along the runway centerline from 3.5 to 5.7 nautical miles from the start of the takeoff roll.

The average of the noise measurements taken at points along the noise sensitive portion of the ground track was used to compare the various takeoff profiles. The takeoff that produced the least average noise, 90.5 EPNdB, used takeoff flaps of 10° and a climb airspeed of V_2+50 knots to 1500 ft altitude, at which point power was reduced to yield a 750 ft/min rate of climb. (Flaps were retracted soon after takeoff while the aircraft was accelerating to V_2+50 knots.) The average noise of a reference profile was 96.4 or 5.9 EPNdB more than the optimum profile. The reference profile used 27° of flaps throughout the takeoff-climbout and a climb airspeed of V_2+15 knots to 1500 ft altitude where the power was reduced to yield a 500 ft/min rate of climb. These results verify previously obtained analytical calculations.

The landing profiles were flown along a 3° glide slope at constant flap settings of 50°, 27°, 10°, and 0°. The approach speed for each profile was 1.3 V_{S_1}+10 knots (V_{S_1} refers to stall speed of the aircraft at the flap setting and gross weight used in the approach). In addition, a decelerating profile with engines at flight idle and 0° flaps was flown over a single noise measuring station at an altitude of 1000 ft. Reducing the flap setting from 50° to 0° on the approach reduced the noise from 110.5 to 106.5 EPNdB along the ground track between 5 and 1 nautical miles from the touchdown. The decelerating overflight with engines at flight idle reduced the noise an additional 12.5 EPNdB compared to the 0° flap approach at the same altitude.

NOISE MEASUREMENTS FOR A THREE-ENGINE TURBOFAN TRANSPORT AIRPLANE DURING CLIMBOUT AND LANDING APPROACH OPERATIONS

By W. Latham Copeland and Lorenzo R. Clark
Langley Research Center

SUMMARY

Noise measurements have been made for a three-engine turbofan transport airplane during climbout and landing approach operations in which the airplane operating procedures were carefully controlled. These controlled procedures included an orderly scheduling of operating variables such as engine power, speed, altitude, and flap settings. The results of these studies are presented for seven climbout operations involving various climb speeds, flap settings, and engine power settings and three for landing approach operations involving various glide-slope angles. The noise data were correlated with airplane operating procedures and position.

In general, the results from the climbout studies indicated that lower noise levels (6 dB to 14 dB) were associated with profiles employing lower engine powers during second-segment climb. Also, for a given climb profile and climb rate, slightly higher noise levels are associated with operations employing fixed flaps than with a specified flap retraction schedule.

The results from the landing approach studies indicated that generally lower noise levels were associated with the steeper glide slopes. For these steeper glide slopes the noise reductions attained (4 dB to 9 dB) resulted from both the increased altitude and the lower engine powers.

EFFECTS OF AIRCRAFT OPERATION ON COMMUNITY NOISE

by

M. C. GREGOIRE

and

J. M. STRECKENBACH

THE BOEING COMPANY
COMMERCIAL AIRPLANE GROUP
SEATTLE, WASHINGTON

June 1971

EFFECTS OF AIRCRAFT OPERATION ON COMMUNITY NOISE

M. C. Gregoire and J. M. Streckenbach
The Boeing Company
Commercial Airplane Group
Seattle, Washington

ABSTRACT

Several means of reducing community noise through changes in airplane operations are discussed and specific examples given. The discussion is divided into two general areas of responsibility: regulatory changes affecting traffic in the airport vicinity and operational or procedural changes available to the airlines. The latter category is further divided into those procedures currently optional to the pilot and airline and those that can be made available through airplane system modifications. Flight profiles for specific airplanes at specific airports are included, along with the noise reductions available. System block diagrams and actual flight data are provided when available. It is concluded that significant reductions in community noise can be attained through operating changes, without affecting safety, and at low cost. Recommendations are made for a course of action to define and implement feasible techniques.

INTRODUCTION

Public pressure is increasing daily against the airlines, the airframe and engine manufacturers, and local airport authorities to reduce aircraft-generated noise in airport communities. Three general areas of community noise improvement have been and continue to be studied to solve this ever-increasing problem. The three areas can be summarized as:

1) Reduction of the noise at its source by quieting the engine installations on the aircraft

2) Changes in land utilization in airport communities

3) Changes in operational procedures in the vicinity of airports

The first of these areas has been the subject of extensive investigation by industry and government agencies for several years. Recent enactment of Federal Air Regulations, Part 36, by the Federal Aviation Administration has established noise criteria for the design and certification of new aircraft not previously certificated. Although not the subject of this paper, considerable work now being done in industry and government programs is related to examining means of retrofitting the existing fleet of commercial fanjet transport aircraft to significantly reduce their community noise levels. As would be expected, the magnitude of noise reduction attained is closely related to technical feasibility and to the economics of airplane modification and operation.

To summarize the second area, it will only be stated here that both Federal and local agencies are continuing to study the possibilities of community noise relief through better land utilization. Such studies encompass the subjects of improved planning for new airports, tightened building codes and zoning restrictions, and revised land utilization around existing airports. Obviously, as in the case of retrofitting the current fleet with quieter engine installations, economics is an important and unavoidable consideration in land utilization studies.

The third area, noise-abatement operating procedures, is discussed as the main topic of this paper.

NOISE REDUCTION THROUGH OPERATIONAL CHANGES

A potential for significant relief of the community noise problem at relatively low cost lies in several areas of airplane operation in the vicinity of airports. In 1966, Oscar Bakke of the FAA presented a paper that discussed several aspects of air traffic control and flight procedures as related to reducing community noise.[1] Some of the general areas discussed by Mr. Bakke are covered in this paper, with the added benefit of several years' study and actual flight testing conducted since his paper. Examples are presented for specific aircraft in an attempt to add emphasis to the feasibility of several methods of reducing community noise.

Recommendations of the International Civil Aviation Organization (ICAO) relative to safety considerations in establishing noise abatement operating procedures[2] are recognized as typical constraints in the discussions that follow.

Potential areas of noise reduction through operating procedures fall roughly into two categories: (1) Federal or local air regulations and (2) operating procedures that are or may be made available to the airlines.

Regulatory	Operational
• Holding and maneuver altitudes	• Delayed flap and gear extension
• Optimized traffic patterns	• Two-segment approaches
• Glide slope	• Flap position for landing
• Glide slope intercept altitude	• Takeoff procedures

As will be discussed later, any consideration of these potentials for noise relief must include their relationship to safety, airplane performance constraints, aircraft modification requirements, pilot acceptance, the geography of the specific airport, and the economic aspects of the change.

Regulatory Changes

In general, any action taken to increase the height of aircraft over a community will reduce noise in the community. Many complaints in the past have been based on aircraft flying at low altitude for miles over the community during landing approach. The FAA "keep 'em high" order,[3] released on September 19, 1970, has community noise reduction as one of its purposes. Approach and departure handling of commercial jets at many airports are already reflecting the benefits of this order. Specific quantitative examples of implementation of such procedures will be shown later in this paper.

Holding and Maneuver Altitudes. The holding or maneuver altitudes over suburban areas are shown in figure 1 to have a sizeable effect on noise under the aircraft. The example shown is based on a 727-200 airplane at a landing weight of 150,000 lb. Besides the noise-reduction benefits of increasing the altitude, additional benefits exist in selection of airplane configuration (e.g., flaps and landing gear). As illustrated, in the zero-flap, gear-up configuration, a noise reduction of 9 EPNdB* results from increasing the altitude from 1500 to 3000 ft. Avoiding flap and gear extension until really required, combined with the 1500-ft altitude increase, gives noise reductions of as much as 16 EPNdB.

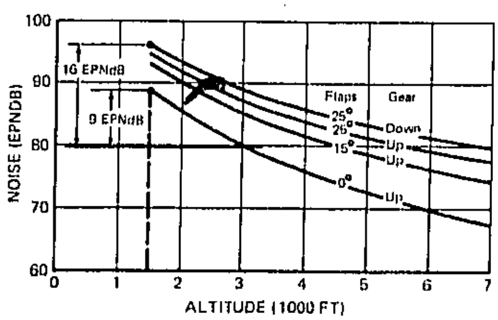


Figure 1. Effect of Holding or Maneuver Altitudes on Noise

It is apparent from this that, in any cases where holding or maneuver altitudes can be raised and clean configurations maintained within constraints established by traffic requirements, definite reductions in community noise can be realized at little or no cost.

Optimized Traffic Patterns. The noise benefits available through optimizing traffic patterns are mainly related to routing of arriving and departing aircraft over nonsensitive areas of the community. This is being done at many aiports now, in some cases at the expense of traffic handling flexibility. Rerouting of traffic in the JFK International Airport area in New York to avoid flying over densely populated areas has severely restricted the traffic handling flexibility of that airport, but there is no questioning the direct benefit of such action to the noise-sensitive public.

Glide Slope. Standard glide slopes at airports throughout the world have been generally established on the basis of safety, pilot acceptance, and airplane performance capabilities. This should not preclude a further look at glide slope changes as a potential area for noise abatement, as long as these same factors are kept in mind. The easiest point of departure for discussing glide slope changes starts with the fact that 3° glide slopes are generally accepted and are standard at many airports today. However, approximately 30% of present glide slopes at major United States airports are as low as 2.5°.

Numerous actual test flights have been conducted by Northwest Airlines[4] on 707, 727, and 747 aircraft at glide slopes on the order of 1/2° above the ILS slope. These flights have demonstrated approach noise reductions of 1 to 5 PNdB, depending on the airplane type and microphone location. The flights have been conducted by visually mismatching the reference airplane symbol and the flight director command bars, so that the airplane followed a path above the ILS glide slope. These flights have demonstrated that raising glide slopes is worthy of consideration as a noise-abatement action.

Analyses conducted by Boeing generally confirm the Northwest Airlines flight data. Figure 2 illustrates the trades between glide slope angle and noise for the 727-200 airplane at various distances from the runway threshold. Noise reductions on the order of 5 to 7 EPNdB are shown for a 1° increase in glide slope. Similar benefits are available with other aircraft.

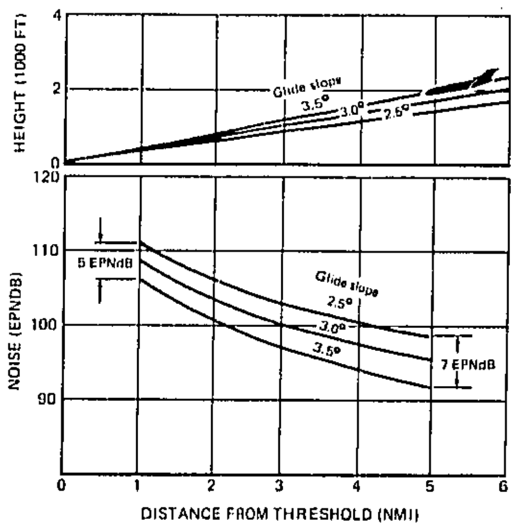


Figure 2. Effect of ILS Glide Slope on Noise

Another way of looking at the noise benefits of higher glide slopes is the change in community area in square miles subjected to a given noise level. Figure 3, again using the 727-200 airplane as an example, shows the area in the community under the approach path subjected to a noise level of 90 EPNdB or higher as a function of glide slope angle. Note that a change from 2.5° to 3.5° glide slope will result in nearly a 70% reduction in the community area subjected to the reference noise level. This can be related to 70% of the population in a residential area.

The foregoing discussion has related to small changes in glide slope that we believe could be implemented at relatively low cost at all airports without degrading safety.** They represent changes that appear to be well within the region of acceptance by most airline pilots flying current-generation jet transport aircraft. Precedence has been established and demonstrated by the 3.22° ILS glide slope at San Diego International and by hundreds of jet landings per week for several years on the 3.5° ILS glide slope on runway 27L at Berlin's Tempelhof Airport. To our knowledge, no landing accidents have occurred at Tempelhof that could be attributed to the glide slope angle. Pilot acceptance of 3.5° glide slopes, without need for changes in approach techniques, has been indicated by the Air Line Pilots' Association.[5]

*The EPNdB noise unit incorporates adjustments for the subjective effects of aircraft noise on humans, including corrections for tone and duration, as defined in Federal Air Regulations, Part 36, dated November 3, 1969.

**For Category II landings, FAA Advisory Circular 120-29, dated September 25, 1970, specifies a 3° maximum glide slope. Reconsideration of this limitation may be justified in the future in light of community noise benefits of increased glide slope angles.

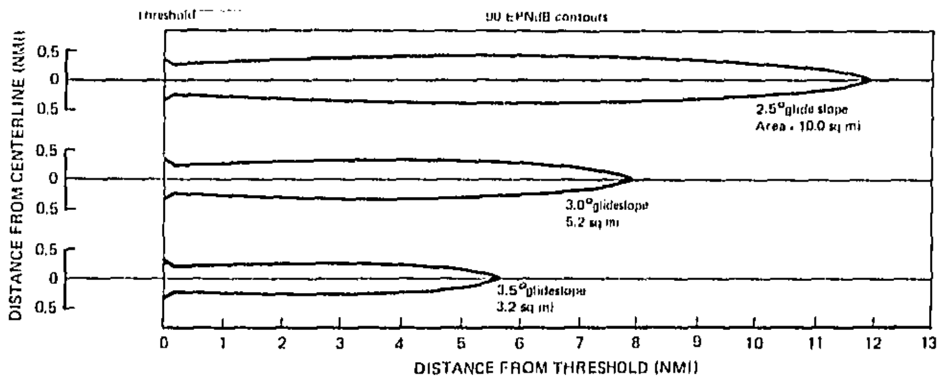


Figure 3. Noise Footprint Comparisons of Various Glide Slope Angles

Future development of the currently planned microwave scanning-beam guidance system will provide additional noise-reduction capability in the areas of traffic patterns and glide slopes. Such a system will provide pilots with programmed, curved, precision flightpath guidance data in both elevation and azimuth, permitting steeper descents and avoidance of residential communities.

Glide Slope Intercept Altitude. The effect on community noise of glide slope horizontal intercept altitude is illustrated in figure 4. Here again, using the 727-200 in a simplified example, the airplane is shown approaching the ILS glide slope at altitudes of 1500 and 3000 ft. In both approaches, the same flap and gear positions are used. The 7 EPNdB lower community noise for the airplane at 3000 ft is due only to the altitude difference. This simple case illustrates the type of noise benefits currently being attained through implementation of the FAA "keep 'em high" order discussed previously.

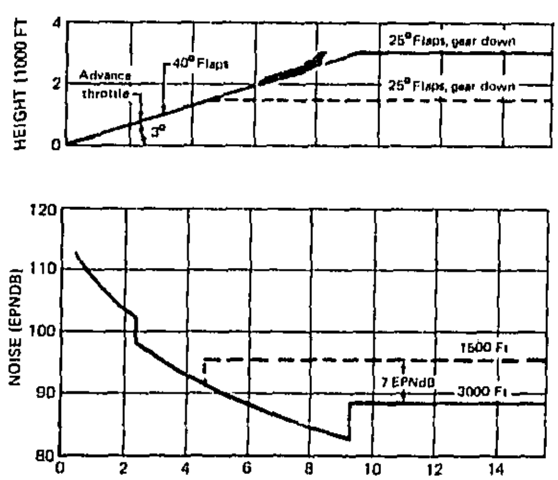


Figure 4. Effect of Horizontal Intercept Altitude on Community Noise

Now let us take a situation in which the noise abatement principles of the FAA order have been implemented at a major airport. Figure 5 shows two arrival profiles into Love Field, Dallas, Texas, using runway 13L. The Bridgeport Two arrival was in use prior to August 20, 1970. Since then the Holly One arrival has been instituted for noise control. We have constructed the illustration using a 727-200 airplane, following our understanding of typical Love Field approaches by these two arrival routes, including vectors to final approach course. Although the ground tracks for the two approaches are different, their respective altitudes above the community serve to compare the differences in noise levels under the flightpath attributed to low versus high profiles. Similar noise benefits can be shown for any jet transport approaching Love Field on these profiles.

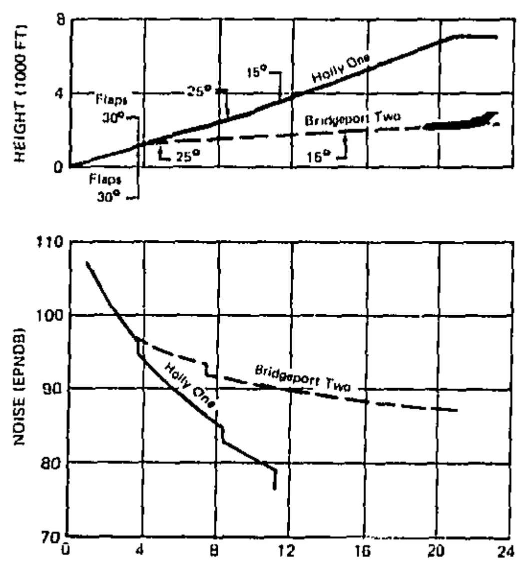


Figure 5. Effect of Increased Altitude on Noise in Dallas-Love Field Arrival Routes

Another example of what higher intercept altitudes will do for community noise is shown in figure 6. Here a 707-320B airplane is shown at various intercept altitudes approaching the 2.75° ILS glide slope on JFK runway 22L in New York City. Again, as in the Dallas illustration, it is seen that implementation of higher altitudes over the community provides significant noise relief at minimal cost.

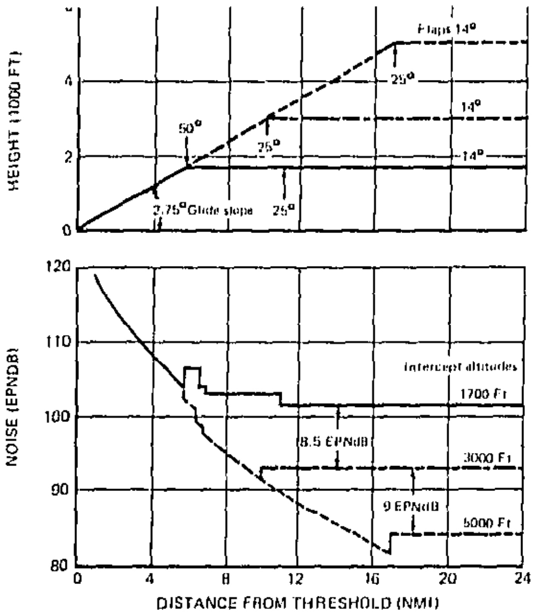


Figure 6. Effect of Increased Altitude on Noise in New York–JFK Arrival Routes

Airline Operational Changes

The foregoing discussion has shown some of the community noise benefits attainable through changes in Federal and local regulations related to holding altitudes, traffic patterns, glide slopes, and glide slope intercept altitudes. Now let us look at some of the procedural options available (or that can possibly be made available) to the airlines for reducing community noise, separate from regulatory changes. In some cases, as will be discussed, equipment modification may be necessary or desirable to permit certain procedures without adverse effects on safety or pilot acceptance.

Delayed Flap and Gear Extension. Noise in the community can be reduced by delaying landing flap and gear extension until close to the runway threshold. Figure 7 compares two cases for a 727-200 airplane. Note that, for several miles over the community, the delayed flap and gear extension reduces the noise on the order of 7 EPNdB. This option is available to the airlines without airplane modification. The minimum distance from the threshold at which landing flaps and gear are extended is subject to pilot discretion but can be considerably closer in than is often practiced, with no effect on safety.

Whatever the distance from the threshold may be for the above technique, using current airplane systems, the distance can be reduced even further if sufficient systems automation is provided to avoid increasing pilot workload or degrading safety. To gain the maximum noise benefit from delayed flap and gear extension, the procedure must be capable of maintaining reduced thrust levels until the airplane is beyond the noise-sensitive area, e.g., probably less than 1 nmi from the threshold.

Figure 8 shows that, using the same profiles as in figure 7 but delaying extension of landing flaps until closer in and with the aid of systems automation, the noise reduction under the flightpath continues to within less than 1 nmi from the runway threshold.

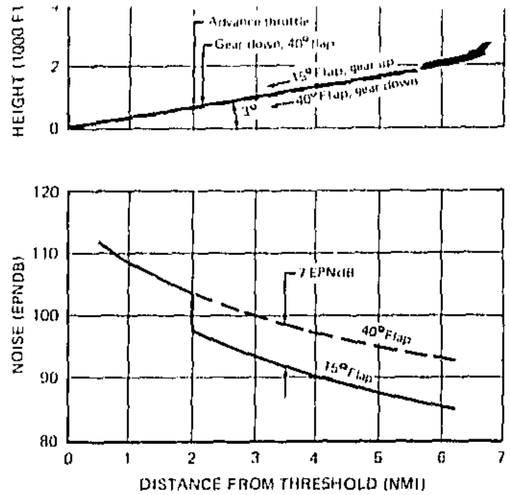


Figure 7. Noise Reduction by Delayed Flap and Gear Extension

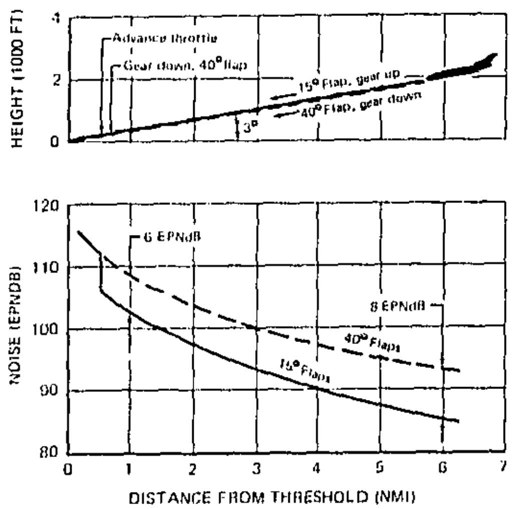


Figure 8. Noise Reduction by Delayed Flap and Gear Extension–Automated Approach

Figure 9 compares the noise levels of figures 7 and 8 by means of noise footprint contours. The contour for flying down the glide slope with 40° flaps and gear down has an enclosed community area of 5.2 sq mi. By delaying extension of flaps and gear, this area is seen to reduce by 64% or 72%, depending on whether the profiles of figures 7 or 8 are used.

As previously stated, delaying flap and gear extension to as late as shown in figure 8 requires sufficient system modifications to avoid increasing pilot workload or degrading safety. The Boeing Company has improvised a closed-loop system that holds to these guidelines. A closed-loop system is one that has a programmed schedule but has the inherent logic and feedback to correct for deviations from the schedule. The system has been

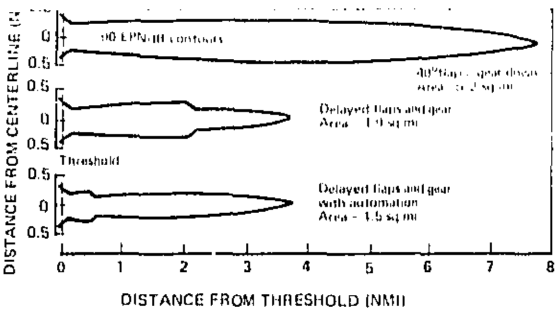


Figure 9. Noise Footprint Comparisons of Delayed Flap and Gear Approaches

operated in a flight simulator and flight tested on the company-owned 727-200. The components of the system, shown in the block diagram of figure 10, consist of:

1) Autothrottles
2) Electrohydraulic flow valves
3) Flap position transmitters
4) Control panel
5) Autoflap coupler
6) Autothrottle computer
7) Visual landing aid sight and computer
8) Central air data computer

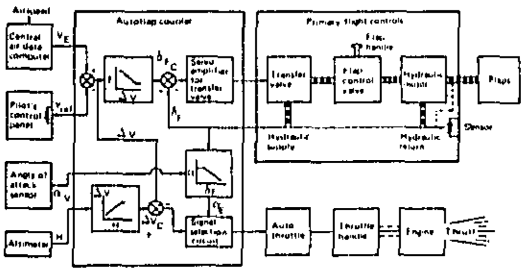


Figure 10. Autoflap Schematic—Approach Mode

The procedure that has been the most successful follows:

1) The pilot establishes approach configuration—flaps 15°, gear down, altitude above 1500 ft, and airspeed equal to V_{ref} + 55 kn.

2) Prior to intercepting the glide slope, the autoflap system is armed by selecting the LAND mode on the control panel.

3) The flap handle is then moved to the desired final flap setting, and the corresponding final approach speed is set on the speed index (bug).

4) The glide slope is captured and final descent initiated.

5) As the airplane passes through approximately 1200 ft above the runway, the system is triggered.

6) The altitude change demands a speed reduction that is accomplished by retarding the throttle.

7) The flaps are controlled by airspeed and extend as speed is reduced.

8) When flaps reach the final desired position and the airspeed is within 5 kn of the final speed set on the bug, the throttles advance automatically to arrest the deceleration. At this point, the airplane is about 200 ft above the runway. The airspeed then stabilizes and is constant until landing flare is initiated.

Throughout the autoflap approach, because of speed programming, the airplane's body attitude remains constant. The sample flight profile, figure 11, demonstrates the automatic flap management experienced with the Boeing flight test airplane. This particular profile was flown without use of the autopilot by manually following the instrument cues.

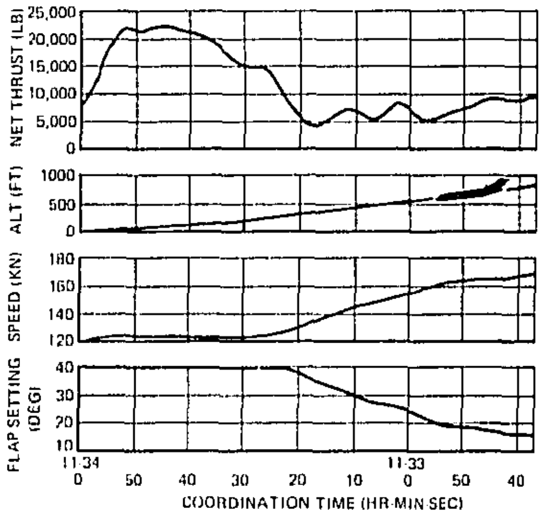


Figure 11. Autoflap Approach—727-200 Flight Test

Note that the low thrust level for approach flaps is held during the flap extending period until the 350-ft altitude point. The speed and altitude are bled off smoothly as the flaps extend. The maximum throttle movement during flap extension was 1.3°. (System refinements, such as automatic trimming devices and autopilot, are being investigated to reduce this amount even further.) At the point where flaps are full down and speed is V_{ref} + 5 kn, thrust required to hold the glide slope (about 21,000 lb) is applied automatically. The remainder of the approach is flown normally.

In view of the substantial noise reduction shown in figure 8, this concept merits further development.

Two-Segment Approaches. Significant reductions in community noise result from intercepting the final glide slope from a steep descent, say 6°, as compared to flying the glide slope from many miles out. Figure 12 compares the approach profiles and corresponding community noise levels of a 727-200 airplane following a normal (3°) glide slope, and the same airplane performing a two-segment approach with steep descent to the glide slope. Flap and gear configurations are the same in both profiles, so the noise benefits shown are related only to differences in airplane descent angles. Note that the transition is made at 1000 ft altitude (about 3 nmi from the threshold†). This will give the pilot adequate time to stabilize on the glide slope without revisions to the current airplane systems.

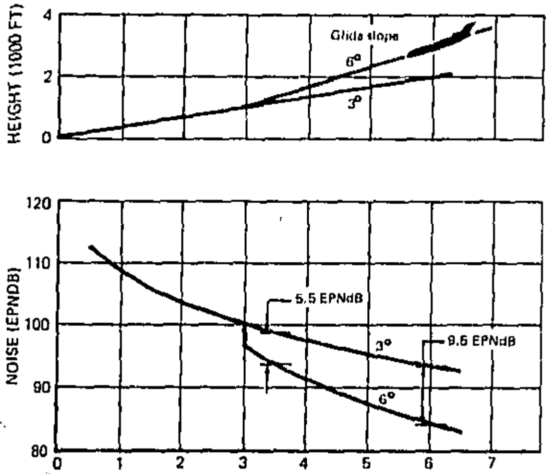


Figure 12. Two-Segment Approach

By providing system automation to permit transition from the steep descent segment to the glide slope closer to the airport, the noise benefit to the community improves, as shown in figure 13. This illustration uses the same airplane configurations as shown in figure 12, but transition from 6° to 3° slopes is initiated at 250 ft altitude, less than a mile from the threshold. Figure 13 shows noise reductions on the order of 5 to 13 EPNdB at distances of 1 to 6 nmi from the runway threshold. These are significant reductions, certainly of a magnitude readily discernable to residents living under the approach flightpath of the airplane.

Figure 14 compares the noise footprint contours of the above two-segment approaches with a normal 3° glide slope. Note the significant noise benefit of a 73% area reduction in the contour for the close-in transition of figure 13.

Regarding the feasibility of operating on such a profile, let us discuss means of accomplishing this steep descent with close-in transition within limits of safety and pilot acceptance.

Simulator development and flight testing of the Boeing model 367-80 (707/KC-135 prototype), conducted in 1968 under the NASA/Boeing investigation of noise abatement landing approaches(7)(8), demonstrated that two-segment approaches

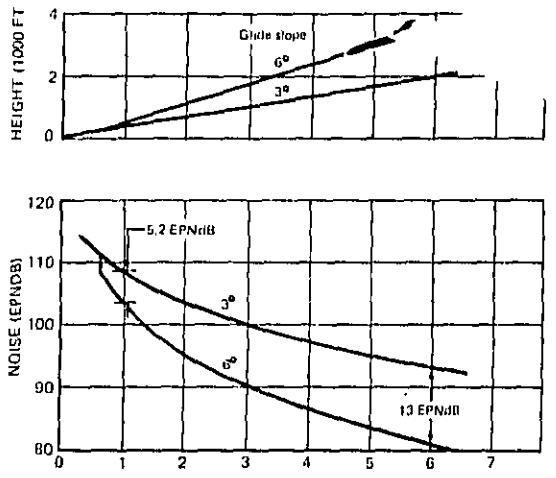


Figure 13. Two-Segment Approach with Close-In Transition

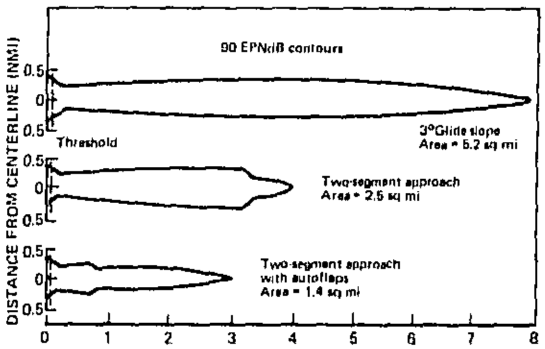


Figure 14. Noise Footprint Comparisons of Two-Segment Approaches

with close-in transition are feasible. This investigation was flown at Oakland International Airport using the existing glide slope of 2.65° and steep descent of 6° with intercept altitudes of 250 and 400 ft. The research airplane was equipped with improvements over current jet transports, including a modified flight director, an autothrottle, and stability augmentation that improved longitudinal and lateral directional handling qualities. The test profiles were flown by one airline pilot, six FAA pilots, and four NASA pilots under simulated instrument conditions.

The conclusions reached were that two-segment profiles could be flown in a modified jet transport with the same precision as a conventional instrument approach without a significant increase in pilot workload and with a significant reduction in community noise.

Adoption of such procedures for airline use would require further development and tests to establish the requirements and operational limitations of two-segment approaches in an environment more representative of airline operations and under conditions of combined adverse weather and airplane equipment or guidance failures.

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†Bolt, Beranek, and Newman, Inc.(6) considered two-segment approaches in their 1970 study, with transition from 6° to 3° slopes at 3 nmi from the threshold.

community noise reduction is the pilot option of flap position selection during approach and landing. We have probably all experienced actual flights in which landing flaps were dragged for many miles over a residential community prior to intercepting the glidepath. Figure 15 compares two approaches for the 727-200 in the same profile but at different flap positions. It shows that, at the same altitude, there is a noise difference of from 3 to 7.6 EPNdB between these two cases. As a comparison, a 707-320B or C landing at 25° flaps is about 3 to 4 EPNdB quieter at 1 nmi from the threshold than when using the normal 50° flaps. Modification to permit 25° landing flaps on these airplanes has been determined feasible. The 5-kn higher landing speed for 25° flaps would result in about a 340-ft increase in landing field length.

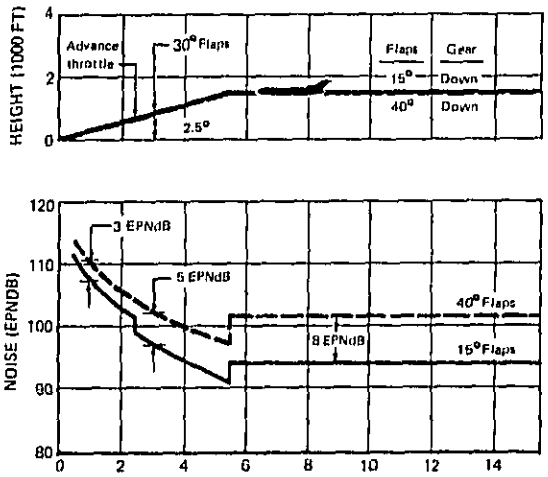

Figure 15. Effect of Flap Setting on Approach Noise

If we now combine the above flap options with the effects of intercept altitude and moderate change in glide slope discussed earlier, we have the picture shown in figure 16, showing significantly greater noise reductions than in figure 15.

Both of these profiles are within the limits of current airplane capability and operating procedures and we believe would not require any special equipment or techniques.

Now let us include the capabilities available through the approach system automation discussed in connection with delayed flap and gear extension and with steep, two-segment descents. Modifying the figure 16 profiles to include these capabilities as well as a 3.5° glide slope, we arrive at figure 17, which represents the total potential noise reduction available through adoption of approach noise abatement regulations and procedures and development of appropriate equipment.

Noise Abatement Takeoff Procedures. Many takeoff profile choices can be, and have been, investigated for reduction of community noise. The most obvious, involving only the choice between takeoff power all the way versus power cutback at some acceptable altitude, is recognized as a means of reducing noise in the close-in community.

Mr. Bakke[1] compared several takeoff procedures proposed by the FAA, by the Air Line Pilots' Association, and standard

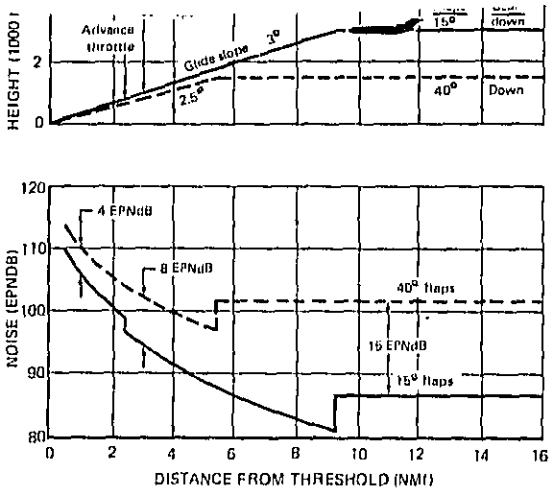

Figure 16. Combined Effects of Flaps, Altitude, and Glide Slope on Approach Noise

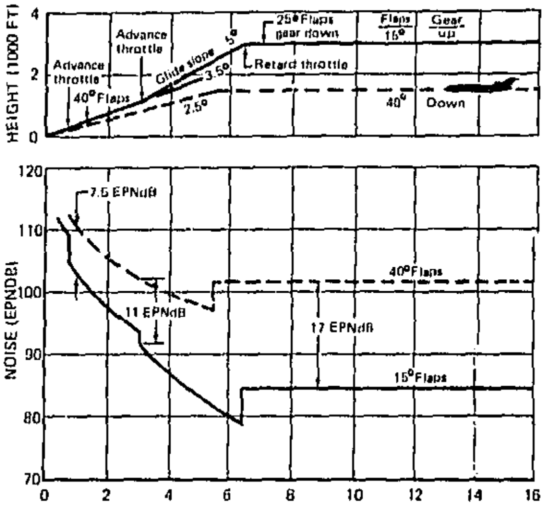

Figure 17. Approach Noise Reduction Potential Through Combination of New Techniques

operating practices of five major airlines. Some of these procedures, monitored in actual day-to-day operations at JFK International Airport, demonstrated noise reductions over the community on the order of 4 to 7.5 PNdB. Such reductions are to be encouraged. Studies at Boeing have generally confirmed these findings. Noise-abatement takeoff procedures can be performed effectively with virtually all present-day jet transport aircraft without modification of the aircraft, with no effect on safety, and with little effect on pilot workload. Beyond this, techniques involving some automation and capable of even greater noise benefits are believed within easy reach. Discussions of specific examples of both types of procedures follow.

Again, using the 727-200 airplane as an example, figure 18 compares two takeoff profiles, both employing power cutback at 3.5 nmi from brake release but using different flaps. Power cutback in both cases is to the level that would maintain level

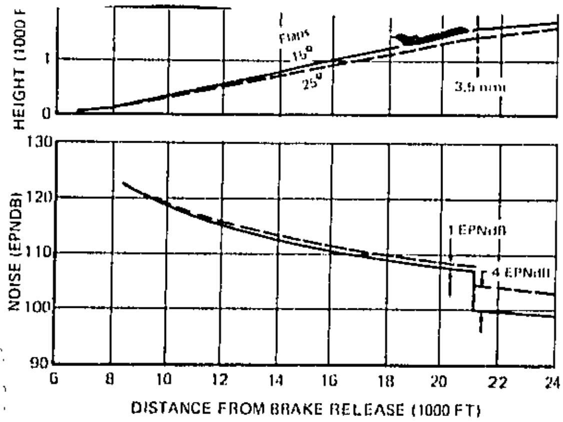

Figure 18. Comparison of Two Takeoff Profiles - Manual Flap Retraction

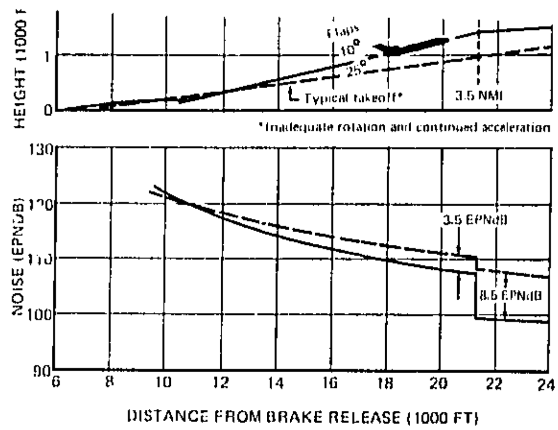

Figure 19. Comparison of Two Takeoff Profiles—Automated Flap Retraction

flight with one engine inoperative. Both airplanes take off with 25° flaps. One maintains this flap setting throughout climbout, whereas the other, after accelerating to V_2 + 10 kn, retracts flaps to 15°. Note that the 15° climbout permits a steeper climb gradient (lower noise at takeoff power) and cutback to lower thrust (one-engine-out level flight thrust for 15° instead of 25°), resulting in lower noise after cutback due to both greater altitude and lower thrust. In the case illustrated, the noise reductions are 1 EPNdB and 4 EPNdB before and after cutback, respectively.

This procedure is optional to pilots, requires no airplane modifications, and is similar to operations being used at the present time by certain airlines. Comparable noise reductions were experienced by NASA during 1968 noise abatement takeoffs[9] of the Ames CV-990 airplane at Wallops Station.

An improvement in the noise picture of figure 18 is attainable by incorporating an automated flap system, permitting speed-controlled programming of flaps during climbout. Figure 19 illustrates such a procedure, in which, in one case, the flaps are programmed to 10° after a 25° takeoff, and in the other case, the flaps are 25° all the way. Figure 20 shows a reduction of 50% in the land area enclosed by the 90 EPNdB footprint contour for the autoflap profile.

The additional noise benefit of this procedure seems to justify further investigation of means by which it can be accepted as routine. The closed-loop system mentioned earlier, but in a takeoff mode has been simulator tested and flight tested by Boeing. The system is shown in the block diagram, figure 21, and consists of a simplification of the approach mode.

The takeoff procedure is simple, utilizing the following:

1) Pilot selects the takeoff flap position.

2) He then arms the autoflap system by selecting the TAKEOFF mode on the control panel.

3) The flap handle is moved to the position to which the flaps will be retracted.

4) The flaps do not move until an electrohydraulic transfer valve is opened.

5) The transfer valve will not open until the following conditions are satisfied:

    a) Airspeed must exceed V_2 + 10 kn for the takeoff flaps.

    b) Landing gear must be up and doors closed.

6) When the above conditions are met, the flaps retract at the normal rate to the position selected previously.

7) When this position is reached, the airplane establishes best climb profile.

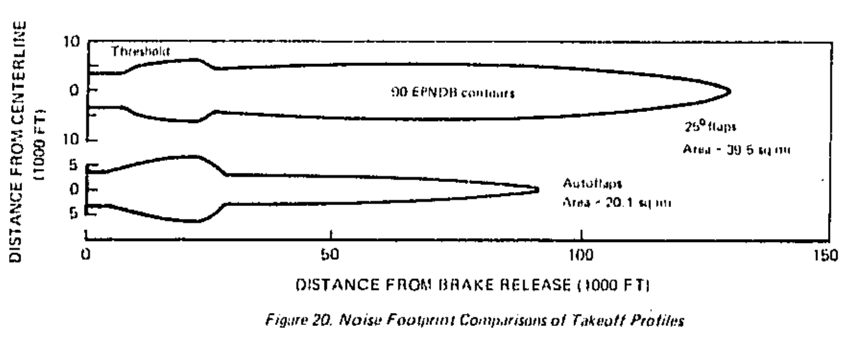

Figure 20. Noise Footprint Comparisons of Takeoff Profiles

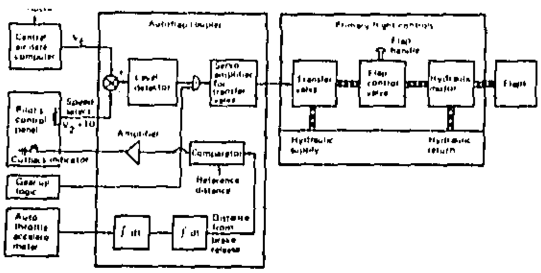

Figure 21. Autoflap Schematic--Takeoff Mode

The system also has the capability of sensing horizontal distance. This information is obtained from the autothrottle accelerometer, which uses double integration to compute the horizontal distance. The computed distance then is compared to a reference distance, and, if exceeded, a light will be illuminated in the cockpit to alert the pilot to initiate noise-abatement thrust cutback procedure.

CONCLUSIONS

On the basis of the foregoing discussion and on the results of testing conducted by NASA, the FAA, the aircraft industry, and the airlines, the following general conclusions are drawn:

1) Significant reductions in community noise can be attained through early adoption of readily available regulatory and procedural operations changes in the vicinity of airports. Such changes can be made at little cost, would require no particular increase in pilot skill or pilot workload, and are not considered to have any effect on safety.

2) Further noise reduction benefits are available through certain additional operating procedures requiring development of techniques and equipment modifications to avoid increasing pilot workload.

These conclusions were generally supported in an April 1971 paper,[5] presented by the Air Line Pilots' Association at the FAA National Aviation System Planning Review Conference.

RECOMMENDATIONS

Because of the potential community noise benefits to be gained through noise abatement operating procedures, a two-phase positive course of action to define and implement feasible techniques is recommended. We suggest that such a program be conducted under FAA sponsorship as an industry cooperative effort, with AIA, ATA, and ALPA working together as a team.

Phase I would entail early implementation of regulatory and operational procedures that can be accomplished at little cost and with little or no equipment modification. Typically, they include:

1) Establishing minimum holding pattern and maneuver altitudes of 3000 ft or higher over the terrain

2) Routing traffic over low population densities to the extent feasible

3) Raising all glide slopes to a minimum of 3°, with 3.5° being given serious consideration

4) Establishing minimum glide slope horizontal intercept altitudes of 3000 ft or higher over the terrain

5) Delaying extension of landing flaps and gear as long as practical

6) Using reduced landing flap settings whenever operating conditions permit (at the expense of some increase in landing speeds and landing field lengths)

7) Using segmented takeoff profiles adaptable to each airplane type, specifics of such profiles to be worked out cooperatively by the airlines, the manufacturers, and the FAA

Phase II would include development of additional noise abatement procedures, discussed in this paper, requiring airplane and/or ground equipment modification to preclude degrading safety or increasing pilot workload. The program should consider all U.S. subsonic turbojet-powered commercial transport aircraft as candidates.†† Participating AIA companies would develop techniques and related equipment modifications for their respective models and flight test the procedures using company, FAA, and airline/ALPA pilots. It would be desirable to standardize procedures, to the extent permitted by individual airplane characteristics, to simplify adoption by the airlines.

Firm technical data would be derived to form a basis for maximum exploitation of the noise-abatement benefits of regulatory and operational changes, including appropriate ground and airborne systems modifications. The program should aim toward ensuring adequate safety; attaining worthwhile noise reduction; eliminating those procedures determined not feasible or worthwhile; and gaining FAA, airline, and pilot acceptance.

It is further recommended that applicable air regulations, such as FAR, Part 36, be modified such that encouragement and incentive is given to noise abatement through operating procedures. This should be an inherent part of the overall effort to reduce community annoyance.

REFERENCES

1. Oscar Bakke, "Air Traffic Control and Flight Procedures," paper included in a report of the Jet Aircraft Noise Panel, *Alleviation of Jet Aircraft Noise Near Airports*, Office of Science and Technology, Executive Office of the President, March 1966.

2. ICAO letter AN 1/54.6-70/32, app. A, annex 16, atch. C, "Guidance Material Relating to Safety Considerations in the Establishment of Aircraft Noise Abatement Operating Procedures," March 19, 1970.

3. *Arrival and Departure Handling of High-Performance Airplanes*, FAA order 7110.22, September 19, 1970.

4. William S. Hieronymus, "New Landing Method Aimed at Reduction in Approach Noise," *Aviation Week*, March 1, 1971, pp. 46 and 47.

†† The program should include the results of the FAA-sponsored measurement program currently being conducted by Hydrospace Research Corporation.[10] Four different airplanes are being subjected to noise measurements while flying a variety of noise-abatement approach and takeoff profiles.

5. Captain Robert N. Rockwell (Chairman, Noise Abatement Committee, Air Lines Pilots' Association), "Airport Noise and Aircraft Operations," paper presented at the FAA National Aviation System Planning Review Conference, Washington, D.C., April 29, 1971.

6. D. E. Bishop and R. D. Horonjeff, *Noise Exposure Forecast Contours for Aircraft Noise Tradeoff Studies at Three Major Airports*, Final Report FAA-NO-70-7, Contract FA 68WA-1900, Bolt, Beranek, and Newman, Inc., July 1970.

7. Clarence C. Flora, Gerhard K. L. Kriechbaum, and Wayne Willich, *A Flight Investigation of Systems Developed for Reducing Pilot Workload and Improving Tracking Accuracy During Noise-Abatement Landing Approaches*, NASA Final Report CR-1427, Contract NAS 2-4200, The Boeing Company, October 1969.

8. Hervey C. Quigley, C. Thomas Snyder, Emmett B. Fry, Leo J. Power, and Robert C. Innis of Ames Research Center; and W. Latham Copeland, Langley Research Center, *Flight and Simulation Investigation of Methods for Implementing Noise-Abatement Landing Approaches*, NASA Technical Note TN-D-5781, May 1970.

9. H. Rodney Peery and Heintz Erzberger, *Noise Measurement Evaluation of Takeoff and Approach Profiles Optimized for Noise Abatement*, NASA Technical Note TN D-6246, March 1971.

10. *Operational Procedures Noise Reduction Program*, FAA contract awarded to Hydrospace Research Corporation. Program procured under FAA RFP WA5R-1-0236, November 16, 1970. Scheduled for completion (final report draft) on July 1, 1971.

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MEASUREMENT AND ANALYSIS OF NOISE FROM FOUR AIRCRAFT DURING APPROACH AND DEPARTURE OPERATIONS (727, KC-135, 707-320B, AND DC-9)

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transpo 72
U.S. International Transportation Exposition
Dulles International Airport
Washington, D.C.
May 27–June 4, 1972

SEPTEMBER 1971

FINAL REPORT

Availability is unlimited. Document may be released to the National Technical Information Service, Springfield, Virginia 22151, for sale to the public.

DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION
Systems Research and Development Service
Washington, D.C. 20591

ABSTRACT

The objective of this work was to measure, evaluate, and identify the noise levels along the flight track generated by 727, KC-135, 707-320B, and DC-9 aircraft. The aircraft were directed to operate in a wide variety of takeoff and approach procedures. The effort involved acquisition of acoustical, meteorological, aircraft tracking, and aircraft operational data. Microphones were located four feet above the ground in an array parallel to the flight track along the extended runway centerline up to 10 nautical miles from the runway threshold. All tests were conducted at the National Aviation Facilities Experimental Center (NAFEC) during a four-week period in April 1971.

Table II. Takeoff Procedures

Run No.	Takeoff Weight	Parameters	Segment A-B	Altitude hb	Segment B-C	Altitude hc	Segment C-D	Segment D-E (3000 ft)
T1	Max Land	Speed	V_2 10*	400	250K	NA	250K	NA
		Thrust	T.O.		T.O.		ERCT	
		Flap	T.O.		Clean		Clean	
T5	Max T.O.	Speed	V_2 10*	400	250K	NA	250K	NA
		Thrust	T.O.		T.O.		ERCT	
		Flap	T.O.		Clean		Clean	
T3	Max Land	Speed	V_2 10	1000	V_{zf}**	NA	V_{zf}	250K
		Thrust	T.O.		T.O. EPR-1		EPR-1	Climb T.
		Flap	T.O.		Clean		Clean	Clean
T4	Max Land	Speed	V_2 20	1000	V_2 20	NA	V_2 20	NA
		Thrust	T.O.		EPR-2		EPR-2	
		Flap	T.O.		T.O.		T.O.	
T2	Max Land	Speed	V_2 20	1000	V_2 20	NA	V_2 20	NA
		Thrust	T.O.		EPR-1		EPR-1	
		Flap	T.O.		T.O.		T.O.	
T6	Max T.O.	Speed	V_2 20	1000	V_2 20	NA	V_2 20	NA
		Thrust	T.O.		EPR-1		EPR-1	
		Flap	T.O.		T.O.		T.O.	
T7	Max Land	Speed	V_2 20	1000	V_2 20	NA	V_2 20	NA
		Thrust	T.O.		EPR-1		EPR-1	
		Flap	5		5		5	
T8	Max Land	Speed	V_2 10	1000	V_2 10	2500	250K	NA
		Thrust	T.O.		1.6 EPR		1.72 EPR	
		Flap	T.O.		14		Clean	

EPR-1 Thrust necessary to maintain straight and level flight at maximum takeoff weight with one engine out
EPR-2 An EPR setting intermediate between EPR-1 and takeoff settings (ERCT)
NA Not applicable
T.O. Takeoff setting
ERCT Enroute climb thrust

* Maximum 15-degree pitch angle.
** Zero flap speed.

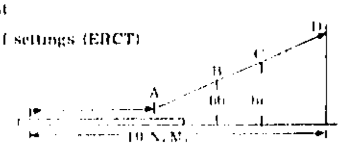
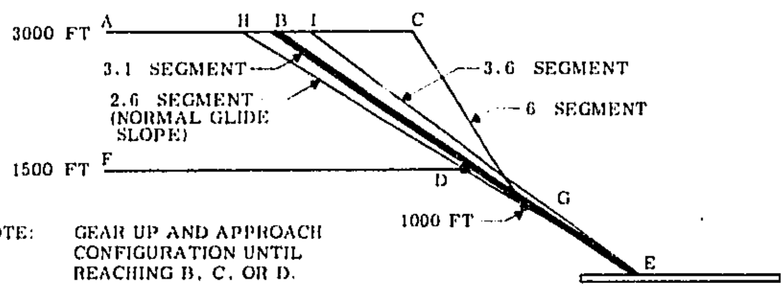


Table III. Approach to Landing Procedures (Maximum Landing Weight)



NOTE: GEAR UP AND APPROACH CONFIGURATION UNTIL REACHING B, C, OR D.

Profile	Configuration: Land-Max	Configuration: Land-Alt	Configuration: Approach
Conventional (1500 ft-F-D-E)	A11*	A12	A13
Conventional (3000 ft-A-H-E)	A21	A22	A23**
Two Segment (A-C-G-E)	A41		
High Glide Slope (3000 ft-A-I-E)	A31		
Middle Glide Slope (3000 ft-A-B-E)	A51		

* Segment F-D of profile A11 will be flown at two different configurations; A11A as identified. A11B will be flown at a lesser flap setting.

** Reconfigure to landing flap, max, at 500 feet.

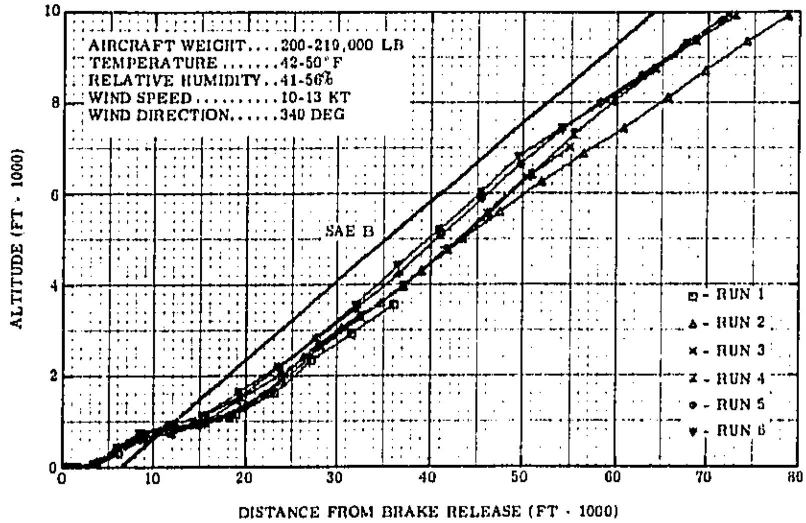


Figure C-3. Takeoff Profile T1, 707-320B Aircraft

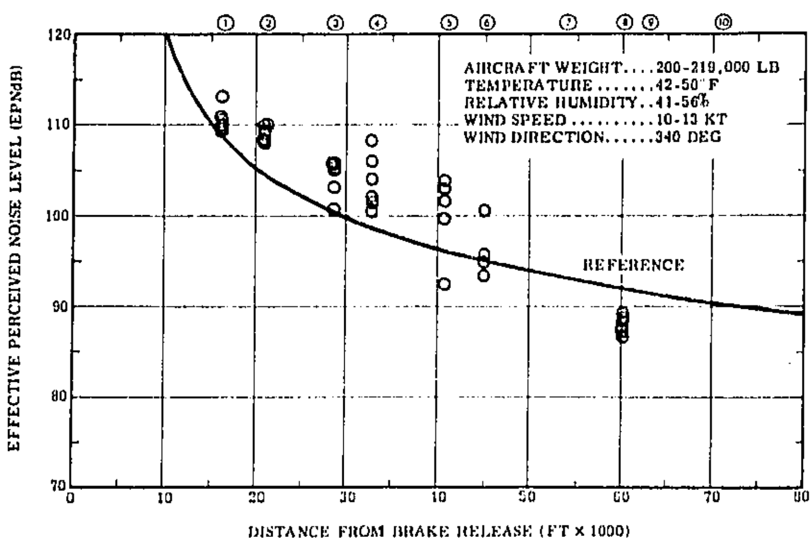


Figure C-1. Takeoff Noise Levels for Profile T1, 707-320B Aircraft

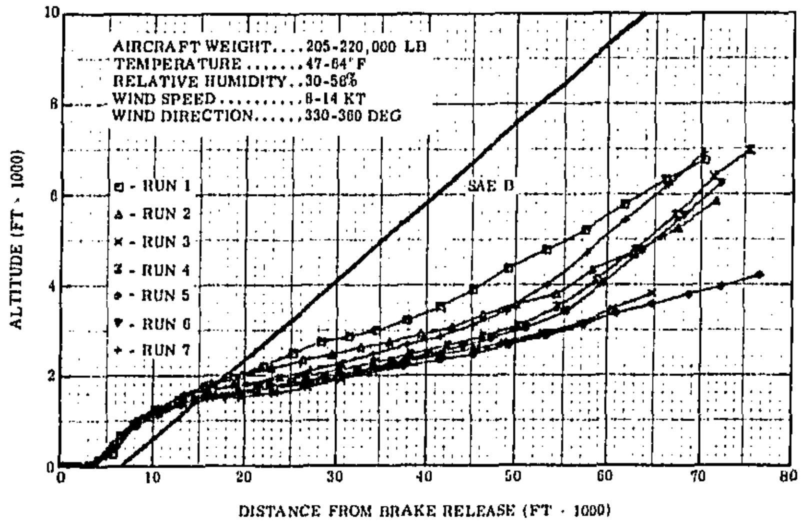


Figure C-11. Takeoff Profile T3, 707-320B Aircraft

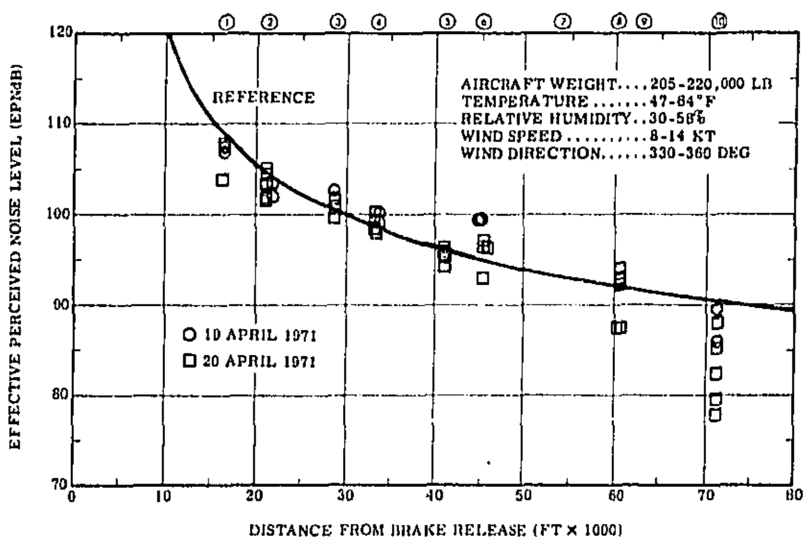


Figure C-9. Takeoff Noise Levels for Profile T3, 707-320B Aircraft

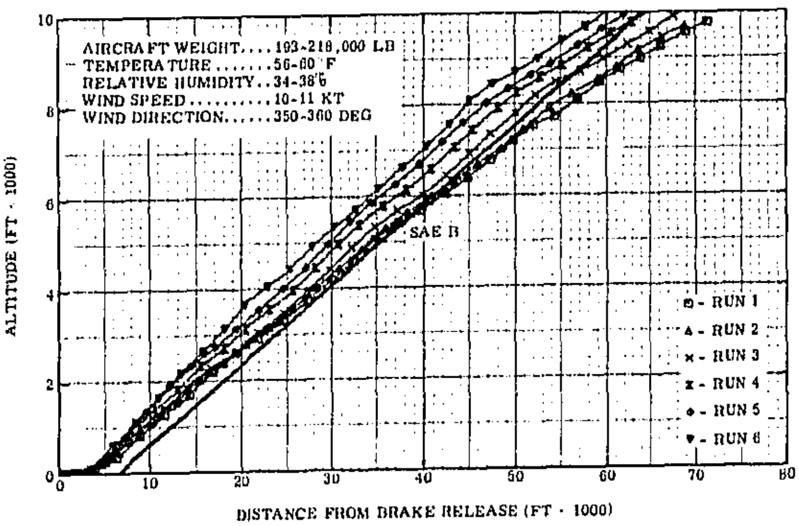


Figure C-15. Takeoff Profile T4, 707-320B Aircraft

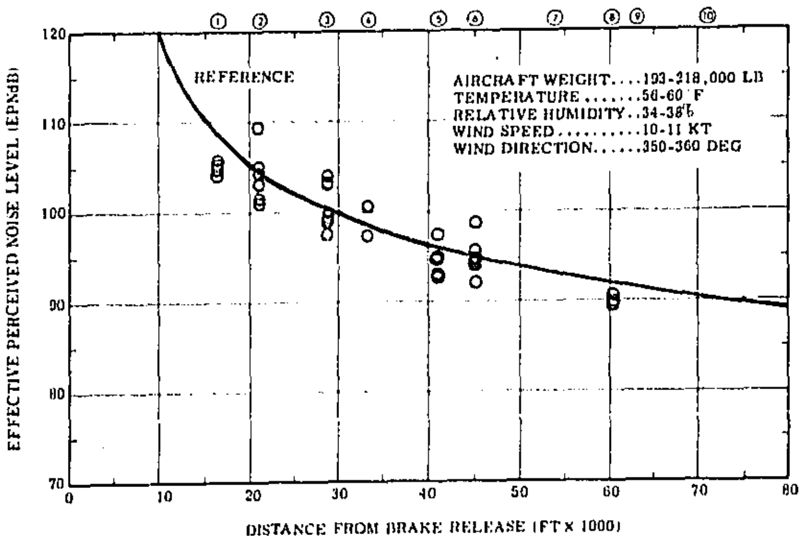


Figure C-13. Takeoff Noise Levels for Profile T4, 707-320B Aircraft

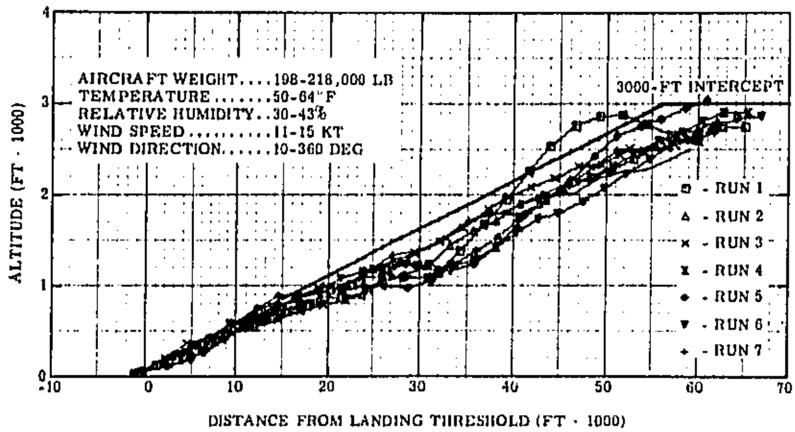


Figure C-39. Approach Profile A21, 707-320B Aircraft

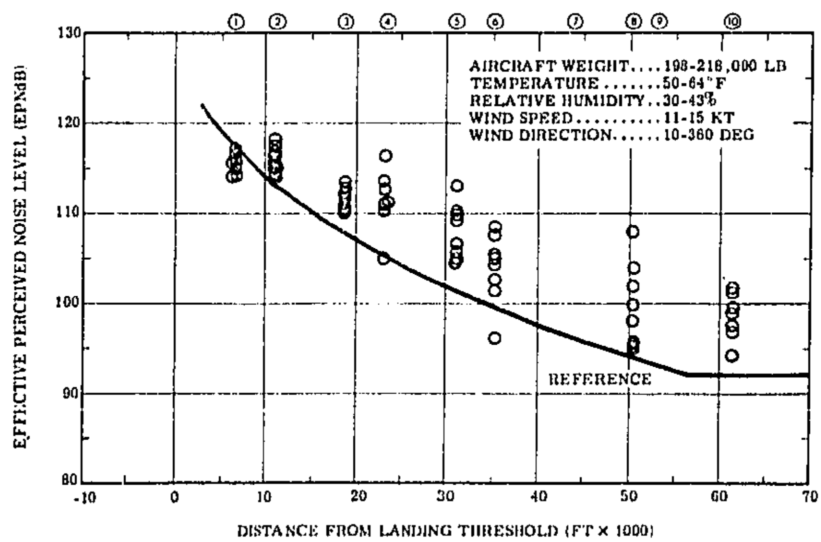


Figure C-37. Approach Noise Levels for Profile A21, 707-320B Aircraft

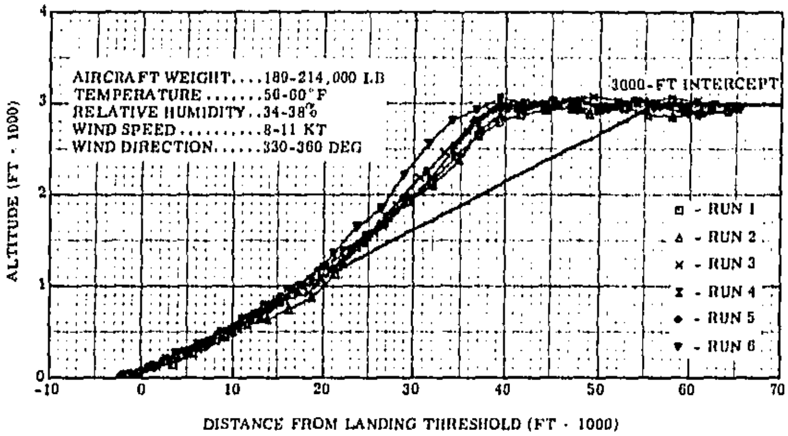


Figure C-55. Approach Profile A41, 707-320B Aircraft

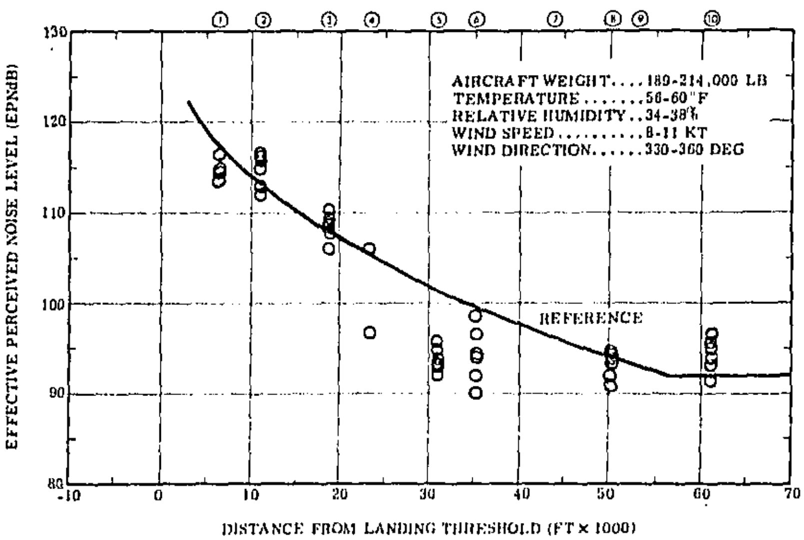


Figure C-53. Approach Noise Levels for Profile A41, 707-320B Aircraft

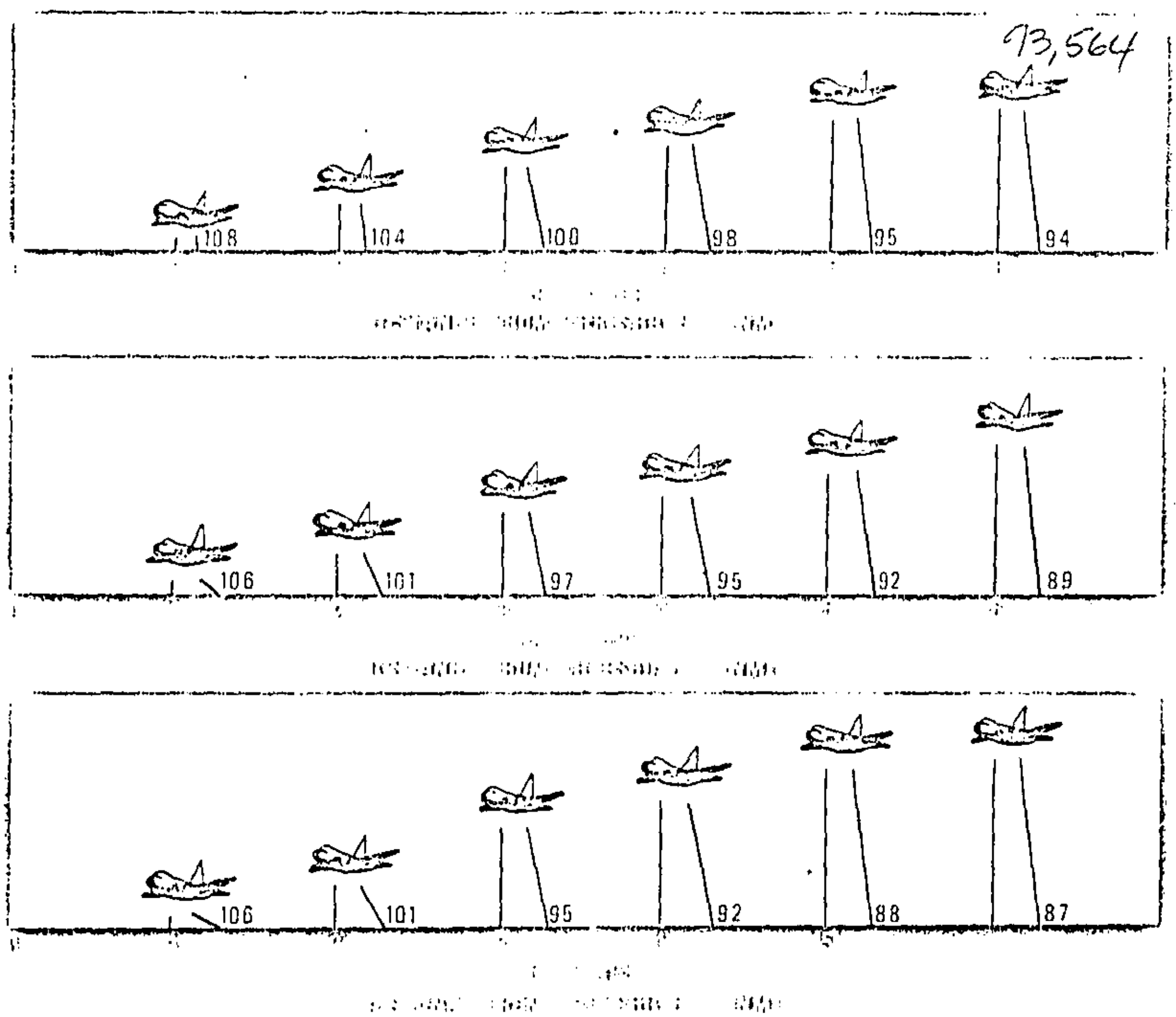
FAA Paper on Noise Abatement

The FAA's Office of Environmental Quality, established in January 1971, is moving to curb the noise problems created in the past and impacting citizens and communities today.

The problem of reducing approach noise has been more knotty than reducing departure noise. With today's navigational equipment, operational deviations are difficult and preferential routings cannot be used for noise abatement. However, with the development of systems such as microwave instrument landing systems such flexibility will be possible.

Concurrently with the development, simulation and test of departure procedures, we were working on noise reduction procedures for approach. Six weeks after the new departure procedures were begun, the airlines instituted a new standard approach procedure that provides considerable relief to people on the ground in the approach area.

In this new procedure the aircraft operates with a lower landing flap setting when permissible and a lesser approach flap setting throughout the approach. By using a lesser flap setting, draft is reduced and a lower power setting is required to maintain a steady descent. This results in lower sound levels. Figure 4 shows three approaches by a 727 on a standard 3° glide slope beginning at 6 miles from runway touchdown. Some pilots have assumed landing flaps of 40° at this 6 mile point while others have used 30° flaps. In the new standard (bottom part of the figure), 25° approach flaps are used until the aircraft is descended to 1,000 feet (3 miles) where it transitions to 30° flaps by 2 miles. This results in up to 7 db less noise at 6 miles from runway touchdown with a reduction in noise evident at 3 miles. No improvement is evident closer in except when compared with those aircraft using 40° flaps. This procedure is not limited to the 727, and, in fact, greater noise reductions can be achieved by some of the noisier aircraft.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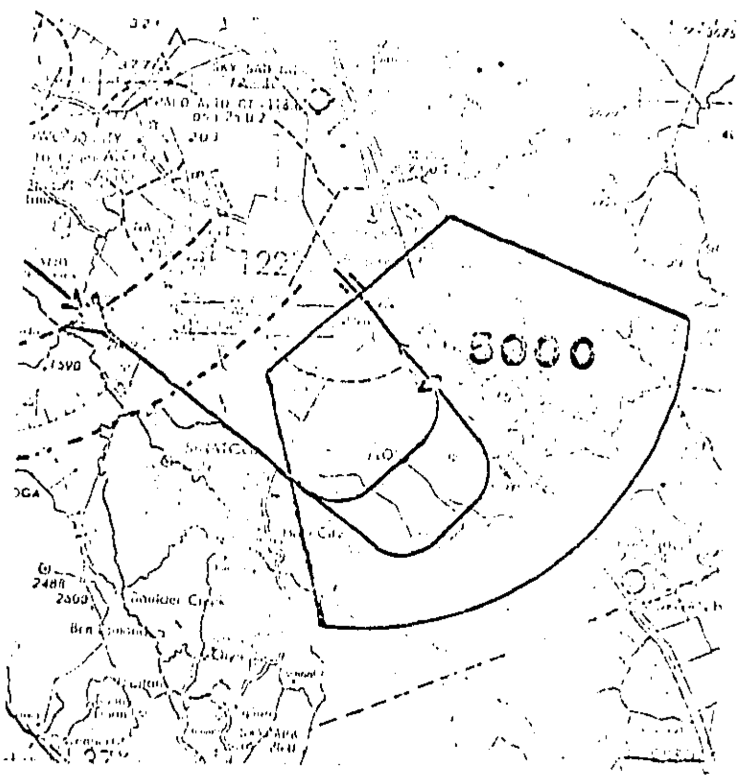
San Jose Airport Keep-em-High Procedures

The FAA, in cooperation with the San Jose Municipal Airport, has established "keep-em-high" procedures for SJC. This procedure, designed to minimize noise and reduce conflicts between large and small aircraft, requires air carrier aircraft on approach to maintain at least 5000 feet altitude until within the designated "descent area" (see Figure 1). This effectively confines noise from aircraft to the final approach corridor.

VFR approaches may make visual descents from 5000 feet after crossing the 180° radial from SJC, shown as the heavy dotted line in Figure 1. The result is that in VFR conditions many pilots make approaches at a descent angle of approximately 4° (to shorten the distance travelled) instead of the normal 3°, thus reducing noise considerably.



AIRCRAFT NOISE REDUCTION TECHNOLOGY

A Report by the National Aeronautics and Space Administration to the Environmental Protection Agency for the Aircraft/Airport Noise Study

March 30, 1973

III - OPERATING PROCEDURES FOR AIRCRAFT NOISE REDUCTION

Operational procedures can be used effectively for noise control in both landing-approach and the takeoff-climbout phases of the mission. The interrelated factors of aircraft altitude, engine throttle setting, flap angle setting, and aircraft speed are significant.

NASA, in cooperation with FAA and the airlines, has been involved in developing and evaluating operational procedures for noise reduction for a number of years, both for takeoff-climbout and landing-approach situations. The takeoff-climbout studies (refs. 1 to 4) have been helpful in evaluating the noise reduction potential for various flap angle and engine throttle schedules for a number of aircraft. These data have also been useful as a guide in defining the optimum procedures for particular operations.

A main finding of these takeoff-climbout studies is that the optimum conditions for noise alleviation depend on the configuration details (particularly, type of engine) and operating characteristics of the aircraft and thus will probably be different for each new aircraft. The landing-approach studies on the other hand have indicated potentially larger noise reductions, and they are not so configuration oriented. Three noise reduction techniques that have been proposed are the two-segment approach, the energy management or decelerating approach, and the curved ground track approach.

The two-segment approach concept is illustrated in figure III-1. The upper profile represents the two-segment approach, and the lower profile is a standard instrument landing approach. Using the two-segment approach, the aircraft approaches on a steeper

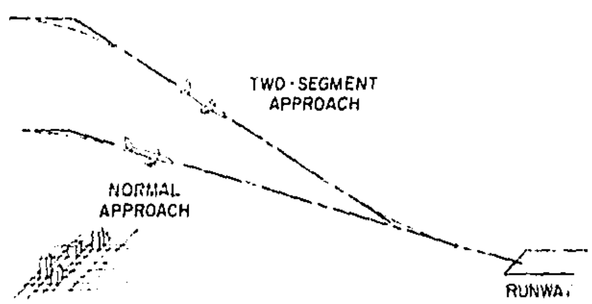


Figure III-1. - Two-segment approach concept.

than normal glide slope and then makes a transition to the standard approach path in time to stabilize before landing. By keeping the aircraft higher above the ground and reducing the engine power because of the steeper angle, the two-segment approach lessens the community noise near airports.

In the energy management or decelerating approach, the aircraft initiates the approach at a relatively high airspeed and then slowly decelerates to landing speed at greatly reduced power. Because of the reduced power, the noise under the approach path is reduced. The decelerating approach is attractive because it has the potential of providing some noise relief all the way to the threshold. This technique might be combined with the two-segment approach in order to use the best feature of each.

The third procedure is based on avoiding noise sensitive areas by approaches on a curved ground track. This technique is being used under visual conditions today. With the advent of area navigation and the microwave landing system, this technique can be extended to instrument flight conditions and combined with the two-segment approach.

Although these noise abatement flight procedures are well within the performance capability of current day jet transports, they impose new requirements on the pilot duties and workload, on the pilot displays, on the guidance and navigation system, on the aircraft control system, on Air Traffic Control (ATC) flow of aircraft to high density runways and on parallel runway operations, and possibly different wake turbulence effects. A substantial effort is therefore required to develop suitable avionics for noise abatement procedures and to obtain sufficient experience so that they are accepted for routine operations.

For the purpose of this report, the NASA program directed towards developing operational procedures for noise abatement is divided into two parts. The first part is aimed at developing operational avionics and flight procedures that will allow aircraft to make two-segment approaches under instrument flight conditions during routine scheduled operation. This part of the program is currently under way, and significant progress has been made. The second part is aimed at determining the feasibility of other techniques for noise abatement such as the decelerating approach or curved ground track approach. The second part of the program also addresses the problem of how to best utilize new navigational aids such as the microwave landing system. Work related to the second part of the program has not yet been initiated.

PROGRAM HISTORY

The FAA and NASA have conducted several studies to obtain a preliminary determination of the feasibility of using modified operating procedures to reduce the noise perceived by the airport community. Both agencies have determined that significant noise reduction can be achieved by using the two-segment approach. NASA has been primarily concerned with the evaluation of pilot displays that would be required to make noise abating two-segment approaches (refs. 5 to 8). The FAA has been primarily concerned with developing the necessary guidance systems (refs. 9 and 10). In these studies, experimental equipment was evaluated to assess concept feasibility.

NASA and American Airlines recently completed a program to incorporate the results of the previous studies into operational equipment. The goal of the program was to assess the operational feasibility of the two-segment approach as a method of reducing airport community noise (ref. 11). For these tests, an area navigation system was used to compute the upper segment, and the instrument landing system (ILS) glide slope was used for the lower segment. The localizer was used throughout the approach. A key feature of the program with American Airlines was the provision of a continuous vertical steering command on the flight director. This was required to insure that transitions from level flight to the upper segment could be made without overshoots and those from the upper to the lower segment could be made without going below the normal ILS. The additional power needed to correct for going below the ILS is particularly objectionable because it creates higher perceived noise on the ground in the region of the transition. This effect is illustrated in figure III-2.

The tests with American Airlines were conducted during a 30-day period in the summer of 1971 at the Stockton, California, Metropolitan Airport. Stockton Metropolitan Airport was selected for these tests because of the low traffic density and good visibility

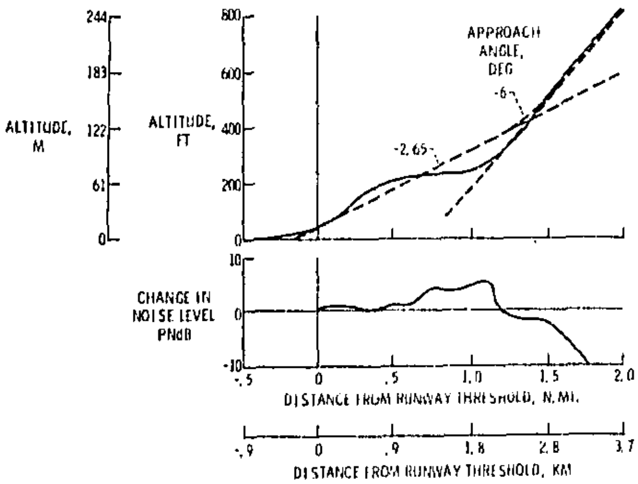


Figure III-2. - Effects of inadequate guidances.

prevalent during the test period. The program demonstrated that two-segment approaches might be operationally feasible and warranted a much more extensive and thorough evaluation under actual operational conditions.

The results of the program with American Airlines were presented to the NASA Research and Technology Advisory Committee on Aeronautical Operating Systems and to the Ad Hoc Panel on Noise Abatement by Operational Procedures. These advisory committees are composed of individuals representing the airlines, airframe manufacturers, avionics suppliers, the Air Transport Association (ATA), the Air Line Pilots Association (ALPA), FAA, and DOT. The committees agreed that the two-segment approach appeared operationally feasible and warranted additional evaluation. They recommended that further flight evaluations be conducted under representative operational conditions in two aircraft types: A Boeing 727 aircraft, because these aircraft account for the largest number of arrivals and departures and are owned by more air carriers than any other aircraft, and a long-range aircraft such as the DC-8 or Boeing 707 because these aircraft differ significantly from the Boeing 727 and have a larger noise footprint. The panel also recommended that the results of these two flight programs be extrapolated through analysis and simulation to determine the applicability of the two-segment approach to the other aircraft in today's fleet.

TWO-SEGMENT APPROACH

The first part of this program consists of several steps. The first two steps are being conducted with United Air Lines and call for separate flight evaluations using a Boeing 727-200 and a McDonnell-Douglas DC-8-61, each equipped with different avionics for providing vertical guidance during the approach. The Boeing 727 will be equipped with a special purpose glide slope computer, and the DC-8 will be equipped with an area navigation system. Both systems will be designed and built by the Collins Radio Company under contract to NASA. The glide slope computer system is being evaluated as an inexpensive retrofit for aircraft not equipped with area navigation equipment. The area navigation system is being evaluated to determine the operational feasibility of modifying the existing airborne area navigation equipment to provide the two-segment capability. If the aircraft has an installed area navigation system, this concept appears to be the least expensive way to add the two-segment approach capability. Another step in this part of the program involves the extension of the flight results to the other aircraft in today's fleet.

STEP A: DEVELOPMENT AND FLIGHT EVALUATION OF A SPECIAL PURPOSE GLIDE SLOPE COMPUTER IN A BOEING 727-200 AIRCRAFT

NASA Ames Research Center began work on this program with United Air Lines and the Collins Radio Company in July 1972. The program objectives are to develop an inexpensive avionics retrofit kit that will make an aircraft capable of a two-segment approach and to evaluate the two-segment approach in a Boeing 727-200 aircraft during regular scheduled service.

The program includes avionics design and fabrication; a simulation study aimed at developing a procedure and profile that is safe under adverse conditions; an engineering flight evaluation devoted to equipment checkout, certification, and verification of the approach profile established during the simulation study; a 1-month series of off-line flight evaluations; and a 6-month evaluation in revenue service.

The avionics design and fabrication, the simulation study, the engineering flight evaluation, and the off-line pilot evaluation have been completed. The results of these phases have not been completely reviewed and analyzed, but preliminary indications are that the avionics and two-segment approach are operationally feasible in the Boeing 727 and acceptable to the airline community.

In the simulation study the task was to make the concept into a practical, operational reality since the basic concept of the two-segment approach had been established by previous studies and research projects. In the design of the two-segment procedures, the basic profile was divided into eight parts as illustrated in figure III-3. The effect of

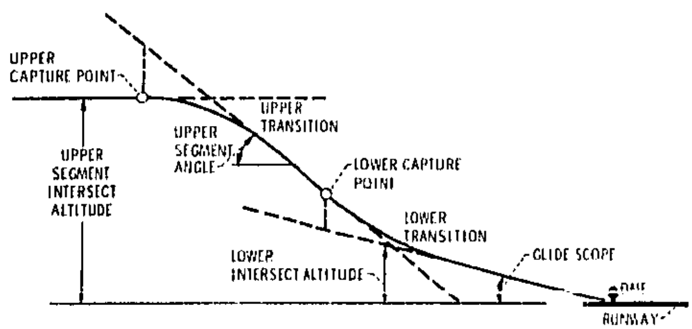


Figure III-3. - Noise abatement approach profile simulation variables.

each part on the approach was examined. Comments regarding these eight parts are contained below:

(1) Upper segment intercept altitude - The system must function such that this part can vary to 6000 feet (ft) altitude flight level (AFL) (and even higher is desirable). Also, it must not be fixed but either climbing or descending.

(2) Lower intersect altitude - This part was made to vary from 1500 ft AFL down to runway threshold height. A practical operational range would be smaller, but it was felt that its influence on the approach should be tried over this range.

(3) Upper segment angle - This part was made to vary from 4° to 7°, although 8° and 10° were added to check the validity of previous information about these descent angles.

(4) Glide slope - This part was expanded from the nominal glide slope range of 2.5° to 3.0° to 3.5°. The system was designed so as to provide a bias allowing the pilot to have guidance to hold the additional angle increment over the standard ILS glide slope.

(5) Upper capture point - This part was considered very important to the pilots acceptance and passenger comfort. It was so designed to compensate for varying closure rates to the upper segment angle.

(6) Lower capture point - This part was also considered important to safety, pilots acceptance, and passenger comfort. It was designed to compensate for varying closure rates to the glide slope.

(7) Upper transition - This part, important to passenger comfort, was designed to allow wide variations that enable the pilot to get to the upper segment without additional constraints or disturbances to the passengers.

(8) Lower transition - This part was considered the key to pilot acceptance and was designed so that the pilot could make this transition using a normal instrument close check and normal flight technique, and not feel that he was performing an unusual maneuver that would require him to restabilize the aircraft at its completion.

The effects of some of the external variables that the pilots might encounter were examined in the simulation. A summary of some of these are listed here:

(1) Turbulence - The two-segment approach during simulation was not adversely affected by turbulence. Any turbulence level flyable on the standard ILS was flyable on the two-segment approach. In the airplane the two-segment approach required less effort than the standard ILS when there was significant turbulence.

(2) Icing - With engine and wing anti-icing on and temperatures -7° C or above, the low pressure turbine rpm is about the minimum of 55 percent. In these conditions a tail wind of about 15 knots can be offset by using 40° flaps. But if the icing is such that 70 percent N_1 is required for anti-icing, or the tail winds are in excess of 15 knots, then the approach, as constituted, could not be flown. These conditions exist less than 1 percent of the time.

(3) Winds - Tail winds in excess of 30 knots present a problem of airspeed stabilization and throttle position. Less than 30 knots are maneuverable. Cross wind effect is the same as the standard ILS. Wind shear effect is very similar also, except that the upper segment can be followed easier than the glide slope when troublesome wind shear is present.

(4) Visibility - No noticeable difference between the two-segment approach and the standard ILS was detected.

(5) Lighting - The two-segment approach profile permits a better view of the terminal area under all lighting conditions than does the standard ILS, yet the descent angle is not so steep as to give the pilot the impression of his descending into a hole at night.

(6) Airports - The relationship of the two-segment approach and the standard ILS is very similar at Los Angeles, San Francisco, and Stockton.

(7) Navaid failures - No difference, except that the colocated distance measuring equipment (DME) adds in one more system that must be in operation for the two-segment computer to function.

The two-segment approach that resulted from the simulation evaluation was used in the engineering flight evaluation. The upper intersect altitude was designed to go as high as 6000 ft AFL. The altitude was tested and found successful up to 14 000 ft (mean sea level). The upper and lower capture points occurred as designed and were very satisfactory. The upper segment angle was selected to be 5.2° to 7.0°. The lower value was found to have good noise improvement when associated with low-lower intersect altitudes. It also allowed the Boeing 727 to use full anti-ice capability when 40° flaps were used.

The upper value was determined to be the greatest angle expected at any time during any two-segment approach with a Boeing 727. The Supplemental Type Certificate (STC) demonstrations were made at this angle. The glide slope angle will be the same that the ILS has for the airport concerned. The values 2.5° to 3.5° covers all ILS glide slope angles that would be of concern.

The system is capable of flying high on the glide slope with a fixed bias. This was flown during the engineering flight evaluation and was found to have merit, but it will not be used during the on-line flight evaluation.

The lower intersect altitude range was 400 to 800 ft AFL. The nominal value determined by flight evaluation was about 700 ft. The ground noise measurements were made at the high and low values of this range. The two-segment approach profile, resulting from the flight evaluation, was used for the off-line pilot's evaluation and is basically the same as will be used for the on-line pilot's evaluation.

The Stockton, California, profile is shown in figure III-4. The San Francisco and Los Angeles profiles are very similar. The angle of the standard ILS is different, and

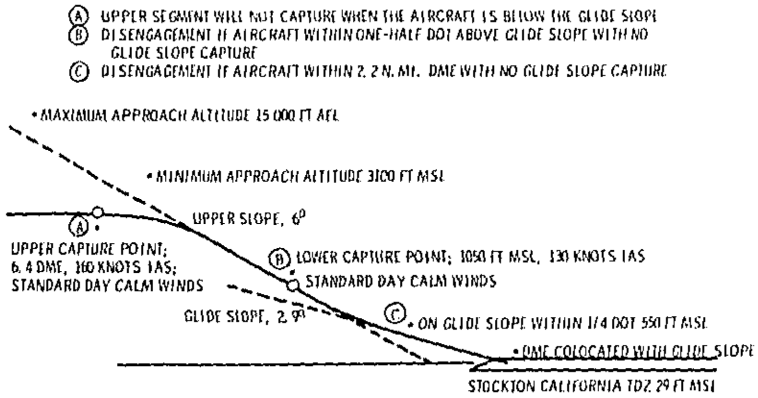


Figure III-4. - Two-segment approach profile used at Stockton, California, resulting from flight evaluation.

this results in a shift of the lower intersect altitude and the lower capture point. The shift with the lowest angle glide slope, flown at the lowest airspeed, is about 100 ft lower. The upper segment can be captured and flown very satisfactory, as high as 15 000 ft AFL. Localizer capture or alignment is not necessary for guidance on the upper segment.

Safety factors were designed into some areas of the profile to increase the flight safety margins for the approach. In the event the baro set, the DME, or the airport elevation panel set malfunctions, the upper segment could be presented prematurely. To prevent a guided approach that would cause a descent below the standard glide slope, the upper segment is prevented from capturing when the aircraft is below the glide slope. If the aircraft is flying the upper segment and gets to within one-half dot deflection above the glide slope, the auto pilot will disengage and the flight director bars bias out of view. This prevents the system from providing guidance that would take the aircraft below the glide slope. If the upper segment is presented late, it would be possible to descend so that the glide slope would be reached very low or not at all. In that case the system will disengage if the aircraft reaches 2.2 nautical miles DME and the glide slope is not captured.

The upper and lower transitions were a key to pilot acceptance. If the pilot can get into and out of the upper segment without any significant change in his flight technique, he should accept the two-segment concept as operationally sound.

The upper transition starts at the upper capture point. If the aircraft is approaching at a high speed or is climbing, the capture point occurs early. If the aircraft is at a low speed or is descending, the capture occurs late. In either case, the aircraft is pitched nose down slowly and smoothly, such that the upper segment is reached in 500 to 800 ft below the initial altitude at capture.

The lower transition is a smooth, easy pitch change that starts at the lower capture point. The lower capture point will adjust according to the speed at which the aircraft is closing on the glide slope. At high speeds the capture occurs earlier and provides a more gradual pitch change than at low speeds. The result is that the transition seems similar to both pilot and passengers. Passengers do not detect the lower transition. The point at which the glide slope is reached does not shift to any great extent.

The upper segment tracking with its transitions was determined to be very satisfactory. It required no additional pilot skills for routine operation of the Boeing 727-200 aircraft.

The off-line evaluation consisted of a two-phase program to thoroughly familiarize the guest pilot with the two-segment approach, thereby enabling him to evaluate the approach in detail. Phase I was the viewing of an audio-visual package followed by a crew briefing and a 1-hour and 30-minute simulator flight. The simulator involved a syllabus of 11 approaches intermixing the standard ILS with the two-segment ILS under varying weather conditions and operational techniques. Phase II consisted of an aircraft period during which an eight approach syllabus was flown, which again compared the standard ILS with the two-segment ILS in a real world environment.

The expected 90- and 95-effective perceived noise decibels (EPNdB) contours for a Boeing 727-200 aircraft using this two-segment approach procedures are compared in figures III-5 and III-6 with the contours expected as a result of using a standard instrument landing approach. The 90-EPNdB impacted area is reduced during the two-segment approach by 3.7 square miles (67 percent reduction). The 95-EPNdB impacted area is reduced by 1.1 square miles (48 percent reduction).

By increasing the upper intersect altitude, there can be a significant improvement in ground noise outside the outer marker. Altitude of up to 6000 ft AFL can produce noise improvement over large areas in approaching the airport. The aircraft safety is enhanced by staying high in the heavy traffic area, which reduces exposure to many low flying aircraft. It was noticed that the approach with a 6° upper segment could accommodate up to 190 knots (indicated air speed) at 3000 ft AFL to the point of upper segment capture. This speed can be increased as altitude increases up to 250 knots at 6000 ft AFL or higher. The result is lower power setting at higher altitudes and less time at high power settings. This could produce a side benefit of lower fuel consumption of each approach.

The avionics system being evaluated by United Air Lines retains the coupled flight director feature used in the American Airlines program and adds the autopilot coupling so that the pilot can make a two-segment landing with all the aids available for standard approaches.

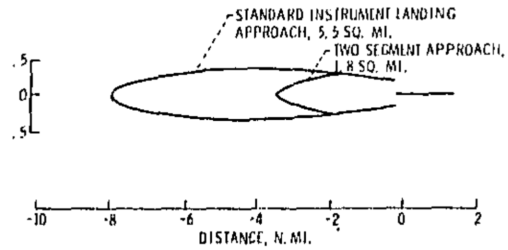


Figure III-5. - 90-EPNdB approach contours for Boeing 727.

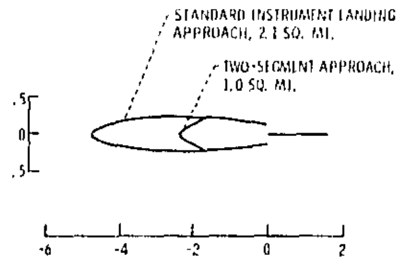


Figure III-6. - 95-EPNdB approach contours for Boeing 727.

United's implementation of the two-segment system stressed adherence to standard procedures to such an extent that one-switch operation and an airport elevation input are the only features that distinguish the two-segment procedure from United's standard ILS procedure.

The special purpose glide slope computer developed by Collins uses a signal from a DME transmitter colocated with the ILS glide slope and barometric corrected pressure altitude to position the aircraft on the upper segment and uses the ILS glide slope deviation to position the aircraft on the lower segment. The two-segment computer also uses altitude rate information from the Central Air Data Computer (CADC) for vertical path damping and airspeed from the CADC to drive an autothrottle.

DME transmitters, colocated with the ILS glide slope, are not standard equipment in an instrument landing system. However, the FAA currently plans to add these facilities at a rate of five in FY 75, 50 in FY 76, 30 in FY 77 and 40 in FY 78. The necessary colocated facilities are available at the airports being used in the program.

Although it is very difficult to estimate the cost of retrofitting United Air Lines fleet of Boeing 727's with this system, it is thought that the cost will be approximately $31 400, for a dual installation. The $31 400 assumes $26 600 for equipment, $4000 for installation, and $800 for flight check. Out-of-service and training costs are not included. It is assumed that installation could occur when the aircraft are out of service for other reasons and that training could be incorporated into the normal training and review curriculum.

For several reasons, the present program is providing a much broader basis for evaluating the feasibility of the two-segment approach than in previous programs. First, the avionics have been designed, built, and environmentally tested to FAA Technical Standard Order specifications. The system performs internal selfchecks and, in the event of a failure, provides the pilot with a warning similar to warnings provided in the event of a failure during an ILS approach. Second, the procedure and system have been tested both in the simulator and in flight under a wide variety of operational conditions. Approaches have been made under instrument flight conditions; in the presence of tail winds, wind shears, and turbulence; at dusk and at night; and at several airports including Los Angeles and San Francisco. Third, over 50 pilots have participated in the off-line pilot evaluation: 15 line pilots representing ALPA and APA, 19 management pilots from the different airlines, 11 FAA pilots, five engineering test pilots, and one USAF pilot. Finally, a broader spectrum of line pilot reactions will be obtained as a result of the in-scheduled service evaluation, which begins in late April 1973 and lasts through October 1973. This will be the first time a two-segment guided approach system has been placed into routine line service. During this period it is expected that over 96 crews will evaluate the system and that over 500 two-segment approaches will be made.

STEP B: DEVELOPMENT AND FLIGHT EVALUATION OF TWO-SEGMENT AVIONICS USING THREE-DIMENSIONAL AREA NAVIGATION FOR GUIDANCE IN A DC-8-61

United Air Lines and the Collins Radio Company initiated work, under contract with NASA, on this program in December 1972. The program objectives are to determine the operational feasibility of modifying a three-dimensional area navigation system to provide the two-segment approach capability and to evaluate the two-segment approach in a DC-8-61 aircraft in regular scheduled service.

The program contains the same basic phases as the Boeing 727 evaluation covered in STEP A. However, the avionic concept and aircraft characteristics are substantially different.

In this step an existing area navigation system will be modified to include the two-segment capability. An inherent advantage of this concept is that, if the aircraft is equipped with an area navigation system, a modification to the system represents an inexpensive way of incorporating the two-segment approach capability. A second advantage is that the system can be used to make precision approaches to ILS equipped runways without requiring a colocated DME transmitter facility. The system can also be used to make nonprecision noise abating approaches into non-ILS equipped runways.

The Boeing 727 aircraft used in STEP A is particularly well suited for the two-segment approach. It has relatively high drag in the landing configuration and requires positive thrust component to come down the 6° glide slope at reference velocity. It is also equipped with relatively new and complete avionic systems so that the two-segment guidance interface with the autopilot and flight director is straight forward.

On the other hand, the McDonnell-Douglas DC-8 has relatively little drag in the landing configuration and requires near idle thrust to come down a 6° glide slope at reference velocity. In addition to the low drag characteristics, the DC-8 has an autopilot older than the Boeing 727 autopilot. Even though preliminary flight tests indicate that the DC-8 autopilot can follow the two-segment guidance command, the interface between the two-segment guidance system and the autopilot may require more extensive modifications than are required on the Boeing 727. For these reasons, it is the opinion of the airlines, the FAA, and the pilots that the two-segment evaluation must be conducted in the DC-8 in order to establish the envelope of acceptable two-segment approach profiles for the fleet of commercial aircraft.

Although the DC-8 is more difficult to adapt to the two-segment approach, the expected noise benefits are significant. The 90- and 95-EPNdB contours for a DC-8-61 aircraft during a $6^{o}/3^{o}$ two-segment approach with a 690-ft intercept altitude are compared in figures III-7 and III-8 with noise contours estimated for a standard instrument landing approach. The 90-EPNdB impacted area is reduced by 6.3 square miles (54 percent reduction), and the 95-EPNdB impacted area is reduced by 3.3 square miles (50 percent reduction).

Cost estimates to provide a fleet of aircraft already equipped with area navigation with the two-segment capability have not yet been worked out in detail. However, the cost will be substantially less than required to retrofit with the special purpose glide slope computer system. An estimate of this cost is $9000, which includes equipment and installation charges. Out-of-service costs and training costs are not included. It is assumed that installation could occur when the aircraft are out of service for other reasons and that training could be incorporated into the normal training and review curriculum. If the two-segment capability is provided as a part of the area navigation package prior to installation, it appears that the added cost could become quite small.

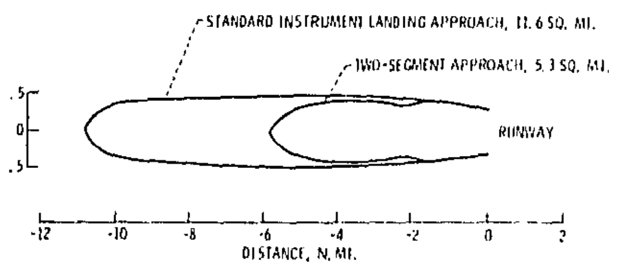


Figure III-7. - 90-EPNdB approach contours for DC-8.

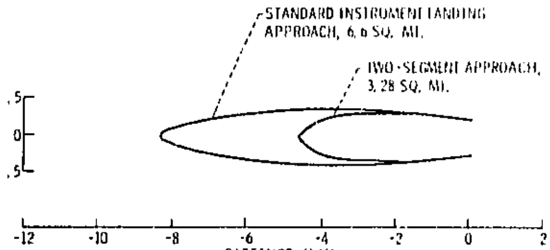


Figure III-8. - 95-EPNdB approach contours for DC-8.

STEP C: STUDY TO DETERMINE THE APPLICABILITY OF THE TWO-SEGMENT APPROACH TO ADDITIONAL JET TRANSPORTS

The preceding steps are aimed at determining the operational feasibility of the two-segment approach for only two aircraft types. The purpose of this step is to extrapolate the results of these flight programs to cover the McDonnell-Douglas DC-9 and DC-10 and the Boeing 707, 737, and 747 jet transports by an analytical and simulation program.

Contracts will be awarded to Boeing and McDonnell-Douglas Aircraft companies in FY 73 to make a preliminary determination of the approach profiles that would achieve maximum noise abatement while maintaining adequate safety margin and pilot acceptance for their different aircraft. These feasibility studies will not include flight simulations.

Contracts will then be awarded to an airline contractor (or contractors) in FY 74 to conduct a simulation study wherein the operational feasibility of making two-segment approaches in these aircraft will be examined in detail. These studies will look at the effect of extreme wind shear, pilot abuses, and system failures on the safety of the procedure.

STEP D: STUDY TO DETERMINE THE SUITABILITY OF THREE-DIMENSIONAL AREA NAVIGATION TO PROVIDE VERTICAL GUIDANCE

An analytical study will be conducted to determine the requirements on the location of the ground navigational aids used as inputs to the airborne navigation equipment in order to provide sufficient accuracy for two-segment guidance. The study will also define procedures that can be used to flight check the adequacy of existing ground navigational aids for establishing the upper segment guidance at individual airports.

It is expected that this study will be conducted by the FAA in conjunction with their existing program aimed at defining area navigation requirements.

STEP E: STUDY TO DETERMINE THE IMPACT OF THE TWO-SEGMENT APPROACH ON ATC

Aircraft making two-segment approaches will have to mix with aircraft making standard ILS approaches. In addition, it appears that two-segment approaches for different aircraft types will require different upper segment glide slopes. A study will be conducted to determine the impact on ATC of intermixing different approach profiles in the terminal area. It is expected that this study will be conducted by the FAA.

OTHER TECHNIQUES FOR NOISE ABATEMENT

FLIGHT TEST OF NOISE ABATEMENT APPROACHES USING A MICROWAVE LANDING SYSTEM

By the end of the FY 73 considerable expertise and understanding will have developed with respect to the usefulness of the noise abatement operational procedures when flying the landing approach pattern using the conventional NAVAIDS, that is, ILS, DME, and VORTAC. It is hoped that the FY 73 program and the anticipated follow-on programs for FY 74 will provide sufficient momentum to carry noise abatement procedures using conventional ground NAVAIDS into practice in the airlines. Beyond 1974, however, the question arises as to the impact of the microwave landing system, being developed under FAA contract, on the noise abatement flight procedures. In this respect, no real problems are anticipated in flying noise abatement procedures using the microwave landing system. However, it is almost inevitable, based on past flight test experience, that certain unanticipated problems will surface.

Therefore, a flight test program is planned wherein noise abatement approaches are flown using a microwave landing system in an attempt to take advantage of the full capability of this system and to expose problems that could influence the microwave landing system design. Tests conducted in FY 74 should provide results soon enough to influence the preliminary design and development of the microwave system.

The basic objectives of this program are to determine how to best use the unique capabilities of the microwave landing system for noise abatement and to determine if there are any navigation, guidance, control, and operational problems associated with this type of system.

FLIGHT EVALUATION OF CURVED APPROACHES FOR NOISE ABATEMENT

Area navigation potentially provides the capability of flying the aircraft along curved approach paths in order to avoid noise sensitive areas. A simulation and flight program is planned, for FY 74 or FY 75, to determine the operational feasibility of using this technique in conjunction with the two-segment approach. The program will be largely conducted in-house and will include analysis, simulation, and flight test. A brief description of the effort planned in these phases follows:

In this phase, the necessary steering signals will be defined and presentation to the pilot will be evaluated. Pilot workload and ability to fly these approaches will offer the greatest obstacle. A principal purpose of the simulation will be to determine the amount of automation required to keep the workload at a level comparable with that required during a standard instrument approach. The effects of winds, wind shears, and pilot abuses will be evaluated. Flight tests will be conducted using the NASA research Boeing 737 aircraft in the Terminal Configured Vehicle and Avionics Program at the NASA Langley Research Center.

NOISE ABATEMENT USING DECELERATING APPROACHES

Two modifications to the standard approach procedure can be proposed for reducing the noise. One consists of flying a steeper-than-standard approach path (i.e., two-segment approach), which increases the aircraft's altitude over the noise sensitive area and reduces the thrust used in the approach. The other is to make a decelerating approach on a standard glide slope with the engines at idle power. In this method, the aircraft begins the approach at relatively high airspeed and then slowly decelerates to the landing speed, using the kinetic energy as a power source to overcome the drag forces. A third method is also possible by combining the two.

If we assume that the approach is flown along the standard ILS glide slope, then, in principle, the decelerating approach can be started at any point on the ILS beam. The single most important variable in a decelerating approach is the airspeed of the aircraft at the starting point. This airspeed must be chosen such that the aircraft can fly safely from the outer marker to a desired point with all engines operating at minimum permissible thrust, with arrival at the specified point with full flaps, and with the desired landing speed. Assuming the aircraft arrives at the starting point with the proper airspeed, it begins its gliding and decelerating flight along the ILS beam while either the pilot or an automatic landing system maintains the aircraft's flight along the beam. As the aircraft is slowly decelerating, the flaps are extended according to a computed schedule. The novelty of the proposed technique lies in the use of flap angle modulation rather than the more commonly encountered thrust modulation as a method of deceleration control. If the proper airspeed was selected at the starting point and if the flaps are extended at the proper rate, the landing speed and the full-flap configuration will be reached close to the interception of the glide path with the runway or at any other point along the glide path designated at the terminal point of the deceleration. Since this procedure allows thrust to be maintained at the lowest possible value throughout the approach, engine noise is kept to a minimum. There are safety questions related to this approach because of the time required to spool up the engines if a go-around is required.

ANALYSIS

In this phase, the principle objectives are to make a preliminary evaluation of the profile to be flown; that is, whether the decelerating approach should be flown along the standard ILS glide slope or along a two-segment glide slope; perhaps along a $3\frac{1}{2}^{\circ}$ to $4\frac{1}{2}^{\circ}$ glide slope and then about a mile from the runway threshold transition to the normal ILS glide slope. In this phase, the optimum speed profile, flap extension schedule, transition point, flight director requirements for aided manual guidance, guidance laws and interfaces with autopilot and autothrottle for automatic approach, as well as the navigation requirements must be determined.

Piloted Simulation

Pilot workload and ability to fly these trajectories will offer the greatest obstacle. Considerable automation will be required to keep workload from increasing beyond that of standard approaches. A principal purpose of the simulation will be to determine the minimum level of automation needed to keep the workload reasonable. The simulation program will also evaluate cockpit displays, check out flight director guidance laws and automatic guidance, determine missed approach procedures, study the effect of gusts and wind shears, and define pilot procedures for the manual approach.

Flight Test

It is planned that the flight test program will be conducted using NASA Boeing 737 aircraft in the Terminal-Configured Vehicle and Avionics Program. The main objective of the flight test phase will be to refine the operation of the "decelerating approach" system, further develop the operational procedures, and assess system performance in the actual flight environment. The final objective of course, is to reduce this experimental approach technique to practice.

AERODYNAMIC NOISE

Recent computations and measurements have suggested that there may be an aerodynamic noise floor in the approach and landing configuration of large jets about 10 PNdB below the FAR Part 36 noise level. Operational procedures such as the two-segment and curved ground track approaches, which increase the separation of the observer and the aircraft, are effective at reducing the impact of aerodynamic as well as engine noise. The aerodynamic noise varies as a high power of the flight speed. Therefore, the decelerating approach, which approaches at higher speed, would have a higher aerodynamic noise floor.

In order to obtain better data on the aerodynamic noise floor and understand the relationship between aerodynamic noise and engine noise and the different types of noise abatement approaches (the steep glide slope, the two-segment approach, the curved ground track, and decelerating approach) NASA Ames is planning a flight test program with the NASA CV-990, four-engine jet aircraft and possibly other aircraft.

REFERENCES

1. Hilton, D. A.; Copeland, W. L.; and Dibble, A. C., Jr.: Measurements of Noise Produced by a BAC-111-400 Series Turbofan Transport Airplane During Takeoff-Climbout Operations. LWP No. 211, April 13, 1966.
2. Copeland, W. L.; Hilton, D. A.; Huckel, V.; Dibble, A. C., Jr.; and Maglieri, D. J.: Noise Measurement Evaluations of Various Takeoff-Climbout Profiles of a Four-Engine Turbojet Transport Airplane. NASA TN D-3715, 1966.
3. Copeland, W. L.: Noise Measurements During Takeoff Climbout Operations of Four Jet Transports. Presented at 74th Meeting of the Acoustical Society of America, Miami Beach, Florida, November 1967.
4. Copeland, W. L.; and Clark, L. R.: Noise Measurements for a Three-Engine Turbofan Transport Airplane During Climbout and Landing Approach Operations. NASA TN D-6137, 1971.
5. Schaefer, W. T., Jr.; and Copeland, W. L.: Noise Abatement Approach Flight Test Investigation of a Convair 880M Airplane. LWP No. 305, 1966.

6. Zalovcik, J. A.: Effect of Thrust and Altitude in Steep Approaches on Ground Track Noise. NASA TN D-4241, 1967.

7. Sawyer, R. H.; and Schaefer, W. T.: Operational Limitations in Flying Noise Abatement Approaches. NASA TN D-5497, 1969.

8. Quigley, H. C.; Snyder, C. T.; Fry, E. G.; Power, L. J.; and Innis, R. C.: Flight and Simulation Investigation of Methods for Implementing Noise Abatement Landing Approaches. NASA TN D-5781, 1970.

9. Meyersburg, R. B.; and Williams, C. H.: The Two-Segment Noise Abatement Approach to Landing. Presented at the International Conference on the Reduction of Noise and Disturbance Caused by Civil Aircraft, London, England, November 1966.

10. Chubboy, R. A.: An Operational Evaluation of the Two-Segment Approach for Noise Abatement. FAA Report No. FAA-RD-71-72, April 17, 1972.

11. Denery, D. G.; Bourquin, K. R.; White, K. C.; and Drinkwater, F. J., III: Flight Evaluation of Three-Dimensional Area Navigation for Jet Transport Noise Abatement. AIAA Paper No. 72-814, 1972.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Working Paper No. [illegible]

NOTE ON EFFECT OF THRUST AND ALTITUDE ON NOISE IN STEEP APPROACHES

by John A. Zalovcik

SUMMARY

A brief analysis was made of the sound pressure level measured at four ground stations during 3° approaches of a four-engine medium-range turbojet transport for several flap deflections. The results of the analysis, when applied to steeper-than-normal approaches, showed good agreement with sound pressure levels measured in steep approaches. For the airplane used in the analysis, increasing the glide slope from 3° to 6° reduced the sound pressure level 11.5 to 13.5 dB depending on the ground station location. Of this reduction 7 dB was due to the reduction in thrust and the remainder (4.5 to 6.5 dB) to increase in altitude.

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from NASA

AIAA Paper No. 72-814

FLIGHT EVALUATION OF THREE-DIMENSIONAL AREA NAVIGATION FOR JET TRANSPORT NOISE ABATEMENT

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AIAA 4th Aircraft Design, Flight Test, and Operations Meeting

LOS ANGELES, CALIFORNIA / AUGUST 7-9, 1972

Concluding Remarks

The first phase of research aimed at determing the operational feasibility of the two-segment approach as a noise abating technique, has been completed. A total of twenty-eight pilots representing the airlines, professional pilot associations, NASA, and the FAA participated. In general, the evaluation pilots considered the procedures to be operationally feasible. However, there was concern expressed over the general acceptance of the procedure until the equipment can be proven sufficiently reliable and not prone to inducing pilot errors.

Although the program was not aimed at passenger evaluation of the procedure, the on-board observers who participated did not express any special concern or discomfort during the two-segment approaches.

The area navigation system used for these tests was capable of establishing an upper glide slope using the VOR and DME signals from the Stockton VORTAC. The effect of other VORTAC locations on the accuracy with which the upper glide slope can be established was not considered as a part of these tests.

The flight director and raw data displays provided the pilot with adequate information for making a smooth two-segment approach. The upper segment capture was consistently made with less than a 40 ft overshoot. Having captured the upper glide slope, the pilots were able to follow it to within a 75 ft vertical deviation. The transition to the ILS glide slope was also smooth and resulted in a maximum undershoot of 8 ft, and, in most cases, the transition was accomplished without any undershoot.

The procedure resulted in a noise reduction, using an ILS approach for comparison, of 18 EPNdB at the outer site and 8 EPNdB at a site located about 1 n. mi. from touchdown.

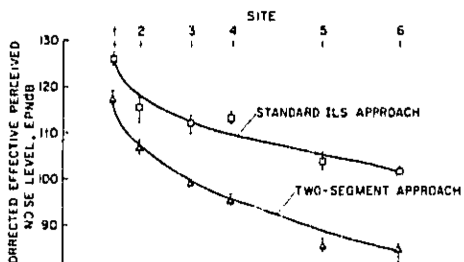

Fig. 10. Comparison of noise measured during two-segment approach and standard ILS approach.

FLIGHT AND SIMULATION INVESTIGATION OF METHODS FOR

IMPLEMENTING NOISE-ABATEMENT LANDING APPROACHES

Hervey C. Quigley, C. Thomas Snyder,
Emmett B. Fry, Leo J. Power,
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Ames Research Center

and

W. Latham Copeland

Langley Research Center

SUMMARY

A flight and simulator investigation has been conducted to determine methods for implementing steep two-segment and decelerating landing approaches. For the research jet transport used in the study a reduction in noise of approximately 11 PNdB (9EPNdB) at a point 1.1 nautical miles from the runway threshold was achieved with a two-segment approach with an upper segment of 6° and a lower segment of 2.65° which intercepted at an altitude of 250 feet. The two-segment profiles with an intercept at 400 feet reduced noise about 10 PNdB at a point 1.5 nautical miles and 13 PNdB (11 EPNdB) at a point 3.4 nautical miles from the threshold. Decelerating approaches on a normal approach angle (2.65°) reduced noise only moderately 3 to 4 PNdB, but combining decelerating with steeper or two-segment approaches reduced noise 11 PNdB (9 EPNdB) at a point 1.1 nautical miles from the runway threshold.

The noise abatement landing approach profiles evaluated in this program could be flown in a modified jet transport with the same precision as conventional instrument landing approaches without a significant increase in pilot workload. The pilots preferred two-segment approach profiles with an intercept altitude of 400 feet. The research airplane had improvements over current jet transports including a flight director modified for noise abatement profiles, an autothrottle, and stability augmentation that improved longitudinal and lateral directional handling qualities. The evaluation flights were flown under simulated instrument conditions in daylight and in near-ideal weather. Further research is needed to examine the requirements and operational limitations of two-segment approaches in an environment more representative of airline operations.

Inglewood
california

STEEP APPROACHES FOR AIRCRAFT NOISE ABATEMENT -

A COLLECTION OF RESEARCH STUDIES

JULY 1972

I. NASA FLIGHT TESTS OF STEEP APPROACHES

NASA flight tested steep approaches at Oakland Airport using a modified Boeing 367-80 (707 prototype). Noise measurements were made in conjunction with the flight tests. The flights were made in ideal weather but under simulated instrument conditions (pilot unable to see outside cockpit).

The tests included 6^{o} approaches to touchdown and $6^{o}/2.65^{o}$ two-segment approaches with intercept altitudes of 250 and 400 feet (see Figure 1). The noise measurements showed that the 6^{o} approach to touchdown reduced noise by about 18 PndB throughout the approach (Figure 2). The two-segment approaches reduced noise by approximately 10 PndB just prior to the intercept point and by approximately 17 PndB at a point four nautical miles from the runway threshold (Figure 3).

The NASA test pilots found that under simulated instrument conditions rates of descent greater than 1000 feet per minute were unsatisfactory at altitudes less than 200 feet above the ground. This would render a single segment 6^{o} approach (with a descent rate of 1600 feet per minute) unsatisfactory under instrument conditions. However, the report indicated that a noise reduction of 5 PndB or more is possible by an increase in approach angle to 4^{o} without a large increase in rate of descent.

To avoid the problem of high descent rates near the ground, the two-segment approaches were used. The pilots felt slightly rushed on some approaches with 250 foot intercept altitudes and therefore preferred the 400 foot intercept altitude.

Under simulated instrument conditions there was a tendency for pilots to drop below the 2.65^{o} glide slope during transition from the 6^{o} glide slope if there was no supplementary guidance information provided. When the aircraft was modified to include a flight director which provided supplementary guidance for two-segment approaches as well as an autothrottle and both longitudinal and directional stability augmentation the two-segment approaches could be flown with the same precision as normal approaches (never exceeding 30 feet below the glide slope) as shown in Figure 4. With such equipment modifications there was no increase in pilot workload.

Reference

Fry, Emmett B.;Innis, Robert C.; and Quigley, Hervey C."Flight Investigation of Methods for Implementing Noise-Abatement Landing Approaches." Progress of NASA Research Relating to Noise Alleviation of Large Subsonic Jet Aircraft. NASA Ames Research Center for Langley Research Center Conference, October 8-10, 1968. NASA SP-189, pp. 377-394.

TEST PROFILES

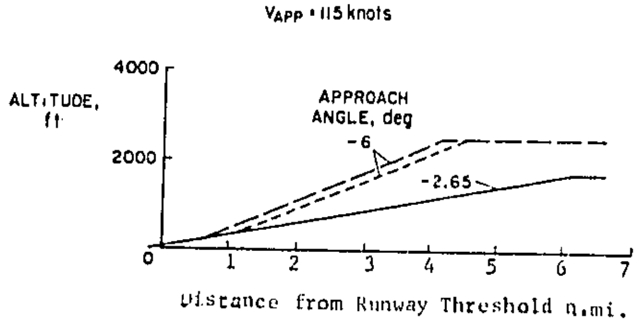


FIGURE 1

RATE OF DESCENT AND NOISE REDUCTION WITH APPROACH ANGLES

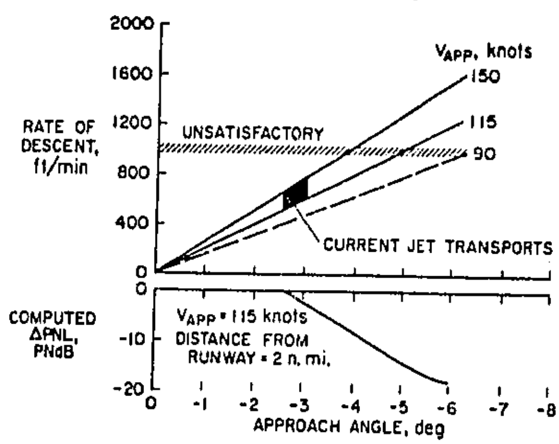


FIGURE 2

COMPUTED NOISE REDUCTION FOR TEST PROFILES

V_{APP} = 115 KNOTS

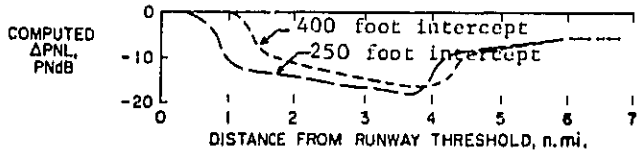


FIGURE 3

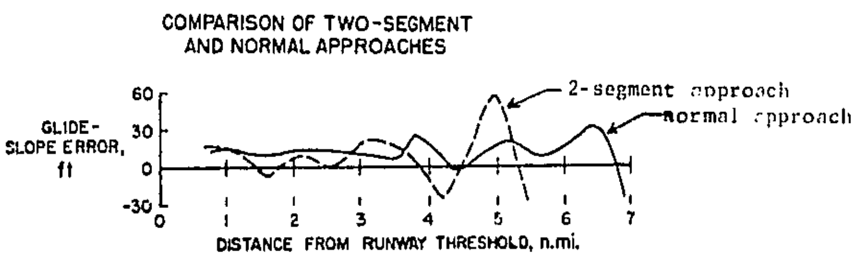


FIGURE 4

V. NATIONAL AIRLINES TWO-SEGMENT APPROACH PROCEDURE

National airlines is flying two-segment steep approaches with Boeing 727 aircraft at Miami International Airport. The procedure requires no equipment other that what is already in the aircraft. The procedure is used only when the cloud ceiling is at least 3,000 feet and the visibility at least 5 miles.

The procedure is depicted in Figure 8. From an altitude of 2,500 feet at 6 nautical miles from the runway, the aircraft descends at approximately a 5.2° angle until intercepting the glide slope at an altitude of 700 to 1,000 feet and a distance of 3 nautical miles from the runway. Power is not applied until approaching an altitude of 300 to 500 feet because a slightly high airspeed is carried during the steep segment.

A noise reduction of at least 7 EPndB is achieved through the use of this procedure.

Reference

Cunningham, Gerald, Letter to Miami Airline Operations Committee, "VFR Noise Abatement Approach," Air Transport Association November 5, 1971 (Typewritten)

NATIONAL AIRLINES NOISE ABATEMENT SEGMENTED APPROACH
BOEING 727 AIRCRAFT
WEATHER MINIMUMS - 3,000 foot ceiling and 5 miles visibility

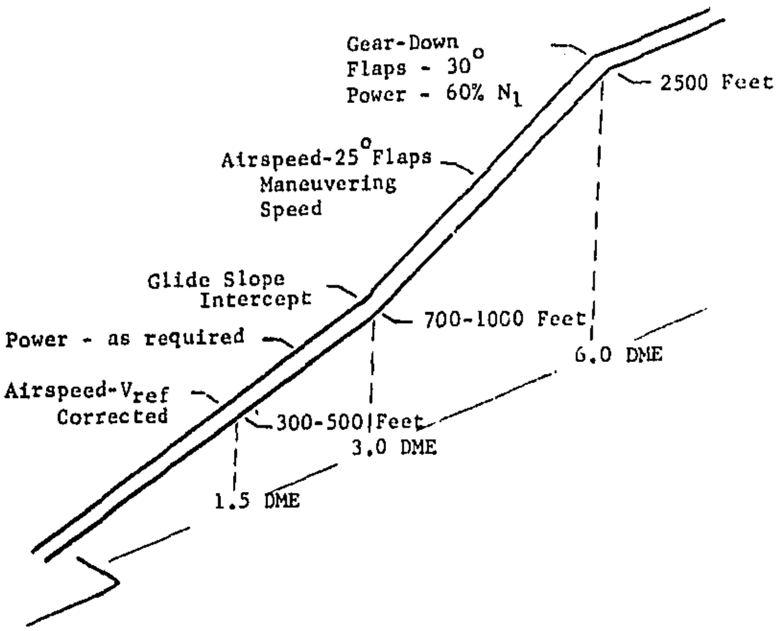


FIGURE 8

VI. PSA TWO-SEGMENT APPROACHES

Pacific Southwest Airlines (PSA), a California intrastate carrier, is flying two-segment steep approaches with Boeing 727 and 737 aircraft at the airports they serve. The procedure requires no equipment other than what is already in the aircraft. The procedure is only used when weather allows the pilot to keep the runway in sight throughout the procedure.

The procedure is depicted in Figure 9. From an altitude of 3,000 feet at 6 nautical miles from the runway, the aircraft descends at approximately a 5.4° angle to an altitude of 1,000 feet at 2.5 nautical miles, then gradually transitions until stabilized on the final 3° glide slope at 1.5 nautical miles.

The City of Inglewood has monitored approach altitudes of PSA and of other carriers under actual operational conditions since the PSA procedure was introduced. Considering all 727 and 737 aircraft combined, the following results were observed:

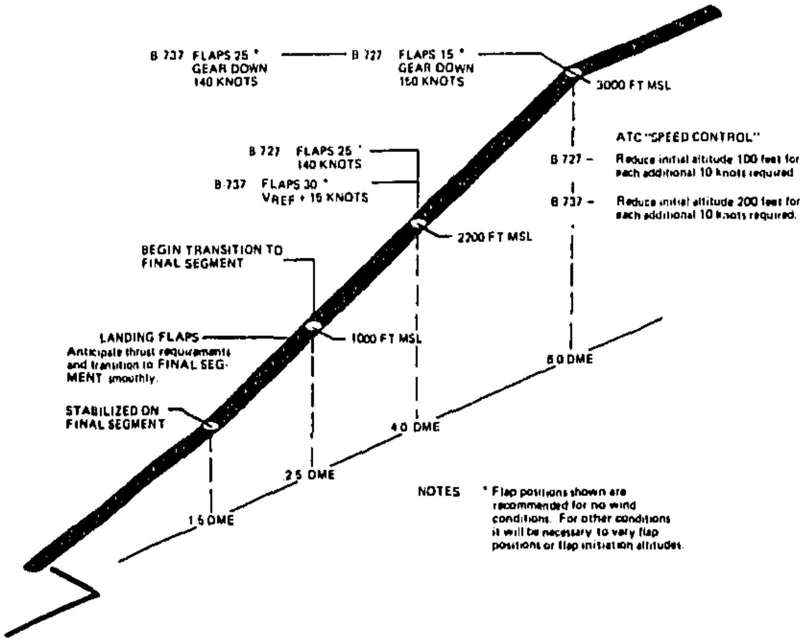
Distance from Threshold	PSA Altitude Above Monitor	All Others Altitude Above Monitor	PSA Glide Path Angle	All Others Glide Path Angle
1.46 nm	565 Feet	502 Feet	3.6°	3.18°
2.51 nm	972 Feet	823 Feet	3.82°	3.04°

The differences in altitudes between PSA and all others were statistically significant at the 99% confidence level. Measurements were attempted at a distance of 3.57 nautical miles from the runway (under the 5.4° segment) but because of dispersion during aircraft turns, insufficient data were obtained to draw any conclusions.

During experimental flight tests PSA reported 17 EPndB noise reduction under the steep segment. Inglewood observed PSA approaches to be approximately 3 EPndB quieter on the average at distances of 2.5 nautical miles or less (under the shallow portion of the approach).

PSA NOISE ABATEMENT SEGMENTED APPROACH

VISUAL CONTACT WITH AIRPORT MUST BE ESTABLISHED
PRIOR TO INITIATING APPROACH AND MAINTAINED
THROUGHOUT ENTIRE APPROACH



APRIL 72

FIGURE 9

VII. AIRPORTS WITH GLIDE SLOPE ANGLES STEEPER THAN 3°

There are a number of airports which have electronically established glide slopes at an angle of greater than 3°. The FAA's National Aeronautical Facilities Experimental Center (NAFEC) has concluded that 3-1/2° glide slopes are better than 2-1/2° glide slopes[1].

The airports known to have steeper glide slopes are:

AIRPORT	RUNWAY DESIGNATION	GLIDE SLOPE ANGLE	TYPE OF APPROACH
Dobbins AFB, Georgia[2]	11	3.2°	Radar
San Diego, California[3]	09	3.22°	ILS
Pope AFB, North Carolina[2]	04	3.25°	Radar
Whidbey Island NAS, Washington[2]	31	3.25°	Radar
Alameda NAS, California[2]	13	3.5°	Radar
Alameda NAS, California[2]	25	3.5°	Radar
Tempelhof Airport, Berlin, Germany[4]	Unknown	3.5°	ILS
San Diego, California[5]	27	4.5°	VASI
Fullerton, California[6]	24	6	Microwave ILS

References:

1. NASA Headquarters, Washington, D.C. Minutes of Meeting of NASA AD HOC Advisory Panel on "Aircraft Noise Abatement by Operational Flight Procedures." September 23, 1971 (Typewritten).

2. U.S. Air Force. IFR-Supplement United States. Aeronautical Chart and Information Center, St. Louis, Missouri. DOD Flight Information Publication (Enroute). 25 May 1972.

3. Jeppesen & Company, "San Diego, California, International - Lindberg Approach Chart, ILS Rwy 9," Airway Manual, Jeppesen & Company, Denver Colorado. May 19, 1972. p.11-1.

4. Blumenthal, V.L.; Russell, R.E.; and Streckenbach, J.M. Noise Reduction Research and Development Summary, The Boeing Company, November 1971, D6-60146, Second Printing, January, 1972.

5. Jeppesen & Company, "San Diego, California, International-Lindbergh Field Airport Diagram" Airway Manual, Jeppesen & Company, Denver, Colorado. May 19, 1972. p.11-1.

6. Hurlburt, Randall L., "Fullerton Microwave ILS," Memorandum to Steep Approach File, and Fullerton File. City of Inglewood, California. December 13, 1972. (Typewritten).

VIII. 5^{o} APPROACHES AT SAN DIEGO AIRPORT

Because of high terrain in the approach path to Runway 27 at San Diego International Airport, approaches must be made substantially above a 3^{o} angle. Until recently, no electronic glide slope was provided, although this is the primary landing runway.

The standard approach procedure is a back course ILS (no glide slope) with a minimum altitude of 2085 feet specified at a point 4.7 nautical miles from touchdown. A constant rate of descent from this point to the runway would result in a 4.17^{o} glide angle. In April, 1972 the FAA installed a VASI (Visual Approach Slope Indicator) for Runway 27 set for an approach angle of 4.5^{o}.

The City of Inglewood actually monitored aircraft altitude at a point 2.6 nautical miles from touchdown at San Diego. The measurements were made during visual flight conditions prior to the installation of the 4.5^{o} VASI. The tests included 2,3, and 4 engine jet transports.

The tests showed the average glide path angle to be 5^{o}, compared to an average of 3.1^{o} at Los Angeles! This approach is being made regularly in spite of the fact that the runway length available for landing at San Diego is only 7,590 feet compared to 11,395 feet at Los Angeles.

If a 5^{o} approach angle such as was flown at San Diego were introduced in Los Angeles, aircraft noise would be reduced approximately 12 EPndB, or 56%.

Reference

Boettger, Wolfgang A., A Comparison of Aircraft Approach Angles At Los Angeles and San Diego International Airports, City of Inglewood, California. May 1972.

IX. ALTITUDES WHEN GLIDE SLOPE INOPERATIVE AT LAX

The City of Inglewood was monitoring aircraft altitude on approach when the ILS glide slope signal failed on August 27, 1971. Thirty-three (33) aircraft were monitored prior to glide slope failure, 21 after glide slope failure. The average altitude prior to failure was 907 feet above the monitor. The average altitude with glide slope out was 990 feet above the monitor. These altitudes translate into angles of 3.24° and 3.54°, respectively. The average altitude difference was statistically significant at the 90% confidence level.

These results show that aircraft fly at higher altitudes without a glide slope than with a glide slope if the glide slope angle is less than 3.5°.

Reference

Hurlburt, Randall L., "Statistical Comparison Study." Memorandum dated June 6, 1972 to Jack Miller, City of Inglewood, California. (Typewritten).

XI. ALTITUDE DISTRIBUTION AT LOS ANGELES AIRPORT

The City of Inglewood has monitored thousands of overflights approaching Los Angeles International Airport. In actual practice there is a wide range of approach angles used.

For example, during the month of November, 1970, Inglewood monitored the altitude of 294 two-engine aircraft, 497 three-engine aircraft, and 828 four-engine aircraft. The monitoring location was approximately 2.64 nautical miles from touchdown on Runway 25L. At this point the glide slope altitude is approximately 813 feet above the monitoring camera.

Although most aircraft were within $\pm$ 100 feet of the glide slope altitude, a substantial number were significantly above it. Ninety (90) aircraft were above 900 feet (a glide path angle of 3.3°), 9 aircraft were above 1200 feet (a glide path angle of 4.5°), and 4 aircraft were above 1450 feet (a glide path angle of 5.3°). The altitude distribution for four-engine aircraft was similar to the overall distribution, indicating that steeper angles were flown not only by small jets. The highest altitude measured was a four-engine jet at 1804 feet (a glide path angle of 6.5°).

If all aircraft would fly close to or above a 4.5° glide path angle instead of holding close to a 3° glide path, the noise reduction would be approximately 9 EPndB.

Reference

Hurlburt, Randall L.; Owen, David A., Inglewood's Noise Monitoring Program. Report on Phase I. City of Inglewood, California. September 30, 1971.

XIII. GUIDANCE AVAILABLE FOR STEEP APPROACHES

Steep approaches can be conducted with or without electronic guidance. They can be performed more easily and more precisely if electronic guidance is available. In approximate order of increasing complexity, the following guidance could be made available:

ILS. At least one ILS (Instrument Landing System) is usually installed at most major commercial airports. The glide slope beam is usually set for a 3° approach angle. Most commercial aircraft have ILS receivers installed. Although a 3° ILS is obviously better for noise abatement than a 2-1/2° ILS, any ILS set for an angle less than 3-1/2° or 4° actually contributes to excess noise because most aircraft would fly at these higher angles if no glide slope were available.

ILS/DME. Two-segment approaches such as those used by National Air Lines and PSA require Distance Measuring Equipment (DME) in the aircraft. Most commercial aircraft have DME.

3½° ILS. Slightly steeper (3½°) approaches can be achieved during all weather conditions by simply adjusting the angle of the ILS glide slope. No new ground or airborne equipment would be required.

4½° VASI. Visual Approach Slope Indicators (VASI's) are installed at some but not all commercial airports. Where installed, the angle is usually 3° but could easily be adjusted upwards to 4½°. At other locations equipment and installation would cost approximately $60,000 but could then be used by all aircraft during visual weather conditions.

VAMSI. The FAA experimented with a Visual Approach Multi-Slope Indicator (VAMSI) at San Diego International Airport.[1] This system generated a visual 5°/3.25° two-segment glide path. However, the trial was discontinued when the FAA found that aircraft sometimes followed the 3.25° beam when they should have been on the 5° beam, thus causing dangerous terrain clearance problems (San Diego has high terrain surrounding the airport). The concept may still have merit for noise abatement purposes at other airports.

VAM. A Visual Approach Monitor (VAM) has been developed by Sundstrand Data Control, Inc. and been tested by Pan American World Airways.[2] This provides a visual display in the cockpit that automatically can guide a pilot through a two-segment approach during visual weather conditions. No ground equipment is required. The cost is approximately $16,000.

R-NAV. The most versatile equipment available for airborne use is area navigation (R-NAV) equipment capable of operating in three dimensions, thus providing vertical navigation (V-NAV). Such equipment allows the pilot to select any desired combination of routes, altitudes, glide path angles, or intercept points. The guidance displays in the cockpit will then cause the pilot to fly the selected approach. One such system (the one used for the tests of Chapter II) costs approximately $20,000.

PAR. Precision Approach Radar (PAR) has not been widely used for noise abatement although some military installations use glide slope angles above 3° to provide terrain clearance. In using PAR, the radar controller constantly tells the pilot what his position is with respect to the desired course and glide path. This system has the capability of being exceptionally versatile if it were developed properly.

References

1. Jeppesen & Company, "San Diego, California, International-Lindberg Approach Chart, VAMSI Rwy 27," Airway Manual, Jeppesen & Company, Denver, Colorado, U.S.A. Page 10-4, December 3, 1971.

2. Elson, Benjamin M. "Visual Approach Monitor Being Certified," Aviation Week, April 3, 1972, pp. 36-39.

March 2, 1973

SUBMITTAL TO EPA

AIRCRAFT/AIRPORT NOISE STUDY TASK FORCE
TASK GROUP 2, OPERATIONS ANALYSIS

LOCKHEED-CALIFORNIA COMPANY
BURBANK, CALIFORNIA

The material submitted is an analysis showing the large reductions in approach noise levels near airports which can be attained by advanced operational procedures. The noise reduction potentials are shown for the Lockheed L-1011 TriStar Transport; however, they are in principle applicable to any airplane.

It has long been known that large approach noise reductions could be attained by use of steep, decelerating, and curved approach paths Such procedures have in the past been considered impractical and unsafe because of pilot workload and/or guidance system limitations.

Recent advances in automatic control and guidance technology require re-evaluation of the traditional position. For example, the Lockheed L-1011 incorporates an advanced Autoland system (FAA certified for Category III A) which, after the pilot selects ILS capture mode, performs a precision landing and rollout without any further action or control from the pilot. Also FAA certified in the L-1011 is the Area Navigation System which, in conjunction with the automatic control system, can fly the airplane along any predetermined three-dimensional path. Integration of the Autoland and Area Navigation System, which is believed feasible, would provide the capability for precision, minimum noise approaches, separately tailored for each airport, to be flown automatically and safely.

Realization of the large potential approach noise reductions in routine operations depends upon conclusive demonstration that the procedures involved do not compromise safety and that they are compatible with the overall air traffic environment.

1. Two Segment Approach

As shown in Figures 2 and 3, the two-segment approach reduces the area exposed to 90 EPNdB or greater by over 60%.

2. Decelerating Approach

A decelerating approach utilizes the momentum of the airplane to provide part of the thrust required. The noise reduction is achieved as a result of the lower engine thrust then required. The reduction in thrust required is directly proportional to the deceleration. For a one-foot/sec/sec deceleration, 35.5 knots/min., the total thrust reduction is 11,100 pounds, or 3700 pounds per engine, resulting in a noise reduction (Figure 1) of about 2.5 PNdB.

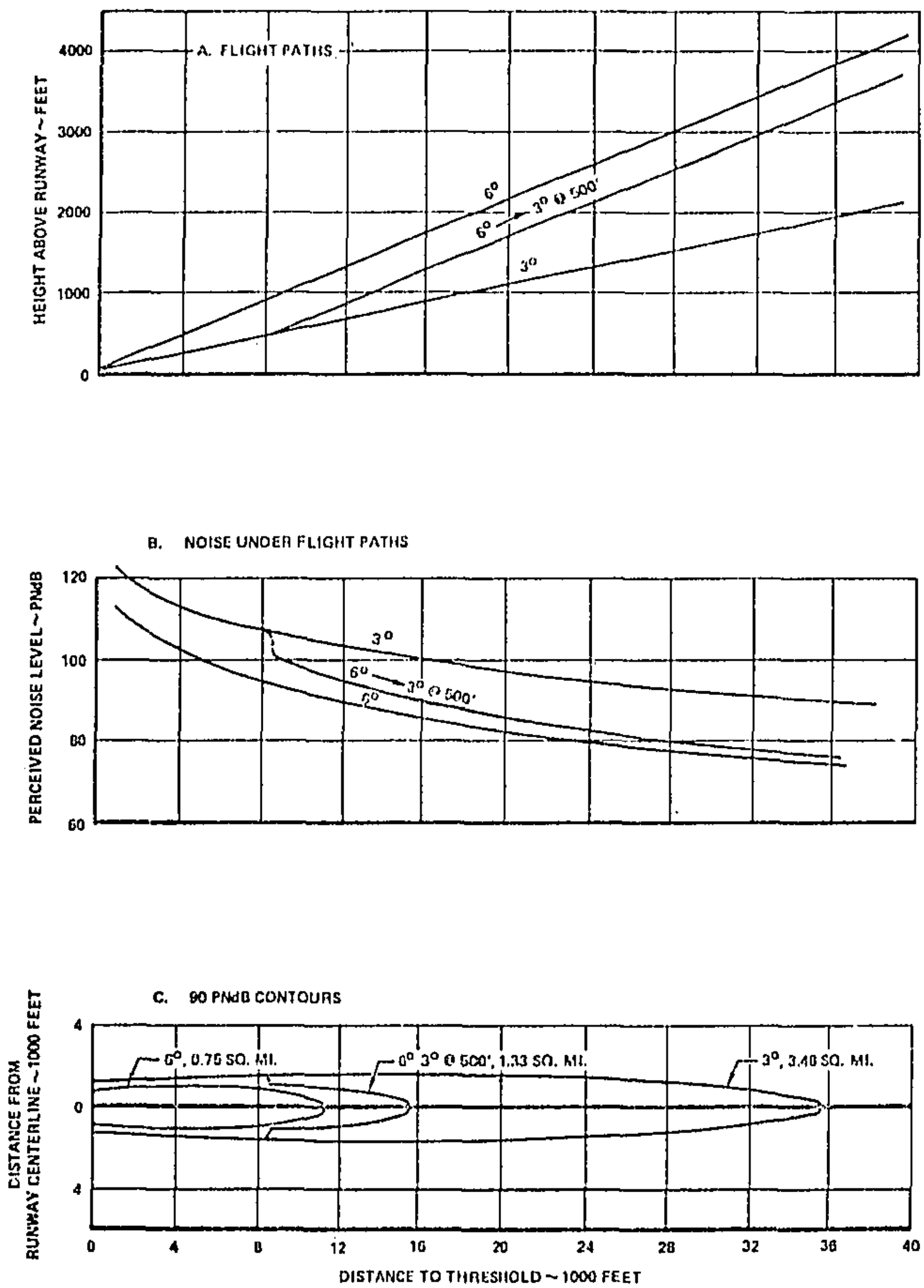


FIGURE 2. TWO-SEGMENT NOISE ABATEMENT APPROACH

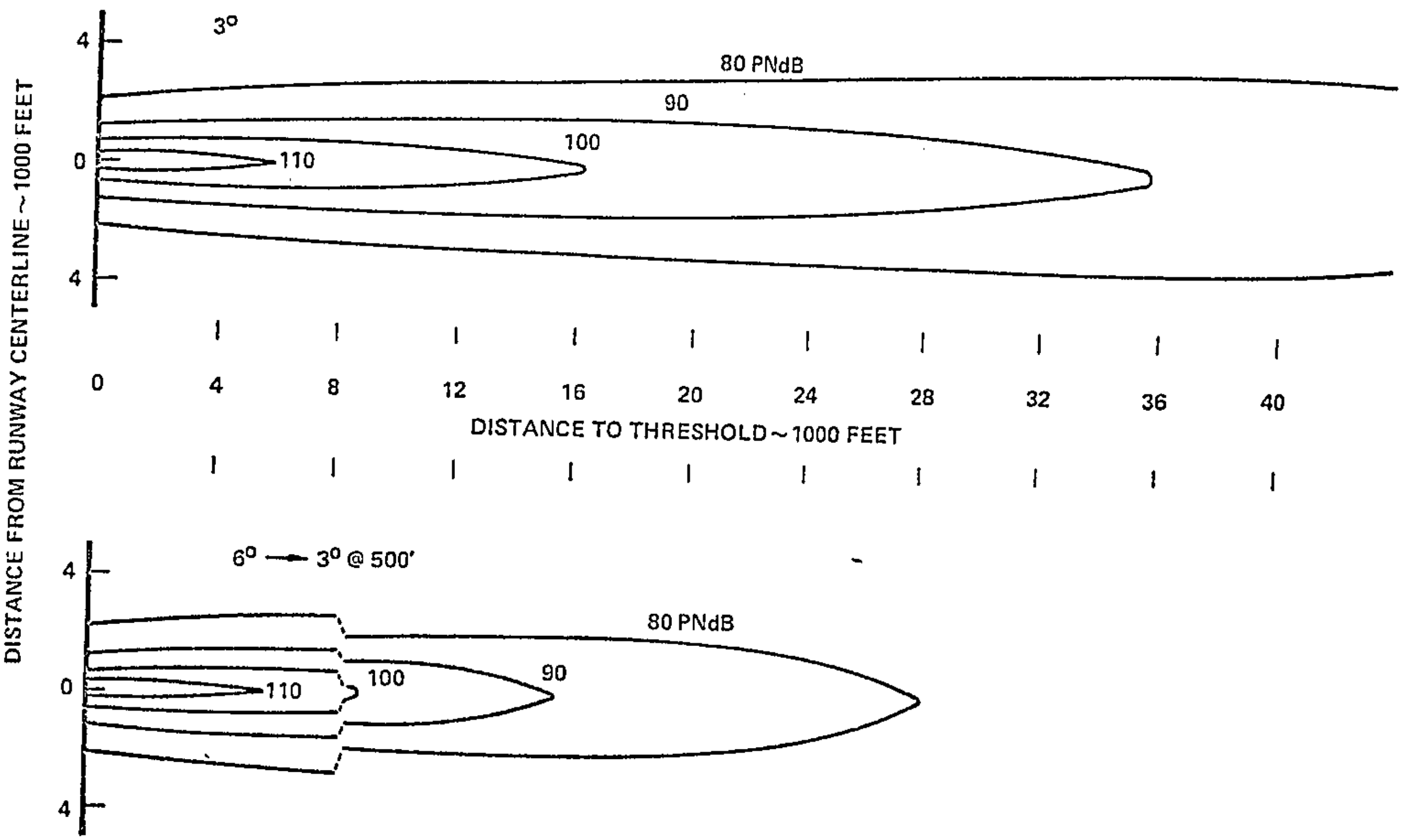


FIGURE 3. NOISE FOOTPRINTS (PERCEIVED NOISE LEVEL)
CONVENTIONAL AND TWO-SEGMENT APPROACH

TC 2 - 94
Received 4/9/73
From NASA

NASA TECHNICAL MEMORANDUM

NASA TM X-62,187

NASA TM X-62,187

INITIAL FLIGHT AND SIMULATOR EVALUATION OF A HEAD UP DISPLAY FOR STANDARD AND NOISE ABATEMENT VISUAL APPROACHES

Kent Bourquin, Everett Palmer, George Cooper, and Ronald Gerdes

Ames Research Center
Moffett Field, Calif. 94035

February 19

A-91

INITIAL FLIGHT AND SIMULATOR EVALUATION OF A HEAD UP DISPLAY FOR STANDARD AND NOISE ABATEMENT VISUAL APPROACHES

Kent Bourquin, Everett Palmer, George Cooper, and Ronald Gerdes

ABSTRACT

A preliminary assessment was made of the adequacy of a simple Head Up Display (HUD) for providing vertical guidance for flying noise abatement and standard visual approaches in a jet transport. The HUD featured gyro-stabilized approach angle scales which display the angle of declination to any point on the ground and a horizontal flight path bar which aids the pilot in his control of the aircraft flight path angle.

Thirty-three standard and noise abatement approaches were flown in a Pan American World Airways Boeing 747 aircraft equipped with a Sundstrand Head Up Display. The HUD was also simulated at Ames Research Center in a research simulator. The simulator was used to familiarize the pilots with the display and to determine the most suitable way to use the HUD for making high capture noise abatement approaches.

Preliminary flight and simulator data are presented and problem areas that require further investigation are identified.

Noise measurements were obtained on all the approaches (ref. 8) and certain ones are summarized in figure 14 where smooth curves have been passed through the average data points. The high capture profile noise data summarized was obtained from those approaches that the radar tracking confirmed were nominally profiles 5 and 6. At 18,000 feet from runway threshold, the average noise during a high capture approach was 13 EPNdB less than the noise measured during a standard 2.5° ILS glide slope approach. At 18,000 ft from the runway threshold, a 3° approach resulted in 5 EPNdB reduction from the -2.5° approach.

CONCLUDING REMARKS

The following observations were made on the normal -3° approaches:

1. Simulation data showed a four-fold increase in precision when the VAM was used on a visual approach.

2. Flight results showed acceptable capture and tracking of the 3° glide slope for normal, low, and high approaches.

3. Some pilots complained of a tendency to "reverse control" in the delta-gamma mode. Alternate symbology is being investigated.

The following observations were made on the high capture noise abatement approaches:

1. Simulation results suggest that the high capture approaches can be flown with the VAM with considerably more precision than non-ILS visual approaches with no VAM.

2. Current HUD hardware symbology is suitable for high capture noise abatement approaches.

3. The best means or conditions for initiating the approach, VAM or DME position fix, remains to be determined although either may be acceptable.

4. The 747 aircraft drag characteristics were low, requiring idle power on the -6° flight path angle at 25° flaps. Future work will be done using 30° flaps and a shallower (-5°) flight path angle if necessary.

5. On those approaches in which the aircraft decelerated during the 6° to 3° transition there was a tendency to undershoot the 3° glide slope. This appears to be related to display errors, not piloting errors and is being investigated. This, of course, was not a problem for standard 3° approaches.

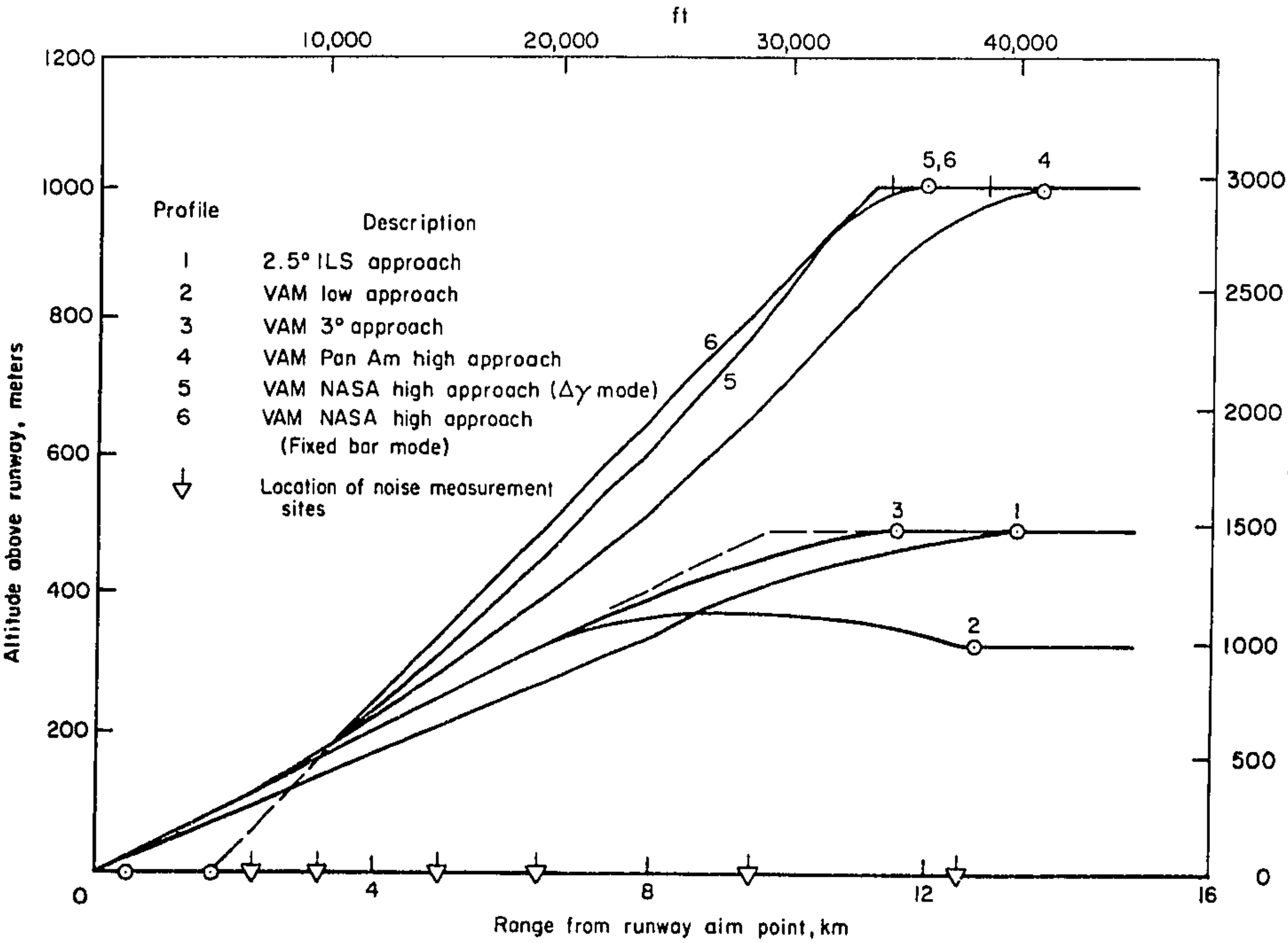


Figure 11.- Flight Profiles.

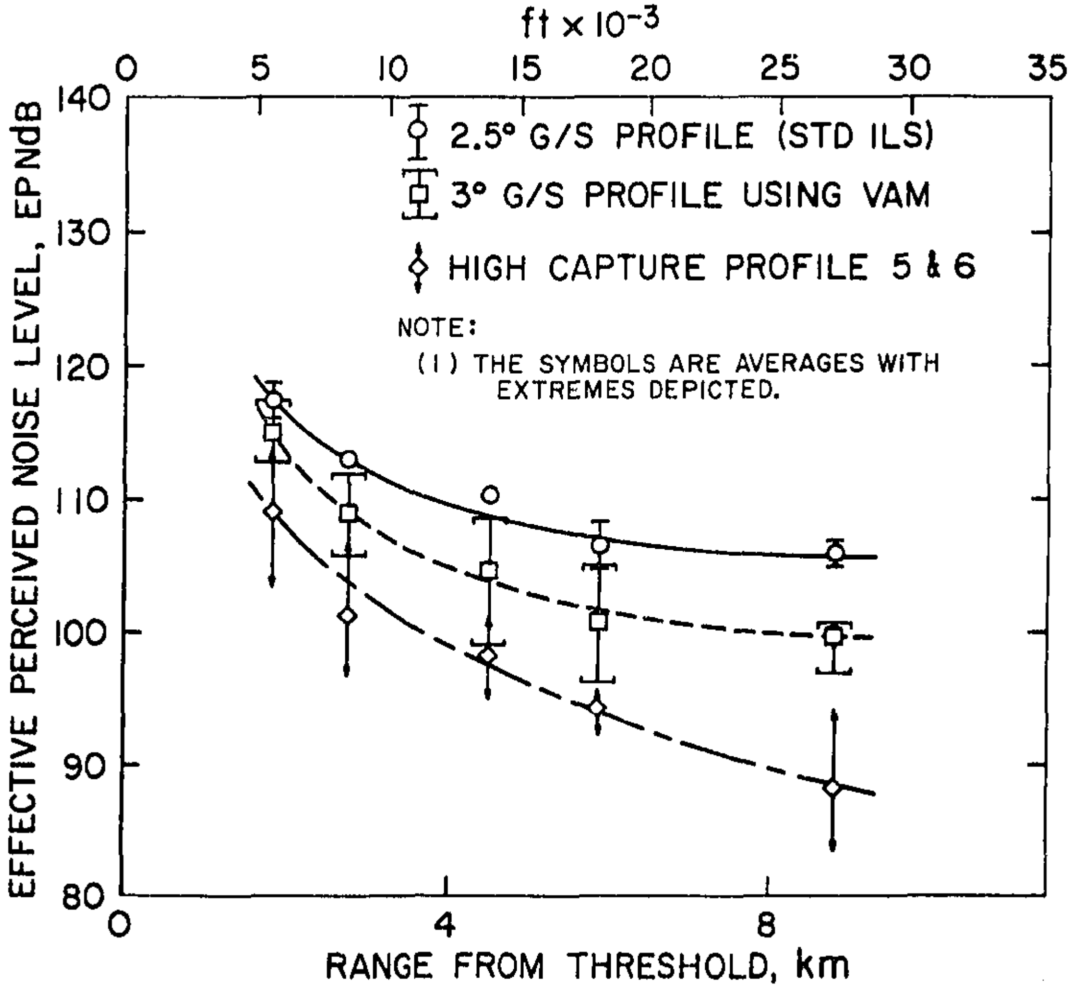


Figure 14.- Summary of Noise Data.

Los Angeles Department of Airports
Five-Point Noise Abatement Program

In a move to reduce the noise impact on residents adjacent to Los Angeles International Airport, the Board of Airport Commissioners today (Dec. 20) adopted a five-phase program based on Federal Air Regulation (FAR) Part 36, which prescribes noise standards for certification of transport aircraft.

Presented to the Board by Department General Manager Clifton A. Moore, the program also is designed to reduce to manageable limits possible liabilities against the City of Los Angeles in nuisance suits.

Dedicated to encouraging a fleet of quiet aircraft at Los Angeles International, such as the new generation DC-10, L-1011, the 747-200 and certain models of the 727-200, the newly adopted program is as follows:

1) A runway preferential use program which would shift all aircraft traffic between 11 p.m. and 6 a.m. to over-ocean approaches and departures--Proposed to start on April 29, 1973, this conforms with the date for airline schedule changes.

The over-ocean system has been under evaluation at Los Angeles International since September 1972, and the Federal Aviation Administration has promised installation of an instrument landing system on Runway 6R to be operational by the program's effective date.

Over-water operations will be possible 90 percent of the time. During the remaining period when weather and wind conditions do not permit such operations, aircraft not complying with FAR 36 will be denied the use of Los Angeles International. Under these conditions, only FAR 36 aircraft will be allowed to land from or takeoff to the east between the hours of 11 p.m. and 6 a.m.

(more)

Instructions will be issued to the FAA designating the north and south inboard runways as preferential for takeoffs under this night-time system.

Penalty for repeated violation by any carrier of the preferential runway useage will result in cancellation of its operating permit and the right to use Los Angeles International Airport.

2) A program of economic incentives to accelerate the use of quiet aircraft--Labeled "dollars for decibels", the program will be implemented on July 1, 1973.

It will feature a schedule of incentive landing fees, ranging from the lowest charge for FAR 36 aircraft to the highest for operators of the noisiest aircraft. This incentive landing fee program will have a direct tie-in with phase three.

3) A fleet noise rule to establish a 100 percent FAR 36 aircraft fleet at Los Angeles International by December 31, 1979--This is a long-range program by which the noisier aircraft are phased out of the airline fleet.

It will be evaluated on the basis of actual operations at Los Angeles International and designed to be 40 percent complete by July 1, 1977, and 100 percent in compliance with FAR 36 by the end of 1979.

This fleet noise rule will stand at Los Angeles International unless a more stringent rule is adopted by the federal government.

4) Creation of a noise enforcement division within the Department of Airports--As a tool to insure compliance, the noise monitoring computer will be programmed to accurately measure FAR 36 noise parameters.

5) Even though this program is designed to insure quieter aircraft, the Airport Commission and staff will continue to urge adoption of appropriate legislation to achieve a stronger method for developing compatible land use in the various communities around Los Angeles International.

(more)

The Airport Commission instructed Department management last August 2 to prepare airport regulations and policies which would diminish liability of the City of Los Angeles in possible nuisance suits, and also provide the minimum noise impact on residents in vicinity of Los Angeles International.

This action by the Commissioners followed a report by City Attorney Roger Arnebergh suggesting closure of Los Angeles International due to implications of the case of Nestle vs. the City of Santa Monica. Decision by the California Supreme Court in this case established, for the first time, that nuisance is a basis for law suits against governmental agencies.

The Department's new five-phase program was formulated after giving careful consideration to pending legal actions. namely the Air Transport Association's recent suit attacking the California Noise Standards and the forthcoming review of the Burbank curfew decision by the U. S. Supreme Court.

# # #

JEF/kr
12-20-72

December 1, 1972

JOINT POLICY STATEMENT ON AIRPORT NOISE

Prepared by elected representatives of the communities of:
El Segundo, Inglewood, Lennox, Playa Del Rey, Westchester

Noise from Los Angeles International Airport has reached intolerable proportions in the communities of El Segundo, Inglewood, Lennox, Playa Del Rey, and Westchester. Efforts to reduce noise have so far resulted in unsatisfactory improvement.

To arrest and abate the noise problem, the communities around LAX are convinced that unified action is necessary. They have therefore met together and hereby submit the following joint proposals to the Los Angeles Department of Airports. The Department of Airports is invited to meet with representatives of the surrounding communities on a regular basis to seek implementation of these or any other measures to reduce noise. The proposals are:

1. Night Curfews: The airport should be closed to all jet operations during the sleeping hours from 11 PM to 7 AM.

2. Noise Barriers: A wall or earth berm should be constructed along the north and/or south runways wherever it would reduce noise.

3. Runup Restrictions: Maintenance runups of jet engines on or off aircraft should be prohibited unless conducted in a noise suppressor which will reduce noise to 65 dBA or less at any residential property line.

4. Reduced Takeoff Power: Except where inconsistent with safety, reduced engine power should be used for all takeoffs from the start of takeoff roll.

5. Rolling Start Takeoffs: To reduce the excessive time duration of noise near the start of the takeoff roll, all takeoffs should be begun from a rolling, not standing, start with gradual addition of power.

6. Flat Takeoff Profile: To reduce sideline noise, takeoffs should be planned to lift off as far down the runway as possible and climb out initially at as low an altitude as is consistent with safety of flight.

7. Takeoff Runway Restrictions: To reduce sideline noise, takeoffs should be permitted only from the inner runways (24L-6R, 25R-7L).

8. Steep Approaches: To reduce noise produced by landings from the east, the ILS glide slope angle should be raised from 3 to 3½ degrees, and 4½ degree Visual Approach Slope Indicators (VASI's) should be installed.

9. No Thrust Reversers: Except where inconsistent with safety, the use of thrust reversers on landing should be prohibited.

10. Retrofit: No aircraft, including SST's, should be permitted to land or take off from LAX after January 1, 1976 which have not been originally manufactured or subsequently retrofitted to meet the noise level standards of FAR Part 36.

11. Noise Abatement Plan: The airport should adopt a noise abatement plan which will achieve compatibility between the airport and surrounding communities.

12. Noise Abatement Committee: Airport officials should meet regularly with official representatives of the surrounding communities to develop jointly acceptable noise abatement plans.

These proposals are not necessarily the total answer to the noise problem at LAX, nor are they the only areas of agreement among the communities near the airport. They represent reasonable steps which may be taken to reduce noise for all. Data to support these proposals is available on request.

Signed:

E L Balmer

E. L. Balmer
Mayor, City of El Segundo

Merle Mergell

Merle Mergell
Mayor, City of Inglewood

Kenneth Hahn

Kenneth Hahn
Supervisor, County of Los Angeles

Pat Russell

Pat Russell
Councilman, City of Los Angeles

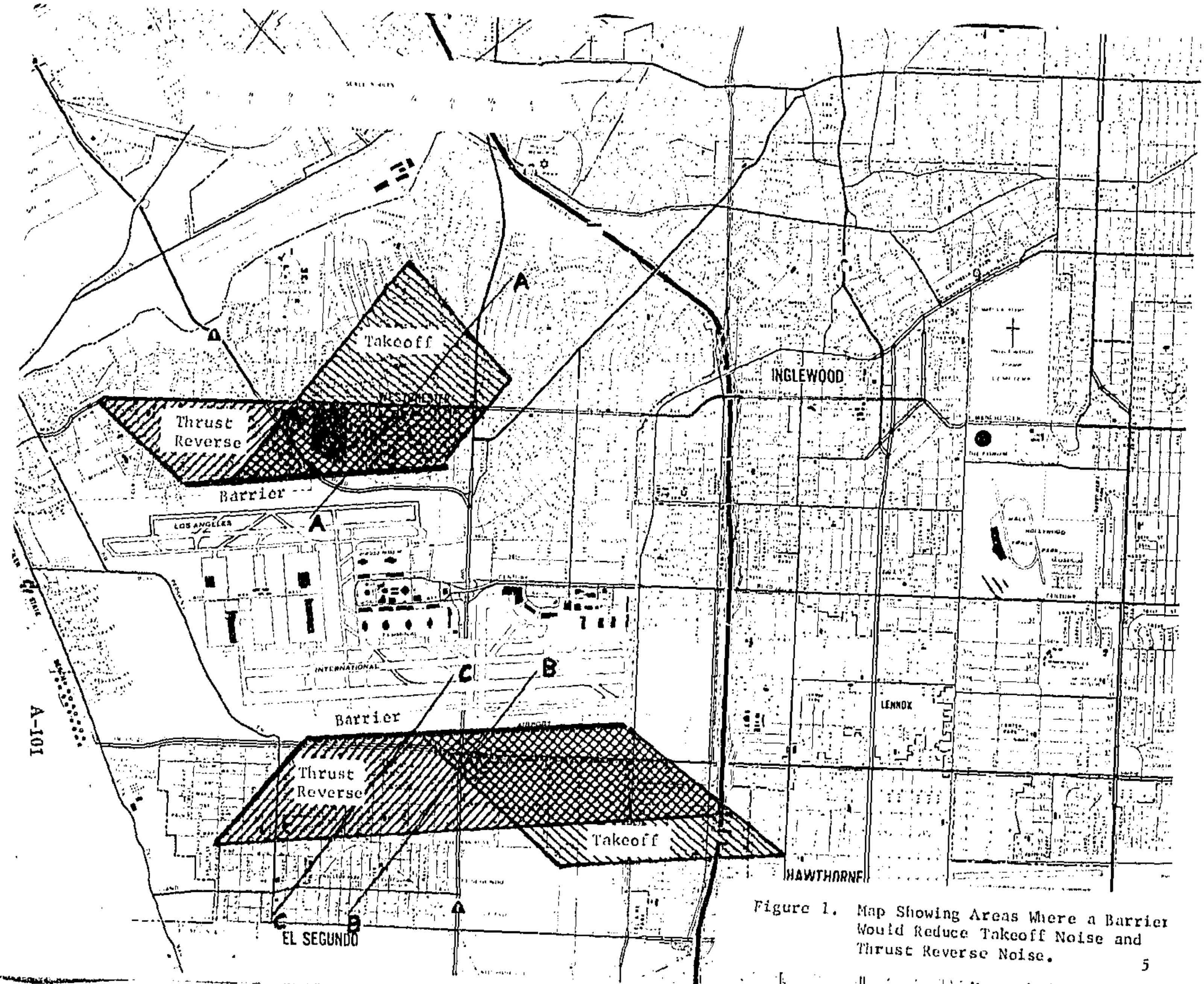


Figure 1. Map Showing Areas Where a Barrier Would Reduce Takeoff Noise and Thrust Reverse Noise.

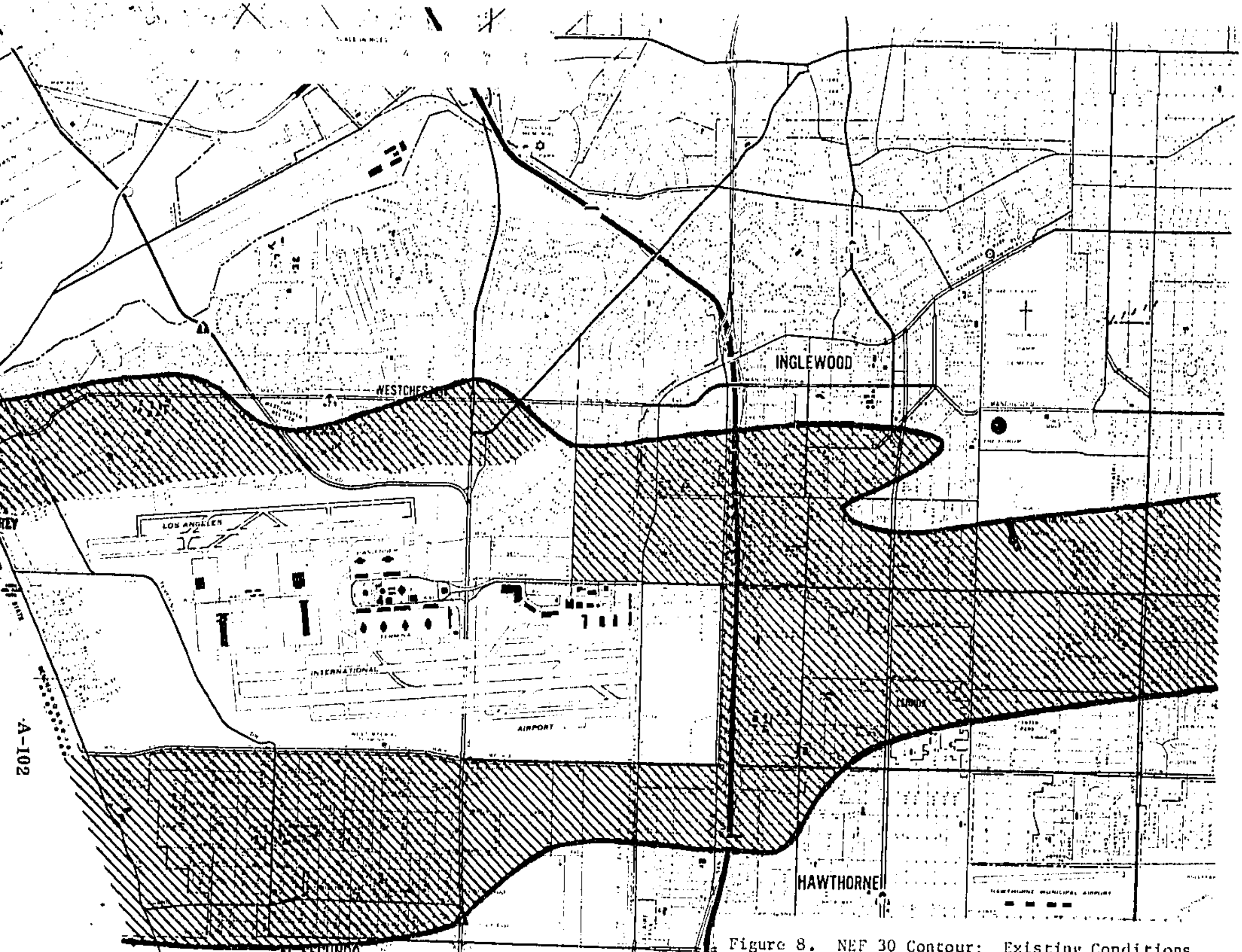


Figure 8. NEF 30 Contour: Existing Conditions

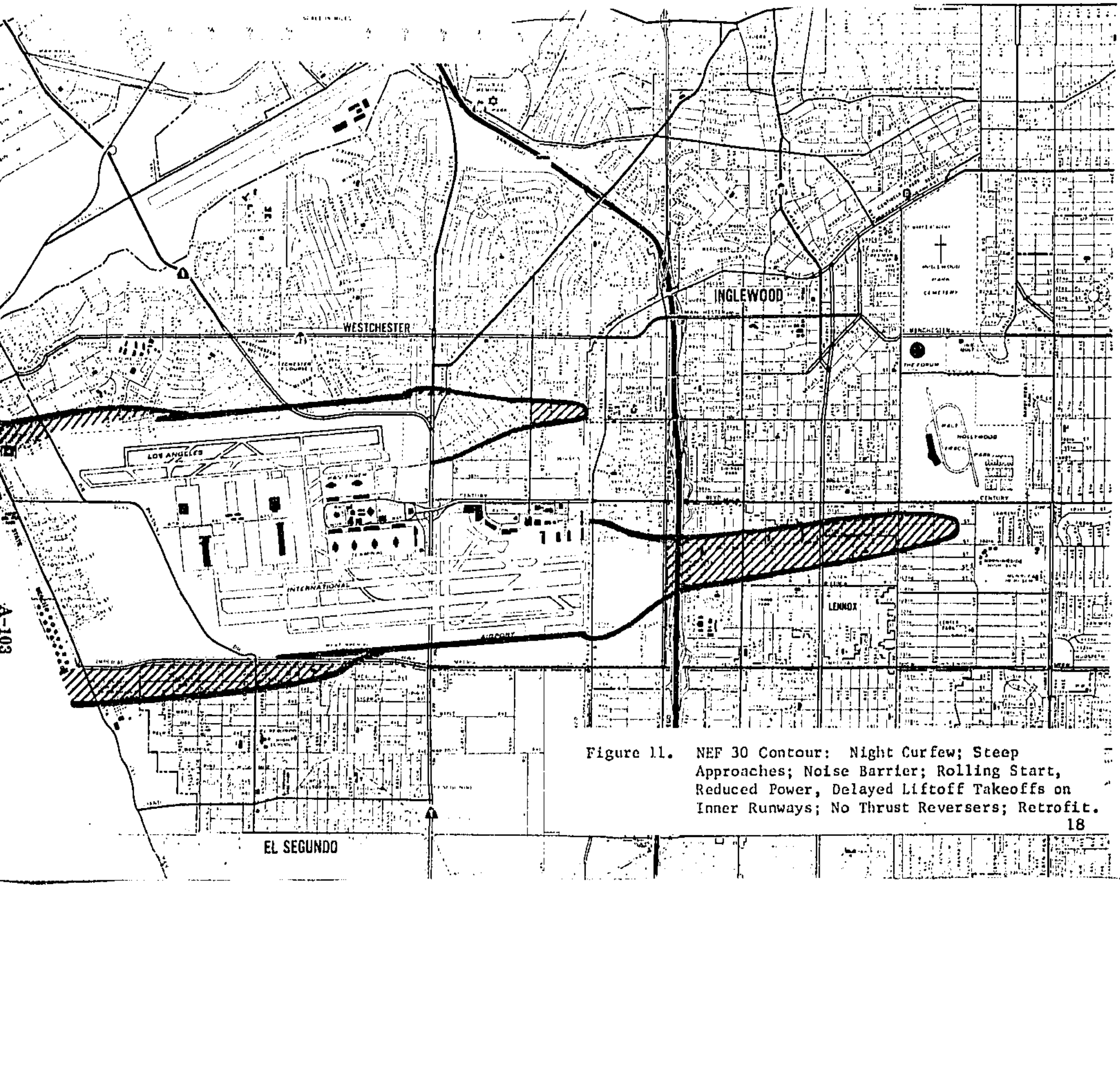


Figure 11. NEF 30 Contour: Night Curfew; Steep Approaches; Noise Barrier; Rolling Start, Reduced Power, Delayed Liftoff Takeoffs on Inner Runways; No Thrust Reversers; Retrofit.

FAA-RD-71-83

TG 2-69
Rec'd 3/29/73
from FAA

MEASUREMENT AND ANALYSIS OF NOISE FROM FOUR AIRCRAFT IN LEVEL FLIGHT (727, KC-135, 707-320B AND DC-9)

Carole S. Tanner

EG&G

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transpo 72
U.S. International Transportation Exposition
Dulles International Airport
Washington, D.C.
May 27-June 4, 1972

SEPTEMBER 1971

FINAL REPORT

Availability is unlimited. Document may be released to the National Technical Information Service, Springfield, Virginia 22151, for sale to the public.

DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION
Systems Research and Development Service
Washington, D.C. 20591

INTRODUCTION

In an effort to obtain information regarding the effective perceived noise levels (EPNL) of various aircraft flybys, a test program at National Aviation Facilities Experimental Center (NAFEC) was performed as a follow-on to work reported in Reference 1.

The broad program objectives were 1) to determine curves of EPNL versus slant range at the closest point of approach (CPA) as a function of three power settings, 2) obtain information as to the effects of changes in EPNL as a function of the angle of elevation between the ground and the slant range, and 3) acquire data that may be useful in providing further information as to the magnitude of sound absorption in the atmosphere for the higher frequencies.

This report presents the noise and appropriate tracking data for the 727, KC-135, 707-320B, and DC-9 aircraft. Plots of EPNL as a function of slant range at CPA, power setting, and angle of elevation are included for three ranges of power settings.

CONCLUSIONS

During the course of the data processing and data evaluation, several factors have arisen that are noteworthy of comment. First, the considerable variation and speed of the winds encountered during testing and the resultant effects on the aircraft performance and acoustics may warrant further investigation.

Considerable problems were encountered in obtaining useful data from the 7000-foot microphone. These problems included excessive background noise from nearby vehicular traffic and high ambient wind noise levels. Therefore, a large portion of this data was disregarded.

Comparisons of the test data with current state-of-the-art noise predictions indicates reasonable agreement (±5 EPNdB) for the 100 percent and minimum EPR conditions where $\beta > 15°$. The test data does indicate that the reference noise levels are a bit on the high or conversative side. The decrease in level due to angle of elevation effects is most noticeable on the 727 and KC-135 data at 100 percent and power cutback EPR.

Comparisons of level flyby data contained in this report can be made with flyover data from Reference 1 to provide a body of information suitable for noise predictions.

CIVIC CENTER
105 EAST QUEEN STREET / INGLEWOOD, CALIFORNIA 90301

July, 1972

REPORT SUMMARY

A SURVEY OF AIRCRAFT NOISE STANDARDS AND MONITORING SYSTEMS AT INTERNATIONAL AIRPORTS

By Wolfgang A. Boettger

In an effort to improve understanding of airport noise monitoring procedures worldwide, the City of Inglewood surveyed all airport authorities known to have monitoring systems. The results show that the United States lags behind other nations in the effort to reduce airport noise.

This report is primarily based on the answers to written requests for information which were sent out in February, 1971. Those airports known to have noise monitoring systems are:

United States

New York (Kennedy) Airport, New York
New York (La Guardia) Airport, New York
New York (Newark) Airport, New Jersey
Santa Ana (Orange County) Airport, California
Los Angeles International Airport, California

Worldwide

London (Heathrow) Airport, England
Gatwick Airport, England
Zurich (Kloten) Airport, Switzerland
Stuttgart Airport, Germany
Frankfurt (Rhein-Main) Airport, Germany
Munich Airport, Germany
Paris (Orly) Airport, France
Osaka International Airport, Japan
Tokyo International Airport, Japan

Environmental Standards Division
Department of Planning & Development
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This report briefly describes the noise monitoring system at each airport. It also describes the procedures, standards, and penalties in effect at each airport.

In general the report shows that there are more airports with monitoring systems in other parts of the world than in the United States. Except for the New York airports, other countries had noise monitoring systems 5-10 years earlier than the United States (the monitoring system at Los Angeles, although reported, is still not operational). All airports except Tokyo and Los Angeles reported a noise standard of some kind. Five of the airports in other countries have nighttime curfews or nighttime restrictions on flight operations; only Santa Ana Airport in the U.S. has a nighttime curfew. The only airport which invokes penalties for violation of their noise standards is Frankfurt Airport, Germany. A more detailed summary is contained in the attached table.

Although the United States has more advanced technology, builds more aircraft, and exposes more people to aircraft noise than any other nation, it is last in attacking the noise problem. The State of California is now attempting to take the lead by establishing statewide airport noise standards to become effective December 1, 1972.

RECOMMENDATION

The recommendation of this report is that the United States Government require that noise standards be established at all commercial jet airports based on the most advanced technology available including engine retrofit, steep approaches and scheduling control. These standards should be enforced using advanced monitoring systems and penalties for violators.

AIRPORT	OPERATIONS 197[illegible]	TYPE OF AIRCRAFT	MONITORING SYSTEM	NOISE STANDARDS	PROCEDURES	OTHER RESTRICTIONS	ENFORCEMENT PENALTIES
LONDON (HEATHROW)	270,360	707,727,737, 747,DC-8,DC-9, BAC-111,VC-10, Trident	13 fixed monitors. Installed 1960.	110 PNdB(7a.m.-11p.m.) 102 PNdB(11p.m.-7a.m.)	Approach: radar monitoring	No general aviation jets from 11 p.m.-7 a.m. Quota of 3500 commercial jets in summer.	No penalties. Airline notified.
ZURICH	130,470	707,727,737 747,DC-8,DC-9 BAC-111,IL-62, VC-10, Comet, TB-104	9 fixed monitors. Several mobile units. Automatic central processor. Installed 1964	99 dBA (6a.m.-10p.m.) 95 dBA (10p.m.-6a.m.)	Approach: at or above 3º Preferential runway. Departure: thrust reduction. Maximum climb	10 p.m. - 6 a.m.: no thrust reverser. No run-ups	No penalties. Airline notified. Pilot reprimanded. Violations published monthly.
STUTTGART	117,630	707,727,737, DC-8,DC-9, Caravelle, Trident,BAC-111	7 fixed monitors. Automatic central processor.	96 dB(A) (Monitor 6) 90 dB(A) (Monitor 1)	Departure: routing	10p.m.-6a.m.:no thrust reversers. No jet take-offs except 10 p.m.-11:30 p.m. and airmail service	No penalties.
FRANKFURT	200,000	707,727,737,747, DC-8, DC-9, BAC-111,Trident, Caravelle	13 fixed monitors. Automatic central processor. Installed 1964	Daily variable standard.	Standard instrum. departure routes are minimum noise routes	None	Pilot can be fined.
PARIS (ORLY)	190,700	707,727,737, 747,DC-8,DC-9, Caravelle,BAC BAC-111,Trident	3 fixed monitors. Graphic level recorder at central station.	Compare measured dBA or PNdB with calculated level for each type.	Departure: thrust reduction. Maximum climb.	Commercial jet curfews 11:30 p.m.-6 a.m.	No penalties. Airline notified and explanation requested.
OSAKA	150,730	707,727,737, DC-8,DC-9, CV-880,YS-11, F-27	2 fixed monitors. Automatic central processor.	100 dBA(6:30a.m.-7a.m.) 107 dBA(7a.m.-8p.m.) 100 dBA(t/o)(8p.m.- 107 dBA(lands)(10:30p.m.) 75 dBA(10:30p.m.-6:30 a.m.)	Departure: Routing. Performance	Jet curfew between 11 p.m. - 6 a.m.	No penalties. Airline notified and explanation requested.
TOKYO	163,300	707,727,737 747,DC-8, CV-880,YS-11	2 fixed monitors. Central station installed 1966	None	None	Jet curfew between 11 p.m. - 6 a.m.	No penalties.
NEW YORK (KENNEDY)	40[illegible],[illegible]00 (19[illegible])	707,727,737 747,DC-8,DC-9, DC-10,VC-10, BAC-111	3 fixed monitors. 3 mobile monitors. Automatic central station. First system installed 1960. New automatic system 1971	112 PNdB at residential areas.	Approach: Routing Departure: Routing, Performance (thrust,weight)	10 p.m. - 7 a.m.: preferential runways.	No penalties. Airline notified.
SANTA ANA (ORANGE COUNTY, CALIFORNIA)	555,000	737, DC-9, Jetstar,HS-125, F-27,Twin-Otter, Light aircraft	5 fixed monitors. Automatic central processor. Installed 1970.	California State Standards	Departure: Routing	Jet curfew between 11 p.m. - 7 a.m.	No penalties. Operator notified.
LOS ANGELES (INGLEWOOD)	516,000	707,727,737, 747,DC-8,DC-9, DC-10, L-1011, DC-10, CV-880, F-27	15 fixed monitors. Automatic central processor. Installed 1972 4 fixed monitors. 1 mobile monitor. Installed 1970.	None (Standard only for run-ups of unmounted engines.)	Approach: Preferential runway Departure: Routing	11 p.m. - 6 a.m.: No run-ups. Tower clearance for engine start-up.	No penalties.

AIRPORT ACTIVITY STATISTICS

OF

CERTIFICATED ROUTE AIR CARRIERS

ISSUED SEMIANNUALLY

12 MONTHS ENDED JUNE 30, 1971.

PREPARED JOINTLY

BY

CIVIL AERONAUTICS BOARD.

DEPARTMENT OF TRANSPORTATION

FEDERAL AVIATION ADMINISTRATION

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INTRODUCTION

This edition presents the volume of revenue passenger, freight, express, and mail traffic handled by the Nation's certificated route air carriers at each airport served by these airlines during the 12 months ended June 30, 1971. In addition, a presentation of aircraft departures is shown including detail by aircraft type for total departures performed in scheduled, nonscheduled, and all services.

Certificated route air carriers include the domestic trunk, local service, helicopter, intra-Alaska, intra-Hawaii, all cargo, international and territorial, and other route carriers holding Certificates of Public Convenience and Necessity issued by the CAB authorizing the performance of scheduled air transportation over specified routes. Data for supplemental, commuter, intra-state, and foreign-flag air carriers are not included in this publication.

SOURCE OF DATA

The data in this publication are compiled from information reported quarterly to the CAB by the certificated route air carriers on Schedule T-3(a)(b)(c), Airport Activity Statistics of CAB Form 41, Report of Financial and Operating Statistics For Certificated Air Carriers.

PRESENTATION OF DATA

The data in this publication are presented in seven tables. The first two tables contain summary data by type of operation and type of service for carrier groups and individual air carriers and summary figures by area, State, and Country. Tables 3, 4, and 5 show activity in air carrier system operations at large, medium, and small air traffic hubs. The last two tables in the publication present detailed statistics by community and airport. In addition, the last table has a presentation of total aircraft departures performed by specific aircraft type. In this table, an asterisk printed to the left of the aircraft designation denotes that the statistics shown relate to all-cargo service.

In Tables 6 and 7, each community is listed under the State in which it is located without regard to the location of the airport. Cincinnati, Ohio, for example, is shown under Ohio although the Greater Cincinnati Airport is located at Covington, Kentucky. An exception to this policy occurs in those cases where a hyphenated point shown in a Certificate of Public Convenience and Necessity is served by a single airport and a State line separates the communities named. In those cases the data are listed under the State in which the airport serving the communities is located. For example, Quincy, Illinois-Hannibal, Missouri, is a hyphenated point. Since the airport is located in Quincy, Illinois, the data for both communities are shown under that city and State. In this publication, some community groupings have been made in accordance with the Federal Aviation Administration's concept of the air traffic hub structure. In this regard, single certificated points or hyphenated points that are in Standard Metropolitan Statistical Areas (SMSA) are listed under the SMSA regardless of the way the CAB Certificate is written or of the location of the airport. (See AIR TRAFFIC HUBS).

To facilitate the location of hyphenated and combined points, there is a list at the end of this section (page vii) which cross-references the cities so certificated.

CRITERIA FOR INCLUSION OF DATA

Data are included for only those online airports reported on Schedule T-3 at which aircraft departures were performed in scheduled service. Data for airports that are offline for the reporting carrier are excluded. These criteria of inclusion or exclusion are applied individually to each of the four quarterly reports comprising the source of these data.

AIR TRAFFIC HUBS

The air traffic hub structure was developed by the Federal Aviation Administration and is used to measure the concentration of all civil air traffic. The hub structure is FAA's principal operations control and the fundamental control for most of the FAA's economic and operations research procedures. Within this one medium are consolidated the social and economic factors that influence a community's ability to generate air carrier or general aviation traffic.

Air traffic hubs are not airports; they are the cities and Standard Metropolitan Statistical Areas requiring aviation services. A SMSA is a county that contains at least one city of 50,000 population, or twin cities with a combined population of at least 50,000, plus any contiguous counties that are metropolitan in character and have similar economic and social relationships. These metropolitan areas constitute a primary focal point for the transportation research program of the FAA, and the analyses of individual cities within an area are treated in relationship to the entire area. In those instances where two or more individually certificated communities are located in a SMSA, those communities are grouped under the SMSA definition in Table 6 and in the air traffic hub tables (3, 4, and 5).

Individual communities fall into four hub classifications as determined by each community's percentage of the total enplaned revenue passengers in all services and all operations of U.S. certificated route air carriers within the 50 States, the District of Columbia, and other U.S. areas designated by the Federal Aviation Administration. Table 6 contains the type of hub for each community: "L" (large), "M" (medium), "S" (small), and "N" (nonhub). Classifications in this issue are based on 160,063,182 total enplaned revenue passengers.

The percentage and number of enplaned passengers in the hub classifications for fiscal year 1971 are:

Hub classification	*Percent of total enplaned passengers*	*Number of enplaned passengers*
Large (L)	1.00 or more	1,600,632 or more
Medium (M)	0.25 to 0.99	400,158 to 1,600,631
Small (S)	0.05 to 0.24	80,032 to 400,157
Nonhub (N)	less than 0.05	Less than 80,031

The geographic locations of the air traffic hubs are shown in the map on page iv and the airport activity of the hubs is summarized in Tables 3, 4, and 5.

The hub tables show that for the 12-month period ended June 30, 1971, there were 151 air traffic hubs. These hubs represented 19 percent of the 798 certificated points in the 50 States, the District of Columbia, and other U.S. areas receiving air carrier service during the period. The dominance of the hubs in the air traffic patterns is brought out by the fact that of the 160,063,182 passenger enplanements during the period, 96.3 percent (154,185,863) were recorded at the 151 hubs, while the nonhubs accounted for only 3.7 percent (5,877,319). Of the 96.3 percent of the passenger enplanements recorded at the hubs, the 24 large hubs accounted for 70.3 percent, the 37 medium hubs accounted for 19 percent, and the small hubs 10.7 percent.

TABLE 3.

AIRCRAFT DEPARTURES, ENPLANED REVENUE PASSENGERS, AND ENPLANED REVENUE TONS OF CARGO AND MAIL IN TOTAL OPERATIONS, ALL SERVICES AT LARGE AIR TRAFFIC HUBS

12 MONTHS ENDED JUNE 30, 1971

Community (Airport Name) Percent of Enplanements	Aircraft departures: Total performed	Aircraft departures: Scheduled	Aircraft departures: Scheduled completed	Enplaned passengers	Enplaned revenue tons: Freight	Enplaned revenue tons: Express	Enplaned revenue tons: US Mail: Priority	Enplaned revenue tons: US Mail: Nonpriority	Enplaned revenue tons: Foreign mail
1	2	3	4	5	6	7	8	9	10
ATLANTA, GEORGIA (WILLIAM B HARTSFIELD INT'L) 5.23	174477	175403	171077	4377166	89887.20	10553.82	34912.09	22124.51	.17
BOSTON, MASSACHUSETTS (LOGAN INTL AIRPORT) 2.69	93511	91753	88251	4319274	62248.17	3798.06	9091.73	7529.39	.15
CHICAGO, ILLINOIS (MIDWAY) 0.30	25439	23076	22191	495455	1936.55	35.98	590.56	4172.54	
(MEIGS FIELD) 0.00	1991	1615	1094	1329					
(O'HARE INTERNATIONAL) 8.24	268290	267561	260982	13200771	250245.33	22145.54	51056.26	39341.67	1.57
COMMUNITY TOTAL 8.54	295720	291752	284267	13697555	252181.88	22179.52	57646.82	43514.21	1.57
CLEVELAND, OHIO (HOPKINS INTERNATIONAL APT) 1.47	56164	56131	55353	2359298	41197.42	4038.62	4377.82	7182.01	
(BURKE LAKEFRONT AIRPORT) 0.00	99	108	99	275					
COMMUNITY TOTAL 1.47	56263	56239	55452	2359573	41197.42	4038.62	4377.82	7182.01	
DALLAS/FT. WORTH, TEXAS (GREATER SOUTHWEST INTL.) 0.00	1								
(LOVE FIELD) 3.24	124662	125485	122551	5192629	56908.55	5191.63	19094.86	16277.08	14.53
COMMUNITY TOTAL 3.24	124663	125485	122551	5192629	56908.55	5191.63	19094.86	16277.08	14.53
DENVER, COLORADO (STAPLETON INTERNATIONAL) 2.34	84535	86157	83978	3768521	55512.05	4638.03	7592.55	8585.84	.52
DETROIT/ANN ARBOR, MICHIGAN (DETROIT CITY AIRPORT) 0.00	99	108	99	292	.03				
(DETROIT METROPOLITAN WAYNE CTY) 2.14	80487	80182	78453	3425552	65019.47	7175.18	9730.23	10176.81	.01
(WILLOW RUN AIRPORT) 0.00	223	261	112		1416.24	42.69		1.73	
COMMUNITY TOTAL 2.14	80809	80551	78661	3425844	66435.70	7217.87	9730.23	10178.54	.01
HONOLULU, OAHU, HAWAII (HICKAM AFB) 0.00	104	104	104	3837	201.02		107.28	.17	
(HONOLULU INTERNATIONAL) 1.64	46712	41728	39798	2692868	31829.40	26.25	10016.16	15862.38	68.44
COMMUNITY TOTAL 1.64	46816	41832	39902	2696705	32030.42	26.25	10123.44	15942.55	68.44
HOUSTON, TEXAS (HOUSTON INTERCONTINENTAL) 1.37	64155	65105	62835	2202577	21786.19	1579.12	5757.32	4695.44	8.93
(WILLIAM P HOBBY) 0.07	2839	2844	2626	115147	551.02	96.79	136.01	160.75	
COMMUNITY TOTAL 1.44	66994	68149	65461	2317724	22337.21	1676.11	5893.33	4856.19	8.93
KANSAS CITY, MISSOURI (INTERNATIONAL AIRPORT) 0.00	229	48	46	2859	3.70	1.50	8.24	2.26	
(KANSAS CITY MUNI) 1.23	55628	56156	53842	1975503	20224.03	3123.36	6874.22	6720.71	.81
COMMUNITY TOTAL 1.23	55857	56204	53888	1978362	20227.73	3124.86	6882.46	6722.97	.81
LAS VEGAS, NEVADA (MC CARRAN INTL) 1.14	43131	42362	40174	1834453	1530.01	128.71	391.73	841.65	
LOS ANGELES/BURBANK/LNG.BCH.,CAL (HOLLYWOOD-BURBANK AIRPORT) 0.05	* 3865	3920	3689	84207	443.49	.47	.15	.04	
(LONG BEACH AIRPORT) 0.02	1218	1194	1175	37672	77.91	.14	.09	.02	
(LOS ANGELES INTERNATIONAL) 4.92	157200	158099	152436	7882277	194414.46	9779.00	28226.33	25143.82	5.33
(ORANGE COUNTY AIRPORT) 0.06	2849	2730	2377	105494	209.24	1.77	.14		
(VAN NUYS AIRPORT) 0.00	1			24					
COMMUNITY TOTAL 5.05	164931	165337	159676	8109674	195144.10	5781.35	28226.71	25143.88	5.33
MIAMI/FT LAUDERDALE,FLORIDA (FT. LAUDERDALE-HOLLYWOOD INTL) 0.54	21858	21675	21290	876314	1595.49	222.98	274.25	389.25	
(MIAMI INTERNATIONAL) 2.84	95217	93428	91534	4549721	84103.12	2059.66	9046.78	6183.06	184.00
COMMUNITY TOTAL 3.38	117075	115103	112824	5426035	86099.11	2282.64	9321.03	6572.31	184.00
MINNEAPOLIS/ST. PAUL,MINNESOTA (MINNEAPOLIS-ST PAUL INTL) 1.51	53171	51659	50915	2423935	26269.56	3307.56	6645.32	9064.09	.10

TABLE 3
AIRCRAFT DEPARTURES, ENPLANED REVENUE PASSENGERS AND ENPLANED REVENUE TONS OF CARGO AND MAIL IN TOTAL OPERATIONS, ALL SERVICES AT LARGE AIR TRAFFIC HUBS
12 MONTHS ENDED JUNE 30, 1975

Community (Airport Name) Percent of Enplanements	Aircraft departures			Enplaned passengers	Enplaned revenue tons				
	Total performed	Scheduled	Scheduled completed		Freight	Express	U.S. Mail		Foreign mail
							Priority	Nonpriority	
1	2	3	4	5	6	7	8	9	10
NEWARK, NEW JERSEY (NEWARK AIRPORT) 1.92	81532	81263	78239	5084559	65693.12	4236.26	11270.42	11526.96	.20
NEW ORLEANS, LOUISIANA (NEW ORLEANS INTL/MOISANT FLD/) 1.14	53416	54286	52590	1966067	16776.70	1611.53	3325.11	2617.08	.02
NEW YORK, NEW YORK (JOHN F KENNEDY INTL) 6.18	122047	125615	120675	6703119	268915.76	7403.24	46739.06	41837.45	37.60
(LA GUARDIA) 3.96	138946	137441	131841	6321565	19260.71	2250.15	4502.66	7547.57	
(WALL STREET HELIPORT) 0.00	508	588	505	1957	.19				
COMMUNITY TOTAL 8.12	266501	264144	253021	13026641	288176.66	9653.39	51241.72	49385.02	37.60
PHILADELPHIA, PA/CAMDEN, NJ (INTERNATIONAL AIRPORT) 1.98	79089	80255	77973	3175766	51219.75	3730.72	6675.50	16865.93	
PITTSBURGH, PENNSYLVANIA (ALLEGHENY COUNTY APT.) 0.00	1								
(GREATER PITTSBURGH) 1.65	85309	86177	84566	2961182	22709.97	4338.38	4839.83	6782.48	
COMMUNITY TOTAL 1.65	85310	86177	84566	2961182	22709.97	4338.38	4839.83	6782.48	
ST. LOUIS, MISSOURI (LAMBERT-ST LOUIS MUNI) 1.91	86276	86528	84151	3057391	27280.20	3953.92	8810.01	9542.66	
SAN FRANCISCO/OAKLAND, CAL. (BERKELEY MUNICIPAL HELIPORT) 0.00	3357	3519	3157	12425	.45	2.99	112.26		
(MARIN COUNTY HELIPORT) 0.01	3577	3480	3577	16288	3.37	29.86	8.49		
(OAKLAND METROPOLITAN INTL) 0.17	16212	16100	15537	279578	888.58	405.13	137.61	249.29	
(SAN FRANCISCO INTL) 3.28	119793	120495	116436	5257538	169792.30	3653.55	32653.77	51856.27	7.08
COMMUNITY TOTAL 3.46	142959	143594	138905	5565829	170685.66	4091.61	32911.63	52105.56	7.08
SAN JUAN, PUERTO RICO (PUERTO RICO INTERNATIONAL) 1.06	23111	22719	22051	1709661	28800.31	52.90	1960.14	199.83	11.66
SEATTLE/TACOMA, WASHINGTON (BOEING FIELD INTL.) 0.08	4282	4253	4117	137362	691.75	86.18	224.03	73.47	
(SEATTLE-TACOMA INTERNATIONAL) 1.45	46318	45670	44576	2312273	45956.03	965.68	13552.98	16973.66	14.86
(TACOMA INDUSTRIAL) 0.00	482	526	481	167	.51				
COMMUNITY TOTAL 1.53	51082	50449	49176	2449802	46648.29	1049.86	13776.52	17047.13	14.86
WASHINGTON, DIST. OF COL. (DULLES INTERNATIONAL) 0.56	28822	28779	28143	900970	9056.00	320.07	4355.13	5287.02	.42
(WASHINGTON NATIONAL) 2.95	105401	104160	101509	4730004	18537.05	4769.02	9999.56	10843.59	
COMMUNITY TOTAL 3.51	134223	132939	129652	5630974	27593.05	5089.09	14354.69	16130.61	.42
OVER-ALL TOTAL, LARGE HUBS 67.58	2462050	2453494	2377566	104961740	1731580.36	109582.33	363095.78	364266.54	356.36

TABLE 4

AIRCRAFT DEPARTURES, ENPLANED REVENUE PASSENGERS AND ENPLANED REVENUE TONS OF CARGO AND MAIL IN TOTAL OPERATIONS, ALL SERVICES AT MEDIUM AIR TRAFFIC HUBS

12 MONTHS ENDED JUNE 30, 1971

Community (Airport Name) Percent of Enplanements	Aircraft departures: Total performed	Aircraft departures: Scheduled	Aircraft departures: Scheduled completed	Enplaned passengers	Enplaned revenue tons: Freight	Enplaned revenue tons: Express	U.S. Mail: Priority	U.S. Mail: Nonpriority	Foreign mail
1	2	3	4	5	6	7	8	9	10
ALBANY, NEW YORK (ALBANY COUNTY) 0.26	13151	13149	12944	416848	1310.87	501.95	725.56	901.66	
ALBUQUERQUE, NEW MEXICO (ALBUQUERQUE SUNPORT/KIRTLAND AFB) 0.37	22218	22397	21828	593463	2140.21	428.66	936.84	1126.35	
BALTIMORE, MARYLAND (FRIENDSHIP INTERNATIONAL) 0.77	47686	48261	46965	1555862	17355.54	1304.08	5500.91	3501.37	1.88
BIRMINGHAM, ALABAMA (BIRMINGHAM MUNI) 0.30	20026	20057	19697	492745	2559.41	257.14	1176.57	1609.80	
BUFFALO/NIAGARA FALLS, NEW YORK (GREATER BUFFALO INTERNATIONAL) 0.65	27656	27720	27048	1034178	12571.29	1449.57	2171.98	1445.68	
CHARLOTTE, NORTH CAROLINA (DOUGLAS MUNI) 0.52	30318	30131	29965	838830	19041.15	496.18	2948.82	1332.97	
CINCINNATI, OHIO (GREATER CINCINNATI) 0.76	45612	46248	45036	1221556	17171.26	2066.27	3465.05	2780.52	
COLUMBUS, OHIO (PORT COLUMBUS INTERNATIONAL) 0.53	24802	24987	24192	851063	5140.22	1537.13	2417.61	2553.86	
DAYTON, OHIO (JAMES M COX DAYTON MUNI) 0.42	28205	28140	27626	674958	12095.27	1342.01	1850.38	2178.12	
DES MOINES, IOWA (DES MOINES MUNI) 0.25	13356	13491	13161	403413	2420.95	374.24	717.85	1687.19	
EL PASO, TEXAS (EL PASO INTERNATIONAL) 0.29	16519	16781	16381	473728	3065.45	194.80	739.39	613.96	
GREENSBORO/HIGH PT/WINSTN-SALEM, N.C. (GREENSBORO-HIGH PT-WINSTN REG.) 0.24	15965	16156	15522	369420	6488.36	461.72	1044.45	929.89	
(SMITH-REYNOLDS AIRPORT) 0.02	5540	5475	5087	45642	325.92	19.25	54.15	6.74	
COMMUNITY TOTAL 0.26	21511	21631	20609	415102	6814.28	500.97	1098.60	932.61	
HARTFORD/SPRINGFLD/WESTFLD, CONN (BRADLEY INTL) 0.56	28125	28424	27405	870365	17232.13	1054.75	3177.75	2690.91	
HILO, HAWAII, HAWAII (GENERAL LYMAN FIELD) 0.28	9289	8834	8512	460597	8777.64	.22	255.19	422.45	
INDIANAPOLIS, INDIANA (INDIANAPOLIS MUNI/WEIR-COOK) 0.63	37750	38191	37361	1013570	16717.22	2259.10	3083.93	4217.27	
JACKSONVILLE, FLORIDA (JACKSONVILLE INTERNATIONAL) 0.42	20068	20186	19735	671382	2843.16	431.05	2532.86	1708.41	
KAHULUI, MAUI, HAWAII (KAHULUI) 0.36	16048	15324	14602	574644	1688.85		313.24	472.49	
LIHUE, KAUAI, HAWAII (LIHUE) 0.35	8562	7559	7297	537503	601.33		90.76	262.08	
LOUISVILLE, KENTUCKY (STANDIFORD FIELD) 0.55	32210	32102	31550	866492	6656.87	1321.55	1779.26	2337.41	
MEMPHIS, TENNESSEE (MEMPHIS INTERNATIONAL) 0.90	51442	51991	50441	1441571	19885.53	7256.13	4645.73	3952.07	
MILWAUKEE, WISCONSIN (GENERAL MITCHELL FIELD) 0.55	34369	34686	33299	895470	10602.87	1474.89	1588.16	2961.14	
NASHVILLE, TENNESSEE (NASHVILLE METRO) 0.40	25230	25161	25022	641108	7867.01	1008.48	1623.56	1655.78	
NORFOLK/VA BCH/PORTSMOUTH, VA. (NORFOLK REGIONAL APT.) 0.37	19420	19706	19301	604366	2376.85	204.63	1607.58	846.96	
OKLAHOMA CITY, OKLAHOMA (WILL ROGERS WORLD) 0.40	23023	23444	22644	616463	3327.50	545.15	1964.83	2151.17	
OMAHA, NEBRASKA (EPPLEY AIRFIELD) 0.42	21118	21379	20805	675190	5422.32	861.69	1542.94	2261.96	
ORLANDO, FLORIDA (MCCOY AFB) 0.33	21737	21776	21501	531690	4532.17	202.86	851.60	2471.00	
PHOENIX, ARIZONA (PHOENIX SKY HARBOR INTL) 0.93	37165	37246	35913	1476310	7477.73	728.92	1709.57	2506.68	

TABLE 4

AIRCRAFT DEPARTURES, ENPLANED REVENUE PASSENGERS, AND ENPLANED REVENUE TONS OF CARGO AND MAIL IN TOTAL OPERATIONS, ALL SERVICES AT MEDIUM AIR TRAFFIC HUBS

12 MONTHS ENDED JUNE 30, 1971

Community (Airport Name) Percent of Enplanements	Aircraft departures			Enplaned passengers	Enplaned revenue tons				
	Total performed	Scheduled	Scheduled completed		Freight	Express	U.S. Mail		Foreign mail
							Priority	Nonpriority	
1	2	3	4	5	6	7	8	9	10
PORTLAND, OREGON (PORTLAND INTERNATIONAL) 0.76	39251	19708	[illegible]	1222366	11560.30	591.65	[illegible]	2651.01	.51
RALEIGH/DURHAM, NORTH CAROLINA (RALEIGH-DURHAM) 0.31	16673	16652	16036	500941	3561.57	286.70	[illegible]	1742.76	
ROCHESTER, NEW YORK (ROCHESTER-MONROE COUNTY) 0.40	20063	20205	19690	653262	[illegible]	1019.93	[illegible]	[illegible]	
SALT LAKE CITY, UTAH (SALT LAKE CITY INTL) 0.66	28613	28666	27769	1069721	7165.29	505.60	6000.55	1967.60	
SAN ANTONIO, TEXAS (SAN ANTONIO INTERNATIONAL) 0.52	25686	25508	24965	813511	6919.30	362.38	2775.55	1916.86	5.99
SAN DIEGO, CALIFORNIA (SAN DIEGO INTNL-LINDBERGH FLD) 0.60	21101	21363	20633	969960	6860.75	165.55	1665.93	1361.66	
SYRACUSE, NEW YORK (CLARENCE E HANCOCK) 0.40	18063	17782	17239	612963	6650.65	696.73	965.26	1151.05	
TAMPA/ST. PETERSBURG/CLEARWATER, FLA (TAMPA INTERNATIONAL) 0.95	61592	61789	61000	1523552	11367.72	476.87	1705.52	3100.59	.11
TUCSON, ARIZONA (TUCSON INTL) 0.28	14315	14655	13896	440680	1716.36	170.20	502.86	581.30	
TULSA, OKLAHOMA (TULSA INTL) 0.31	21032	21135	20690	507536	3138.07	402.76	734.68	2616.15	
OVER-ALL TOTAL, MEDIUM HUBS 18.15	969776	954581	928807	29298730	278214.78	28136.58	67904.98	74823.13	8.75

TABLE 5
AIRCRAFT DEPARTURES, ENPLANED REVENUE PASSENGERS, AND ENPLANED REVENUE TONS OF CARGO AND MAIL IN TOTAL OPERATIONS, ALL SERVICES AT SMALL AIR TRAFFIC HUBS

12 MONTHS ENDED JUNE 30, 1974

Community (Airport Name) Percent of Enplanements	Aircraft departures: Total performed	Aircraft departures: Scheduled	Aircraft departures: Scheduled completed	* Enplaned passengers	Enplaned revenue tons: Freight	Enplaned revenue tons: Express	U.S. Mail: Priority	U.S. Mail: Nonpriority	Foreign mail
1	2	3	4	5	6	7	8	9	10
AKRON/CANTON, OHIO (AKRON-CANTON) 0.10	7219	7301	7148	169247	1369.42	485.56	772.41	8.18	
ALLENTOWN/BETHLEHEM/EASTON, PA (ALLENTOWN-BETHLEHEM-EASTON) 0.08	6183	6269	6141	135789	299.13	91.25	198.17	31.52	
AMARILLO, TEXAS (AMARILLO AIR TERMINAL) 0.10	6976	7029	6746	160667	596.61	66.72	217.70	214.86	
ANCHORAGE, ALASKA (ANCHORAGE INTERNATIONAL) 0.24	12448	10712	10192	349173	15970.10	26.26	8144.06	2780.75	.10
(ELMENDORF AFB) 0.00	2								
COMMUNITY TOTAL 0.24	12450	10712	10192	349173	15970.10	26.26	8144.06	2780.75	.10
ASHEVILLE, NORTH CAROLINA (ASHEVILLE MUNI) 0.07	7725	8037	7671	120610	854.33	101.16	230.50	133.70	
ASHLAND, KY./HUNTINGTON, W.VA. (TRI-STATE /WALKER-LONG FIELD/) 0.05	8127	8122	8031	80956	312.20	99.79	119.43	71.55	
AUGUSTA, GEORGIA (BUSH FIELD) 0.11	10201	10310	10072	164715	441.20	67.07	287.18	330.18	
AUSTIN, TEXAS (ROBERT MUELLER MUNI) 0.16	11115	11155	10873	265233	752.37	185.51	699.98	376.74	.02
BANGOR, MAINE (BANGOR INTERNATIONAL) 0.05	2678	2692	2606	85993	337.66	101.61	109.36	212.96	
BATON ROUGE, LOUISIANA (RYAN) 0.07	8651	8695	8566	119586	528.09	54.17	286.10	33.26	
BILLINGS, MONTANA (LOGAN FIELD) 0.10	8766	8744	8673	172693	545.36	92.76	309.81	406.70	
BOISE, IDAHO (BOISE AIR TERMINAL /GOWEN FLD/) 0.14	9593	9638	9475	248886	574.72	96.94	277.66	601.86	
BRISTOL/KINGSPRT/JOHNSON CITY, TENN (TRI CITY) 0.10	11068	11220	10745	162023	497.66	202.22	231.37	130.09	
CEDAR RAPIDS/IOWA CITY, IOWA (CEDAR RAPIDS MUNI) 0.09	6731	6790	6669	157066	1632.16	231.77	338.03	50.28	
CHAMPAIGN/URBANA, ILLINOIS (UNIVERSITY OF ILLINOIS-WILLARD) 0.05	6106	6205	5993	92228	230.64	48.41	188.69	30.97	
CHARLESTON, SOUTH CAROLINA (CHARLESTON AFB/MUNI) 0.17	10515	10616	10150	277168	980.90	85.77	396.22	348.06	
CHARLESTON/DUNBAR, W. VIRGINIA (KANAWHA) 0.13	10676	11010	10611	208321	641.69	146.85	242.16	337.57	
CHARLOTTE AMALIE, VIRGIN IS.,US (HARRY S.TRUMAN) 0.14	6600	6614	6177	217526	785.86		103.03	6.29	
CHATTANOOGA, TENNESSEE (LOVELL FIELD) 0.12	10061	10173	9930	198893	1383.66	249.39	602.68	520.91	
CHRISTIANSTED, ST.CROIX, V.I., US (ALEXANDER HAMILTON) 0.07	4971	4992	4812	116528	362.97		48.38	.31	.03
COLORADO SPRINGS, COLORADO (PETERSON FIELD) 0.13	9561	9775	9421	210632	765.76	129.07	246.23	226.43	
COLUMBIA, SOUTH CAROLINA (COLUMBIA METROPOLITAN) 0.18	12909	12938	12668	294908	1163.34	157.86	423.80	617.40	
COLUMBUS, GEORGIA (COLUMBUS METROPOLITAN) 0.09	9304	9633	9180	155525	727.62	40.94	276.77	241.41	
CORPUS CHRISTI, TEXAS (CORPUS CHRISTI INTERNATIONAL) 0.10	8154	8301	8095	161941	443.96	49.61	920.08	89.51	.10
DAYTONA BEACH, FLORIDA (DAYTONA BEACH REGIONAL) 0.06	4656	4716	4600	137667	398.23	44.85	10.61	1.66	
DULUTH, MINN./SUPERIOR, WIS. (DULUTH INTERNATIONAL) 0.06	6157	6229	6085	106606	638.52	113.90	133.73	177.35	
ERIE, PENNSYLVANIA (ERIE INTL) 0.06	6859	7166	6699	111873	1061.65	235.06	209.69	132.59	

TABLE 5

AIRCRAFT DEPARTURES, ENPLANED REVENUE PASSENGERS AND ENPLANED REVENUE TONS OF CARGO AND MAIL IN TOTAL OPERATIONS, ALL SERVICES AT SMALL AIR TRAFFIC HUBS

12 MONTHS ENDED JUNE 30, 1971

Community (Airport Name) Percent of Enplanements	Aircraft departures: Total performed	Aircraft departures: Scheduled	Aircraft departures: Scheduled performed	Enplaned passengers	Enplaned revenue tons: Freight	Express	U.S. Mail: Priority	U.S. Mail: Nonpriority	Foreign mail
1	2	3	4	5	6	7	8	9	10
EUGENE, OREGON (MAHLON SWEET FIELD) 0.05	4067	4177	3976	91457	460.31	45.66	91.47	102.41	
EVANSVILLE, INDIANA (EVANSVILLE DRESS REGIONAL) 0.13	5723	5771	5645	161900	1145.65	310.25	191.40	26.65	
FAIRBANKS, ALASKA (EIELSON AFB) 0.00	1								
(FAIRBANKS INTERNATIONAL) 0.09	7439	6449	6351	154561	18564.59	5.12	2317.55	1410.86	8.34
COMMUNITY TOTAL 0.09	7440	6449	6351	154562	18564.59	5.12	2317.55	1410.86	8.34
FARGO, N.D./MOORHEAD, MINNESOTA (HECTOR FIELD) 0.05	3617	3606	3362	82601	213.66	79.46	104.83	358.98	
FAYETTEVILLE, NORTH CAROLINA (FAYETTEVILLE MUNI/GRANNIS FLD) 0.07	7960	8122	7666	120376	479.33	35.71	246.79	11.46	
FORT MYERS, FLORIDA (PAGE FIELD) 0.05	3359	3483	3361	82941	547.68	21.50	69.01	.74	
FORT WAYNE, INDIANA (FORT WAYNE MUNI/BAER FLD) 0.09	5115	5163	5042	154181	1912.66	532.39	362.20	3.05	
FRESNO, CALIFORNIA (FRESNO AIR TERMINAL) 0.13	6642	6615	6360	223071	1043.17	72.15	149.94	17.53	
GRAND JUNCTION, COLORADO (WALKER FIELD) 0.03	4250	4372	4038	90166	164.47	32.14	58.67	4.80	
GRAND RAPIDS, MICHIGAN (KENT COUNTY) 0.14	11665	11616	11557	227115	1651.02	656.40	434.14	60.61	
GREAT FALLS, MONTANA (GREAT FALLS INTERNATIONAL) 0.07	6116	6153	5900	126081	449.54	59.32	136.19	253.87	
GREEN BAY/CLINTONVILLE, WIS. (AUSTIN-STRAUBEL FIELD) 0.13	10649	10539	10359	212394	1076.47	260.21	288.80	172.85	
GREENVILLE/SPARTANBURG, S.C. (GREENVILLE-SPARTANBURG) 0.10	7176	7362	7349	171180	501.85	176.13	626.46	124.17	
GUAM ISLAND (AGANA) 0.07	3447	3611	3754	122576	7046.32		804.52	545.24	1.62
HARRISBURG/YORK, PA. (OLMSTED STATE) 0.13	8125	8224	6961	212690	868.98	304.10	1295.33	484.80	
HUNTSVILLE/DECATUR, ALABAMA (MADISON COUNTY JETPORT) 0.13	6598	6365	6106	213256	1619.76	180.39	496.88	51.67	
INDIO/PALM SPRINGS, CALIFORNIA (PALM SPRINGS MUNI) 0.07	4791	5012	4960	112922	165.41	26.86	12.33	5.83	
JACKSON-VICKSBURG, MISS. (ALLEN C THOMPSON FIELD) 0.16	14603	14764	14460	270029	1638.23	164.95	532.76	634.12	
(VICKSBURG MUNI) 0.00	126	159	126	151	7.00	.49			
COMMUNITY TOTAL 0.16	14729	14923	14586	270180	1645.23	165.44	532.76	634.12	
JUNEAU, ALASKA (JUNEAU MUNI) 0.05	6297	5935	4078	86219	711.50	2.14	780.19	57.17	
KAILUA, KONA, HAWAII (KE-AHOLE AIRPORT) 0.11	6891	6527	6515	186433	545.67		38.36	109.41	
KALAMAZOO-BATTLE CREEK, MICH. (KALAMAZOO MUNI) 0.04	3813	3942	3600	65726	341.17	235.33	198.61		
(W K KELLOGG REGIONAL AIRFIELD) 0.01	2821	2661	2796	25611	58.20	11.43	251.11	.01	
COMMUNITY TOTAL 0.05	6634	6603	6396	91337	399.37	246.76	449.72	.01	
KNOXVILLE, TENNESSEE (MC GHEE TYSON) 0.21	17209	17281	16695	341756	2165.40	316.85	507.36	660.96	
LANSING, MICHIGAN (CAPITAL CITY) 0.07	6698	6519	6192	111226	266.62	271.32	221.16	16.02	
LEXINGTON/FRANKFORT, KENTUCKY (BLUE GRASS) 0.08	7837	7956	7562	140695	863.06	185.48	566.36	3.87	

TABLE 5.
AIRCRAFT DEPARTURES, ENPLANED REVENUE PASSENGERS, AND ENPLANED REVENUE TONS OF CARGO AND MAIL IN TOTAL OPERATIONS, ALL SERVICES AT SMALL AIR TRAFFIC HUBS

12 MONTHS ENDED JUNE 30, 1971

Community (Airport Name) Percent of Enplanements	Aircraft departures: Total performed	Scheduled	Scheduled completed	Enplaned passengers	Enplaned revenue tons: Freight	Express	U.S. Mail: Priority	Nonpriority	Foreign mail
1	2	3	4	5	6	7	8	9	10
LINCOLN, NEBRASKA (LINCOLN MUNI) 0.06	4666	4475	4769	111134	569.70	111.51	99.13	92.86	
LITTLE ROCK, ARKANSAS (ADAMS FIELD) 0.19	13675	14229	13732	307257	1963.91	237.83	473.08	910.64	
LUBBOCK, TEXAS (LUBBOCK REGIONAL) 0.11	10550	10621	10416	180519	376.46	59.60	211.55	65.90	
MADISON, WISCONSIN (TRUAX FIELD) 0.12	10001	10300	9751	193442	1617.56	717.19	487.17	198.46	
MELBOURNE, FLORIDA (CAPE KENNEDY REGIONAL) 0.06	4490	4519	4451	107714	405.46	20.17	199.05	224.61	
MIDLAND/ODESSA, TEXAS (MIDLAND-ODESSA REGIONAL) 0.10	10658	10751	10572	168752	571.29	33.50	198.61	66.66	
MOBILE, ALABAMA (BATES FIELD) 0.13	9185	9529	9106	208928	473.63	83.79	198.52	163.69	
MOLINE, ILLINOIS/DAVENPORT, IOWA (QUAD-CITY) 0.12	8602	8603	8491	193648	1068.06	158.35	465.85	76.66	
MONTGOMERY, ALABAMA (DANNELLY FIELD) 0.09	8025	8076	7940	149891	550.11	153.31	238.35	271.96	
NEWPORT NEWS/HAMPTON, VIRGINIA (PATRICK HENRY) 0.11	9618	9649	9563	186615	621.36	61.28	281.79	398.56	
ONTARIO/SAN BERNARDINO, CAL. (ONTARIO INTERNATIONAL) 0.14	8838	8795	8685	232370	575.82	21.23	11.99	19.27	
PENSACOLA, FLORIDA (PENSACOLA MUNI/HAGLER) 0.10	5619	5607	5457	168225	667.66	55.11	610.05	283.05	
PEORIA, ILLINOIS (GREATER PEORIA) 0.06	6769	8619	8595	160195	873.66	176.93	368.96	43.00	
PORTLAND, MAINE (PORTLAND INTERNATIONAL JETPORT) 0.06	3914	3760	3890	110510	560.53	131.46	258.11	63.18	
PROVIDENCE, RHODE ISLAND (THEODORE FRANCIS GREEN STATE) 0.24	14418	14679	14309	390021	2765.10	617.92	1210.28	708.96	
RAPID CITY, SOUTH DAKOTA (RAPID CITY REGIONAL) 0.05	5599	5756	5419	94511	329.45	32.73	110.40	169.27	
RENO, NEVADA (RENO INTL) 0.23	9936	9686	9550	375345	850.33	116.68	299.56	240.26	
RICHMOND, VIRGINIA (RICHARD E BYRD FLYING FIELD) 0.22	14009	14113	13941	353686	1626.60	265.70	873.90	548.70	
ROANOKE, VIRGINIA (ROANOKE MUNI) 0.16	15390	15340	14858	263669	1934.01	299.82	398.42	239.36	
ROCHESTER, MINNESOTA (ROCHESTER MUNI) 0.06	6298	5762	5576	100670	192.59	72.77	150.16	4.51	
SACRAMENTO, CALIFORNIA (EXECUTIVE AIRPORT) 0.00	7	1		177					
(SACRAMENTO METROPOLITAN) 0.24	11013	11204	10696	387619	967.31	96.71	610.18	510.61	
COMMUNITY TOTAL 0.24	11020	11205	10696	387796	967.31	96.71	610.18	510.51	
SAGINAW/BAY CITY/MIDLAND, MICH. (TRI CITY) 0.06	6661	6706	6627	139827	676.22	169.96	251.36	32.08	
SALINAS/MONTEREY, CALIFORNIA (PENINSULA AIRPORT) 0.12	4530	4507	4391	193962	556.13	40.76	53.61	12.09	
SAN JOSE, CALIFORNIA (PALO ALTO MUNICIPAL) 0.00	531	420	331	572	.09				
(SAN JOSE MUNI) 0.09	6055	6016	5765	152122	1112.03	166.91	16.65	1.85	
(SUNNYVALE HELIPORT) 0.00	357	381	357	2694	.20	13.36			
COMMUNITY TOTAL 0.09	6743	6419	6473	155388	1112.32	182.29	16.65	1.85	
SANTA BARBARA, CALIFORNIA (SANTA BARBARA AIRPORT) 0.07	3228	3290	3166	114152	362.19	59.19	3.06	3.50	

TABLE 5
AIRCRAFT DEPARTURES, ENPLANED REVENUE PASSENGERS, AND ENPLANED REVENUE TONS OF CARGO AND MAIL IN TOTAL OPERATIONS, ALL SERVICES AT SMALL AIR TRAFFIC HUBS

12 MONTHS ENDED JUNE 30, 1971

Community (Airport Name) Percent of Enplanements	Aircraft departures: Total performed	Scheduled	Scheduled completed	Enplaned passengers	Enplaned revenue tons: Freight	Express	U.S. Mail: Priority	Nonpriority	Foreign mail
1	2	3	4	5	6	7	8	9	10
(SANTA MARIA PUBLIC) 0.05	1642	1690	1639	26673	45.06	4.73	61.06		
COMMUNITY TOTAL 0.08	4470	4466	4405	160825	407.25	64.17	64.70	3.50	
SARASOTA/BRADENTON, FLORIDA (SARASOTA-BRADENTON) 0.10	6919	6122	6162	172713	520.78	26.96	126.55	3.73	
SAVANNAH, GEORGIA (SAVANNAH MUNI) 0.11	6926	6956	6326	180332	640.96	56.94	263.89	271.24	
SCRANTON/WILKES-BARRE, PENNA. (WILKES-BARRE-SCRANTON) 0.07	3895	3770	3673	113379	850.00	131.01	239.16	1.92	
SHREVEPORT, LOUISIANA (GREATER SHREVEPORT MUNI) 0.17	15965	16166	15700	284675	1657.91	179.36	644.85	767.66	
SIOUX FALLS, SOUTH DAKOTA (JOE FOSS FIELD) 0.11	12556	12754	12456	183576	570.48	148.01	269.80	789.24	
SOUTH BEND, INDIANA (ST JOSEPH COUNTY) 0.08	5981	6077	5922	139170	1642.11	126.75	346.50	1.53	
SPOKANE, WASHINGTON (SPOKANE INTERNATIONAL) 0.22	10683	10493	10298	354688	1156.47	117.65	640.50	669.89	
SPRINGFIELD, MISSOURI (SPRINGFIELD MUNI) 0.05	5672	5439	5408	95342	302.47	137.16	109.59	1.78	
TALLAHASSEE, FLORIDA (TALLAHASSEE MUNI) 0.09	5969	6165	5955	150811	191.79	75.77	161.59	186.75	
TOLEDO, OHIO (TOLEDO EXPRESS) 0.13	7762	7705	7614	211152	1092.50	471.40	438.85	11.21	
WATERLOO, IOWA (WATERLOO MUNI) 0.05	6398	6493	6266	93619	926.18	131.12	137.56	194.99	
WEST PALM BEACH/PALM BEACH, FLA (PALM BEACH INTERNATIONAL) 0.24	13910	13762	13567	371599	1116.29	177.04	357.36	516.53	
WICHITA, KANSAS (WICHITA MUNI) 0.20	12855	13075	12599	301266	1808.71	377.18	838.59	993.80	
YOUNGSTOWN, OHIO (YOUNGSTOWN MUNI) 0.08	5208	5277	5196	130365	696.22	152.41	193.18	8.35	
OVER-ALL TOTAL, SMALL HUBS 9.81	723592	730676	707335	16627391	110768.11	13526.86	39171.21	22678.68	10.72

Appendix B

POSITION ANNEX

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 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 draft reports, were solicited. For the most part, these position papers are in the form of a response to a "Position Questionnaire" distributed by the chairman at meeting number 3. The Position Questionnaire and the various Position Papers are included in this appendix.

Position Annex

Contents

POSITION QUESTIONAIRRE
Task Group 2
3/19/73

Please answer the following questions giving the reasons for your answers, modifications you would suggest, or alternative rules you would like to see proposed.

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GENERAL.

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15. To what airports should any of the above considerations apply?

ADDITIONAL QUESTIONS

16. Are there any other rules which should be considered?

17. Are there any safety or technology considerations other than those which you have already mentioned in conjunction with the above questions?

TASK GROUP ...
From Air California
Rec 4/15/73

AIR CALIFORNIA

March 29, 1973

TO: United States Environmental Protection Agency
Office of Noise Abatement and Control
Mr. Randall L. Hurlburt, Chairman

FROM: John R. Tucker
Director of Operations, Air California

SUBJECT: Response to Task Group 2 Questionnaire

RECEIVED
APR 9 1973

P.O. BOX Z, NEWPORT BEACH, CALIFORNIA 92660 / TELEPHONE (714) 540-3220
EXECUTIVE OFFICES: 4400 CAMPUS DRIVE, NEWPORT BEACH, CALIFORNIA

TAKE-OFF

Q1. Should there be operating rules to establish take-off and departure procedures? (Reworded)

Answer: It is very unlikely that an operating rule could be developed to establish a specific take-off or departure procedure because of differences between airplane types and the airport locations relative to noise senstive communities. However, certain basic concepts might be introduced in rule-form which would require a measure of standardization in the different take-off segments. Subsequent tailoring of the basic procedure would then consider the particular airport and/or other variables.

Q2. What do you think the appropriate take-off procedure should be?

Answer: Appropriate take-off procedure rules should consider the aircraft and flight crew capability in a standard format. I would envision such rules to include the following:

*a. Preferential runway program

b. Definition of take-off power

*c. A reference initial climb speed commensurate with safety for a particular aircraft, i.e. B-737 = V_2 + 15 knots.

d. The body angle should not be limited provided there is adequate stall protection and maneuvering margin.

e. Bank angle not to exceed 15 degrees below 1000 ft.

*f. A reduction of thrust to occur at a specified altitude to provide optimum noise reduction over the desired area.

g. The amount of thrust reduction not to exceed that required to produce engine-out climb performance should an engine be lost.

*h. Acceleration and flap retraction schedule must be consistant with good operation practices.

*i. Preferential ground track compatable with standard instrument departures.

*Tailored to airport or aircraft.

NOTE: The basic procedure and airport variable could be published in a format similar to Jeppesen approach plates. It should be noted that instrument approaches are not standardized (airport for airport), and therefore I see no reason why tailoring a flight procedure could not be as effective. The community benefits are obvious.

LANDING

Q3. Should there be a rule establishing minimum maneuvering altitudes prior to the commencement of approach? What should these altitutdes be?

Answer: This concept, has been standard procedure at San Jose Municipal Airport, California since mid-December 1972. There is undoubtedly merit in the "keep em high" program from a noise viewpoint, however, numerous delays have been imposed upon the airlines operating in this area as a result of traffic sequencing difficulties, incompatable operating speeds between aircraft, and inability of some aircraft to cope with steep descent angles associated with tail-wind components. These delays are "inflight" and do expose the communities under the approach course to noise over a longer period of time. Should such a rule be adopted, the minimum altitude must depend upon the selection of the type of approach used, the aircraft capability and the requirement for ATC to review and revise their standard procedures now being used at lower approach altitudes.

Q4. Should there be a rule raising ILS glide slopes immediately to 3.5 degrees?

Answer: In my opinion, a change to 3.5 degrees would be beneficial in the reduction of approach noise, and could be flown in complete safety, however it would not be acceptable to the industry if it derogated the present approach minimums for any airport. A careful study of this aspect should be undertaken to determine what, if any, changes in landing minimums would result by an increase in glide slope angle, also what effect would a 3.5 degree glideslope have on the proposed two segment final intercept.....or.....would it impose a new safety consideration for other future developments? Perhaps a more logical approach would be to "bias" the flight director as an airport variable when required.

Q5. Should operators be required to install instrumentation which would provide guidance during a two-segment approach?

Answer: I am not too sure that a two-segment approach is the ultimate answer to all airports and/or operators. Obviously whatever type of approach is finally decided upon, the operator would be required to install instrumentation suitable for the condition. Economics, of necessity, must be interjected at this point since the costs of such installation would be very high. Anti-noise procedures have been studied and developed through tremendous efforts in research and engineering and huge sums of money expended in modifications, retrofit kits, and new instrumentation. All of this effort has been made to improve the environment for the public and it is unreasonable to presume that either the airlines or airport operators can absorb these costs, individually or collectively. It therefore behoves the Environmental Protection Agency to pursue cost studies and make recommendations as to the eventual responsibility of the public in assuming the cost burdens.

Q6. Should there be operating rules requiring pilots to fly noise abatement approaches? What intercept altitude should be specified? What should be the angle of the upper segment? Should the rule initially be VFR only? When should VFR and IFR rules be effective? (Reworded)

Answer: Yes, there should be regulatory means which require a pilot to fly noise abatement approaches over noise sensitive areas. If it is determined that a two segment approach is the desired procedure, the initial intercept altitude of 5000' to 6000' AGL should be specified. This will produce adequate noise relief and also provide good flexibility of performance. The upper segment angle should be limited to 6 degrees for the same reasons. I see no reason to establish a VFR rule in the initial phase...... once the procedure is determined and airborne installations made, the flight crews would be trained in an "instrument conditions" environment. It is doubtful that a "trial VFR" period of any extent would be necessary since standardized approach techniques should be used for all approaches irrespective of VFR vs. IFR conditions.

Q7. Should there be a rule prohibiting the use of thrust reversers on dry runways unless required by Air Traffic Control or unless runway length or atmospheric conditions require their use in the interests of safety?

Answer: There should be no rule which raises the question of legality in the operation of a safety device such as thrust reversers. Such a rule would "force" the pilot to make a determination, and thereafter justify his action, on each landing made. Irrespective of the safety and justification aspect, the thrust reverser is a valuable tool in shortening runway occupancy time, thus permitting faster acceptance of aircraft on approach, etc. In view of the above, I positively reject the proposed thrust reverser rule.

GENERAL

Q8. To what aircraft should any of the rules considered above apply?

Answer: Noise Abatement rules should apply to all airplanes over 12,500 lbs. maximum gross take-off weight and additionally to all turbo-jet airplanes, when it is determined that a noise problem, in fact does exist.

AIRPORTS

Q9. Should airports be certificated for noise?

Answer: No, the question of noise certification of airports would best be handled elsewhere than in special regulations. It is presumed the Federal Air Regulations would spell-out operating rules for pilots, while other parameters would be covered by appropriate agencies. It would therefore seem that airport certification would be a duplication of effort and would increase the work-load and responsibilities of the airports.

Q10. Should airport operators be required to assure that no area is exposed to unacceptable noise as defined by task group 3? By when?

Answer: No, the airport operators should not be expected to assume the burden of assuring that no area is exposed to unacceptable noise.....there is a lack of positive standards at the present time which would make such a task impossible and the existing technology could not insure the reduction of unacceptable noise levels to that point which would preclude the "shut-down" of numerous airport operations.

Q11. Should airport operators be authorized to specify maximum single event noise levels for aircraft or procedures to be used by pilots?

Answer: No, in the case of noise levels, the State of California has established SENEL limits which have already been challenged in Federal District Court. I would prefer to rely upon the recommendations of task groups 1 and 3 in response to this part of the question. In regards to airport operators being authorized to specify procedures to be used by pilots, I cannot justify any reason to concur with this proposition. Such an authorization would be in direct opposition to the airline industry's operational "know how" and the resultant procedures derived from this task group 2 study.

Q12. Should airport operators be authorized to designate preferential runways, establish curfew hours on designated runways, limit ground maintenance runups, establish airport use fees based on noise, restrict the number of operations at the airport, restrict use of the airport to aircraft of specified type, weight, trip length, etc., or otherwise conduct the operation of the airport in such a manner as to assure that no area is exposed to hazardous noise?

Answer:

1. Preferential runways: Yes, the airport operator should be authorized to establish a preferential runway use program. I believe they have this authority at the present time.

2. Curfew hours: No, such a drastic measure would not be in keeping with the national welfare, trade and commerce. The long term effects of such a ruling should be studied very closely before arriving at a decision.

3. Ground maintenance run-ups: Yes, limitations could be established (particularly for night time run-ups) with the cooperation of the airlines assured.

4. Use fees: An airport use fee, based upon aircraft noise, is qualitatively consistent with the Los Angeles plans for a noise-related landing fee. The legal status of any type of such monetary inducement for noise reduction must, of course, be determined by legal counsel. Presuming however, that other regulatory measures assure compliance with established standards, a performance bond or use fee would not be necessary, and indeed might not be prudent.

5. Operations restrictions: No, those restrictions designed to minimize the number of flights, limit gross weights and trip lengths, all tend to require an increased frequency of operations which in turn will increase the noise impact somewhere. Airline schedules are basically predicated upon public demand and "prime time" utilization, therefore should not be unduly restrictive.

Q13. If local conditions require, should airport operators be authorized to specify a lower level of noise as unacceptable and adjust their airport operations accordingly? (Reworded)

Answer: No, the appropriate Federal agency should have a responsibility to establish standards and set limits that airport operators can "live with". Each airport will discover a "local condition" and will apply for a variance accordingly..... at that time, we have lost the concept of standardization in a maze of individual restrictions.

Q14. Should noise monitoring be required for single event noise? For cumulative noise? How often and at how many locations should monitoring be conducted?

Answer: The availability of a noise monitoring system at any airport provides an important tool which can be used to confirm predicted data, particularly when new concepts are in the development stages. It is also a great political tool, but one which should be chosen with great care. Any system required should be simple in design and inexpensive in operation. The type of monitoring system chosen must fit the requirements of the community as well as the eventual regulations. Aircraft manufacturers do now have certification standards applicable to new aircraft and new rules concerning retrofit, etc. will be forthcoming. The required implementation of these rules will negate the requirements for noise monitoring at airports.

Q15. To what airports should any of the above considerations apply?

Answer: The proposed regulations should include, as a minimum, any airport which has the capability of accepting aircraft in excess of 12,500 lbs. gross take-off weight and turbojet aircraft. Other airports, at which a noise problem is known to exist, should also be considered.

ADDITIONAL QUESTIONS

Q16. Are there any other rules which should be considered?

Answer: Serious consideration should be given to the manner in which noise abatement procedures are presented to the airlines and pilots who have a need to know. Rule making, as such, cannot provide the answers in developing techniques for compliance with the regulations, nor exemplify approved modifications applicable under a given set of circumstances. With this thought in mind, I would suggest a D. O. T. /F. A. A. Advisory Circular be published, presenting approved guidelines for the alleviation of aircraft noise in the flight operations area. A similar Advisory Circular might approach the problem from the airport operators viewpoint. In this manner, valuable information can be documented and made available. In fact, such a document might void the necessity of developing certain regulations which could otherwise be handled in an instructional format.

Q17. Are there any safety or technology considerations other than those which you have already mentioned in conjunction with the above questions?

Answer: None.

TG 2-93 received 4/9/73 from AOPA

FROM: Aircraft Owners and Pilots Association

POSITION QUESTIONNAIRE

TASK GROUP 2

TAKEOFF

1. It is AOPA's opinion that an operating rule requiring specific flight procedures should not be established.

2. Appropriate takeoff procedure: Keep aircraft as steep as possible within the airport boundary if flight is over or near a noise sensitive area.

LANDING

3. There should be no rule establishing minimum maneuvering altitudes prior to commencement of approach.

4. ILS glide slopes should not be raised to 3.5 degrees. Large impact on auto couplers and lower minimum approaches make this operationally unacceptable. Also, it would violate ICAO standards.

5. Operators should not be required to install instrumentation which would provide guidance during a two-segment approach.

6. The two-segment approach should not be required of pilots.

7. Thrust reversers should not be prohibited.

GENERAL

8. No comment.

9. Airports should not be certificated for noise. It is the vehicles using the airport that cause the noise and control and abatement should start with them.

10 and 11. No comment.

12. Restrictions on operations at an airport should be kept at a minimum. Curfew hours on designated runway opposed. Also opposed are: restricting the number of operations; restricting use of airport by certain types of aircraft, based on type, weight, trip length, etc., and establishing airport use fees based on noise.

13. Noise should be reduced as much as possible on a voluntary basis.

14. Noise monitoring at an airport should not be required.

AIR LINE PILOTS ASSOCIATION

STATEMENTS OF POLICY OR POSITION ON

NOISE ABATEMENT PROCEDURES

Noise Abatement Policy

The Association maintains the position that aircraft noise should be reduced by engineering and design and not by marginally safe flying techniques.

ALPA shall refuse to endorse or accept noise abatement procedures which require:

1. Clearances or communication designed to change headings at low altitudes for noise abatement purposes.
2. Turns below 600 feet for noise abatement purposes.
3. Reduction of power, earlier or to a greater extent than good operating practice would dictate.
4. Climbs at air speeds less than maneuvering speeds for the existing flap configuration.
5. Procedures when weather is below 1000'-3 miles.
6. Preferential runway for noise abatement purposes when:
   a. Runways are wet.
   b. A wind of greater than 10 kts. velocity or a wind angle which exceeds 80 degrees from the runway heading exists.
   c. A tailwinu greater than 5 kts. for takeoff or landing.
7. Requirement that approaches be conducted above glide slope for noise abatement purposes.
8. Communication other than those required for standard traffic separation during takeoff and approach. Pilot judgement will remain as the overriding factor in determining whether or not noise abatement policy will be followed based upon flight conditions incurred. (Board August 1966)

Noise Certificate Tests Policy

The Air Line Pilots Association insists that line pilots be included in the noise certification tests of all air line transport aircraft to aid in determining the acceptability of the procedures used and, further, that the takeoff/climb profile shall conform to the proposed FAA Draft Advisory Circular dated May 1968, entitled "Criteria for Implementation of Jet Noise Abatement Takeoff Profile." (Board 1968)

Noise Abatement Procedures Policy

The Association and its members shall refuse to accept or comply with noise abatement procedures which in the judgement of the pilot adversely affect safety and the Central Safety Chairman shall be notified immediately of instances where unacceptable procedures have been offered. Through his MEC the Central Safety Chairman shall take prompt effective action to remove unacceptable noise abatement procedures from company directives and manuals. (Board 1960)

Statements of Position

Takeoff

While we do not believe in the proliferation of regulations, if any operating rule for takeoff must be established, it should be established by the FAA. This rule should specify a standardized takeoff procedure for each aircraft type. Any attempts to tailor takeoff procedures to individual airports can only result in a degradation of safety. The benefits of standardization in aviation safety cannot be ignored.

We believe any standardized takeoff procedure must provide adequate margin above the stall speeds for each aircraft configuration. In this respect we would like to see adopted the takeoff procedure outlined in the FAA Draft Advisory Circular entitled, "Criteria For Implementation of Jet Noise Abatement Takeoff Profile" dated March 28, 1968. This procedure involves an accelerated climb schedule during which flaps are retracted. Speeds during this climb should be the maneuvering speeds for each particular flap configuration employed. Maneuvering speeds provide the maximum capability for collision avoidance and for following ATC clearances. At 1500' with the aircraft in a clean configuration, power can be reduced to that which would provide the appropriate certificated enroute climb gradients should the loss of an engine occur.

While meeting all the safety constraints which we feel are necessary, this type of procedure would put the aircraft in an optimum performance configuration. Climb gradients associated with clean configured aircraft are substantially higher than those in a takeoff configuration. The result of this is that a thrust reduction of a greater magnitude can be accomplished while maintaining an appreciable rate of climb.

While this type of procedure will produce slightly more noise close to the airport, it will result in less noise at distances further from the runway. This and other operational procedures have been extensively investigated by NASA and your attention is drawn to the following NASA Technical Notes:

1. TN D-5182 — "Technique For Calculating Optimum Takeoff And Climbout Trajectories For Noise Abatement"

2. TN D-6137 "Noise Measurements For a Three-Engine Turbofan Transport Airplane During Climbout And Landing Approach Operations"

While the accelerated climb profile can be effective in reducing noise of second generation jet aircraft, i.e., B-727, DC-9, BAC 1-11, other type aircraft may require a different procedure. In any event, adequate margins must be preserved in any procedure particularly speed margins. We can see no rationale for requiring a minimum margin above stall of 30% for approaches yet something less than this for prolonged climbout.

Minimum Approach Altitude

We do not believe there should be a specific rule for establishing minimum maneuvering altitudes prior to the commencement of an approach. These altitudes may have to vary operationally for a number of reasons such as terrain, weather, etc. The "Keep Them High" program deals fairly adequately with initial approach altitudes.

Normal Glide Slope Angles

Approximately one year ago the FAA Advisory Circular on Category II criteria stated that the "optimum glide slope angle is 2 1/2°." Since then this Advisory Circular has been revised and the FAA has a program to raise all glide slope angles to 3°. While we have concurred with this increase in glide slope angles, we believe it would be irresponsible to propose raising ILS glide slope angles further without a scientific study of the effects this would have on low visibility approaches. We would be strongly opposed to any arbitrary raising of glide slope angles beyond 3°.

Use of Reverse Thrust

The suggestion that a rule be proposed prohibiting the use of reverse thrust is so preposterous as to not require a response. Nevertheless, we would oppose any attempts to restrict the use of thrust reversers during aircraft landings. There may be and certainly are times and conditions when a pilot could and does vary the amount of reverse thrust used during a landing roll, but this use of a pilot's judgement cannot be preselected based on runway conditions, etc. That judgement can only be made at the time of touchdown and during the subsequent rollout.

Two-Segment Approaches

It is our position that with the present aircraft equipment and instrumentation, two-segment approaches are not feasible for day-in and day-out line operations. When and if such equipment and instrumentation is available, we would certainly review our position on this subject.

Currently, some ALPA pilots are evaluating the UAL/NASA two-segment approach procedures on the Boeing 727. It should be noted that this evaluation has not been completed and any attempts at this time to specify criteria for two-segment approaches is premature.

Aircraft Noise Monitoring

If takeoff and landing procedures are safe and easy to follow, we see no need for noise monitoring systems, unless the data from these monitors is used on a statistical basis. The use of single event noise levels has questionable value in determining whether or not a noise abatement procedure has been followed. Past noise abatement procedure test in which the same pilot flew the same procedure on the same day on the same aircraft under the same conditions produces a range of noise values over the same point on the ground. If under controlled conditions this variability exists, it should be expected that under line conditions some greater variability will also exist. As an example, refer to the following reference:

> Measurement and Analysis of Noise From Four Aircraft During Approach and Departure Operations, FAA RD-71-83 and FAA RD-71-84, September 1971

In response to the question regarding the authority of the airport operators to establish procedures to be used by pilots, we wish to state that airport operators are not competent by training or experience to establish procedures for pilots.

Reduced Thrust Takeoff Procedures

The use of reduced thrust procedures for takeoff has been greeted with mixed emotions by members of the Association. While these procedures were instituted for the purpose of increasing engine life, their use under certain conditions could significantly reduce the safety margins available in the takeoff regime. The concern of the ALPA Airworthiness and Performance Committee over the use of these procedures resulted in the following ALPA Policy:

> "The Airworthiness and Performance Committee is concerned over the use of reduced thrust takeoff procedures, and the Association urges all pilots to use the utmost discretion in such use of reduced thrust takeoff procedures. Further, the Association will use all available resources in support of any pilot who is coerced, harassed, or disciplined for exercising his best judgment in not using reduced thrust procedures for a takeoff." (Board - 1971)

Further, it is felt that the small reduction in sideline noise that is achieved by the use of reduced thrust on takeoff is far outweighed by the resultant increase in the noise footprint caused by the increase in the distance covered during climb.

TG 2-87
Rec'd 4/3/73
from Boeing

BOEING

COMMERCIAL AIRPLANE GROUP P.O. BOX 3707 SEATTLE, WASHINGTON 98124

March 30, 1973

6-7270-1-360

Mr. R. L. Hurlburt, Chairman Task Group 2
Environmental Protection Agency
Washington, D. C. 20460

Subject: Boeing Comments for EPA Task Group 2

Dear Sir:

Attached please find some general comments pertaining to Task Group 2 activities, and our answers to the specific questions asked at the last meeting.

In general, we find it difficult to be as constructive and definitive as we would like to be. The main reason is the early state of development of data and information in the subject area under study by Task 2. We have attached general comments in an attempt to point out the technical problems that must be solved before implementation of modified procedures can be started, and to attempt to point out the depth of work required and the timing involved. We do not consider this a complete report on the subject, but offer the material to advise caution regarding the complexity of the task.

We have also attempted to provide answers to the specific questions asked at the last meeting. It became clear as we attempted to answer these questions, that the "rule" philosophy expressed was in many cases impossible to endorse. The complexity of the situation in many cases made a hard and fast "rule" approach seem unworkable. You will therefore see reference to establishing "guidelines" that can better be adopted to the local situation on an airport by airport basis, taking into consideration the operational situation at each airport.

We would like to make the following general recommendations for Task Group 2 activities.

RECOMMENDATIONS

1. Task Group 2 should provide a specific time schedule in support of any recommended system implementation. This should include a schedule of development, certification, and implementation by system and for each aircraft type.

2. The Task Group should in addition provide a detailed buildup of total system cost for each system recommendation made.

3. The Task Group should provide specific estimates of noise reduction, for both suppressed and unsuppressed airplane types, to quantify the benefits expected for each system recommended.

It seems incumbent upon Task Group 2 to provide the above, in close coordination with the output of other Task Groups in order to establish a valid cost, benefit and schedule basis for rule recommendations.

Very truly yours,

BOEING COMMERCIAL AIRPLANE COMPANY

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

Attachment

GENERAL COMMENTS FOR TASK GROUP 2

Achieving additional noise reduction through operational procedures will require coordinated actions by Government and industry. In the case of aircraft related noise the "industry" involved is the aircraft, engine, and avionics systems manufacturer and the operator. Noise abatement procedures are not confined to actions by the operator. They also involve the manufacturer and the Government through the changes to the airplane and its systems that require FAA certification. Boeing has actively carried out many programs aimed at reducing the noise generated by aircraft. The effort devoted to analyzing the effects of aircraft operation includes both Government sponsored and Boeing in-house research.

Included in the material which has been entered on the record of the "Aircraft/ Airport Operations Analysis Task Group" (Task 2) is the 1971 paper presented by M. C. Gregoire and J. Streckenbach, "Effects of Aircraft Operation on Community Noise." Data and conclusions from the paper were also quoted several times during the meetings of the Task 2 Group. The Boeing Company believes that the general trends, conclusions and recommendations presented in that paper are still valid. In fact, in the intervening period, some of the recommended procedures have been implemented and the noise advantages have been observed. However, it should be realized that specific details such as the minimum altitudes for establishing the final configuration/glide slope require further study and flight test verification.

The Gregoire/Streckenbach paper based its discussion on the basic untreated engine installation on the Boeing 727. Nacelle treatment changes the noise characteristics so that, in some cases, the incremental noise reduction realized through operational procedures is less for airplanes equipped with noise treated nacelles. Although there is still a noise reduction and the recommended procedures may still be appropriate for the quieter airplanes, additional work is required to establish the optimum combination of nacelle suppression <u>and</u> modified procedures.

The benefits of higher glide slope intercept altitudes discussed in the paper should be re-emphasized. Standard Terminal Arrival Route (STAR) charts and FAA approved instrument approach procedures should be modified wherever possible to increase the altitude for intercepting the glide slope. Air Traffic Control (ATC) should be encouraged to develop a policy of keeping incoming traffic as high as practicable to relieve the community of noise generated by approaching aircraft.

Some of the operational procedures being considered require new or modified systems for guidance and/or control. One example is the two-segment approach system currently under development by the NASA Ames Research Center with United Air Lines and Collins Radio Company. This work has provided estimates of the cost of the airborne equipment required. The cost of associated ground equipment has not yet been reported. It is most important to recognize <u>total</u> system costs in any of the concepts being considered. The system being evaluated on the Boeing 727-200 requires a DME transmitter that is colocated with the ILS glide slope. At present there are relatively few (less than ten) airports so equipped. Plans to adopt this system widely must include the time and cost involved in installing the required DME equipment.

Another system being evaluated uses 3D area navigation. For this concept, additional ground equipment or its modification has not been defined. Moreover, the cost of the airborne equipment is substantially more than that required for the 727 system mentioned above and relatively few airlines have selected area navigation system as standard items for their fleets.

A recommendation to implement widespread use of a two-segment approach must recognize the various options available and their state of development. The large number of airplane types, airlines and airports involved may preclude a singular equipment solution. Sufficient time must be allowed to design, develop and test production hardware compatible with its intended use. Depending on the particular system involved, this can require one to two years of development time including FAA certification for each combination of airframe and avionics. For Boeing this could represent on the order of 12 to 15 development programs to cover our airframe/avionics combinations.

The system being evaluated on the 727-200 is planned by the NASA to provide a Supplemental Type Certificate (STC) in FY74. If this STC is made available to all airlines, only the 727-200 could be so equipped. The timing and rate of implementation would be established by the airlines (availability for installation and the manufacturer (production rate and installation time required). Application of similar equipment on other airplane types will require additional time for adaptation to that model and obtaining the required FAA certification.

Plans to implement more sophisticated systems are obviously more remote in time. Experience to date indicates how long it can take to achieve operational status on relatively simple systems based on current technology. The initial Boeing 720 work by NASA with American Airlines began in 1971 and the current program with the 727-200 is planned to be complete late this year or in the first half of 1974. It is significant that these systems are only a modification of accepted and proven procedures. Development of new procedures based on more advanced technology systems, both airborne and ground based, such as curved approach paths using Microwave Landing Systems guidance will require extensive development before they can be implemented on a widespread basis.

The work of Task Group 2 should be coordinated closely with Task Group 4 (Source Noise Abatement Technology and Costs) to assure that the procedure concepts considered are consistent with available technology. Further, realistic schedules for implementing particular procedures should be a fundamental consideration for Task Group 5 (Regulatory Actions by the FAA).

POSITION QUESTIONNAIRE

Task Group 2

3/19/73

NOTE: "no comment" means we believe we are not qualified to answer, or we believe others such as the airlines, port authority, etc, should respond.

TAKEOFF

1. Should there be an operating rule establishing specific flight procedures for takeoff?

2. What do you think the appropriate takeoff procedure should be?

(1 and 2.) The purpose of establishing, and requiring the use of, a takeoff operating procedure is to reduce noise over the nearby communities. However, all such communities do not have the same location relative to the airport. Nor is the airplane performance constant for all takeoff weights, airport temperatures, altitudes, and winds. It is thus apparent, that to truly minimize community noise, the takeoff procedure should be tailored to the particular airport and its surrounding communities and recognize the operational variables of the aircraft. On the other hand, a considerable degree of procedural standardization is desired for a safe and practical operation. A suitable "middle ground" which largely satisfies both objectives would be to adopt, and use for all takeoffs, a minimum speed, steep climb procedure of the general type ATA and others have proposed. There should be, however, one important degree of flexibility and that is the altitude at which initial thrust reduction, or cutback, is accomplished. Through appropriate selection of the thrust reduction altitude, near-optimum noise reduction can be achieved around the airport with minimal increase in piloting complexity. The pilots now fly according to a set of operating speeds selected for the particular takeoff condition. To that set of variables would be added the particular altitude for thrust reduction. Just as training routines now teach takeoff as a standard procedure with certain variable inputs, so the noise abatement takeoff can be taught as a standard procedure with but one additional input variable. The operational experience of the airlines and the FAA should have a strong influence on the takeoff procedure formulation.

LANDING

3. Should there be a rule establishing minimum maneuvering altitudes prior to the commencement of approach? What should these altitudes be?

It is recognized that to minimize the noise annoyance of aircraft nearing the airport, it is important to "keep them high and keep them clean." It must also be recognized that while maneuvering in level, or near-level flight, there is no procedure other than "keep them clean" to reduce airplane thrust requirements. Thus, if noise on the ground is to be held to low levels, proposed guidelines should probably be established to to maintain a reasonably high altitude, such as 5000 feet where feasible, during terminal area maneuvers. The specific application of these guidelines must be coordinated with FAA Air Traffic Control on an individual airport basis.

4. Should there be a rule raising ILS glide slopes immediately to 3.5 degrees?

Increasing all glide slopes to approximately 3 degrees is an appropriate action that would yield a benefit in reducing approach noise. Some ILS installations are already set at this angle but the majority are set at a lesser one. Raising the glide slope an additional one-half degree requires further investigation and test. Aircraft that operate at an approach speed of 150 knots would have a stabilized sink rate of 930 ft/min at 3.5 degrees compared to 796 ft/min on a 3 degree flight path. Such an increment in sink rate must be examined for its effect on landing flare. It is possible that some aircraft could not operate safely at 3.5 degrees resulting in 3 degrees being a reasonable upper limit for the near term.

5. Should operators be required to install instrumentation which would provide guidance during a two-segment approach?

On-board guidance will be required to perform two-segment approaches under all operating conditions. The benefit of a two-segment approach system should be compared to its cost. It is known that the noise reduction resulting from the two-segment approach is related to the noise suppression at the source. It would be unwise to require operators to install a two-segment approach system without knowing the full benefit or evaluating alternatives.

Before such a system can be made available to the operator, several steps are required. The system concept must be developed to the point that it is safe, acceptable to the flight crew, and compatible for terminal airport operations by ATC. As an example, the DME concept requires nationwide installation of DME ground equipment before the system could become operational. Further, the system selected must be compatible with the aircraft on which it is installed. Production hardware for each airplane model must be designed, developed, tested, certified by the FAA and made available for installation before promulgating such a rule.

6. Should there be an operating rule requiring pilots to fly two-segment approaches? What intercept altitude should be specified? What should be the angle of the upper segment? Should the rule initially be VFR only? When should VFR and IFR rules be effective?

Operating rules for pilots depend totally on the results from question 5. Regarding the two-segment approach, the noise benefit will increase with increasing upper segment intercept altitude. The altitude at which the steep and shallow glide slopes intersect also has a strong infulence on approach noise. The specific altitudes selected will depend upon the type of guidance and how well it blends in with other approach procedures being used at a particular airport and other nearby airports. The angle of the upper segment must be matched with the flight path performance capability of each particular aircraft. Any implementation of a two-segment approach should be for both VFR and IFR. When it can be effective is a matter that concerns the airlines and the FAA.

7. Should there be a rule prohibiting the use of thrust reversers on dry runways unless required by Air Traffic Control or unless runway length or atmospheric conditions require their use in the interest of safety?

No. Reverse thrust should be a pilot option.

GENERAL

8. To what aircraft should any of the rules considered above apply?

If noise abatement procedures for aircraft are to be legislated, it is logical that they be applied to any and all aircraft contributing to the noise annoyance.

AIRPORTS

9. Should airports be certificated for noise?

Guidelines and principles of operation for aircraft should be established to minimize noise exposure from an airport to the surrounding community. These guidelines should minimize noise exposure by prescribing arrival and departure routes, vector and approach altitudes, departure procedures including noise abatement thrust reduction, and preferential runways. These guidelines should exclude curfews. Although such noise abatement techniques have been implemented at some airports, it is believed that significant improvements can be accomplished at many additional noise-sensitive airports. Verification that each airport operation is in compliance with these EPA guidelines would require joint airport operator-FAA-airline coordination, and could probably be accomplished by the FAA.

10. Should airport operators be required to assure that no area is exposed to unacceptable noise as defined by Task Group 3? By when?

No. It is not clear that Task Group 3 can technically establish such a level. Even if such a level could be established and verified with subjective data, requiring airport operators to "assure that no area is exposed" could curtail or shut down airport operations in many cases. Technology does not exist to reduce noise levels to the extent implied in this question. In addition, the airport operator does not have the direct authority to modify operating procedures, or to purchase land.

11. Should airport operators be authorized to specify maximum single event noise levels for aircraft or procedures to be used by pilots?

No. Even though port operators appear to currently have authority to regulate single event noise levels, the potential impact on interstate and international air commerce of such unilateral and uncoordinated efforts would cripple the air transportation industry. Flight procedures as indicated in response to question 9 should be coordinated by the airport operators, FAA, and operating airlines.

12. Should airport operators be authorized to:

Designate preferential runways?

Yes, with approval of the FAA.

Establish curfew hours on designated runways?

Yes, so long as the end result is not to close the airport during curfew hours.

Limit ground maintenance runups?

No comment.

Establish airport use fees based on noise?

No comment.

Restrict the number of operations at the airport?

No, especially considering that halving the number of operations has been judged as worth perhaps 3 dB reduction in noise exposure and a reduction of this magnitude would not be perceived by many community residents. It is apparent that restricting the number of operations to effectively contribute to noise reduction would amount to closing the airport.

Restrict the use of the airport to aircraft of specified type, weight, trip length etc?

Even though it appears they currently have such authority, it is not recommended for the same reasons as given in response to question number 11.

Or otherwise conduct the operation of the airport in such a manner as to assure that no area is exposed to unacceptable noise?

Even though it appears they currently have such authority, it is not recommended for the same reasons as given in response to question number 11.

13. If local conditions require, should airport operators be authorized to specify a lower level of noise as acceptable and adjust their airport operations accordingly?

Even though it appears they currently have such authority, it is not recommended for the same reasons as given in response to question number 11.

14. Should noise monitoring be required for single event noise?

No; it is not clear what noise monitoring would accomplish. Noise certification has already been established as the mechanism to ensure the application of noise reduction technology that is reasonable and practicable for a new type design. Retrofit or FNL type rules, if and when enacted, will do the same for the existing fleet. Noise monitoring would only confirm the wide distribution of noise level from an airport fleet, and would confirm once again the vagaries of acoustic measurements from day to day, and under various weather conditions. In accordance with question 9, implementing minimum noise procedures at each airport, and monitoring and enforcing such procedures, would negate the need for noise monitoring. Noise monitoring would seem to be an unwarranted expense for little return.

14. (continued)

For cumulative noise:

No, same as above.

15. To what airports should any of the above considerations apply?

No comment.

ADDITIONAL QUESTIONS

16. Are there any other rules which should be considered?

Compatible land use planning and conversion should be thoroughly analyzed and assessed at the Federal and local level, to establish what can be done, for existing noise sensitive airports, new airports and airports that do not currently have a problem. Such a study should be directed by the Federal Government, and should culminate in a written report on the subject. EPA in conjunction with other Federal agencies such as HUD, HEW, etc, could then establish guidelines and rules to minimize existing problems, and to eliminate the growth of future community noise problems.

17. Are there any safety or technology considerations other than those which you have already mentioned in conjunction with the above questions?

The air transport industry has compiled an excellent safety record. The noise abatement procedures being discussed would modify some of the present procedures. At this time it cannot be said that the suggested procedures are specifically unsafe. Yet since airplanes will, with some abatement procedures, regularly fly closer to airworthiness limits than they now do in normal practice and be exposed for longer periods to minimum performance levels, it is probable there is a safety consideration. Because the safety implications are not precisely known, operational analyses and probability studies should be conducted to dimensionalize the safety impact and assure that noise abatement procedures do not cause an unfavorable shift in future safety statistics.

The impact of modified flight procedures on aircraft emissions and energy consumption should also be understood before such procedures are implemented.

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

June 29, 1973
6-7270-1-442

Mr. R. L. Hurlburt
Office of Noise Abatement and Control
Environmental Protection Agency
Washington, D. C. 20460

Subject: Boeing Commercial Airplane Company Position on Task Group 2, "Operations Analysis Including Monitoring, Enforcement, Safety, and Costs"

References:

1) Boeing Letter 6-7270-1-443, V. L. Blumenthal to H. E. von Gierke.
2) Boeing Letter 6-7270-1-444, V. L. Blumenthal to W. C. Sperry.
3) Boeing Letter 6-7270-1-445, V. L. Blumenthal to W. C. Sperry.

Dear Mr. Hurlburt:

The following are comments relative to the Task Group 2 report on "Operations Analysis Including Monitoring, Enforcement, Safety and Costs."

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 consensus, we would suggest that any inference of unanimity of opinion be expurgated.

The position stated in previous correspondence (Letter 6-7270-1-360 dated March 30, 1973, V. L. Blumenthal to R. L. Hurlburt) is still valid and should be included with this correspondence in the Final Report.

A DIVISION OF THE BOEING COMPANY

In the section titled "Airport Noise Controls" the figure presenting U. S. Air Carrier Fleet - Approach Noise Levels shows the 747-100 airplane at its pre-December 1971 levels. The correct 747-100 approach noise levels for airplanes currently being delivered should be plotted as 107/105 EPNdB.

In the section titled "Nationwide Benefit Cost Analysis," the "Normal Effort Schedule" shows no action on several items that are scheduled on the "Accelerated Effort Schedule." It should be noted that the "Normal Effort" does not include some actions that are already being taken. This results in a greater difference in the relative social benefit resulting from the "normal" and "accelerated" cases and could influence the conclusions. It is recommended that the "Normal Effort Schedule" be revised.

We commend you for your efforts in this important work and appreciate the opportunity to participate.

Very truly yours,

BOEING COMMERCIAL
AIRPLANE COMPANY

Vaughn Blumenthal

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

Rec'd 3/5/73
from Roger Flynn, ATA

(25)

The recommended steps for noise abatement approach for use at all airports with all types of approaches (ILS, VOR, Visual, etc.), both IFR and VFR are as follows:

1. Approach the airport area at as high an altitude as possible (at airport with control towers, "Keep-em-high" assists here);

2. Remain in a clean configuration for as long as possible;

3. Proceed in-bound from the final approach fix, or a similar distance for a visual approach, with flaps set at one "notch" less than final landing flaps planned for the particular landing;

4. Extend final landing flaps at a point on final approach at which the aircraft is 800 to 1000 feet above field elevation;

5. Use the lowest allowable landing flap setting which is permissible for the particular landing, e.g., on B-727 use 30 degrees flap setting for landing, whenever the specific runway and runway conditions will allow.

To maximize noise abatement benefits, it is further recommended that initiation of each successive flap extension be made at a speed near the minimum speed for that particular configuration rather than at the maximum speed allowable for the particular configuration.

Assistance from ATC will be useful in implementation of Steps 1 and 2 of the procedure.

Step 4 contemplates final approach stabilization at not less than 500 feet above field elevation.

Some airlines are working with the manufacturer to accomplish certification of a lesser landing flap setting for the B-707-300 series airplanes, i. e., reducing the presently certificated B-707-300 series landing flap setting from 50 degrees to 40 degrees.

I. First Segment - Takeoff of 1500 Feet

1. Takeoff power
2. V_2 + 10 (+)
3. Takeoff flaps

II. Second Segment - at 1500 Feet to 3000 Feet

1. V_2 + 10 (+)
2. Optimum flap setting speed permitting*
3. Reduce to not less than climb power

* Retract or retain flap setting as required

III. Third Segment - at 3000 Feet

1. Retract flaps on schedule
2. Normal en route climb

It was recognized that under certain conditions, departure from the normal procedure would be required, for example, where specific ATC instructions are not compatible with the procedure. It was also recognized that each airline will expand the above procedure in its manuals with company directives to pilots covering operational techniques, etc., within the confines of the broad standard.

Specific comments on the above procedures that may assist in its understanding and im0lementation are as follows:

I. First Segment

Referral to use of takeoff power and flap means that takeoff power and flap setting required for the load and the runway being used. It was recognized that some aircraft may have difficulty in maintaining V_2 + 10 without too steep a body angle. The speed recommended should be maintained as far as possible but without exceeding the aircraft body angle limitation. To cater to this difference, however, the symbol "(+)" has been used in the procedure to allow speed acceleration beyond V_2 + 10 if body angle limited.

II. It was recognized that it may be necessary to increase speed to achieve the optimum flap setting required in entering the second segment at 1500 feet. Thus, again the symbol "(+)" is used for the airspeed at 1500 feet to 3000 feet to allow speed acceleration when required to enable a lesser flap setting. It is <u>not</u> to be interpreted to permit unlimited airspeed. Strict speed discipline is required to make the procedure beneficial and in order that departure separation established by ATC not be jeopardized. The asterisk after the instructions for optimum flap setting in this segment refers to the case where takeoff flaps for a particular operation were desired to be maintained to 3000 feet, i.e., leave flaps at takeoff setting or commence a partial setting if airspeed will otherwise allow. Reduction of power at 1500 feet would achieve the best noise reduction for the greatest number of people in the area under or near the takeoff path. The single "climb power" desired would approximate a 1000 foot per minute climb.

III. Third Segment

Self explanatory - but reapplication of power should be gradual to avoid excessive peak noise buildup.

Submitted by Roger [illegible]
ATA
3/5/73

Approach Procedures

On March 6, 1973, I submitted the ATA/FAA Approach Procedure currently in use. Essentially, this procedure calls for keeping the aircraft clean and high for as long as possible prior to descent to the airport. When committed to approach, gear is not lowered until the outer marker and one notch less flap is used throughout to minimize drag and use of excess thrust.

The visual flight rule (VFR) two segment approach now used some of the time by PSA, was first evaluated by National Airlines. Because the procedure could only be used under VFR conditions, interstate carriers operating into weather conditions more severe than those encountered in California require for safety's sake the development of a two-segment approach that could be used under all conditions, visual or instrument throughout the airline system.

Under the auspices of NASA both American and United have been flying aircraft with instrumentation to provide guidance on a $6^{o}/3^{o}$ approach. The United aircraft on this project is about to commence evaluations on West Coast routes that will permit pilots from other airlines to fly the aircraft on two segment approaches.

Currently, such approaches are limited to ILS (Instrument Landing System) approaches to airports equipped with DME (distance measuring equipment). In the future it is believed that aircraft equipped with Area Naviation equipment will be able to make two segment approaches to any runway, independent of ILS/DME.

Departure Procedures

On March 6, 1973, I submitted the ATA/FAA Departure Procedure currently in use by the scheduled airlines. This procedure was carefully developed, tested, monitored and compared to other procedures in use and proposed, including the Soderlind/Northwest procedure, and found to be quieter. In fact Captain Soderlind participated in its development. It incorporates adequate margins of safety, reducing the noise footprint from a point about three miles from brake release to ten miles out.

Thrust Reversal

While some advocate discontinuance of the use of thrust reversal, it is a fact that use of this equipment is required for safety, shortens runway occupancy time and the landing/taxi cycle, thereby reducing pollution.

Preferential Runways

Use of preferential runways have always been advocated when it is possible to avoid built-up areas. They are used worldwide within the operating capability of the aircraft as defined in FAA Order 7110.13.

This Order defines runway selection within the following limits: "Use noise abatement runways when acceptable to the pilot for all airplanes over 12,500 pounds and all turbojet airplanes, provided the following conditions are met:

(1) Runways are clear and dry: i.e., there is no ice, slush, etc., which might make use of a noise abatement runway undesirable.

(2) Wind velocity does not exceed 15 knots.

(3) Any crosswind does not exceed 80 degrees from either side of the centerline of the runway in the direction of use.

"When it is determined that turboprop airplanes of less than 12,500 pounds create a noise problem such airplanes shall be subject to the formal runway use program established for that airport."

Preferential Flight Paths

Preferential flight paths are often employed to take advantage of parkland, waterways or other uninhabited areas. They are tailored, of course, to the particular airport/air traffic control situation. The San Jose example is a good one. There are numerous airports at which these types of routings are used.

Curfews

Curfews as a method of noise alleviation would be detrimental to the national welfare, commerce, trade and national defense. The full effects of a national curfew on interstate and foreign commerce would take at least a two year study and therefore is beyond the capability and time restraints now on EPA. While some communities may advocate such drastic measures, they presently have as much knowledge of the effects as a man who turns off the city generator to shut off his bathroom light.

Weight Limitations

There are some who advocate weight limitations on aircraft to permit the aircraft to climb higher, faster or to use less thrust on approach. Such advocacy loses sight of the fact that the cargo or passengers left behind must use another aircraft. Thus, two aircraft are required to do the work of one. It is well known that frequency of operations is a source of noise annoyance. Also, if less fuel is carried, this may dictate a stop at an intermediate airport, thus increasing noise exposure at the intermediate fuel stop.

Runup Restrictions

At a very few airports in the U.S. where overnight aircraft maintenance is performed, complaints have been received from airport neighbors about engine runup noise. Where this has been a problem, airport management has prohibited maintenance engine runups during night hours and/or have selected runup areas remote from the community for such operations. Aircraft operators have cooperated and adhered to these restrictions.

Noise Monitoring

Airport noise monitoring is in its infancy. While point source monitoring has been practiced at places like Kennedy and London for some time, aircraft can adjust thrust to avoid triggering these monitors but when thrust is reapplied communities beyond the monitors suffer. No one if fooled by this dodge. The airport operator knows it. The aircraft operator knows and the public beyond the monitor suffers.

As I understand it, two types of monitoring systems are proposed in one state. One would attempt to monitor at prescribed points on takeoff and landing paths, while the other would perform area monitoring to describe neighborhood noise values.

Some airport operators have asserted that the first system would be used to measure variations from FAR 36 levels to form a basis for penalties against the aircraft operator. This is totally unrealistic, as FAR 36 is like the bench test of a rifle on a one-time basis under carefully prescribed range conditions by trained test pilots. While useful in comparing the noise characteristics of one aircraft against another, duplication of this noise footprint in line operations with differing wind directions and velocities, temperature, humidity, pressure, terrain, cloud cover, etc. is impossible to achieve. Some other scheme for singling out an operation that is not using the best available procedures must be invented.

Neighborhood noise monitoring under a variety of weather conditions and in different time periods might be useful in developing a data base other than the theoretical NEFs, etc. It would be useful, too, in assessing progress as flight procedures or equipment improve and change.

Operations Monitoring

Operations monitoring by skilled personnel with appropriate tools can develop the data for any scattering in aircraft operations. It should be noted that takeoff flight profiles will vary between the same aircraft types as a function of gross weight. Nevertheless, operations that ignore prudent noise abatement techniques should be sorted out by monitoring methods, reported and corrected if all other methods fail. Compliance requires communications with pilots at frequent intervals since the pilot population at any airport changes and secondly, all humans require reminders from time to time.

The most effective operational monitors are the public. Given a place to call and a receptive, respectful, interested organization that can quickly check and investigate with an open mind, good results are achieved. Several major airports operate "noise complaint" offices. As a result of the public input, adjustments have been made to operational procedures that have been beneficial.

Answers of
Roger G. Flynn
to

POSITION QUESTIONNAIRE

Task Group 2
3/19/73

TAKEOFF

1. Should there be an operating rule establishing specific flight procedures for takeoff?

Ans. 1. Yes.

2. What do you think the appropriate takeoff procedure should be?

Ans. 2. See ATA procedures previously submitted.

LANDING

3. Should there be a rule establishing minimum maneuvering altitudes prior to the commencement of approach? What should these altitudes be?

Ans. 3. Minimum maneuvering altitudes for each airport have already been established. These altitudes are directly related to the traffic control procedures and obstruction clearances. In addition to these, the "Keep 'em High" program is the best possible solution. This FAA program directs all tower facilities to keep the aircraft as high as possible before committing the aircraft for approach. Rule making is not indicated.

4. Should there be a rule raising ILS glide slopes immediately to 3.5 degrees?

Ans. 4. No. Airline operations executives have reviewed the glide slope angle question time and again. They have concluded that with today's aircraft, flying in all weather conditions, with all flight crews, that for the sake of safety 3° degrees is the maximum glide slope for effective use of the airspace and to serve the public. It goes without saying that this question is directed to the heart of aircraft design, certification and pilot proficiency and safety. It must apply to the least and the best. Some descent figures in feet per minute are provided together with normal approach speeds ranging from small to large jets. You will note that descent rates that exceed 600 fpm exceed the design certification goal.

GLIDE SLOPE ANGLES AND RATES OF DESCENT

1 GS Angle	2 130 knots	3 140 knots	4 150 knots	5 160 knots
3^{o}	689 fpm	742 fpm	795 fpm	848 fpm
3.5^{o}	804 fpm	866 fpm	927 fpm	989 fpm
4^{o}	918 fpm	989 fpm	1060 fpm	1130 fpm

5. Should operators be required to install instrumentation which would provide guidance during a two-segment approach?

Ans. 5. No, not until the equipment has been evaluated and proven completely safe. It should be noted that the present experiments are being conducted only at airports with ILSs and co-located DME. It is our understanding that there are only about 350 ILS runways at U.S. air carrier airports. If satisfactory guidance can be developed, some method will have to be devised that goes beyond the present 350 ILS runways. Note: There are about 2400 air carrier runways in the U.S.

6. Should there be an operating rule requiring pilots to fly two-segment approaches? What intercept altitude should be specified? What should be the angle of the upper segment? Should the rule initially be VFR only? When should VFR and IFR rules be effective?

Ans. 6. No, not until the evaluation is completed and the equipment accepted. We recommend an intercept altitude to the 3^{o} glide slope at 1000 feet above the runway thresh-hold altitude. We do not believe that two-segment approaches should be flown VFR only initially. If the assessments of the equipment are satisfactory, the equipment and techniques should provide for VFR and IFR approaches under all weather conditions down to CAT III minimums for maximum noise benefits.

7. Should there be a rule prohibiting the use of thrust reversers on dry runways unless required by Air Traffic Control or unless runway length or atmospheric conditions require their use in the interest of safety?

Ans. 7. No. See "remarks" on this subject in my previous paper.

GENERAL

8. To what aircraft should any of the rules considered above apply?

Ans. 8. I don't know. When your conclusions are drawn, perhaps some answers will be possible.

AIRPORTS

9. Should airports be certificated for noise?

Ans. 9. It is likely that attempts to certificate airports for noise will result in stultifying efforts to constantly reduce noise. The California effort to describe noise around the airport and to set noise goal limits by legislative fiat has two edges. Technology might readily achieve the design noise goal and stop, thus preventing further reduction. On the other hand, if the design goal is unachievable in a reasonable time frame, the airport neighbors will be frustrated by the so-called legislative promise.

It is more reasonable to foster and support noise reduction technology. Such technology, if practicable, readily finds its way into the market place. As examples, the high bypass engines and acoustical nacelles on the 747, L-1011 and DC-10 come to mind. It can be reasonably stated that aircraft noise is on the down turn, thanks to airline demands, aircraft and engine manufacturers continuing work, and improvement in the state of the art as the result of on-going research.

10. Should airport operators be required to assure that no area is exposed to hazardous noise as defined by Task Group 3? By when?

Ans. 10. I don't know what hazardous noise is. It is undefined. Much depends on the definition of the term.

11. Should airport operators be authorized to specify maximum single event noise levels for aircraft or procedures to be used by pilots?

Ans. 11. No. This needs to be done on a national basis if we are to continue to provide a national air transportation system for the public.

12. Should airport operators be authorized to designate preferential runways, establish curfew hours on designated runways, limit ground maintenance runups, establish airport use fees based on noise, restrict the number of operations at the airport, restrict use of the airport to aircraft of specified type, weight, trip length, etc., or otherwise conduct the operation of the airport in such a manner as to assure that no area is exposed to hazardous noise?

Ans. 12. Breaking question 12 down into its components, the answers are as follows:

Q. Should airport operators be authorized to designate preferential runways?

A. Preferential runways should continue to be established through the cooperative efforts of FAA, aircraft operators on the airport and the airport operator. No difficulties have been encountered and therefore this should be non-controversial.

Q. Should airport operators establish curfews on designated runways?

A. No.

Q. Should airport operators be authorized to limit ground maintenance runups?

A. There is no objection if they do so in a reasonable even-handed manner. This item is also non-controversial and cooperation has been good.

Q. Should airport operators establish airport use fees based on noise?

A. No. Such fees do not strike at the heart of reducing noise.

Q. Should airport operators be authorized to restrict the number of operations at the airport?

A. No. Applying this restriction to the air transport system willy-nilly would fragment any semblance of a unified air transport system.

Q. Should airport operators be authorized to restrict use of the airport to aircraft of a specified type?

A. No. This suggestion is frivolous and does not take into account the long lead times and capital outlays by carriers to provide equipment that can serve the public convenience and necessity within that airline's system.

Q. Should airport operators be authorized to restrict weight of aircraft or trip length?

A. No. Use of either of these proposed restrictions might purchase a small gain at that airport but would require the carrier to make additional intermediate landings for fuel, thus increasing the noise burden on other airports.

The last part of question 12 refers back to question 10 and so far Task Group 3 has not provided Task Group 2 with any definition of hazardous noise.

13. If local conditions require, should airport operators be authorized to specify a lower level of noise as hazardous and adjust their airport operations accordingly?

Ans. 13. Same as 11.

14. Should noise monitoring be required for single event noise? for cumulative noise? How often and at how many locations should monitoring be conducted?

Ans. 14. No. Noise monitoring should not be required though its use, on an airport by airport basis, would be of value so long as it is not used as an enforcement tool. Too many variables in aircraft operating weights and weather to use it as an enforcement tool. We do not see hcw it can be used for enforcement purposes for either single or cumulative noise purposes.

15. To what airports should any of the above considerations apply?

Ans. 15. Impossible to determine at this time.

ADDITIONAL QUESTIONS

16. Are there any other rules which should be considered?

Ans. 16. a) It would be appropriate to advocate an approach procedure rule as a corollary to question 1.

b) As stated in question 2, although addressed to approach procedures, I would recommend the ATA procedure at this time.

17. Are there any safety or technology considerations other than those which you have already mentioned in conjunction with the above questions?

Ans. 17. I don't know. I have tried to identify those most obvious ones.

CITY OF INGLEWOOD CALIFORNIA
CIVIC CENTER
105 EAST QUEEN STREET / INGLEWOOD, CALIFORNIA 90301

March 26, 1973

TA 2-73
Rec'd 3/2/73
from Inglewood

Mr. John Schettino, Director
Regulation and Standards Development Staff
Office of Noise Abatement and Control
Environmental Protection Agency
1835 "K" Street, N.W.
Washington, D. C. 20460

Dear Mr. Schettino:

The City of Inglewood welcomes the opportunity of submitting to the Environmental Protection Agency pertinent information, data and experiences relating to aircraft noise. Inglewood will support the Aircraft/Airport Noise Study Task Force in the effort to formulate meaningful aircraft noise standards as mandated by the Noise Control Act of 1972.

We feel that the following steps should be taken without delay in order to improve the compatibility between airports and neighboring communities:

1. Implement steep approaches under visual flight rules immediately.
2. Implement steep approaches for instrument flight rule conditions as soon as special navigational aids are introduced to ensure a safe performance of the procedure.
3. Require jet engine retrofit for aircraft not meeting FAR Part 36 standards.
4. Lower FAR Part 36 noise levels in time intervals to provide for continued reduction of future jet noise levels.
5. Consider lowering of the present community noise equivalent level (CNEL) criterion of 65 dBA as acceptable limit value for residential areas. This criterion should not be applied uniformly to all residential areas around airports.

Sincerely,

Merle Mergell
Mayor

MM:WAB:lm

OFFICE OF THE MAYOR
MERLE MERGELL

TELEPHONES: 213/674-7111
LOS ANGELES: 213/678-7221

March 28, 1973

TG 2-83
Rec'd 4/2/73
from Lockheed

SUBMITTAL TO EPA

AIRCRAFT/AIRPORT NOISE STUDY TASK FORCE
TASK GROUP 2, OPERATIONS ANALYSIS

LOCKHEED-CALIFORNIA COMPANY
BURBANK, CALIFORNIA

In Submittal to EPA dated March 2, 1973, an analysis was provided indicating the large noise reduction potential for the L-1011 TriStar. The key position taken in this analysis was that the ability to achieve the large noise reductions shown during Approach is greatly facilitated, and perhaps dependent, on the type of automated equipment such as is incorporated in the L-1011 certificated for Category IIIA or IIIB type landings, as well as an Area Navigation System which permits the airplane to fly along any predetermined three-dimensional path. Conceivably, with such equipment, preferential takeoff paths would also be greatly facilitated and be more compatible with consistent use of prescribed operating procedures.

The use of the word "Rule" throughout the questionnaire needs clarification. There has been general agreement that all operating procedures must be subject to judgment of the pilot for its implementation during any particular landing or takeoff operation. This dependence on pilot's judgment would not reduce the effectiveness of such recommended procedures as long as they are demonstrated to be safe procedures for use other than unusual weather or traffic conditions. Since the word "Rule" implies use of the particular requirement at all times, it is suggested that a different word be selected to be associated with all the proposals in this Task Group.

TAKEOFF

In Takeoff, the concept of effecting thrust cutback should be re-evaluated to determine whether, on a footprint basis, the procedure does indeed provide a noise improvement for the community. The concept of preferential runways also would appear to be a valid concept for minimizing noise during takeoff.

Because of the different characteristics of two, three, and four engine aircraft, both of the existing type and the new widebody jets, it will not be possible to establish a single takeoff procedure. It will probably be necessary to recommend a specific procedure for each type aircraft that does result in lowest noise for the community as a whole.

LANDING

The information provided by Mr. Meyersburg indicated that an approach slope of $3\frac{1}{2}^{\circ}$ could be implemented immediately. If this information is valid, then implementation of such a change does offer noise reduction for both single and two-segment approach. The effect of such a change in the operation of all existing transport aircraft should be conducted and, if there is no impact on safety, then it should be implemented immediately. Testing on two-segment approach presently accomplished or in progress by American and United Airlines, as well as studies conducted by the airframe manufacturers including Lockheed, highly recommend the implementation of this type of approach as soon as possible. Aircraft containing the type of sophisticated electronics such as available and certificated on the L-1011 will facilitate and hasten the acceptance on a safety basis by the airline pilots. Since it is by far the most effective method developed to date for reducing noise during landing, every effort should be made to encourage its use at all airports and under all weather conditions where it is feasible. The use of thrust reversers after landing has not been demonstrated to be a community noise problem except in certain small percentage of airports. Further, there is little data available on noise caused by thrust reversers. Until such information is gathered and the magnitude of the problem determined, there does not appear to be any valid reason for prohibiting its use under either normal or hazardous conditions.

AIRPORTS

The detail problems and requirements that airport operators must resolve are best known to the operators themselves. The airframe manufacturers and airline operators have said repeatedly during the last five to six years that an answer to the community noise problem cannot be resolved completely by noise reduction at the source and operational procedures. In fact, it will require the maximum application of rational land use techniques. To date this last noise reduction technique has received little or no attention. The airport operators must be the leaders in activating government agencies to implement this most important weapon in resolving the community noise problem. Initiation of this noise reduction method will then temper the restrictions which the airport operator might be forced to designate on aircraft using the airport. The airport operators' authority to establish such restrictions is best answered by legal experts rather than Task Group No. 2.

GENERAL

All of the recommended practices discussed above should be applicable to all the aircraft serving a particular airport. This, however, must take into account earlier statements indicating that all aircraft cannot comply with given operating procedures, but rather should comply with those which result in the greatest noise reduction for them.

TG 2-50
Rec'd 3/26/73
LAX

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CLIFTON A. MOORE
GENERAL MANAGER

March 22, 1973

MEMORANDUM

TO: Randall L. Hurlburt
Chairman, Task Group 2

FROM: Bert J. Lockwood
Assistant General Manager
Operations

SUBJECT: Task Group 2 -- Position Report

The following comments are submitted in accordance with your request at the March 19, 1973, meeting of Task Group 2. As you will note, I am submitting my comments in two forms. The first is concerned with general comments on the items discussed at the March 19 meeting followed by a narrative on the numbered questions that were submitted as a position questionnaire with the agenda.

My comments are submitted on the basis that air safety has an overriding priority over all other considerations. I also feel that technological feasibility and the ability of the air transportation system to operate with a high degree of efficiency to reasonable operating weather minimums and to reasonable volumes of traffic must also have high priority.

In discussing takeoff procedures, I feel that a minimum of two procedures must be established that considers the location of the noise problem areas around an airport. It is rather obvious that some airports have a sideline problem while other airports have a problem under the departure flight path. Procedures must recognize this difference. Present FAA sound abatement departures that specify a high initial climb rate followed by a power reduction to maintain a minimum climb profile reduce the levels under the departure flight path. Departure procedures for lighter weight aircraft that use a lower engine EPR for takeoff obviously are aimed at the runway sideline problem. These types of procedures or combinations of them must be tailored to the requirements of specific airports. No procedures, however, should be required without a complete flight test validation by the appropriate authorities of FAA concerned with flight engineering and flight safety.

Landing procedures should be specified after complete validation as to flight safety and the ability to land under very low visibility conditions. I feel that the two-segment approach procedure combined with various flap management procedures should be adopted after adequate on-board guidance is developed and certificated for passenger operations. As a follow on procedure with the complete certification of microwave ILS, multi path approaches should also be utilized where it can be demonstrated that the overall impact can be reduced. This, of course, must recognize airspace requirements of all users and be compatible with the airway system.

Monitoring can be considered a valuable working tool to assess the results of the various procedures that are tailored to each individual airport. The monitoring system, however, should utilize the simplest of single event and impact methodologies. If this is not done, the entire procedure becomes to sophisticated or complicated for handling by local authority and understanding by the local populous and their political representatives. It should also be done in the simplest way possible to reduce the overall cost of the process.

I would like to make it very clear that any change recommended in flight procedures must remain within the existing state of the art and not impose an unreasonable financial penalty.

The following are comments on the numbered questions in the position questionnaire:

1. Operating rules should establish specific flight procedures for takeoff for each type and model of aircraft. I feel a minimum of two procedures should be developed recognizing the location of the problem areas as sideline or under the departure path.

2. Same as No. 1.

3. Minimum maneuvering altitudes prior to the commencement of approach have very well been established already by the FAA. For most airports at this time this is between 3,000 and 4,000 feet above runway elevation. Minimum altitudes must recognize the airspace requirements of all users in the area and must be at such an altitude to permit proper -ture of the glide slope.

4. In looking at glide slope angles we must recognize that their most important function is to provide proper descent guidance under low visibility conditions. The steepness of the angle must recognize that there is a definite limit to vertical descent rates in the critical landing phase of each operation. Glide slopes should not be increased in any location where the angle would derogate the safety of the flight. I would, therefore, oppose increasing the angle to 3-1/2 degrees for IFR operations unless it can be demonstrated by extensive flight tests that the operation would be completely safe. It should also be pointed out that increasing the angle 1/2 degree produces only minimal reductions in sound level.

5. For sake of standardization and safety, the installation of navigational approach aids must remain an FAA Federal Government responsibility. Operators have no business or expertise in these areas and should not become involved.

6. Two-segment approaches should become standard operating procedure for air transport category aircraft after all equipment has been completely certificated and the whole range of procedures approved as to safety. Studies at the present time with present technology aircraft would indicate that the upper segment should not exceed 6 degrees because of difficulty in stabilizing the aircraft on a steeper approach For safeties sake, in the first phase of a two-segment operation it perhaps should be limited to VFR until all potential problems with the system are solved.

7. Whether or not thrust reversal is used must remain within the judgment of the pilot in command. It should be pointed out here that if thrust reversal was not used most aircraft would roll out the full length of the runways, which would then place a larger number of airplanes on the ground with idling engines. This would then be trading off a slight thrust reversal sound level for a greater increase in air pollution due to idling engines.

8. The rules we are considering here should apply to the transport category aircraft and to the noisier types of business or general aviation types that are jet powered.

9. Certifying airports for noise would serve no useful purpose. The noise control would be handled through operational procedures and the certification of the aircraft.

10. This question makes no sense at this time, as we have no indication of the results of Task Group 3 work.

11. Airport operators have no expertise when it comes to considering flight procedures used by the pilots. This is something that can only be handled at a Federal level for standardization purposes by experts in the field of aircraft flight.

12. Airport operators at this time have authority to regulate the use of their facilities. The use of the words "hazardous noise" makes no sense in this question, as no agency has been able to develop a definition in regard to this.

13. In order to maintain a viable national air transportation system, the standards for airports should be set at Federal level and the Federal Government should completely preempt the areas of noise and flight regulation.

These are my comments.

Very truly yours,

Bert J. Lockwood
Assistant General Manager
Operations

BJL:sm

NASA
4/2/73

ITG 2-85
Rec'd 4/2/73
from NASA

TAKE-OFF

1. Should there be an operating rule establishing specific flight procedures for take-off?

Comment: Operating procedures can be used effectively for noise control in both landing approach and the take-off-climbout phases of the mission. Optimum conditions for noise reduction during take-off-climbout depend on the configuration details (particularly, type of engine) and operating conditions of the aircraft and thus will probably be different for each new aircraft.

2. What do you think the appropriate take-off procedure should be?

Comment: Thrust reductions will reduce aircraft noise at the source but at the same time also reduce climb gradient. Hence, evaluating noise reduction departures requires that one balance noise reduction at the source against the loss of climb gradient. Thus, one must also evaluate the effectiveness of noise abatement departures within the context of particular aircraft/airport scenarios, i.e., aircraft type and performance and the location of the area where noise reduction is required. Reduced power climbout may or may not reduce noise, depending upon the location of the noise sensitive area. For example, use of reduced power climb contracts the width of the noise footprints while expanding the length down the flight track. Hence, side-line observers along the flight track are benefitted but additional observers will be exposed down the flight track. Thus, a reduced power climb after take-off will shift the incidence of the noise by trading sideline effects against longitudinal effects. This can be considered effective if the trade-off shifts the noise from sensitive areas to non-sensitive areas. Thus, a take-off procedure for one runway may not be the optimum one for another runway. Optimum take-off procedures may have to be tailored to each runway. On the other hand, different operating procedures for each airport into which a pilot is required to operate pose additional burdens upon the pilot in maintaining familiarity with the differences and perhaps safety of operation. It is recommended that segmented take-off profiles adaptable to each airplane type be established, specifics of the profiles should be worked out cooperatively by the airlines, the manufacturers and the FAA.

3. Should there be a rule establishing minimum maneuvering altitudes prior to the commencement of approach? What should these altitudes be?

3

Comment: The ground noise outside the outer marker can be significantly reduced by maintaining a higher maneuvering altitude. Altitude of up to 6000' can produce noise improvement over large areas in the approach path to an airport. During flight evaluation of two-segment avionics in the B-727 it was noticed that the approach with a 6° upper segment could accommodate up to 190 kts IAS at 3000' to the point of upper segment capture. This speed can be increased as altitude increases up to 250 kts at 6000' or higher. The result is lower power setting at high altitude and less time at high power settings, 3000' feet is considered a minimum and higher is desirable. Where holding and maneuvering altitudes can be raised, definite reductions in community noise can be realized.

4. Should there be a rule raising the ILS glide slope immediately to 3.5 degrees?

Comment: Three degree glide slopes are generally accepted today and are standard at many airports. All new installations are planned for a 3° glide slope wherever siting conditions permit. However, about 1/3 of present glide slopes are as low as 2.5°. Noise reduction on the order of 2 to 3 dB can be had for a ½ degree increase in glide slope. No problems are foreseen as far as the aircraft and airborne equipment are concerned in flying 3.5 degree glide slopes.

5. Should operators be required to install instrumentation which would provide guidance during a two-segment approach?

Comment: A key feature of the two-segment approach which would permit approaches in both VFR and IFR conditions is provision of a continuous vertical steering command on the flight director. This is required to insure that transitions from level flight to the upper segment can be made without overshoots and those from the upper to lower segment can be made without going below the normal ILS. In addition to the safety features, the additional power needed to correct for going below the ILS is particularly objectionable because it creates higher perceived noise on the ground in the region of the transition.

6. Should there be an operating rule requiring pilots to fly two-segment approaches? What intercept altitude should be specified? What should be the angle of the upper segment?

5

Should the rule initially be VFR only? When should VFR and IFR rules be effective?

Comment: The basic concept of the two-segment approach has been well established. Recent effort has been to make the concept into a practical operational reality. The basic profile of the two-segment has been studied using both a B-720 and a B-727 and the effect of the two-segment variables are discussed below:

Upper Segment Intersect Altitude Effects - The ground noise outside the outer marker can be reduced significantly by increased altitude. A minimum altitude of 3000 feet is recommended. Altitude of up to 6000 feet can produce noise improvement over large areas in the approach path to an airport. Aircraft safety is enhanced by staying high in the heavy traffic area reducing exposure to many low flying aircraft.

Lower Segment Intersect Altitude - The ground noise inside the outer marker is greatly influenced by the lower intersect altitude. The noise improvement of a 6 degree upper segment transitioning from 3000 feet to a 2.5 degree glide slope is about 6 EPNdB for a B-727 for each 340 feet of change in the lower intersect altitude. The transition height from the 6° to the 3° glide slope has a significant effect on the centerline noise level below the aircraft. There is very little effect, however, on footprint area for transition heights from 400 to 800 feet. Low altitudes raise the question of flight safety with respect to higher rate of descent at lower altitudes and the accumulative altitude errors in any system. An additional consideration to pilot acceptance is the feeling of being stabilized in the approach. The pilots were not comfortable even when the aircraft had unchanging airspeed and zero deviation from the computed path if they didn't have about a minute to get set, following the lower transition. It is thought that experience would change this situation, as when pilots have flown many two-segment approaches, they appear to need less "set time."

Upper Segment Angle: The effect of the upper segment angle is to place the aircraft at a higher altitude and at the same time, require a lower power setting to maintain the desired airspeed. Angles above 6.5 degrees provide good sound improvements, but the transitions become more difficult and the aircraft will not stabilize with tail winds.

7

External Variables: The two-segment approach was not adversely affected by turbulence. For the B-727 aircraft, with engine and wing anti-icing on and temperatures -7°C or above, the N_1 rpm is about the minimum of 55%. In these conditions a tail wind of about 15 kts can be offset by using 40 degrees flaps. But if the icing is such that 70% N_1 is required for anti-icing, or the tail winds are in excess of 15 kts, then the approach, as constituted, could not be flown. These conditions exist less than 1% of the time. Tail winds in excess of 30 kts present a problem of airspeed stabilization and throttle position. Less than 30 kts are maneuverable. Cross wind effect is the same as the standard ILS. There is no noticeable difference in visibility between the two-segment approach and the standard ILS. The two-segment approach permits a better view of the terminal area under all lighting conditions than does the standard ILS, yet the descent angle is not so steep as to give the pilot the impression of his descending into a hole at night.

General Consensus: A summary of the reactions of guests pilots who participated in the off-line evaluation of two-segment approaches in the B-720 and the B-727 to the question, "Do you feel the two-segment approach you have flown can be flown in normal line operation?" is given below:

1. The two-segment approach is practical and acceptable and easier to fly than anticipated.

2. Safety is not compromised

3. There is considerable similarity to the standard ILS.

4. Workload increase is slight

5. Stabilization on the glide slope occurs sufficiently above the TDZ.

6. Positive guidance is provided throughout

7. Annunciation and instrumentation are satisfactory.

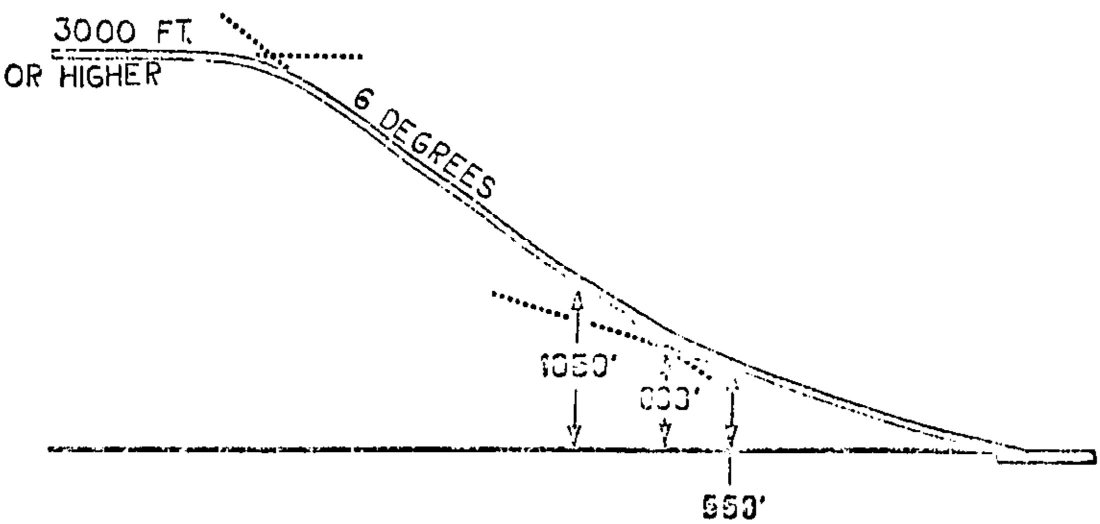
8. Transition to upper segment and glide slope are smooth.

9. Operational techniques involved are basically similar to the standard ILS.

10. Utilize conservative weather minimum for introduction into line service with a gradual reduction as experience is gained and system reliability demonstrated.

As noted above, the operational feasibility of the two-segment approach as presently constituted has been

2-SEGMENT PROFILE



determined for only two aircraft types. Steps are now underway to provide a similar evaluation in the DC-8. Also the results will be extrapolated to the DC-9, DC-10, B-737, B-707 and B-747 jet transports by an analytical and simulation program. These efforts will be completed prior to the end of FY 74.

Before implementation of a two-segment approach, there should be a study to determine the impact on ATC of intermixing different approach profiles in the terminal area especially during a transition period. An analytical study should be conducted to determine the requirements on the availability and location of the ground navigational aids used as inputs to the airborne navigation equipment used in generating the upper glide slope.

It is considered very desirable for the same profile and procedures to be used in both VFR and IFR conditions.

As far as availability of ground and airborne avionics are concerned, start of implementation of two-segment approaches could commence within one year from the time action is taken requiring implementation. It is estimated that it would require from three to four years to equip all aircraft and equip approximately fifty runways where noise is a severe problem and where two-segment approaches could provide some relief.

7. Should there be a rule prohibiting the use of thrust reversers on dry runways unless required by ATC or unless runway length or atmospheric conditions require their use in the interest of safety?

Comment: Use of thrust reversers have many beneficial effects including safety, shortening runway occupancy time, pollution reduction because of less taxi time, and less maintenance cost to the airlines for brakes and tires.

AIRPORTS

9. Should airports be certificated for noise?

Comment: There should be several levels of certification, and an airport should be certified at a level which would depend on a number of factors such as location in the urban complex, type of aircraft which will use the airport, hours during which it will permit operations, etc.

12. Should airport operators be authorized to designate preferential runways, establish curfew hours on designated runways, limit ground maintenance runups, establish airport

use fees based on noise, restrict the number of operations at the airport, restrict use of the airport to aircraft of specified type, weight, trip length, etc., or otherwise conduct the operation of the airport in such a manner as to assure that no area is exposed to unacceptable noise?

Comment: The air transportation system is a national system of airports, aircraft and airways. Restrictions imposed locally may have far reaching implications. The complexity of scheduling and operation, and the limited availability of some of the essential aspects of the air transportation system such as airports, aircraft, traffic routes, and aircraft maintenance facilities all seem to indicate that there should be national uniformity of regulations wherever possible so that air transportation may be conducted with maximum safety and efficient use of the National Aviation System.

ADDITIONAL QUESTIONS

16. Are there any other rules which should be considered?

Comment: While many laws and rules relative to aircraft are or have been proposed and enacted by various regulatory bodies, very few laws are in effect regarding proper land use in the vicinity of airports. New residential communities, apartments, schools, etc. are continually being constructed under the approach and departure paths to over present airports. Thus, some remedies of the noise problem should be sought through rezoning sound proofing of present structures, relocation, and prevention of residential use of land in the vicinity of airports. A primary cause of environmental incompatibility between the surrounding neighborhood and the airport operations is the result of uncontrolled urban encroachment upon the airports after they have been developed.

Task Group 1(3)
Mastered
rec'd 5/14/73
from NBAA

NATIONAL . . ASSOCIATION, Inc.

May 14, 1973

Mr. Randall L. Hurlburt
Office of Noise Abatement and Control
Environmental Protection Agency
1835 K Street, N. W.
Washington, D. C. 20460

Dear Mr. Hurlburt:

The following are the NBAA responses to your questionnaire dated March 19, 1973:

1. Optimized takeoff procedures should be developed for each airplane type to reduce noise pollution. These procedures should be incorporated in the FAA-approved airplane flight manual and/or Part 91 of the Federal Air Regulations for each particular airplane. The two procedures, one for a standard takeoff and one to be used when a noise-sensitive area is in the proximity of the departure end of the runway, should be developed and widely publicized for the education of and adherence by all pilots operating each airplane type. It is quite possible that some airplane types, which amply meet the requirements of FAR Part 36, would only require a single takeoff procedure. This could be determined by proper analysis of FAR 36 certification data.

2. Appropriate takeoff procedures should be determined by the FAA and the aircraft manufacturer after a thorough and concise analysis of all performance data.

3. A rule establishing minimum maneuvering altitudes prior to the commencement of an approach appears unnecessary. However, the United States Standard for Terminal Instrument Procedures (TERPS) which prescribes standardized methods for use in designing instrument flight procedures, should be amended to specifically require the use of higher minimum maneuvering altitudes consistent with safety and acceptable airspace/air traffic management.

4. The FAA is currently pursuing a program to raise all ILS glide slopes to approximately three degrees. Increasing the glide

slope angle to 3.5 degrees may reduce the margin of safety, increase the Category I weather minimums, and increase the aircraft landing or rollout distance. We encourage further study of this subject.

5. & 6. NBAA has, for many years, supported the use of the two segment (6 and 3 degree) approach under VFR conditions. Likewise, NBAA has and will continue to encourage further development of instrumentation and procedures which will permit use of the two segment approach under all weather conditions. Our final position on the two segment approach will await the results of the current on-going program.

7. NBAA would oppose a rule prohibiting the use of thrust reversers on dry runways. The definition of dry runway is not present in the aviation dictionary and the non-use of thrust reversers can effectively reduce runway capacity.

8. Noise reduction operating techniques should apply to all turbojet and heavy aircraft.

9. Airports should not be certificated for noise. Aircraft noise reduction can be achieved through (1) improved operational/procedural techniques, (2) quieter aircraft engines, (3) selection of quieter engines for aircraft not meeting the requirements of FAR Part 36, (4) retrofitting existing engines if technologically proven and economically reasonable, (5) retiring the noisier aircraft types, (6) prohibiting the continued production of non-FAR Part 36 aircraft, (7) wise land use planning, and (8) reclaming certain land areas around the most noise sensitive airports.

10. No comments. Hazardous noise has not been defined.

11. Noise levels for aircraft and procedures to be used by pilots must be established and approved at the national level if we are to maintain a viable national air transportation system. The Noise Control Act of 1972 must not be interpreted as a nullification of the Federal Aviation Act of 1958. Rather this legislation (Public Law 92-574) portrays increasing Congressional interest in this nation's airport system and that system's contribution to the continued growth of intrastate, interstate, and international air commerce.

12. through 15. The FAA is charged with ensuring the safe and efficient use of the nation's airspace, and with fostering civil aeronautics and air commerce. The FAA is the sole authority for designating preferential runways. Appropriate procedures, which provide for consideration and analysis of the needs of airport management and near-airport neighbors, are contained in FAA Order 7110.13, FAR Part 91, and the Terminal Air Traffic Control Handbook, 7110.8. Experience shows

that preferential runways have and are being designated at those airports having an aircraft noise problem. At a few airports (for instance, the Latrobe Airport near Pittsburgh, Pa.) preferential runway use program has been wisely implemented before the noise problem surfaced.

The dividing line where the FAA's authority ceases and the airport operator's authority begins is a classic legal question, certain aspects of which are now being considered by the Supreme Court of the United States. However, aircraft owners and operators, who successfully meet the Federal requirements for owning and operating private aircraft and pay registration, tire & tube, and fuel taxes to the Federal, state and/or local governments, rightfully demand unrestricted access to the nation's airport and airway system. These same owners and operators fully support all reasonable attempts to reduce aircraft noise pollution through quieter engines certificated by the Federal government, optimized operational procedures prescribed by the FAA, and wise land use planning and reclamation around the nation's airports. They are willing to curtail ground maintenance runups during the normal sleeping hours and they accept this requirement as a part of a landlord/tenant contract.

16. No comment.

17. The owners/operators of a few turbine powered and heavy aircraft have equipped their aircraft with 3D RNAV equipment. A very small number have, with the cooperation of the FAA, obtained approval for 3D approaches at a few low density airports. As more lower cost 3D RNAV equipment becomes available, it can be safely assumed that more business aircraft operators will equip their aircraft with this equipment. The FAA, in the published FAA/Industry RNAV task force report dated February 23, 1973, has stated that it will continue to develop 2D/3D approaches for all airports to the extent practicable, consistent with IFR requirements. It is at these airports that business aircraft need such a capability which, while providing non-precision approach minimums, will also provide for steeper and/or varied approach slopes and reduce noise pollution.

Sincerely,

Lawrence P. Bedore
Manager, Airports Services

LPB/te

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National Organization to Insure a Sound-controlled Environment

TG 2-87
From NOISE
Rec'd 4/2/73

April 2, 1973

TO: Randall L. Hurlburt, Chairman
Task Group 2
Aircraft/Airport Noise Report Study

FROM: Lloyd Hinton

SUBJECT: Response to Position Questionnaire dated 3/19/73

N.O.I.S.E. believes that the earliest and greatest reductions in aircraft noise can be achieved through the urgent implementation of optimized operating procedures. The FAA and the airlines, through the ATA, have done little more than "talk" about the availability of procedural changes since they were officially recommended in the Report of the President's Airport Commission, "The Airport and Its Neighbors," submitted to President Truman in May of 1952. Finally, in August 1973, the ATA member airlines "voluntarily" adopted a noise abatement departure procedure which the FAA subsequently last November incorporated it in toto in a "Project Report" which acknowledges the need for noise abatement operating procedures.

While the ATA/FAA takeoff procedure is hardly optimized for either reduced noise or operating efficiency (unaccountably), it does represent at least recognition such procedures are necessary, do not necessarily derogate safety and must be implemented on a systemwide basis.

The increased interest in operating procedures on the part of the ATA/FAA undoubtedly is a result of the growing pressure for acoustic retrofit. This writer believes noise reductions comparable to those obtainable with full nacelle treatment are available through procedural innovations. On approach, such changes will require new instrumentation and control equipment which is readily available. In addition to reduced noise, the use of noise procedures with associated equipment will result in improved safety, operating economies, and all weather capability.

It is appropriate to note that the NWA takeoff procedure developed by Captain Soderlind has a far better effect in close-in severe noise impacted areas than does the ATA/FAA procedure. Furthermore, while I have not corroborated the point with Captain Soderlind, I feel certain he would not agree--as claimed by Captain Treece and Roger Flynn of ATA--that the ATA/FAA procedure results in greater noise reduction, improved safety, or any other benefit other than operator convenience and the opportunity to claim again that "everything" humanly possible is being done.

The following are my comments on your questions:

Takeoff

1. Yes--"voluntary" regulation does not work as evidenced by the poor compliance since last August with the ATA procedure.

2. Essentially the NWA procedure with one important difference. The need for standardization so fully met in the NWA procedure should be made flexible to the extent that two related techniques be employed as follows:

a) Designate each runway served by turbine engine aircraft as Noise Control A or Noise Control B. "A" would be designed to best serve the situation where the problem area is greatest upwind of the runway. "B" would account for the rarer situation typified by LAX, where exposure on the sideline constitutes the greater problem.

b) Noise Control Takeoff "A"

1. Rotate precisely on the numbers.
2. Establish foredetermined deck angle
3. Maintain V_2 + 10 knots.
4. At 1,000 feet reduce deck angle to 35% of initial climb angle.
5. Accelerate (at max. power) to V_{zf}.
6. Retract flaps as soon as speed schedule permits.
7. Upon reaching V_{zf}, reduce power to "quiet thrust" per NWA schedule.
8. Maintain V_{zf} and quiet thrust to 4,000 feet (rate of climb about 1,200-1,500'/minute).
9. At 4,000 feet reapply max. continuous power.

Note: The following common errors were observed with NWA execution of its procedure. Failure to reduce deck angle sufficiently to allow rapid acceleration. Failure to retract flaps as early as speed permits. Failure to reduce to "quiet thrust" as flaps reach zero.

c) Noise Control Takeoff "B"

1. Accelerate to V_2 + 20 prior to rotation.

2. Rotate to angle equal to one half that needed to maintain V_2 + 10 at max. power.

3. Accelerate to V_{zf} maintaining low deck angle.

4. At V_{zf} retract flaps to zero.

5. At zero flaps reduce power to "quiet thrust" per NWA schedule.

Landing

3. Yes--3,000 feet AFL obstructions permitting.

4. No--rule or order raising all ILS glide slopes--on a crash program basis--to 3.0 degrees (actual not "nominal") would be most beneficial. Going higher than 3.0 degrees will likely result in inhibiting introduction of two segment and/or decelerating approaches.

5. Yes--such instrumentation would pay for itself through operating economies in one to two years. The instrumentation should be RNAV having three dimensional capability rather than requiring co-located DME on each ILS equipped runway. Back course glide slopes should also be installed on all runways serving jet equipment where only VASI or no instrumentation currently exists.

6. Yes--the operating rule should require immediate use of visual two segment procedure per PSA/Air California/ National at Miami. IFR procedure should be implemented on a schedule commensurate with the instrument manufacturers' ability to provide equipment. Indoctrination and training of pilots should proceed simultaneously. This writer prefers use of decelerating technique as having greater potential for safety and operating efficiency over today's methods. According to the results of the NASA-Ames tests conducted by American Airlines in August/September 1971, the six degree initial interception of the three degree glide slope at 400 feet is completely safe and offers maximum noise benefits.

7. No.

General

8. All aircraft systemwide. In emergency situations aircraft could very well be exempted from employing the upper segment or the decelerating technique if selected.

Airports

9. Yes--just as all operating civil aircraft should be certificated for noise control purposes, so too should airports as to the impact of their operations on adjacent land areas. An additional logical extension is the certification of pilots as to their training and competence in flying noise abatement procedures.

10. Yes--EPA must establish noise control "guidelines" which become mandatory upon airport operations. If aircraft changes including operating procedures are insufficient to contain the area of exposure to avoid noise sensitive land uses and land use changes cannot be adequately implemented, the ultimate alternative is curtailment of airport operations leading even to shutdown (presumably a new or alternate airport would be available). No more than ten more years (1983) should elapse before a total solution must be achieved by each airport/community with curtailed operations following that.

11. No--maximum single event levels should be specified by EPA standard. If state government desires lower levels (both single event and cumulative), it has constitutional authority to impose limits on airports within state. Asking airport operators to establish and impose such standards places them in untenable position in which they cannot act.

12. Yes--airport operators currently have proprietary authority--which FAA has long exercised at WNA--to accomplish the full range of noise control measures. However, for unknown reasons the airport operators collectively have not had sufficient incentive to act. As in the case of some airlines, some airport operators have acted out of humanitarian reasons.

13. No--State governments acting at the request of or authorizing local governments should select standards. The

point is that general purpose government rather than single purpose entities such as airport operators should resolve conflicts between environmental and commercial interests.

14. Undecided.

15. Nationwide including military and general aviation. (Note: military requires additional consideration since aircraft will not be designed with noise control as a mission requirement.)

Additional Questions

16. Yes--EPA sets national noise exposure criteria which becomes mandatory guidelines. FAA, HUD and other federal agencies administering state and local grant funds be required to use implementation of noise control/land use measures as additional criterion.

17. Yes--improved ground and airborne instrumentation/ control systems have long been needed for safety and operating efficiency as well as safety. NASA should be formally assigned full R&D role responsibility for civil aeronautics including certification for safety. FAA role should be redefined and limited to routine enforcement of standards and procedures set by EPA and developed and certificated by NASA.

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203 - 633-2835
National Organization to Insure a Sound-controlled Environment

TG 2-175
from NOISE
Rec'd 7/2/73

Mr. Randall Hurlburt
Chairman, Task Group 2
Aircraft / Airport Noise Study Task Force
U.S. Environmental Protection Agency
Crystal Mall Building 2
Arlington, Va. 20460

Dear Mr. Hurlburt,

I have attended all meetings of Task Group 2, and have reviewed the Draft Report "Operation Analysis Including Monitoring, Enforcement, Safety, and Costs" dated June 1st, 1973. I am familiar with and have long participated in the development of aircraft noise abatement takeoff and approach procedures. I have conducted pilot training programs in the use of these procedures.

Our organization presents the following as our position on this subject:

1. We subscribe to the recommendation that airport certification, as discussed in our position paper to Task Group 1, be used as a means of controlling aircraft noise exposure in areas around airports.
2. We recommend that NASA be required to certify noise abatement aircraft configurations and operating procedures and the FAA be required to implement noise level limits and operating procedures by promulgating regulations.
3. We recommend that airport certification by the FAA be based on a selection by the airport operator, working with the regional land-use planners, of land areas which are to be subjected to aircraft noise exposure above specified levels. These areas can be selected using aircraft types, numbers of operations, time of day and operating procedures required to provide the desired air transport service and, at the same time hold the size of the areas exposed to specified levels to quantities which can be zoned for or converted to land uses compatible with these noise exposure levels.
4. Having defined the noise exposure contour for the airport as a whole, the airport operator can assign portions of this noise exposure to the various airlines operating at this airport. The

airlines will then select aircraft types, numbers of operations, times of day and operating procedures, to stay within their assigned contribution to the total noise exposure.

Sincerely,

Lloyd V. Hinton

Executive Director

<u>POSITION QUESTIONNAIRE COMMENTS</u>

<u>TASK GROUP 2</u>

<u>ROCKWELL INTERNATIONAL</u>

The following comments are directed to the TG-2 Position Questionnaire dated 3/19/73. All observations are made from the viewpoint of a General Aviation manufacturer of light single and twin engine aircraft including turbo-prop and business jets.

<u>TAKEOFF</u>

We oppose a rule establishing specific flight procedures for takeoff. Each airport and its surroundings are unique in one respect or another. Aircraft configuration and performance features vary as a function of design. A noise abatement procedure at one airport may be entirely inadequate, unsafe, or even unnecessary at another. We believe that aircraft should be certificated in accordance with the applicable FAA regulation (FAR-36, for example) and that any supplementary noise abatement requirements should be included, at those airports where such procedures are considered necessary, in Jeppsen charts or other mission planning guides.

<u>LANDING</u>

A rule establishing minimum maneuvering altitudes prior to commencing approach appears reasonable at some locations. Such a rule should not be promulgated, however, without a comprehensive evaluation program to establish altitude limits for the various classes of aircraft.

A 3.5 degree glide slope also appears feasible but should be carefully studied before establishing any new rule. We would recommend an evaluation program including general aviation type of aircraft and then, if the procedure proves safe and effective, an interim rule for VFR only. Operators should not be required to install two segment approach instrumentation at this time.

We oppose any rule that would limit the use of thrust reversers because of possible compromises to safety of operations.

AIRPORTS

We believe that airport operators should have considerable latitude in defining the requirements for operations in and around their facilities. We do not believe, however, that such latitude should extend to the authorization to specify a given level of noise as hazardous. Such knowledge would normally be beyond the qualifications of an airport operator. We believe that noise monitoring equipment would prove beneficial but we see no useful purpose in certificating airports for noise.

Rec'd 4/3/73
from Bennin (NY)
AGN - 8170

To: Task Group 2

From: Robert Bennin

Date: March 27, 1973

Subject: Response to Position Questionnaire.

TAKEOFF

1. Yes. Operating procedures similar to those discussed in FAA project report by R.D. Shreve should be implemented immediately as a FAA rule. As part of the operating procedure the deck angle of the aircraft should be increased to greater than the present 14° - 15°. Some discussion centers around a deck angle of 20° plus.

2. The takeoff procedure should be developed from the findings of the work being done by Northwest, Air California, Pacific Southwest Airlines, and the Shreve report mentioned above.

LANDING

3. Yes. While I am aware of the data and discussion regarding minimum maneuvering altitudes, I can only say that they must be high enough to mimimize the noise impact on the ground and yet provide safe transition for a two-segment approach. PSA and Air California data should be studied carefully so that a standard operating procedure applicable to all of the national airports can be developed.

4. Yes. Those airports that have ILS would provide for proper attitude of aircraft during descent. There should be an increase in the glide slope angle to a minimum of 3° and then incrementally to 3.5° while operating procedures for two segment operations are being developed.

5. Yes. Maneuvering instrumentation should be installed by the same agency responsible for installing navigational aids, radar and other safety devices.

6. The existing framework of FAA rule making should be used to implement two-segment approaches. This would be similar to the take off procedures specified in the Project Report by R.D. Shreve, Ammendment to FAA Regulations, To Provide For a Take-off Noise Control Operating Rule, dated Nov. 15, 1972 and Nov. 21, 1972.

Intercept and maneuvering altitudes should be developed to provide maximum height over the community and to be applicable at all the nation's airports.

Some variation of a two segment approach should be VFR only. As instrumentation and installation at airport runway proceeds, tighter two-segment glide angles should be imposed based on IFR.

7. Other considerations than those listed should be reviewed eg. length of time aircraft is on active runway, duration of air and noise pollution because of increased taxi operation. We might consider a combination of thrust reversal and brakes to optimize the factors listed.

GENERAL
Immediately

8. The rules considered above should apply to all category jet transport as listed in Part 36. Rules for general aviation aircraft should also be considered for later implementation.

9-10. Airports should be certificated for noise in the same way as for safety. It is suggested that airport operators be responsible for monitoring and maintaining the cumulative noise exposure that is being suggested in TG 3. Under the airport certification, the airport operators would be authorized to use receiver control options listed in 12.

Using an incremental time frame, beginning immediately with VFR operating procedures, and then going to tighter procedures as IFR instrumentation is installed. Dates are still to be determined depending on full equipment availabliity and cost.

11. Yes. The purpose would be to isolate chronic offenders and permit the airport operators to intiate special action when necessary.

12. See questions 9 -10.

13. It is hoped that the standards set will be the lowest possible; the best standard would be one that applied to all airports equally.

Noise levels should be prescribed in such a manner that it should never be necessary for the airport operator to exersize individual judgement in this matter. To permit individual operators to specify noise levels would only serve to further confuse the picture.

14. Noise monitoring should be required for both single noise events and cumulative noise measurements. The single event could be combined in the cumulation, using a threshold to flag excessive levels. Location of monitors should be dictated by the size of the airport and the community exposed, these will vary from airport to airport.

15. These rules should apply to all airports described by FAR 36 in the jet transport category.

A priority to install instrumentation for operating procedure should be established on the basis of those airport communities most severely impacted and could include the following considerations:

a. property exposed

b. frequency of flights
c. type of aircraft
d. topographic constraints
e. weather constraints
f. lenght of runways
g. land locked

R. Bennin
4/3/73

DRAFT - WORKING DOCUMENT

REGULATORY FRAMEWORK
Airport/Aircraft Regulation

The airport/aircraft regulation as proposed here is intended to substantially enlarge the scope of existing FAA regulations and regulatory procedures. The regulations adopt the procedural framework of FAA rule making, thus affording uniform adminstrative compliance with regard to aircraft operations. The proposed regulations incorporate a number of substantive noise abatement procedures and technology and divide the responsibility for controlling noise emissions from aircraft operations.

I The first of these regulations addresses itself to airport certification and contains a list of those activities deemed to be under the control of the airport operator. This section sets no specific sound level standards for aircraft, nor does it attempt to relate the setting of sound level standards to the framework of airport/aircraft activities. It does, however, set penalties for noisy aircraft operations and incentives for control technology.

II The second of these regulations is divided into two sections and applies to certain activities and devices deemed to be under the control of the aircraft operators/owner. Since noise emission levels depend heavily on individual aircraft characteristics, control is best achieved by operating procedures and/or technical retrofit.

III The third regulation establishes the maximum permissible noise levels for different thrust/class engines and sets the time frame for their manufacture. This section provides the framework for an advanced technology of quiet engines.

PROVISIONS

I AIRPORT CERTIFICATION

This section authorizes the airport operators to act to protect the inhabitants within a given noise contour, from the effects of noise, and establishes the responsibility for monitoring and maintaining the cumulative noise exposure level. This section further provides that the airport operator extablish by a specific date, airport procedures included but not limited to:

- landing fee schedules
- quotas
- restrictions
- preferential runways
- curfews
- land use
- land acquisition

II AIRLINE OPERATOR/OWNER

This section provides that the airline operator/owner, implement take off and landing procedures and a schedule of engine retrofit in accordance with the following:

Date/Immediate/takeoff procedures and 1 segment glide angle

Date/+1 takeoff procedures and 2 segments VFR glide angle

Date/+2 takeoff procedures and 2 segments steep VFR glide angle

Date/+3 takeoff procedures and nacelle retrofit

Date/+4 takeoff procedures stop nacelle retrofit and begin reform program

This section also provides that the airline operator/owner shall be responsible for maintaining the established maximum permissible noise level for individual aircraft or the mix of aircraft in their fleet.

III AIRCRAFT ENGINE MANUFACTURERS

This section requires the development of a new generation of aircraft engine to be installed on aircraft manufactured after a specified date.

Date	Engine,Class	Allowable Level
+1		5 below FAR 36
+2		10 " "
+3		15 " "

COUNTY OF ORANGE

ROBERT J. BRESNAHAN
DIRECTOR OF AVIATION

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ORANGE COUNTY AIRPORT

April 4, 1973

Mr. Randall L. Hurlburt
Office of Noise Abatement and Control
Environmental Protection Agency
Washington, D.C. 20460

Dear Randy:

Listed below are the Orange County Airport's answers to the position questionnaire for Task Group 2 submitted by you on March 19, 1973:

TAKEOFF

1. Should there be an operating rule establishing specific flight procedures for takeoff?

   Answer: Yes. At some of the larger airports we would agree that probably two procedures should be developed for departure profiles depending on the airplane model. At some airports, like Orange County Airport where we have seven to ten business jets a day, it is imperative that a rule be established to require this type of aircraft to be flown in a specific flight procedure. There is absolutely no reason to legally allow a Lear Jet to depart any airport climbing at 500 feet a minute.

2. What do you think the appropriate takeoff procedure should be?

   Answer: A standard procedure should conform to the recommended procedures of the International Civil Aviation Organization's "Report of the Special Meeting on Aircraft Noise in the Vicinity of Aerodromes" dated 25 November-17 December 1969. These procedures are superior to the ATA, ALPA, or proposed changes to FAR Part 91 because they do not require one-engine-out power on all engines at all times and do authorize power cutback at 700 feet AGL where it does some good for airports with a close-in noise problem. I also feel that the FAA should establish climb profiles and enforce them.

LANDING

3. Should there be a rule establishing minimum maneuvering altitudes prior to the commencement of approach? What should these altitudes be?

   Answer: Yes. 3000 feet AGL.

4. Should there be a rule raising ILS glide slopes immediately to 3.5 degrees?

   Answer: I am not convinced that we could raise the ILS glide slopes immediately to 3.5 degrees, but if a thorough study indicates it is safely possible, I feel it should be done.

5. Should operators be required to install instrumentation which would provide guidance during a two-segment approach?

   Answer: I am assuming that the operator referred to in this question is the aircraft operator and not the airport operator. Again, I am not convinced that the hardware is available for a safe two-segment approach. I do feel, however, that the Task Group ought to make strong recommendations to Congress to appropriate research and development money to accelerate the research and development necessary for this project.

6. Should there be an operating rule requiring pilots to fly two-segment approaches? What intercept altitude should be specified? What should be the angle of the upper segment? Should the rule initially be VFR only? When should VFR and IFR rules be effective?

   Answer: Two-segment approaches should become standard operating procedure once the procedures and hardware have been developed that would require them to be completely safe. The intercept altitude and the angle to the upper segment will be established by research and thorough investigation. I can see no reason why two-segment approaches cannot be made now under VFR conditions. Any time the weather is 3000 feet, 5 mile visibility the airlines ought to be able to safely fly two-segment approaches.

7. Should there be a rule prohibiting the use of thrust reversers on dry runways unless required by Air Traffic Control or unless runway length or atmospheric conditions require their use in the interest of safety?

Answer: Abolutely no. Noise from thrust reversers is not a major problem at most airports.

GENERAL

8. To what aircraft should any of the rules considered above apply?

   Answer: The rules we are considering on this Task Group should apply to the transport category aircraft and to the business or general aviation type that are jet powered.

9. Should airports be certificated for noise?

   Answer: No. As a matter of fact I do not visualize how an airport could be certificated for noise. It appears that any contour established by the Federal Government in a certification plan would certainly be drawing the boundary lines for litigation.

10. Should airport operators be required to assure that no area is exposed to hazardous noise as defined by Task Group 3? By when?

    Answer: This question is premature. I do feel, however, that once the Federal Government has established a hazardous noise level we would all work toward reducing the hazard to people on the ground within a specific time frame, maybe within ten years.

11. Should airport operators be authorized to specify maximum single event noise levels for aircraft or procedures to be used by pilots?

    Answer: Yes. The Orange County Airport has adopted a single event noise level and we intend to prohibit aircraft exceeding that level during the safe operation of the aircraft.

12. Should airport operators be authorized to designate preferential runways, establish curfew hours on designated runways, limit ground maintenance runups, establish airport use fees based on noise, restrict the number of operations at the airport, restrict use of the airport to aircraft of specified type, weight, trip length, etc., or otherwise conduct the operation of the airport in such a manner as to assure that no area is exposed to hazardous noise?

Answer: In my opinion airport operators now have the authority to establish curfew hours, limit ground maintenance runups, establish airport use fees based on noise, restrict the number of operations at the airport and restrict the use of the airport to aircraft of specific weights. The Orange County Airport is now doing all of the above. Taking all of the steps mentioned above does not assure that the operation of the airport will be compatible with the neighboring communities. The term "hazardous noise" should be removed from this question since it has not yet been established.

13. If local conditions require, should airport operators be authorized to specify a lower level of noise as hazardous and adjust their airport operations accordingly?

    Answer: No. I feel that whatever level of noise is classified as "hazardous" must be developed and established by the Federal Government and applied to all airports.

14. Should noise monitoring be required for single event noise? for cumulative noise? How often and at how many locations should monitoring be conducted?

    Answer: Yes. I agree that noise monitoring at the larger air carrier airports probably would not accomplish very much, but for smaller general aviation airports that do have a problem it is a very effective public relations tool, and the proper monitoring system will allow the airport operator to establish noise abatement procedures most effective for his airport. Sometimes all it takes is a 10 degree turn to reduce the noise impact of residential areas.

15. To what airports should any of the above considerations apply?

    Answer: All airports served by certificated scheduled airlines.

16. Are there any other rules which should be considered?

    Answer: I feel that it should be mandatory to give training to general aviation jet pilots in noise abatement and the effect of noise on people on the ground. The use of simulators by business jet aircraft manufacturers could do a great deal in training general aviation pilots on the noise problem and the most effective way to fly the aircraft to reduce that problem.

Randall L. Hurlburt
April 4, 1973
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It is important that members of the Task Group keep in mind that air safety must have an overriding priority over all other considerations when discussing the noise problem and operational changes that might alleviate the effect of noise on persons on the ground. The noise problem cannot be solved overnight, and now is no time to panic into attempting untested procedures or operational changes that may place the pilot in an embarrassing position.

Respectfully submitted,

Robert J. Bresnahan
Director of Aviation

RJB:b

Task Group 2-136
rec'd 4/14/73
(from San Jose)

CITY OF SAN JOSE
CALIFORNIA

AIRPORT DEPARTMENT

April 4, 1973

Mr. R. L. Hurlburt, Chairman
Task Group 2
Environmental Protection Agency
Washington, D. C. 20460

Dear Randy:

The following are my answers to your Position Questionnaire of 3/19/73:

1. Yes, there should be rules, however, it will probably be necessary to have more than one rule, since some variation in departure will be desirable to accommodate the differences in the areas surrounding airports.

2. In our particular case, maximum climb consistent with safety appears to be the most acceptable. In most cases, it is recognized that a power cutback is desirable at many airports.

3. I do not believe this is necessary, and the problem can better be handled by controlling departure and patterns to be used under all conditions.

4. I do not believe this should be done immediately. There appears to be questions as to the degree of safety. Should be implemented if and when it is determined to be a safe operation and would would not adversely affect Category II operations. While glide slopes have a preponderance to reducing noise in an area under a given noise trend, if the 4.5 degree glide slope were used at San Jose, it would diminish our approach problem to a land area that is easily controlled.

5. If, by operators, you mean airport operators, then "No". It is historically provided by the FAA. If you mean airline operators, then "Yes", and they may wish the financing to come from a user fee in the form of a ticket or head tax.

6. Yes, two-segment approaches should be effective under VFR conditions, with intercept altitude from 800' to 1000'. I would recommend that initially the upper angle be 5 degrees rather than 6 degrees, to make it more easily adapted to by pilots. IFR rules should be effective upon installation of the proper equipment and proper pilot training.

7. No, I would rather state, as policy, that the amount of power to be used on dry runways be held to low values for noise abatement purposes. Reverse thrust should be used to a small degree to be in position for safety in deceleration.

8. To all jet and turbojet aircraft.

9. No, it should not be done without the Federal unless they are willing to assume the liability for noise generated within their criteria.

10. I cannot answer this until I know how "hazardous noise" is defined by Group 3.

11. Yes. The maximum noise level should be specified by the airport operator and if unreasonable or unsafe, the air carriers can refuse to serve the airport, as well as an airport assuming liability for noise generated as a result of the use of the airport must have the jurisdiction of controlling the noise generated.

12. Yes, to all except the last phrases; I will have to see the definition of "hazardous".

13. Yes, as well as airports are legally liable. No, if they are held to be not liable for noise.

14. While noise monitoring can be very useful, I believe it should not be required at every airport.

15. Should be left to the discretion of the airport and surrounding community; to all airports having traffic consisting of turbojet or jet powered aircraft.

16. Airports must be able to set VFR patterns used by air carrier and all other aircraft. This is extremely important in controlling

traffic as to flight pattern and altitude in relation to noise sensitive areas near the airport, and should be done with new legislation.

17. No Comment.

Very truly yours,

James M. Nissen
Airport Manager

JMN:ej

Appendix C

TASK GROUP 2 MEMBERSHIP

Chairman

Randall L. Hurlburt	Environmental Protection Agency

Members

William B. Becker	Air Transportation Association
Lawrence P. Bedore	National Business Aircraft Association
Russ Belles	Rockwell International
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James Johnson	Environmental Protection Agency
H. Ray Lahr	Air Line Pilots Association
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Charles P. Miller	Aircraft Owners & Pilots Association
James Mullins	Federated Department Stores
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Donald A. Schelp	Boeing Company
William R. Sonneman	Trans World Air Lines
James R. Thompson	Lockheed Corporation
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GLOSSARY

AC	Advisory Circular
AFL	Above Field Level
ALPA	Air Line Pilots Association
AOCI	Airport Operators Council International
AOPA	Aircraft Owners and Pilots Association
ATA	Air Transport Association
ATC	Air Traffic Control
dB	Decibels
dBA	Decibels A-Weighted
DME	Distance Measuring Equipment
EPA	Environmental Protection Agency
EPNdB	Effective Perceived Noise Decibels
FAA	Federal Aviation Administration
FAR's	Federal Aviation Regulations
FY	Fiscal Year
IFR	Instrument Flight Rules
ILS	Instrument Landing System
L_{dn}	Day/Night Average Noise Equivalent Level
NASA	National Aeronautics and Space Administration
NBAA	National Business Aircraft Association
NEF	Noise Exposure Forecast
NOISE	National Organization to Insure a Sound-controlled Environment
PNdB	Perceived Noise Decibels
PSA	Pacific Southwest Airlines
R-Nav	Area Navigation
V_2	Safety Speed in Takeoff Configuration
V_x	Maximum Angle of Climb Speed
VAM	Visual Approach Monitor
VASI	Visual Approach Slope Indicator
VFR	Visual Flight Rules
V-Nav	Vertical Navigation
VORTAC	Very high frequency Omnidirectional Range and Tactical Air Navigation Radio Navigation Facility

Pacific Southwest Airlines

NOISE ABATEMENT SEGMENTED APPROACH

VISUAL CONTACT WITH AIRPORT MUST BE ESTABLISHED
PRIOR TO INITIATING APPROACH AND MAINTAINED
THROUGHOUT ENTIRE APPROACH