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NATIONAL MEASURE OF AIRCRAFT NOISE IMPACT THROUGH THE YEAR 2000

JUNE 1975

U.S. Environmental Protection Agency
Washington, D.C. 20460

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Prepared for:

U.S. ENVIRONMENTAL PROTECTION AGENCY
Office of Noise Abatement and Control
Washington, D.C. 20460

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Preface

In releasing this report for public availability, some comments are appropriate to provide the reader with a balanced perspective related to the assumptions and conclusions provided herein.

- The data base for this report utilized the noise, performance, and operational assumptions and forecasts developed for the DOT 23 airport study (Reference 1). That study was initiated in 1972 and was modified in late 1973. This report therefore reflects a set of data available during that time period.

- The fleet forecast assumption in Reference 1 (relatively high number of quiet wide bodies) did not factor-in the effect of the energy "situation" or of the subsequent economic downturn.

- The implementation of SAM retrofit and two-segment approach procedures were assumed to be initiated by 1/1/75 in the referenced DOT study.

- Due to the preceding considerations, the absolute levels of benefit accrued as a result of alternative actions, as well as the date for their realization, is subject to review. However, the relative relationships among the alternatives should remain consistent with a time phase shift. Also, the benefits of retrofit versus a do-nothing alternative should be significantly enhanced, since quieter aircraft will not be entering the fleet as rapidly as indicated in the study.

ABSTRACT

This program was undertaken for the Office of Noise Abatement and Control, Environmental Protection Agency, to evaluate the nationwide community impact of aircraft noise through the year 2000, considering a number of aircraft/airport noise reduction alternatives. The study was based on the evaluation of operations at three airports – Los Angeles International, St. Louis, and Washington Dulles. Primary noise reduction alternatives were applied at each of the facilities for the 1987 and 2000 time periods. Secondary abatement alternatives were evaluated for 1987 only. The effectiveness of the various alternatives was measured in terms of the total area impacted under the NEF 30 and 40 contours at the three airports. This area was then increased by a constant factor to obtain an estimate of the impact at the national level. The report also contains an estimate of the total area within the NEF 20 contours and the impacted land area for NEF 20, 30, and 40 exclusive of airport property and water. This study utilized, in part, the much more detailed results for 23 airports from the "Airport Noise Reduction Forecast" study recently completed by Wyle for the Department of Transportation. However, this study differs substantially from the Department of Transportation program in that it is based on analysis at only three airports, includes no cost or population data, extends beyond the year 1987, and focuses only on estimating trends in aircraft noise impact to the year 2000 in order to evaluate the potential requirement for research on new aircraft/airport noise reduction alternatives which may not currently be under development.

ACKNOWLEDGMENTS

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1. INTRODUCTION

Under Section 4(c)(1) of the Noise Control Act of 1972, the Environmental Protection Agency is charged with the responsibility of coordinating the programs of all federal agencies relating to noise research and noise control. Since aircraft have been identified as one of the primary sources of noise, this responsibility includes formulation of plans relative to the alleviation of noise exposure in the vicinity of airports. The primary intent of this study is to provide EPA with a rationale for specifying such plans by demonstrating the effectiveness of the various alternatives available for reducing the impact of aircraft noise including reduction of noise at the source, modification of operational procedures, and changes in compatible land use.

The analysis of the various noise reduction alternatives was based in part on the results of an airport noise reduction forecast study for 23 airports recently completed by Wyle Laboratories for the Department of Transportation.[1*] As discussed in the Wyle/DOT report, the 23 airports are estimated to encompass a majority of the U. S. population exposed to aircraft noise. Three of these 23 airports were selected in this study for the evaluation of noise abatement alternatives applied to the years 1987 and 2000. The principal assumptions utilized for these two studies may be compared as follows:

	Wyle/DOT Report	Current Report
Number of airports	23	3
Final Year	1987	2000
Baseline for future years	6°/3° approach	No noise reduction alternatives
New aircraft	New technology aircraft constitute only 8 percent of fleet in 1987 and are represented by current technology SAM-retrofitted aircraft	New technology aircraft constitute 65 percent of fleet by the year 2000 and are assumed to comply with FAR 36-10 limits

*Superscripts refer to references listed on pages R-1 and R-2.

	Wyle/DOT Report	Current Report
Air carrier fleet forecasts	Estimate to 1987 by detailed analysis of required and available air carrier transport capacity	Extrapolation beyond 1987 with gradually reducing rate of growth of required capacity, and unit productivity
Airport operations forecasts	Estimate to 1987 based on detailed analysis of forecast passenger and cargo traffic at each airport and aircraft capacity by type	Extension of forecasts to year 2000 considering growth in aircraft capacity, and improved operating efficiency of airports
Extrapolation of noise impact to nation	Not attempted	Extrapolation to nation based on evaluation of current and forecast profile of air carrier airports by number of operations

The three airports – Los Angeles International, St. Louis, and Dulles – were chosen on the premise that they were generally representative of air carrier airports as defined by their respective operational categories, i.e., greater than 250,000 annual operations, between 100,000 and 250,000, and less than 100,000 annual operations, respectively. This grouping was based on an analysis of air traffic activity at 350 air carrier airports for 1972.[2]

The analytical model to compute the reduction in noise exposed area incorporates the baseline plus six primary reduction alternatives for the projected operating levels in 1987 and 2000 plus four secondary alternatives applied in 1987 only. These alternatives are listed as follows:

Primary Alternatives

- Baseline aircraft,* standard operating procedures
- $6^{\circ}/3^{\circ}$ glide slope approaches
- Power cutback takeoffs
- Quiet nacelle treatment (identified as SAM – Sound Absorption Material) to aircraft equipped with JT3D and JT8D engines for both standard 3° and $6^{\circ}/3^{\circ}$ glide slope
- Engine modification (identified as REFAN) of all 727-200 and DC-9 aircraft and SAM treatment of all JT3D, 727-100 and 737 aircraft.
- SAM treatment of all JT3D aircraft and REFAN treatment of all JT8D aircraft
- Aircraft noise levels at 5, 10, 15, and 20 dB below current FAR 36 aircraft levels applicable to all air carrier aircraft operating at U.S. airports.

Secondary Alternatives

- Uniform percentage changes in fleet size
- Changes in flight procedures (flight track scatter)
- Changes in fleet composition
- Night curfew

Total area within NEF 30 and 40 contours is evaluated as well as the impacted land area for the three airports and subsequently applied in the development of a nation-wide impact model. For this study, the impacted land area is defined as the total area within a contour less the airport and water area within the same contour.

The results of this study and recommendations are summarized in Section 2 of this report. The noise analysis and aviation system analysis elements of the study are presented in Sections 3 and 4. Additional supporting data are provided in the appendices.

*Baseline aircraft assumes normal attrition and replacement forecast.

The conclusions and recommendations made in this report, although based on a limited sample, are believed to be representative on the broader national scale within the constraints of the assumptions applied.

Recognizing these limitations, however, the general conclusions and change in values of estimated noise impact are considered reasonable to the year 1987 (assuming no major technological breakthroughs or unforeseen societal changes occur). The current emphasis on fuel conservation could have an impact on the study results. However, the consideration of the secondary alternatives, such as the effects of fleet size or fleet composition, as discussed in Section 3, provide some insight into the possible effects of a long range energy conservation program. Although less confidence must be assigned in the 26-year projection to the year 2000, the relative ranking of the effectiveness of the various alternatives is considered sufficient to serve as a valid guideline for long range research planning.

It should be pointed out that this analysis of aircraft/airport noise impact accounts only for the principal component based on today's trends, mainly noise impact around air carrier airports served by conventional takeoff and landing jet aircraft. The additional components of aircraft noise impact attributable to military, general aviation, or V/STOL aircraft are not included in this study. With the possible exception of noise impact from future V/STOL airports, these components are expected to be relatively small compared to the problem considered in this study.

Finally, it must be emphasized that the estimates of total impacted area should be interpreted in terms of relative changes rather than absolute values. This qualification is consistent with the basic intent of NEF contours as quantitive guides for planning and not precise measures of noise impact.

2. CONCLUSIONS AND RECOMMENDATIONS

This section summarizes the principal results of this study and outlines some of the problem areas which were beyond the scope of the study and which should be evaluated in the future.

2.1 Conclusions – Primary Noise Reduction Alternatives

The primary noise reduction alternatives listed in the previous section were evaluated in a series of scenarios of progressively greater noise reduction. This was achieved by evaluating the cumulative effect of combining two or more alternatives with greater and greater noise reduction potential. The effectiveness of each of these scenarios is evaluated in terms of the total area, extrapolated to the nation, within the NEF 30 and 40 contours for each time period.

Table 2-1 summarizes the number of aircraft for the years 1987 and 2000 for which the SAM or REFAN Retrofit alternatives are applied as well as the total aircraft fleet mix. Figures 2-1 and 2-2 illustrate the time trend for the specific aircraft and operational alternatives currently under active development or consideration which were considered in this study. Note that while the time of initial effectiveness of the various alternatives are only approximate, an attempt has been made, for this study, to estimate the shape of the transition in noise-impacted area between these initial years and the year 1987. For the year 1987, the various scenarios of noise reduction alternatives differ substantially in absolute and relative effectiveness. By the year 2000, the alternatives do not differ in effectiveness nearly as much from each other nor do they achieve in total as much relative reduction. This is primarily because most of the current technology aircraft will have been retired and replaced by quieter new technology aircraft which comply with FAR 36-10 limits. In this case, the relative benefits of two-segment approach or power cutback are reduced.

Figure 2-3 illustrates the time trend for the nonspecific improved technology (aircraft noise level) alternatives in combination with the 6°/3° glide slope and power cutback alternatives. In this case, even with the substantial initial effectiveness of

Table 2-1

Number of Candidate Jet Aircraft for Each of the Retrofit Options and Total U.S. Fleet Size (From Reference 1 and 3)

Technology	Year	Aircraft Type	Number of Aircraft in Fleet Retrofitted		Total Fleet Size
			SAM	REFAN	
0	1987	Propeller	-	-	78
I		4 Eng NB (707/DC-8)	170	-	170
		3 Eng NB (727)	341	458	601[a]
		2 Eng NB (737/DC-9)	407	407	492[a]
II		4 Eng WB (747)	-	-	660
		3 Eng WB (DC-10/L-1011)	-	-	1470
		2 Eng WB (A300)	-	-	445
III		100-250 Seat[b]	-	-	350
IV		SST	-	-	125
		Total	918	865	4391
I	2000	Narrow Body			325
II		4 Eng WB	-	-	600
		3 Eng WB	-	-	500
		2 Eng WB	-	-	400
III		100-250 Seat[b]	-	-	1625
		250-400 Seat[c]	-	-	1300
		>400 Seats[d]	-	-	1300
IV		SST	-	-	450
		Total			6500

[a] Includes new aircraft not candidates for retrofit.

[b] Range, 0-500/500-2500 miles (short and medium range).

[c] Range, 500-2500 miles.

[d] Range, >2500 miles.

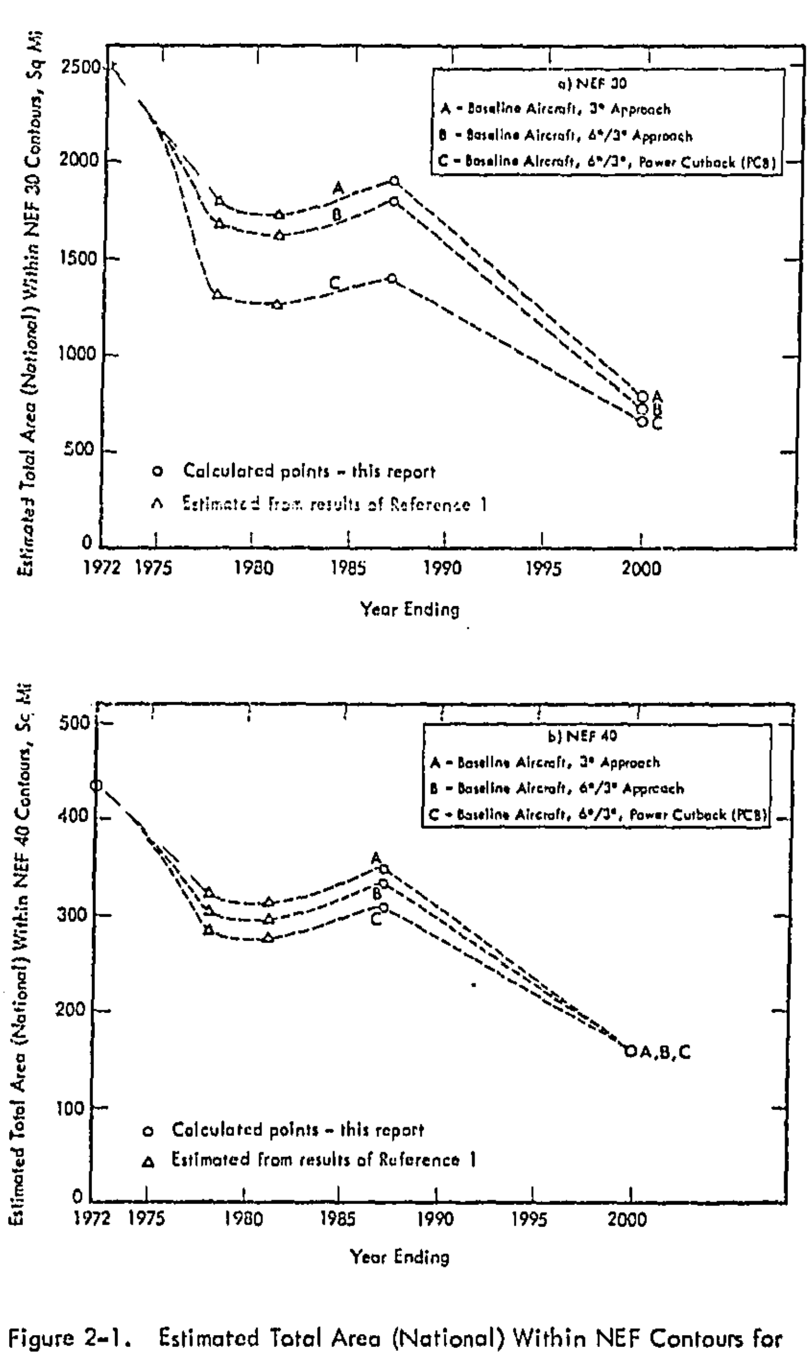


Figure 2-1. Estimated Total Area (National) Within NEF Contours for Approach and Takeoff Noise Reduction Alternatives for 1972, 1987, and 2000

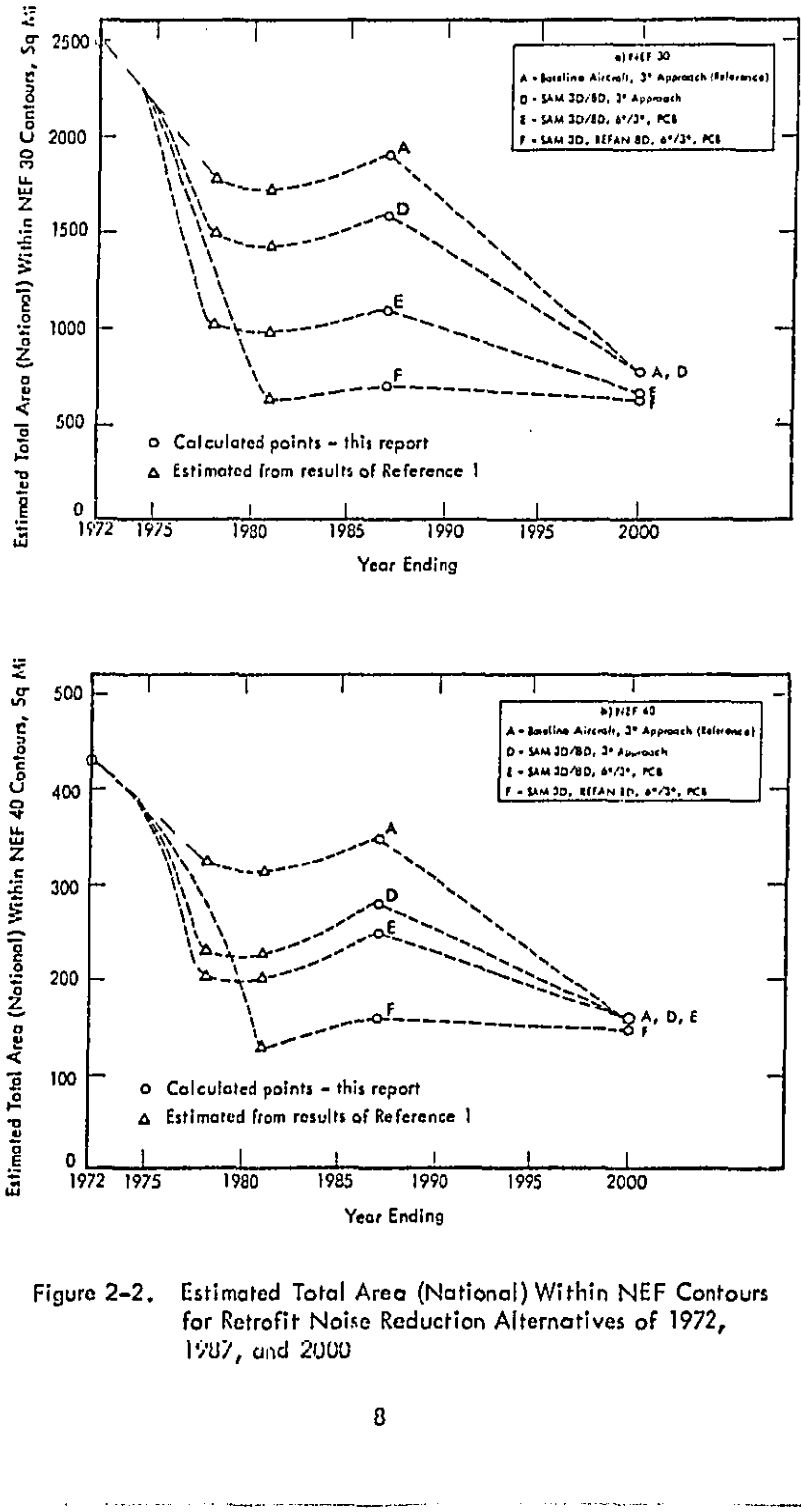
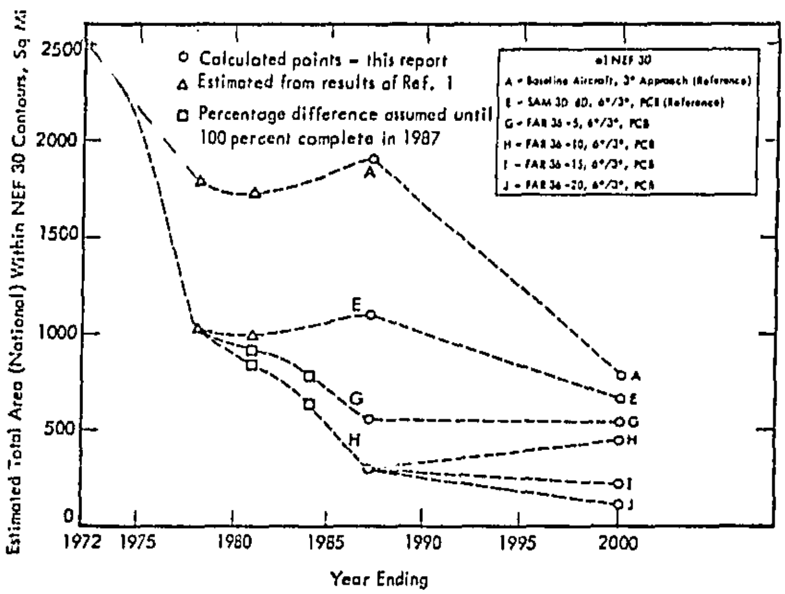


Figure 2-2. Estimated Total Area (National) Within NEF Contours for Retrofit Noise Reduction Alternatives of 1972, 1987, and 2000



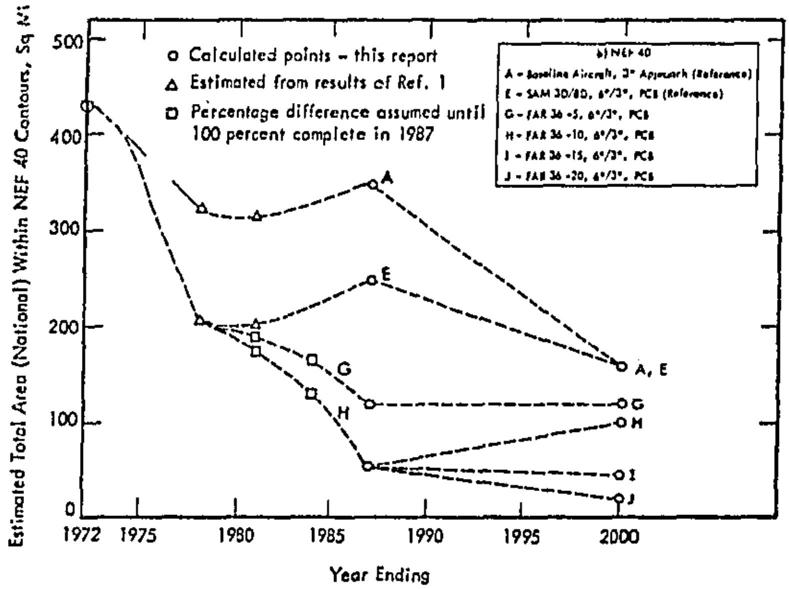


Figure 2-3. Estimated Total Area (National) Within NEF Contours for Improved Technology Noise Reduction Alternatives for 1972, 1987, and 2000

the two operational procedures and the projected conversion of the entire fleet to quieter aircraft, these alternatives show a high degree of noise reduction effectiveness, particularly for the year 1987 when, without retrofit or improved technology assumptions, there would still normally be a substantial number of aircraft in the fleet not complying with FAR 36 levels. However, it must be emphasized that the resultant impact data for each alternative is an optimistic projection, i.e., the entire fleet meets or exceeds the assumption criteria of the given point in time. Practical economics may, in fact, preclude this from occurring, thereby slipping the effectivity date. Nevertheless, the results of this projection indicate the potential for improved airport noise environments achievable in the future by various assumed alternatives.

Since no data were analyzed for the time period between 1972 and 1987 in this report, the trend lines indicated in Figures 2-1 to 2-3 were estimated, using data from the Wyle/DOT 23 Airport study as a basis.[1] For that period, the "B" trend line (Baseline Aircraft, 6°/3° Approach) was estimated for the 1978 and 1981 time periods by extrapolating the results of the 23 Airport Study to the nation on the basis of equivalent aircraft operations as explained in Section 3.2.2 and in Appendix A. Having these estimates, values for the "A" trend line (Baseline Aircraft, 3° Approach) were computed for 1978 and 1981 by assuming that the percentage separation between these two lines would be constant and the same as the percentage separation in 1987. A straight line estimate was assumed from 1972 to 1978 for the "A" trend line. The 6°/3° approach alternative was assumed to be initiated by year end 1974 and in full operation by year end 1978. Points for the "C" trend line (Baseline Aircraft, 6°/3° Approach, Power Cutback (PCB)) were generated for 1978 and 1981, using the same percentage comparison method with the "B" trend line. In a similar manner, the "D", "E", and "F" trend lines were constructed with points computed for appropriate time periods. For the trend lines representing retrofit categories, points were estimated for the transitional period from start of retrofit to completion, using the implementation schedule specified in Reference 1, and lines were faired using these points to estimate the trends over the entire implementation period. For the trend lines representing the FAR 36-5 and -10 options, the

SAM 3D/8D, $6^{\circ}/3^{\circ}$, PCB trend (line E) was assumed up to 1978 and the percent accomplishment of the difference between the 1978 and 1987 values was assumed to be 20 percent by 1981, 50 percent by 1984, and 100 percent by 1987. It was assumed that the FAR 36-15 and -20 options would not be initiated until after 1987. For all cases considered, straight lines were used to represent the trends between 1987 and 2000.

The following explanation gives the rationale for the trend variations in Figure 2-3 between 1987 and the year 2000 for the cases involving FAR 36-X.

There are three counteracting factors which can influence these trends in total contour areas:

1) A tendency to increase from 1987 to 2000 due to increased number of operations. This influence is constant for all four FAR 36-X cases between 1987 and 2000 in Figure 2-3.

2) A tendency to decrease from 1987 to 2000 due to the normal attrition of the noisier Level I and II technology aircraft and replacement by the quieter Level III technology aircraft. This influence is also constant for all four FAR 36-X cases between 1987 and 2000.

3) A tendency in the FAR 36-X trend lines to decrease as X is increased because the number of aircraft involved by each FAR 36-X level changes from 1987 to 2000. For example, the imposition of FAR 36 -5, and -10 levels would affect <u>26</u> percent and <u>90</u> percent of the fleet, respectively, in 1987 while these same levels would affect only <u>12</u> percent and <u>35</u> percent, respectively, of the fleet in the year 2000. One hundred percent of the fleet would be affected by FAR 36 -15 or FAR 36 -20 levels in the year 2000.

The combined action of these three factors results in the trends observed. The first two factors nearly balance out for the FAR 36 -5 level which influences a relatively small part of the fleet in both 1987 and 2000. For the FAR 36 -10 level, however, a major part (90 percent) of the fleet is influenced in 1987 but much less (35 percent) is influenced in 2000 so that the net effect of more operations and less aircraft affected overrides the downward tendency from quieter aircraft and results in a net trend upward in this case. The overriding influence of the FAR 36 -15 and -20 levels on all the fleet result in a net downward trend in both cases.

A desirable national goal could be to reduce the impacted land area within NEF 20 ($\sim L_{dn}$ 55) contours to zero by the year 2000. Estimates of the impacted area (excluding airport property and area over water) within NEF 20, 30, and 40 are presented in detail in Appendix A and are briefly summarized in Table 2-2 for NEF 20 and 30 contours. Even with the FAR 36-20 aircraft noise level alternative there is an estimated remnant of about 310 square miles of impacted land within the NEF 20 contour by the year 2000. However, this is a reduction by a factor of about 35 from the estimated 11,000 square miles of impacted land within NEF 20 contours around air carrier airports today. The relative changes in estimated impacted land area in Table 2-2 clearly indicate the substantial downward trend in airport noise projected for the future due to the present transition to quieter wide-body aircraft and the forecast transition to new technology (FAR 36-10) aircraft in the future. Thus, an effective long-term resolution of the problem of airport noise impact will require additional noise reduction developments beyond current technology in order to counteract the projected reescalation of noise due to future air transport demand.

2.2 Conclusions – Secondary Noise Reduction Alternatives

The estimated total contour area, on a national basis, for various secondary noise reduction alternatives in combination with the two-segment approach alternative, is shown in Figure 2-4. These alternatives indicate the general sensitivity of the final result to changes in some of the key assumptions made in the study, as well as indicating

Table 2-2

Summary of Estimated Impacted Area for Nation Within NEF 20 and 30 Contours Expressed as a Percentage of Impacted Area for Base Year 1972*

Alternative	1987 NEF 20	1987 NEF 30	2000 NEF 20	2000 NEF 30
No Change - Base Aircraft	69%	72%	29%	27%
6°/3°	65%	67%	26%	24%
PCB + 6°/3°	53%	52%	24%	22%
SAM 3D/8D	58%	61%	29%	27%
SAM 3D/8D + PCB, 6°/3°	39%	39%	24%	22%
SAM 3D, REFAN 8D + PCB, 6°/3°	25%	23%	23%	20%
FAR 36-5 + PCB, 6°/3°	20%	17%	20%	17%
FAR 36-10 + PCB, 6°/3°	10%	7%	16%	13%
FAR 36-15 + PCB, 6°/3°	-	-	7%	5%
FAR 36-20 + PCB, 6°/3°	-	-	3%	1%

*Base impact area for 1972 = 11,000 and 1,800 square miles inside NEF 20 and 30 contours, respectively, for nation, excluding airport property and water. Based on detailed data in Table A-2, Appendix A.

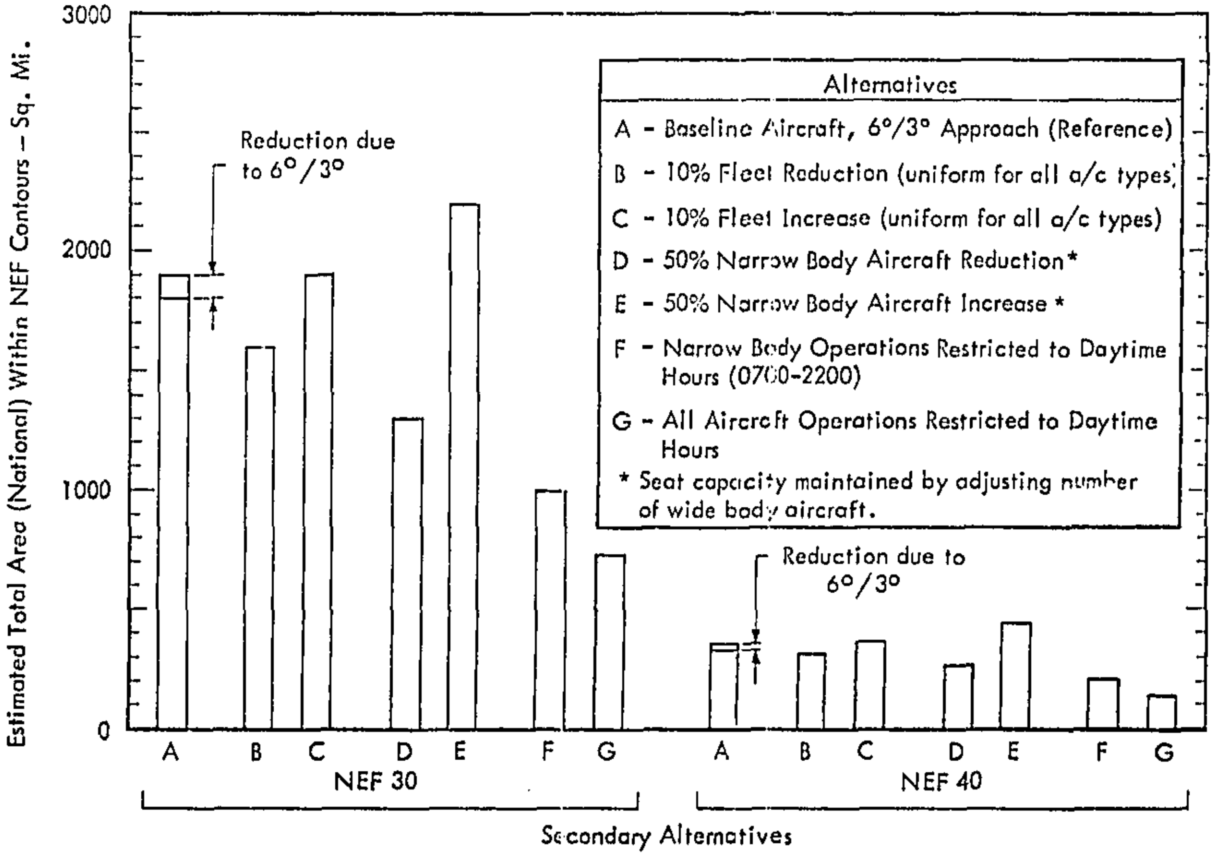


Figure 2-4. Comparisons of Estimated Total Area (National) Within NEF Contours Resulting from the Application of Various Secondary Effect Alternatives for the Year 1987

the effectiveness of night curfew alternatives. The substantial influence of the percentage of narrow body aircraft and night curfew procedures is quite apparent. The effect of flight track dispersion, not illustrated in Figure 2-4, was relatively small for the lower noise levels. A 9-degree dispersion in takeoff or approach paths produced a 3.7 percent decrease in area within the NEF 30 contour. These results are based on a simplified analysis and are only intended to indicate trends.

2.3 Recommendations

The results of this forecast study on noise impact around the nation's airports can provide a useful insight into the effectiveness of many of the aircraft/airport noise reduction alternatives under consideration. It is recommended that an additional effort be carried out to improve the utility and validity of these projections. The areas for further study would include:

- Refinement of the secondary reduction alternative analyses to evaluate, more completely, the effects of variations in the basic study assumptions.
- Evaluation of trends in noise impact for the entire aviation system, i.e., include military (including joint use) and general aviation airports.
- Evaluation of effectiveness in terms of projected number of people impacted using forecasts of population trends around a sample of airports.
- A more detailed evaluation of the amount of compatible land within projected contours for all of the nation's airports (i.e., refinements in the national airport noise impact model).
- A detailed evaluation of the potential effectiveness of a Fleet Noise Level (FNL) taking into account the principle that the noise level of any given fleet is a function of the engine noise of each aircraft in that fleet and the total number of takeoffs and landings of each aircraft in that fleet: 1) determine the noise levels of each aircraft in that fleet; 2) determine the total number of operations (takeoffs and landings) for each aircraft

type for a representative 90-day period; 3) calculating FNL as a mean logarithmic value; and 4) establishing a precise limit on fleet noise levels. The simplified analysis carried out in this study of several versions of an aircraft noise limit indicates the potential benefits that might be achieved by such noise regulations.

3. NOISE ANALYSIS

The analysis of airport noise impact is based on the development of contours of equal Noise Exposure Forecast (NEF) around three sample airports (Los Angeles International, St. Louis, and Dulles). These results, in conjunction with the results of Reference 1, were then utilized in the development of the national impact estimate. The analysis is divided into three basic categories of aircraft noise reduction effects.

1) Baseline fleet mix in which no change in aircraft or operational practices occur except normal transitions to quieter aircraft that have already been initiated and were extrapolated to the future.

2) Progressive application of primary noise reduction alternatives.

3) Application of secondary alternatives in combination with the two-segment approach.

The impact analysis is based on actual operational data in the 1972 baseline case and on fleet and operational forecasts provided by R. Dixon Speas Associates for 1987 and 2000.[3] Forecasts include type of aircraft (existing and new generation replacement aircraft), aircraft mix, stage lengths, and day/night ratios for each of the three airports. The baseline NEF contours for 1987 and 2000 were then modified to reflect the five primary noise reduction alternatives. The 1987 case was further analyzed to reflect the secondary alternatives. Analyses were made of the total impact area change resulting from the individual and cumulative effects of applying the alternatives. The impact was analyzed primarily in terms of the total area within NEF 30 and 40 contours and included estimated areas down to NEF 20 (i.e., $\sim L_{dn}$ 55). Additional evaluation of the results provided an estimate of the impacted land area within these contours exclusive of airport property and area over water.

3.1 Noise Reduction Alternatives

The various noise reduction alternatives applied in this study are defined below. The scenarios of progressive application of these alternatives, which were used for the noise analysis, are summarized in Table 3-1. A baseline set of contours was also developed for each time period, i.e., a reference base situation reflecting no noise reduction practices against which all primary noise reduction alternatives were compared. The reference condition for the secondary alternatives consisted of the baseline aircraft using a two-segment approach procedure.

3.1.1 Primary Alternatives

- Baseline

Using the operating levels for 1972 and those forecast for 1987 and 2000, it was assumed that aircraft use ATA takeoff procedures defined in Table 3-2 and a 3° glide slope for all approaches.

- $6^{\circ}/3^{\circ}$ Glide Slope

Using the operating levels forecast for 1987 and 2000, the aircraft were assumed to use a $6^{\circ}/3^{\circ}$ glide slope on approach. This procedure involves intercepting the 6° portion of the glide slope at an altitude of 3000 feet or above, then descending at a 6° angle until reaching an altitude of 690 feet where the transition to the 3° portion begins. The aircraft is established on the 3° glide slope at or above an altitude of 500 feet. The 3° descent angle is maintained until touchdown. The procedure is approximated by straight line segments for the NEF computer program model as shown graphically in Figure 3-1. Normal aircraft approach intercepts for a 3° glide slope at the three study airports occur at 2500 to 3500 feet altitude, depending on the ground track. For the $6^{\circ}/3^{\circ}$ glide slope procedure, the 6° portion of the approach is initiated at a minimum of 3000 feet. This necessitates adjusting the entire traffic pattern existing at each airport, so that the minimum intercept occurs at 3000 feet. Therefore, the intercept altitude for $6^{\circ}/3^{\circ}$ glide slope occurs at 3000 feet to 4000 feet for Los Angeles International and Dulles and at 3000 feet for St. Louis.

Table 3-1

Scenarios of Noise Reduction Alternatives

Noise Reduction Alternatives	Scenarios of Alternatives																
	1972	1987 and 2000											1987 Only				
Primary	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Baseline - 3°, Approach	x	x	x														
Operational - 6°/3°, Approach				x	x	x	x	x	x	x	x	x	x	x	x	x	x
Operational - PCB, Takeoff					x	x	x	x	x	x	x	x					
Nacelle Treatment - 3D			x			x	x	x									
Nacelle Treatment - 8D (All Types)			x			x											
Nacelle Treatment - 737/727-100 Only							x										
Refan - 8D								x									
Refan - 727-200/DC-9 Only							x										
Aircraft Noise Level (FAR-36) - 5 dB									x								
Aircraft Noise Level (FAR-36) -10 dB										x							
Aircraft Noise Level (FAR-36) -15 dB (2000 only)											x						
Aircraft Noise Level (FAR-36) -20 dB (2000 only)												x					
Secondary																	
Fleet Size (±10 Percent Change)													x				
Fleet Mix (±50 Percent Change in Narrow Body Aircraft)														x			
Dispersion in Flight Tracks (9 Degrees)															x		
Night Curfew - No Narrow Body Nighttime Flights																x	
Night Curfew - No Nighttime Flights																	x

Table 3-2

Takeoff Climb Procedures with Reduced Power Setting
(from References 4 – 6)

Segment	Parameter	ATA	ALPA*	FAR 36
1	Alt	• 0-1500'	• 0-400'	• 0-1000'-3 eng. or less 0-700' - 4 eng.
	Pwr	• Takeoff	• Takeoff	• Takeoff
	Speed	• $\geq V_2$ + 10 kts	• V_2 + 10 to 20 kts	• V_2 + 10 kts
	Flaps	• Takeoff	• Takeoff	• Takeoff
2	Alt		• 400-1500	
	Pwr		• Takeoff	
	Speed		• Accelerating.	
	Flaps		• Retracting	
3 (Cutback)	Alt	• 1500-3000'	• 1500-4000'	• 1000' (min)-3 eng. or less 700' (min)-4 eng.
	Pwr	• $\geq$ Climb Pwr	• Thrust required for one engine out gradient.**	• Thrust required for level flight (one engine out) but not less than thrust for 4% gradient
	Speed	• $\geq V_2$ + 10 kts	• 210 kts	• V_2 + 10 kts
	Flaps	• Optimum	• Up	• Takeoff
4	Alt	• > 3000'	• > 4000'	
	Pwr	• Climb	• Climb	
	Speed	• 250 kts	• 210 kts	
	Flaps	• Retract on Schedule	• Up	

*Refer to Figure 3-2.

**Climb gradient γ' (with one engine out) not less than:[6]

1.2% for 2-engine aircraft
1.5% for 3-engine aircraft
1.7% for 4-engine aircraft

Climb gradient (all engines operating) $\gamma = \frac{N\gamma'}{N-1} + \left(\frac{1}{N-1}\right)\frac{D}{L}$ (derivation from Appendix D with L/D = 10)

12.4% for 2-engine aircraft
7.3% for 3-engine aircraft
5.6% for 4-engine aircraft

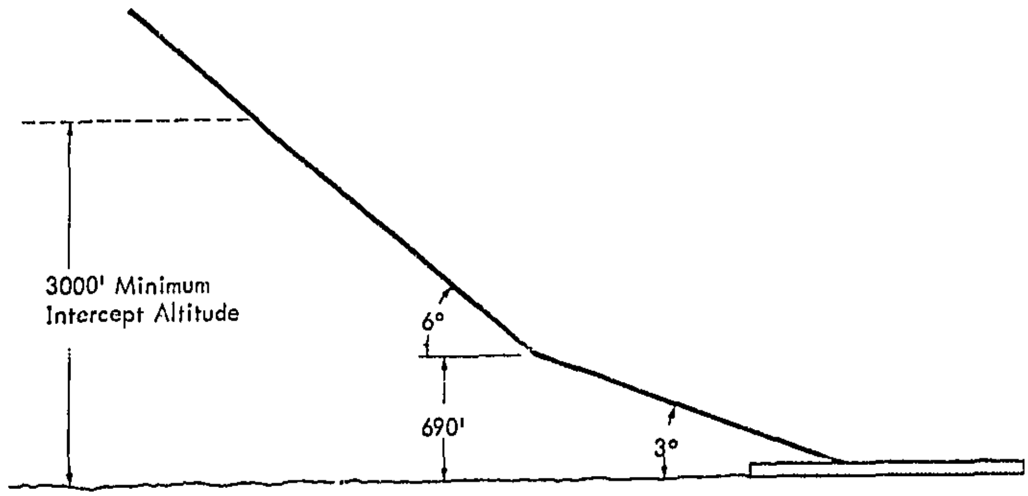


Figure 3-1. 6°/3° Glide Slope Procedure

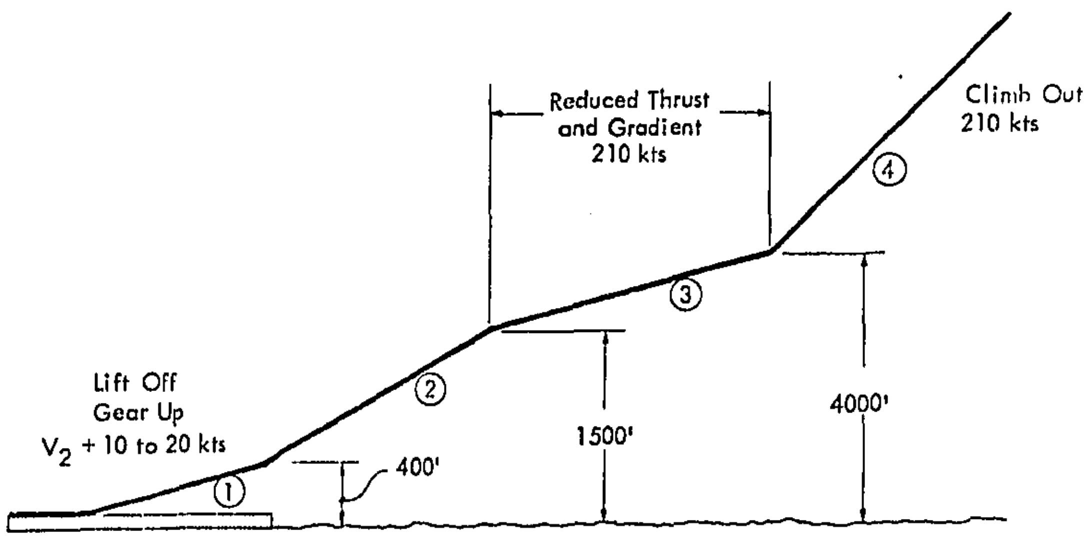


Figure 3-2. ALPA Takeoff Profile

- Power Cutback

The noise abatement procedure, recommended by the Air Transport Association, is currently used during takeoff at many air carrier airports. However, it was recognized that this procedure does not provide as much noise reduction as a) the procedure recommended for a noise reduction power cutback (PCB) by the Airline Pilots Association (ALPA) or b) the PCB procedure allowed for a FAR 36 aircraft noise certification. The basic characteristics of each of these procedures are summarized in Table 3-2 which defines the flight parameters for each of the segments of the takeoff profile illustrated in Figure 3-2.

For this study, the minimum power setting employed during power cutback was that which just allowed level flight with critical engine out. As illustrated in Table 3-3, this procedure resulted in a varying climb gradient and thrust, relative to maximum takeoff thrust, depending on the number of engines. As indicated in the last column, the average climb gradient during power cutback for 2-, 3-, and 4-engine aircraft was close to that given by a simple aerodynamic performance model developed in Appendix D which predicts that for all engines operating at the power necessary to maintain level flight with critical engine out, the gradient is

$$\text{Climb Gradient} = 100 \left(\frac{1}{N-1}\right)\left(\frac{\text{DRAG}}{\text{LIFT}}\right) \quad \text{, percent}$$

where N = number of engines.

The values of the predicted gradients given in Table 3-3 are based on a typical lift to drag ratio of 10 to 1. The resulting climb gradient meets the FAR 36 requirements for 2- and 3-engine aircraft and is about 20 percent below the FAR 36 requirements for 4-engine aircraft. The gradients are also about 35 to 40 percent below those indicated for the ALPA power cutback procedure in Table 3-2. Although climb gradients for 4-engine aircraft are not exactly compatible with FAR 36, the difference in noise impact

Table 3-3

Average Climb Gradient and Relative Thrust
During Power Cutback Condition

Number of Engines (N)	Reduced Thrust* / Maximum Takeoff Thrust		Climb Gradient	
			Average*	Predicted**
	Minimum T.O.W.	Maximum T.O.W.	%	%
2	0.74	0.75	9.3	10
3	0.61	0.68	5.3	5
4	0.47	0.64	3.2	3.3

*Average values for all Level I and II (current technology) aircraft for minimum and maximum takeoff weight (T.O.W.).

**Predicted climb gradient = 100[1/(N-1)] (Drag/Lift) for power setting equal to that required to maintain level flight with critical engine out.

is not large since 4-engine narrow body aircraft constitute less than 4 percent of the total fleet in 1987 and even less in 2000. Therefore, the cutback procedure used here is considered essentially equivalent to that allowed by FAR 36.

The ALPA procedure corresponds to a climb gradient defined in Table 3-2. Thus, the ALPA power cutback procedure would be expected to produce slightly less noise reduction than that employed in this study. Based on the decreased reduction in thrust that would be allowed, it is estimated that ALPA power cutback procedures would produce approximately 75 percent of the reduction in impacted area computed by the power cutback procedures followed in this study.

The benefit of power cutback in takeoff procedures is greatest in the 1972 to 1987 period and diminishes as the year 2000 is approached. This occurs because the JT3D and JT8D engine takeoff noise can be reduced significantly with power cutback. After 1987, all aircraft produced conform to FAR 36 requirements or better and hence the benefit of power cutback decreases.

- Quiet Nacelle

The quiet nacelle or SAM treatment, analyzed in Reference 1, for current technology narrow body aircraft, was applied to all JT3D and JT8D aircraft in combination with either the standard 3° glide slope during approach or the combination of the 6°/3° glide slope and power cutback on takeoff.

- REFAN

This condition was evaluated by applying engine REFAN modifications, also evaluated in Reference 1, for current technology JT8D-powered narrow body aircraft (i.e., 727, 737, and DC-9) and applying the quiet nacelle treatment to all JT3D aircraft (i.e., 707, DC-8). A second REFAN case was also developed by refanning only the 727-200 and DC-9 aircraft and applying the quiet nacelle (SAM) treatment to the 727-100, 737, and all the JT3D-powered aircraft.

- Aircraft Noise Level

Up to this point, the noise reduction alternatives considered have consisted of available operational procedures or aeronautical system changes currently being developed. In order to examine the potential effectiveness of further noise reduction steps, a series of progressively greater reductions (i.e., -5 to -20 dB) relative to current FAR 36 certification limits were explored. This study did not attempt to determine the feasibility or practicability of achieving these arbitrary reductions in aircraft noise levels. Rather, the objective was to develop a better perception of the relative noise reduction value of these alternatives if, in fact, they were to become available in future years.

The following procedure was used to evaluate the aircraft noise level alternative. The basic approach consisted of uniformly reducing the noise level characteristics of each type of aircraft by the amount necessary for the revised noise levels to conform to FAR 36-5, -10, -15, or -20 certification levels. Table 3-4 defines the approximate noise level, in terms of EPNL values relative to FAR 36 limits, for each type of aircraft and two FAR 36 measurement positions.* The relative EPNL levels are specified, in all cases, for the baseline unmodified aircraft. Relative EPNL values are also specified for existing narrow body aircraft in the SAM or REFAN configurations. It can be seen from the data in Table 3-4 that when SAM or REFAN alternatives are applied, the resulting aircraft noise levels would either equal or fall significantly below FAR 36 criteria for many aircraft types. For example, the 727 easily meets a FAR 36-5 level for the REFAN option at all FAR 36 measurement locations.[7] However, the same aircraft would not meet a FAR 36-10 in the approach and takeoff mode. Thus, referring to the REFAN column under Approach for the 727, the relative EPNL level is 7 dB below existing FAR 36 levels so that an additional 3 dB decrease in level would be required to achieve a FAR 36-10 limit. This 3 dB correction was applied (uniformly at all distances and at all thrust levels) to the existing REFAN noise versus slant range curves[7] to achieve the desired FAR 36 -10 limit on approach. This simple correction process to

*The sideline FAR 36 position is not listed since relative FAR 36 aircraft noise levels at this point were always less than relative levels for approach or takeoff positions.

Table 3-4
EPNL Values Relative to Current FAR 36 Limits, dB[1]
(All Numbers Calculated from Noise and Profile Curves
in Reference 7 or Appendix B)[2]

FAR 36 Position	Approach			Takeoff		
Aircraft \ Alternative	Base	SAM	REFAN	Base	SAM	REFAN
DC-9	+5	0	-2	+1	0	-7
737	+8	+4	-2	-2	-2	-8
727	+4	-1	-7	0	-2	-8
DC-8 (Turbofan)	+11	-3		+9	-2	
707 (Turbofan)	+9	-4		+9	-2	
DC-10	-4			-7		
747	-3			-3		
L 1011	-4			-4		
2 Eng. Wide Body	-3			-9		
Level III, Small	-11			-16		
Level III, Medium	-15			-10		
Level III, Large	-10			-10		

[1]Plus (+) indicates EPNL is higher than FAR 36 limits while minus (-) indicates EPNL is below FAR 36 limits.

[2]These relative FAR 36 levels were computed on the basis of the following assumptions:

- 59°F day (not adjusted to 77°F FAR 36 standard day).
- On takeoff, FAR 36 power cutback (see Table 3-2) applied for current narrow body aircraft at 3.5 n mi point.
- Approach flap settings correspond to actual (typical) values used in Reference 1 which were based on industry data.
- Approach landing weight was assumed to be maximum allowable.

The relative FAR 36 levels for current technology narrow and wide body aircraft in this table do not necessarily reflect the latest certificated or estimated FAR 36 noise level data from FAA. These data show that SAM retrofitted aircraft can comply with FAR 36 (Reference 18). For example, the certificated EPNL for 737 (SAM) aircraft on approach with 30° flap setting is within FAR 36 limits (Reference 18).

achieve a specified level below current FAR 36 requirements resulted, as expected, in hypothetical aircraft noise characteristics which just met the desired limit at one of the three certification points but usually fell well below the allowed limits at the other points. This same process was followed for each aircraft type and revised FAR 36 levels to obtain the hypothetical noise performance curves that would comply with the respective lower FAR 36 limits. Note that, for the existing narrow body aircraft, the retrofit configuration with the lowest levels (SAM or REFAN as appropriate) was used arbitrarily as the starting point to achieve levels below FAR 36 and further noise reductions were then assumed as required.

The resulting changes in EPNL level and the configuration to which they were applied to achieve the various aircraft noise level alternatives are summarized in Table 3-5. In all cases, each of these alternatives was combined with the 6°/3° approach and power cutback alternative for evaluation in the program.

3.1.2 Secondary Alternatives

In order to evaluate the sensitivity of the results to small variations in some of the key air traffic parameters and to explore other possible operational noise reduction alternatives, the following secondary alternatives were evaluated.

- Fleet Size and Load Factor

The fleet size as projected to the year 1987 was modified by a factor of ±10 percent. This appears to be a reasonable range of possible error based on historical forecasts and probabilities of air traffic demand (see Figure 3-3).[8] For a constant air carrier passenger demand, the fleet size will vary inversely with the load factor as expressed by the formula:

$$\text{Fleet Size (in number of available seats)} = \frac{\text{Demand}}{\text{Load Factor}}$$

Thus, a 10 percent decrease in fleet size corresponds to a 10 percent increase in load factor for a constant demand. In either case, the changes in fleet size or load

Table 3-5

ΔEPNL Corrections Applied Uniformly to Noise Curves to Achieve FAR36-X Levels, dB

Aircraft	FAR 36-5	FAR 36-10	FAR 36-15	FAR 36-20
DC-9*	REFAN-3	REFAN-8	REFAN-13	REFAN-18
737*	REFAN-3	REFAN-8	REFAN-13	REFAN-18
727*	REFAN-0	REFAN-3	REFAN-8	REFAN-13
DC-8*	SAM-3	SAM-8	SAM-13	SAM-18
707*	SAM-3	SAM-8	SAM-13	SAM-18
DC-10	-1	-6	-11	-16
747	-2	-7	-12	-17
L 1011	-1	-6	-11	-16
2 Eng. Widebody	-2	-7	-12	-17
Level III, Small	0	0	-4	-9
Level III, Medium	0	0	-5	-10
Level III, Large	0	0	-5	-10

*REFAN and SAM indicate to which noise curve sets the given modifications were applied. (Reference 7)

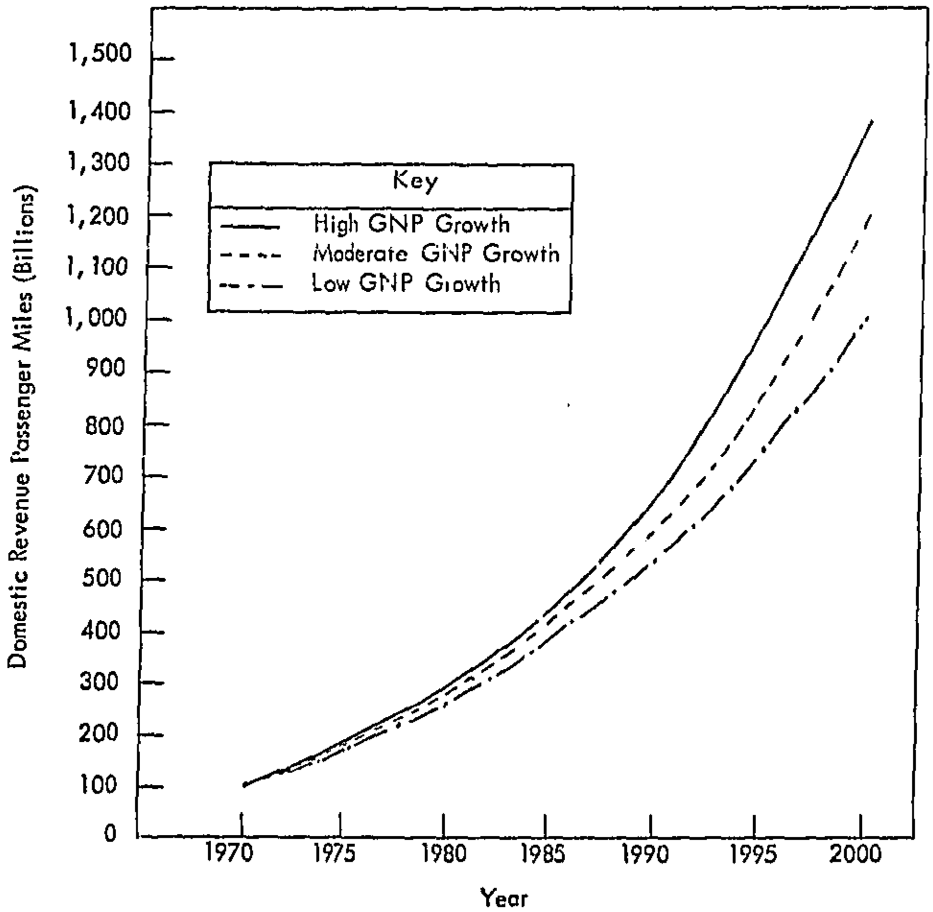


Figure 3-3 Forecast of U.S. Domestic RPM
(Certificated Carriers, Scheduled Service)

(Data from Reference 8, 1972)

factor were evaluated by varying the number of operations, assuming a constant demand and constant fleet mix.

- Fleet Composition

The basic variation applied here was a ±50 percent change in the number of narrow body aircraft in the national fleet. It is obvious that the fleet size is significantly affected through this manipulation. The fleet size was modified so that total seats available was maintained constant by adding or subtracting corresponding wide body aircraft to make up for the change in the number and seating capacity of narrow body aircraft.

- Flight Track Scatter

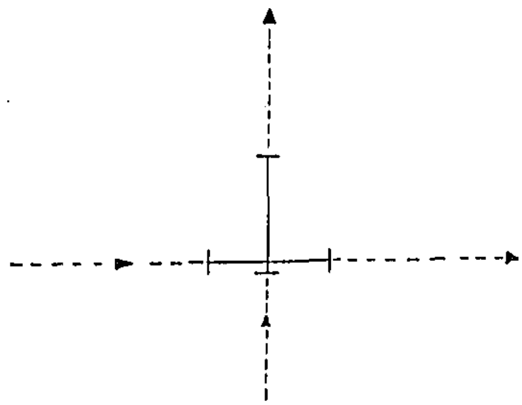
Flight track scatter is demonstrated using a hypothetical airport configuration but applying the Dulles 1987 operating levels and aircraft mix. Two cases are evaluated for a two-runway configuration – one runway perpendicular to the other, as shown in Figure 3-4a. The first case represents a single straight in (approach) and out (takeoff) track for each runway. The second reflects 20 tracks for each runway, with 9 incremental one-degree left and right turns on approach and takeoff, as seen in Figure 3-4b.

- Night Curfews

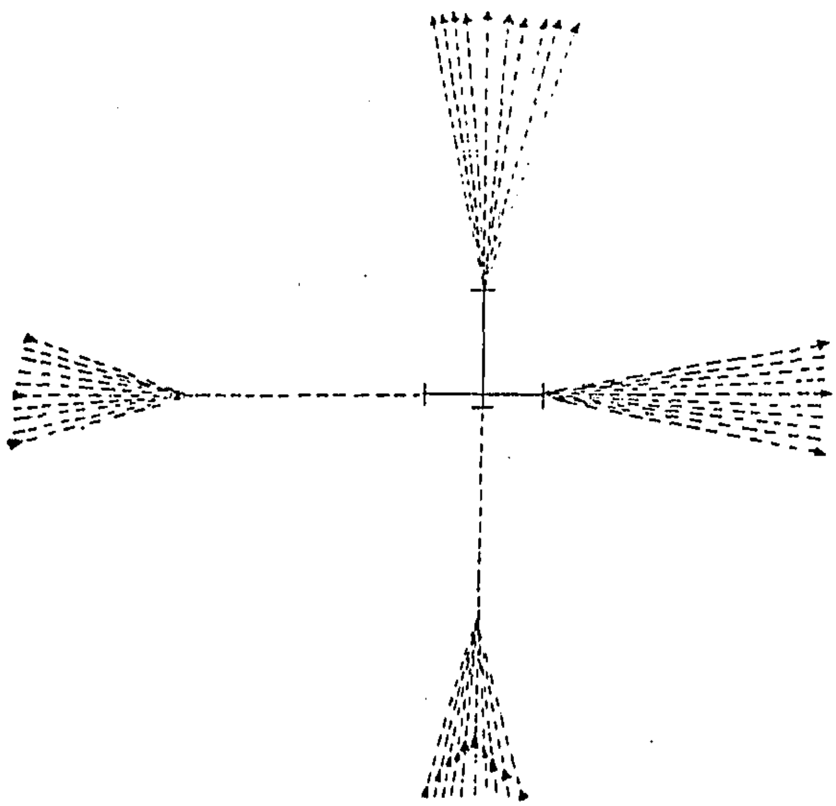
Two night restriction alternatives are evaluated. The first reassigned all narrow body aircraft operating between 2200 - 0700 hours to daytime (0700 - 2200) operation. The second represents a total ban on night operations for all aircraft, reassigning these to daytime operations. In both cases, fleet mix and available air carrier capacity remain constant.

3.2 National Model for Noise Impact Evaluation

The evaluation of the noise impact on the national level involved the following basic steps.



a) Straight Flight Tracks



b) Track Separation 1°

Figure 3-4. Model for Evaluating Effect of Dispersion of Flight Tracks.

1. Selection of a representative sample of airports for analysis. (The resources for this program necessarily limited the approach to an analysis of a few of the 23 airports studied in the Airport Noise Reduction Forecast program.[1])

2. Extrapolation of the results for the sample airports to an estimate for the nation.

3. Extrapolation of the analysis carried out for total areas within the NEF 30 and NEF 40 contours to estimate the total area within the NEF 20 contours. The latter NEF value can be considered as approximately equivalent to the Day-Night Average Sound Level (L_{dn}) of 55 dB recently identified as a possible lower limit for outdoor noise to protect health and welfare with an adequate margin of safety.[9]

4. Estimation of the area within the NEF 20, 30, or 40 contours excluding airport property and water, i.e., impact area.

The first two steps are treated in this section since they represent the two basic steps required to obtain the fundamental total area values within the NEF 30 or 40 contours. The remaining two extrapolation steps are discussed in Appendix A.

3.2.1 Selection of Sample Airports

Annual level of operations was the sole criterion for selecting a sample of three airports for analysis. For the year 1972, Los Angeles International (LAX) was considered representative of airports with greater than 250,000 operations, St. Louis (STL) represented the airports between 100,000 and 250,000 operations, and Dulles (IAD) represented those with less than 100,000 annual operations. To examine validity of this sample, data from the 23 Airport Study were used to relate the total area within the NEF 30 contour to the number of operations. These data included the airports considered in this study, since the three airports selected are part of the 23.[1] The general agreement between calculated areas versus operations for LAX, STL, and IAD and the corresponding least square regression lines computed for all 23 airports was generally good and improved as one proceeded from 1972 to later years and as aircraft noise levels decreased (see Figure 3-5). This evaluation indicated that LAX, STL, and IAD represented a reasonable sample of airports to use in formulating a national model. However, it also was apparent that the most accurate estimate for a 1972 national baseline would be best provided by using the data from Reference 1 for all 23 airports.

3.2.2 Extrapolation of Results to the Nation

After considering several methods for extrapolating results for the three airports to an estimate for the nation, the following simple scaling procedure was chosen as the most straightforward and practical for this study.

For any given year and alternative, the area A_N within an NEF contour for the nation is estimated to be:

$$A_N = A_{Ref} \left[\frac{N_{N(eq)}}{N_{Ref(eq)}} \right] \text{, square miles}$$

where

A_{Ref} = total contour area for the reference sample of airports for a given year and noise reduction alternative

$N_{N(eq)}$ = total equivalent jet aircraft air carrier operations in the nation for the specified year – assumed equal to the total air carrier operations minus 90 percent of the nonjet operations

$N_{R(eq)}$ = corresponding total equivalent operations for the reference sample airports in the specified year

The assumptions upon which this scaling procedure are based may be stated as follows:

1. The total area within a given noise contour is directly proportional to the number of equivalent (jet) aircraft operations. Thus, for two airports with different number of total operations, but otherwise identical, the total areas within a given contour level at each airport is expected to vary in direct proportion to the ratio of equivalent operations (evidence to support this concept is presented in Appendix A).

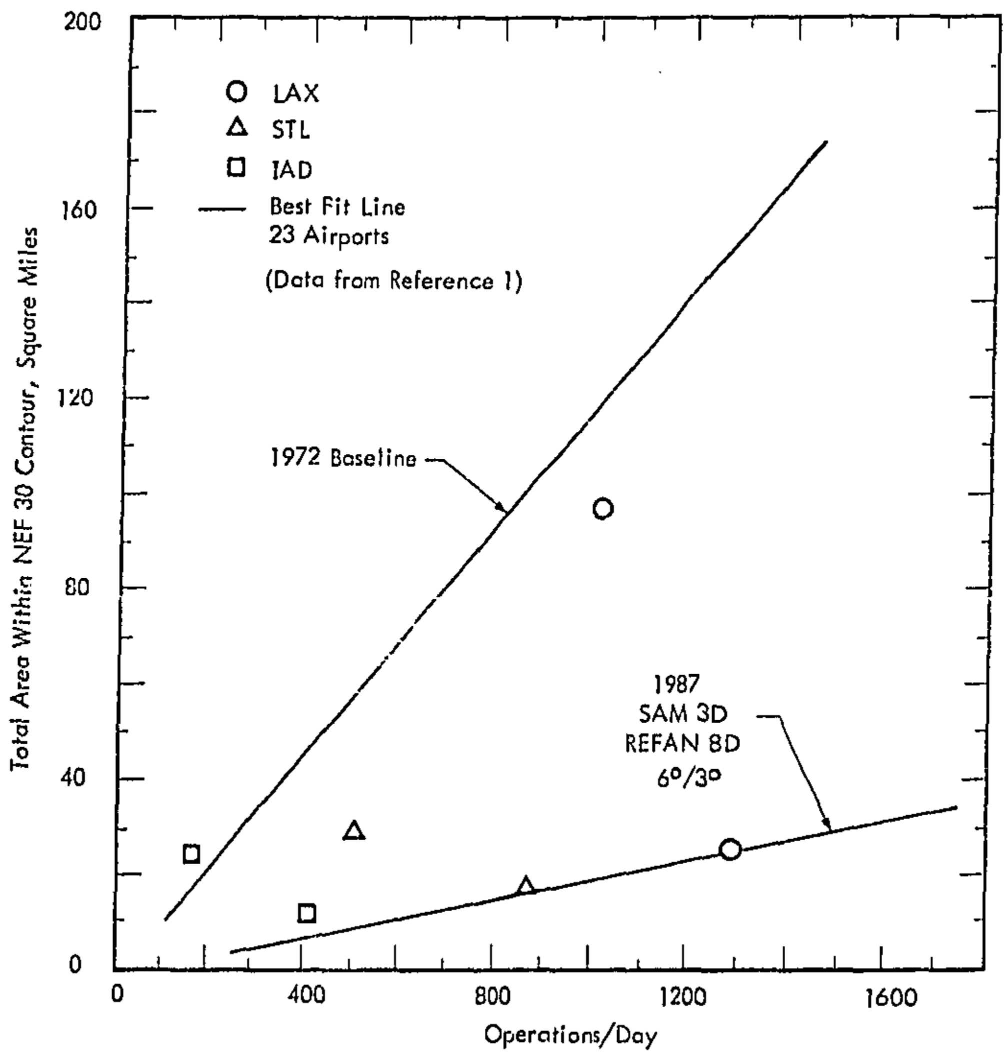


Figure 3-5. Relationship Between Total Area Within NEF 30 Contours and Total Operations

2. With one exception, obvious secondary effects on contour area for a constant number of operations will tend to vary in random fashion over a representative sample so that variations in the relationship between contour area and equivalent operations between specific airports will tend to average out over a large sample, i.e., the population of all the nation's air carrier airports.

3. The exception to neglecting secondary effects is to lump all air carrier aircraft into just two types – jet and nonjet – and to count the noise impact of the latter by counting 10 nonjet aircraft operations as equivalent to one jet aircraft operation. This highly simplified model for equivalent operations is considered justifiable for this initial forecast estimate of national airport noise impact.

For maximum accuracy in defining the 1972 baseline area for the nation, the larger 23 airport sample is used as the reference sample to define A_{Ref} and $N_{R(eq)}$.

For the years 1987 and 2000, the three airports evaluated in this study are used as the reference sample for consistency in future years. In general, as illustrated in Figure 3-6, the correlation between the total contour areas for comparable cases for the 23 and three airport samples is quite good. However, upon closer examination, it becomes clear that the total contour area for the three airports (A_3) is correlated better with the area for 23 airports (A_{23}) for 1987 cases only than for all of the years combined. Furthermore, it was clear that for the 1972 baseline case, the results for the three airports would not be a reliable model for NEF 30 areas for the 23 airports and thus, similarly unreliable for extrapolating to the nation. In summary, therefore, the 23 airport data were used, with the preceding equation, to estimate the national values prior to 1987 and the results for the three airports in this study were used for the years 1987 and 2000. In all cases, the specific scaling factors employed are summarized as follows:

Table 3-6.

Summary of Scaling Factors Used to Extrapolate Results to Nation

Year	No. of Reference Airports	Equivalent Jet Operations*		Ratio of Equivalent Jets (Nation) / Equivalent Jets (Reference Airports)
		Reference Airports	Nation	
1972	23	11,650	22,231	1.91
1978	23	13,722	26,623	1.94
1981	23	15,007	30,205	2.01
1987	3	2,499	38,493	15.4
2000	3	3,414	54,795	16.1

*Equivalent Jets = Jet Air Carrier plus 10 percent of Propeller Air Carrier Operations Per Day

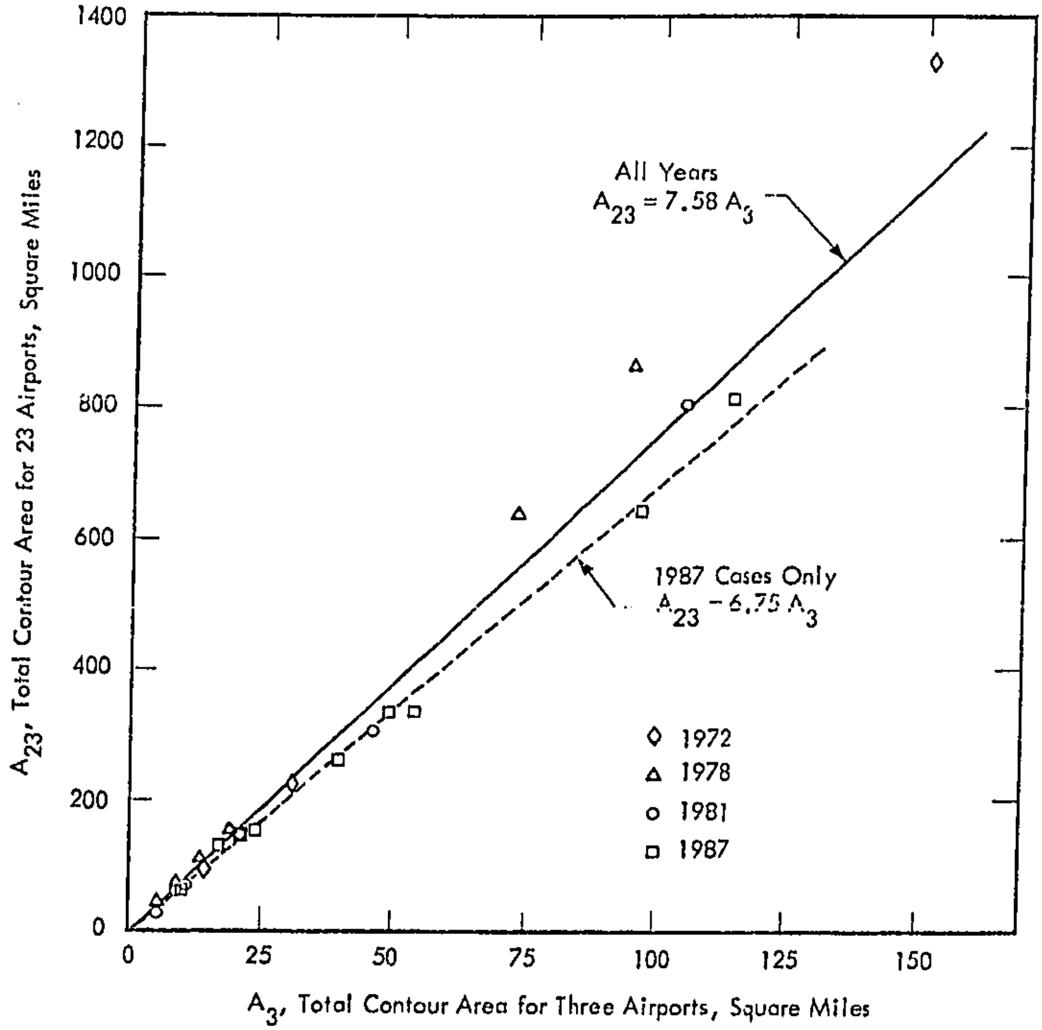


Figure 3-6. Relationship Between Total Contour Area for 23 Airports (A_{23}) and Three Airports (A_3). (For the sake of illustration these simple regression lines were forced through the origin.) Data from Reference 1 for all alternatives and NEF values.

4. AIRPORT/AIRCRAFT FORECAST ANALYSIS FOR U.S.

The airport operations data base, as indicated earlier, was derived from information from the Wyle/DOT 23 Airport Study,[1] FAA aviation statistics,[2] and a special study,[3] which is contained in this report, conducted by R. Dixon Speas Associates. The following paragraphs summarize the data and projections from these sources which were used in this study.

4.1 Forecast of Fleet and Airport Operations

The information in this section, prepared by R. Dixon Speas Associates, contains:

1. A forecast of the general types and numbers of transport aircraft expected to be in operation in the U.S. air carrier fleet in the year 2000.

2. A forecast of the numbers of daily movements of aircraft of each general type expected to be operating in the year 2000 at Los Angeles International, St. Louis, and Dulles Airports.

The U.S. fleet forecast is based on a prediction of continued advances in aircraft technology, and without significant changes in the nature of air transportation services provided in response to a forecast of continuous growth and demand.

The airport operations forecasts reflect a prediction of continued existence of these major hub airports, growth in the average size of air carrier aircraft, and constraints on the development of airport capacity relieved by improved operating efficiency and acceptance rates.*

4.1.1 Long Term Fleet Forecast

The forecast of the future makeup of the aircraft fleet proceeded with the following steps:

1. Forecast of traffic demand

2. Forecast of capacity required to satisfy demand

*Thus, for the purpose of this report in developing operational data for the year 2000, airport capacity was considered to be unconstrained (improvements made to take care of new loads).

3. Forecast of future aircraft unit productivity

4. Forecast of required fleet size

5. Forecast of aircraft categories in the fleet

- Forecast of Traffic Demand

The traffic forecast used in this analysis was an extension to the year 2000 of the forecast (through the year 1987) developed by Speas Associates for the Wyle/DOT Airport Noise Reduction Forecast Study.[1] The new resulting forecasts coincide in the year 1987 with those in Reference 1 and reflect conservative estimates of required air carrier capacity by the year 2000.

- Forecast of Capacity Required

The required total fleet capacity, in available ton-miles (ATMs), was computed using the following load factors:

Scheduled Domestic Passengers	60 Percent
Scheduled International Passengers	60 Percent
Nonscheduled	85 Percent
Cargo	42 Percent

Based on these data, and a gradually decreasing rate of growth, the required capacity through the year 2000 was estimated to be:

1980	112 billion ATMs
1985	185 billion ATMs
1987	218 billion ATMs
1990	278 billion ATMs
1995	385 billion ATMs
2000	500 billion ATMs

- <u>Forecast of Future Aircraft Unit Productivity</u>

Aircraft unit productivity (annual ATMs per aircraft) has increased dramatically in recent years. In 1960, the average aircraft productivity was about 5 million ATMs per year and by 1970 it was about 18 million, reflecting the period of transition from propeller aircraft to larger, faster jets.

Unit productivity is forecast to continue to increase, but at a somewhat lower rate. The increase is mainly attributable to:

- Continued increases in aircraft utilization (hours per aircraft per year)
- Some additional increases in average aircraft speed (due, in turn, to continued retirement of propeller aircraft in the near term and introduction of SSTs in the long term)
- Increases in aircraft capacity, averaged over the fleet, from the present level of about 20 tons to about 50 tons by the year 2000.

- <u>Forecast of Required Fleet Size</u>

The final estimates of the traffic demand and resulting estimates of the total fleet size, calculated by dividing the total capacity required by the average unit productivity, are given in the following table.

Table 4-1

Forecast of Traffic Demand and Fleet Size

Year	Revenue Passenger Miles (Billions)	Revenue Cargo Ton Miles (Billions)	Capacity Required ATMs (Billions)	Average Annual Unit Productivity ATMs (Millions)	Fleet Size
1980	450	17	112	36.4	3080
1985	730	30	185	45.5	4050
1987	850	36	219	49.8	4400
1990	1075	47	278	58	4800
1995	1470	67	385	69	5600
2000	1885	90	500	77	6500

The method for applying these estimates of fleet size to the definition of specific aircraft operations at the three representative airports has been developed in detail in Reference 1. To summarize for this report, the development of estimated fleet mixes for each of the study airports involves three primary steps. The first step involves estimating passenger traffic and total operations at each airport. The second step required that the projected distribution of the U.S. fleet be converted into a distribution of operations of the U.S. air carrier fleet. The third step developed airport mixes based on a comparison of their present air carrier operations mix versus mix for total U.S. operations, and extrapolated a general relationship into the forecast years. The average aircraft size estimate for forecast years was utilized in this step as a general controlling number. Details of the forecast aircraft categories follow.

4.2 Forecast of Aircraft Categories

The major aircraft categories considered for projection of the U.S. fleet are characterized by five "levels of technology:"

- Level 0 (Zero) Propeller aircraft, both piston- and turbine-powered.

- Level I Turbojet and low bypass ratio turbofan aircraft based upon the technology of the early 1960's. These are typically "narrow body" aircraft with normal operating speeds in the Mach .80 to .84 range. Examples are B707, B727, B737, DC-8, and DC-9. New production of these aircraft beyond 1974, designated in the airport activity forecast tables in Appendix C as "unspecified," were assumed to be equipped with quiet nacelles (SAM).

- Level II High bypass ratio turbofan aircraft based upon the technology of the late 1960's. These are the current generation of "wide body" aircraft and their expected evolutionary developments. Examples are B747, DC-10, L-1011, and A.300B.

- Level III Aircraft based on the technology of the later 1970's and early 1980's. These are assumed to differ from the Level I and II families through substantial improvements in propulsion, aerodynamic, and structural efficiency, as well as advanced noise reduction technology. The changes assumed reflected these improvements.

- Level IV Supersonic transport aircraft in the Mach 2 to 3 range based upon conservative evolutionary developments from the technology of the 1970's. (SST aircraft noise impact was included in this study by assuming noise characteristics were equivalent to current 4-engine narrow body turbofan aircraft with SAM retrofit.)

Figure 4-1 indicates the history and forecast of the distribution by category of the U.S. fleet. The figures show the rapid displacement of the Level 0 (propeller) aircraft by Level I during the 10 years, 1959 to 1969. The Level II aircraft are projected to expand their share of the fleet over the 1975 to 1985 period, but this will not be as dramatic a transition as was the initial changeover to jets because the relative improvements in vehicle productivity and efficiency of the total air carrier fleet will not be so great. Beginning in the early 1980's, the retirement of the older Level I jets with 15 to 20 years of service will lead to the introduction of new technology (Level III) aircraft of small-medium capacity, and by the late 1980's, large capacity aircraft of this same general technology level will begin to supplant the large Level II aircraft. Supersonic transports (Level IV) are forecast to be introduced in the early 1980's, gradually reaching about 450 aircraft by the year 2000.

Table 4-2 summarizes the resulting estimate of the fleet for the year 2000, indicating the forecast numbers of aircraft by size and range category.

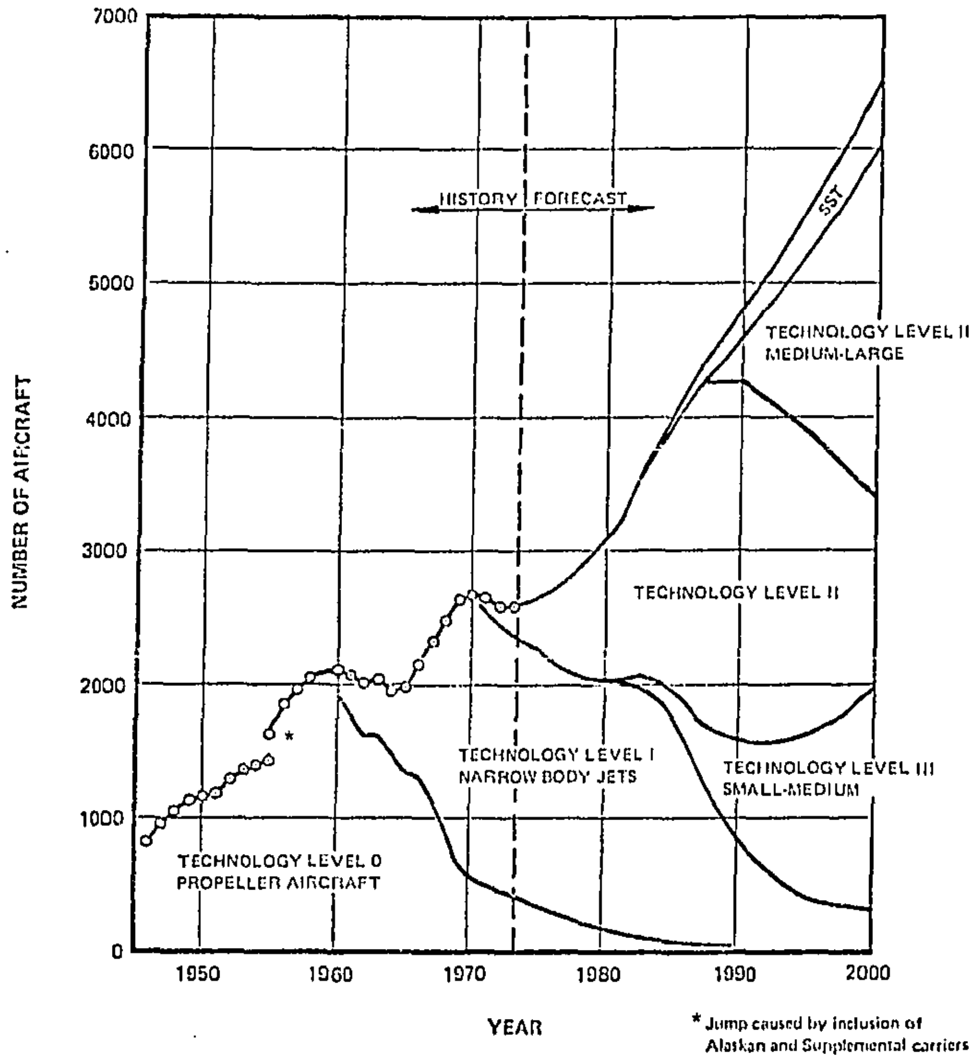


Figure 4-1. History and Forecast - U.S. Air Carrier Fleet (Reference 3)

Table 4-2

Fleet Forecast Summary Year 2000

Technology Level	Aircraft Size*	Seating Capacity	Number of Aircraft	Stage Lengths
I		90 to 200	325	0 to 2500 miles
II	Small	200 to 300	400	0 to 500 miles
	Medium	250 to 400	500	0 to 2500 miles
	Large	>400	600	>500 miles
III	Small	100 to 250	1,625	0 to 2500 miles
	Medium	250 to 400	1,300	500 to 2500 miles
	Large	>400	1,300	500 to >2500 miles
IV	SST	150 to 300	450	>2500 miles
		Total	6,500	

*Small ~2-Engine
Medium ~3-Engine
Large ~4-Engine

4.3 Forecast of Level III Aircraft Characteristics

Based on the projections given in the preceding section, two-thirds of the U.S. fleet will consist of Level III aircraft in the year 2000. Therefore, it was necessary to make some assumptions about Level III aircraft noise and performance characteristics.

4.3.1 Performance Characteristics

Although industry studies have been recently carried out on performance and noise characteristics of advanced technology aircraft, these studies were not considered applicable for purposes of this report.[10] Therefore, assuming potential weight savings due to improved structural design and material selection, and weight savings due to improved propulsion efficiency and aerodynamic performance, it is estimated that Level III aircraft should have approximately the same cruise performance capability as current wide body aircraft with the same payload and range but with a lower maximum takeoff weight. To account for the resulting improvement in aircraft takeoff performance, the climb angles during takeoff for current wide body (Level II) aircraft were modified to correspond to a reduction in takeoff weight. The noise reduction due to increased distances to the aircraft (higher takeoff profiles with larger thrust to weight ratios) or reduced noise output for lower engine thrusts are assumed to be roughly similar. The final takeoff profile curves selected for the Level III aircraft are shown in Appendix B.

4.3.2 Aircraft Noise Characteristics

The basic approach for estimating the noise characteristics of Level III aircraft consisted of four basic steps summarized below.

- Define a reference noise spectrum for current 3-engine wide body aircraft.
- Estimate the decrease in this noise spectrum for Level III aircraft assuming a "quiet nacelle"-type treatment is incorporated in the latter.

- Use the modified sound spectrum, along with corrections, for duration and propagation loss to estimate Effective Perceived Noise Levels versus slant range for the reference (maximum thrust) condition.
- Empirically correct the levels to other thrust conditions and to 2- and 4-engine Level III aircraft based on corresponding data for Level II aircraft.

These procedures are outlined in more detail in the following.

- Reference Spectrum – Level II Aircraft

The reference spectrum consisted of published one-third octave band sound levels of a 3-engine wide body aircraft, normalized to a distance of 200 feet, an angle of 110 degrees to the engine inlet, a maximum takeoff thrust and standard day conditions.[11,13] The resulting spectrum is shown by the upper solid line in Figure 4-2.

- Reference Spectrum – Level III Aircraft

It was assumed that the advanced technology (Level III) aircraft would be designed with noise suppression for the fan inlet and exit comparable to that achieved by an advanced "quiet nacelle" system that could be employed.[12] Representative values for the additional attenuation obtainable for this design were estimated in the following manner.

1. The levels observed for the current 3-engine wide body aircraft (top line in Figure 4-2) were compared to predicted levels for the same engines without any nacelle treatment using jet engine noise prediction methods developed by The Boeing Company.[12] This provided a measure of the amount of fan noise reduction achieved with current technology aircraft.

2. The maximum total attenuation obtainable with a quiet nacelle treatment was then estimated using nacelle attenuation prediction methods in the same reference.[12]

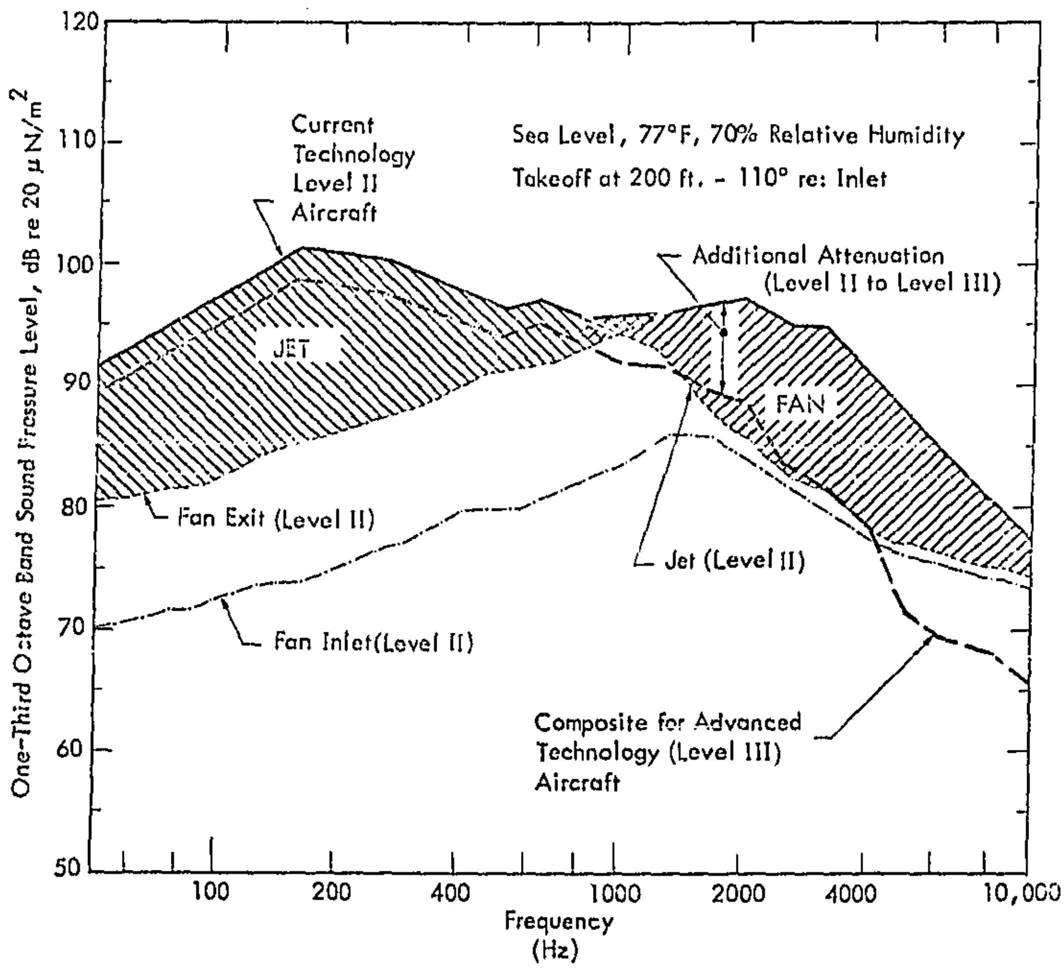


Figure 4-2. Three-Engine Wide Body Reference Spectra (Data for Level II Aircraft from References 11, 12, and 13. Data for Level III Aircraft Computed – see Text)

3. The difference between this latter maximum attenuation for advanced technology aircraft and that predicted from step 1 for current technology aircraft was then applied as the incremental increase in fan noise reduction anticipated for Level III aircraft. This approach insured that one consistent industry-developed method was used to evaluate only the incremental change in fan noise attenuation.

It was also assumed that the jet noise portion of the current engine noise signature, in Figure 4-2, was attenuated by an additional 3 dB. For reference purposes, Figure 4-2 shows, in addition to the overall noise level for Level II aircraft, estimated levels of its major components and, finally, the resulting estimate of the composite attenuated noise signature for Level III aircraft.

- Effective Perceived Noise Level Versus Distance

To obtain values of EPNL versus distance, the new reference spectrum was first used along with an improved air absorption propagation loss model[16] to compute maximum Perceived Noise Level (PNLM) versus slant range. EPNL versus slant range was then computed from an empirical correction between EPNL and PNLM versus slant range, reported in Reference 12, which was derived from extensive experimental data on current narrow body jet aircraft. The air absorption propagation loss model actually employed provides attenuation values nearly the same as those computed from the industry standard for standard day conditions.[15]

- Corrections for Varying Thrust and Number of Engines

The EPNL versus slant range values (at maximum takeoff power for a Level III 3-engine aircraft) were extrapolated to lower thrust levels using the same comparable changes in EPNL noted for Level II aircraft.[7] The 3-engine noise curves were adjusted for application to the 2-engine Level III aircraft by subtracting 1.8 EPNdB, which accounts for the difference in the number of engines. For the 4-engine Level III aircraft, the 3-engine noise curves were increased by 3 EPNdB, which accounts for the difference in the number of engines and the difference in maximum corrected net thrust. The resulting final values of EPNL versus slant distance for Level III aircraft are given in Appendix B.

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APPENDIX A

AIRPORT NOISE IMPACT ANALYSIS

This appendix outlines a procedure for extrapolating estimates of the total area within NEF 30 or 40 contours to the area within NEF 20 contours. The latter value corresponds approximately to a Day-Night Average Sound Level (L_{dn}) of 55.[9] In addition, a method is defined for estimating the total impacted area which excludes the portion within the airport boundary and area over water. This method is then applied to development of a procedure for estimating the total and impacted area for the nation's air carrier airports. The latter procedure includes the evaluation of the distribution of air carrier airports, according to their number of daily operations, for the years 1972, 1987, and 2000. Finally, the detailed tables of computed areas for the three airports and estimated values for the nation are provided.

A.1 Extrapolation to NEF 20 Areas

By combining data from a few specific cases for the three airport sample for which NEF 20 contours were computed with data from the Airport Noise Reduction Forecast study, it was possible to show the relationship indicated on Figure A-1 for enclosed area relative to the area within the NEF 30 contour. The average relationship indicated in the figure is equivalent to a doubling of area within NEF contours for each decrease of NEF by 4.1 dB or, alternately, an increase in area by a factor of about 2.33 for each decrease in NEF by 5 dB. On the basis of this scaling law, the areas computed for NEF 30 were increased by a factor of 5.44 to obtain the estimate for areas within NEF 20 using the equation shown in Figure A-1.

A.2 Evaluation of Impacted Land Excluding Airport Property and Area Over Water

Drawing, again, on the detailed data from the Airport Noise Reduction Forecast Study in Reference 1, Figure A-2 shows the systematic relationship obtained between the sum of the total areas within NEF 30 to 45 contours for the 23 airports

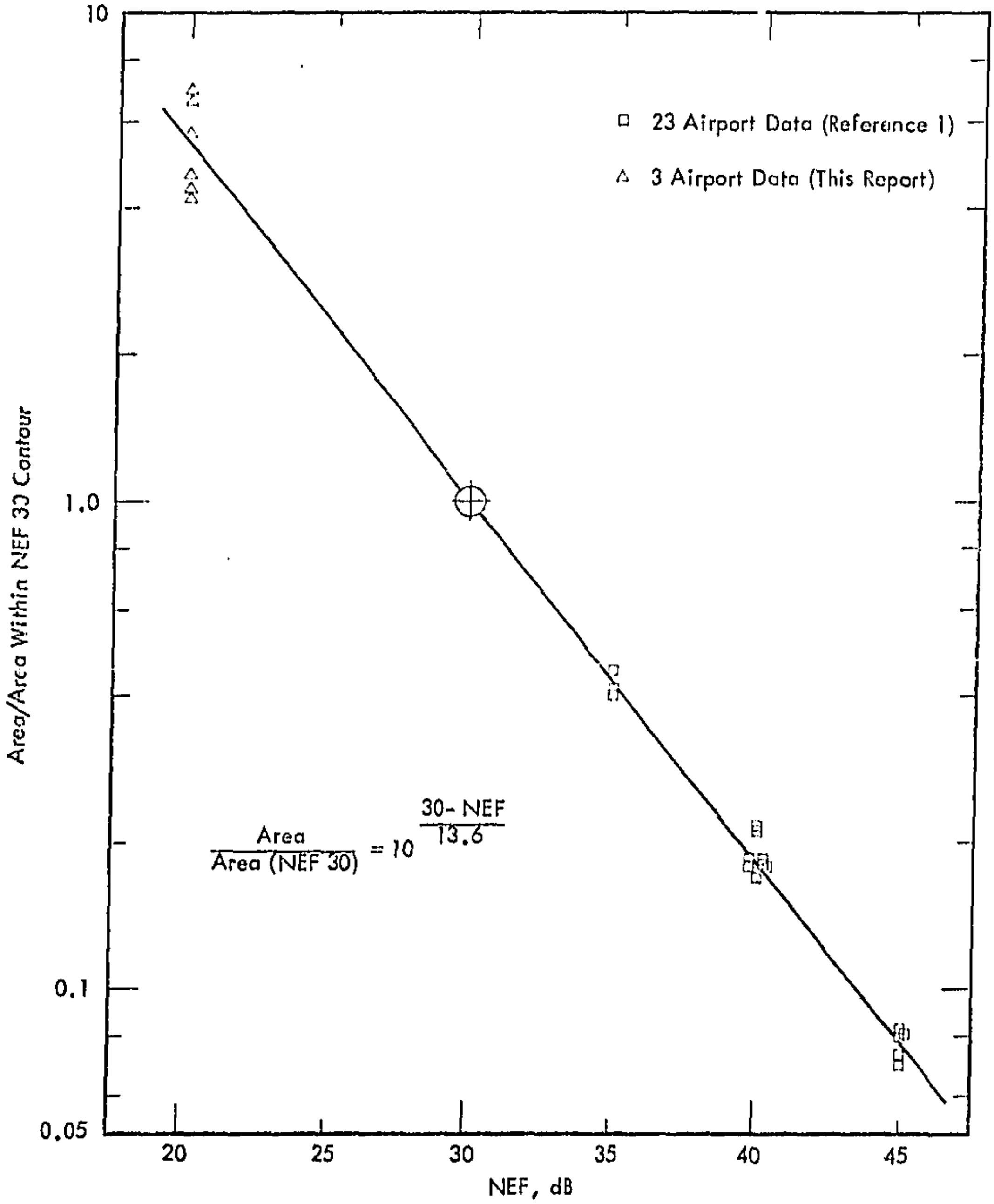
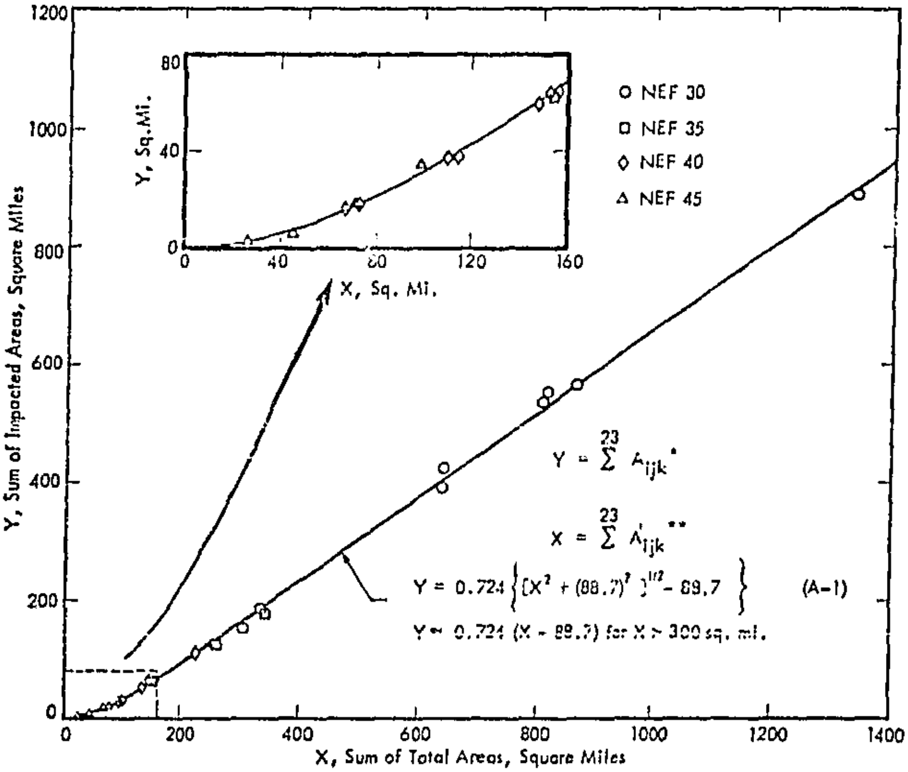


Figure A-1. Relative Change in Total Area Within NEF Contours As a Function of NEF Value



$^{*}A_{ijk}$ = total area at the ith airport for the jth alternative within the kth NEF value contour.

$^{**}A'_{ijk}$ = Impacted land area at the ith airport for the jth alternative within the kth NEF value contour.

Figure A-2. Impacted Land Area Versus Total Area for Sums of Areas for Alternatives and NEF 30-45 Values at 23 Airports (Data from Reference 1) and the total impacted area which excludes airport property and area over water. Note that this figure also includes the effect of verious alternatives and time periods (1972 - 1987) on the relationship between total and impacted areas. We will examine this type of relationship in more detail later in this appendix. The linear trend shown in Figure A-2 for large values of total contour area can be fairly well explained in terms of a simple model which would predict that for the 23 airports, the impacted area is 72.4 percent of the total contour area in excess of a fixed minimum (non-impacted) area of about 89 square miles representing airport property within the contour. The more complex equation shown on the figure (Equation A-1) represents a hyperbola which fits the nonlinear relationship between total area and impacted area when the former is less than about 300 square miles (for the 23 airports).

A.3 Method for Extrapolation of Study Results to the Nation

The following technique was developed in order to extrapolate the results of the airport sample considered in this study (23 airports for the 1972 baseline and 3 airports for the years 1987 and 2000) to estimated national values for total and impacted area. The technique involved the following elements to predict the total contour area.

- Estimate the profile of the nation's air carrier airports by number of air carrier operations for the years 1972, 1987, and 2000.
- Estimate the percent of nonjet air carrier operations at each airport (grouped according to number of operations). Add 10 percent of these nonjet operations to the jet air carrier operations to obtain the "equivalent jet" operations.
- Estimate the total contour area for each airport category according to the number of equivalent jet air carrier operations.
- Sum up the total contour areas using the previously developed profiles of airports by numbers of operations.

To estimate the total impacted land area, the following additional steps were taken:

- Estimate the components of nonimpacted area (i.e., airport property and water area inside the contour). It was found possible to roughly estimate these nonimpacted area components by knowing the number of air carrier operations at an airport, and its general proximity to water.
- Use the preceding profile of air carrier airports (for 1972) to compute the total impacted land area for the 1972 baseline case for all of the nation's airports.
- Use these results to modify results of Section A.2 which were based on the 23 airport data, to a form suitable for estimating impacted land area for all of the nation's airports.

The following considers each of these elements in more detail.

A.3.1 Profile of the Nation's Air Carrier Airports by Number of Operations

The total number of air carrier operations in the U.S. were forecast in Reference 1 through the year 1987. Based on the additional forecasts on air carrier activity to the year 2000 discussed in Section 4.1, it was possible to estimate the growth in air carrier operations to the year 2000 for the U.S. air carrier fleet. Starting from a figure of 14.3 million operations per year in 1987,[1] it was estimated that annual operations would grow at the rate of 2.6 percent per year to reach 20 million operations per year by the year 2000.* This estimate was consistent with the forecast growth in air carrier capacity (available ton-miles), unit productivity (available ton-miles per aircraft), number of air carrier aircraft and the corresponding slow decrease in the average number of daily operations per aircraft, as the size and trip lengths of the fleet-average

*The forecast of total operations at the three sample airports in this study increased at a rate equivalent to 2.4 percent per year from 1987 to 2000. For the purpose of this report in developing operational data for the year 2000, airport capacity was considered to be unconstrained (improvements made to take care of new loads).

aircraft tend to increase. Several variations on this empirical extrapolation of operations to the year 2000 produced similar results so that a more detailed analysis was not considered warranted.

The forecast trends in these parameters are shown in Figure A-3. The values from 1987 on, including some previously listed in Section 4.1, are summarized as follows. (Values for these parameters before 1987 may be computed or obtained from the data in Reference 1.)

Year	Annual Operations $\times 10^6$	Average Daily Operations Per Aircraft	ATM (Annual Total) $\times 10^9$	U.S. Fleet Size
1987	14.3	8.9	219	4400
1990	15.4	8.8	278	4800
1995	17.6	8.6	385	5600
2000	20.0	8.4	500	6500

With the knowledge of total operations, it was now possible to estimate the profile of operations per airport using an extrapolation of airport operations forecast data from Reference 17. The latter provides values of actual (FY 1973) and forecast (FY 1985) operations at each of the air carrier airports in the U. S. This includes all airports with FAA control towers plus a large number of smaller airports without FAA control towers. The estimated cumulative distribution of these airports by number of operations per day in the study years 1972, 1987, and 2000 is shown in Figure A-4. The cumulative distribution is shown in terms of number of operations in logarithmically-spaced intervals for which the geometric center points differ by 10 to the 0.1 power.

The estimated distributions for the years 1972, 1987, and 2000 were constructed as follows. For 1972, the profile of operations for the 23 airports were used along with values from Reference 2 for the other larger airports (32 or more operations per day). The

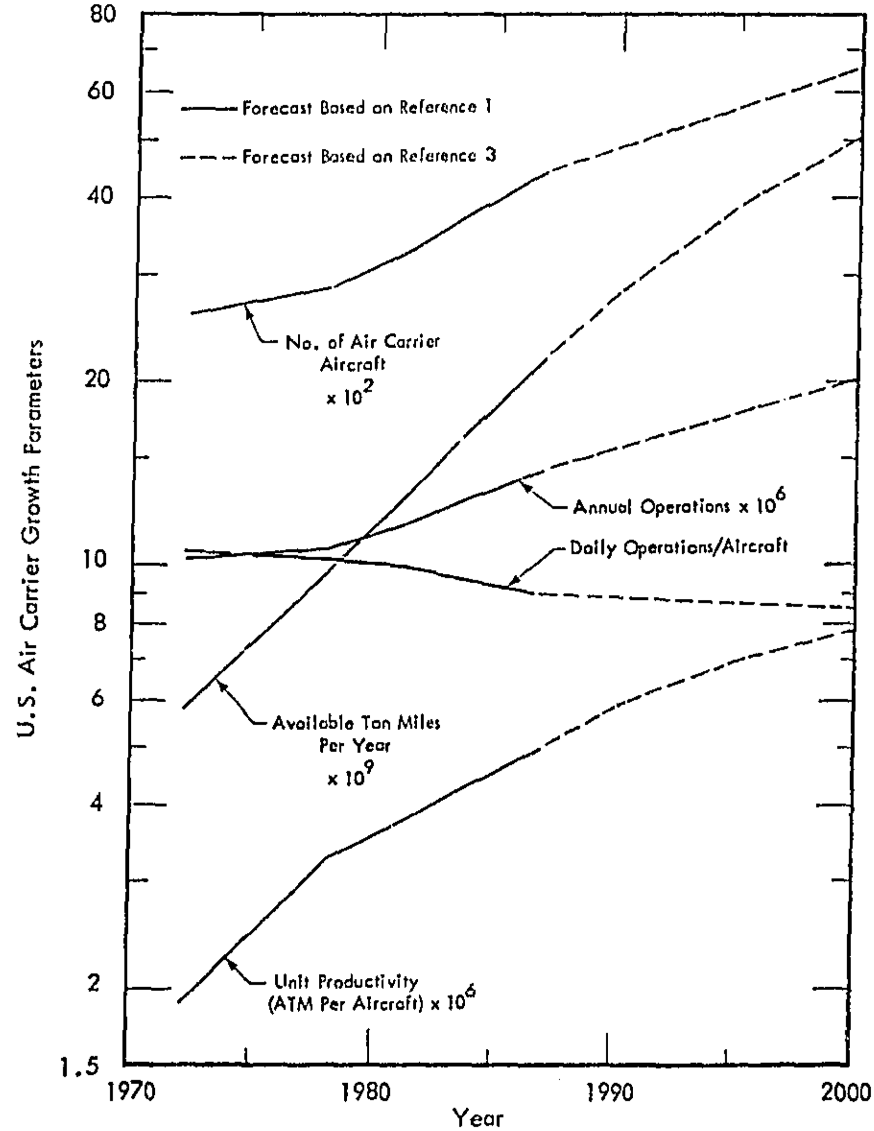


Figure A-3. Forecast of Size and Activity of U.S. Air Carrier Fleet

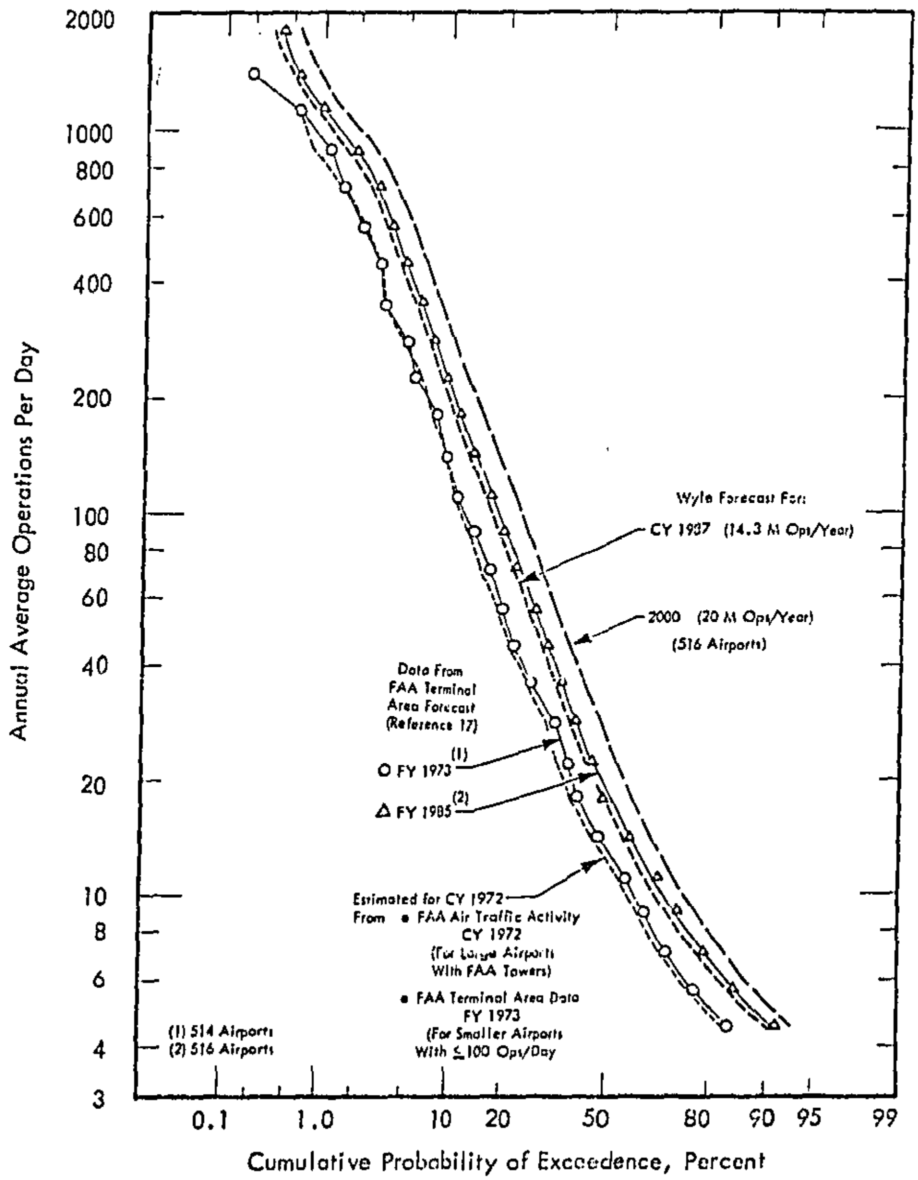


Figure A-4. Cumulative Distribution of Percent of Airports with Air Carrier Operations Greater Than a Given Number Per Day operations for smaller airports were estimated by adjusting the FY 1973 distribution until the total integrated number of operations at all the airports agreed with the value of 10.02 million operations per year cited in Reference 1 for CY 1972. The adjustment was a minor one and was only made to provide a consistent profile of operations for the 1972 baseline.

For the years 1987 and 2000, the FY 1985 profile of airports in Figure A-4 was adjusted by shifting the curve horizontally along the percent axis. The shift was just that necessary to change the mode of the distribution (i.e., the 50 percent point) by the same ratio as the ratio of total operations forecast in Reference 17 for FY 1985 and the desired total operations for 1987 or 2000. This empirical approach provided a new distribution which, within 1 to 2 percent, added up to the desired number of total operations. No further adjustment was made to try to eliminate the remaining small residual error in total number of operations. Furthermore, no attempt was made to include the addition of new, very small, air carrier airports in this distribution which could occur as new cities are formed. However, it should be noted that the forecast distribution of airports for future years show a steadily increasing number with more than 10 air carrier operations per day, (i.e., 292 airports in 1972, 319 in 1987, and 365 in the year 2000). This is considered to represent the increase in airports with sufficient operations to cause a significant noise impact. As shown later on, it was estimated that, for the 1972 baseline case, less than 10 air carrier operations per day did not show any significant noise impact. This is due, in part, to the estimated higher proportion of low-noise prop aircraft at such small airports. In future years, as prop aircraft are replaced with jets, the decreasing noise levels of these newer jets will tend to minimize any significant increase in noise impact for such low levels of operations. Thus, while there will undoubtedly be an increase in the total number of air carrier airports in the future, the increase, over and above the number accounted for in the projections in Figure A-4, is expected to occur in categories of very low operations per day below the level of significant impact. When specific operations data had to be estimated (i.e., small airports for 1972 and all airports for 1987 and 2000), the total operations were computed by the sum of the number (n_i) of airports in a given (i^{th}) category of operations per day multiplied by the geometric mean (N_i) of the operations per day in each i^{th} category.

Thus, the total for all airports was simply

$$N_T = \sum_{i=1}^{I} N_i \cdot n_i \;, \qquad \text{operations} \qquad \text{(A-2)}$$

where the index I represents the number of categories

A.3.2 Nonjet (Propeller) Aircraft Operations

Based on an analysis of the 1972, 23 airport sample and 1972 aircraft traffic data for a 10 percent sample of the smaller airports, an estimate of the relative number of jet aircraft operations was made as a function of number of daily departures for each interval in the airport distribution. As shown in Figure A-5, the estimate for 1972 ranged from 6 percent nonjet operations at the large airports with a smooth transition to 100 percent nonjet operations at airports with less than two operations per day. For 1987, the estimated shift in percent distribution of propeller aircraft was made so that the decrease in total number of propeller operations predicted, according to the forecast profile of total operations, corresponded approximately to the values projected in Reference 1 for total operations of propeller aircraft (i.e., 0.3×10^6 operations per day in 1987). There were no propeller aircraft operations forecast by the year 2000 (see Section 4.2).

The nonjet operations were counted for this study, at 10 percent of their actual value and added to the actual jet operations to provide the total equivalent jet operations as a conservative basis for estimating impact from all air carrier aircraft.

A.3.3 Total Area Within NEF 30 Contours Versus Equivalent Jet Operations

Using the 23 airport data from Reference 1, a regression line between total area within the NEF 30 contours (for 1972 baseline conditions) and total (equivalent) jet operations for 1972 was constructed. A correlation coefficient (r) of 0.839 was obtained when the logarithm of total contour area (A_t) was plotted versus the log of total equivalent operations (N_{eq}) to produce a regression equation given by:

$$A_t = 0.097 \, (N_{eq})^{1.012} \qquad \text{(A-3)}$$

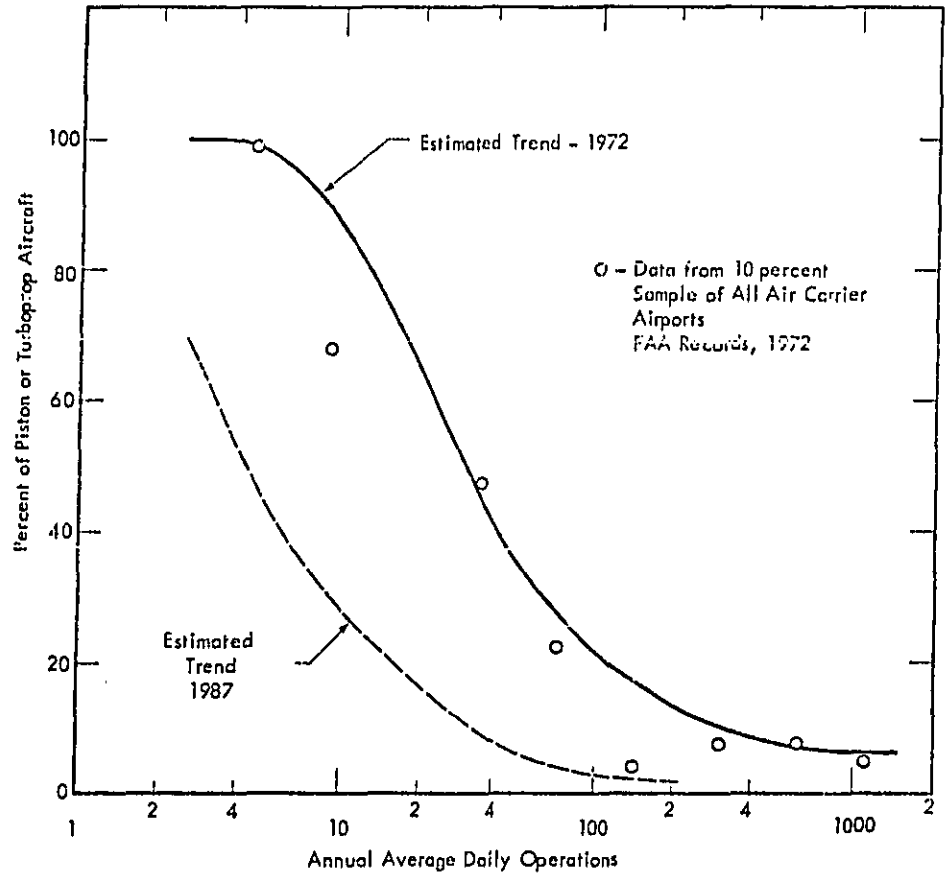


Figure A-5. Estimated Percent of Airport Operations Carried Out by Propeller Aircraft

However, as shown in Figure A-6, a simpler expression can be used which is based on a forced linear fit of the data. This linear expression, which also assumes zero contour area for zero operations, is given by:

$$A_t = 0.114\, N_{eq} \tag{A-4}$$

Such a linear scaling law simply expresses the concept that total contour area would vary directly with number of equivalent jet operations. The proportionality constant would, of course, depend on the contour level and aircraft mix or noise reduction alternative. This general trend towards a simple linear scaling law was observed for other NEF levels and alternatives.

However, for estimating the total contour area for other cases, for the nation, it is not necessary to define the particular proportionality constant involved for each case. Rather the simple linear scaling law defined earlier in Section 3.2 of the main body of the text can be used. This linear scaling of total contour area by the ratio of equivalent jet operations follows immediately from the type of linear equation (A-4) cited above.

A.3.4 Projected Total Contour Area for the Nation

Applying the techniques defined in the preceding paragraphs, including the analysis of the airport/operations profiles, the percent nonjet operations, plus airport operating data for this study in Reference 1, produced the following figures for total and equivalent jet operations for the nation and the two airport samples for the study years.

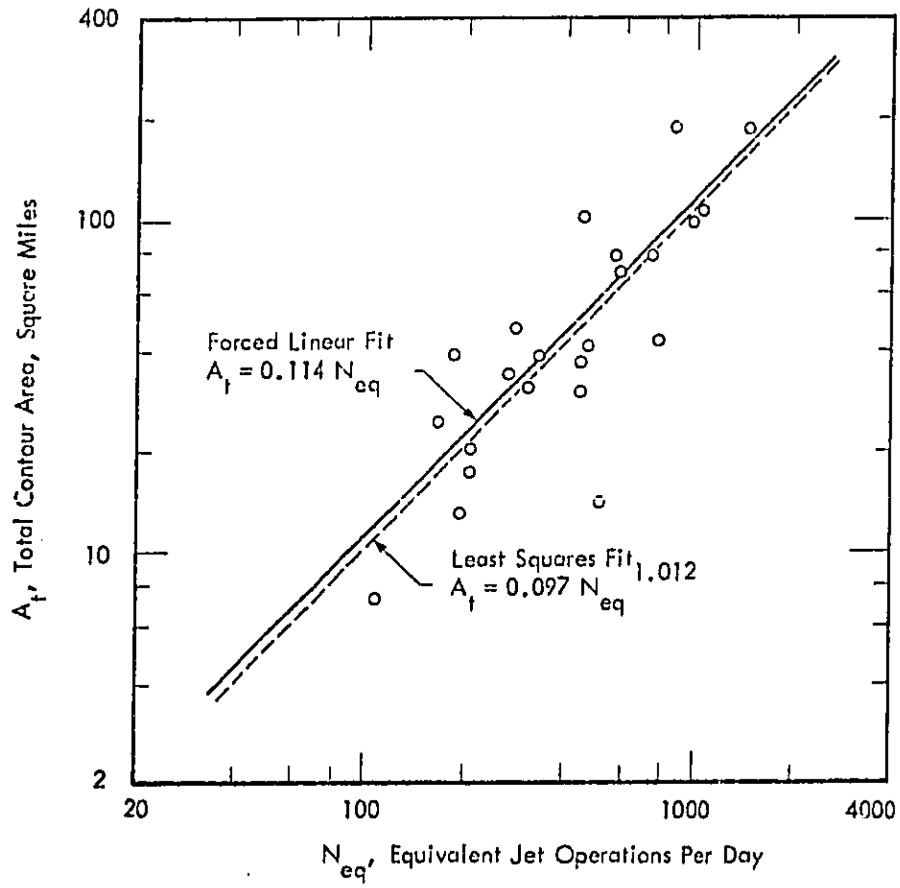


Figure A-6. Relationship Between Total Contour Area and Equivalent Jet Operations for the NEF 30, 1972 Baseline Case From the 23 Airport Study (Reference 1)

Year	Total Operations Per Day (Nation)	Total Equivalent Jet Operations Per Day Nation	23 A/P	3 A/P
1972	27,452	22,231	11,650	1605
1987	39,233	38,493	17,571	2499
2000	54,795	54,795	-	3414

These values of equivalent jet operations were used, as specified in Section A.3.3, to predict the national contour areas.

For the 1972 baseline case, the total sample areas employed from the 23 airport study were as follows:

NEF 30 1333 square miles

NEF 40 226 square miles

The total sample areas from the three airports used in this study are summarized in Section A.4 of this appendix along with the areas scaled to the nation.

A.3.5 Impacted Area for the Nation

Evaluation of the components of nonimpacted land area obtained from the results of Reference 1 made it possible to define the following approximate predictions for (a) the portion of airport property inside a contour in terms of total airport property (A_p) and total contour area (A_t), and (b) the portion of contour area over water (A_w) for airports near water.

Airport Area - FAA Form 5010-2 records as of June 1, 1974 indicate 981 square miles of property area for 463 certificated airports.[14] These national figures and the specific property areas for 36 major U.S. airports with a total area of 201 square miles provided the basis for the following rough estimates for total property areas within any of the nation's airports in terms of total operations per day (N_t).

$$N_t \geq 180/\text{day}, \quad A_p = 0.2 + 0.0086\, N_t, \ \text{mi.}^2 \qquad \text{(A-5)}$$

$$N_t < 180/\text{day}, \quad A_p = 1.8\ \text{mi.}^2 \qquad \text{(A-6)}$$

These relationships are based on a rough approximation of the airport property area versus operations data shown in Figure A-7.

Impacted Area for Airports Not Near Water - For all of the airports in the 23 airport sample, when the area over water (A_w) was added (where applicable) to the impacted land area (A_i), it was found that this sum (equal to the total contour area minus only the airport area within the contour) could be predicted for the total of the 23 airports, or the total of the 7 smallest of these 23, by the following expression

$$A_i + A_w = \left[(.8A_p)^2 + (A_t)^2\right]^{\frac{1}{2}} - 0.8A_p\ , \text{mi.}^2 \qquad \text{(A-7)}$$

As shown in Figure A-8, the curvilinear relationship obtained for small values of the total contour area (A_t) is well defined by Equation (A-7) for either the entire sample of 23 or the 7 smallest airports. Thus, this equation provided a good estimate of impacted land area for any airport not near water (those for which A_w was zero) and was applied to the detailed national estimate of impacted land area for the 1972 baseline.

Impacted Area for Airports Near Water - Based, again, on the 23 airport data for airports near water, it was possible to roughly predict the area over water (A_w) in terms of the total contour area, A_t. The following simple relationships, which depended on airport size, are shown in Figure A-9.

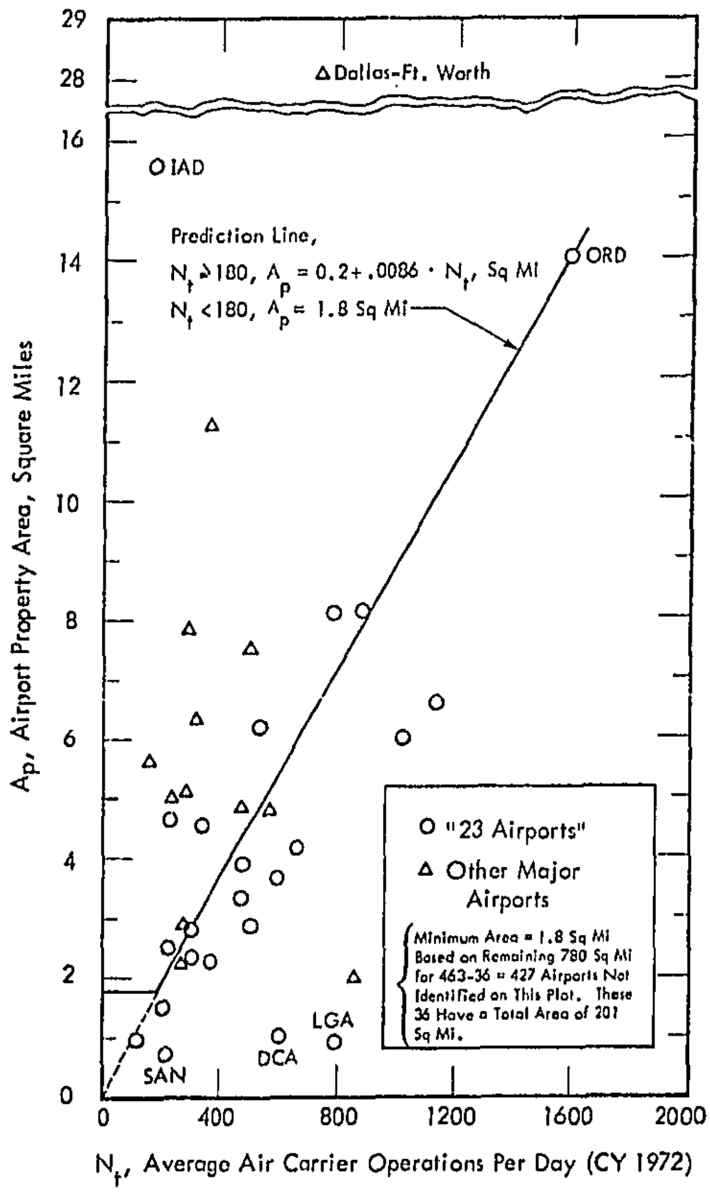


Figure A-7. Airport Area Versus Average Daily Operations for 36 Major U.S. Air Carrier Airports

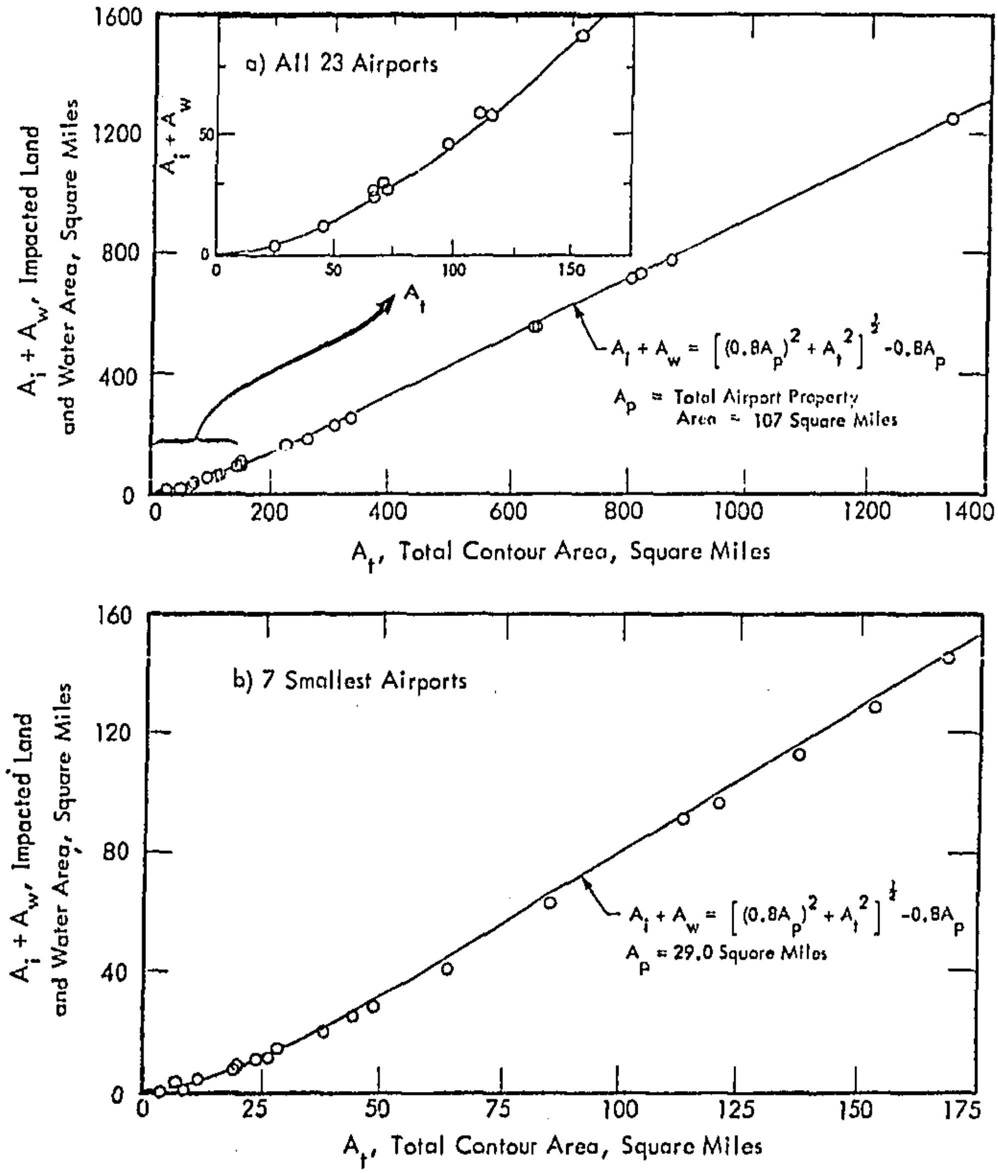


Figure A-8. Total Impacted Land Area Plus Water Area Versus Total Contour Area for All and Seven Smallest of 23 Airports. (Data from Reference 1)

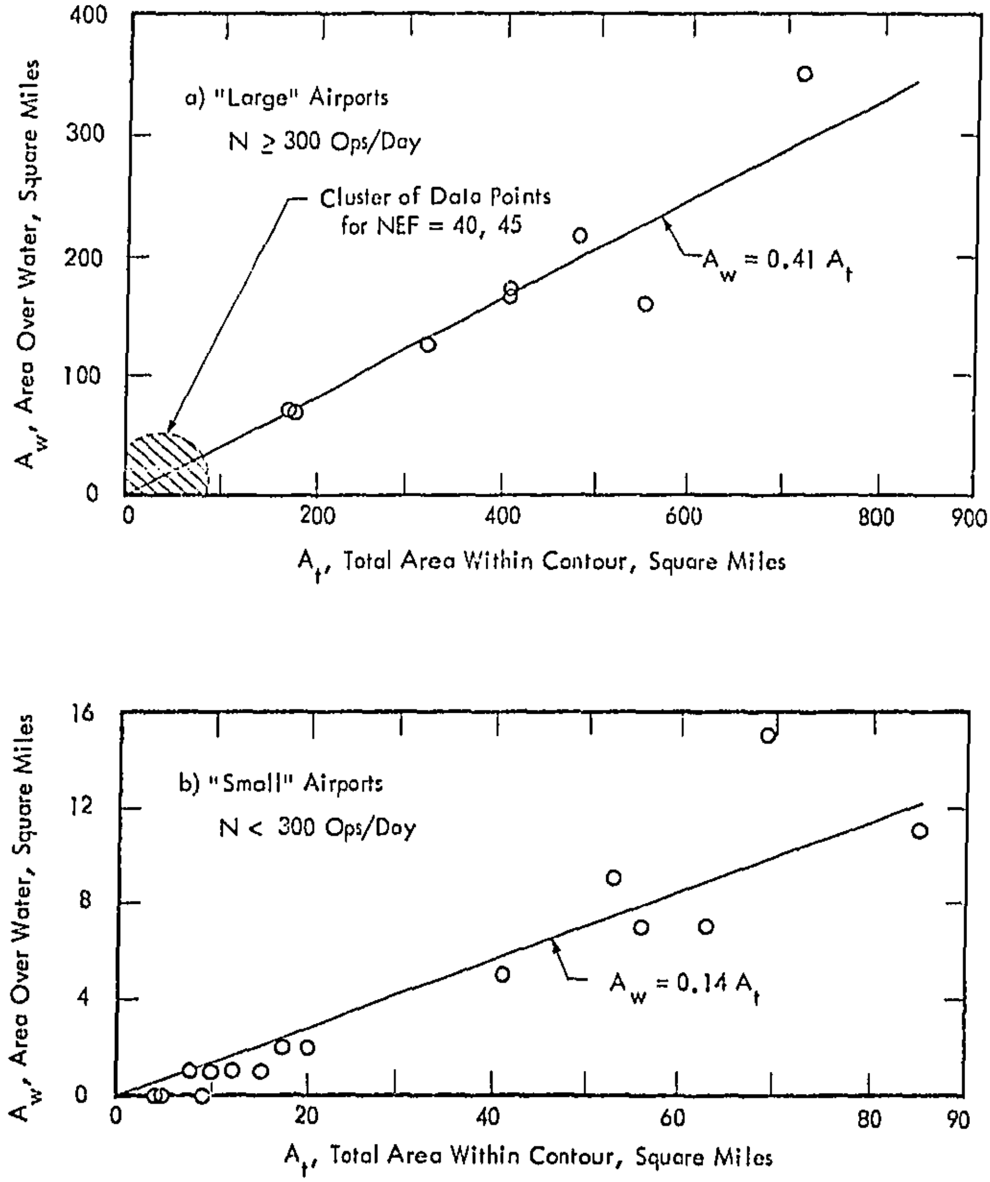


Figure A-9. Estimated Area Over Water Predicted from Results of 23 Airport Study (Reference 1)

$$\text{For } N \geq 300 \text{ operations/day,} \quad A_w = 0.41\,A_t, \text{ square miles} \qquad \text{(A-8)}$$

$$\text{For } N < 300 \text{ operations/day,} \quad A_w = 0.14\,A_t, \text{ square miles} \qquad \text{(A-9)}$$

From a rough sampling of about 250 of the air carrier airports, it was estimated that about 21 percent are located near water with part of the contour areas lying over water. This proportion was applied later, along with Equations A-8 and A-9, in making the detailed estimates of impacted area.

Estimate of Total Impacted Land Area for 1972 Baseline - The preceding techniques have been used to make a detailed estimate of the impacted land area for the nation for the 1972 baseline case. It was anticipated that a simplified method could be developed from this analysis which would be patterned after the simple approach for estimating impacted land area discussed earlier in Section A.2.

The profile of airports by operations for 1972 and the resulting analysis of the total contour area and impacted land area for the nation for NEF 30 is presented in Table A-1. As indicated, the known results for the 23 airports from Reference 1 are not included in the analysis. Thus, only the remaining 491 air carrier airports (514-23) were analyzed for this base case. The resulting estimate of total contour area for the nation within NEF 30, including the 23 airports, is 2589 square miles — just 2 percent higher than the value obtained by scaling the total contour area for 23 airports to the nation according to the ratio of equivalent jet operations. The total impacted land area for the nation was computed to be 1854 square miles.

The same result for impacted land area could be obtained by adjusting Equation A-1 shown in Figure A-2 which related total contour area and impacted land area for all of the 23 airport study cases from 1972 to 1987. First, an adjustment was made to increase the constant term (88.7) in this expression by the ratio of total operations for the nation to the total operations for the 23 airport sample. For the years 1972 to 1987, this ratio averaged 2.12 ± 0.08. The logic of this adjustment is that, as illustrated earlier, airport property scales roughly as the number of operations and this

Table A-1

Analysis of Total and Impacted Area Within NEF 30 for 1972 Baseline at Air Carrier Airports Excluding the 23 in Reference 1

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
Operations/Day			Distribution of Airports		Total Operations		Propeller Aircraft Operations	Total Propeller Aircraft	Equivalent Jet Operations		Total Contour Area		Airport Area	Total Airport Area		Impacted Area		Impacted Area	Total
Minimum	Maximum	Geometric Mean	No Water	Near Water	No Water	Near Water	In percent	Operations	No Water	Near Water	No Water Sq. Mi.	Near Water Sq. Mi.	Per Airport	No Water	Near Water	No Water	Water Area	Near Water	Impacted Area
1250	1600	1410	-	-	-	-	6.2	-	-	-	-	-	12.3	-	-	-	-	-	-
1000	1250	1120	-	-	-	-	6.5	-	-	-	-	-	9.8	-	-	-	-	-	-
800	1000	890	-	-	-	-	6.7	-	-	-	-	-	7.9	-	-	-	-	-	-
630	800	710	1	-	723	-	7.0	5	719	-	81.9	-	6.3	6.3	-	77.0	-	-	77.0
500	630	560	1	-	560	-	7.5	47	522	-	59.5	-	5.0	5.0	-	55.6	-	-	55.6
400	500	445	-	1	-	483	8.0	4	-	480	-	54.7	4.0	-	4.0	-	22.4	29.2	29.2
315	400	355	1	-	360	-	9.5	34	329	-	37.5	-	3.3	3.3	-	35.0	-	-	35.0
250	315	280	3	2	871	583	11.0	154	740	525	84.4	59.7	2.6	7.8	5.2	78.3	8.4	47.4	125.7
200	250	225	3	1	693	237	13.0	121	612	211	69.8	24.1	2.1	6.4	2.1	64.8	3.4	19.0	83.9
160	200	180	4	1	677	171	15.0	128	595	151	66.8	17.2	1.7	7.0	1.7	61.4	2.4	13.5	74.9
125	160	140	5	4	706	597	17.5	228	595	505	67.8	57.6	1.8	9.0	7.2	61.0	8.1	44.0	105.0
100	125	110	7	3	823	372	20.0	239	675	264	77.0	30.1	1.8	12.6	5.4	67.5	4.2	21.9	89.4
80	100	89	12	2	1039	389	24.0	293	815	141	92.9	16.1	1.8	21.6	3.6	77.2	2.3	11.2	88.4
63	80	71	9	2	638	132	27.5	212	467	99	54.7	11.3	1.8	16.2	3.6	43.3	1.6	7.2	50.5
50	63	56	16	4	874	234	32.0	355	622	167	70.9	19.0	1.8	28.8	7.2	51.5	2.7	11.5	63.0
40	50	45	9	1	392	43	38.0	167	253	37	29.4	3.6	1.8	16.2	1.8	19.2	0.5	2.0	21.2
31.5	40	35	20	8	704	277	45.0	441	417	165	47.8	18.3	1.8	36.0	14.4	27.0	2.6	7.9	34.9
25	31.5	28	21	8	606	220	52.0	430	372	117	36.7	13.3	1.8	37.8	14.4	17.3	1.9	4.2	21.5
20	25	22	13	3	284	77	61.5	222	127	34	14.5	3.7	1.8	23.4	5.4	4.9	0.5	0.9	5.9
16	20	18	13	1	207	29	69.5	164	73	11	0.9	1.3	1.8	23.4	1.8	2.0	0.2	0.3	2.3
12.5	16	14	21	3	271	49	77.0	267	87	15	10.1	1.7	1.8	37.8	5.4	1.7	0.2	0.1	1.7
10	12.5	11	23	6	264	65	83.5	275	65	16	7.5	1.5	1.8	41.4	10.8	0.8	0.3	0.0	0.8
8	10	9	15	3	141	25	89.5	149	27	5	3.1	0.6	1.8	27.0	5.4	0.2	0.1	0.0	0.2
< 10			190	51	351	94	95.0	423	51	14	5.8	1.6	1.8	342.0	91.8	0.1	0.2	0.0	0.1
Total			387	104							919.3*	336.6*							966.7*

Key to Table A-1

Column	Description
A	Minimum number of operations per day.
B	Maximum number of operations per day.
C	Geometric mean of daily operations ($= \sqrt{AB}$).
D,E	Includes airports without FAA tower.
F,G	Includes airports without FAA tower.
H	See Column C and Figure A-5.
I	$(F + G) \cdot H/100$
J	$F(1 - 0.9H)$ — Equivalent to subtracting all propeller operations and adding back 10 percent.
K	$G(1 - 0.9H)$ — Equivalent to subtracting all propeller operations and adding back 10 percent.
L,M	See Equation A-4.
N	See Figure A-7, Equations A-5, -6 and Column C.
O	Column D times Column N.
P	Column E times Column N.
Q	See Equation A-7, also $A_w = 0$, A_p = Column O and A_t = Column L.
R	See Figure A-9, Equations A-8, -9 and Columns M and C.
S	See Equation A-7, also A_w = Column R, A_p = Column P and A_t = Column M.
T	Column Q plus Column S

* Excludes corresponding Areas for 23 Airports in Reference 1

constant (88.7) can be taken to represent the total airport area inside the contours for only the 23 airports. The second adjustment was to increase the first constant (0.724) in Equation (A-1) to 0.77 so that the resulting final expression produced the same estimate of impacted land area (1854) as was obtained from the more detailed analysis in Table A-1. The logic for this minor correction is that the smaller airports are expected to have less contour area lying over water so that the net impacted area would tend to be greater. The resulting final expression for estimating impacted area (A_i) in terms of total contour area (A_t) for all the nation's airports is

$$A_i = 0.77 \left\{ \left[A_t^2 + (186)^2 \right]^{\frac{1}{2}} - 186 \right\} \text{, square miles} \qquad \text{(A-10)}$$

Since this type of relationship proved valid for the 23 airports, it was considered valid as a predictor for the national estimates of impacted land in this study.

A.4 Summary of Results

The values for total and impacted land area for the nation are given in Table A-2 for NEF 20, 30, and 40. They were computed with the procedures specified in the preceding sections of this appendix.

Table A-3 contains the raw data on total area within the NEF 30 and 40 contours for each airport and primary noise reduction scenarios. Table A-4 contains the raw data and corresponding national estimates for the secondary alternatives evaluated for 1987 only.

Table A-2

Estimated Total Area (National) and Impact Area (National) for Noise Abatement Alternatives for 1972, 1987 and 2000
(Area in Square Miles and Rounded to Two Significant Digits)

Year	Operational Procedures			Acoustic Linings			Refanned Engines		Aircraft Noise Level				NEF		NEF		NEF	
	Approach		Takeoff	SAM			REFAN		FAR 36				20		30		40	
	3°	6°/3°	Cutback	3D	8D	727/727-100	727-200/DC-9	8D	-5	-10	-15	-20	Total	Impact*	Total	Impact*	Total	Impact*
1972	X												14000	11000	2500	1800	430	220
1987	X												10000	7600	1900	1300	340	150
	X			X	X								8500	6400	1600	1100	270	110
		X											9600	7200	1800	1200	330	150
		X	X										7700	5800	1400	940	300	130
		X	X	X	X								5800	4300	1100	710	240	90
		X	X	X		X	X						4100	3000	760	460	180	56
		X	X	X				X					3800	2800	700	410	160	45
		X	X						X				3000	2200	550	300	120	27
		X	X							X			1600	1100	290	120	54	6
		X	X								X**		700	410	130	31	25	1
		X	X									X**	290	120	54	6	11	0
2000	X												4300	3200	790	480	160	45
	X			X	X								4300	3200	790	480	160	45
		X											4000	2900	740	440	160	45
		X	X										3600	2600	670	390	160	45
		X	X	X	X								3600	2600	670	390	160	45
		X	X	X		X	X						3500	2600	630	360	150	40
		X	X	X				X					3400	2500	630	340	150	40
		X	X						X				3000	2200	540	300	130	31
		X	X							X			2500	1800	460	240	100	19
		X	X								X		1200	790	230	84	47	4
		X	X									X	560	310	100	19	22	1

*Estimated impacted area excluding airport boundary and area over water, using Equation 10.

**These cases were computed but were not assumed to be achievable by 1987 (see text - page 11).

Table A-3

Summary of Raw Data Showing Total Area Within NEF 30 and 40 Contours at Each Airport
(Area in Square Miles)

Year	Operational Procedures			Acoustic Linings			Refanned Engines		Aircraft Noise Level				LAX Area-sq.mi.		STL Area-sq.mi.		IAD Area-sq.mi.	
	Approach		Takeoff	SAM			REFAN		FAR 36				NEF		NEF		NEF	
	3°	6°/3°	Cutback	2D	8D	737/727-100	727-200/DC-9	8D	-5	-10	-15	-20	30	40	30	40	30	40
1972	X												97.2	20.5	29.9	5.4	74.2	4.6
1987	X												45.4	9.6	29.8	5.3	46.7	7.5
	X			X	X								37.4	7.3	28.1	5.0	35.8	5.4
		X											42.2	9.2	26.8	5.1	43.2	7.2
		X	X										40.6	8.3	22.8	4.8	27.1	6.7
		X	X	X	X								27.0	6.3	21.5	4.5	20.6	5.1
		X	X	X		X	X						22.2	5.4	15.6	3.4	11.4	2.6
		X	X	X				X					21.5	5.2	14.4	3.1	9.5	2.1
		X	X						X				17.0	3.8	10.9	2.4	7.7	1.3
		X	X							X			8.7	1.8	5.5	1.1	4.4	0.6
		X	X								X		4.0	0.9	2.6	0.5	1.8	0.2
		X	X									X	1.7	0.4	1.2	0.2	0.6	0.1
2000	X												25.8	5.0	11.7	2.5	11.3	2.5
	X			X	X								25.8	5.0	11.7	2.5	11.3	2.5
		X											23.8	4.9	11.2	2.5	10.7	2.5
		X	X										20.9	4.8	10.4	2.5	10.3	2.5
		X	X	X	X								20.9	4.8	10.4	2.5	10.3	2.5
		X	X	X		X	X						20.2	4.6	9.0	2.2	10.2	2.5
		X	X	X				X					20.1	4.6	8.7	2.2	10.2	2.5
		X	X						X				17.2	3.7	8.1	2.0	8.5	2.1
		X	X							X			14.2	3.0	6.9	1.6	7.2	1.8
		X	X								X		6.0	1.4	3.5	0.7	3.7	0.6
		X	X									X	3.1	0.6	1.6	0.4	1.7	0.4

Table A-4

Results of Secondary Alternatives for 1987***
(in square miles and rounded to 2 significant digits)

Alternative	Total Area Inside Contours: LAX		STL		IAD		National Total Area		National Impact Area	
	NEF 30	NEF 40	NEF 30	NEF 40	NEF 30	NEF 40	NEF 30	NEF 40	NEF 30	NEF 40
Fleet - 10%	39.4	8.6	26.5	4.7	40.0	6.8	1600	310	1100	130
Fleet + 10%	44.9	9.8	31.1	5.4	46.9	7.7	1900	350	1300	160
N.B. - 50% *	32.4	7.1	22.6	4.2	28.3	6.0	1300	270	840	100
N.B. + 50%	52.3	11.1	34.9	5.9	57.9	11.1	2200	430	1600	210
N.B. Daytime**	28.2	5.9	21.7	3.9	14.3	3.1	1000	200	620	65
No Night Flights	19.7	3.8	12.3	2.4	14.2	3.1	710	140	410	37

* N.B. denotes narrow body jets.

** Daytime = 0700 to 2200 hours.

***The reference for the alternatives is baseline aircraft, 6°/3° glideslope for approach and standard takeoff procedures.

APPENDIX B

DETAILED NOISE AND PERFORMANCE CHARACTERISTICS OF ADVANCED TECHNOLOGY (LEVEL III) AIRCRAFT UTILIZED FOR THIS STUDY

The assumptions for estimating the noise and performance characteristics of the Level III aircraft were discussed in Section 4.3 of this report. This appendix provides the specific noise versus slant range and takeoff profile curves utilized in the NEF computer program for these aircraft. The corresponding data for the current technology Level I and Level II aircraft are contained in Reference 1.

Figures B-1 through B-3 show the noise (Effective Perceived Noise Level in EPNdB) versus slant distance curves for the 2-, 3-, and 4-engine advanced technology aircraft respectively. Each graph shows the predicted noise level at several corrected net thrust levels and includes, for comparison, the corresponding curve for the Level II (current wide body) aircraft for one comparable corrected net thrust condition only.

Note that the maximum values of corrected net thrust shown on the graphs (thrust/δ) do not correspond to the maximum static thrust values normally associated with the aircraft engines. Net thrust is a function of static thrust and velocity of the aircraft. At takeoff, conditions and velocity less than 250 knots, net thrust decreases very rapidly with increasing velocity. For example, a typical wide body aircraft engine has a static thrust of 40,000 pounds/engine at zero velocity and 100 percent rpm corrected to normal atmospheric conditions, while the same aircraft after brake release at 32 knots and 98 percent rpm has a net thrust of 35,300 pounds/engine; further, at rotation, 176 knots and 98 percent rpm, the net thrust equals 31,000 pounds/engine.

In most cases, the noise curves in the program for each of the existing aircraft were calculated by the aircraft manufacturer from actual flyover measurements. These test measurements were performed while the aircraft velocity was 140 to 200 knots. Noise curves were constructed by the manufacturer from these data on the basis of corrected net thrust and normalized to 160 knots. Noise levels at other thrusts were obtained by linear interpolation/extrapolation of corrected net thrusts. Note that the noise curves for the Level III aircraft were computed from one analytical model, outlined in Section 4.3.2. which is based, in part, on measured data from a 3-engine (Level II) wide body aircraft.

Figures B-4 through B-6 show the corresponding takeoff profiles for the advanced technology aircraft.

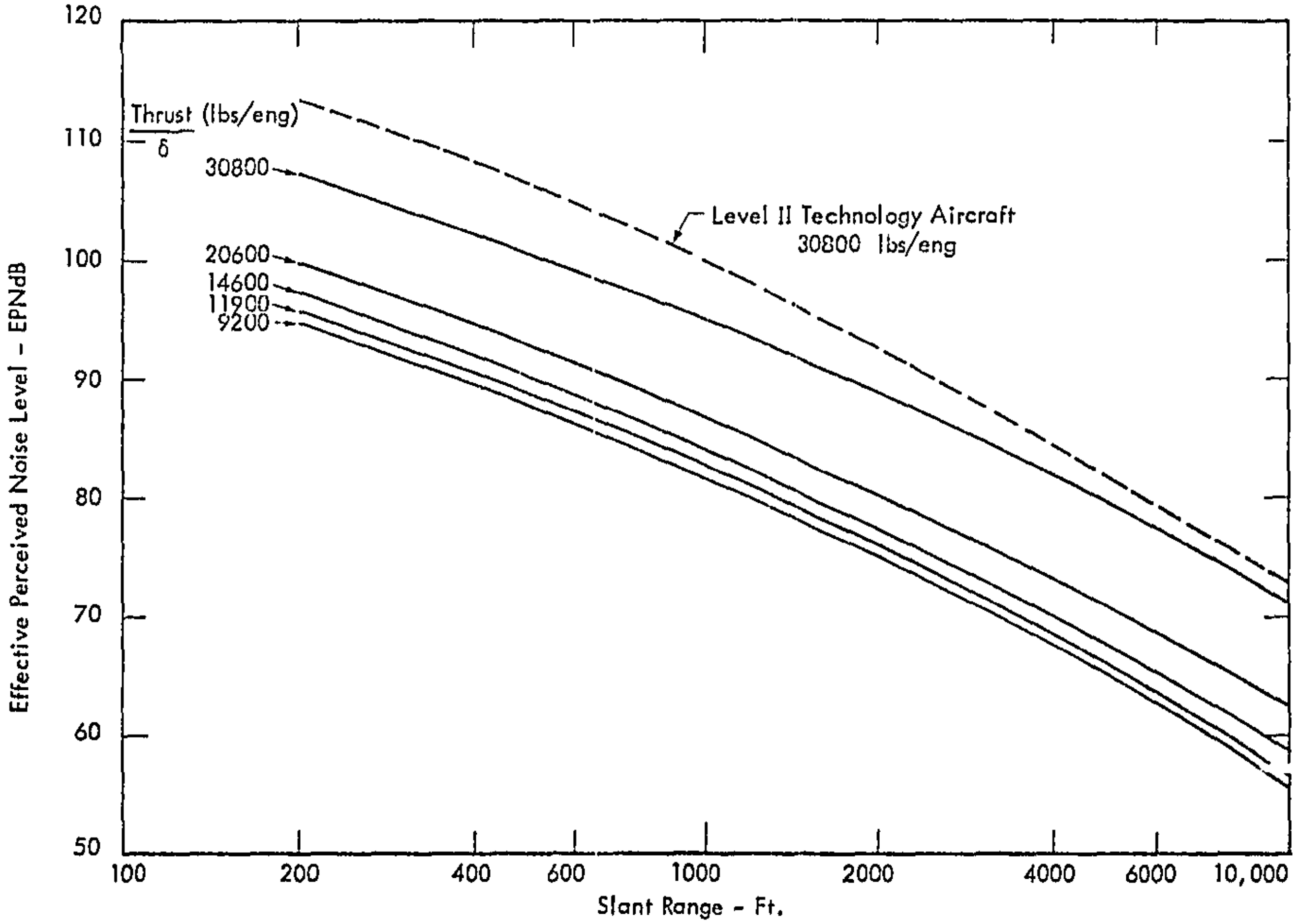


Figure B-1. Noise Curves for Level III Technology - 2 Engine Aircraft.

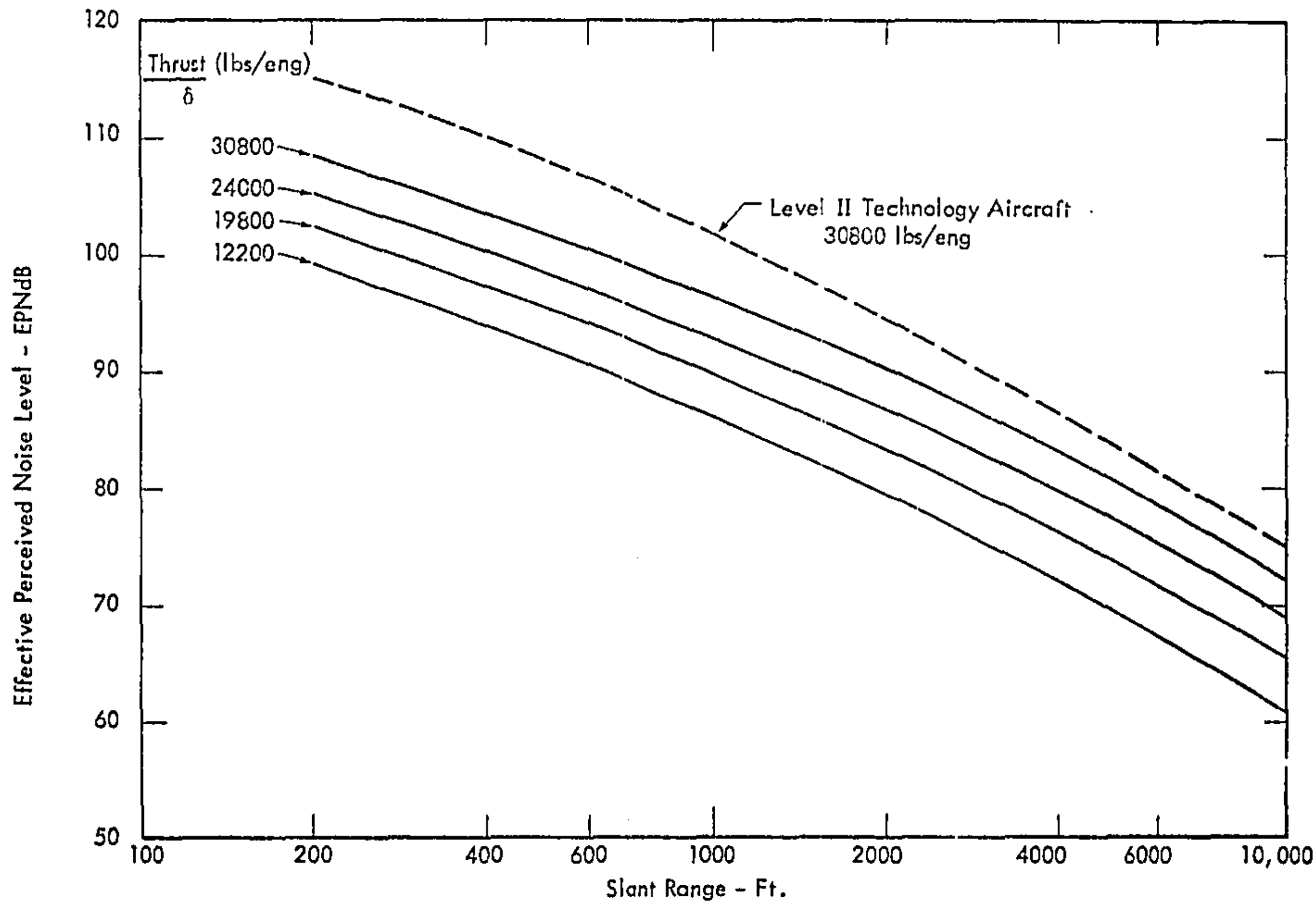


Figure B-2. Noise Curves for Level III Technology - 3 Engine Aircraft.

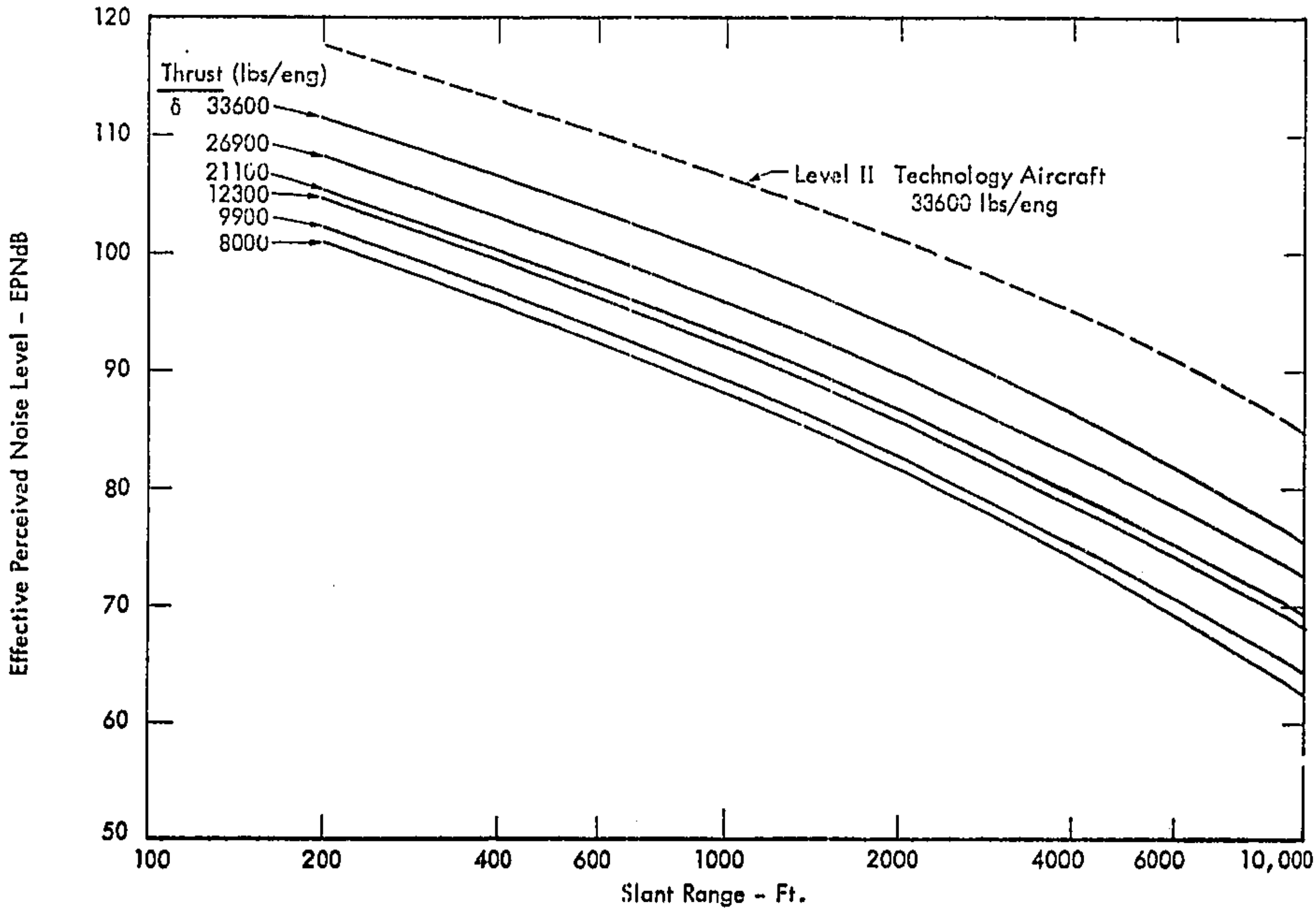


Figure B-3. Noise Curves for Level III Technology - 4 Engine Aircraft.

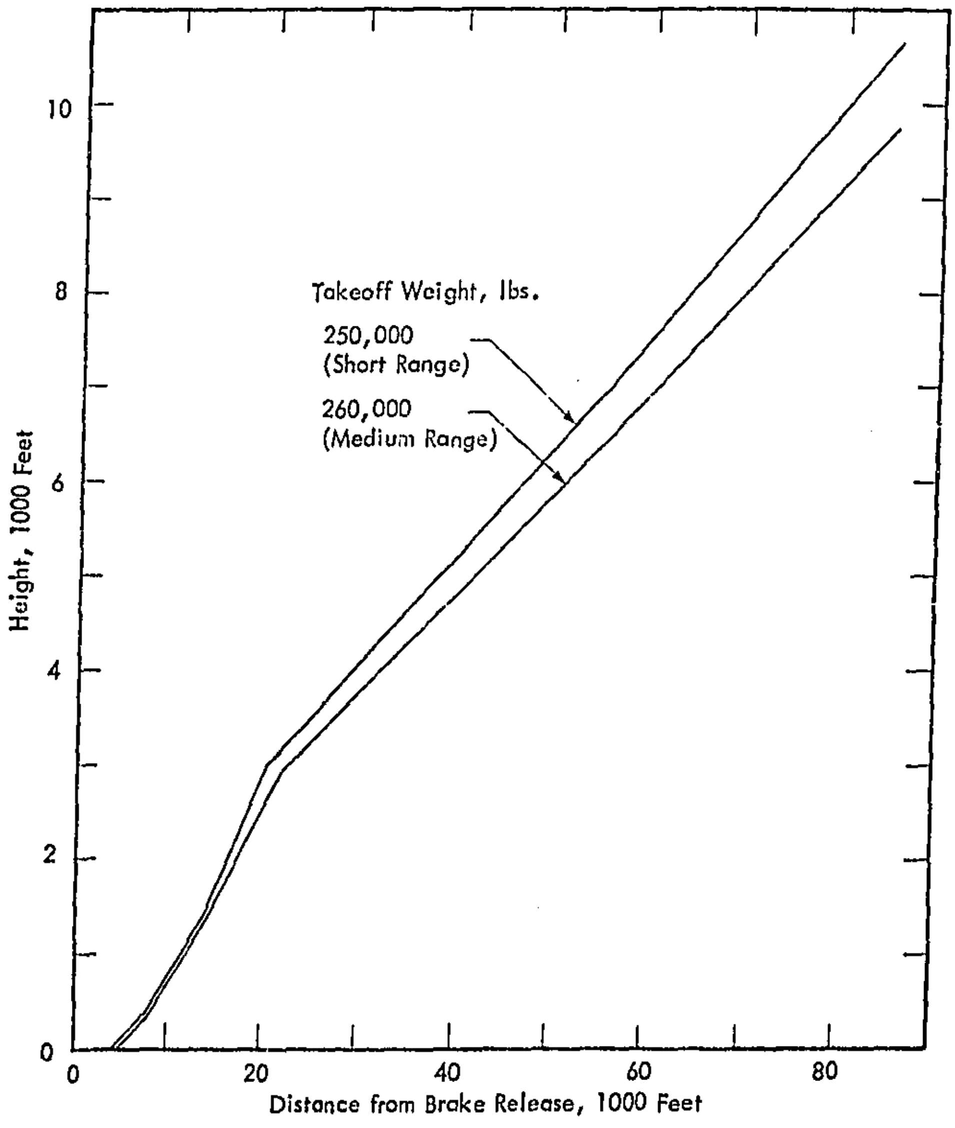


Figure B-4. Takeoff Profiles for Level III Technology, 2-Engine Aircraft

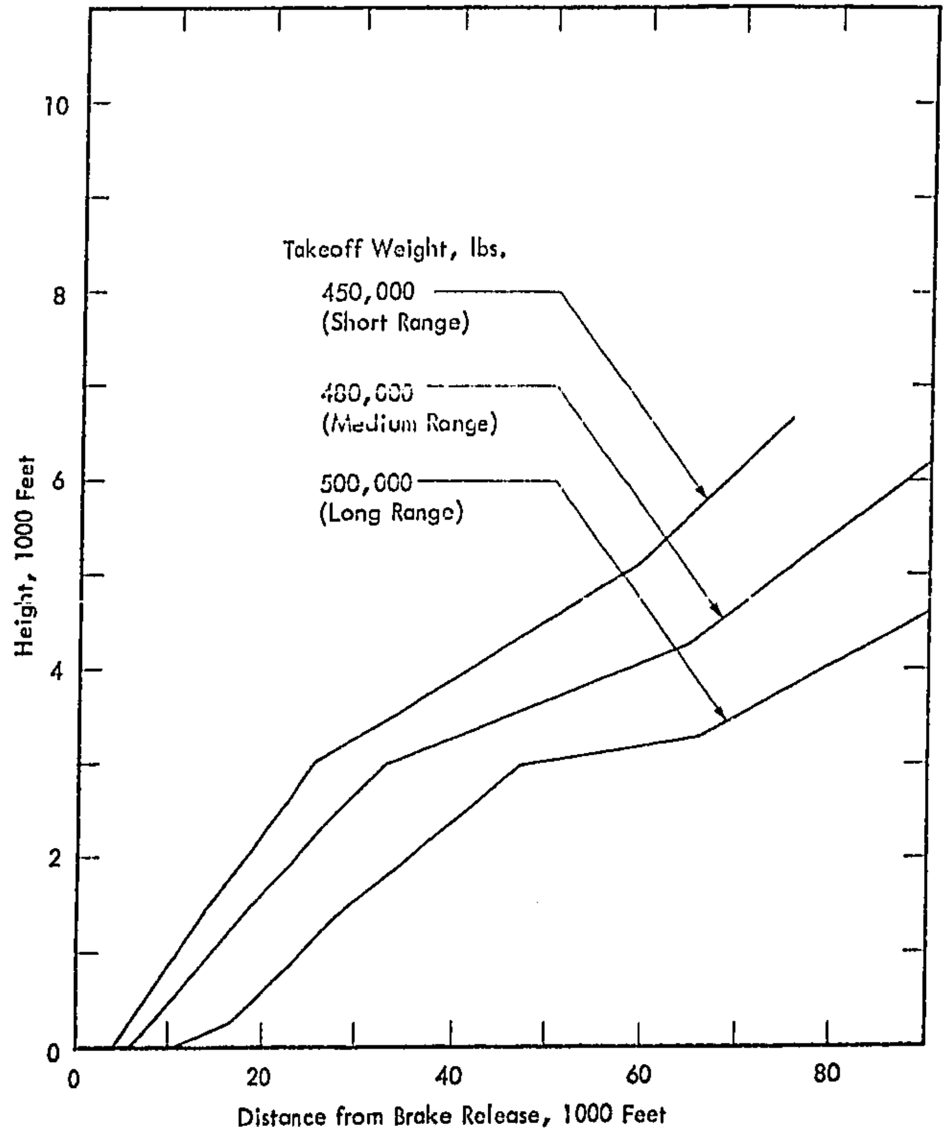


Figure B-5. Takeoff Profiles for Level III Technology, 3-Engine Aircraft

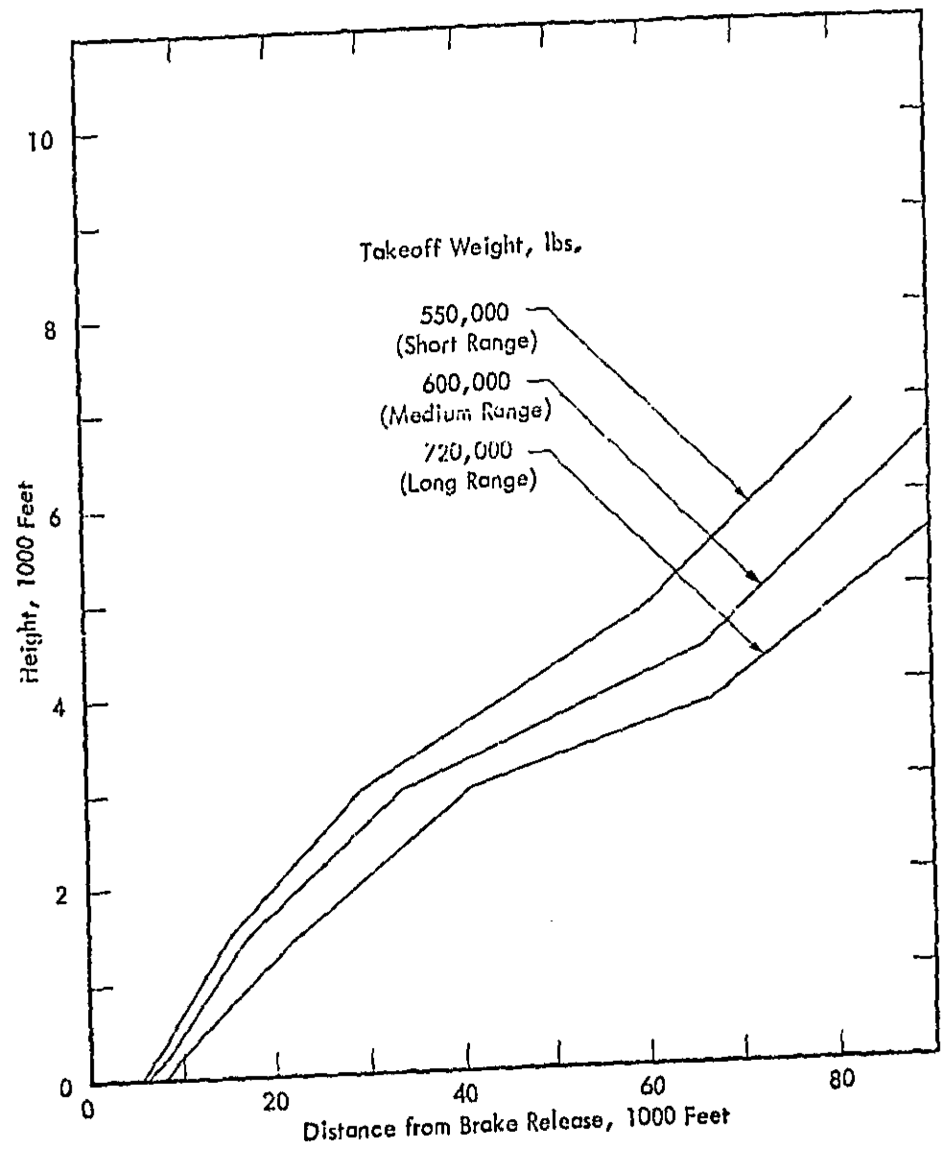


Figure B-6. Takeoff Profiles for Level III Technology, 4-Engine Aircraft

APPENDIX C

AIRPORT ACTIVITY DATA

The airport operations data for Los Angeles International, St. Louis, and Dulles Airports are given in Tables C-1, C-2, and C-3 respectively. Part (a) of each table are actual figures with total operations based on FAA records for calendar year 1972, while parts (b) and (c) provide forecast activity data for 1987 and 2000 respectively.

New technology (Level III) aircraft introduced before 1987 are included in the 1987 operations forecast as unspecified (unspec.) Level I category aircraft. Noise characteristics for these new aircraft are assumed equal to that for their corresponding current technology aircraft treated with quiet nacelles so as to not exceed FAR 36 limits.

Table C-1a

Airport Activity

Los Angeles - 1972

Aircraft Type*	Arrivals Day/Night**		Departures by Stage Distance (Statute Miles) 0 500	500 1000	1000 1500	1500 2500	2500 3500	3500 4500	4500 5500	Over 5500
720B	D	31	9	7	5	8	2			
	N	3	1	1	0	1	0			
707-320B/C	D	16	5	1	0	8	2			
	N	3	0	0	1	0	2			
707-120B	D	39	9	1	5	22	2			
	N	11	2	0	0	9	0			
DC-8-30	D	5	0	0	2	3				
	N	1	0	0	1	0				
DC-9-15	D	10	2	8						
	N	0	0	0						
DC-8-55	D	31	12	1	1	15	2			
	N	14	5	0	0	8	1			
DC-8-61(-63)	D	12	4	0	1	4	0	1	0	2
	N	10	0	2	1	5	2	0	0	0
DC-9-32	D	10	9	1						
	N	1	1	0						
DC-10-10	D	16	1	3	2	9	1			
	N	2	0	1	0	1	0			
L-1011	D	2	0	0	0	2				
	N	0	0	0	0	0				
VC-10	D	1	0	0	0	1				
	N	0	0	0	0	0				
707-120/-320	D	10	4	0	0	0	2	1	1	2
	N	8	1	0	0	7	0	0	0	0
727-200	D	97	68	11	15	3				
	N	7	5	1	1	0				
720	D	8	4	4						
	N	2	2	0						
727-100	D	42	15	5	6	16				
	N	13	4	2	1	6				
737-100/-200	D	46	41	5						
	N	5	4	1						
747-100	D	34	3	0	2	18	9	2		
	N	6	0	0	1	2	3	0		
CV 880	D	1	0	0	0	1				
	N	0	0	0	0	0				
Turboprop (STOL)	D	12	12							
	N	0	0							

* Excludes General Aviation and Military Operations.

** Day: 7:00 AM - 10:00 PM
Night: 10:01 PM - 6:59 AM

Table C-1b

Airport Activity Forecast
Los Angeles – 1987

Aircraft Type*	Range Capability	Model**	Day/Night***	Arrivals	Departures by Stage Distance (Statute Miles): 0–500	500–1000	1000–1500	1500–2500	2500–3500	3500–4500	4500–5500	Over 5500
I	Short-Medium	737	D	23	21	2						
			N	3	2	1						
		DC-9	D	19	17	2						
			N	2	2	0						
		Unspec.	D	21	18	3						
			N	1	1	0						
I	Medium	727-100	D	10	4	1	1	4				
			N	3	1	1	0	1				
		727-200	D	81	57	9	13	2				
			N	6	4	1	1	0				
I	STOL	Unspec.	D	35	30	5						
			N	1	1	0						
I	Medium-Long	707	D	7	3	0	0	0	1	1	0	2
			N	6	1	0	0	5	0	0	0	0
		DC-8	D	11	5	0	0	6				
			N	3	1	0	0	2				
		Unspec.	D	16	2	0	0	12	2			
			N	3	0	0	0	3	0			
II Small	Short-Medium	Unspec.	D	89	57	9	6	17				
			N	19	8	5	1	5				
II Medium	Medium	DC-10	D	15	1	3	2	8	1			
			N	2	0	1	0	1	0			
		L-1011	D	16	1	3	2	9	1			
			N	3	0	2	0	1	0			
		Unspec.	D	51	13	0	6	32				
			N	8	0	0	0	8				
II Medium	Long	DC-10	D	3	1	0	1	1				
			N	1	0	0	0	1				
		Unspec.	D	69	9	8	8	39	5			
			N	18	2	5	0	11	0			
II Large	Medium-Long	747	D	83	8	4	6	43	20	2		
			N	17	0	4	1	3	9	0		

* Excludes General Aviation and Military Operations.
** Models indicated as "Unspecified" may include current aircraft and/or new aircraft not yet in production.
*** Day: 7:00 AM – 10:00 PM
Night: 10:01 PM – 6:59 AM

Table C-1c

Airport Activity Forecast
Los Angeles -- 2000

Aircraft Type*	Day** Night	Arrivals	Departures by Stage Distance (Statute Miles) 0 500	500 1000	1000 1500	1500 2500	2500 3500	3500 4500	4500 5500	Over 5500
I Unspecified (737/DC-9 Type with SAM)	D N	4 1	3 1	1 0						
I Unspecified (727 Type with SAM)	D N	7 2	5 2	2 0						
I Unspecified (707/DC-8 Type with SAM)	D N	27 5	11 3	3 1	2 0	11 1				
II Small	D N	47 9	38 5	9 4						
II Medium	D N	58 11	4 4	11 1	7 2	36 4				
II Large	D N	70 13	0 0	7 0	4 1	36 5	20 6	3 1		
III Small	D N	190 35	75 19	115 16						
III Medium	D N	173 32	12 11	33 3	21 6	107 12				
III Large	D N	173 32	17 0	10 0	75 2	49 11	7 14	10 3	5 2	
IV SST	D N	11 0	0 0	0 0	0 0	6 0	0 0	0 0	0 0	5 0

*Excludes General Aviation and Military Operations.
**Day: 7:00 AM -- 10:00 PM.
Night: 10:01 PM - 6:59 AM.

Table C-2a

Airport Activity
St. Louis - 1972

Aircraft Type*	Arrivals Day/Night**		Departures by Stage Distance (Statute Miles) 0–500	500–1000	1000–1500	1500–2500	2500–3500	3500–4500	4500–5500	Over 5500
707-320B/C	D	2	0	0	1	0	0	1		
	N	2	0	0	1	0	0	1		
707-120B	D	14	10	2	0	2				
	N	3	1	1	0	1				
DC-9-15	D	31	30	1						
	N	4	2	2						
DC-9-32	D	53	50	3						
	N	8	4	4						
L-1011	D	1	0	0	0	1				
	N	0	0	0	0	0				
707-120/-320	D	1	0	1						
	N	2	1	1						
727-200	D	30	16	11	2	1				
	N	1	1	0	0	0				
727-100	D	47	26	17	2	2				
	N	4	0	2	2	0				
737-100/-200	D	3	1	2						
	N	1	0	1						
CV-880	D	7	2	3	1	1				
	N	0	0	0	0	0				
BAC-111	D	5	5							
	N	0	0							
Turboprop (STOL)	D	29	29							
	N	4	4							

* Excludes General Aviation and Military Operations.
** Day: 7:00 AM - 10:00 PM
Night: 10:01 PM - 6:59 AM

Table C-2b

Airport Activity Forecast
St. Louis — 1987

Aircraft Type*	Range Capability	Model**	Day*** Night	Arrivals	Departures by Stage Distance (Statute Miles) 0–500	500–1000	1000–1500	1500–2500	2500–3500	3500–4500	4500–5500	Over 5500
I	Short-Medium	737	D	3	1	2						
			N	1	0	1						
		DC-9	D	107	101	6						
			N	17	9	8						
		Unspec.	D									
			N									
I	Medium	727-100	D	20	11	7	1	1				
			N	2	0	1	1	0				
		727-200	D	64	34	24	4	2				
			N	2	2	0	0	0				
I	STOL	Unspec.	D									
			N									
I	Medium-Long	707	D									
			N									
		DC-8	D									
			N									
		Unspec.	D									
			N									
II Small	Short-Medium	Unspec.	D	35	19	13	2	1				
			N	3	0	2	1	0				
II Medium	Medium,	DC-10	D	50	0	0	0	50				
			N	0	0	0	0	0				
		L-1011	D	50	0	0	0	50				
			N	0	0	0	0	0				
		Unspec.	D									
			N									
II Medium	Long	DC-10	D									
			N									
		Unspec.	D	12	0	0	0	12				
			N	0	0	0	0	0				
II Large	Medium-Long	747	D	35	0	0	17	0	0	18		
			N	34	0	0	17	0	0	17		
		Unspec.	D									
			N									

* Excludes General Aviation and Military Operations.
** Models indicated as "Unspecified" may include current aircraft and/or new aircraft not yet in production.
*** Day: 7:00 AM - 10:00 PM
Night: 10:01 PM - 6:59 AM

Table C-2c

Airport Activity Forecast
St. Louis – 2000

Aircraft Type*	Day** Night	Arrivals	Departures by Stage Distance (Statute Miles) 0 500	500 1000	1000 1500	1500 2500	2500 3500	3500 4500	4500 5500	Over 5500
I Unspecified (737/DC-9 Type with SAM)	D N	17 4	10 2	7 2						
I Unspecified (727 Type with SAM)	D N	14 0	7 0	4 0	3 0					
I Unspecified (707/DC-8 Type with SAM)	D N									
II Small	D N	29 5	23 3	6 2						
II Medium	D N	52 8	28 1	19 3	2 3	3 1				
II Large	D N	13 2	2 0	4 0	1 0	3 1	3 1			
III Small	D N	118 19	88 12	30 7						
III Medium	D N	136 21	20 2	22 2	40 8	33 5	21 4			
III Large	D N	28 4	0 0	0 0	8 2	12 2	8 0			
IV SST	D N	None								

*Excludes General Aviation and Military Operations.
**Day: 7:00 AM - 10:00 PM.
Night: 10:01 PM - 6:59 AM.

Table C-3a

Airport Activity
Dulles - 1972

Aircraft Type *	Arrivals Day/Night **		Departures by Stage Distance (Statute Miles)							
			0 500	500 1000	1000 1500	1500 2500	2500 3500	3500 4500	4500 5500	Over 5500
720B	D	1	0	0	0	1				
	N	0	0	0	0	0				
707-320B/C	D	6	3	0	0	2	0	1		
	N	1	0	0	0	1	0	0		
707-120B	D	13	7	0	3	3				
	N	2	0	0	0	2				
DC-9-15	D	11	6	5						
	N	0	0	0						
DC-8-55	D	8	3	1	1	3				
	N	2	2	0	0	0				
DC-9-32	D	3	1	2						
	N	0	0	0						
DC-10-10	D	2	0	0	0	2				
	N	0	0	0	0	0				
VC-10	D	1	0	0	0	0	0	1		
	N	0	0	0	0	0	0	0		
707-120/-320	D	2	1	1						
	N	0	0	0						
727-200	D	2	0	1	1					
	N	2	2	0	0					
727-100	D	17	6	2	9					
	N	2	1	0	1					
737-100/-200	D	3	3							
	N	0	0							
747-100	D	4	0	1	0	2	0	1		
	N	0	0	0	0	0	0	0		
Turboprop (STOL)	D	2	2							
	N	0	0							

* Excludes General Aviation and Military Operations.
** Day: 7:00 AM - 10:00 PM
Night: 10:01 PM - 6:59 AM

Table C-3b

Airport Activity Forecast

Dulles – 1987

Aircraft Type*	Range Capability	Model**	Day/Night***	Arrivals	Departures by Stage Distance (Statute Miles): 0–500	500–1000	1000–1500	1500–2500	2500–3500	3500–4500	4500–5500	Over 5500
I	Short-Medium	737	D	4	4							
			N	0	0							
		DC-9	D	23	8	15						
			N	0	0	0						
		Unspec.	D									
			N									
I	Medium	727-100	D	23	8	3	12					
			N	3	2	0	1					
		727-200	D	13	0	7	6					
			N	13	13	0	0					
I	STOL	Unspec.	D									
			N									
I	Medium-Long	707	D	17	8	9						
			N	0	0	0						
		DC-8	D	11	4	1	2	4				
			N	3	3	0	0	0				
		Unspec.	D	4	0	0	0	0	0	4		
			N	0	0	0	0	0	0	0		
II Small	Short-Medium	Unspec.	D	11	7	1	3					
			N	1	1	0	0					
II Medium	Medium	DC-10	D	10	0	0	0	10				
			N	0	0	0	0	0				
		L-1011	D	8	0	0	0	8				
			N	0	0	0	0	0				
		Unspec.	D									
			N									
II Medium	Long	DC-10	D	10	0	0	0	10				
			N	0	0	0	0	0				
		Unspec.	D	12	0	0	0	12				
			N	0	0	0	0	0				
II Large	Medium-Long	747	D	36	0	9	0	18	0	9		
			N	0	0	0	0	0	0	0		
		Unspec.	D									
			N									

* Excludes General Aviation and Military Operations.

** Models Indicated as "Unspecified" may include current aircraft and/or new aircraft not yet in production.

*** Day: 7:00 AM - 10:00 PM
Night: 10:01 PM - 6:59 AM

Table C-3c

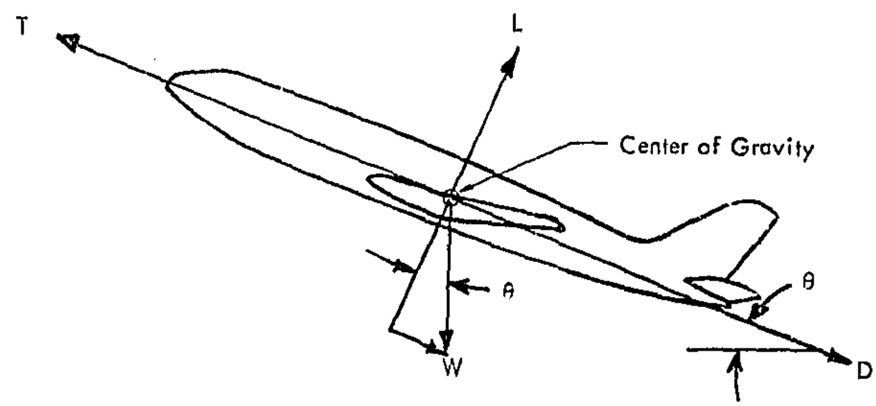
Airport Activity Forecast
Dulles – 2000

Aircraft Type*	Day** Night	Arrivals	Departures by Stage Distance (Statute Miles) 0–500	500–1000	1000–1500	1500–2500	2500–3500	3500–4500	4500–5500	Over 5500
I Unspecified (737/DC-9 Type with SAM)	D	2	2							
	N	0	0							
I Unspecified (727 Type with SAM)	D	3	3							
	N	0	0							
I Unspecified (707/DC-8 Type with SAM)	D	22	8	14						
	N	0	0	0						
II Small	D	19	16	3						
	N	2	2	0						
II Medium	D	32	11	3	6	12				
	N	4	0	0	1	3				
II Large	D	41	0	5	15	7	14			
	N	5	0	1	1	2	1			
III Small	D	64	41	6	17					
	N	8	3	2	3					
III Medium	D	53	6	15	19	4	9			
	N	5	0	1	2	0	2			
III Large	D	60	0	16	0	28	0	16		
	N	7	0	2	0	2	0	3		
IV SST	D	10	0	0	0	0	0	6	4	
	N	0	0	0	0	0	0	0	0	

*Excludes General Aviation and Military Operations.
**Day: 7:00 AM – 10:00 PM.
Night: 10:01 PM – 6:59 AM.

APPENDIX D

DERIVATION OF CLIMB GRADIENT FOR ENGINE OUT CONDITION



Assume a simple linear first approximation model of flight performance for an aircraft. Define the following parameters:

V = Velocity

T = Thrust

D = Drag

W = Weight

θ = Climb Angle

Then, summing forces through the center of gravity

$$T - D - W\sin\theta = \frac{W}{g}\frac{dV}{dt}$$, along the thrust axis

and

$$L - W\cos\theta = 0$$, normal to the thrust axis

For unaccelerated climb $\frac{dV}{dt} = 0$, so that these two equations combine to give: $\sin \theta = \frac{T - D}{W}$, or, for small climb angles,

$$\sin \theta \simeq \tan \theta \simeq \gamma = \text{climb gradient}$$

$$\therefore \quad \gamma = \frac{T}{W} - \frac{D}{W}$$

$$W = L \cos \theta \simeq L \text{ for small } \theta$$

$$\gamma = \frac{T}{W} - \frac{D}{L}$$

$$\gamma = \frac{NF_N}{W} - \frac{D}{L}$$

where

N = number of engines and F_N = net thrust/engine.

$\therefore$ For one engine out, the climb gradient γ' is

$$\gamma' = \left(\frac{N - 1}{W}\right) F_N - \frac{D}{L}$$

Solving for the net thrust per engine,

$$F_N = \frac{W}{N - 1} \left(\frac{D}{L} + \gamma'\right)$$

Substituting this back in the equation for γ gives:

$$\gamma = \left(\frac{N}{N - 1}\right) \gamma' + \left(\frac{1}{N - 1}\right) \frac{D}{L}$$

which is the approximate climb angle for an engine thrust setting, for all (N) engines, equal to that necessary to maintain a climb angle γ' with (N - 1) engines or one engine out. For this simple model, the lift to drag ratio (L/D) is assumed constant in all cases.

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15. Supplementary Notes

16. Abstract

This program was undertaken for the Office of Noise Abatement and Control, Environmental Protection Agency, to evaluate the nationwide community impact of aircraft noise through the year 2000, considering a number of aircraft/airport noise reduction alternatives. The study was based on the evaluation of operations at three airports – Los Angeles International, St. Louis, and Washington Dulles. Primary noise reduction alternatives were applied at each of the facilities for the 1987 and 2000 time periods. Secondary abatement alternatives were evaluated for 1987 only. The effectiveness of the various alternatives was measured in terms of the total area impacted under the NEF 30 and 40 contours at the three airports. This area was then increased by a constant factor to obtain an estimate of the impact at the national level. The report also contains an estimate of the total area within the NEF 20 contours and the impacted land area for NEF 20, 30, and 40 exclusive of airport property and water. This study utilized, in part, the much more detailed results for 23 airports from the "Airport Noise Reduction Forecast" study recently completed by Wyle for the Department of Transportation. However, this study differs substantially from the Department of Transportation program in that it is based on analysis at only three airports, includes no cost or population data, extends beyond the year 1987, and focuses only on estimating trends in aircraft noise impact to the year 2000 in order to evaluate the potential requirement for research on new aircraft/airport noise reduction alternatives which may not currently be under development.

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