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EN ROUTE NOISE ANNOYANCE LABORATORY TEST - PRELIMINARY RESULTS

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A symbols and abbreviations list appears at the end of this paper.

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INTRODUCTION

Until recently concerns about the impact of aircraft noise on people have centered around the takeoff and landing operations of aircraft in the vicinity of airport terminals. The development of the advanced turboprop (propfan) engine, modifications to air corridors, and the desire to maintain a natural environment in national parks and recreation areas have now focused attention on the impact at ground level of the en route noise produced by aircraft at cruise conditions and altitudes. Compared to terminal area noise, en route noise is characterized by relatively low noise levels, lack of high frequency spectral content, and long durations. Much research has been directed towards understanding and quantifying the annoyance caused by terminal area aircraft noise, but relatively little research has been conducted for en route noise. To address this need, a laboratory experiment was conducted to quantify the annoyance of people on the ground to en route noise generated by aircraft at cruise conditions. The objectives of the experiment are given in figure 1.

OBJECTIVES

- **Determine the annoyance prediction ability of noise measurement procedures and corrections when applied to en route noise.**

- **Determine differences in annoyance response to en route noise and takeoff/landing noise.**

- **Determine differences in annoyance response to advanced turboprop en route noise and conventional jet en route noise.**

Figure 1

EXPERIMENT DESIGN

Figure 2 describes the noise stimuli used in the experiment. Thirty-four noises were presented to test subjects at three nominal L_D levels of 60, 70, and 80 dB. Six additional presentations of the B-727 takeoff noise were made at L_D levels of 50, 55, 65, 75, 85, and 90 dB for a total of 108 noise stimuli. The advanced turboprop en route noises were recordings of the NASA Propfan Test Assessment aircraft made during tests at the White Sands Missile Range in New Mexico. The conventional jet en route noises were recorded near Gordonsville, Virginia, by the DOT Transportation Systems Center.

- **8 PTA ADVANCED TURBOPROP EN ROUTE NOISES**
  - **ALTITUDES: 30k, 15k, 9k, 2k ft.**
  - **MACH NUMBERS: .5, .7, .77**
  - **DURATIONS: ~ 40 to 160 sec.**
- **6 CONVENTIONAL JET EN ROUTE NOISES**
  - **B-727, B-737, B-757, B-767, DC-9, DC-10**
  - **ALTITUDES: 28k to 37k ft.**
  - **DURATIONS: ~ 40 to 160 sec.**
- **10 CONVENTIONAL TURBOPROP TAKEOFF AND LANDING NOISES**
  - **DASH-7, P-3, YS-11, NORD 262, SHORTS 330**
  - **DURATIONS: ~ 30 to 60 sec.**
- **10 CONVENTIONAL JET TAKEOFF AND LANDING NOISES**
  - **A-300, B-707, B-727, DC-9, DC-10**
  - **DURATIONS: ~ 30 to 60 sec.**
- **EACH NOISE PRESENTED AT 3 LEVELS**
  - **NOMINAL L_D = 60, 70, 80 dB**
- **32 TEST SUBJECTS**

Figure 2

EN ROUTE NOISE L_A TIME HISTORIES

L_A time histories of two of the en route noises are shown in figure 3. The time histories illustrate three features of special interest: (1) the different time history shapes caused by the presence of low frequency pure tones in the PTA noise (see figure 4); (2) the large fluctuations in level with time; and (3) the long duration of the noises.

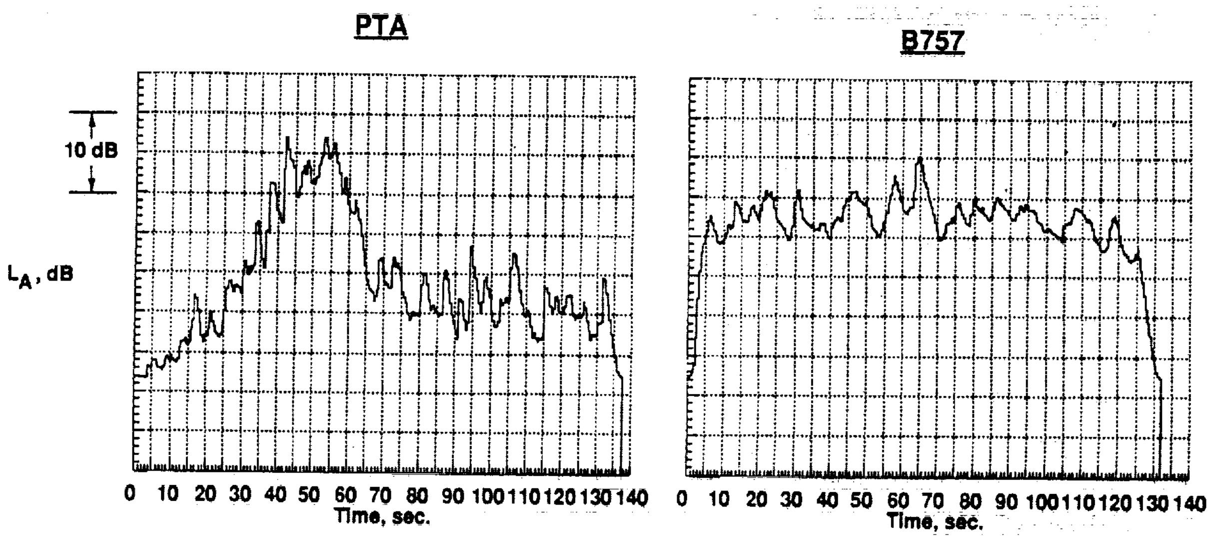

Figure 3

EN ROUTE NOISE SPECTRA AT PEAK L_A

One-third-octave-band spectra at peak L_A of two of the en route noises are shown in figure 4. The two spectra illustrate the main spectral difference between advanced turboprop and conventional jet en route noise. The advanced turboprop spectrum is dominated by a low frequency pure tone at the blade passage frequency; whereas, the conventional jet spectrum is predominantly low frequency broadband noise.

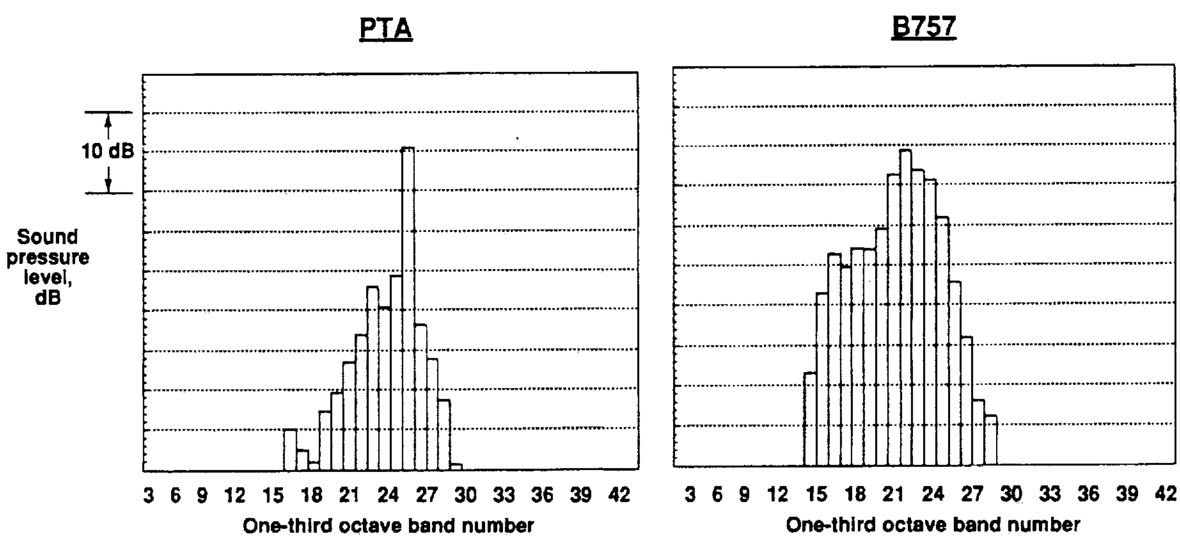

Figure 4

TEST FACILITY

A small anechoic room in the Langley Acoustics Research Laboratory was used as the test facility in the experiment (figure 5). Thirty-two test subjects judged the annoyance of each noise stimulus using a numerical category scale. The scale was a unipolar, 11 point scale from 0 to 10. The end points of the scale were labeled "EXTREMELY ANNOYING" and "NOT ANNOYING AT ALL." The term "ANNOYING" was defined in the subject instructions as "UNWANTED, OBJECTIONABLE, DISTURBING, OR UNPLEASANT."

Figure 5

CONVERSION OF ANNOYANCE JUDGMENTS TO SUBJECTIVE NOISE LEVELS

The means (across subjects) of the annoyance judgments were calculated for each stimulus. In order to obtain a subjective scale with meaningful units of measure, these mean annoyance scores were converted to "subjective noise levels," L_S, having decibel-like properties through the following process. Included in the experiment for the purpose of converting the mean annoyance scores to L_S values were six additional presentations of the B-727 takeoff recording having L_D values of 50, 55, 65, 75, 85, and 90 dB. A third order polynomial regression analysis was performed using data obtained for the nine B-727 stimuli. The dependent variable was the calculated PNL and the independent variable was the mean annoyance score for each of the nine stimuli. The regression equation thusly determined was subsequently used to predict the level of the B-727 takeoff noise which would produce the same mean annoyance score as each of the other noise stimuli in the experiment. These levels were then considered as the "subjective noise level" for each stimulus.

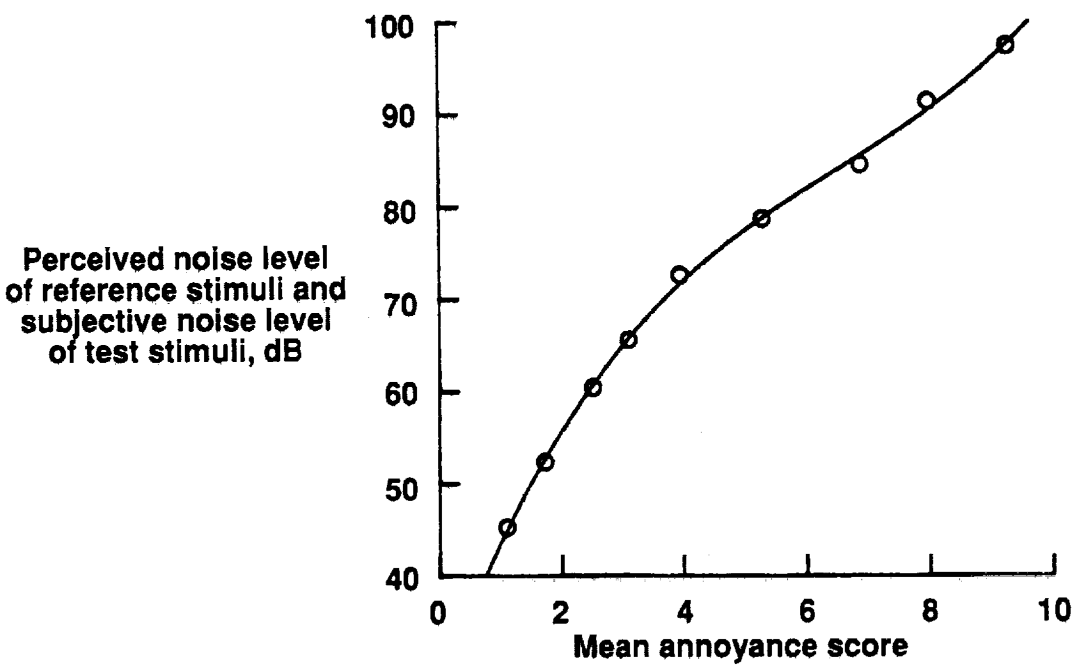

Figure 6

NOISE MEASUREMENT PROCEDURES AND CORRECTIONS

Each noise stimulus was analyzed to provide one-third-octave band sound pressure levels from 20 Hz to 20 kHz for use in computing a selected group of noise metrics. In addition to OASPL, the group included the simple weighting procedures L_A and L_D and the more complex calculation procedures LL_Z, PL, and PNL. Twelve different variations of each of the noise procedures were calculated. The first was the peak or maximum level occurring during the noise. Two other variations were calculated by applying two different tone corrections. Nine more variations were attained by applying three different duration corrections to the non-tone corrected level and the two tone corrected levels. The first duration correction and the first tone correction are identical to those used in the EPNL procedure defined in the Federal Aviation Administration FAR 36 regulation (ref. 1). The second tone correction is identical to the first except that no corrections are applied for tones identified in bands with center frequencies less than 500 Hz. The second and third duration corrections were identical to the first except that the corrections were based on the 15 and 20 dB down points instead of the 10 dB down points.

Comparisons of the different noise metrics and the subjective noise level were made to determine the annoyance prediction ability of each noise metric when applied to the en route noise stimuli. Basing the duration correction on the 15 and 20 dB down points instead of the 10 dB down points did not improve annoyance prediction. The effects of duration and tone corrections on annoyance prediction were inconsistent across noise procedures. Based on preliminary analyses, L_A with duration and tone corrections was the best predictor of annoyance to en route noise.

MEASUREMENT PROCEDURES	TONE CORRECTIONS	DURATION CORRECTIONS
OASPL	NONE	NONE
L_A	FAR 36	D_{10}
L_D	FAR 36 ≥500Hz	D_{15}
PNL		D_{20}
PL		
LL_Z		

Figure 7

COMPARISON OF ANNOYANCE RESPONSES USING L_A

Figure 8 compares the annoyance responses to PTA aircraft at cruise, conventional jet aircraft at cruise, and conventional turboprop and jet aircraft takeoffs and landings. The figure plots subjective noise level versus L_A for each of the three combinations of aircraft type and operation. Simple linear regression lines for each of the three combinations are also shown. For L_A, the conventional jet cruise noises were slightly more annoying than the PTA cruise noises. Although the differences in annoyance are small, indicator (dummy) variable analyses for L_A show significant differences in slope and intercept between the appropriate regressions for the three sets of noises.

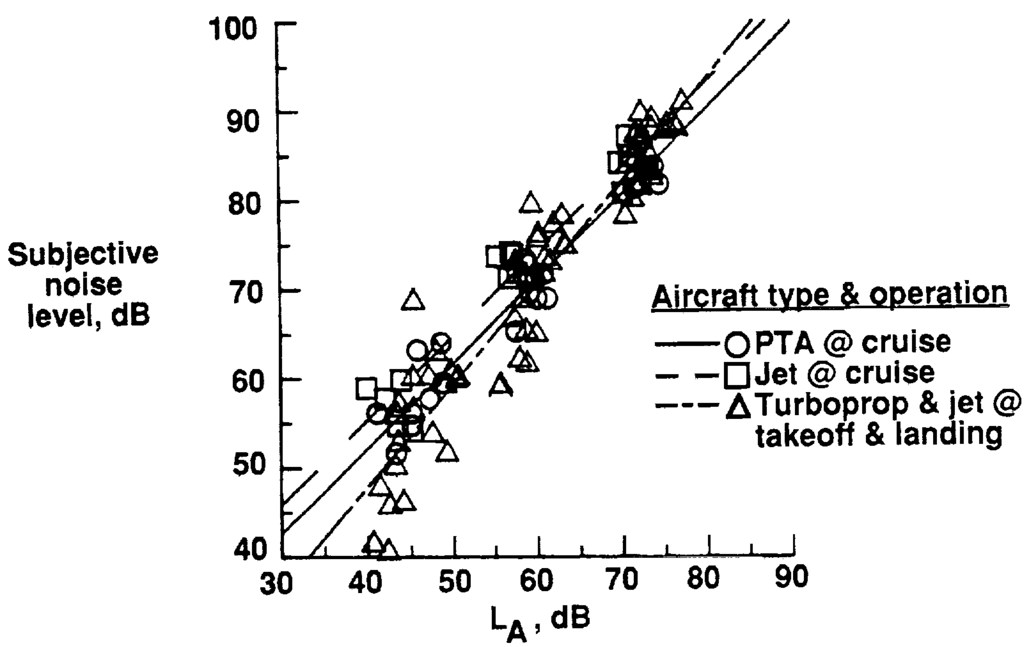

Figure 8

COMPARISON OF ANNOYANCE RESPONSES USING DURATION CORRECTED L_A

Figure 9 compares the annoyance responses to PTA aircraft at cruise, conventional jet aircraft at cruise, and conventional turboprop and jet aircraft takeoffs and landings using duration corrected L_A. Adding duration corrections to L_A results in the conventional jet cruise noises being slightly less annoying than the PTA cruise noises. This is the reverse of the results in figure 8 for L_A. As in the previous figure, indicator variable analyses indicate significant differences in slope and intercept between the appropriate regressions for the three types of noises.

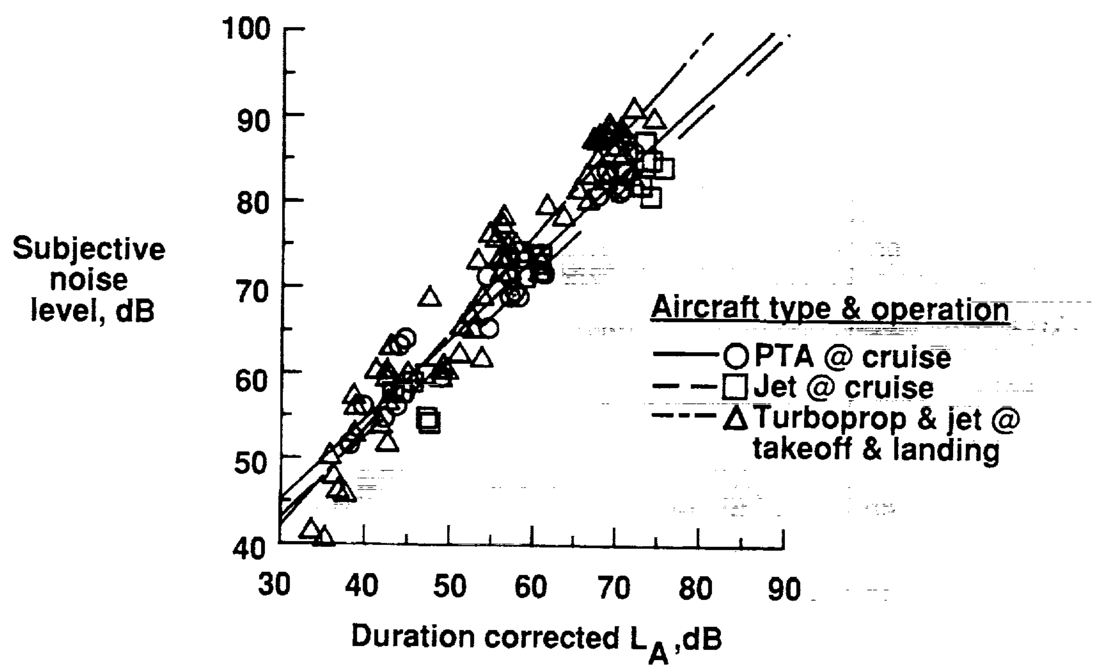

Figure 9

COMPARISON OF ANNOYANCE RESPONSES USING EPNL

Figure 10 compares the annoyance responses to PTA aircraft at cruise, conventional jet aircraft at cruise, and conventional turboprop and jet aircraft takeoffs and landings using EPNL. Results are similar to those for duration corrected L_A in figure 9.

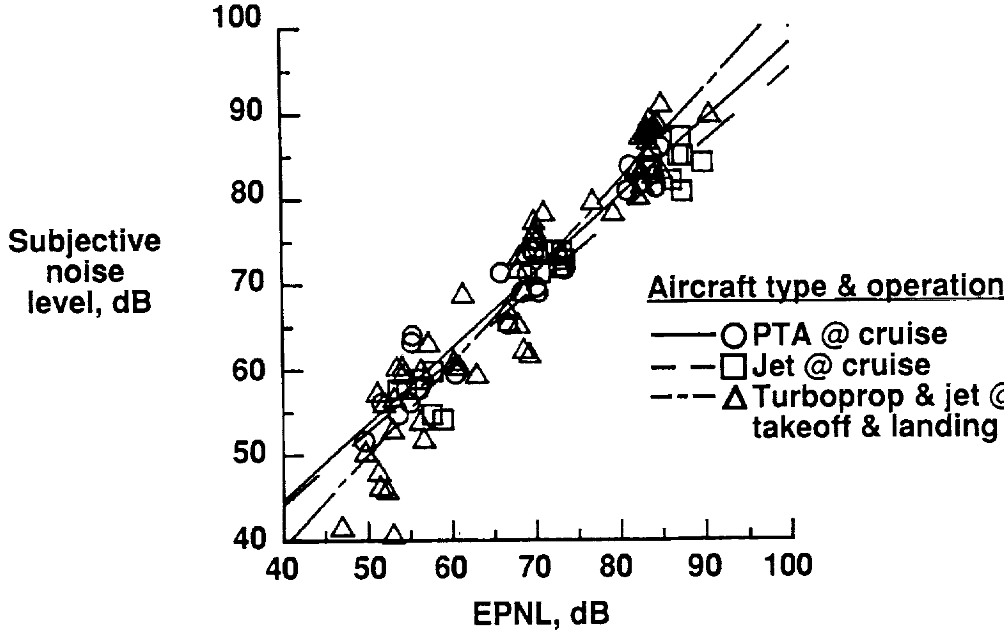

Figure 10

SUMMARY

A laboratory experiment was conducted to quantify the annoyance of people on the ground to en route noise generated by aircraft at cruise conditions and altitudes. Thirty-two test subjects judged the annoyance of 24 PTA advanced turboprop en route noise stimuli; 18 conventional jet en route noise stimuli; and 60 conventional turboprop and jet takeoff and landing noise stimuli in an anechoic listening facility. Figure 11 lists the preliminary results.

- **Based on preliminary analyses and results**
  - **Significant differences in annoyance response between en route noise and takeoff/landing noise**
  - **Significant differences in annoyance response between advanced turboprop and conventional jet en route noise**
  - **Effects of duration and tone corrections are inconsistent**
  - **L_A with duration and tone corrections is best predictor of annoyance to en route noise**

Figure 11

SYMBOLS AND ABBREVIATIONS

ATP	advanced turboprop
EPNL	effective perceived noise level, dB (ref. 1, 2)
FAR	Federal Aviation Regulation
L_A	A-weighted sound pressure level, dB (ref. 2)
L_D	D-weighted sound pressure level, dB (ref. 2)
L_S	subjective noise level, dB
LL_Z	Zwicker's loudness level, dB (ref. 2)
OASPL	overall sound pressure level, dB (ref. 2)
PL	perceived level (Stevens Mark VII procedure), dB (ref. 2)
PNL	perceived noise level, dB (ref. 1, 2)
PTA	Propfan Test Assessment

REFERENCES

1. Noise Standards: Aircraft Type Certification, Federal Aviation Regulations, Vol. III, pt. 36, FAA, 1978.
2. Pearsons, Karl S.; and Bennett, Ricarda L.: Handbook of Noise Ratings. NASA CR 2376, 1974.