LONG-RANGE VERTICAL PROPAGATION

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Development of the advanced turboprop has led to concerns about en route noise. Advanced turboprops generate low-frequency, periodic noise signatures at relatively high levels. As demonstrated in a flight test of NASA LeRC's Propfan Test Assessment (PTA) airplane in Alabama in October 1987, the noise of an advanced turboprop operating at cruise altitudes can be audible on the ground. The assessment of the en route noise issue is difficult due to the variability in received noise levels caused by atmospheric propagation and the uncertainty in predicting community response to the relatively low-level en route noise, as compared to noise associated with airport operations.

The En Route Noise Test was designed to address the atmospheric propagation of advanced turboprop noise from cruise altitudes and consisted of measuring the noise of an advance turboprop at cruise in close proximity to the turboprop and on the ground. Measured and predicted ground noise levels will be presented in this paper. Participants in the En Route Noise Test were NASA LeRC, the FAA, and NASA LaRC.

EXPERIMENT DESCRIPTION

The test airplane was NASA LeRC's PTA airplane which has a 2.7 m (9 ft) diameter, eight-bladed, tractor-configured advanced turboprop mounted on its left wing. The test airplane was instrumented to measure the near-field turboprop noise levels, as well as, engine and other pertinent parameters. During the microphone array flyovers, the test airplane was tracked with a C-band beacon.

The En Route Noise Test was performed at the White Sands Missile Range in New Mexico in April 1989. Eighty-eight PTA airplane passes or runs over the ground microphone array were recorded. The array was an eight element, linear microphone array with an inter-element spacing of 122 m (400 ft). The completed test matrix is illustrated in Table I. The majority of the runs were performed at altitudes of 4.6 and 9.2 km at a tangential tip speed of 240 meters per second (bpf of 226 Hz) and a nominal power setting of 90 percent. Seventeen runs were flown at other tip speeds in the range of 190 to 260 m/s. Meteorological profiles were measured during the flyovers from ground level up to 12 km.

PTA SPEED, M	ALTITUDE, km AGL			
	.6	2.7	4.6	9.2
.5	4	4	23	
.7			19	32
.77				6

Table I. Completed test matrix.

DATA ANALYSIS

The basic analysis used in the results presented in this paper is ensemble-average time histories[1]. Data from the eight ground mounted digital microphones (SR=2344 sps) are high-pass filtered at 80 Hz and then shifted based on the airplane ground speed to give all eight individual microphone time histories a common source emission time base. Each individual microphone time history consists of a series of 1/2-second root mean square pressure levels. The shifted time histories are then averaged. An ensemble-average time history has less variability than a single microphone time history and increased statistical confidence.

RESULTS

Data Variability.- To investigate long-term, between day, data variability, peak Overall Sound Pressure Level (OASPL) for each run was calculated from the ensemble-average time histories. No corrections were applied for deviations from a nominal flight path and no runs were rejected. The peak levels were averaged for like test conditions on a daily basis. Results are given in Table II for the 4.6 and 9.2 km runs with a tip speed of 240 m/s. Average OASPL valves ranged from 61 to

75 dB. In general, the repeatability within a particular test day was good. The standard deviation of the average OASPL of the 11 similar runs which were flown in a 90 minute period during the 6th test session was .7 dB. However, the average levels for the same test condition varied from day to day. For the 9.2 km, .7 M test condition, there was an 11 dB difference in average levels across days. For the same test condition and runs, a boom microphone on the PTA aircraft exhibited a range of 3 dB in the blade passage frequency noise level. The ground measured OASPLs were dominated by the blade passage frequency sound pressure level. This indicates, as expected, that the variability observed in the ground measurements is largely due to propagation. Another observation is that on the 3rd day the .5 M, 4.6 km average levels are greater by 3 dB than the .7 M, 4.6 km average levels.

		TEST SESSION							
TEST CONDITION	KEY	1	2	3	4	5	6	7	8
9.2 km, .7 M	AVG, dB	60.7	69.0	60.7	65.1			67.4	72.1
	σ, dB	1.4	.6	.2	.9			2.2	.8
	No.	2	4	4	4			3	4
4.6 km, .7 M	AVG, dB	74.8	72.6	67.6	69.7	74.8			74.0
	σ, dB	1.8	.5	1.3	.9	1.5			1.9
	No.	2	2	4	4	3			4
4.6 km, .5 M	AVG, dB	72.2		70.6	70.2	74.7	74.3		
	σ, dB	.6		.9	.2	.1	.7		
	No.	2		4	3	2	11		

Table II. Averaged ensemble-average time history peak OASPL.

Comparison To Ray Tracing.- Figure 1 is a comparison of a ray tracing predicted time history to an ensemble-average time history. The measured data are from a 9.2 km, .7 M run with a tip speed of 240 m/s. Included in the figure are the ensemble-average 80 percent confidence bounds. The acoustic source used in the ray tracing propagation model was an ANOPP[2] prediction based on nominally measured advanced turboprop operating conditions. An amplitude correction was applied to the predicted source levels for each run type based on the difference between a predicted and measured boom microphone amplitude for each run. A radiosonde weather profile was used in the two-dimensional ray tracing model which incorporates the effect of the wind by calculating an effective sound speed which includes the component of the assumed horizontal wind in the vertical plane containing the airplane and the receiver. This comparison between measured and predicted time histories is fair. The peak level is overpredicted by 4 dB, and there is a small time shift in the prediction.

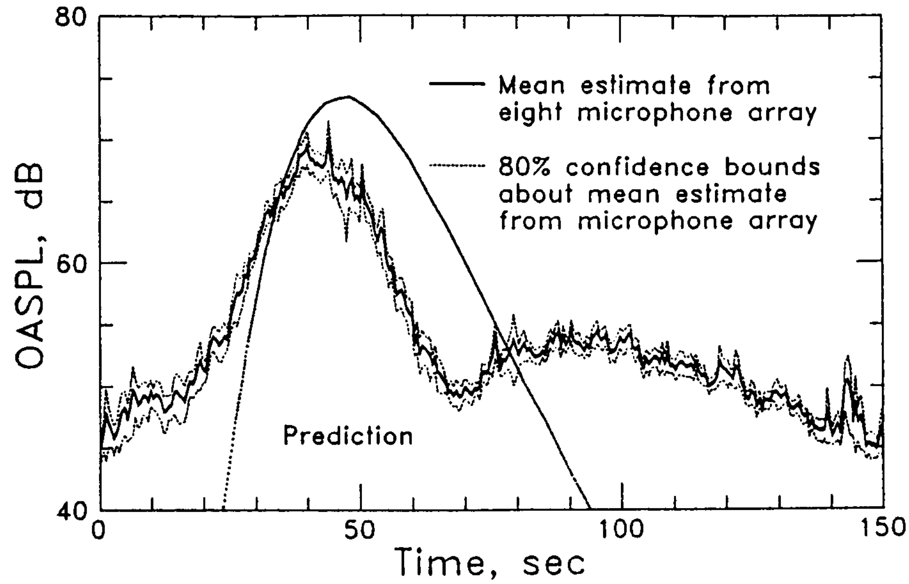

Figure 1. Ray trace prediction compared to ensemble-average time history.

Prediction Error.- To illustrate prediction error, the measured versus predicted overall SPLs for the 9.2 km, .7m; 4.6km, .7 m, and the 4.6 km, .5 m runs are plotted, respectively, in figures 2a through 2c. The dashed line in the plots is the perfect agreement line. The middle solid line is a regression line, and the 80% confidence levels about the regression line are represented by the two remaining solid lines. For the first two test conditions, 9.2 km and 4.6 km with a .7 m, the perfect agreement line falls within the 80% regression confidence bounds. There is an approximately 2 dB underpredicted basis in the 4.6 km, .5 m results. The reason for the basis is not currently known. The procedure for estimating source levels is being carefully reviewed. In general, the agreement between measurement and prediction is judged to be good.

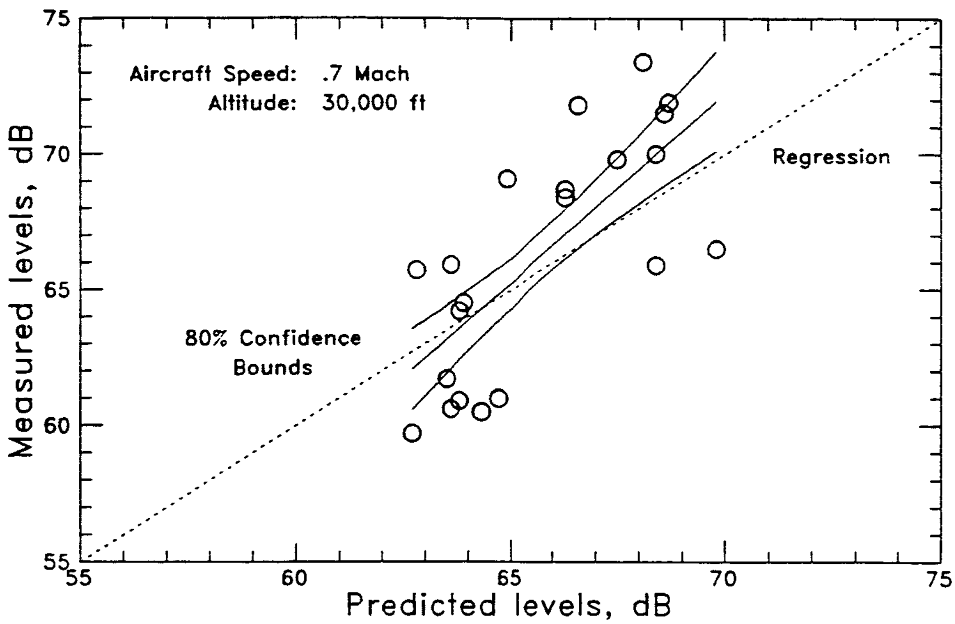

Figure 2a. Prediction error result for Mach .7, 30,000 ft. altitude condition.

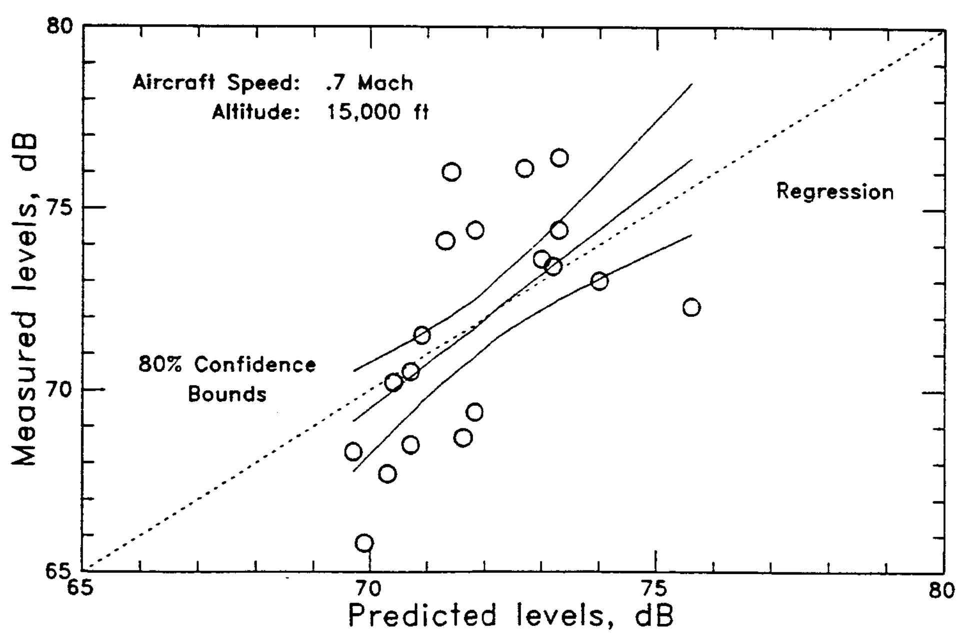

Figure 2b. Prediction error result for Mach .7, 15,000 ft. altitude condition.

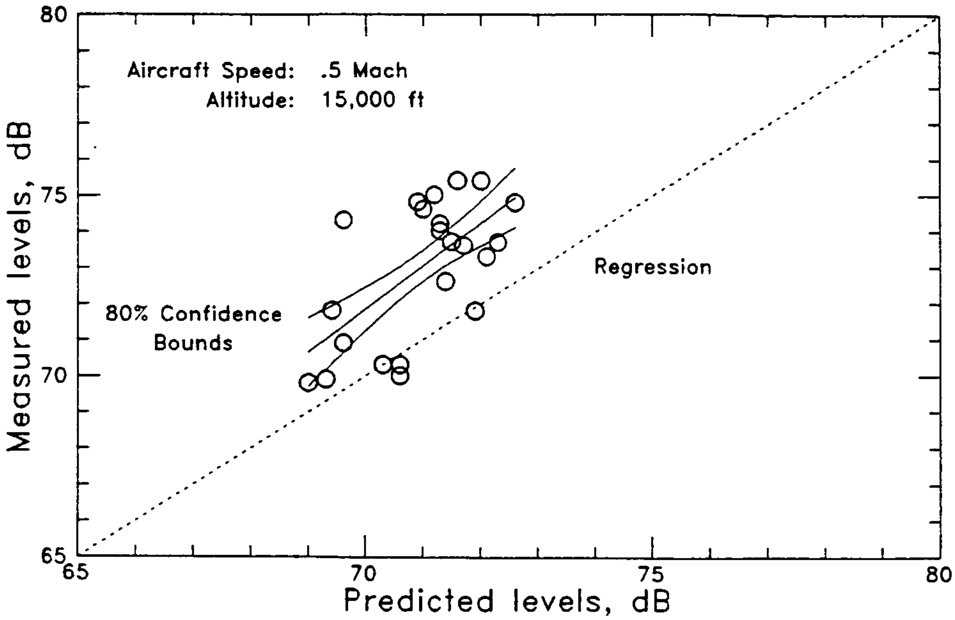

Figure 2c. Prediction error result for Mach .5, 15,000 ft. altitude condition.

SUMMARY

A flight experiment was conducted to investigate the propagation of advanced turboprop noise from cruise altitudes. The experiment was designed to use ensemble averaging and to measure weather profiles concurrently with the acoustic measurements. Data repeatability of ensemble-average Overall Sound Pressure Levels was good within a particular test day. Day to day average level variations existed. A two-dimensional ray tracing propagation model coupled with an empirically amplitude corrected predicted source noise directivity predicted the observed day to day average variability trends. Future research is aimed at understanding short-term, within a day, variability.

REFERENCES

1. O. Kipersztok: Uncertainty of Flyover Noise Data, AIAA Paper 83-0701, April 1983.

2. Aircraft Noise Prediction Program Theoretical Manual, NASA TM 83199, June 1986.