EN ROUTE NOISE - NASA PROPFAN TEST AIRCRAFT

(CALCULATED SOURCE NOISE)

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1. INTRODUCTION

The second phase of a joint National Aeronautics and Space Administration (NASA) and Federal Aviation Administration (FAA) program to study the high-altitude, low-frequency acoustic noise propagation characteristics of the Advanced Turboprop (propfan) Aircraft was conducted on April 3-13, 1989 at the White Sands Missile Range (WSMR), New Mexico. The first phase was conducted on October 26-31, 1987 in Huntsville, Alabama. These en route noise investigations were conducted as part of the NASA Propfan Test Assessment (PTA) high altitude flight test program.

Surface noise measurements were made by the U.S. Department of Transportation - Transportation Systems Center (DOT/TSC) for the Office of Environment of the FAA. NASA (Lewis) measured the source noise of the test aircraft during both phases while NASA (Langley) measured surface noise only during the second phase.

A unique feature of the propfan engine is the noise it generates. The unshrouded blades of a propfan engine propagate more low frequency acoustic energy, especially at the blade passage frequency (BPF) and its harmonics, than conventional shrouded jet aircraft. Low-frequency noise is absorbed to a lesser extent by the atmosphere than the high-frequency noise from conventional jet aircraft.

FAA/NASA designed a program to obtain noise level data from the propfan test bed aircraft, both in the near field and at ground level, during simulated en route flights (35,000 and 20,000 feet ASL), and to test low frequency atmospheric absorption algorithms and prediction technology to provide insight into the necessity for regulatory measures.

2. EXPERIMENTAL APPROACH

The acoustic noise propagation characteristics of the NASA SR-7L propfan, driven by a 6000 SHP Allison Model 501-M78 engine mounted on a modified Gulfstream GII test bed aircraft, were measured during the periods of October 26-31, 1987 (Alabama) and April 3-13, 1989 (New Mexico). NASA (LeRC) measured the source noise of the PTA test bed aircraft using an instrumented Learjet chase plane at prescribed locations on the surface of a 500 foot cylinder around the propfan engine. In addition, NASA measured the source noise on the test bed aircraft itself, using wing-boom and fuselage mounted sensors.

Surface noise measurements were made by TSC when the PTA aircraft (without chase plane) was flown at nominal altitudes of 35,000 and 20,000 feet (AGL) in Alabama, and by both NASA (Langley) and TSC when the PTA aircraft was flown at nominal altitudes of 30,000, 15,000 and 2,000 feet (AGL) in New Mexico.

Five surface measurement sites were deployed by TSC in Alabama: one each under the flight path and at ±5 miles and ±10 miles laterally from the flight track. Two sites were deployed by TSC in New Mexico: one under the flight track and one positioned 5 miles laterally from

the flight track. In addition to 4.0-foot microphones, inverted ground plane microphones were used at each site. Each inverted microphone was mounted with a 7 mm gap on a metal ground plate, 40-cm in diameter.

NASA provided aircraft position data synchronized to the recorded noise data. Weather balloons were launched 10 miles south of the surface noise measuring sites in Alabama and at the measuring site in New Mexico to obtain a meteorological data profile during the tests.

3. MEASUREMENT DATA

Figures 1-2 contain synchronized graphic level time histories as measured at the five measurement sites in Alabama. The representative data presented for flights at 35,000 and 20,000 feet (AGL), show the temporal nature of the aircraft sound at the ground measurement stations and the relative time of arrival of the sound at the centerline and ±5 and ±10 mile sites.

Figures 3-4 contain synchronized history data from the New Mexico tests for representative flights at 30,000 and 15,000 feet AGL at the centerline and 5 mile sites. Figure 5 contains noise level history data for a representative fly-by at 2,000 feet (AGL) only at the centerline measuring station.

For comparison, figures 6-7 contain graphic level time history data for several en route commercial jet aircraft using the same time scale and detector averaging characteristics (fast sound level meter response).

4. SOURCE NOISE

Using an instrumented Learjet aircraft as a chase plane, NASA measured the source noise of the PTA test bed aircraft at prescribed points relative to the power plant on the surface of an imaginary 500 foot cylinder around the propfan.

Plots of the NASA Alabama source data at nominal altitudes of 35,000 and 20,000 feet AGL are shown in figures 8 and 9.

5. CALCULATED SOURCE NOISE

To test the low-frequency absorption algorithm, adjustments were applied to the TSC "as measured" 7mm ground data to adjust the levels back to the source. (Or, more specifically, to the surface of the imaginary 500 foot cylinder around the propfan source.) A direct comparison with the NASA chase plane data could then be made.

The following adjustments were applied:

1) Free field adjustment
2) Spherical spreading losses

3) Atmospheric absorption
4) Characteristic impedance (Rho-c)

After adjustment as above, like events were grouped (e.g. by altitude, speed, measurement site) and the BPF* tone level (1/3-octave band data) versus emission angle were entered into a curve fitting program to obtain a second-order best fit curve.

Approximately ten points were selected for curve fitting over the period of each event. These included the maximum level and intermediate points where the measured signal was found to "peak" (i.e.: points representing the peak envelope (see figure 10). The resultant calculated noise source data are presented in paragraphs 5.1 and 5.2

5.1 ALABAMA TEST

Figures 11-12 contain calculated source noise data derived from ground measurements at the Alabama centerline and ±5 and ±10 mile measurement sites (nominal altitudes of 35,000 and 20,000 feet AGL; shaft horsepower: 4658; propeller tip speed: 840 fps).

Figure 13, derived from ground level measurements at the centerline site, contains calculated source noise data from overflights at 20,000 feet with two shaft horsepower settings (4658 and 3853 SHP) and three propeller tip speed settings (840, 700 and 620 fps).

5.2 NEW MEXICO TEST

Figures 14-15 contain calculated source noise data derived from the New Mexico ground measurements at the centerline and 5 mile sites (nominal altitudes of 30,000 and 15,000 feet AGL; 90% SHP; 800 fps).

Figure 16 presents a comparison of the calculated source data derived from New Mexico centerline data with the aircraft at nominal altitudes of 15,000 and 2,000 feet AGL (90% SHP; 800 fps). Figure 17 contains calculated source data with the aircraft at 30,000 feet AGL for four different operating parameters.

6. SUMMARY

The curves of calculated source noise versus emission angle are based on a second order best-fit curve of the peak envelope of the adjusted ground data. Centerline and sideline derived source noise levels are shown to be in good agreement. A comparison (figures 18-19) of the Alabama "chase plane" source data and the calculated source noise at centerline for both the Alabama and New Mexico data shows good agreement for the 35,000 and the 20,000 feet (ASL) overflights. With the availability of the New Mexico in-flight data, further in depth comparisons will be made.

*blade passage frequencies

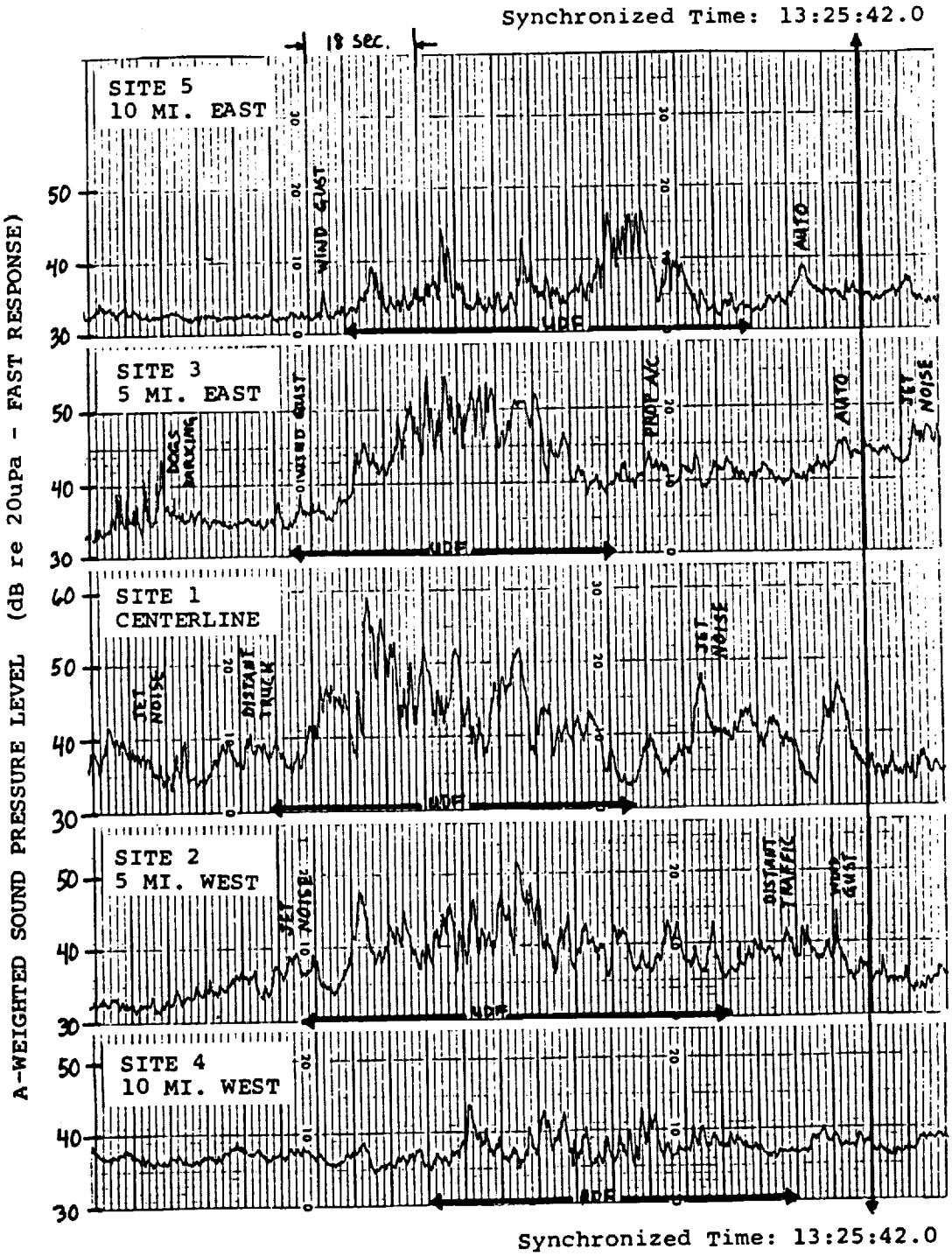


FIG. 1 SYNCHRONIZED NOISE LEVEL TIME-HISTORIES
EN ROUTE NOISE - HUNTSVILLE, AL

Flight 52 Event 19-6 10/30/87
35kft., 0.8 MACH, 2963 HP, 840 fps

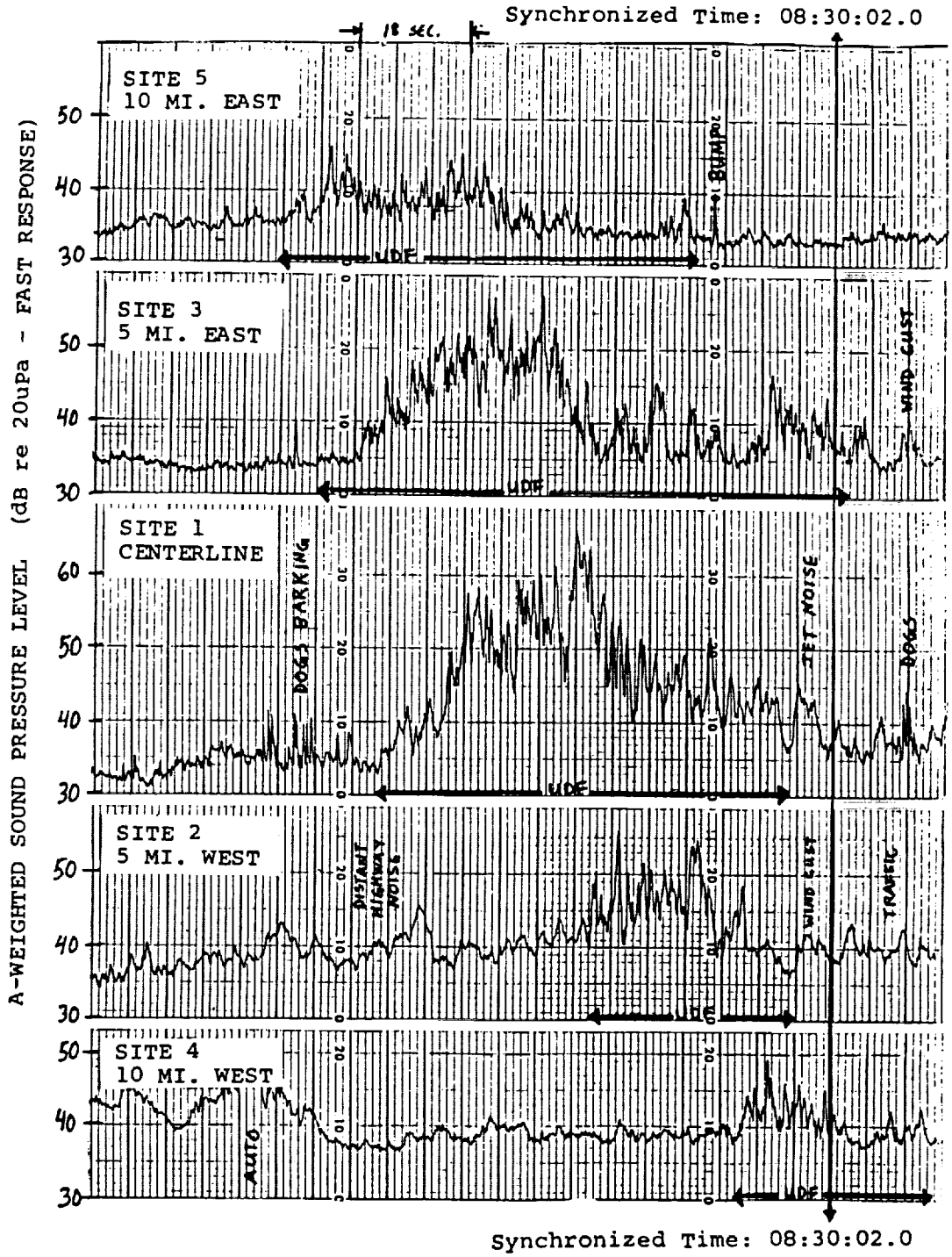


FIG. 2 SYNCHRONIZED NOISE LEVEL TIME-HISTORIES
EN ROUTE NOISE - HUNTSVILLE, AL

Flight 51 Event 15-2 10/30/87
20kft., 0.7 MACH, 4658 HP, 840 fps

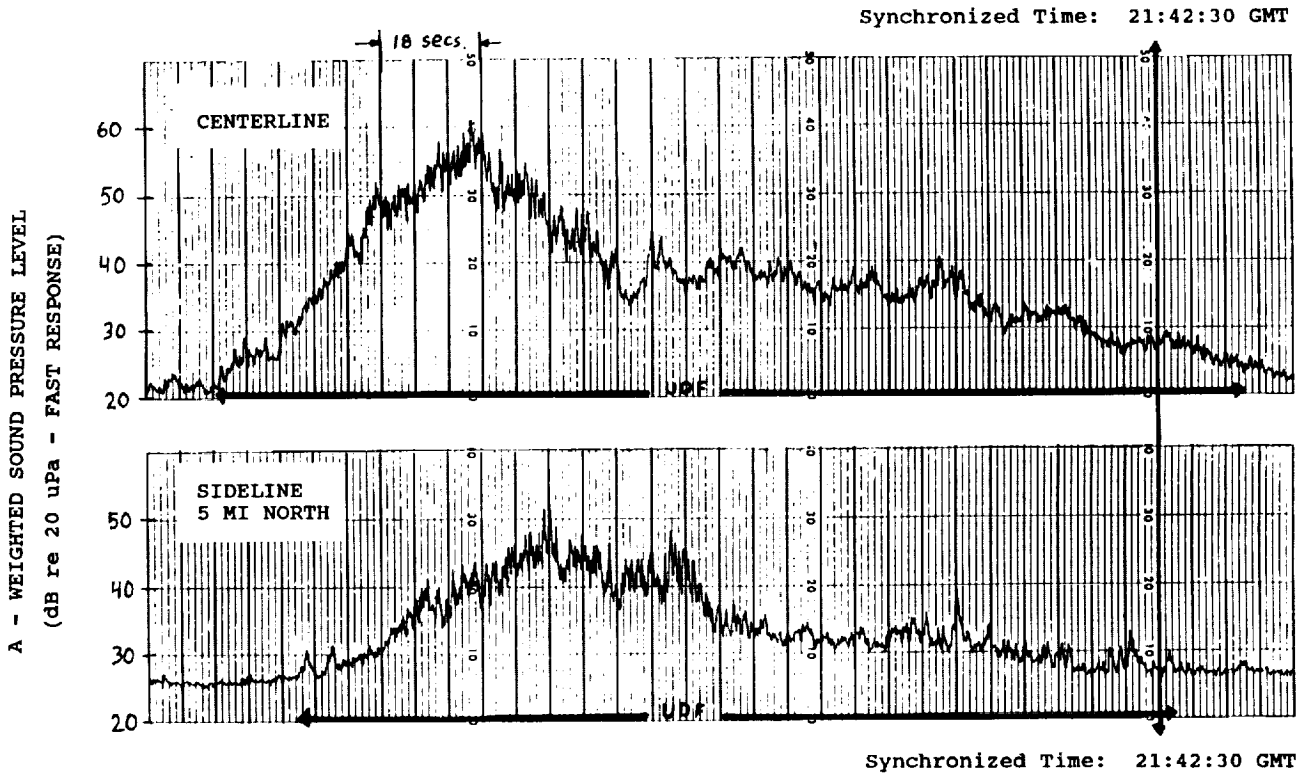


FIG. 3 SYNCHRONIZED NOISE LEVEL TIME-HISTORIES
EN ROUTE NOISE - WHITE SANDS, NM
Event 103 4/4/89
30kft. AGL, 0.7 MACH, 90% SHP, 800 fps

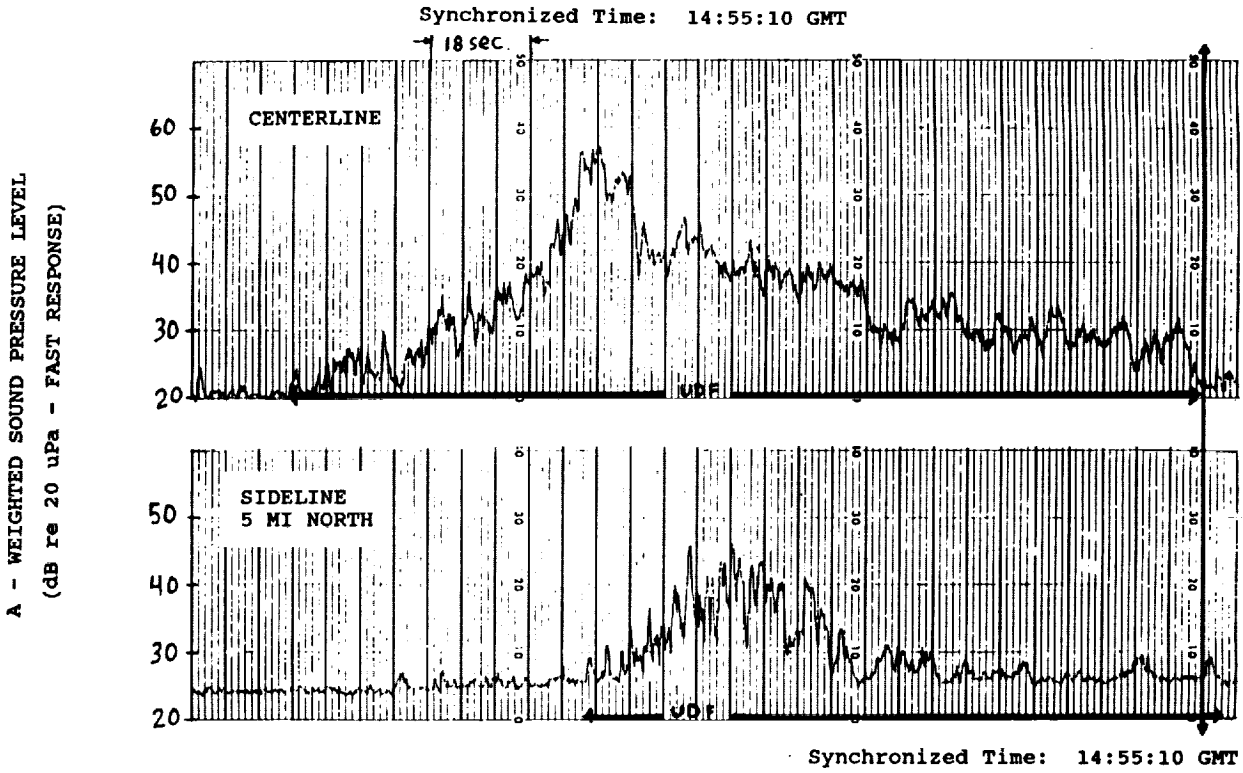


FIG. 4 SYNCHRONIZED NOISE LEVEL TIME-HISTORIES
EN ROUTE NOISE - WHITE SANDS, NM
Event 206 4/5/89
15kft. AGL, 0.7 MACH, 90% SHP, 800 fps

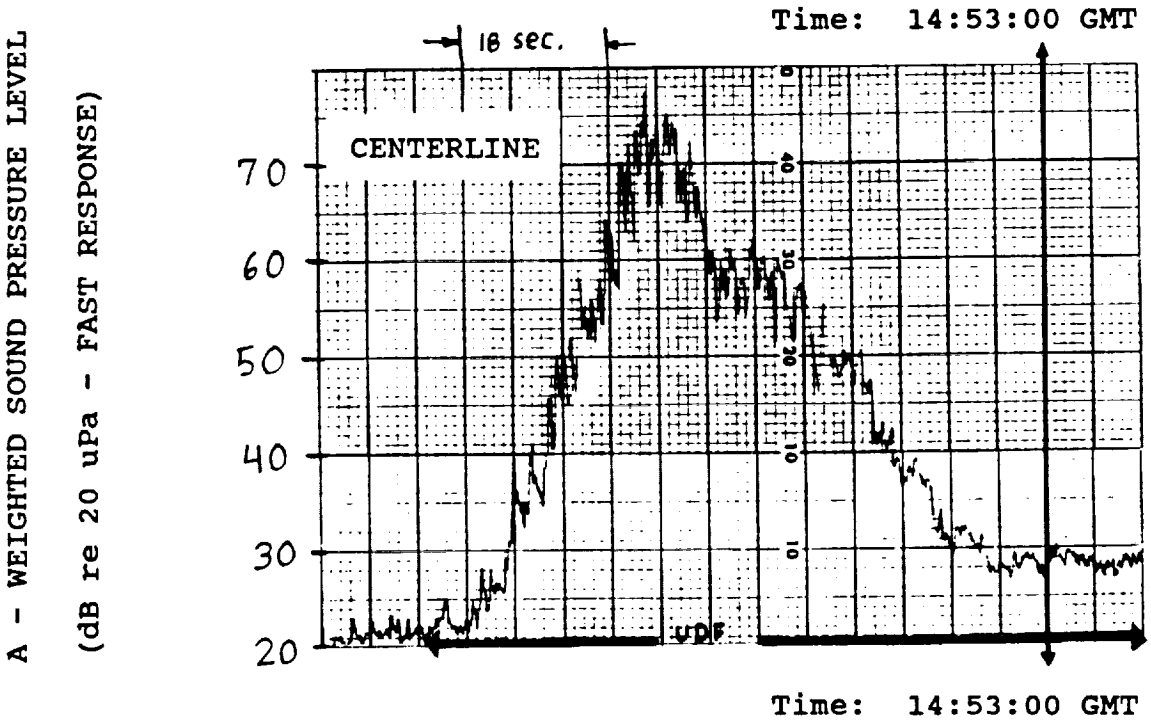


FIG. 5 NOISE LEVEL TIME-HISTORIES
EN ROUTE NOISE - WHITE SANDS, NM
Event 502 4/6/89
2kft. AGL, 0.5 MACH, 90% SHP, 800 fps

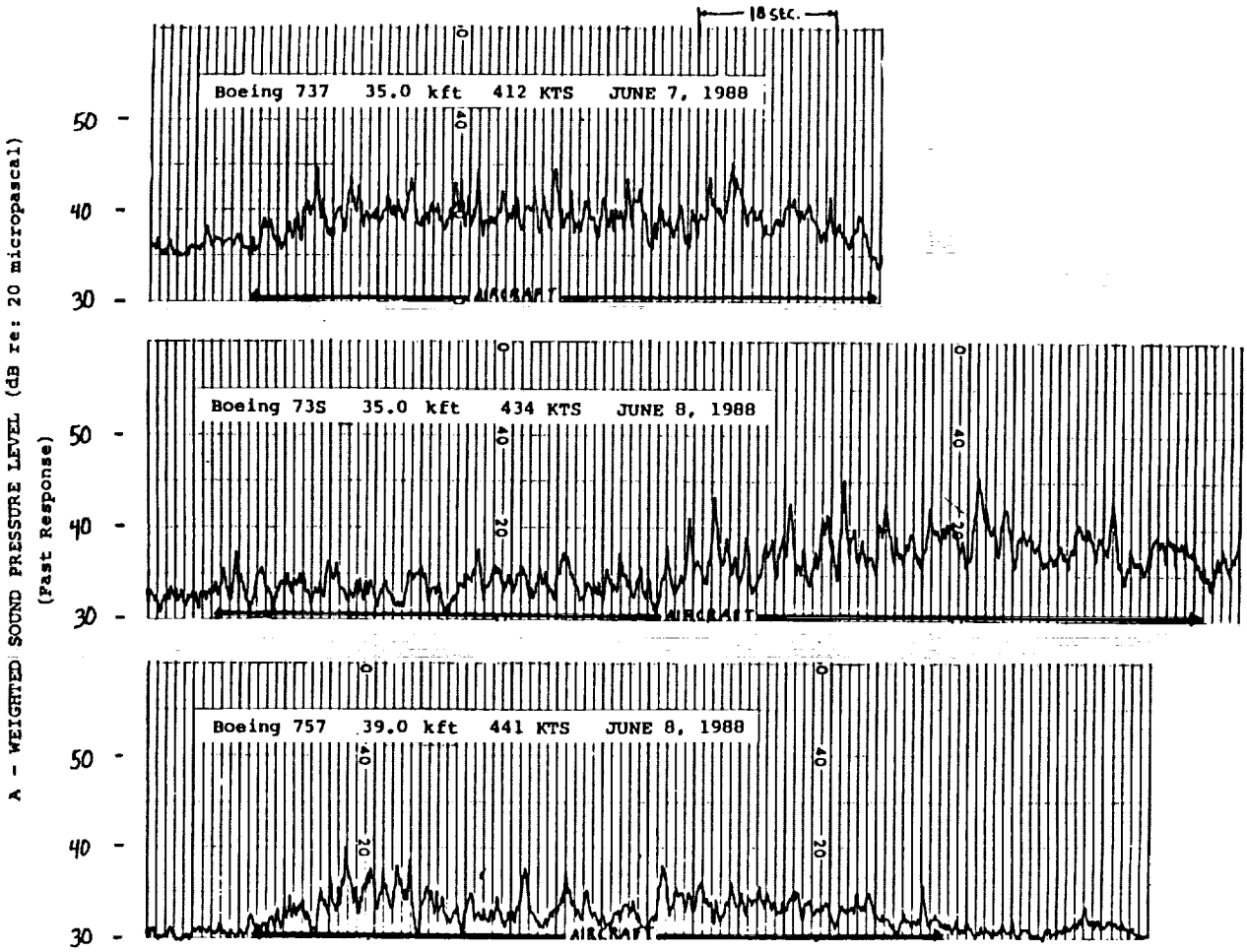


Fig. 6 NOISE LEVEL TIME - HISTORIES

EN ROUTE AIRCRAFT NOISE DATA

GORDONSVILLE , VA.

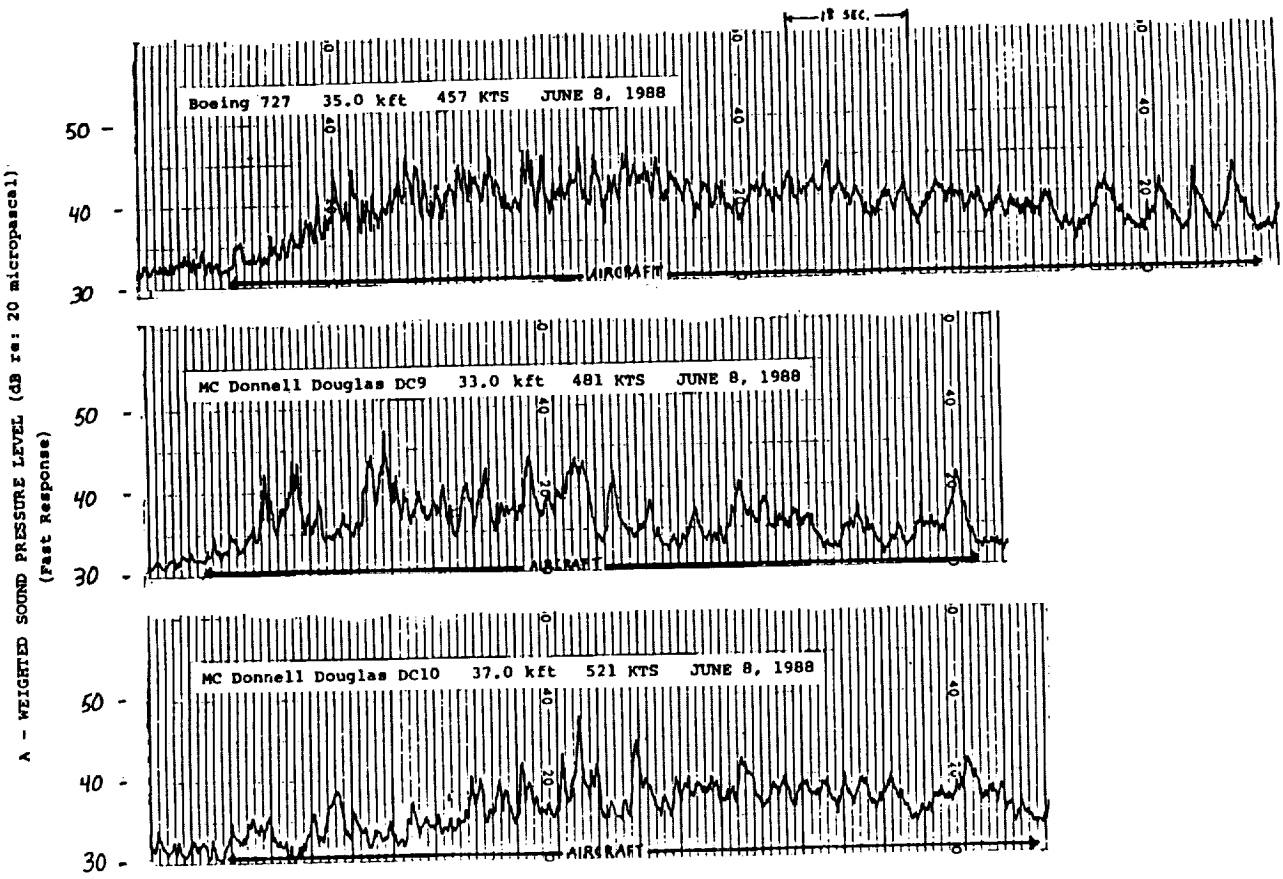


Fig. 7 - NOISE LEVEL TIME - HISTORIES

EN ROUTE AIRCRAFT NOISE DATA

GORDONSVILLE, VA.

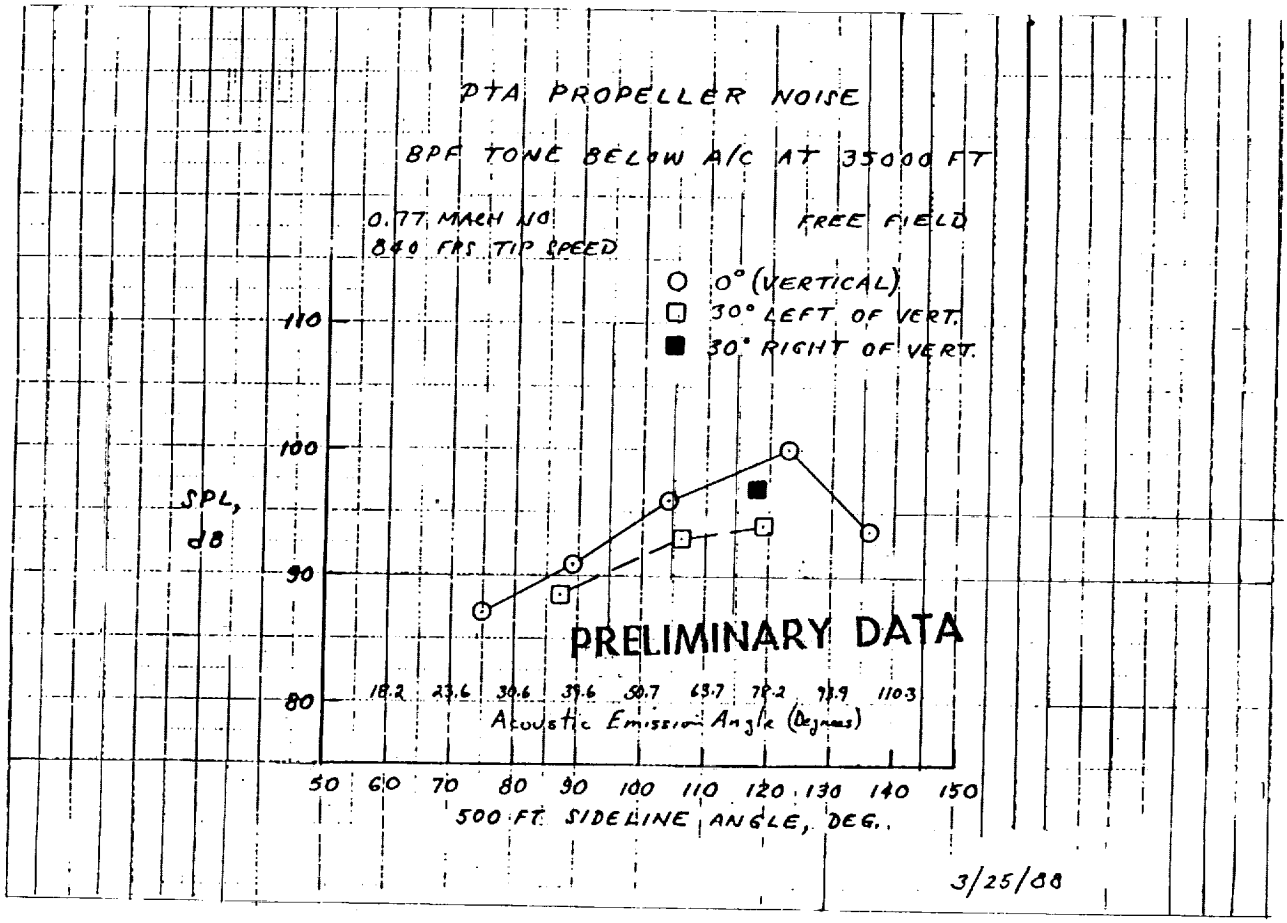


Fig. 8 - Source Noise (NASA Chase Plane)

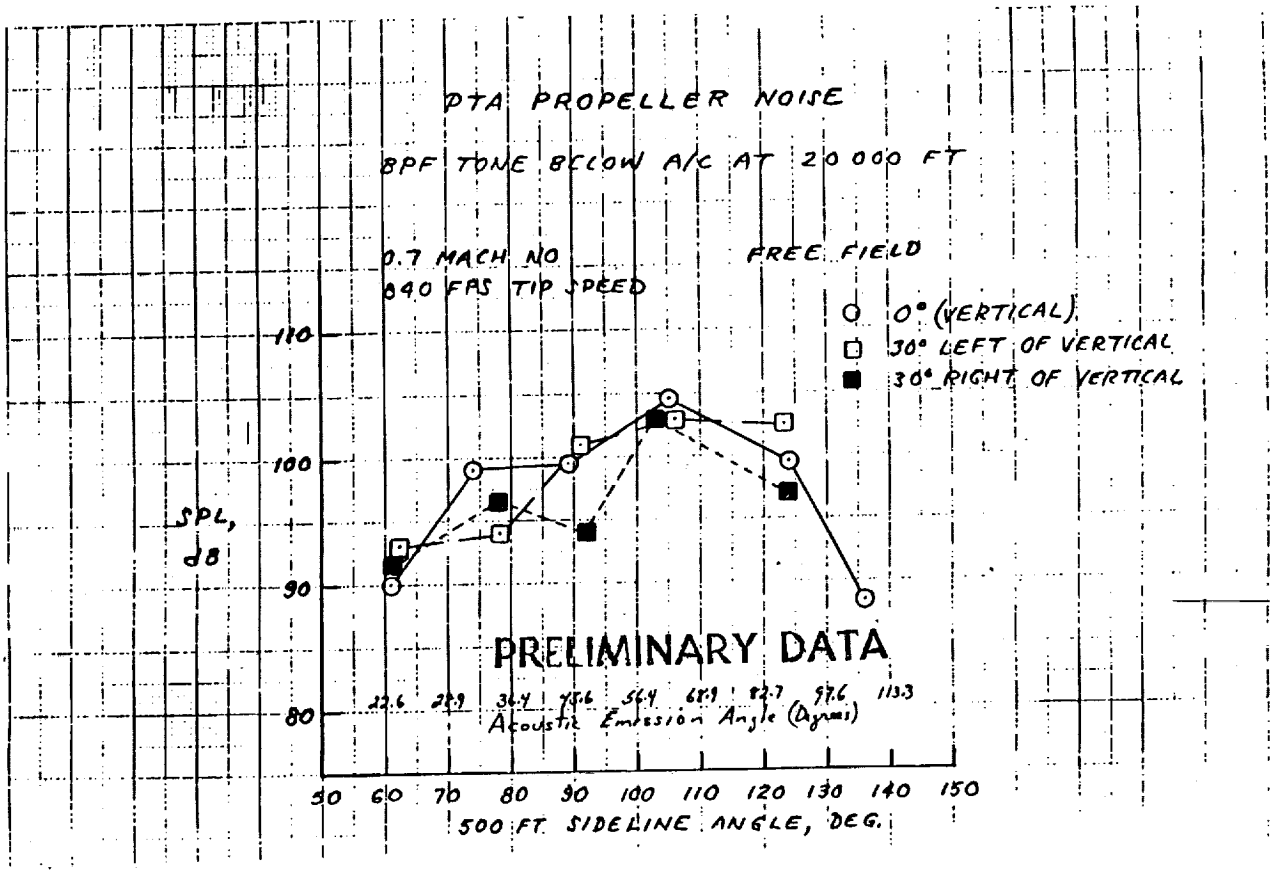


Fig. 9 - Source Noise (NASA Chase Plane)

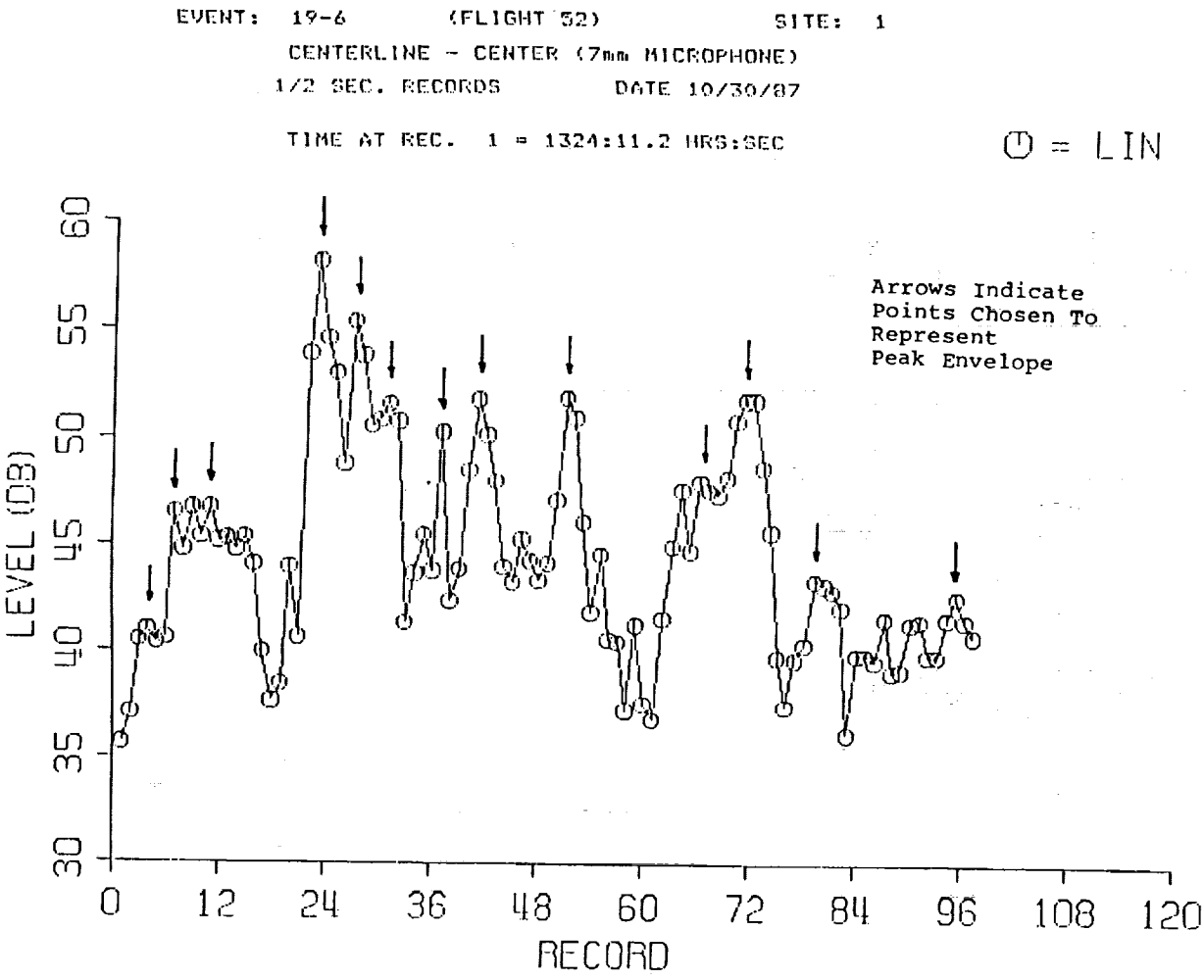
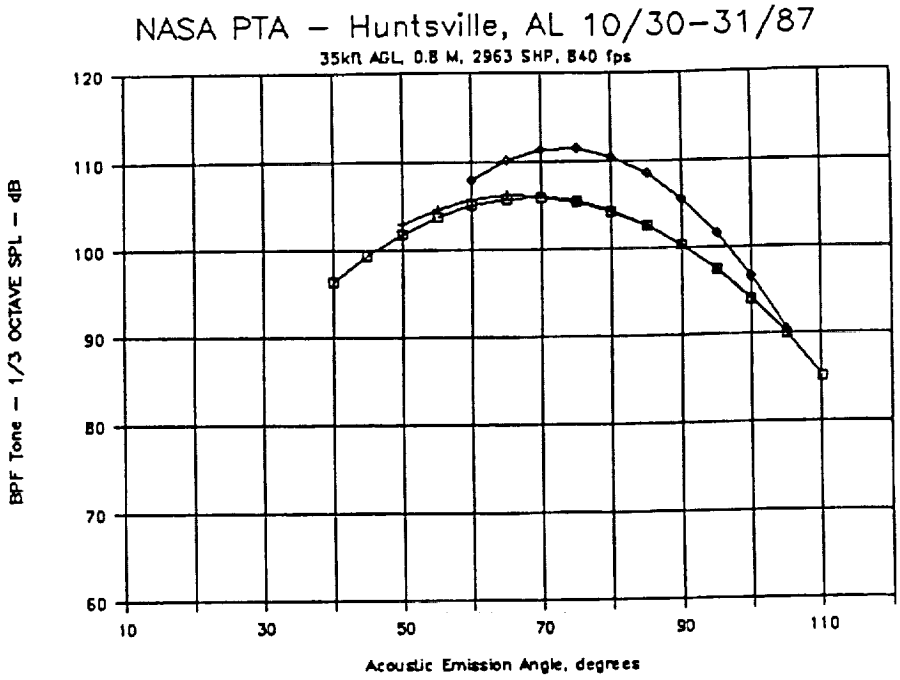


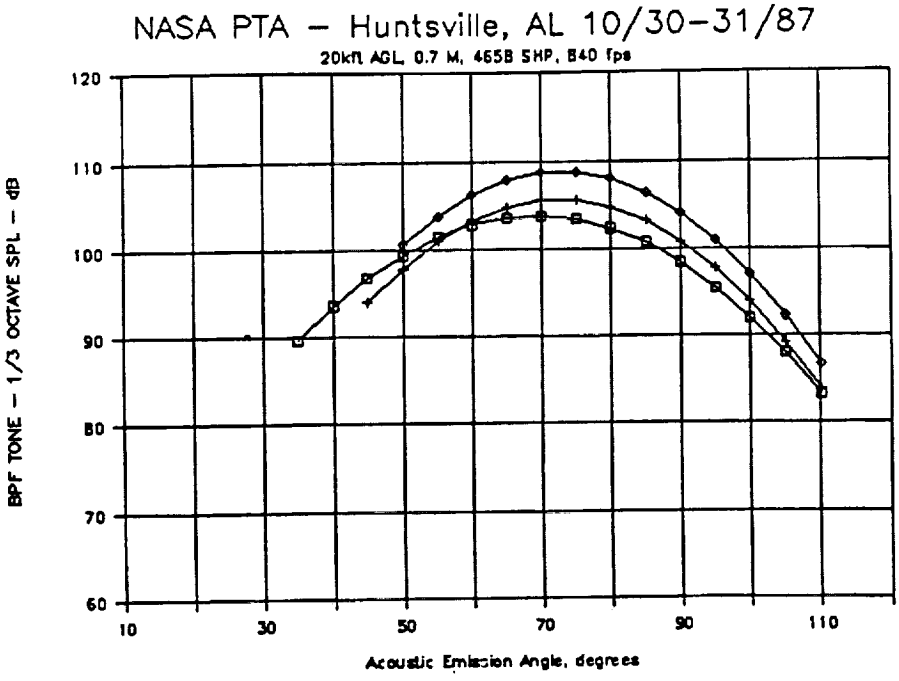
Fig. 10 - Noise Level Time History



□ CENTERLINE DATA

\+ 5 Mi SIDELINE DATA ◇ 10 Mi SIDELINE DATA

FIGURE 11 CALCULATED SOURCE NOISE



□ CENTERLINE DATA

\+ 5 Mi SIDELINE DATA ◇ 10 Mi SIDELINE DATA

FIGURE 12 CALCULATED SOURCE NOISE

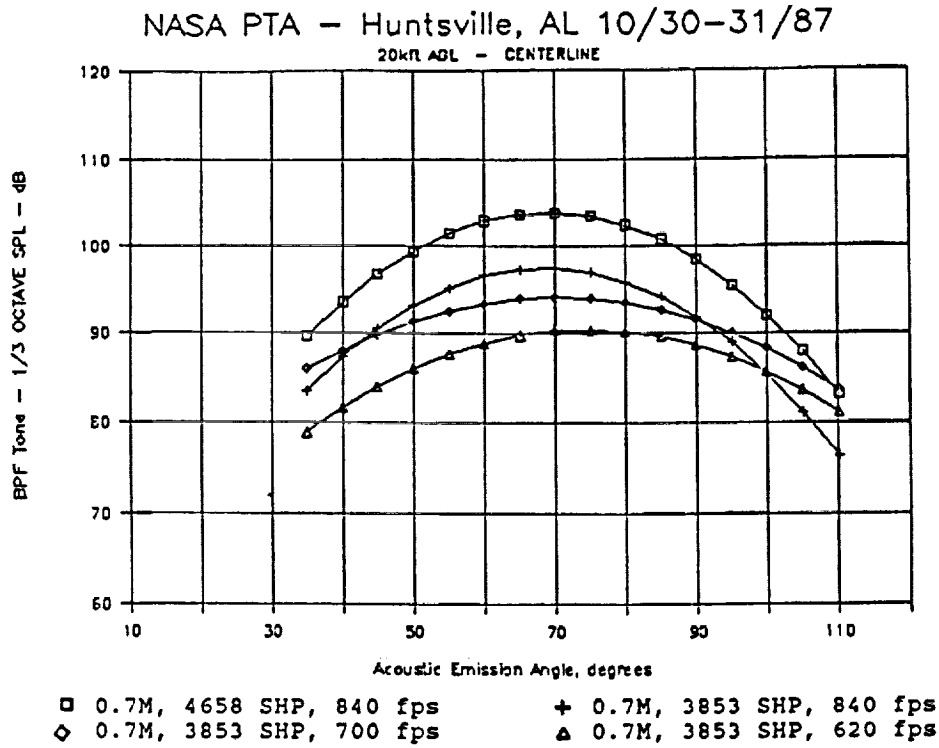


FIGURE 13 CALCULATED SOURCE NOISE

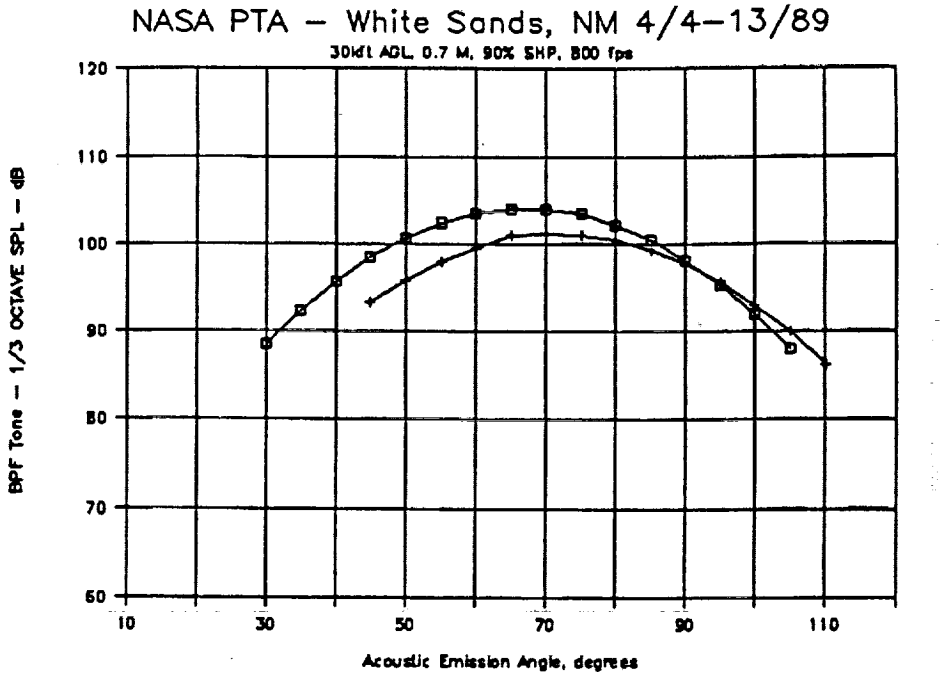
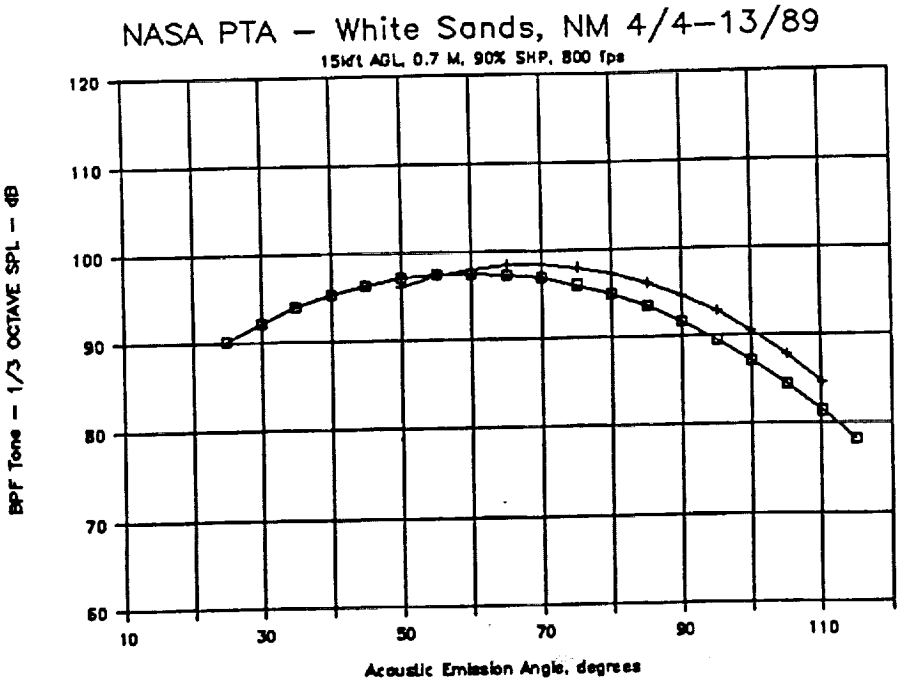
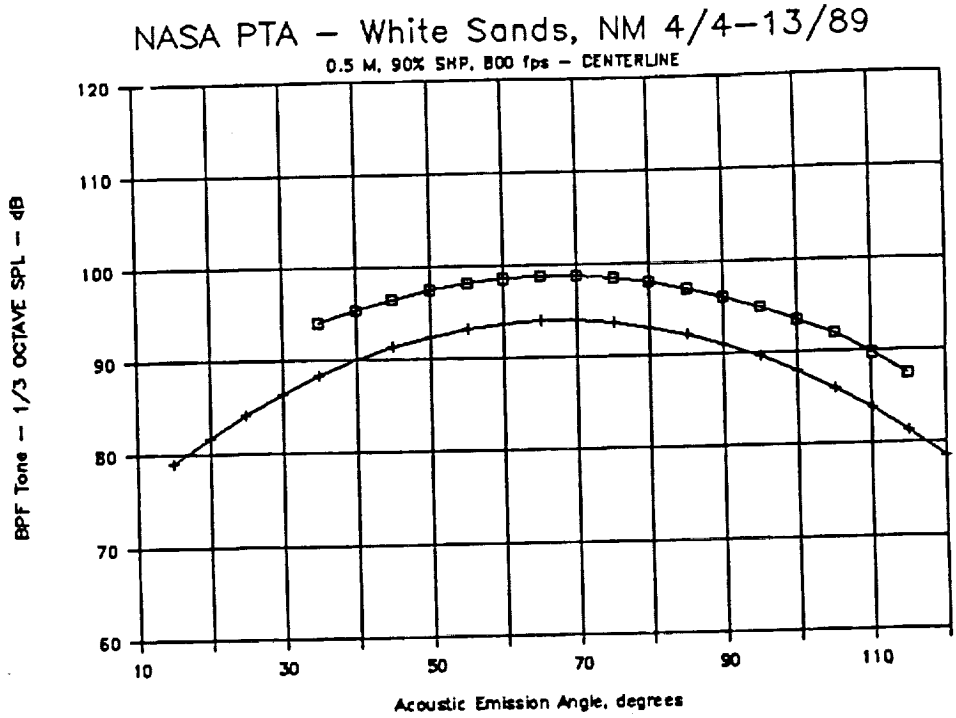


FIGURE 14 CALCULATED SOURCE NOISE



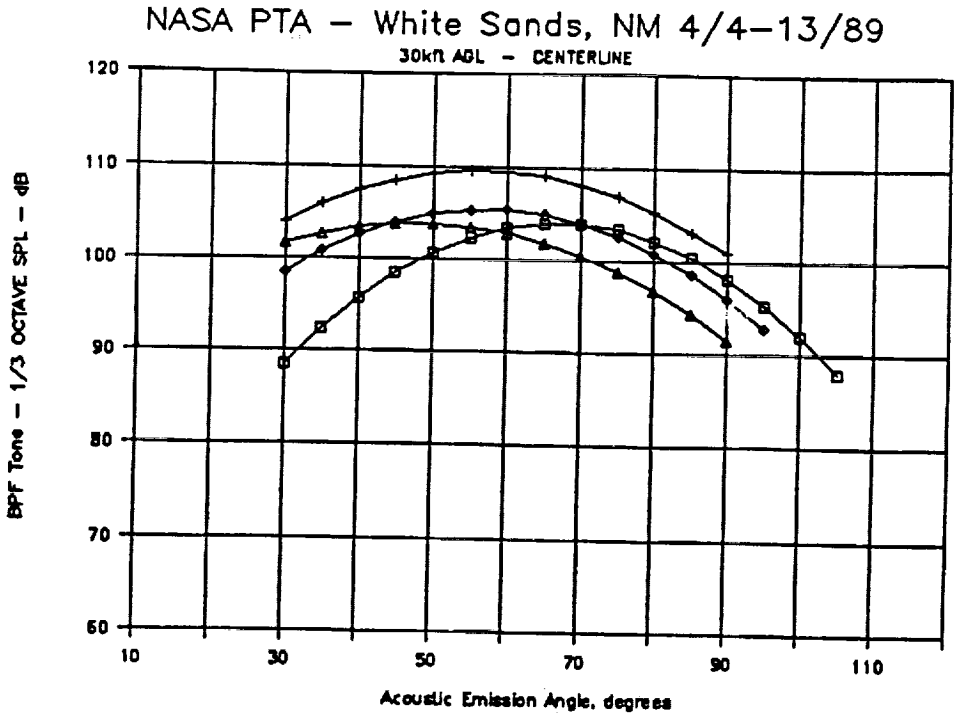
□ CENTERLINE DATA + 5 Mi SIDELINE DATA

FIGURE 15 CALCULATED SOURCE NOISE



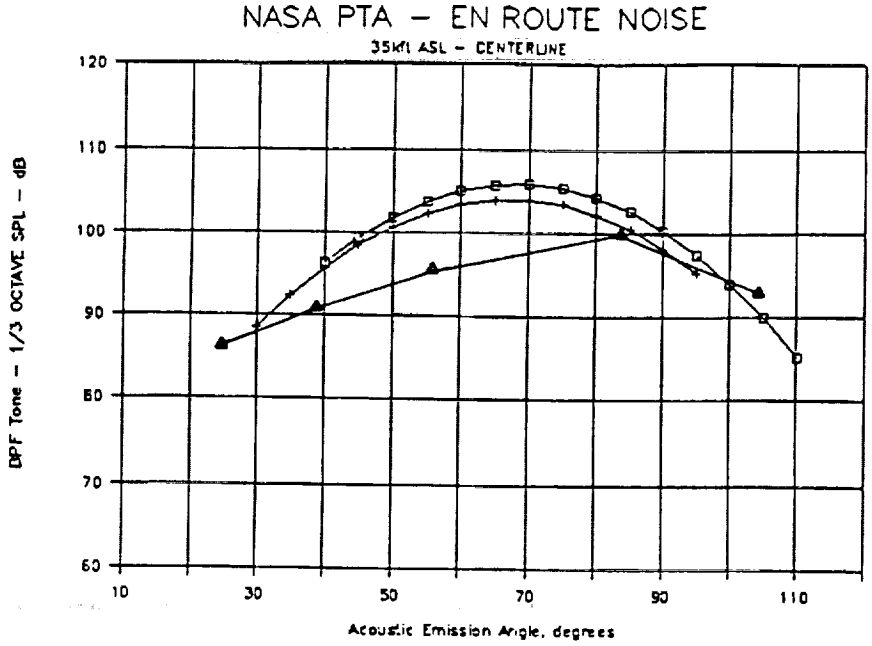
□ 15kft AGL + 2kft AGL

FIGURE 16 NOISE SOURCE COMPARISON



□ 0.7M, 90% SHP, 800 fps
◇ 0.7M, 90% SHP, 700 fps
+ 0.77M, 100% SHP, 840 fps
△ 0.7M, 90% SHP, 620 fps

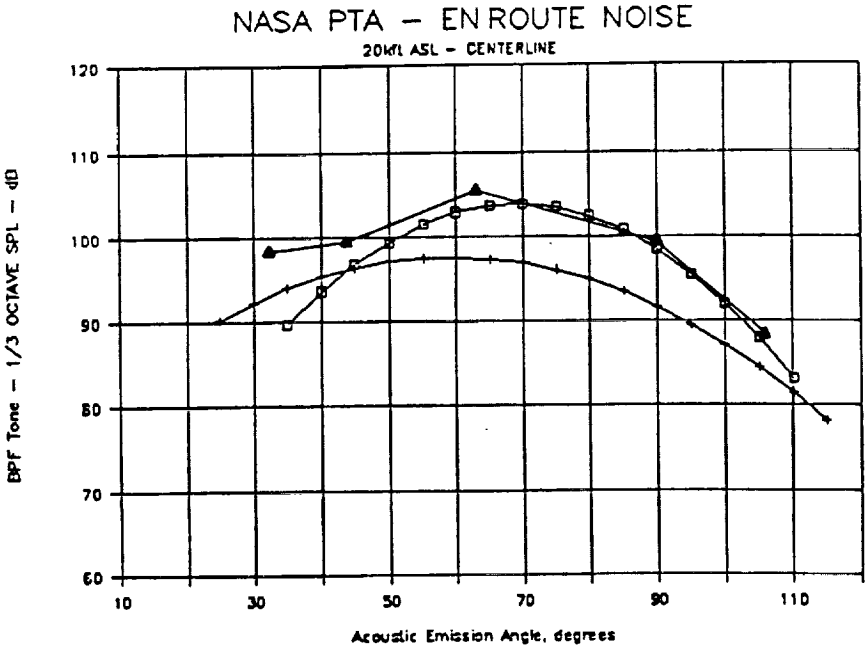
FIGURE 17 CALCULATED SOURCE NOISE



Calculated Source Noise:
□ Alabama 35kft AGL, 0.8 Mach, 2963 SHP, 840 fps, 10/87
+ New Mexico 30kft AGL, 0.7 Mach, 90% SHP, 800 fps, 04/89

Measured Source Noise :
△ Alabama 35kft AGL, 0.77 Mach, 2963 SHP, 840 fps, 10/87

FIGURE 18 NOISE SOURCE COMPARISON



Calculated Source Noise:
□ Alabama 20kft AGL, 0.7 Mach, 4658 SHP, 840 fps, 10/87
+ New Mexico 15kft AGL, 0.7 Mach, 90% SHP, 800 fps, 04/89

Measured Source Noise :
△ Alabama 20kft AGL, 0.7 Mach, 4658 SHP, 840 fps, 10/87

FIGURE 19 CALCULATED SOURCE NOISE