HIGH PERFORMANCE JET-ENGINE FLIGHT TEST DATA BASE FOR HSR

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[redacted]UISITION OF AN ANOPP VALIDATION BASE

The primary acoustic priority of the flight test data base for HSR is the validation of the NASA Aircraft Noise Predication Program (ANOPP) and other source noise codes. Also, the noise measurements are an important support function for the High Lift Program devoted to HSR. Another concern that will be addressed is a possible noise problem 7-20 miles from take-off during climbout. The attention arises from the higher speeds envisioned for the HSCT compared to conventional aircraft causing levels to increase because of Doppler amplification in conjunction with high source levels due to jet noise. An attempt may be made to measure airframe noise for the F-16XL test which would provide an assessment of this noise component for delta wing aircraft.

GOALS FOR ACQUISITION OF AN ANOPP VALIDATION DATA BASE

I. The primary acoustic goal is the acquisition of a data base to validate ANOPP and source noise codes

II. Support the High Lift Program

III. Look at the potential noise problem during climb-out (7 to 20 miles out)

IV. Consider the possibility of measuring airframe noise

CRITERIA FOR SELECTING AIRCRAFT

The first acoustic concern in the selection of the aircraft for the flight test program is that they be equipped with turbojet or low-bypass turbofan engines with afterburner. This requirement guarantees that the dominant noise source will be jet noise. Also, it would be beneficial for the aircraft to have calibrated engines since this would reduce any errors in the engine state data input to ANOPP. Single engine vs. dual engine powered aircraft is another topic of consideration. A single engine aircraft will provide a more detailed description of the noise mechanisms (mixing, shocks, etc.). But since the HSCT will be multi-engined a dual engine aircraft would show the effects of jet shielding. The F-16XL, which is single engined, has a planform similar to that envisioned for the HSCT. It also will be equipped with high lift devices (slats, flaps) proposed for the HSCT. In addition, the F-16XL could provide an airframe-noise data base for delta-wing-configured aircraft. The F-18 satisfies the dual engined proviso.

CRITERIA FOR SELECTING AIRCRAFT

I. Similarity to the HSCT
   1. Turbojet engine with afterburner
   2. Planform
   3. High lift capability
   4. Calibrated engines
   5. Single vs. dual engines

II. Two planes considered
   1. F-16XL
      a. Delta wing with planform similar to the HSCT
      b. Modified version will have high lift capability
      c. Single engine
      d. Could provide delta wing data base for airframe noise
   2. F-18
      a. Dualed engined; includes jet shielding effects
      b. Would provide an independent data base for ANOPP

PROPOSED AIRCRAFT OPERATING CONDITIONS AND RESULTING DATA SET

The flight test program can be divided into four segments. Of primary importance are level flyovers at constant velocity where ensembled averaged data is collected to validate ANOPP. This acoustic data can also be used to characterize jet noise. Measurements will also be performed on the aircraft in take-off and landing flight modes. This procedure will provide some insight into certification and community noise issues. The proposed speeds at particular altitudes that the HSCT is expected to experience during climbout must be emulated in the test phase and acoustic data collected. By doing this could yield some knowledge about the community noise concerns due to increased jet noise levels and Doppler amplification. Measurements carried out during a static test should be included in the data base. Use can be made of this data in ANOPP validation and characterization of noise source mechanisms.

PROPOSED AIRCRAFT OPERATING CONDITIONS AND RESULTING DATA SET

Operating condition	Data set
I. Level flyover at constant velocity	Ensemble averaged data; characterization of jet noise; ANOPP validation
II. Take-off and landing	Certification; community noise
III. Climb-out	Community noise; Doppler amplification
IV. Static test	ANOPP validation; source characterization (spectral content, directivity)

ANOPP VALIDATION

For the ANOPP validation phase of the test program both the accuracy of the measured acoustic data and the measured input parameters to ANOPP are critical. Accurate tracking of the aircraft flight path is essential for input to ANOPP and ensemble averaging the measured data to enhance the confidence in the collected data. An instrumented, tethered balloon will be employed to collect the weather data to be input to ANOPP (temperature, pressure, humidity). The effect of ground impedance can be minimized by mounting the microphones in planar ground boards. Engine state data for the particular aircraft involved in the test should be provided before the test program is initiated. During the data analysis that will result from the data base, accurate tracking histories are required for ensemble averaging. Also, the narrow-band spectra must be converted to 1/3-octave band spectra to compare against ANOPP.

ANOPP VALIDATION

I. ANOPP input requirements
   1. Flight profile
   2. Atmosphere (temperature, pressure, humidity)
   3. Ground impedance
   4. Engine deck to characterize noise sources

II. Data collection requirements
   1. Ensembled averaged data
   2. 1/3-octave band spectra
   3. Accurate aircraft tracking data
   4. Measure ambient conditions (temperature, pressure, humidity)

FLIGHT TEST CONDITIONS FOR LEVEL FLYOVER - ANOPP VALIDATION

For the level flyover segment of the flight test program, the purpose of which is to validate ANOPP, one altitude is selected, 1200 ft. Nine passes are proposed of the microphone array at the stipulated Mach numbers. Each case should be flown at least twice to check repeatability.

FLIGHT TEST CONDITIONS FOR LEVEL FLYOVER - ANOPP VALIDATION

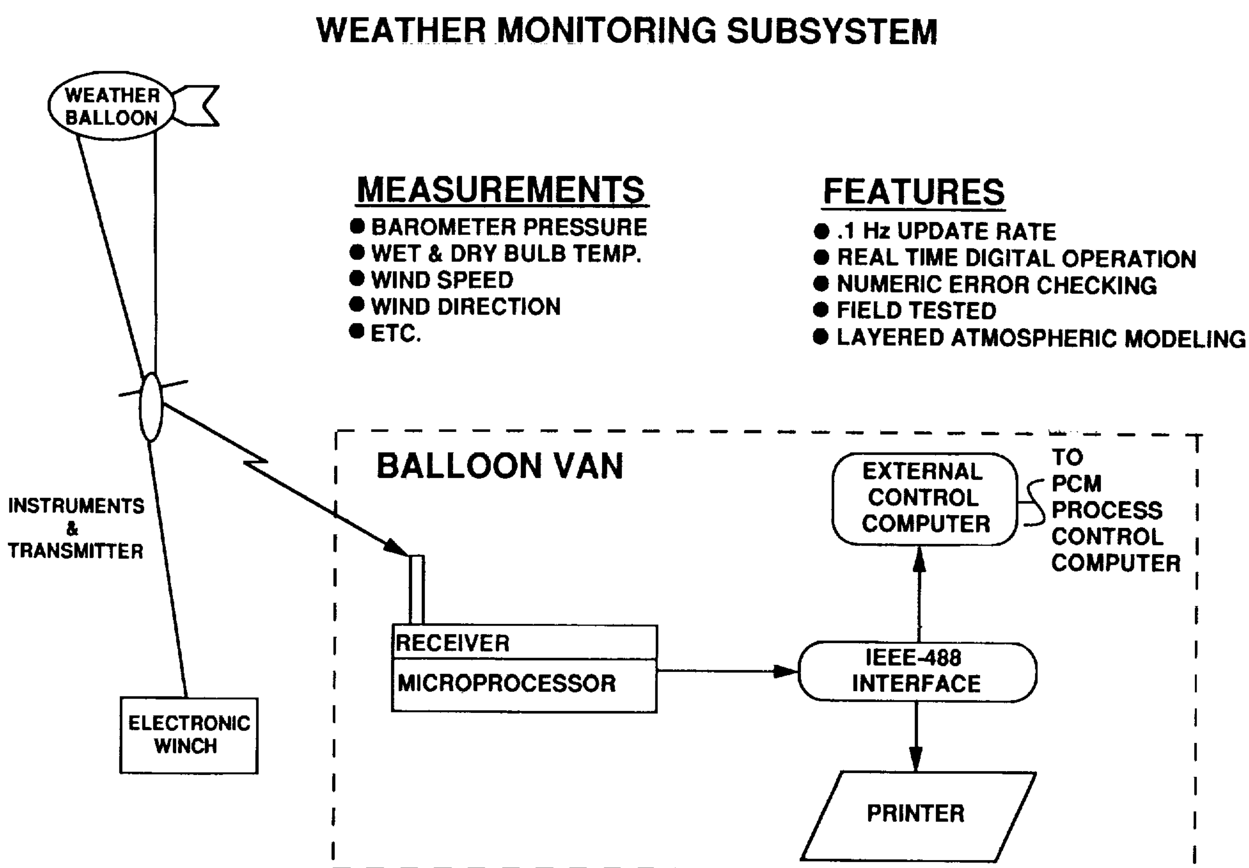
Altitude = 1200 ft.

Aircraft Mach number	Aircraft speed, ft./sec
.2	223
.3	335
.4	446
.5	558
.6	669
.7	781
.8	892
.9	1004
.95	1059

Fly each case twice to check repeatability

WEATHER MONITORING SUBSYSTEM

An instrumented, tethered balloon system will provide values for the ambient atmosphere for input to ANOPP (temperature, pressure, humidity). Prior to the flyovers, the atmosphere can be surveyed by the balloon system up to the flight altitude of 1200 feet, thus providing the ambient quantities as a function of altitude.



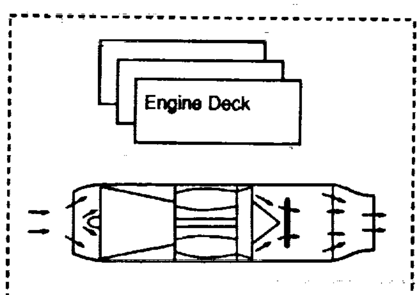
ENGINE STATE DATA REQUIRED FOR ANOPP PREDICATION

The evaluation of turbojet or turbofan engine noise source levels by ANOPP requires that the inlet and exit conditions for area, fuel-to-air ratio, mass flow rate, total pressure, total temperature and rotational speed be specified. This must be done for all four engine stages or components, i.e., fan, core, turbine and jet.

ENGINE STATE DATA REQUIRED FOR ANOPP PREDICTION

[Area, Fuel-to-Air Ratio, Mass Flow Rate, Total Pressure, Total Temperature, Rotational Speed]

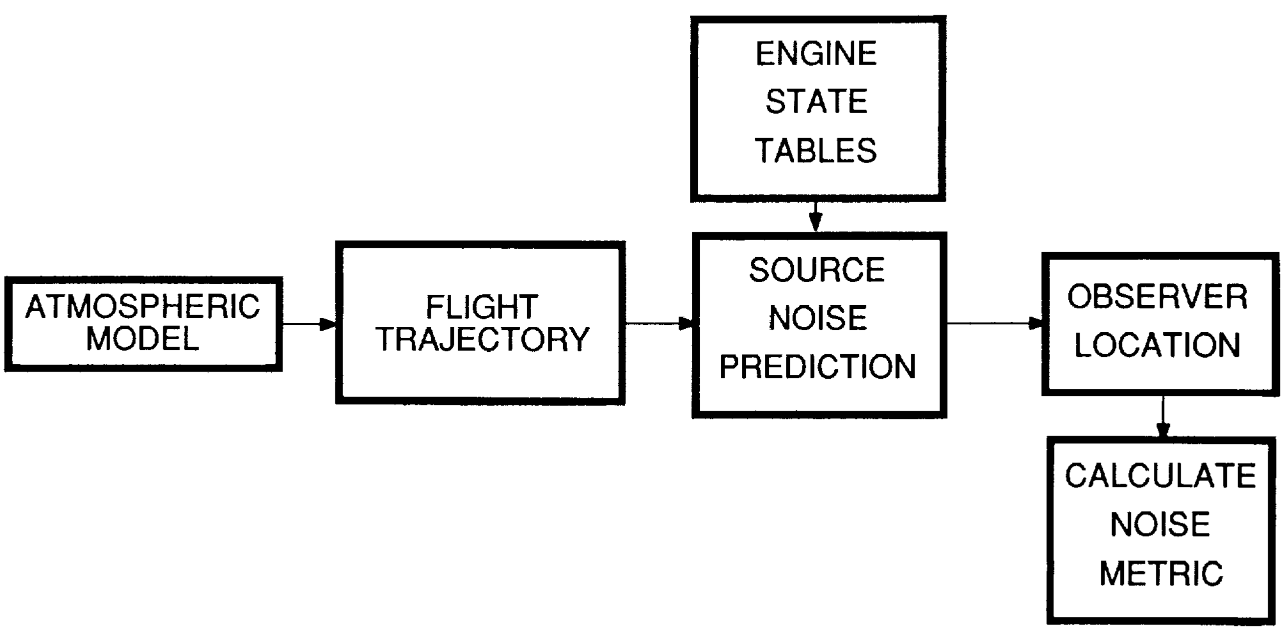
FAN	**INLET**
	EXIT
CORE	**INLET**
	EXIT
TURBINE	**INLET**
	EXIT
JET	**PRIMARY**
	SECONDARY



HSR NOISE PREDICTION SYSTEM

Use of ANOPP can be made in the prediction of noise levels that may impact community noise regulations concerning operation of the HSCT. To accomplish a prediction of a noise metric, ANOPP must be supplied with the ambient atmospheric quantities, flight trajectory and engine state tables.

HSR NOISE PREDICTION SYSTEM



MICROPHONE CONFIGURATION

A linear array of nine microphones will be used to acquire the acoustic data. Spacing between the microphones is tentatively set at 200 feet. The analog-to-digital conversion unit is in the microphone housing. Thus, each channel will be recorded in a digital format. The sample rate of the A-D unit will be greater than 25 kHz so that the Nyquist frequency will be above 12.5 kHz.

MICROPHONE CONFIGURATION

Linear array of at least 9 microphones will be employed

Microphones are digital, i.e, the A-D unit is in the microphone

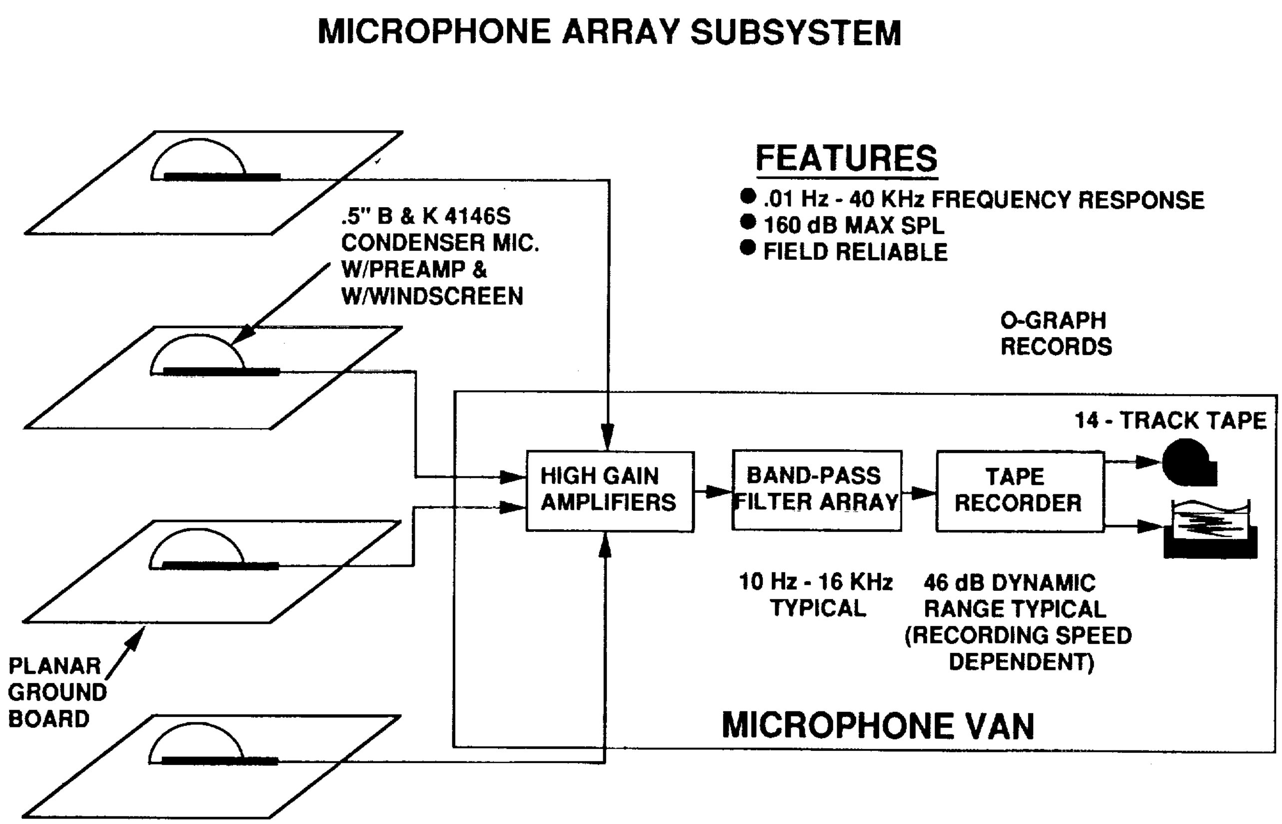
Signals will be recorded in a digital format

Microphones will be deployed on planar ground boards to reduce the effect of ground impedance

Sample rate of the A-D unit will be greater than 25 kHz, thus Nyquist frequency will be above 12.5 kHz

MICROPHONE ARRAY SUBSYSTEM

The microphones will be mounted on planar ground boards to reduce reception of reflected signals. The usual procedures will be taken to avoid aliasing (sufficiently fast sample rate, low-pass filter). Calibration of the microphones is to be performed immediately prior to the flight test.

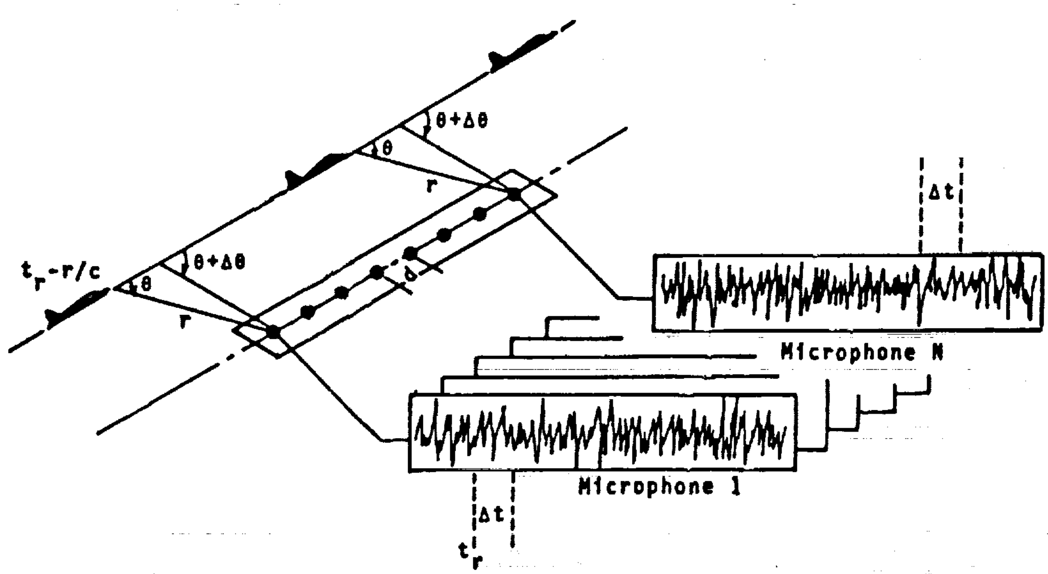


GROUND - PLANE MICROPHONE DEPLOYMENT
(4 SHOWN, 6 PER ROW PROPOSED)

FLIGHT ENSEMBLE AVERAGING

With the use of a laser/radar tracking system accurate position data can be determined and thus providing a means of correlating the position history of the aircraft with the microphone pressure time histories. For the level flyover situation, this allows ensemble averaging across the microphones that see the same emission angles.

FLIGHT ENSEMBLE AVERAGING



DIGITAL SIGNAL ANALYSIS PARAMETERS

For digitally recorded signals the sample rate, Δt, is determined at the time of acquisition and is a set value of the A-D unit. But, the number of points, per block N, can be varied during the signal processing. The window duration is determined from the relation $T=N\Delta t$. From the reciprocal of this (1/T), the bin width or frequency resolution is deduced, i.e., $\Delta f = 1/T$. The number of blocks, n_d, per segment for each channel defines the segment length, $T_{TOT} = n_d T$. The number of averages involved in the the FFT samples is given by n_dx the number of microphones.

DIGITAL SIGNAL ANALYSIS PARAMETERS

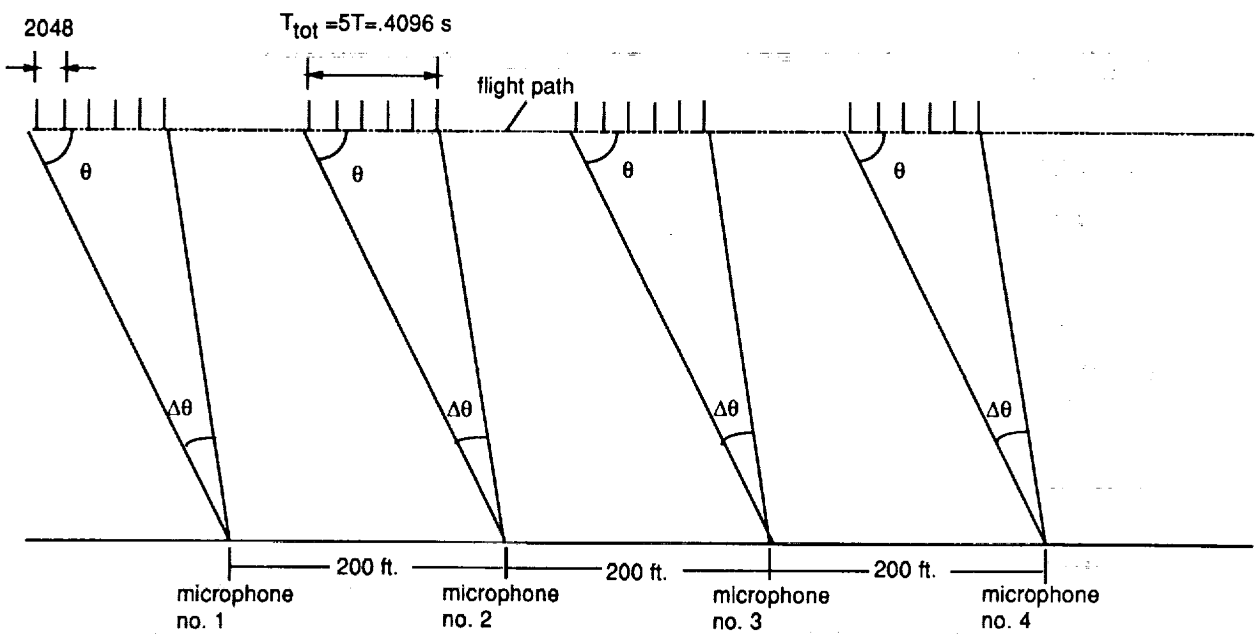
Example for two different bin widths

	case 1	case 2
sample rate (sec)	.00004	.00004
number of points per block	2048	16384
window duration (sec)	.08192	.65536
frequency resolution (Hz)	12.2	1.53
number of blocks per segment	5	1
segment length (sec)	.4096	.65536
number of microphones	9	9
number of samples in ensemble average	45	9

ILLUSTRATION OF RECORD DETERMINATION FOR A BIN WIDTH OF 12.2 Hz

For smear angles, $\Delta\theta$, small enough, ensemble averaging can be implemented within each microphone measurement in addition to across the array. This increases the number of averages which reduces noise in the signal. But a trade-off is that decreasing the smear angle implies that the window duration, T, also decreases and leads to a loss in resolution.

ILLUSTRATION OF RECORD DETERMINATION FOR A BIN WIDTH OF 12.2 HZ



TAKE OFF AND LANDING TEST CONDITIONS

For take-off and landing flight modes the passes are to be performed over the same linear microphone array as was used for the level flyovers. In addition, the three certification microphones on 1.2 meter poles are now included. Ensemble averaging presents a problem since each microphone sees a different time history. By executing multiple passes, ensemble averaging might be performed across these passes if repeatability presents no problem. Since jet noise is in general broadband ensemble averaging is not as important as in highly tonal spectra. An ILS equipped runway would provide the aircraft with the appropriate glide slope to obtain the required altitude above the certification microphone. During some of the take-off passes afterburner operation is to be included, since this is the worse case scenario for community noise. For the F-16XL on approach, if engine power can be reduced so that the level of jet noise is below the estimated value for airframe noise, acoustic data will be collected.

TAKE-OFF AND LANDING TEST CONDITIONS

Include the three certification microphones on 1.2 meter poles

Desirable to vary approach and climb angle and their associated speeds within the performance limit of the aircraft

Advantageous to have an ILS equipped runway to guarantee the 397 ft. of altitude above the approach certification microphone

Afterburner operation should be included in some of the take-off flights

For the F-16XL an attempt may be made to measure airframe noise if power can be reduced enough without jeopardizing flight safety

LEVEL FLYOVER TEST CONDITION TO EMULATE CLIMB-OUT ALTITUDES AND VELOCITIES

Level flyovers of the microphone array will be performed to emulate climb-out altitudes and speeds. These flyovers are to be executed at a Mach number of .95 from 2000 to 30000 ft. as shown in the figure. Due to Doppler amplification caused by the envisioned higher speeds of the HSCT and the higher source jet noise, noise annoyance could arise in previously unaffected areas.

LEVEL FLYOVER TEST CONDITIONS TO EMULATE CLIMB-OUT ALTITUDES AND VELOCITIES

Higher speeds envisioned during climb-out for the HSCT compared to conventional aircraft could produce significantly higher levels due to Doppler amplification

Use the linear microphone array to collect the data

Compare measured values with ANOPP

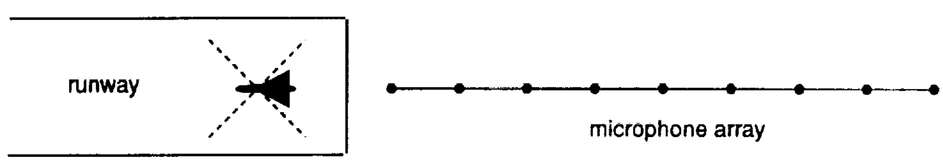
Test to be performed at a fixed flight Mach number of .95 at the following altitudes

Test case	Altitude (ft.)
1	2000
2	5000
3	10000
4	15000
5	20000
6	25000
7	30000

STATIC TEST

A static test is to be performed in the vicinity of the microphone array. By executing a rosette, the aircraft will display a directivity pattern to the array in the horizontal plane. At each test orientation, the sound field will be stationary and this can yield a reference data base to characterize the noise mechanisms of the aircraft. The measured data can then be compared to ANOPP predictions which in this situation can isolate the performance of individual modules.

STATIC TEST



Aircraft executes a rosette, thus array will record the directivity of the noise sources in a horizontal plane

Sound field will be stationary: this will provide a reference data base to characterize the noise

Compare measured data with ANOPP: this would give a better idea of the performance of individual modules than flight data

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