Proceedings of the Iowa Academy of Science

Volume 85 | Number

Article 6

1978

Prediction of Airbase Noise Contours

D. K. Holger
Iowa State University

Proc. Iowa Acad. Sci. 85(1):14-17. 1978

Prediction of Airbase Noise Contours

D. K. HOLGER

Department of Engineering Science and Mechanics
and the Engineering Research Institute Iowa State University Ames, Iowa 50011

The USAF NOISEMAP computer program predicts noise exposure contours around airbases from input information about aircraft types, operations, and flight paths. The program uses measured noise data together with standard propagation equations to compute the contribution to the sound pressure level at a given grid point for each aircraft as it flies along its flight path. All contributions are then combined to predict an overall equivalent noise exposure level, such as the day-night sound level, LDN, for each grid point. A contouring subroutine is used to produce a LDN contour map of the airbase vicinity. An experimental validation study indicates excellent agreement between predicted and actual LDN values.

INDEX DESCRIPTORS: Airbase noise, aircraft noise, NOISEMAP computer program.

Environmental impact of aircraft noise in the vicinity of United States Air Force installations is currently estimated through the use of the NOISEMAP computer program which predicts noise exposure from input operational and noise data. Proper application of the numerical prediction procedures of NOISEMAP provides an accurate assessment of the noise environment near an air base or airport. In addition, the program makes it possible to quantitatively estimate possible changes in the existing noise environment near a base. Computer runs using current operational data can provide valuable information about existing or possible acoustically incompatible land use areas. Changes in base missions, aircraft types, flight operations, or operating procedures can cause major changes in the noise environment near a base. The NOISEMAP computer program allows the effects of such changes to be estimated before they are made. At the present time the NOISEMAP computer program permits accurate estimates of the noise impact of proposed changes and acquisitions with sufficient lead time to be a major influence on command decisions.

This paper describes how day-night level, LDN, contours are generated by the NOISEMAP program and briefly discusses the capabilities and accuracy of the program. More detailed information on the program and how it is used is contained in a series of eight reports published by the USAF Aerospace Medical Research Laboratory [1-8]. The discussion throughout the paper will be in terms of the use of NOISEMAP for noise level predictions near Air Force bases. The reason for this emphasis is that at the present time the Air Force is the primary user of the program. However, the computer program itself is purely a means for predicting environmental noise exposure due to aircraft flight and ground operations. The program can be used to predict noise exposure for any type of aircraft under any geographical or meteorological conditions. It has been applied by the Air Force to nearly 100 domestic bases involving all types of locations and aircraft. Noise data are available for virtually all military and commercial aircraft as well as some general aviation aircraft.

The program could very easily be used to predict day-night sound levels in the vicinity of an airport such as Des Moines, Iowa. In order to carry out such a procedure data on all operations at the airport on a typical or several sample days would be necessary as well as noise data for each type of aircraft in use. The NOISEMAP program is available on the Control Data CYBERNET time sharing system and the documentation cited as references 1-8 is available from the National Technical Information Service. Several noise exposure descriptors are available as output, but the day-night sound level or LDN as used in this paper is in accordance with the U.S. Environmental Protection Agency's recommendations for Environmental noise [9].

THE NOISEMAP COMPUTER PROGRAM

The discussion of the NOISEMAP computer program which follows will consider the program in three parts. The first part, the input data required by NOISEMAP, consists of geographic and geometric information, operational data, and noise data. The second part is the main program which reads and validates the input data, carries out noise computations, and obtains LDN values for each point in a large grid. The third part is the output generated by NOISEMAP, which consists of a detailed data log — the "chronicle," values of LDN at grid points, plots of LDN contours, and the area enclosed by various contours.

Geographic and operational data are obtained from the base for which a run is to be made. Primary geographic information consists of a Coast and Geodetic Survey map of the vicinity within a minimum of 12.9 km of a base. A base layout map showing runway lengths and locations, runup pad locations, and navaid locations is also required. Geometric data consists of detailed flight track maps and flight path altitude profiles. Figure 1 is an example of the flight track maps for a base. A flight path is the actual three-dimensional path followed by an aircraft, and a flight track is the trace on the ground of that path. Because of the way in which computations are performed by the

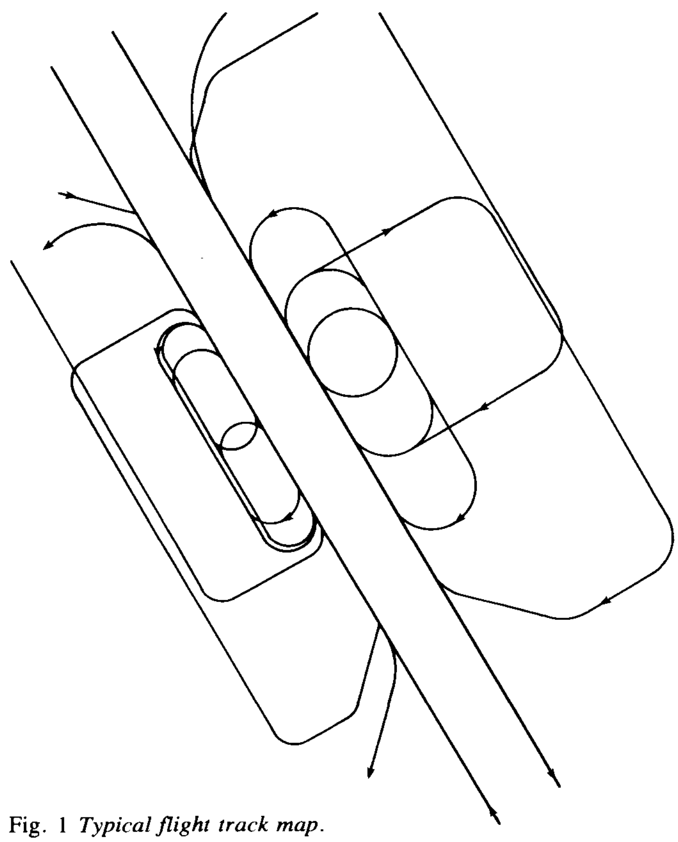

Fig. 1 *Typical flight track map.*

NOISEMAP computer program, input data defining flight path is in the form of a flight track and altitude profile along the flight track. This is also the way in which a flight path is operationally specified.

Operational data includes information on runway, flight track, and flight path utilization. This data must include a complete breakdown by actual aircraft version, type of operation, operational procedure and configuration, and time of day. Information about operational or procedural restrictions or limitations is also necessary. Data on engine runup and test is included in a similar manner. All operational data concerning numbers of operations is on a per day basis for a representative day at the base under study. In cases where operations or procedures vary considerably, several runs may be necessary for a single base. Figure 2 is an example of how runway utilization, take-off, and landing data are received from a base.

In addition to geographic and operational data, the NOISEMAP program requires detailed noise data for each aircraft at a base. Such data has been acquired through an extensive experimental program and is stored as a master noisefile with the NOISEMAP program. The flight noise data were acquired from fly-by measurements under various power and flight conditions. The data consist of tables of SEL vs distance for various operating conditions for virtually all military and commercial aircraft. Here SEL is the sound exposure level with the conventional definition,

$$\mathrm{SEL} = 10 \log_{10} \left\{ \frac{1}{T} \int_{t_1}^{t_2} 10^{\frac{AL}{10}} \, dt \right\}$$

where AL is the time dependent A weighted sound pressure level in dB, T is specified to be one second, and $t_2 - t_1$ is the duration of the event. The SEL thus takes into account the duration of a noisy event by using a time integral involving the commonly used A weighted sound pressure level. In a similar way the noisefile contains a table of AL vs distance for a prescribed set of angles around an aircraft during a ground runup. Flight or ground runups at points or operating conditions not in the noisefile table are handled by interpolation or specific corrections read in as data.

The NOISEMAP main program begins by performing all necessary computational initializations. It reads input data and, through the use of sophisticated diagnostic algorithms, validates virtually all input data. The main program also tabulates required noise data and sets up an appropriate grid for computations on the basis of geographic and grid input information.

In the actual grid computation phase the program uses a basic geometric algorithm to compute the distance from a flight path point to a grid point. Once that distance is determined the tabular or interpolated noise data in the form of SELS are determined for each grid point and each operation. Then for each aircraft and flight operation

$$\mathrm{LDN}_{ij} = \mathrm{SEL}_{ij} + 10\log_{10}[\mathrm{ND}_{ij} + 10\mathrm{NN}_{ij}] - 49.4 \text{ dB}$$

where ND_{ij} is the number of times aircraft j performs operation i from 0701-2200 hours, and NN_{ij} is the number of time aircraft j performs operation i from 2201-0700 hours. SEL_{ij} is the SEL for the j-th aircraft and i-th operation and is estimated from the tabular noise data. The SEL_{ij}'s are corrected for actual operating procedure, curved or straight path, actual distance to a grid point, and ground to ground or air to ground propagation. This last correction is necessary because at small angles of line of sight with the horizon, ground effects must be included in the propagation algorithm.

For ground operations, such as runups, the procedure for obtaining LDN_{ij} is as follows:

$$\mathrm{LDN}_{ij} = \mathrm{AL}_{ij} + 10\log_{10}\mathrm{D}_{ij} - 49.4 \text{ dB}$$

for 0701-2200 hrs and

$$\mathrm{LDN}_{ij} = \mathrm{AL}_{ij} + 10\log_{10}\mathrm{D}_{ij} - 39.4 \text{ dB}$$

for 2201-0700 hrs. In these equations D_{ij} is the duration of the i-th ground operation by the j-th aircraft in seconds.

All LDN_{ij}'s for ground and flight operations are then combined to give a LDN for each grid point. Since the LDN_{ij}'s are in decibels

$$\mathrm{LDN} = 10\log_{10}\sum_i \sum_j 10^{\mathrm{LDN}_{ij}/10}$$

for each grid point. In a typical run a 100 × 100 point grid with 1000 foot spacing is often used. Thus, the LDN must be calculated for 10,000 points in a typical case. Since the LDN value for each grid point is desired for output, the program actually works with $10^{\mathrm{LDN}_{ij}/10}$ rather than LDN_{ij} to facilitate combining the LDN_{ij}'s.

After LDN values for grid points have been calculated, the program

RUNWAY UTILIZATION SCHEDULE

Runway 06 is in use for takeoffs 60% of the day, 80% of the night, and
is in use for landings 60% of the day, 80% of the night.*
Runway length (A) available formlandings is 10,000 ft.

Runway 24 is in use for takeoffs 25% of the day, 20% of the night, and
is in use for landings 25% of the day, 20% of the night.
Runway length (B) available for landings is 8700 ft.

Total usable takeoff runway length is 10,000 ft.

TAKEOFF SCHEDULE

Ground Track Code 06/Tb

Takeoff from Runway

Proceed 28,000 ft

Turn 60° to the RIGHT with radius 13,000 ft

Proceed 150,000 ft

This ground track is followed by these aircraft:

Aircraft Type	Mission* Number	Number of Takeoffs 0701-3300	2201-0700	(Start at inter-section with:)
F-4D	1	4.154	1.385	
F-4E	1	1.385	0.461	
F-8	1	0.665	0.222	

LANDING SCHEDULE

Ground Track Code 06/Lc

Landing into Runway 06 Glide Slope 2.85°

This ground track is followed by these aircraft:

Aircraft Type	Number of Landings 0701-2200	2201-0700
F-4D	13.846	4.615
F-4E	4.615	1.538
F-8	13.242	4.430

Fig. 2 *Sample of data from a base.*

will perform further manipulations as specified to yield output in several forms. It is capable of generating equal LDN contours in two ways. If appearance and accuracy are not the primary consideration, NOISEMAP has an internal contouring routine which will generate a contour plot of LDN on a line printer. If appearance and accuracy are important, NOISEMAP generates output for use by a CalComp plotter general purpose contouring program (GPCP). In addition, the program is capable of estimating the area enclosed by specified LDN contours.

The output of NOISEMAP consists of data verification information, tabular results, and graphical results. The data verification output is in the form of a detailed data log or chronicle. A sample page from a chronicle is shown in Fig. 3. This particular page shows initialization data at the top followed by typical runway, mission, and altitude information. The program may be run in a nonprocess mode to verify that data are correct before actual noise computations are performed.

```
07/76 MCCHORD AFB WASHINGTON                                   PAGE 1

+++ NEW AIRFIELC MCCHCRD AFB WASHINGTON
   EXTERNAL LOCATION OF GRID ORIGIN X=100000. Y=200000.
   MAGNETIC DECLINATION  21.5 DEG TO EAST
   FIELD ALTITUDE      -0.0 FT CORRECTICN  0.0 DB
   GRID SPACING IS  1000.0 FT CONTOUR PGM SPACING 1000.0 FT
   OPTIONS  PROGRAM WILL PROCESS INPUT CATA  (ENGLISH UNITS)
         FOR DAY-NIGHT AVERAGE LEVEL CALCULATICNS
            USING NO TONE CORRECTICN NC RUNUP WEIGHTING
            DATA BASE CARRIED FORWARD UNCHANGED
   FILES KNOWN TC PROGRAM
   UNIT 10 BINARY WITH  0 DUMPS
+++ ENTER NAVAIC LAC AT X = 129721.. Y = 202620. FT
                            -------------------------
+++                             R U N W A Y  34
                            -------------------------
    LENGTH 10099.2 FT. GL. SLOPE 2.50 DEG. HEADING 338.6 DEG
    START ( 150000.0.  245000.0). END ( 149938.0.  255099.0)
     DISPLACEMENTS - TAKEOFF    -0.0. LANCING     -0.0
COMMENT      34A = PUGET FOUR RADAR DEPARTURE
+++ TAKE-CFFS    FLIGHT TRACK  34A
                 FROCEED     42000. FT
                 TURN LEFT  45.0 DEG  WITH  10000. FT RADIUS
                 FROCEED   100000. FT
+++ TAKEOFF DESCRIPTOR CLASS NO -      27   A/C - C14134A
                       MISSION NO -      1
                         ALT PRCF -  27341
                         POW PROF -  27341
                         TURN RAD -    0.0 FT
            SUBFLIGHT NOISE PROF  TRACK LIMITS (FT)
            --------- ----------  ----------------
                1         273          0.0 101000000.0
+++ ALTITUDE PROFILE           NAME =   27341  C14134A
      TRACK DIST     ALTITUDE
      ----------   -----------
           -0. FT         -0. FT
         3300. FT         -0. FT
        10000. FT        900. FT
        20000. FT       1600. FT
        25000. FT       2300. FT
        89200. FT      10000. FT
+++ DELTA-SEL   PROFILE        NAME =   27341  C14134A
       TRACK DIST   REL POWER (DB)
      -----------  --------------
            0. FT          7.6
         1650. FT          4.1
         3300. FT          3.6
        25000. FT         -2.3
                FLIGHT OPERATIONS  -  TRACK 34A
                A/C NO  MISSION  -  0701-2200  2201-0700
+++ C14134A       27       1        10.220        .880    7.718
```

Fig. 3 *Typical page of output chronicle.*

In either a nonprocess or actual full scale run, the chronicle summarizes all input data, and the program will plot flight tracks on a plotter and/or altitude profiles on a line printer. Tabular results from the program consist of LDN values for each grid point, an operational summary, and values for areas enclosed by specified contours, if desired. Graphical results take the form of contours plotted on either a line printer or CalComp plotter, as desired. A reduced version of a set of contour plots for the flight paths of Fig. 1 is shown in Fig. 4.

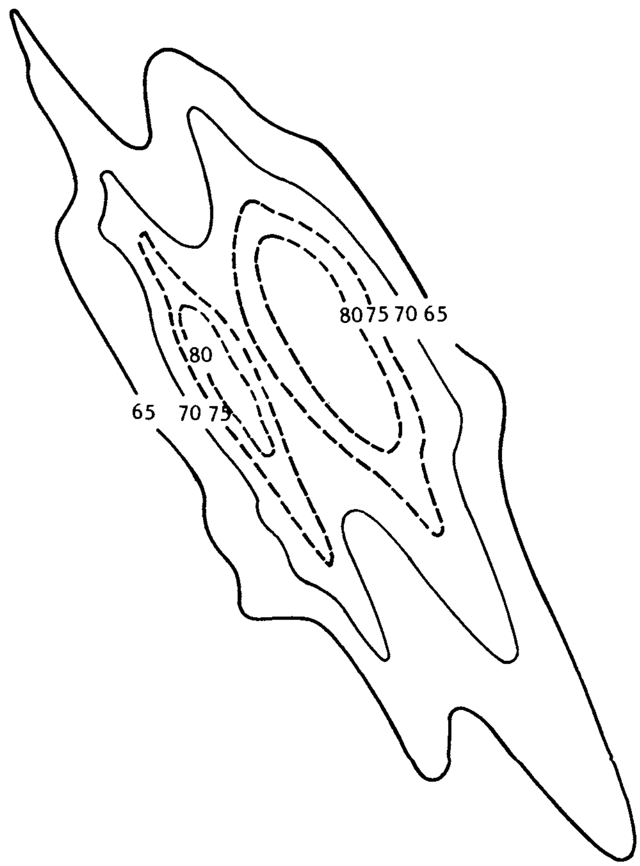

Fig. 4 *Typical LDN contours for a base.*

APPLICATION OF RESULTS

Applications of NOISEMAP predictions may be grouped in the broad categories of land use planning, operational planning, and aircraft design. For land use planning the NOISEMAP program provides an accurate quantitative estimate of noise impact. In fact, preliminary results of an experimental validation study indicate that NOISEMAP predictions are within 1 to 2 dB of measured values which have a standard deviation of 1 to 2 dB [10]. The contours generated by the program make possible the identification of areas where present uses and noise exposures are inconsistent. Such studies provide an excellent basis for zoning, rezoning, and long range land use planning in the vicinity of air bases and airports. In areas where development has occurred or is occurring, the results of NOISEMAP runs can lead to the establishment of appropriate building codes for noise impacted areas. In short, the NOISEMAP program provides a sound technical input for both long and short term land use planning and policies in the vicinity of air bases and airports.

A second area in which NOISEMAP results are applied is operational planning. Military aircraft are and will probably tend to remain comparatively noisy because of the performance requirements of military missions. Thus, the only practical means for controlling noise from military aircraft at the source is often through modifications in operating procedures or distribution of operations. NOISEMAP predictions very effectively indicate the noise impact of changes in volume of operations, operating procedures, volume of operations, time of day at which operations occur, and location and procedures for ground runups. The program also provides a simple means for predicting the effect on noise exposure contours of changes in aircraft type or mix and mission for a particular base. Such applications make the NOISEMAP program a valuable tool for administrative control of the noise sources at an air base.

Finally, the results of NOISEMAP base simulations for new and proposed aircraft can provide valuable information for use in the design and acquisition of new aircraft. A new aircraft for which increased noise levels are measured or expected can have serious implications which should be considered as part of the acquisition decision. A noisy aircraft can lessen stationing flexibility, increase the need for airbase land acquisition, require improved ground runup suppressors, and cause a significant deterioration in community relations. In some cases a new and larger aircraft which is also noisier will make possible a reduction in noise exposure levels through a reduction in the number of operations required. In any event, the NOISEMAP program provides a means for quantitatively assessing the noise impact of new aircraft designs and acquisitions.

CONCLUSIONS

The performance requirements of military aircraft will probably mean that such aircraft will remain relatively noisy in the near future. As the numbers of piston and turboprop aircraft remaining in the inventory are reduced, the noise produced at some bases could potentially increase because of the higher intensities and more annoying frequency content associated with jets. Existing means for modifying the noise impact of military aircraft are operational and procedural modifications, effective land use planning, and an awareness of the noise problem at the design stage. All of these measures for controlling and improving the noise environment around airbases depend on quantitative prediction of noise exposure contours as provided by the NOISEMAP computer program.

In order to maintain and improve the required accuracy for contour predictions, the technical foundations of the NOISEMAP program are continually reviewed and updated. Preliminary results of a detailed experimental validation study indicate that contour predictions are within one standard deviation of the experimental values [10]. As part of the ongoing research connected with the program a series of sensitivity studies have been conducted in an attempt to indicate input parameters which have insignificant or very significant influence on the resulting contours [8, 11]. An example of an ongoing study is an attempt to identify what constitutes a large enough change in base operations to make necessary a new NOISEMAP study for a base [12]. Current research related to the program is also being conducted in the general area of aircraft noise and its propagation.

REFERENCES

1. D. E. BISHOP, "Community Noise Exposure Resulting from Aircraft Operations: Application Guide for Predictive Procedure," AMRL-TR-73-105, Aerospace Medical Research Laboratory, Wright-Patterson Air Force Base, Ohio (November 1974).
2. W. J. GALLOWAY, "Community Noise Exposure Resulting from Aircraft Operations: Technical Review," AMRL-TR73-106, Aerospace Medical Research Laboratory, Wright-Patterson Air Force Base, Ohio (November 1974).
3. D. E. BISHOP and W. J. GALLOWAY, "Community Noise Exposure Resulting from Aircraft Operations: Acquisition and Analysis of Aircraft Noise and Performance Data," AMRL-TR-73-107, Aerospace Medical Research Laboratory, Wright-Patterson Air Force Base, Ohio (August 1975).
4. N. H. REDDINGIUS, "Community Noise Exposure Resulting from Aircraft Operations: Computer Program Operator's Manual," AMRL-TR-73-108, Aerospace Medical Research Laboratory, Wright-Patterson Air Force Base, Ohio (July 1974).
5. N. H. REDDINGIUS, "Community Noise Exposure Resulting from Aircraft Operations: Appendix NOISEMAP Program Operator's Manual," AMRL-TR-73-108, Appendix, Aerospace Medical Research Laboratory, Wright-Patterson Air Force Base, Ohio (February 1976).
6. R. D. HORONJEFF, R. R. KANDUKURI and N. H. REDDINGIUS, "Community Noise Exposure Resulting from Aircraft Operations: Computer Program Description," AMRL-TR-73-109, Aerospace Medical Research Laboratory, Wright-Patterson Air Force Base, Ohio (November 1974).
7. J. D. SPEAKMAN, R. G. POWELL and J. N. COLE, "Community Noise Exposure Resulting from Aircraft Operations: Acoustic Data on Military Aircraft," AMRL-TR-73-110, Aerospace Medical Research Laboratory, Wright-Patterson Air Force Base, Ohio (to be published).
8. D. E. BISHOP, T. C. DUNDERDALE, R. D. HORONJEFF and J. F. MILLS, "Sensitivity Studies of Community Aircraft Noise Exposures (NOISEMAP) Prediction Procedure," AMRL-TR-75-115, Aerospace Medical Research Laboratory, Wright-Patterson Air Force Base, Ohio (March 1976).
9. "Information on Levels of Environmental Noise Requisite to Protect Public Health and Welfare with an Adequate Margin of Safety," U. S. Environmental Protection Agency, Washington, D. C. (March 1974).
10. "Validation of Aircraft Noise Exposure Prediction Procedure," Bolt Beranek and Newman, Contract F33615-76-C-5003, under the technical management of the Biodynamic Environment Branch, Aerospace Medical Research Laboratory, Wright-Patterson Air Force Base, Ohio.
11. D. K. HOLGER, "A Sensitivity Study of NOISEMAP Power Offset Profiles (DSELS)," Participant's Final Report, 1976 USAF-ASEE Summer Faculty Research Program, AFCEC, Tyndall AFB, Florida (13 August 1976).
12. "Sensitivity of NOISEMAP Contours to Changes in Aircraft Operations," Iowa State University, AFOSR Contract 77-3308.