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Aircraft Sound Description System Background and Application

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AIRCRAFT SOUND DESCRIPTION SYSTEM

BACKGROUND AND APPLICATION

MARCH 1973

FINAL REPORT

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16. Abstract

An objective approach to describing aircraft sound levels for areas in the vicinity of airports called "Aircraft Sound Description System" (ASDS), suitable for both manual and computer application, is set forth. The basic premise of the concept is to state exposure to aircraft sound in terms of the amount of time that sound levels exceed a preselected threshold value. The rationale supporting the selection of this procedure, the selection of the threshold value, as well as some operating time constants are covered together with two hypothetical applications.

Some of the key advantages of the ASDS are as follows: (a) Stating exposure in units of time promotes a better understanding of noise exposure analyses by the public, community leaders, as well as local government, Federal Government, and aviation community officials; (b) By dealing with objective measures of noise exposure, individuals may evaluate the significance of their exposure values within the context of local conditions; (c) By establishing a fixed noise threshold level, "direct and common experience" analogies can be developed to enhance the interpretation of noise analyses at the community level; (d) Analyses may be performed for fragmentary periods, such as "night only," "evening only," or "during school hours only," without loss in meaning in the exposure unit (time) as might be the case with acoustic units (decibels).

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PREFACE

This report presents a description of the "Aircraft Sound Description System," a project of the Office of Environmental Quality under the Directorship of Mr. R. P. Skully. The purpose of the report is to bring together the combined contributions of the entire staff as well as those from within and outside of the Federal Aviation Administration who have helped to crystallize the concept.

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I. INTRODUCTION

The Federal Aviation Administration (FAA) has been involved in a series of continuing efforts to develop a suitable technique by which to describe the contribution of aircraft sound to the environment in the vicinity of airports. The interest of the FAA in this effort has been basic in its search for improvements in the noise climate around airports, as well as in fostering a better general understanding of aviation related noises. The requirement to deal effectively with aviation noise has received substantial reenforcement through the passage of Federal legislation (Public Law 90-411, 1968), which enabled the agency to regulate in the area of aircraft noise (e.g., Federal Aviation Regulations Part 36, "Noise Standards: Aircraft Type Certification"), as well as the requirements for environmental analyses established by the National Environmental Policy Act of 1969 and the Airport and Airway Development Act of 1970. Accordingly, a major need was created for effective methods for dealing with and quantifying aircraft sound. In order to satisfy the need, the quantification effort had to yield an effective technique for assessing the relative merits of (a) technological innovations and developments in aircraft design, (b) alternative procedures in aircraft piloting and navigational procedures, and (c) the major requirement of describing and quantifying the noise climate around an airport resulting from its aviation activities.

The quantification problem has received a considerable amount of attention and has led to the development of noise exposure indices such as "Composite Noise Rating" (CNR)1/ and "Noise Exposure Forecast" (NEF).2/ These have been evaluated by the FAA with the result that certain aspects of the techniques have been identified as requiring improvement. These are: (a) improving the objectivity of the methods used for developing the noise index, (b) improving the understandability of the noise index to lay and technical people, and (c) adding on identification of reasonable boundaries beyond which the reliability of noise analysis would be expected to deteriorate.

In view of this, a new methodology, the "Aircraft Sound Description System" (ASDS), was investigated and found to satisfy the basic objectives. The basic premise of the concept is straightforward; exposure to aircraft noise is described in terms of the total amount of time that sound levels exceed a preselected threshold value. As applied to airport area analyses then, for any desired location, a noise exposure quantity is specified which states the exposure as "X" minutes of total exposure to sound levels in excess of 85 dB(A) (a sound level similar to that emitted by some common home appliances).

Some of the benefits of dealing with noise exposure as structured in the ASDS are immediately apparent. For example, the exposure number provides immediate information to the reader relative to the amount of time the noise

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1/ Bolt, Beranek and Newman, Inc., Land Use Planning Relating to Aircraft Noise, October 1964

2/ William J. Galloway and Dwight E. Bishop, Bolt, Beranek and Newman, Inc., Noise Exposure Forecasts: Evolution, Evaluation, Extensions, and Land Use Interpretations, Report No. FAA-NO-70-9, Prepared for the Department of Transportation, Federal Aviation Administration, August 1970 is "on," a quantity which can be correlated to direct and immediate personal experience. In addition, since the noise level of each event must satisfy at least a minimum predefined threshold level, some conceptual appreciation of the approximate "loudness" being dealt with in exposure analyses is possible. These particular distinguishing features of the Aircraft Sound Description System place environmental noise analysis on a basis which can be comprehended by people of diverse backgrounds within the public, local and Federal Government bodies, as well as management and decision-making personnel in the aviation community. The "comprehension" issue is given considerable importance inasmuch as it is in the public's interest to present information which can affect their quality of life in terms which are most meaningful to them.

The ASDS methodology differs in four substantial ways from the traditional manner of dealing with aircraft noise: it is a noise analysis oriented to using A-weighted sound pressure levels in decibels as used for many transportation and non-transportation noise sources (referred to as dB(A)); it states exposure in units of time; it has been oriented to describe noise in objective terms; and it yields information relative to a specific noise level.

The balance of this report is structured to develop, on an element-by-element basis, the underlying rationale involved in the ASDS exposure statement, "X minutes of exposure to sound levels in excess of 85 dB(A)," as well as the presentation of two hypothetical applications. Accordingly, the sections are as follows:

II. The Need for a Straightforward and Objective System

III. The Selection of Time as the Exposure Measure

IV. The Selection of the Basic Acoustic Unit

V. The Selection of the 85 dB(A) Threshold Level

VI. Analysis of Single-Event Exposure Times

VII. Application

VIII. Summary and Conclusions

In addition to the basic point-by-point exposure analysis which is developed through the application of the ASDS, it was found that an optional, but highly useful, aggregate measure of the overall noise situation, a Situation Index, could also be developed from the same data. The application of the ASDS can certainly be extended, at the option of the user, to cover a variety of other possible indices. However, the Situation Index described in Appendix I of this report offers some useful conceptual benefits.

II. THE NEED FOR A STRAIGHTFORWARD AND OBJECTIVE SYSTEM

By definition, objectivity is "the quality of emphasizing the features and characteristics of the thing dealt with rather than the thoughts, feeling, etc., of the writer or speaker." In structuring the "ASDS," it has been attempted to provide a system which is objective in its description of the noise climate around airports on the premise that only in this way can the multiplicity of viewpoints throughout local communities be accommodated. Further, no criteria are specified for the purpose of advising how much exposure is excessive or appropriate, nor are there any implicit personal criteria embodied in the physical and temporal quantities which form its basis.

A review of previous techniques reveals that, in general, because of an orientation to dealing with annoyance reactions, those techniques contain a logarithmic summation of the individual acoustic events. In many instances, a night or evening weighting factor is applied to account for the opinion that events in those time periods of the day should be weighted more severely than equivalent daytime events. Consistent with the apparent goals of trying to anticipate human response in the calculating procedures, variations have been introduced in the acoustic units used to describe sound levels. The basic acoustic unit on which the different techniques operate varies from simple A-weighted sound pressure level to the very sophisticated "Effective Perceived Noise Level" with each increase in sophistication in the acoustic unit representing additional technical judgments as to how to properly adjust observed physical phenomena to anticipate human reaction.

It is apparent that by the time some of these noise exposure methodologies have been carried their full course to derive a noise exposure quantity, the final numerical value represents an abstract mixture of physical and nonphysical measures lacking intuition-giving characteristics. Commenting on the complexity of some of the noise indices in the literature, Ollerhead,[3/] in a comprehensive survey of past work, came to the conclusion that two separate and distinct requirements for noise indices existed; one for aircraft certification and other legislative purposes in which, regardless of complexity, account is made of all possible subjective effects, and the other, for the more general and more coarsely defined problem associated with airport and local planning in which the more complex procedures offered no advantage to compensate for the inconvenience of numerical complexity.

With respect to the "Noise Exposure Forecast" (NEF) methodology, which typifies current noise exposure indices, the firm of Bolt, Beranek and Newman, Inc.,[4/] has pointed out that:

> It is important to point out that when one wishes to determine the specific noise insulation required for a given work activity, definition of the noise environment in terms of the NEF value alone is insufficient. One must supplement the NEF value by more detailed specification of the magnitude of aircraft noise intrusions. In general, this would begin with determining some single-number description of the noise levels (such as Perceived Noise Level or A-Weighted Sound Level) for the different noise intrusions. This must usually be followed by more detailed descriptions of the noise events, in terms of octave band spectra and signal durations, as well as knowledge

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3/ J. B. Ollerhead, Loughborough University of Technology, Estimating Community Annoyance Due to Airport Noise, February 1972

4/ Bolt, Beranek and Newman, Inc., Evaluation of Aircraft Noise in the Vicinity of Detroit Metropolitan Wayne County Airport, Report No. 2149, June 1971 of the background noise levels and interior noise criteria. These steps follow well-defined noise control procedures.

While BBN points out the limitation of that technique with reference to insulation requirements, logic dictates that NEF or other similar acoustic unit would be equally insufficient when judgments as to the amount of speech interference, sleep interference, school interruptions, or the scaling and comparison of aircraft noise relative to other substantial sources of noise in the community are necessary. One problem is that, in using units such as "NEF decibels," no immediate intuitive perception as to the actual loudness, number of occurrences, or total dosage is possible.

What's more, it seems that the above observations have a good deal of general applicability. An examination of a large variety of noise exposure formulas by experts in the field has pointed up the fact that, despite superficial differences, most of them are similar enough to be essentially interchangeable, making the choice between them difficult,[5/] and that many are conceptually identical for all practical purposes, differing only in minor detail.[6/]

It appears that the result of deviation from a strictly objective description of noise exposure, therefore, has been the development of complex indices which inadvertently lose the ability to convey the essence of the message

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5/ Ollerhead, op. cit.

6/ William J. Galloway, "Review of Aircraft Noise Land Use Planning Procedures," Prepared for the Aerospace Medical Research Laboratory, Aerospace Medical Division, Air Force Systems Command, Wright-Patterson AFB, Ohio, March 1972 to be delivered. Therefore, in order to overcome the interpretational difficulties with the more complex noise exposure measures, it becomes necessary to develop accompanying criteria of observed human reactions against which the measures can be compared and without which the measures are inert. However, in a study by NASA,[7/] in which a variety of complex and simple measures were evaluated, it was found that, despite the variety of noise exposure measures, using any of them exclusively to predict annoyance yielded poor results. It was found, indeed, that good predictions could only be obtained through the inclusion of certain attitudinal and/or psychological variables which are unique to each community. This finding was reenforced in a study conducted recently[8/] of aircraft noise annoyance around London (Heathrow) Airport. That report stated that " . . . although annoyance can in part be explained by the physical exposure to noise, it does not lend itself readily to any predictive situation."

In view of the fact that local social, economic, political, and attitudinal factors strongly influence any opinion about the acceptability of aircraft sounds, it appears that subjective adjustments to measured noise phenomena as well as non-community interpretation of the local noise climate should be minimized. In particular, it seems highly appropriate within the spirit of the environmental analyses requirements of the National Environmental Policy Act of 1969 (Public Law 91-190) and the concern with local community goals

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7/ TRACOR, Inc., Community Reaction to Airport Noise, Volume I, Report No. NASA CR-1761, Prepared for NASA, July 1971

8/ Mil Research Limited, Second Survey of Aircraft Noise Annoyance Around London (Heathrow) Airport, Prepared for Social Survey Division on Behalf of the Department of Trade and Industry, London: Her Majesty's Stationery Office, 1971 and objectives of the Airport and Airway Development Act of 1970 (Public Law 91-258) that the aircraft noise situation be presented in as objective a manner as possible and in a manner which would enhance the ability of the public and other parties at the local level to comprehend the situation. Certainly, if it is reasonable to accept that different communities will have different levels of need with respect to air or surface transportation, urban housing renewal, employment, tax base and revenues, to name a few of a probably infinite list of characteristics that make each community unique, then it should also be reasonable to accept that the motives, incentives, and attitudes at the local level for or against an airport project will thusly reflect the consideration of those important background issues.

III. THE SELECTION OF TIME AS THE EXPOSURE MEASURE

As has been pointed out, the prevailing unit by which to describe exposure to aircraft noise has been the decibel. However, there have been some important instances where time of exposure relative to some reference sound level has received attention. In those instances where it has been used, the experience appears to have been favorable. There is considerable appeal to using "time" as an exposure measure. Ollerhead, in a recent report,[9/] states:

> The intuition that the longer a sound lasts, the more annoying it will be is generally borne out in laboratory experiments and to a smaller extent in survey studies. In the latter case the single variable of duration above a certain fixed level, because of its correlation with peak level, is as good an annoyance predictor as peak level. The total duration (above a fixed level), summed for all flyovers, is in fact as good as the combined index $\bar{L} + K \log N$ (where $\bar{L}$ is the mean noise level; N, the number of events; and K, a preselected constant). Somewhat surprisingly, this fact does not appear to have been recognized by the users of noise exposure indices, even though it would appear to offer the distinct advantage of directly transforming noise exposure to the more useful dimension of time for planning and cost benefit analysis.

The premise that total noise "on time" could be a sufficient descriptor of noise exposure also receives substantial support in its precedent-setting application in its use to specify auditory protection limits. James H. Botsford,[10/] working from a report of the National

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9/ Ollerhead, op. cit., p. 77

10/ James H. Botsford, "Simple Method for Identifying Acceptable Noise Exposures," The Journal of the Acoustical Society of America, Volume 42, Number 4, 1967

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Academy of Sciences-National Research Council Committee on Hearing, Bioacoustics, and Biomechanics (CHABA), developed a simple method for identifying acceptable noise exposures. His method produced a set of suggested criteria pictured as "total on-time per day - in minutes" versus "A-weighted sound level and number of exposure cycles per day." This approach was adopted with some modification[11/] by an Intersociety Committee consisting of representatives of the "American Academy of Occupational Medicine," the "American Academy of Opthalmology and Otolaryngology," the "American Conference of Governmental Industrial Hygienists," the "Industrial Hygiene Association," and the "Industrial Medical Association." Each of the participating organizations approved the approach and the noise exposure guidelines.[12/]

The approach was further reenforced when CHABA used the Intersociety Committee report for a recommended hazard criterion for use in coal mines, as well as when the American Conference of Governmental Industrial Hygienists proposed a further simplification which was adopted by the Department of Labor.[13/] At the present time, the technique for describing noise exposure as "X" minutes of exposure relative to selected noise levels

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11/ Robert A. Boole, "Hearing Damage Risk - Criteria and Their Measurement," Sound and Vibration, November 1972

12/ "Guidelines for Noise Exposure Control," Sound and Vibration, November 1970

13/ Boole, op. cit.

in dB(A) is in use by the Department of Health, Education and Welfare,[14/] Health Services and Mental Health Administration, National Institute for Occupational Health and Safety, for the very critical task of specifying occupational protection standards. Nonoccupational noise exposure has received similar attention with identical methodology in a recent paper by Cohen, Anticaglia, and Jones of the Department of Health, Education and Welfare.[15/]

In the area of aircraft generated noise exposure, the story is somewhat different. Because the energy levels and intermittency of aircraft-produced sound produce little risk to hearing damage in nearby communities,[16/][17/] the focus of attention has been to develop methods (such as CNR and NEF[18/]) dealing with acoustic units (decibels) and annoyance. However, it is evident that simpler measures have not been ignored. Paul N. Borsky,[19/]

14/ U.S. Department of Health, Education, and Welfare, Health Services and Mental Health Administration, National Institute for Occupational Safety and Health, Criteria for a Recommended Standard - Occupational Exposure to Noise, 1972

15/ Alexander Cohen, Joseph Anticaglia, and Herbert H. Jones, "'Sociocusis'--Hearing Loss from Non-Occupational Noise Exposure," Sound and Vibration, November 1970

16/ John E. Parnell and David C. Nagel, Environmental Acoustics; and Alexander Cohen, U.S. Department of Health, Education and Welfare, Evaluation of Hearing Levels of Residents Living Near a Major Airport, Report No. FAA-RD-72-72, Prepared for the Department of Transportation, Federal Aviation Administration, June 1972

17/ Ollerhead, op. cit., pp. 42, 91

18/ Cohen, Anticaglia, and Jones, op. cit.

19/ Paul N. Borsky, National Opinion Research Center, University of Chicago, Community Reactions to Air Force Noise, Part II. Data on Community Studies and Their Interpretation, WADD Technical Report 60-689 (II), March 1961 as reported in 1961, found that if the amount of time that noise levels exceeded certain speech interference levels were used, then this index was the most discriminatory for activity disturbance and annoyance responses. In Borsky's words, "It is further believed that the SIL (Speech Interference Level) series was effective because it measured the amount of time a given noise spectrum was exceeded. The use of other spectra besides the SIL series, as a function of time, may prove to be the key physical variables."

NASA, in a report published in 1971,[20/] found that when determining the relative efficiency of some complex (CNR, NEF, et al) and some simple measures of noise exposure (the simpler measures being the total time in which sound levels exceeded a predetermined speech interference level) that all the exposure measures were well correlated and that the choice of noise exposure measures was not particularly critical if exposure in a community as a whole was being determined as an estimate of annoyance.

In view of the preceding, it appears that not only does describing the noise climate in the vicinity of airports in terms of time of exposure to sound levels in excess of a certain threshold represent a technically adequate methodology but, also, it offers some very substantial advantages over present techniques. In capsule, some of the key advantages are:

1. "Time" is a dimension with immediate intuitive value to audiences of almost any background.

20/ TRACOR, Inc., *op. cit.*

2. "Time" of exposure has a substantial precedent as a tool in evaluating physiological and psychological effects of noise.

3. "Time of exposure" appears to lend itself to calibration against any future annoyance or physical limit scales.

4. "Time of exposure" can create a common scale on which the relative impact of varied noise sources can be evaluated.

5. Analyses using "time of exposure" can be fragmented for any part of the day or night during which noise sensitive activities might exist and produce numerical values with no loss in interpretational power.

6. The analytical problems of accounting for duration during takeoff or landing runs, as well as for ground run-up situations, can be more directly handled by using the exact scale on which duration is measured (time).

7. Direct read-out equipment which can be used for on-site determinations of exposure values on a time base is available in the marketplace. In particular, it has been determined that, with minor modifications, pocket wearable dosimeters[21/] about the size of a pack of cigarettes can be produced and marketed, further adding to the ease with which noise exposure times can be determined.

21/ General Radio Co. Noise Exposure Monitor Type 1944-9002, and Noise Exposure Indicator Type 1944-9003

Accordingly, it was determined that using "time" as the unit of which to state exposure to noise would be technically valid and would offer a substantial improvement in the interpretability of community noise exposure analyses.

IV. THE SELECTION OF THE BASIC ACOUSTIC UNIT

Consistent with the goal of achieving a technically adequate, yet simple and effective, community noise exposure measure, it was stated that "time of exposure to sound levels in excess of a certain threshold level" was found to have substantial advantages. Two questions, however, remain to be addressed to complete the statement. What acoustic unit will be used to establish the threshold levels, and what threshold level will be selected? The latter question will be deferred to the next section.

It is evident from a review of the literature that, by and large, the possibility of physical damage by aircraft noise is very low.[22/23/24/] After an extensive analysis conducted by the Department of Health, Education and Welfare,[25/] they determined that it was difficult to state anything definitive about the dose-response relationships between noise and the occurrence of physical and physiological disturbances. In particular, they point out that " . . . the human ear, owing to its sensitivity to acoustic energy, is most vulnerable to damage from over-exposure to sound. Other bodily functions, less sensitive to sound stimuli, would not appear as prone to noise-induced alterations or damage." It is reasonable to see, then, that the principal concern with aircraft noise has been in the question of how it relates to annoyance.

22/ Ollerhead, _op. cit._, p. 44

23/ Parnell, Nagel, and Cohen, _op. cit._

24/ Cohen, Anticaglia, and Jones, _op. cit._

25/ U.S. Department of Health, Education and Welfare, _op. cit._

In order to deal with annoyance then, a wide variety of measures have been developed which, operating on the octave band frequency, energy content, and time history of a noise, develop noise level numbers which try to adjust the measured sound levels from a physical sense to what might be interpreted in psychological sense. For example, if a sound contains discrete tones, unusual frequency spectra, or other objectionable characteristics, then the purely physical quantities associated with the energy of the noise are adjusted by either an electronic weighting network or by a calculating procedure to reflect such characteristics. This would compensate for the fact that certain sounds might, on a strictly physical sense, represent equivalent energy, but might be interpreted differently by a listener. (For a more elaborate discussion of the various noise indices, the reader is referred to any of many references on the subject.[26/]) The most recently adopted acoustic unit[27/] for aircraft certification purposes is the unit of "Effective Perceived Noise Decibels" (EPNdB). This unit is derived from the time history of a complete aircraft flyover and it compensates for the frequency distribution and sound pressure levels, as well as for maximum tones and duration. It is a relatively complex quantity which requires a substantial amount of calculating effort, normally done by computer, and represents a noise quantity "after the fact." Consequently, an event cannot be characterized in units of EPNdB until the event is complete.

26/ For example, U.S. Environmental Protection Agency, Fundamentals of Noise: Measurement, Rating Schemes, and Standards, 31 December 1971

27/ The United States in Federal Aviation Regulations Part 36, entitled "Noise Standards: Aircraft Type Certification," and the International Civil Aviation Organization (ICAO) in Doc. 8857, Noise (1969), Report of the Special Meeting on Aircraft Noise in the Vicinity of Aerodromes

In contrast, there are much simpler procedures in which the instantaneous sound pressure levels at different frequencies are adjusted to compensate for the sensitivity of the human ear and then summed to yield a single number. If this latter procedure is used, the monitoring and measurement task lends itself to small hand-held instruments with needle/gauge indicators which are commonly available.

Inasmuch as one of the key underlying motives of the ASDS was to utilize a technically adequate yet practical methodology, the choice of using noise level as determined by the instantaneous sound pressure levels in decibels weighted in accordance with an "A" weighting network[28/] (referred to in units of dB(A)) was examined. A review[29/] of the precedents supporting the use of this acoustic unit for the purposes of community noise exposure studies, as well as other relevant investigations[30/] and practical considerations, pointed up significant advantages of structuring the ASDS in relation to it. In capsule, some of the essential advantages of selecting decibels on the "A" scale as the acoustic unit are as follows:

28/ IEC Recommendation, Publication 179, "Precision Sound Level Meters," 1965

29/ Richard C. Crewdson, Industrial Noise Services, Inc., "Use of the L_A Scale for Measuring and Evaluating Airport Noise," Prepared for the Department of Transportation, Federal Aviation Administration, January 1973

30/ Serendipity, Inc., Eastern Operations Division, A Study of the Magnitude of Transportation Noise Generation and Potential Abatement, Report No. OST-ONA-71-1, Prepared for the Department of Transportation, November 1970

1. Readings in dB(A) refer to an instantaneous noise level which exists at a point in time and is not complicated, a priori, by the addition of subjective adjustments.

2. Readings in dB(A) in general correlate statistically within a predictable range of a corresponding reading in EPNdB[31/][32/] for the same noise event and, hence, usually one is the approximate equivalent of the other (give or take a constant), thereby making the simpler measure an adequate and immediate proxy for the complex measure.[33/]

3. A massive amount of non-aviation noise data[34/] (transportation and other sources) has been accumulated in terms of dB(A) and, hence, aircraft noise exposures, if stated relative to dB(A), can be placed in perspective with other sources of community noise.

4. dB(A) serves as the basis for establishing statutory noise limits for occupational situations[35/] and for suggested limits for non-occupational situations.[36/]

31/ TRACOR, Inc., *op. cit.*

32/ Ollerhead, *op. cit.*

33/ Crewdson, *op. cit.*

34/ For example, see *Report to the President and Congress on Noise*, Report of the Administrator of the Environmental Protection Agency, Senate Document No. 92-63, February 1972

35/ U.S. Department of Health, Education and Welfare, *op. cit.*

36/ Cohen, Anticaglia, and Jones, *op. cit.*

5. Acoustic instruments capable of measuring noise levels in dB(A) are commonly available, as well as portable statistical units which provide exposure[37] times above selectable noise levels.

6. dB(A) appears to be as effective as more complex units[38][39][40][41][42] in dealing with community response prediction situations.

7. The use of the "A" scale appears to be gaining more widespread use for community noise exposure measurements domestically[43] and internationally.[44]

In view of the preceding advantages as well as the substantial body of supporting opinion in the referenced literature, it was decided to select A-weighted sound pressure level as the acoustic unit for applications of the "Aircraft Sound Description System." ASDS exposure statements will then read as "X" total minutes of exposure to sound levels in excess of 85 dB(A).

37/ For example, Bruel & Kjaer Instruments, Inc., and General Radio Co.

38/ Crewdson, *op. cit.*

39/ TRACOR, Inc., *op. cit.*

40/ Ollerhead, *op. cit.*

41/ Serendipity, Inc., Eastern Operations Division, *op. cit.*

42/ R. Rylander, S. Sorensen and A. Kajland, "Annoyance Reactions from Aircraft Noise Exposure," *Journal of Sound and Vibration* (1972)

43/ For example, California

44/ Germany, Netherlands, and South Africa

V. SELECTION OF THE 85 dB(A) THRESHOLD LEVEL

It has thus far been stated that the ASDS, when applied, will yield noise exposure in terms of "X" minutes of total exposure to noise levels in excess of 85 dB(A). While the ASDS concept can be applied to provide exposure statements relative to any threshold value, and as the computer orientation of the concept advances, such will be the case, there are important technical and practical constraints in the selection of a lower bound for predicting noise levels.

The noise level on the surface resulting from the flight of an aircraft through a variable atmosphere is dependent on a complex set of variables. Those variables can operate independently or in conjunction with each other to confound any attempt to predict noise levels at preselected points on the surface. It is not unusual to find that, during actual airport operations, flights presumably operating under similar conditions create vastly different noise levels on the surface. Variations of ±10 decibels around a mean value are not unusual. Some of the factors that help explain the variability are as follows:

1. Aircraft navigational tracks become very variable as distances from the airport increase because of the effects of wind, collision avoidance procedures, and differences in the locations of flight origins for incoming flights and destinations for outbound flights. Variability in the aircraft navigational track directly affects the distance between the noise source and any preselected point on the surface and, hence, the noise level at that point.

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2. Aircraft altitude profiles are highly variable due to the sensitivity to aircraft weight, configuration (high lift device settings and/or landing gear position), piloting precision, wind, temperature, and collision avoidance procedures. As in 1. above, this directly affects the distance between the noise source and any preselected point on the surface and thereby the noise level at that point.

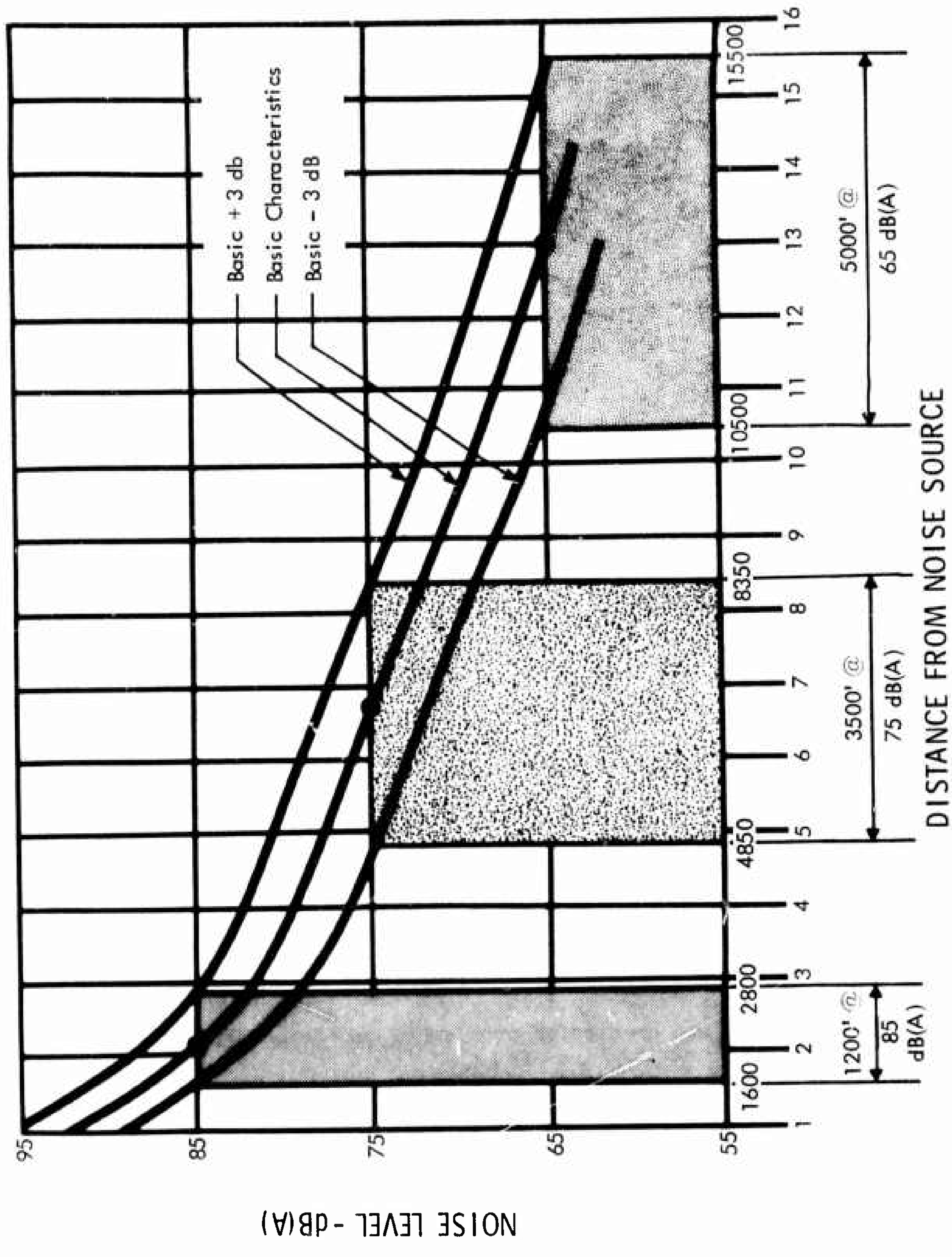
3. The propagation of sound and the eventual sound level on the surface is affected by atmospheric thermal gradients, and wind shear;[45/] variability in the normal ambient conditions (varying combinations of temperature and humidity); as well as the physical and acoustic characteristics of the particular listening point (for example, terrain, structures, and other reflecting or interfering surfaces).

An example of the effects of even small acoustic errors in the location of a particular sound level can be seen graphically in Figure 1. That figure displays the noise characteristics of a common 3-engine turbofan transport aircraft at takeoff power. It also contains a hypothesized $\pm$3 decibel band so that, when reading the distance necessary to detect a particular noise level, a nominal range of variability in that distance can also be seen. For example, it is evident that even if errors could be contained within a $\pm$3 decibel band, it can still result in a 1200 foot range error at 85 dB(A), 3500 feet at 75 dB(A), and 5000 feet at 65 dB(A).

45/ C. Michael Hogan and H. Seidman, Environmental Systems Laboratory, Inc., Refraction of Aircraft Sound Due to Vertical Meteorological Inhomogeneity, 15 February 1972

Reference to Figure 1 will also help to appreciate two other significant characteristics which can contribute to potential errors and variability in a "real life" environment. These are: (1) the altitude of the noise source relative to the receiver, and (2) the distances of the noise source from the point of departure or arrival. On the first point, Figure 1 can be read to indicate that, in order to detect an 85 dB(A) level, the distance between the source and the receiver at the closest proximity of the flight path must be in the order of 2100 feet. At 75 dB(A) this distance becomes about 6700 feet, and at 65 dB(A) it becomes about 13,000 feet. Inasmuch as these distances can also correspond to the altitude over the listener for the particular noise levels, attempts to predict noise levels when the aircraft is at high altitude may be hampered by on-site phenomena such as vertically stratified thermal gradients and wind shear[46/] (random factors which are very site and time specific). Further, the magnitude of such altitudes results in the traversing by arriving or departing aircraft of altitude boundaries established for the orderly control of air traffic. Because of the differences between en route air traffic control and terminal area air traffic control, it is not possible to reliably generalize the sequencing and entry or exit points of arriving and departing air traffic. The flight path prediction problem is certainly made even more difficult to generalize if the effects of weather, prevailing winds, runway usage, airborne traffic distribution, and aircraft performance variations are also taken into consideration.

46/ Ibid.



Basic + 3 db
Basic Characteristics
Basic - 3 dB
1200' @ 85 dB(A)
3500' @ 75 dB(A)
5000' @ 65 dB(A)
1600
2800
4850
8350
10500
15500
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
95 85 75 65 55
DISTANCE FROM NOISE SOURCE
NOISE LEVEL - dB(A)

Figure 1

On the second point, the distance from the point of departure at which specific altitudes would be reached, must also be considered. This becomes highly relevant inasmuch as with increasing distances from a controlled airspace environment, the greater the effect of air traffic conflicts with randomly participating flights and, hence, the greater the possibility of erroneous navigational path predictions. In order to assess the general magnitude of the distance problem, a review was made of the performance characteristics of a common 3-engine narrow body turbofan aircraft. That data indicated that at a climb gradient of approximately 10 percent (realistic at typical operating gross weights), the distances from the departure points at which sound levels of 85, 75, and 65 dB(A) occur can be as great as 4, 12.7, and 24.6 statute miles respectively. Based on Federal Aviation Regulations, it becomes evident that the distances at which sound levels below 85 dB(A) occur can be well beyond airport traffic areas[47/48/] and, therefore, in situations where the random influence of aircraft not conducting landings or departures can be expected. Clearly, not only is the prediction of noise levels on the ground exceedingly difficult, but also, the difficulty increases with lower noise levels and the attendant increase in aircraft altitudes and distances from the airport.

47/ Federal Aviation Regulations Part 1 - "Airport Traffic Area" - " . . . that airspace within a horizontal radius of 5 statute miles from the geographical center of any airport at which a control tower is operating, extending from the surface up to, but not including, an altitude of 3,000 feet above the elevation of the airport."

48/ Federal Aviation Regulations Part 91.85(b) - "Unless otherwise authorized or required by ATC (Air Traffic Control), no person may operate an aircraft within an airport traffic area except for the purpose of landing at, or taking off from, an airport within that area . . . ."

Faced with a desire to select a reasonable, yet similar, threshold noise level for all aircraft, it was decided to deal initially with the constraints of (a) presently established airport traffic areas, and (b) the acoustic and performance characteristics of a typical 4-engine turbofan transport of the variety in common use (Boeing 707 or McDonnell Douglas DC-8) which, to a large extent, is representative of the class of aircraft contributing greatly to noise exposure in airport-affected communities. On this basis, existing technical data[49/] indicated that, under reasonable operating conditions, an 85 dB(A) noise level corresponded approximately with both the altitude and the lateral boundaries of airport traffic areas. A review of existing precedents and potential applications of this bench mark reenforced its reasonableness and usefulness. For example:

1. 85 dB(A) represents the lower bound of monitoring for the recommended occupational safety and health criteria as determined by the Department of Health, Education and Welfare.[50/]

2. With a nominal 15-20 dB(A)[51/] acoustic benefit from housing structures, an indoor awakening threshold level of 70-75 db(A)[52/] should not be exceeded for those areas where noise levels do not reach 85 dB(A).

49/ Carole S. Tanner, Hydrospace Research Corporation, Measurement and Analysis of Noise from Four Aircraft During Approach and Departure Operations (727, KC-135, 707-320B, and DC-9), (707-320B, takeoff T3), Report No. FAA-RD-71-84, Prepared for the Department of Transportation, Federal Aviation Administration, September 1971

50/ U.S. Department of Health, Education and Welfare, op. cit.

51/ Parnell, Nagel and Cohen, op. cit.

52/ Milton Kramer, Thomas Roth, and John Trindar, University of Cincinnati and Veterans Administration Hospital; and Alexander Cohen, U.S. Department of Health, Education, and Welfare, Noise Disturbance and Sleep, Report No. FAA-NO-70-16, Prepared for the Department of Transportation, Federal Aviation Administration, January 1971

3. With a nominal 15-20 dB(A) acoustic benefit from housing structure, indoor speech interference levels (approximately 65 dB on the A-scale at a separation in excess of 8 feet - communicating voices[53/][54/]) should not generally be exceeded for areas where the outdoor noise level does not reach 85 dB(A).

4. With a nominal 15-20 dB(A) acoustic benefit from housing structure, an outdoor noise level of 85 dB(A) should attenuate to an indoor level in the range of that generated by "Quiet Equipment and Small Appliances,"[55/] such as electric can openers, faucets, or electric knives, thereby providing a useful intuitive approximation of the levels discussed in noise analyses. Similar direct and common experience analogies can be developed for outdoor exposure levels which, taken together, should enhance the interpretation of noise analyses at the community level.

5. 85 dB(A) approximates the threshold between judgments of acceptability and noisiness for intermittent single-event noises found in previous studies.[56/]

In view of the above, it was determined that 85 dB(A) would represent a highly useful noise level boundary for aircraft noise analyses in addition

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53/ U.S. Environmental Protection Agency, Fundamentals of Noise: Measurement, Rating Schemes, and Standards, 31 December 1971, p. 29

54/ Report to the President and Congress on Noise, op. cit., p. 1-13

55/ Ibid., p. 2-124

56/ Ibid., p. 2-20

to the highly significant attribute of establishing a boundary beyond which the reliability of noise analyses would be expected to suffer in quality.

VI. ANALYSIS OF SINGLE-EVENT EXPOSURE TIMES

Having established that ASDS exposure statements would be in terms of "total time" of exposure above a threshold value of 85 dB(A), it became necessary to examine the characteristics of the individual single-event exposure times, the sum of which represents the total exposure situation. In order to determine the characteristics of the single event, it is necessary to examine the time history of the noise level at a selected point on the surface as it would be affected by noise level at the source, the distance between the source and receiver at their closest proximity, the directivity characteristics of the noise source, and the speed of the noise source. A review of some common ways in which noise time histories have been documented, however, revealed that by and large they provided limited technical information about the source noise characteristics, distances, or speeds from which generalized procedures could be derived. More so, they were concerned with the events in a manner so as to describe what happened rather than why or how. One alternative, to initiate a program to acquire a full statistical data base, was determined to be a prohibitive task in testing, data acquisition, processing, and analysis, with a substantial possibility of failure given the vagaries of acoustic measurement.

In view of the above, it was concluded that the most effective interim process would be to develop a simplified approximating equation by which to determine the exposure times for a variety of exceedances over 85 dB(A). The following equation in which the assumption of a uniform directional pattern was made (expected to yield values higher than if directivity were accounted for based on a comparison with calculated data[57/] and observed data[58/] for noise level time histories truncated 10 dB and 15 dB below their peak respectively) was derived.[59/]

$$T_i = 2D \frac{(1 - 10^{2K})^{\frac{1}{2}}}{V} \quad \text{where } K = \frac{85 - i}{26.6}$$

T_i = The amount of time the noise level is above 85 dB(A) with a peak at i

D = Source to listener distance corresponding to 85 dB(A) - Feet

i = Peak noise level at listener - dB(A)

V = Aircraft speed at flyby - Feet/second

57/ Bolt, Beranek and Newman, Inc., Analysis of Community and Airport Relationships/Noise Abatement, Report No. RD-65-130, Prepared for Federal Aviation Agency, December 1965

58/ Michael H. L. Hecker and Karl D. Kryter, Stanford Research Institute, Comparisons Between Subjective Ratings of Aircraft Noise and Various Objective Measures, Report No. FAA-NO-68-33, Prepared for Department of Transportation, Federal Aviation Administration, April 1968

59/ Derivation

If:

D = Distance required to detect 85 dB(A)
H = Point of closest approach
i = Peak noise level when aircraft is at "H"
t = Total flyover time for sound levels in excess of 85 dB(A)
V = Aircraft speed
S = Distance traveled by aircraft from first detection of 85 dB(A) to the observer's overhead position

Then:

1. $t = \frac{2\ S}{V}$
2. $S = (D^2 - H^2)^{\frac{1}{2}}$
3. $i = 85 - 26.6 \log_{10} \frac{H}{D}$ (i at any point based on an 8 dB per doubling attenuation rate)
4. (From 3) $H = D\ 10^K$ where $K = \frac{85 - i}{26.6}$
5. (2 and 4) $S = D\ (1 - 10^{2\ K})^{\frac{1}{2}}$
6. (1 and 5) $t = \frac{2\ D}{V}\ (1 - 10^{2\ K})^{\frac{1}{2}}$

When this equation is applied to determine the exposure time corresponding to a variety of noise levels in excess of 85 dB(A), the relationship shown in Figure 2 is developed. It is interesting to note the rapidity with which the exposure time rises in the 0 to 10 dB range and the slow asymptotic approach to (2 D/V) for values greater than 10 dB.

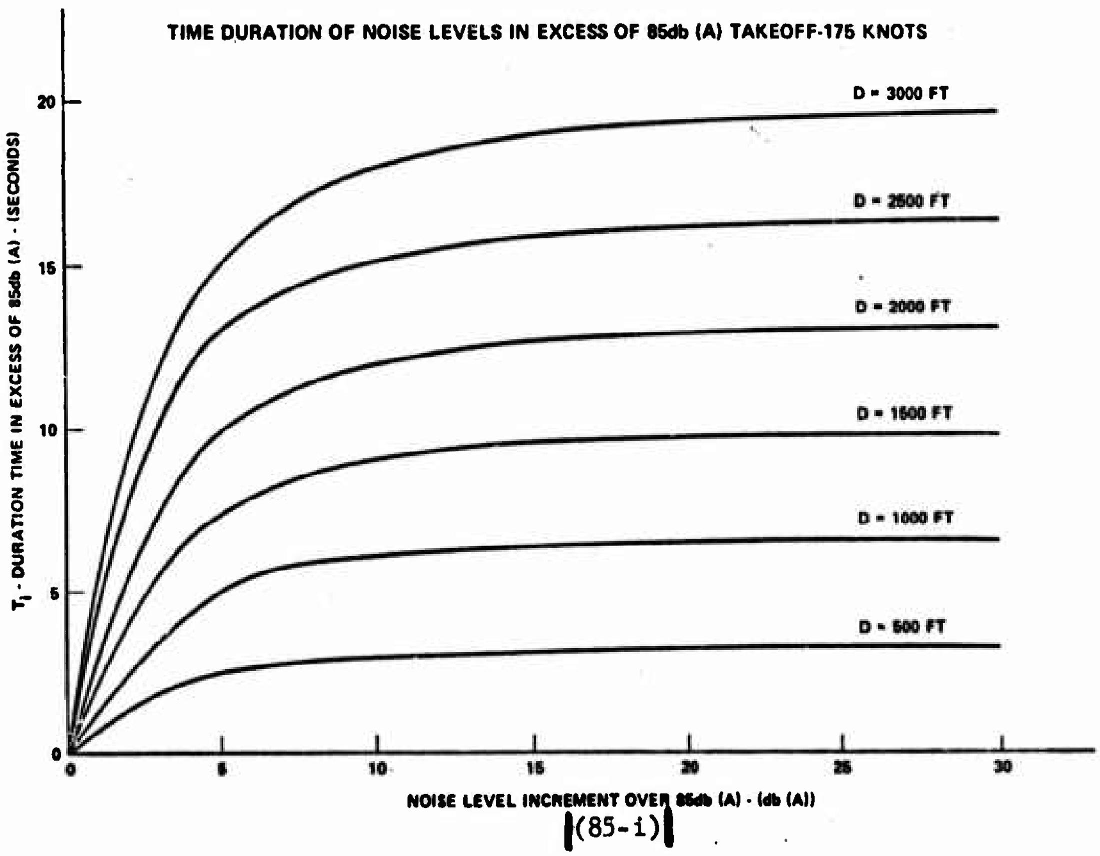


FIGURE 2

Inasmuch as 75 percent or more[60/] of the single-event analysis area is estimated to be in the 85-95 dB(A) zone within which the exposure time

60/ Based on a typical attenuation rate of 8 dB per doubling or halving of distance to the noise source.

values change rapidly, it is evident that a point-by-point, event-by-event exposure analysis would be highly desirable. However, it was determined that for ease of analysis it would also be desirable if a single time constant could be applied across the entire area affected by sounds in excess of 85 dB(A). This "time constant" technique would allow manual application, manual cross-check capability for selected points, and would be reasonable provided certain conditions could be satisfied. These conditions were: (a) the time constant would be sufficiently high so as to not significantly undercount the amount of exposure in inhabited areas around airports, (b) that if no apparent problem with noise exposure emerged as a result of this conservative approach, it would be reasonable to assume that finer detail in the analysis was not needed, and (c) if apparent exposure problems were signaled by this type of application, that a more refined time history analysis would then be warranted. In short, the application of the analysis could be performed at a "signaling level" based on which it would be possible to determine if additional analytical effort was needed.

On this basis then, it was decided to determine for each "D" condition a single time constant, T_c, to be derived as the weighted sum of the exposure times within the areas experiencing 85 dB(A) or higher. The weighting factor selected was the ratio of the area within approximately 1 decibel of the peak noise level to the total area experiencing 85 dB(A) or higher; in essence, an approximation of the median single-event exposure time value throughout the area exposed to 85 dB(A) or higher.

$$T_c = \sum_{i=86}^{115} T_i \left[\frac{A_{(i-1)} - A_i}{A_{85}} \right]$$

A_i = Area contained within range of noise level i 61/

The application of the preceding equation to the range of flyby conditions and noise level conditions described earlier, and using "D" values and speeds representative of the typical fleet of aircraft in airline service today yielded the following results.

Takeoff - 175 Knots		
Aircraft	D (Feet)	T_c (Seconds)
707/DC-8	3100	14.8
727	2100	10.0
DC-10/L-1011	1300	6.2
DC-9/737	1800	8.6
747-200	1600	7.6

Landing - 140 Knots		
Aircraft	D (Feet)	T_c (Seconds)
707/DC-8	1660	9.9
727	960	5.7
DC-10/L-1011	700	4.2
DC-9/737	870	5.2
747-200	700	4.2

As can be seen then, for each aircraft listed a single time constant can be selected to characterize the exposure due to each event. However, it can also be seen that a time constant of 15 seconds for takeoff events and 10 seconds for landing events, if applied across the board to all events regardless of aircraft type, would be sufficiently conservative to result in an overcount of exposure in all situations with the exception of a slight "apparent" undercount in the innermost 50 percent 62/ of area for B-707/DC-8

61/ Since the weighting factor diminishes rapidly at higher sound levels, the summation was terminated at 115 dB.

62/ Based on a typical 8 dB per doubling attenuation rate type aircraft. However, this condition would only be theoretical inasmuch as with any utilization of other aircraft types, as will certainly be the case in a real airport situation, there will be compensating overcounts due to the "time constant" approach, as well as the assumption of a uniform noise directional pattern.

In summary, then, the adoption of a time constant of 15 seconds for takeoff events and 10 seconds for landing events appears to be a useful and practical operating rule for application of the ASDS concept at a "signaling level." It is obvious, however, that inasmuch as the basic premise of the "ASDS" concept is to state noise exposure in terms of the total amount of time that sound levels exceed a threshold value, applications of this concept need not be limited to a "time constant" operating rule. In fact, to reiterate somewhat, the ideal application would be one in which the actual noise level time history would be accounted for in each event. This latter approach is in fact the goal of present development efforts. However, in the interim, should additional detail be necessary in "ASDS" analyses, for example in situations where the application of the "time constant" rule signals potential exposure problems in selected areas of the community, additional detail can be obtained through the use of the tabulated time constants for each individual aircraft type or, preferably, through the solution of the exposure time equation on an aircraft-by-aircraft basis for the point in question.

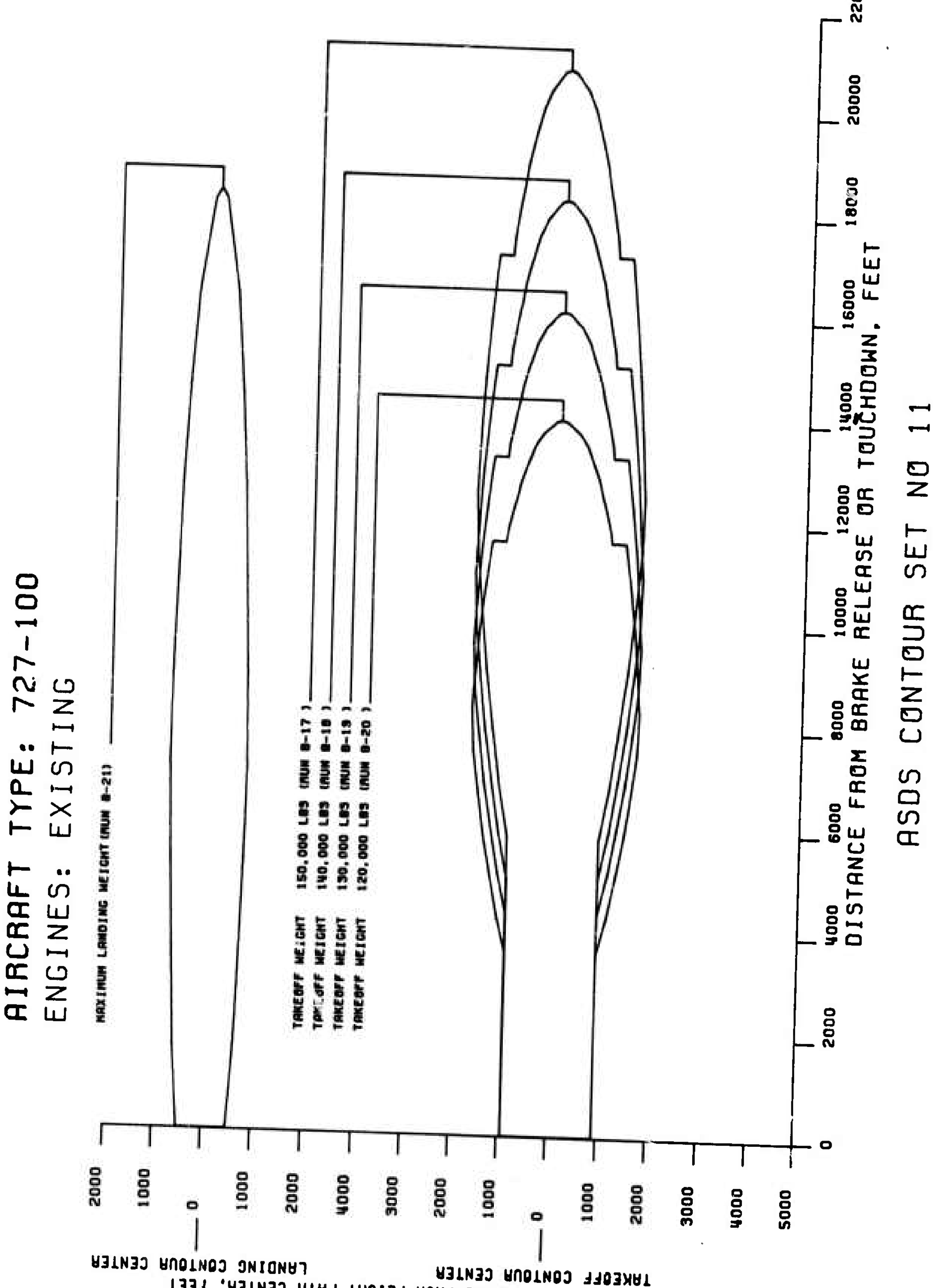
type aircraft. However, this condition would only be theoretical inasmuch as with any utilization of other aircraft types, as will certainly be the case in a real airport situation, there will be compensating overcounts due to the "time constant" approach, as well as the assumption of a uniform noise directional pattern.

In summary, then, the adoption of a time constant of 15 seconds for takeoff events and 10 seconds for landing events appears to be a useful and practical operating rule for application of the ASDS concept at a "signaling level." It is obvious, however, that inasmuch as the basic premise of the "ASDS" concept is to state noise exposure in terms of the total amount of time that sound levels exceed a threshold value, applications of this concept need not be limited to a "time constant" operating rule. In fact, to reiterate somewhat, the ideal application would be one in which the actual noise level time history would be accounted for in each event. This latter approach is in fact the goal of present development efforts. However, in the interim, should additional detail be necessary in "ASDS" analyses, for example in situations where the application of the "time constant" rule signals potential exposure problems in selected areas of the community, additional detail can be obtained through the use of the tabulated time constants for each individual aircraft type or, preferably, through the solution of the exposure time equation on an aircraft-by-aircraft basis for the point in question.

VII. APPLICATION

As has been stated earlier, a conservative application of the ASDS can be carried out by the use of a time constant to represent the noise "on-time" for each event. The time constant selected was 15 seconds for takeoff events and 10 seconds for landing events. If this approach is taken, the application can be very straightforward. All that is required is that the area receiving 85 dB(A) or higher for each aircraft event be identified on a map, and that for selected points (as many as desired), all events affecting it be multiplied by the appropriate time constant and then the results summed. The value for each point will then be a conservative estimate of the total amount of time that sound levels will be in excess of 85 dB(A).

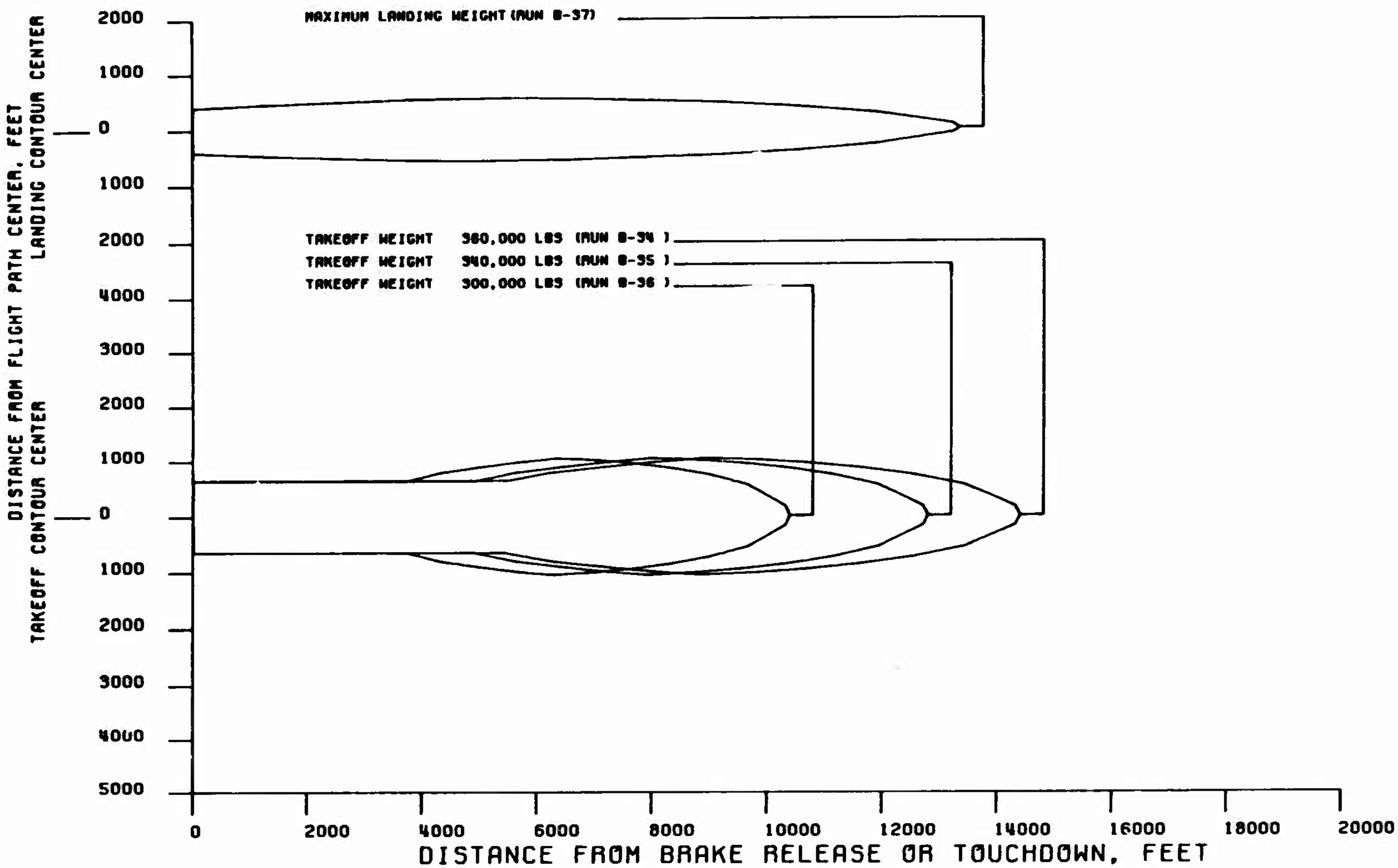
While the procedure is straightforward and amenable to manual application for airport configurations consisting of single runways and minor variations in aircraft types and flight paths, for more complex situations computer-aided techniques can substantially ease the analysis. At the present time, for the examples to follow in this report, three separate computer programs were used. One program was used to develop aircraft sound contours defining the areas on the ground plane estimated to receive 85 dB(A) or higher for each type of aircraft flight and operating condition (for example, as depicted in Figures 3 and 4). Two additional supporting computer programs were developed by outside contractors in cooperation with the FAA for



AIRCRAFT TYPE: 727-100
ENGINES: EXISTING
MAXIMUM LANDING WEIGHT (RUN 8-21)
TAKEOFF WEIGHT 150,000 LBS (RUN 8-17)
TAKEOFF WEIGHT 140,000 LBS (RUN 8-18)
TAKEOFF WEIGHT 130,000 LBS (RUN 8-19)
TAKEOFF WEIGHT 120,000 LBS (RUN 8-20)
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
20000
22000
DISTANCE FROM BRAKE RELEASE OR TOUCHDOWN, FEET
ASDS CONTOUR SET NO 11
2000
1000
0
1000
2000
4000
3000
2000
1000
0
1000
2000
3000
4000
5000
LANDING CONTOUR CENTER
TAKEOFF CONTOUR CENTER
DISTANCE FROM FLIGHT PATH CENTER, FEET

FIGURE 3

AIRCRAFT TYPE: L-1011
ENGINES: EXISTING



ASDS CONTOUR SET NO 24

FIGURE 4

the purpose of relating all contours to any specific airport and flight track geometry situation. These latter programs performed the total areal analysis by cumulating the individual exposure events on a point-by-point basis. Each of the two programs was designed to accept the sound contour coordinate information, as well as the enumeration of aircraft events by aircraft type, type of operation (takeoff/landing), runway usage (for multiple runway airports), navigational pattern (ground track), and frequency of usage of each runway. The principal distinction between the two programs lies in the type of display for the final data. One program[63/] provides a tabular printout in which the total exposure time is presented in numeric form for each 500 feet by 500 feet block in the analysis area. This type of display, when adjusted to an appropriate map scale, permits the direct comparison of an ongoing or projected land use activity to the amount of exposure time anticipated. The other program[64/] applies computer graphics techniques so that all areas exposed to a preselected range of exposure times (e.g., 0-5 minutes, 5-10 minutes, 10-15 minutes, etc.) are bounded within specially shaded zones. This technique permits a rapid evaluation of the detailed exposure map by reducing the large number of discrete exposure presentations to several zones of reasonably similar exposure.

Before proceeding with a description of the two types of "end products" obtainable with the two programs mentioned above, it will be useful, to help

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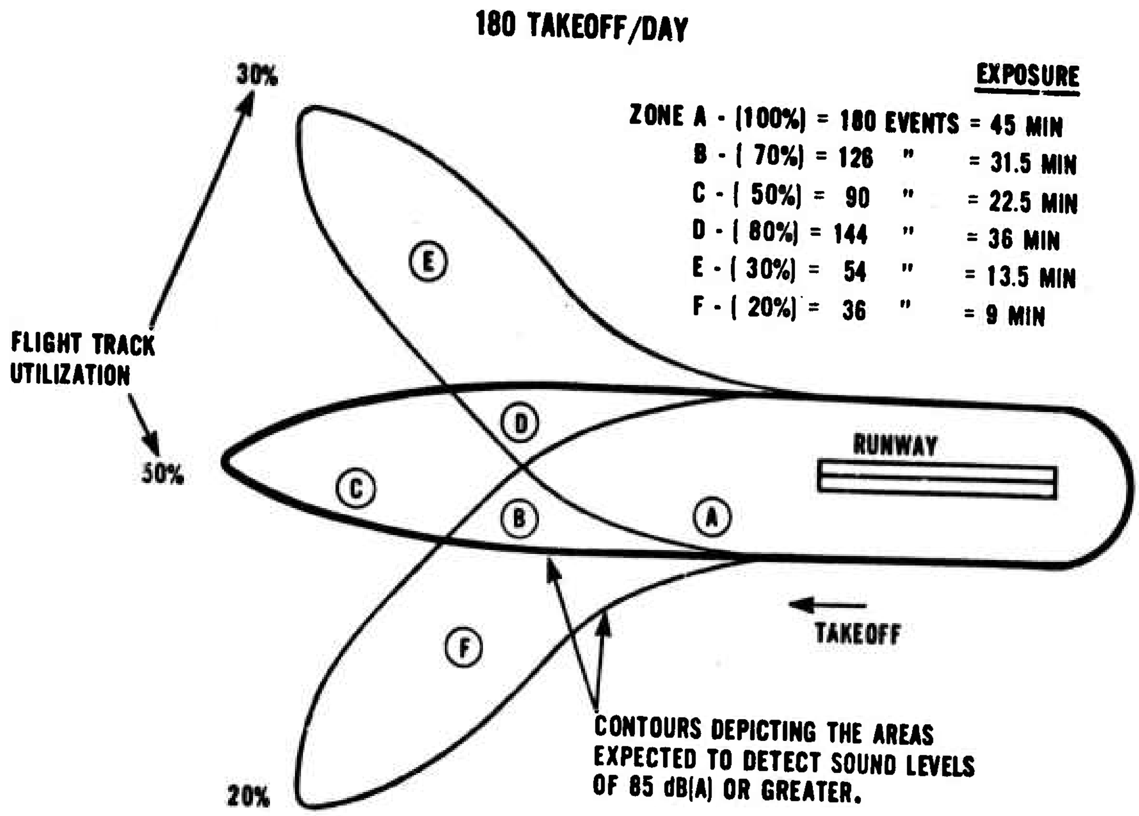
63/ The Mitre Corporation, McLean, Virginia

64/ Automation Industries, Inc., Vitro Laboratories Division, Silver Spring, Maryland establish the ASDS approach in the mind of the reader, to step through a simplified hypothetical example. (Appendix II provides a more elaborate outline of manual procedures.)



The above illustration shows a takeoff exposure analysis for a single runway airport with one aircraft type using three different headings in leaving the airport area. The first step was to depict the contours showing the areas expected to detect 85 dB(A) or greater. This involved the transferring of contour coordinate information for the particular aircraft type and expected gross weight and operating conditions (available from a contour coordinate data base or graphical representations as shown in Figures 3 and 4) to a map utilizing the expected flight tracks as guides. This step, upon completion, clearly illustrates areas or zones which experience different levels of exposure by virtue of the different flight tracks. Six areas are evident in the above example which, based on the respective frequency of use of each flight track, can be classified as six different exposure zones. The tabular data illustrates the straightforward application of the utilization rates to the total member events which, based on a 15 second time constant per event, converts readily to the exposure values shown on the right-hand side. This, in essence, constitutes the type of exposure display which can be generated by the application of the ASDS. However, it is recognized that there will be a significant number of situations where a manual approach will be impossible due to the sheer variety of aircraft types, operating conditions, flight tracks, number of runways, et al. It is in this latter context that the two supporting computer programs described earlier have their greatest benefit.

An example of the display generated by the first of the supporting computer programs is shown in Figure 5. Reference to that figure will show, by column heading, the run type (the identifier of the X-Y coordinate table for the particular event), number of events of that type, the turn-point at which a new navigational heading was taken, the new heading based on a master airport compass orientation, the mode of the operation (takeoff or landing), the aircraft type, the area exposed to 85 dB(A) or higher for each event in acres, and the acreage multiplied by the total number of flights. (This latter figure is used to obtain a "Situation Index," SI, described in Appendix I of this report.)

NORTH GP-RUNWAY 1L

SCALE—EACH BLOCK REPRESENTS AN AREA 500 FEET X 500 FEET

TRAFFIC CROSS-REF.

RUN TYPE	NUMBER	TURNPOINT	ANGLE	MODE	PLANE TYPE	ACREAGE(1 FLIGHT)	ACREAGE(TOTAL FLIGHTS)
B-25	5	27500	100	TAKEOFF	707-320B-22	1721.763	8608.813
B-48	1	27500	100	TAKEOFF	DC-8-60-24K	2020.202	2020.202
B-30	1	27500	100	TAKEOFF	DC-10-340K	401.745	401.745
B-29	1	27500	100	TAKEOFF	DC-10-360K	459.137	459.137
B-18	2	27500	100	TAKEOFF	727-100-14K	975.666	1951.331
B-17	1	27500	100	TAKEOFF	727-100-15K	1113.407	1113.407
B-14	1	27500	100	TAKEOFF	727-200-15K	1021.579	1021.579
B-1	2	27500	100	TAKEOFF	DC-9-10-80K	619.834	1239.669
B-2	2	27500	100	TAKEOFF	DC-9-10-91K	780.532	1561.065
B-8	1	27500	100	TAKEOFF	737-90K	642.792	642.792
B-40	4	27500	10	TAKEOFF	747-100-56K	2387.511	9550.043
B-25	4	27500	10	TAKEOFF	707-320B-22	1721.763	6887.051
B-48	1	27500	10	TAKEOFF	DC-8-60-24K	2020.202	2020.202
B-30	1	27500	10	TAKEOFF	DC-10-340K	401.745	401.745
B-18	1	27500	10	TAKEOFF	727-100-14K	975.666	975.666
B-17	2	27500	10	TAKEOFF	727-100-15K	1113.407	2226.813
B-14	1	27500	10	TAKEOFF	727-200-15K	1021.579	1021.579
B-1	1	27500	10	TAKEOFF	DC-9-10-80K	619.834	619.834
B-2	1	27500	10	TAKEOFF	DC-9-10-91K	780.532	780.532

TOTAL NUMBER OF ACRE-MINUTES= 10875.7813ACRE-MIN.

TOTAL NUMBER OF OPERATIONS= 33

*-RUNWAY CENTERLINE

6000	5500	5000	4500	4000	3500	3000	2500	2000	1500	1000	500	500	1000	1500	2000	2500	3000	3500	4000	4500	5000	5500	6000
									165	450	495	495	450	165									
									165	450	495	495	450	165									
									165	450	495	495	450	165									
									165	450	455	495	450	165									
									165	450	495	495	450	165									
									165	450	495	495	450	165									
									165	450	495	495	450	165									
									165	450	495	495	450	165									
									165	450	495	495	450	165									
									180	480	495	495	480	180									
								135	285	495	495	495	495	285	135								
								135	360	495	495	495	495	360	135								
								135	360	495	495	495	495	360	135								
								165	450	495	495	495	495	450	165								
								225	450	495	495	495	495	450	225								
							135	225	450	495	495	495	495	450	225	135							

		165	450	495	495	450	165		
		180	480	495	495	480	180		
	135	285	495	495	495	495	285	135	
	135	360	495	495	495	495	360	135	
	135	360	495	495	495	495	360	135	
	165	450	495	495	495	495	450	165	
	225	450	495	495	495	495	450	225	
135	225	450	495	495	495	495	450	225	135
135	225	450	495	495	495	495	450	225	135
135	225	450	495	495	495	495	450	225	135
165	225	450	495	495	495	495	450	225	165
165	225	390	495	495	495	495	390	225	165
165	225	390	495	495	495	495	390	225	165
165	225	390	465	495	495	465	390	225	165
225	225	390	405	495	495	405	390	225	225
90	225	390	405	420	420	405	390	225	90
90	225	345	390	405	405	390	345	225	90
90	225	345	390	405	405	390	345	225	90
90	225	345	390	390	390	390	345	225	90
90	225	345	390	390	390	390	345	225	90
90	225	345	345	390	390	345	345	225	90
60	225	300	345	345	345	345	300	225	60
60	225	270	345	345	345	345	270	225	60
60	90	270	345	345	345	345	270	90	60
60	90	270	300	345	345	300	270	90	60
60	60	225	300	345	345	300	225	60	60
	60	225	270	345	345	270	225	60	
	60	225	270	300	300	270	225	60	
	60	225	270	270	270	270	225	60	
	60	90	225	270	270	225	90	60	
	60	90	225	270	270	225	90	60	
	60	90	225	270	270	225	90	60	

B

		90	225	345	345	390	390	345	345	225	90
		60	225	300	345	345	345	345	300	225	60
		60	225	270	345	345	345	345	270	225	60
		60	90	270	345	345	345	345	270	90	60
		60	90	270	300	345	345	300	270	90	60
		60	60	225	300	345	345	300	225	60	60
			60	225	270	345	345	270	225	60	
			60	225	270	300	300	270	225	60	
			60	225	270	270	270	270	225	60	
			60	90	225	270	270	225	90	60	
			60	90	225	270	270	225	90	60	
			60	90	225	270	270	225	90	60	
			60	90	225	225	225	225	90	60	
			60	90	90	225	225	90	90	60	
			60	90	90	225	225	90	90	60	
			60	60	90	90	90	90	60	60	
			60	60	90	90	90	90	60	60	
			60	60	90	90	90	90	60	60	
			60	60	90	90	90	90	60	60	
				60	90	90	90	90	60		
				60	90	90	90	90	60		
				60	60	90	90	60	60		
				60	60	90	90	60	60		
				60	60	90	90	60	60		
				60	60	90	90	60	60		
			60	60	60	60	60	60			
			60	60	60	60	60	60			
60	60	60	60	60	60	60	60	60			
60	60	60		60	60	60	60				

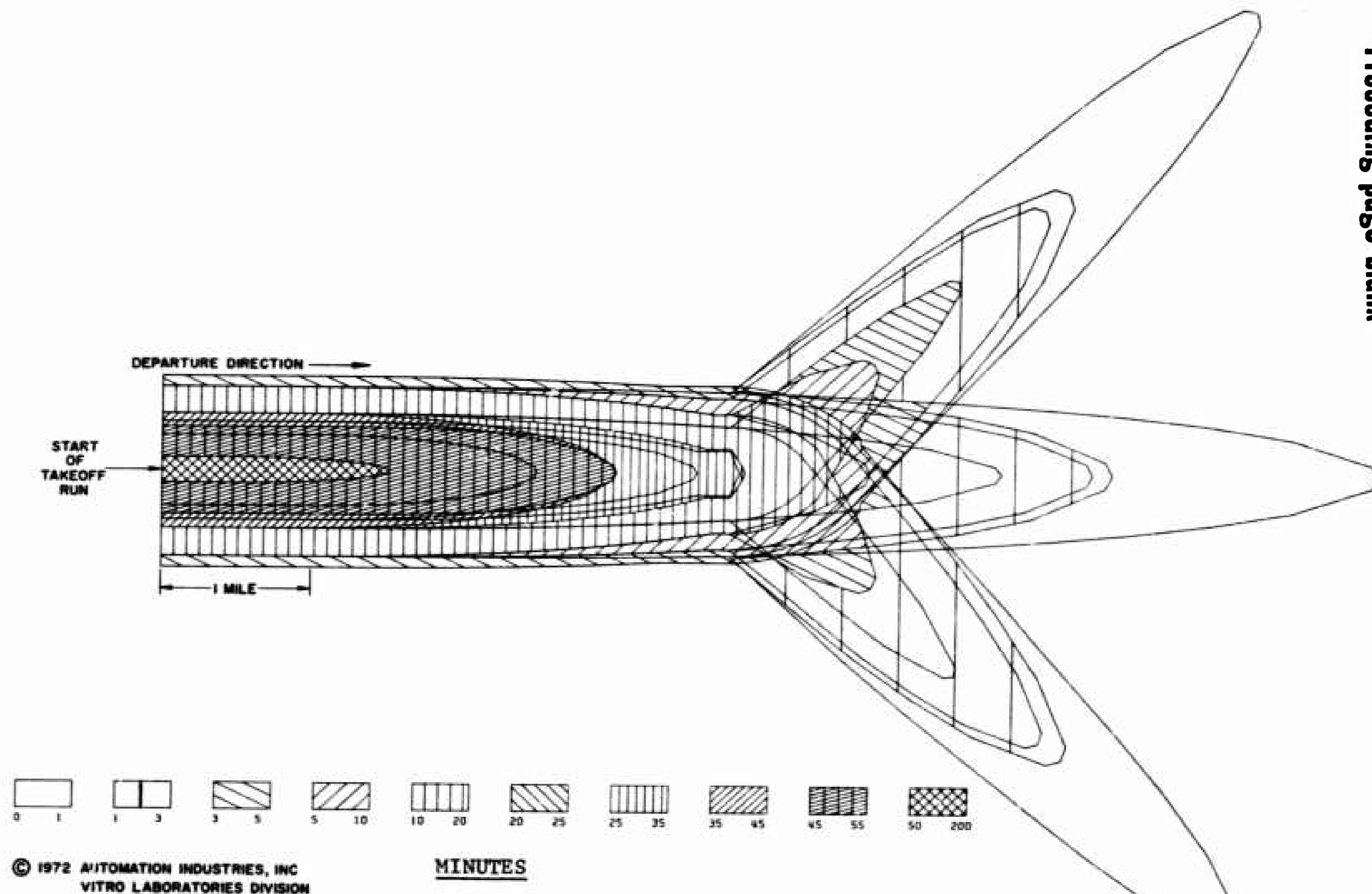
NO OVERFLOW

FIGURE 5

The lower part of the computer printout provides the substantive results of the ASDS application, a discreet block-by-block (500 feet by 500 feet) solution for exposure time which, in this realistic but hypothetical large airport case, is shown in seconds of total exposure during a 24-hour period. This type of format provides specific exposure information in a manner which can be overlaid on a map of suitable scale.

Figure 6 is an example of the type of display generated by the application of the computer graphics techniques. It can be seen that the presentation is largely self-explanatory providing immediate visual information about large tracts of land exposed to similar levels of exposure. This type of presentation is useful for land use and zoning analyses and provides the user with a multiplicity of options relative to the time scale gradations.

In summary, it can be seen that the "Aircraft Sound Description System" can be applied manually for certain airport and aircraft situations, as well as with the aid of computer techniques for more complex circumstances. Of particular interest is the flexibility permitted by the approach in performing an analysis for any baseline period of time. For example, while a 24-hour period is typically examined in noise analyses for airport environs, it is entirely possible that some lesser period of time may in fact be of interest. For example, if noise sensitive activities are anticipated to occur during selected periods of the day (e.g., school or religious activities), then an analysis may be performed to identify the amount of noise exposure during the relevant period only. This latter point is significant inasmuch as it clearly becomes possible to define time periods



MINUTES OF EXPOSURE TO NOISE LEVELS IN EXCESS OF 85 dB(A) DURING A 24-HOUR PERIOD -

A REALISTIC LARGE AIRPORT OPERATION

FIGURE 6

for analysis for which a more realistic description of the airport's operation may be stated. This clearly enables issues like "the amount of nighttime exposure" to be addressed objectively and clearly in terms of the actual amount of exposure and the corresponding description of the airport's nighttime operation. In this manner, the noise exposure situation can be described in a manner which would be equally meaningful to all participants, as well as permitting judgments to be made within the context of local circumstances.

VIII. SUMMARY AND CONCLUSIONS

In summary, it is evident that the use of the ASDS offers substantial advantages over existing techniques used to describe the aircraft noise climate around airports. Some of the key advantages are as follows:

1. The statement of exposure in terms of "total exposure time" places the description of noise intrusion on a basis more commonly understood by the public, community leaders, and Government and aviation officials; a distinct benefit in permitting maximum visibility and comprehension of an environmental issue at the level where it will exist.

2. "Exposure time" as a descriptor of noise exposure provides a scale by which the relative contribution of noises from all sources can be more readily determined and upon which exposure guidelines may be based independent of the noise source.

3. "Exposure time," without subjective adjustments to try to anticipate community reaction, permits subjective evaluations to be made at the personal level of the reviewer; a highly desirable feature in view of the unpredictable variations in social, economic, and attitudinal factors between individuals and from community to community.

4. By establishing a fixed noise reference, direct and common experience noise analogies can be developed. This should aid in the formation of intuitive approximations of the noise levels

discussed in noise analyses as well as the interpretation of those analyses at the community level; a feature missing from current techniques.

5. By using the ASDS technique in which multiple events do not alter the acoustic characteristics of the individual events, the boundaries of the analysis area will more accurately reflect the true noise characteristics of the contributing aircraft.

6. By the use of time as the basic index of exposure, supplementary analyses for any part of the day, evening, or night, or whenever any particular noise sensitive activities might be occurring, can be made without any loss in interpretational value (i.e., the two statements "10 minutes of exposure within a 24-hour period" and "5 minutes of exposure within a 1-hour period" do not present any interpretational difficulties as might be the case when dealing with acoustic units).

7. By applying realistic constraints in the lower bounds of the noise levels to be predicted, the credibility of noise exposure analysis will be increased; a quality which is of importance if the potential consequences of error in major land use planning efforts are considered.

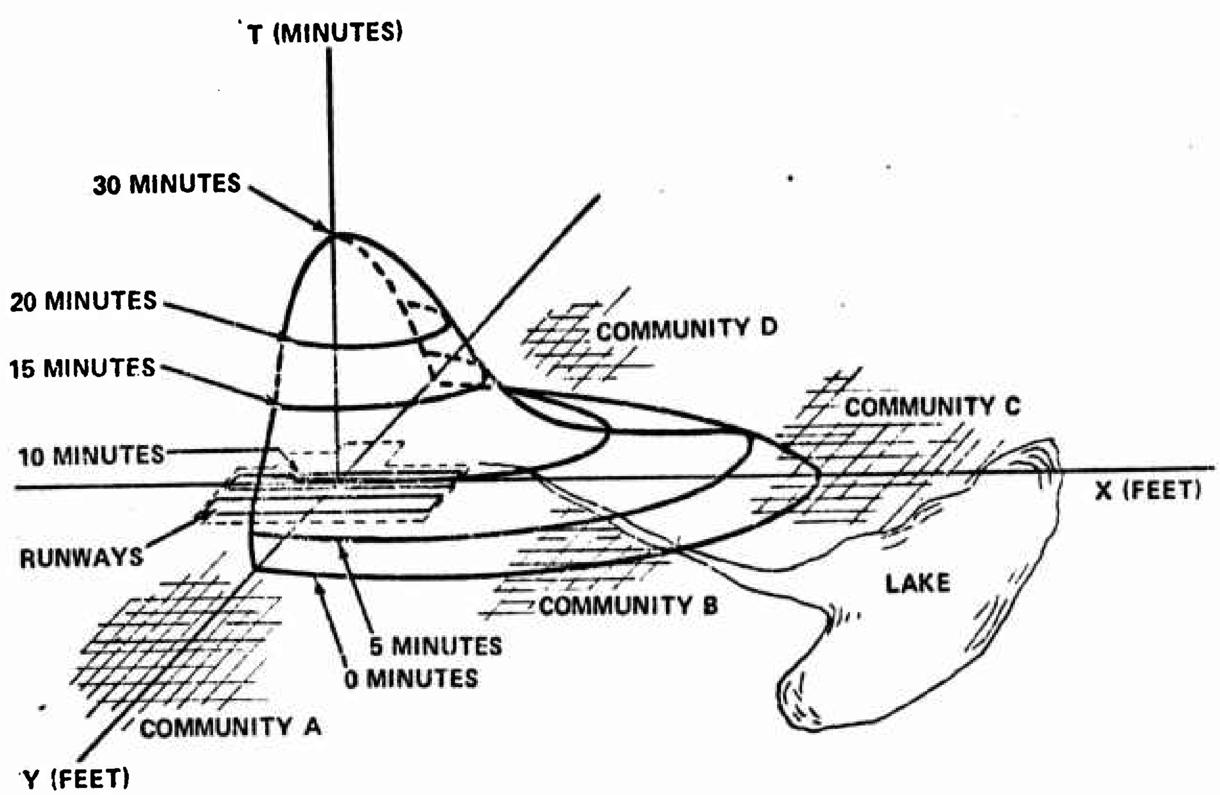
In view of these advantages, it was concluded that the application of the basic concepts of the "Aircraft Sound Description System" would enhance the quality and usefulness of any aircraft noise exposure analysis as well as making a substantial contribution in the effort to place the analysis of environmental issues in a form which can be dealt with at the local community level.

APPENDIX I. DEVELOPMENT OF A "SITUATION INDEX"

The application of the Aircraft Sound Description System will yield a map of the airport and its surrounding area upon which will be superimposed (a) numerical values corresponding to the amount of noise exposure time for each point of interest on the map as in Figure 5, or (b) isopleths of exposure time (lines connecting points of equal exposure) approximately as in Figure 6. At this point, it is not difficult to see that either of these displays will permit a microanalysis in which a comparison can be made between an activity which takes place at a particular point on the map and the corresponding amount of predicted noise exposure. That is the principal application of the ASDS. However, it is also not difficult to recognize that from an overall planning and analysis sense a macroanalysis is also desirable. This latter objective could be oriented towards answering the questions "What is the overall situation?" or "How will the overall situation change if alternative conditions are considered?"

In viewing detailed noise exposure maps derived by any technique, it becomes evident that not only can it be difficult to summarize a single map into one descriptive phrase, but also that side-by-side comparisons of maps derived for any "before and after" uses are often impossible. The underlying reason is that, by and large, noise exposure maps tend to contain a multiplicity of irregularly shaped lines of "constant exposure value" which can "contract here" and "bulge out there" to confound the development of any visual sense of the overall situation or changes to it. Typically, the method that has been used to summarize overall changes is to determine the area contained within selected exposure values. However, this approach yields statements that deal with selected single noise exposure values and, therefore, require multiple statements to fully describe a single situation. In the ASDS, therefore, it was found that a useful single "situation index" (SI) could be obtained which would represent the overall situation by accounting for all of the noise exposure displayed and all of the area affected.

Conceptually, the procedure selected to obtain the "situation index" was simply to view the noise exposure map as existing in three dimensions. In this case then, the airport and its surrounding area could be viewed to lie in an X-Y plane, and the exposure times appropriate to each point as extending perpendicularly to that plane parallel to a time axis (as shown in the following illustration).



If the exposure situation is viewed in this three-dimensional context, then the totality of the situation can be determined by obtaining the volume contained within the exposure surface. If that surface were mathematically definable, then the procedure would be to evaluate the integral $SI = \iint T\, dy\, dx$ for which the value would have units reducible to "acre-minutes." However, since it is unlikely that the exposure surface will have any conveniently derivable mathematical form, an analogous value must be obtained. For those applications of the ASDS in which time constants are applied for the areas receiving 85 dB(A) or higher, the analogous value can be obtained as follows:

$$SI = \sum_{j=1}^{m} \sum_{i=1}^{n} A_{ij} \; N_{ij} \; T_c^i$$

SI = Situation Index value (acre-minutes)

Where A_{ij} = Area (acres) exposed to 85 dB(A) or higher for airplane "j" in event type "i" (event types can be differentiated by operation (takeoff or landing), gross weight, flight path or any other characteristic as desired)

N_{ij} = Number of events of type "i" performed by airplane "j"

T_c^i = Time constant appropriate to event type "i"

m = Total number of airplane types

n = Total number of event types for each airplane

If the fact is recognized that the situation index, "SI," can be derived for any portion of the map and that the map can be derived for any portion of the day, week, year, etc., as well as for any aircraft type, or any airline, to name some possibilities, then its use as a management, planning, and analysis index becomes apparent. Importantly, since "SI" totalizes a complex situation, then it can be used to compare the general state of a situation for any base set of conditions, as well as for any alternative or modified set of hypothetical or projected conditions.

In summary, then, the ASDS technique can provide the detail necessary for a microanalysis by developing the discreet, point-by-point durations of noise exposure, as well as a supplementary situation index, "SI," in acre-minutes, which represents a single valued quantification of the overall noise exposure map.

APPENDIX II. MANUAL APPLICATION OF AIRCRAFT SOUND DESCRIPTION SYSTEM

NOTE: This set of instructions is presented as an example of the procedure to be followed in the case of a manual application of the ASDS when using the suggested single event time constants discussed in the body of this report. While this outline will help to fix the general procedure in the reader's mind, it is not suggested to be a full and all-encompassing instruction. This latter objective will be satisfied by an ASDS applications manual presently under development.

SECTION I

INTRODUCTION

This section contains a step-by-step discussion of how the ASDS is applied to an actual airport situation. There are three basic steps in applying the ASDS concept. They are: gathering the necessary information about the airport and the aircraft using it; selecting and plotting the appropriate set of sound contours; and calculating the necessary sound exposure indices.

Step 1 - Gathering the necessary airport/aircraft information

a. For each runway the number landings and departures by aircraft type and weight must be identified.

b. If curved or segmented inbound and/or outbound flight patterns are used, then the number of times each is used by aircraft type and weight must be identified.

A data sheet with column headings as follows will be useful.

Runway	Aircraft	Flight Track	Weight	Event (Takeoff or landing)	Usage	Contour Number

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Step 2 - Selecting the appropriate set of contours defining the areas expected to detect sound levels of 85 dB(A) or greater.

a. Based on the listed conditions of aircraft type, weight, and flight event (takeoff or landing), the appropriate sound contour data is selected from Section II of this instruction (tc be provided in subsequent developments of an applications manual for the ASDS). The identification number for the contour is entered in the last column of the data sheet described above.

Each contour is accompanied by the following data.

(1) A contour identification number

(2) Area in acres enclosed with the 85 dB(A) contour

(3) Distance to the edge of the 85 dB(A) contour measured perpendicularly from the projection of the flight track on the ground plane. These distances are given at selected increments from brake release in the case of takeoff and from glide slope/runway intercept in the case of landing.

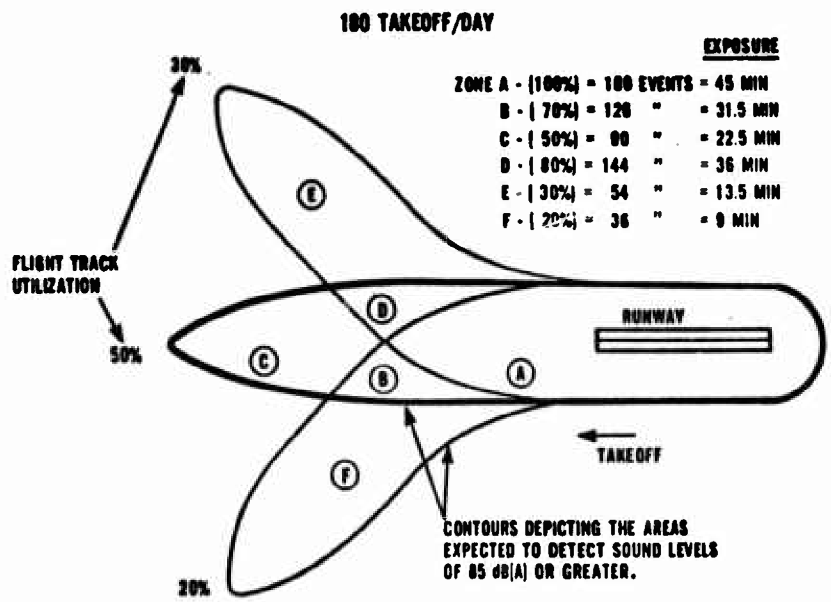
(4) A graphical display of the contour based on a straight approach or departure plotted to a scale of 2000 feet to the inch. The plotting scale was selected to conform with the readily available Coast and Geodetic Survey 7.5 minute Quadrangle maps.

b. The sound contour is then transferred to a map of the airport and its vicinity. This may be done by using the tabular or graphical information provided. This will provide the contour edges.

c. The above steps are repeated for each type of aircraft condition and flight track which is being analyzed.

Step 3 - Calculating the necessary sound exposure indices

a. Exposure Time - Once all desired contours are graphically located on a map, then the total exposure time of any point can be determined. This is done by considering the number of exposures over that point at an exposure time of 1/4 minute for each takeoff event and 1/6 minute for each landing event. The exposure level for each point may be calculated for any desired time span (day, hour, week, etc.). The following illustration showing three flight tracks shows a simple case in which the areas of overlap were identified as zones for which the corresponding exposure time calculations were made.



b. Situation Index - A useful aggregated index in acre-minutes may be developed for the airport as a whole, or by some other subdivision such as by runway, or by aircraft type. It is obtained by multiplying the area in acres affected by each event (takeoff or landing) by the number of events and then by the appropriate time constant (1/4 minute per takeoff event, 1/6 minute per landing event). This is done for all operations and then summed up to yield a total. It should be noted that this aggregate index is not applicable to any particular point on a map but, rather, is a quantity by which changes in the total exposure situation can be gauged. Relative comparisons can be made between runway, time periods, aircraft or air carriers. The user is cautioned that this index is useful mainly in this context, and that land use decisions should not be made without reference to the actual exposure times previously calculated.