NASA/CR-1998-207650

Use of Airport Noise Complaint Files to Improve Understanding of Community Response to Aircraft Noise

Sanford Fidell and Richard Howe
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April 1998

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Prepared for Langley Research Center
under Contract NAS1-20101

April 1998

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1 INTRODUCTION

1.1 STUDY GOAL

The goal of this study was to assess the feasibility of using complaint information archived by modern airport monitoring systems to conduct quantitative analyses of the causes of aircraft noise complaints and their relationship to noise-induced annoyance. This assessment addresses (1) the ability to link complaints with operational and noise exposure information, (2) the nature, completeness, and reliability of complaint files, (3) data accessibility, and (4) the nature of research hypotheses amenable to testing with such information.

1.2 SUMMARY OF FINDINGS

Noise abatement offices of many airports maintain telephone answering systems to record complaints about aircraft operations. Transcriptions of these complaints are commonly entered into a structured file system of a computer-based noise and operations monitoring system, along with addresses, time tags, and at least a cursory summary of complaints. At many airports, complaint files are routinely assembled into a database searchable by complainant name, address, date or time of day, and types of aircraft and complaints.

All computer-based airport monitoring systems provide at least rudimentary tools for performing such searches. Some also permit geocoding of complainants' addresses (that is, conversion into latitude/longitude values for map displays) as well. Airport monitoring systems can also store aircraft transponder ("radar") position information for flights in the airfield vicinity, and provide means for linking individual complaints with temporally and/or spatially proximate flight operations. Archives containing several years of such information are accumulating at a number of large airports in North America and elsewhere. Most monitoring systems can export complaint databases and other archived information for post-processing by other means, including off-line geocoding and automated analyses of enormous quantities of aircraft operational information.

A range of issues about the origins of complaints and relationships between complaints and long-term annoyance can be quantitatively investigated with information contained in databases of airport monitoring systems. These include:

- airport-specific and generic dependence of noise complaints on numbers, times, noise metric values, and types of aircraft operations;
- dependence of complaint rates on calculated properties of flight path distributions (*e.g.*, density, variability, altitude, *etc.*) with respect to geographically-weighted demographic information;
- use of complaint information to independently estimate the non-acoustic component of reported annoyance with aircraft noise exposure;
- sensitivity of complaints and time constants of arousal and decay of complaints following operational changes that alter flight paths; and
- overall stability and predictability of complaint behavior.

Several examples of the form of analyses suited to these issues are outlined in this report.

1.3 REPORT ORGANIZATION

Section 2 of this report describes community response assessment issues that could benefit from detailed analysis of adequate complaint information. Section 3 presents background information about the evolution of airport noise and flight monitoring systems. Section 4 provides examples of testable hypotheses about the origins of complaints and their relationship to long-term annoyance. Section 5 discusses the availability of complaint and related operational information. Conclusions are presented in Section 6. Appendix A provides additional detail about noise event classification issues. Appendix B describes the potential use of complaint rate information to refine predictions of annoyance prevalence rates in airport communities.

2 RELEVANCE OF COMPLAINT DATA TO ASSESSMENT OF COMMUNITY RESPONSE TO AIRCRAFT NOISE

This section reviews the state of the art and the value of developing a useful accounting of aircraft noise complaints. It also describes community response issues that can be investigated in unprecedented detail by analyses of complaint-related information. Additional discussion of analyses of complaint data that may be helpful in predicting noise-induced annoyance may be found in Appendix B.

2.1 CONVENTIONAL UNDERSTANDING OF COMPLAINTS

It has been appreciated from the first studies of community response to noise from jet aircraft operation at civil airports (Wilson Report, 1963)

- that complaints are not monotonically related to cumulative measures of noise exposure;
- that complainants "are not typical of the population at large";
- that complainants are reasonably representative of highly annoyed non-complainants; and
- that complainants "tend to come from those sections of the community who are likely to be more articulate than the average."

This pattern of findings, along with practical impediments (*cf.* Chapter 3) to systematic study of complaint rates and successful alternate approaches to comprehending other forms of community response to aircraft noise, have discouraged subsequent large-scale studies of complaint behavior. An early effort to derive a relationship between the prevalence of annoyance and the prevalence of complaints from surveys conducted in seven cities (Tracor, 1972), suggested that the prevalence of complaints was proportional to the square root of the prevalence of annoyance. This finding has not been extensively confirmed or extended since.

It is widely believed among airport operators that small numbers of complainants generate disproportionate numbers of complaints, and as a corollary, that raw complaint counts do not provide a reliable indication of community response to aircraft noise exposure. Figure 1, based on complaints received at a major airport over the course of two years, illustrates this phenomenon. The figure shows the distribution of complaints per complainant at Denver International Airport over a period of 25 months, from 1 March 1995 through 31 March 1997. The great bulk of complainants who called to complain did so between one and three times during this two-year period. Of the 298 individuals who registered more than 60 complaints, many were chronic complainers, including one address from which an average in excess of 20 complaints per day were received over the entire period — about a tenth of all complaints received by the airport over this period. The fact that a single complainant was responsible for a relatively large proportion of complaints should not obscure the fact, however, that the vast bulk of all complainants reported only a few complaints during the same time period.

2.2 DISTINCTION BETWEEN ANNOYANCE AND COMPLAINTS

The term "community response" to aircraft noise means different things in different contexts. To those preparing NEPA-mandated environmental assessments, or offering nationwide guidance about land use compatibility, or setting aviation-related regulatory policy, the term generally implies the prevalence of an *attitude* — a consequential degree of noise-induced annoyance — in an airport community. To personnel

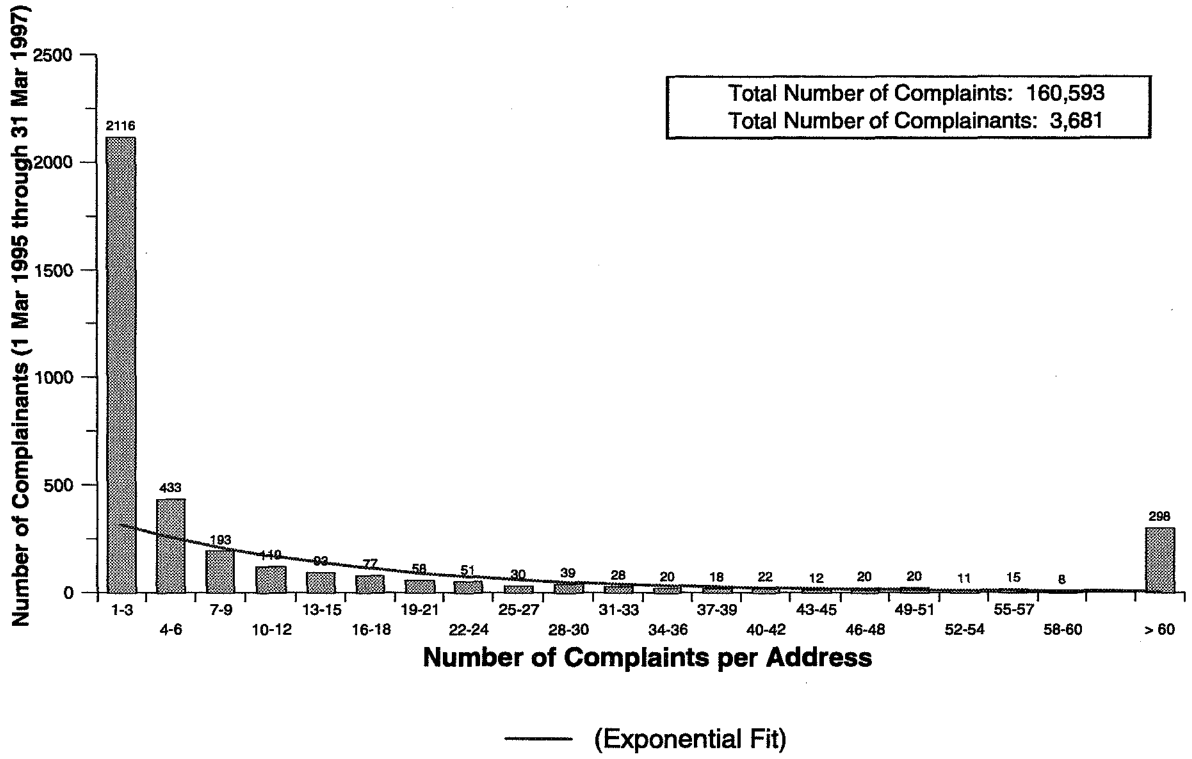

Figure 1 Exponential fit to distribution of numbers of complaints per complainant.

of airport noise abatement offices, however, the term "community response" rarely refers to anything other than complaint *behavior.*

Annoyance and complaints are fundamentally different phenomena not only because of the obvious differences between attitudes and behaviors, but also because of the time scale and implicit causes of the two. As routinely quantified for purposes of assessing aircraft noise impacts, annoyance is a stable, long-term, general, adverse attitude toward noise, with rise and decay times of at least weeks or months (*cf.* Fidell *et al.*, 1985), relatable at least in principle to long-term cumulative noise exposure. As such, the case for using a 24-hour average noise exposure level as a predictor of the prevalence of annoyance is self evident.

As any airport noise abatement officer will attest, however, complaints are short-term responses to individual noise events, and particularly to unusual ones. Complainants do not wait until midnight to lodge retrospective complaints about specific operations or cumulative noise exposure during the preceding 24 hours. Many therefore fail to understand why long-term cumulative noise metrics are plausible predictors of "community response"; *i.e.*, complaints.

2.3 NATURE OF COMPLAINT AND ANNOYANCE DATA AND CURRENT UNDERSTANDINGS OF THEM

Aircraft noise annoyance is an intangible quantity that can be accurately measured only with considerable effort. Telephone complaints are freely volunteered and trivially tallied. Because attitudes are covert mental processes and complaints are easily counted behaviors, it seems superficially at least that complaints are the more "objective" measure of aircraft noise impacts, and that relationships between complaints and aircraft activity must be simpler to discern than relationships between annoyance and aircraft activity. In fact, the reverse is true. A neighborhood telephone tree can produce a flurry of less-than-objective complaint calls or postcards much more easily than it can appreciably change the prevalence of a consequential degree of annoyance in a community.

Although complaints are easily tallied, they are nonetheless relatively rare behaviors, given the number of potential opportunities for complaints in neighborhoods where thousands of households are overflown by hundreds of aircraft every day. Furthermore, the quality of complaint data has until recent years been insufficient to support systematic associations of particular properties of aircraft operations (*e.g.*, altitude, noise level, aircraft type, operation type, *etc.*) with individual complaints.

In contrast, although prevalence rates of noise-induced annoyance can vary considerably in two communities with identical noise exposure, they tend to be quite stable within communities with consistent noise exposure. Thousands of people may be highly annoyed by aircraft noise, even though only a few may lodge telephone complaints.

Even though complaints are more readily measured than annoyance, far more is known quantitatively and systematically about annoyance than about complaints. Fields (1991) has counted well over 300 social surveys of noise-induced annoyance. A recent compilation of paired observations of DNL values and prevalence rates of consequential annoyance (*cf.* Figure 2) demonstrates the extent of this understanding from observations made in 550 neighborhoods.[1] Enough order has emerged from information about the relationship between noise exposure and annoyance prevalence rates to support a dosage-response relationship judged adequate by federal agencies to support nationwide guidelines and regulatory policies.

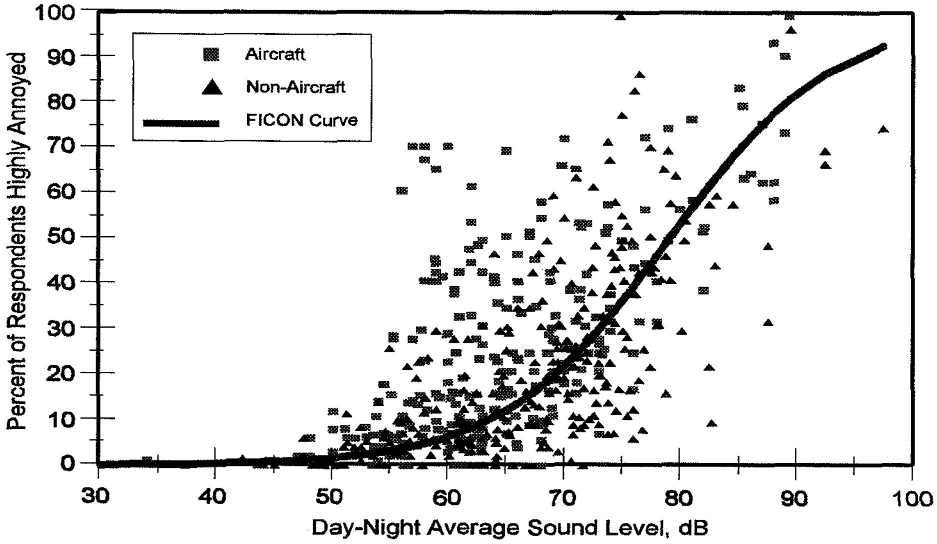

Figure 2 Observations of the prevalence of noise-induced annoyance in 550 neighborhoods.

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[1] The curve seen in this Figure is FICON's (1992) dosage-response relationship.

In contrast, even the most basic phenomena of complaint behavior remain largely unexplored, primarily for lack of opportunities to study complaint phenomena with adequate resolution. For example, no well established answers are available to any of the following questions about aircraft noise complaints:

- How much do population-weighted complaint rates vary at airports with similar operations?
- Why do particular aircraft operations attract complaints, while others with similar objective characteristics (sound exposure level, closest point of approach, time of occurrence, type of aircraft or operation, *etc.*) do not?
- What are typical operational characteristics of flights with low and high likelihoods of complaints?
- Can non-acoustic physical variables (*e.g.*, number of operations, closest point of approach, visual angle subtended at closest point of approach, time of day of operation, temporal density, mean or variance of inter-operation interval, aircraft attitude, *etc.*) account for as much variance in complaint rates as sound exposure levels?
- How much variance in complaint rates cannot be accounted for by physical (acoustic or other) variables?
- Do complaints exhibit sequential dependencies; *i.e.*, how do likelihoods of complaints vary on hourly or daily time scales with increasing number, rate, or duration of flight operations?[2]

2.4 GEOGRAPHIC ORIGIN OF COMPLAINTS

Even though FICON's dosage-response curve depicts a monotonically increasing relationship between the prevalence of annoyance and long-term average sound levels, it is the rule rather than the exception at most airports for the bulk of complaints about aircraft noise to be received from areas of relatively low noise exposure. A recent review (Bucka and Howe, 1994) of the effectiveness of Part 150 and AICUZ studies in defining areas of major noise impact and applying mitigation measures to reduce numbers of complaints at fifteen civil airports and twelve Air Force bases found that at seven of the airports studied, nearly 100% of the complaints came from areas outside the 65 dB contour line. Another six of the airports reported that roughly one-half to two-thirds of noise complaints originated from outside the DNL = 65 dB contour.

An intuitively appealing explanation for this apparent paradox is that the rare high single-event levels likely to give rise to noise complaints may have little influence on the long-term average sound exposure of an airport neighborhood. The adequacy of this explanation has yet to be formally tested or even quantitatively documented.

Other explanations for the absence of a strong relationship between the prevalence of annoyance and complaint rates in airport communities are also plausible, however. For example, the noise metric, DNL, of FICON's dosage-response relationship that accounts for about half of the variance in the prevalence of

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[2] An answer to this question might be particularly valuable in designing a preferential runway use plan. Although DNL (and hence annoyance as predicted from DNL) is unaffected by the temporal sequence of occurrence of noise events within separate daytime and nighttime periods, complaint behavior could be rather sensitive to the temporal distribution of overflights within these periods.

annoyance data is not known to be causally related to annoyance. Current evidence demonstrates only that long-term average sound exposure is correlated with the prevalence of annoyance, not that long-term average sound exposure ***causes*** annoyance.

It is possible that individual noise events influence annoyance in ways not fully reflected by their contributions to annual DNL; or that complaint rates are linked to shorter-term (hourly/daily/weekly) average noise levels; or that complaints are more closely associated with maximum levels or duration of exposure in excess of a threshold value ("time-above"). It is also possible that complaints are influenced by nonacoustic factors to a greater extent than are self-reports of annoyance. These nonacoustic factors are not necessarily limited to unfavorable beliefs and attitudes about airlines and airports, but could potentially include physical factors that may not correlate highly with cumulative noise exposure, such as aircraft type[3] and attitude, unpredictability, frequency of overflight, *etc.*

2.5 CONSEQUENCES OF DISPARATE DEFINITIONS OF COMMUNITY RESPONSE

Regardless of the causes and relationships of annoyance and complaints, the disconnect between airport and federal perspectives on annoyance and complaints as indices of community response to aircraft noise has at least two undesirable consequences:

1. Guidance about "community response" based on FICON's (1992) dosage-response relationship is of only limited practical value to those dealing most directly with airport/community interactions; and

2. For NEPA-related purposes, airport complaint experience offers little support for standard methods of assessing aircraft noise impacts in airport communities.

The disparity in definitions of community response to aircraft noise exposure can be especially troublesome in land use compatibility controversies. FICON's recommendations rely heavily on interpretations of dosage-response relationships between annoyance and long-term noise exposure, as described in Appendix B. Airport proprietors who must explain and defend federal guidance in this area against local development challenges are often ill-equipped to reconcile such guidance against local complaint histories. In California, for example, airport land use planning commissions created by state legislation are not bound by FICON's guidelines, and sometimes view local complaints as more persuasive than nationwide guidelines.

A consistent means for reconciling attitudinal with behavioral manifestations of "community response" would thus be of considerable utility for environmental impact assessment, regulatory, and airport management purposes. Efforts to reconcile the attitudinal and behavioral perspectives on community response, however, have been limited by a lack of reliable and detailed information about the circumstances of aircraft noise prior to lodging of complaints.

Airport monitoring systems at many civil airports have now archived years of noise exposure and complaint data in a manner that permits systematic analysis of relationships between complaints and aircraft

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[3] For example, noise emissions on approach of smaller turboprop aircraft may not differ greatly from those of some much larger jet transports (Fidell *et al.*, 1996).

noise levels, on time scales ranging from individual events to annual averages. This new information, coupled with information about spatial and demographic distributions of residential populations relative to flight tracks, can be exploited in case studies to clarify the relationship (if any) between the probabilities of complaints and various measured or predicted noise metrics during time periods prior to receipt of aircraft noise complaints.

3 EVOLUTION OF NOISE COMPLAINT PROCESSING BY AIRPORTS

Prior to the advent of computer-based monitoring of aircraft noise and flight operations, processing of aircraft noise complaints received by airport proprietors was generally limited to manual entry of telephone and mail complaints on paper forms, filing of paper forms by complainant name, and tallying at occasional intervals. Graphic displays of such information only rarely went beyond pins stuck in wall maps or dots on computer-drawn maps. The advent of highly capable computer-based monitoring systems within the last decade has led to substantial improvements in the nature, standardization, and accessibility of information about aircraft noise complaints.

3.1 DEVELOPMENT OF COMPUTER-BASED AIRPORT MONITORING SYSTEMS

Systematic tracking of aircraft noise in the vicinity of airports by means of permanently installed remote noise monitors began in the early 1970s with the development of affordable digital circuitry for such purposes. Early vendors of permanent community noise monitoring hardware were primarily organizations experienced in acoustic measurement, including BBN, Brüel & Kjær, Hewlett-Packard, Hydrospace, and Tracor. Noise monitoring systems of this era were typically built around a single, stand-alone minicomputer programmed in assembly language, connected by dedicated telephone lines to a small number of nearby noise monitors. The principal output products of early noise monitoring systems were fixed format tabulations of noise measurements and calculated values — hardly more than hardcopy file dumps — and real-time displays of noise levels in airport terminals. Such systems were relatively expensive, provided little functionality beyond noise measurement and reporting at limited numbers of locations relatively close to airports, and required considerable maintenance.

Airport noise monitoring technology evolved rapidly during the 1970s and 1980s with the introduction of Unix workstation and network-based system architectures. Network-based systems permitted airport authorities responsible for multiple airports in the same metropolitan area (*e.g.*, London, Los Angeles, New York, and Washington) to affordably centralize monitoring of aircraft noise and operations for several airports. Rapid advances in digital technology and software engineering in this era were paralleled by trends toward much greater capability in airport noise monitoring systems. These trends included

- substantial improvements in computational speed, storage capacity, and ease of local area networking;
- capability for creating more complex software systems by programming small computing systems in high-level languages;
- decreases in workstation cost; and
- increasing availability of off-the-shelf database management, geoinformation system, spreadsheet, graphics, and other generic software products.

When FAA began permitting distribution of ARTS III radar information, airport noise monitoring systems quickly incorporated means for displaying and archiving information about flight operations as well. This development changed the character of airport monitoring systems from primarily acoustic measurement systems to primarily information management systems. This in turn opened the field to competition from companies with system integration expertise rather than expertise in acoustic instrumentation and analysis *per se*.

Much of the functionality of modern systems for monitoring aircraft noise and aircraft movements was available by the late 1980s. Airport authorities in Salt Lake City and Boston were early adopters of a fully-featured, network-based Larson·Davis "ENOMS" (Environmental Noise and Operations Monitoring System); Technology Integration, Inc. (TII) sold several large-scale "ANOMS" (Airport Noise and Operations Monitoring System) with similar capabilities to major domestic and overseas airports; foreign vendors (*e.g.*, Cirrus, Lochard) and software system integrators (*e.g.*, the Flood Group) sold sophisticated systems to a number of airports in North America and elsewhere; and Brüel & Kjær and Tracor succeeded in selling PC- (rather than Unix workstation-) based systems.

Larson·Davis acquired TII's ANOMS in the early 1990s and licensed its continued development and distribution to HMMH. In recent years, HMMH and Tracor have emerged as major domestic vendors of full-featured noise and operations monitoring systems for airports. None of these systems is truly an off-the-shelf product, since all are customized to operational circumstances of individual airports and to the specifications of competitive procurements. Each is further customized during a "tuning" period typically lasting several months after initial installation, during which algorithms for classifying aircraft noise events and matching flight tracks with complaint locations are adjusted to suit local conditions.

Dozens of large civil airports have been using computer-based monitoring systems to log complaint and aircraft activity information for two or more years. In North America, these include, *inter alia*, Atlanta, Baltimore, Boston, Charlotte-Douglas, Chicago, Denver, Long Beach, Minneapolis, Nashville, New Orleans, New York, Oakland, Orlando, Orange County, Phoenix, Raleigh-Durham, San Jose, San Diego, San Francisco, Seattle, Vancouver, Westchester County, and Winnipeg. Archival information of shorter duration is available from a number of other airports, and yet other airports are in the process of acquiring new systems.

Some reliever and large general aviation airports in metropolitan areas served by multiple airports also use modern systems to track aircraft noise, flight activity, and complaints. A few large civil airports (notably including Los Angeles and Dallas-Ft. Worth) currently operate locally designed, hybrid (multi-vendor), or not yet completed monitoring systems.

3.2 COMPLAINT-RELATED DATA ENTRY AND ANALYSIS CAPABILITIES OF AIRPORT MONITORING SYSTEMS

Entry of complaint information (name, address, time of receipt, time and nature of aircraft activity) into modern airport monitoring systems is usually accomplished manually, generally by transcription of tape recorded telephone calls. Some systems help to automate the preparation of standard written responses to complaints. Automated reports summarizing numbers and generic complaint types (by time period, geographic area, and aircraft type) are common. Interactive specification of data fields for reports prepared from complaint databases is also a common capability.

Most systems employ one of two primary strategies for managing complaint information: an integrated system approach or a tool kit approach. Integrated systems store monitoring information in a large-scale relational database, accessible from the main user interface. This approach, common in systems implemented on Unix workstations, provides consistency of look and feel for the user, and may also provide some assistance in formulating SQL queries.

The tool kit approach stores monitoring information in easily exportable form for off-line manipulation by third-party database software. For example, a Tracor-provided system installed at Phoenix Sky Harbor airport can export selected subsets of data directly from a report screen to Microsoft EXCEL (or other) spreadsheets. Monitoring systems implemented in Windows/PC computing environments often adopt this approach.

In either case, the archived complaint database generally contains, at a minimum, caller lists by name or telephone number, complaint lists, and complaint counts by caller, city, or neighborhood. With varying degrees of accuracy, different systems attempt to automatically link noise events measured at particular monitoring stations to individual aircraft operations, flight tracks, and registered complaints, and to associate such information with aircraft type, operation type, time of day, flight number, aircraft owner, weather conditions, and runway use.

Linked complaint and aircraft noise event data can be reported in multiple formats with varying ease and complexity, depending on the sophistication of the system. Some systems let users define "filters" to include, exclude, or otherwise associate specific complaint, aircraft noise event, and aircraft ownership data in user-defined time periods ranging from minutes to months. If a monitoring software includes GIS capabilities, street addresses of complainants can usually be geocoded (assigned a latitude/longitude by third-party software bundled with the monitoring system), and complaint, flight track and aircraft noise event data can be superimposed over airport vicinity base maps. Some systems permit interactive matching of flight tracks to complaints, as well as estimation of SEL or DNL values at complainants' addresses.

In most cases, however, the emphasis is on (1) production of routine reports and on (2) interactive investigation of individual complaints. No commercial monitoring system is optimized for research purposes such as large-scale statistical analysis of relationships between complaint and operational information.

3.3 CLASSIFICATION OF NOISE EVENTS BY MONITORING SYSTEMS

Airport monitoring systems typically classify identifiable noise events into some of the following categories:

- Noise produced by an individually verifiable (by complete series of transponder responses) aircraft approaching or departing the airport, unaccompanied by noise from any other airborne or groundborne source;
- Noise produced simultaneously at a given measurement station by more than one such aircraft;
- Noise produced by an aircraft other than those operating out of a particular airport;
- Noise produced by an individually identifiable aircraft approaching or departing a particular airport, with some potential contribution from an aircraft not approaching or departing that airport;
- Noise produced by a ground source ("community" noise);
- Noise produced by an individually identifiable aircraft approaching or departing a particular airport, with some potential contribution from a ground source;

- Noise produced by an aircraft not operating from a particular airport, with some potential contribution from a ground source;
- Artifactual noise caused by wind or hardware malfunction; and
- Noise of unclassifiable origin.

The algorithms used to classify noise events differ by monitoring system vendor and installation. Classification algorithms are often implemented as a set of rules in a sequential decision tree, or assertedly in proprietary (neural network and fuzzy logic) schemes. These algorithms may be rather conservative with respect to attributing noise events to aircraft.

The basic decision as to what constitutes a noise event is generally made "on the pole" (that is, by the hardware at the remote noise monitoring station). A noise event is typically defined as a time series of half-second sound levels that exceeds either a fixed or floating (relative to recent ambient levels) threshold, persists for some period of time (often 5-10 seconds), and drops below the initial threshold by some margin (often 2 dB). Definitions of this sort are intended to exclude from further analysis many transient and non-aircraft noises.

The accuracy with which noise monitoring systems classify noise events into various categories is often not established rigorously. Operators of some airport noise monitoring systems are content with assurances from vendors that their systems are performing with reasonable accuracy after having been "tuned" and verified through short-term field observations. Confidence intervals are not usually calculated for noise event classification decisions, nor are formal Receiver Operating Characteristic (ROC) curves prepared, as described in Appendix A.

3.4 LINKAGE BETWEEN COMPLAINTS AND FLIGHT OPERATIONS

While all airport monitoring systems permit linking of aircraft noise complaints with aircraft operations, system vendors — possibly for proprietary reasons — provide few details about how decisions are made to associate particular noise events with particular complaints, nor about how ambiguous data are handled. For example, little detailed information is available about the manner in which complaints are associated with noise events when multiple aircraft fly near complainants' homes in close temporal proximity to receipt of a complaint; nor how flight operations are treated if they cannot (for any of a number of reasons) be associated with a measured aircraft noise event; nor how noise events are classified and reported when their origin is uncertain.

Questions about how accurately airport monitoring systems may associate complaints with aircraft operations are not of central concern for present purposes, however. Such linkages may be established independently of any internal algorithms in the monitoring software, by applying external procedures to exported databases. Such procedures may be as sophisticated as necessary to suit particular analyses. For example, separate flight track and complaint databases may be searched to find the five largest aircraft that passed within a given slant range of a complainant's address within an arbitrary time period prior to receipt of a complaint. Likelihoods may then be assigned to each candidate aircraft by weighting its features against whatever information may be contained in the complaint itself (proximity in time, type of aircraft, nature of complaint, *etc.*)

4 EXAMPLES OF NOVEL ANALYSES

Large, long-term, linkable databases of aircraft operational information and complaint experience at major airports are a rich source of information that can be used to shed light on a range of issues that can improve understanding of community response to aircraft noise. These issues include

- What individual factors (if any) distinguish flight operations that generate complaints from those that do not?
- How effectively may statistical predictors identify combinations of operational characteristics that lead to complaints from those that do not?
- What proportions of flight operations of different types generate similar complaint rates?
- What proportions of the variance in complaint rates can be attributed to acoustic and to non-acoustic factors?
- What can be inferred from complaint rates about the prevalence of a consequential degree of annoyance in airport communities?
- What consistency in complaint rates can be found as functions of seasonality, changes in flight operations, and demographic characteristics of populations living near airports?

The following subsections outline types of analyses that can answer such questions. Note that the information presented to illustrate these analyses is hypothetical in all cases, even though it may be derived from actual flight track or complaint records in some cases.

4.1 ANALYSES OF STATISTICAL PREDICTORS OF COMPLAINTS AND CHARACTERISTICS OF FLIGHT ACTIVITY

Although flight activity must ultimately be regarded as cause (independent variable) and complaints as effect (dependent variable), it can be helpful as a matter of analysis strategy to investigate the relationships between cause and effect from both directions, as noted below.[4]

4.1.1 Statistical Properties of Distributions of Flight Characteristics

4.1.1.1 Central tendency

Differences between mean values of distributions of characteristics of flight operations are an obvious starting point for generating hypotheses about potential predictors of complaints. For example, do the mean numbers of complaints associated with overflights that approach complainants' homes within 1 km differ significantly from than those that remain at greater slant ranges? Are mean numbers of overflights near complainants' homes associated with different complaint rates during different time periods? Do significant differences exist in average characteristics of flights linked to complaints and otherwise similar flights not linked to complaints? Do mean elevation angles of flight paths or visual angle subtended by aircraft wingspans, as viewed from complainants' homes, differ for flights with low and high likelihoods of complaints?

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[4] Tactics for selecting statistical techniques useful for conducting such analyses (*e.g.*, various forms of multiple regression or discriminant function analysis) are not described in this report.

4.1.1.2 Variance

If complaints follow changes in operational patterns, then the variance of distributions of operational parameters may also be of interest. For example, complaint records of neighborhoods can be searched for increases associated with changes in flight paths that lead to increases in numbers of neighborhood overflights. Section 4.3 describes such analyses in greater detail.

4.1.2 Distribution-Related Threshold Analyses

Threshold analyses seek to discover whether critical values of distributions of flight characteristics can be identified such that complaints are rare at lower values and common at higher values. Information about distribution shapes is needed to identify potentially useful thresholds of effect, as illustrated in the two panels of Figure 3. Both panels plot hypothetical distributions of likelihoods of complaints — that is, numbers of complaints lodged per aircraft operation — against slant range at closest point of approach of an overflight to a complainant's address.

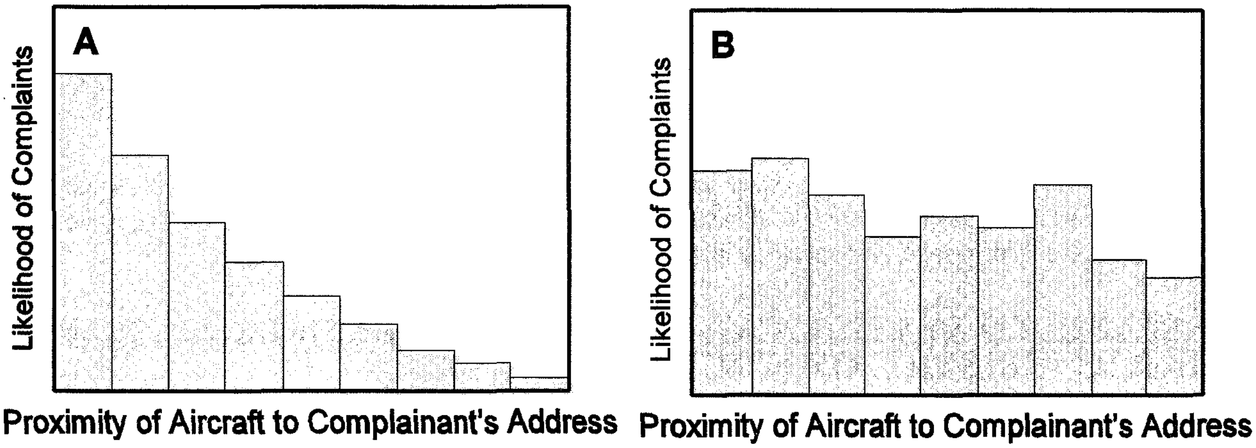

Figure 3 Two hypothetical distributions of complaints with respect to slant range at closest point of approach of aircraft to complainants' addresses.

Panel A illustrates a steep decline in likelihood of complaint with increasing range. Panel B shows a much weaker relationship between the likelihood of complaint and range. In the former case, a criterion value established after the second or third range interval would discriminate the bulk of flights with high likelihoods of complaint from flights with slight likelihood of complaint. In the latter case, no threshold value would permit useful prediction of likelihood of complaints from range information.

4.1.3 Outlier Analyses

Given that most complaints concern specific noise events, and that relatively few flight operations generate complaints, then it must be that unusual or egregious operations are responsible for whatever proportion of complaints are in fact acoustically-driven. The ways in which an overflight may be sufficiently distinctive to generate a complaint may be worth exploration.

Most fundamentally, complainants might distinguish one overflight from others if the operation created an unusually high noise level — say, if it were operating at very high thrust settings on an otherwise unremarkable flight path. However, an overflight could also attract attention without creating egregious noise levels if it were flying at an unusually low altitude, operating on an infrequently-used flight track or flight profile or at an unusual time of day; or if it were conducted by an unusual type of aircraft, or undertaking an unusual operation for a given runway end.

The database processing needed to identify outliers likely to generate complaints is straightforward. Outliers on various dimensions (altitude, speed, ground track, flight profile, direction of flight, *etc.*) can be found by constructing distributions of aircraft flight tracks from a database of flight operations. Distributions for different subsets of operations can be constructed to predict complaint rates in airport-vicinity neighborhoods by further categorizing flight operations by runway ends and distances from them.

Figure 4 shows a notional relationship between the proportion of flights associated with complaints as a function of normalized altitudes lower than the mean altitude for a given neighborhood and/or aircraft type. The shape of the function suggests that relatively few flights operating within two standard deviations of the mean flight path altitude generate complaints, but that operations flying at yet lower altitudes may generate many more complaints. Multivariate analysis can determine which (if any) of the various ways in which flight operations could be considered outliers may be associated with complaints.

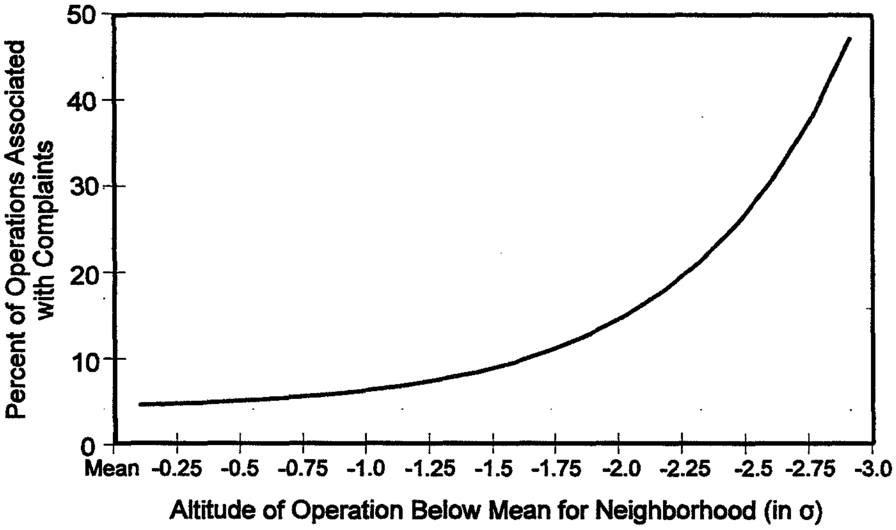

Figure 4 Notional relationship between the proportion of flights associated with complaints as a function of normalized altitudes lower than the mean altitude for a given neighborhood and/or aircraft type.

4.2 SPATIAL ANALYSES

Plotting locations of complainants' geocoded street addresses with respect to airport runways is a standard feature of modern airport monitoring systems. As described below, however, such capability only begins to exploit the ways in which geocoded complaint information can be analyzed to reveal relationships between complaints and noise exposure.

4.2.1 Analysis of "Complaint Contours"

Figure 6 (on page 21) constructs a set of complaint contours from information collected since the opening of Denver International Airport to illustrate a potential use of a complaint database to provide a view of noise impacts rather than of noise sources. Although a set of noise-effect contours may present a very different picture from that of familiar (source-based) noise-emission contours, it may be possible in some cases to interpret such contours in ways useful for land use planning purposes.

For example, it is well established that the prevalence of annoyance in two communities with similar noise exposure can vary greatly. Without conducting a social survey, however, an airport proprietor cannot be confident about the degree of reaction to additional overflights in different communities. Airport proprietors are therefore reluctant to consider adopting preferential runway use or other operational measures on the grounds that simply shifting noise from one neighborhood to another does not guarantee fewer complaints or lesser impacts. When such decisions must be made, however, they could be informed by quantitative understanding of disparities in population-weighted or flight track-weighted complaint rates in different airport neighborhoods.

4.2.2 Pseudo-Terrain Analyses

Processing of spatial characteristics of complaints need not be limited to construction of contour sets, but can also be extended to create pseudo-terrain; that is, a topographic surface whose elevation at a given point is proportional to numbers of complaints within a defined nearby area. Geoinformation system software permits such a surface to be draped over a ground plane or other thematic layers in the vicinity of an airport, color-coded and displayed in various projections, and viewed from different perspectives.

Complaint pseudo-terrain could be constructed for different seasons of the year, for different time periods before or after the dates of operational changes, and for various demographic characteristics such as population density, income, age, and so forth. While Fields (1993) has shown that demographic variables have little value as predictors of annoyance, it is not known whether they might have predictive value for complaints.

4.2.2.1 Spatial distribution of complaints with respect to DNL contours

As described in Section 2.4, no simple relationship is generally evident between the locations of long-term average noise exposure contours and the locations of complainants' homes. It is possible, however, that stronger relationships might be evident between other forms of source-based noise contours (*e.g.*, time above a threshold or maximum A-level contours) and the locations of complainants. Application of spatial analysis software tools can render such relationships evident. Figures 7 and 8 (on pages 21 and 22) depict complaint pseudo-terrain in the vicinity of DIA, constructed by processing information about the street addresses of complainants and the numbers of complaints recorded during various time periods.

The appearance of such pseudo-terrain can be altered to emphasize whatever features are of interest for a particular analysis. Figure 9 (on page 22), for example, is a form of "spot" analysis, emphasizing the great numbers of complaints made by individual complainants. Elevation is scaled in this figure in direct proportion to the arithmetic sum of complaints from a given address. Spatial averaging among complainants' addresses was controlled to yield average numbers of complaints per square mile.

In Figure 10 (on page 23), on the other hand, elevation is scaled in proportion to the logarithm of the number of complaints, compressively reducing the peaks and slopes of the pseudo-terrain. Furthermore, a greater degree of low-pass spatial filtering of complainants' addresses was employed to emphasize major features of complaint terrain rather than individual complainants.

In both figures, complaint density was calculated by creating 500 square meter cells and computing the number of complaints per square mile within 3 miles of each cell.

4.2.2.2 Spatial distribution of complaints with respect to flight track density

This section presents examples at several levels of the sorts of analyses that can be undertaken to link complaints with aircraft operations. The complaint and flight track information on which these illustrative analyses are based was collected since the opening of Denver International Airport.[5]

Just as it is possible to construct a surface from complaint data that can be interpreted as pseudo-terrain, it is possible to construct a surface from flight track data that can be interpreted as pseudo-flight path terrain. In the latter case, the elevation of a given point on the surface would be proportional to the average altitude of flight tracks within a nearby volume of airspace. If actual terrain elevations were subtracted from this surface, its elevations could represent (for example) mean altitudes above ground levels of flights through airspace above residential neighborhoods around airports.

Figure 11 (on page 23) is an example of such a surface. This figure was created by averaging the altitude values of all radar returns within a 5 miles radius of each 500 square meter cell on the ground. It is immediately apparent from the illustration that aircraft approached and departed DIA from all compass directions during the period of time represented in the figure. Radar flight tracks from non-DIA operations are omitted from the figure for purposes of clarity.

If the surfaces that represent pseudo-complaint terrain and pseudo-flight track terrain are cross-correlated, the resulting surface would provide a visual representation over a geographic area of the relationship between complaints and aircraft overflights. Figure 12 (on page 24) is such a figure, created by draping complaint density contours over an arrival and departure flight track density elevation map. In this figure, elevation represents flight track density. The figure shows (*inter alia*) that even though airport proximity does not strongly affect complaint density, the density of complaints can be closely associated with flight track density.

4.2.2.3 Complaint rates as functions of flight track density

Figure 5 illustrates a notional relationship between local flight track density (number of flights per unit of time over a given neighborhood) and population-weighted complaint rates. Constructing such a relationship requires only three steps:

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[5] The time periods for which complaints and flight track information are depicted in some figures do not coincide. Although this mis-match does not affect the illustrative value of the figures, definitive conclusions about relationships between flight tracks and complaints should not be drawn from the figures in this report.

- counting (and classifying by aircraft type, operation or altitude as desired) transponder returns with respect to municipal, census tract, political jurisdiction or other geographic boundaries;

- normalizing the numbers of complaints originating within each land area of interest, either by total population or population within demographic categories of interest; and

- fitting a curve through the resulting pairs of (flight track density, per capita complaint rate) points.

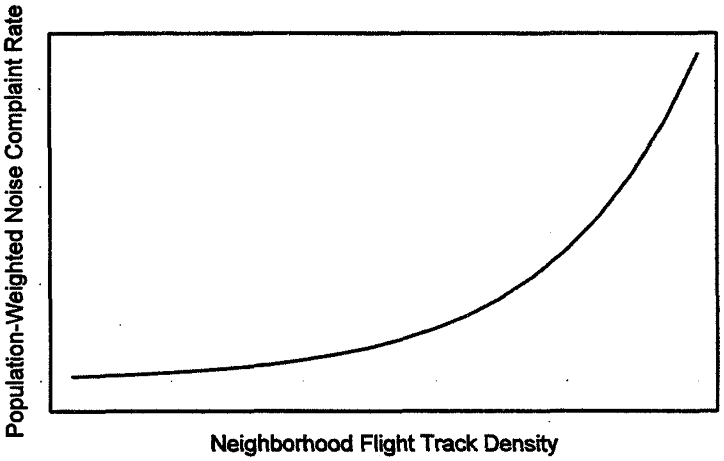

Figure 5 Notional relationship between flight track density in airspace above residential neighborhoods and *per capita* complaint rates.

Similar relationships could likewise be constructed for other statistics and subsets of flight track distributions: nighttime operations, mean altitude, variance in altitude, turboprop and jet aircraft, *etc.* Relationships of this sort might help to establish whether complaints are more predictable from numbers of flight operations than from maximum or integrated noise levels.

4.3 TEMPORAL ANALYSES

Relationships among single event sound levels, short- and long-term average sound levels, and complaints can also be quantified and summarized over varying time periods and exposure conditions. Some neighborhoods near airports with variable air traffic flow from wind-driven alternation between departure and approach operations, for example, experience persistent shifts in cumulative aircraft noise levels of 10 to 15 dB for periods of days at a time. Trend analyses of complaint rates following level shifts of this sort might increase understanding not only of the relationships between complaints and annoyance, but also of the level shifts and time course of complaint behavior. Such analyses may be attempted over a range of time scales, depending on the temporal resolution and reliability of complaint information.

4.3.1 Short-Term Variability in Aircraft Traffic

Predictable daily traffic patterns prevail at most major airports with scheduled flight service. To minimize delay and maximize capacity, large airports with multiple runways have developed standard operating procedures that often segregate aircraft by type and operation. For example, arriving and departing flights at large civil airports may routinely be concentrated on particular runway ends at different times of day. A flurry of arrivals, followed by a flurry of departures 45 minutes to an hour later, is a recurring activity pattern throughout the day at hub airports. Since arrivals and departures generally operate from opposite runway ends, operations at such airports can cycle from one side of an airport to another at roughly two hour intervals throughout the day.

To the extent that complaints are associated with the aggregate short-term noise energy produced by flight operations, complaint records from residential areas at opposite runway ends should in principle reflect hourly L_{eq} values within neighborhoods. If complaints are more closely linked to unusual or unexpected noise events than to total noise exposure, however, airport operating patterns or short-term equivalent noise levels may have little to do with times of complaints.

4.3.2 Potential Sequential Effects of Repetitive Flight Operations

Complaints may be more predictable from sequences of flight operations than from individual overflights. Anecdotally, for example, it is sometimes observed that a stream of arriving flights generates a higher rate of complaints in a neighborhood near the arrival end of a runway than a stream of departing flights in a neighborhood near the departure end of a runway — even though sound exposure levels of departing flights may be considerably higher than those of arriving flights. Because departing flights often diverge from the runway heading shortly after takeoff, variability in the intervals between departing flights (as observed at a given point on the ground) may be greater than for an arriving flight stream, in which aircraft typically maintain the runway heading for several miles.

The net effect for a resident of a neighborhood under a landing path may thus be a seemingly unending sequence of noise intrusions at two minute intervals for hours at a time. It is reasonable to question whether this steady repetition of noise intrusions leads to an increasing likelihood of complaint for later overflights than for earlier, otherwise acoustically similar ones.

4.3.3 Day-to-Day Variability in Flight Patterns

Wind direction, runway repairs, and other short-term operational factors affect runway use patterns on a daily time scale. Figures 13 through 16, on pages 24 through 25, show approach and departure flight tracks for different days at DIA. On 1 July 1997, the bulk of the arriving traffic approached from the south and the bulk of departing traffic left to the north and west. On 15 August 1997, the majority of arriving traffic landed from the north while outbound traffic departed predominantly to the east and west. Examination of complaint histories on days with disparate operating patterns could provide useful documentation of linkages between operational factors and complaints.

4.3.4 Seasonal Variation in Complaint Rates

Distinctions between "open window" and "closed window" complaint seasons are often observed at airports in areas with pronounced climate variation. Analyses of complaint rates as a function of season can yield useful information about potential benefits of noise mitigation measures, and about the effect of noise level *per se* (as distinct from numbers or times of aircraft operations) on community response to aircraft noise. If an historical record of complaints and air traffic extends over several seasonal cycles, it would also be possible to control for operational changes and other nuisance variables that occur from year to year that might otherwise obscure trends of interest.

4.3.5 Time Constants of Complaints Following Changes in Flight Operations

Shifts in air traffic overflying airport neighborhoods may occur from time to time for weather-related reasons, for compliance with preferential runway use schemes, or for other reasons. Each of these can be viewed as a naturally-occurring form of experimental manipulation of noise exposure. The times at which such shifts occur can be deduced from patterns of aircraft transponder position reports (if runway use is not explicitly recorded by the monitoring system), and used to define starting points of intervals during which complaint rates per unit time can be tabulated.

For example, if the primary traffic flow direction at an airport is reversed for a period of hours or days due to changes in prevailing wind, then a community off the usual approach end of a runway may suddenly experience a 10 dB increase in noise exposure while it is overflown by departing traffic. The sensitivity of complaint rates to step changes in noise exposure can be quantified by identifying the times of occurrence of such events, and relating the times of receipt of complaints to them. If a long enough record of complaints and aircraft operations is available, it might be possible to identify dozens of such naturally-occurring experimental manipulations.

The extent to which complaints increase in number and/or rate during times of increased air traffic and noise exposure reflects the degree to which complaints can be related to physically measurable aspects of aircraft operations. If increases in complaint numbers or rates reliably follow changes in flight patterns, both the magnitude and time constants of such increases would be of considerable interest for local noise management purposes as well as for advancing quantitative understanding of community response to noise.

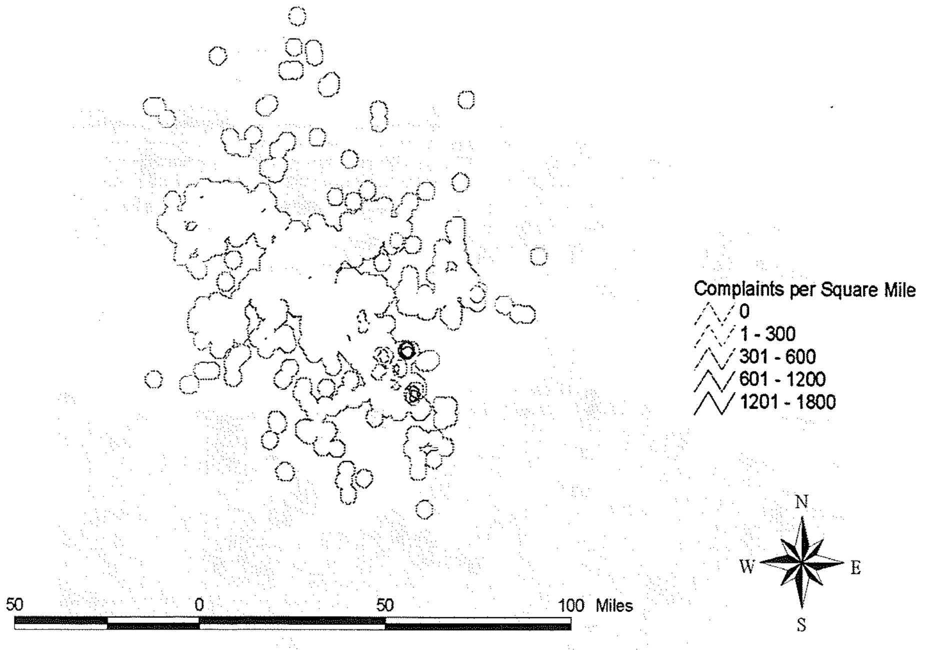

Figure 6 Contours created from aircraft noise complaints lodged with Denver International Airport from January 1995 through March 1997. Runways are lines in center of figure.

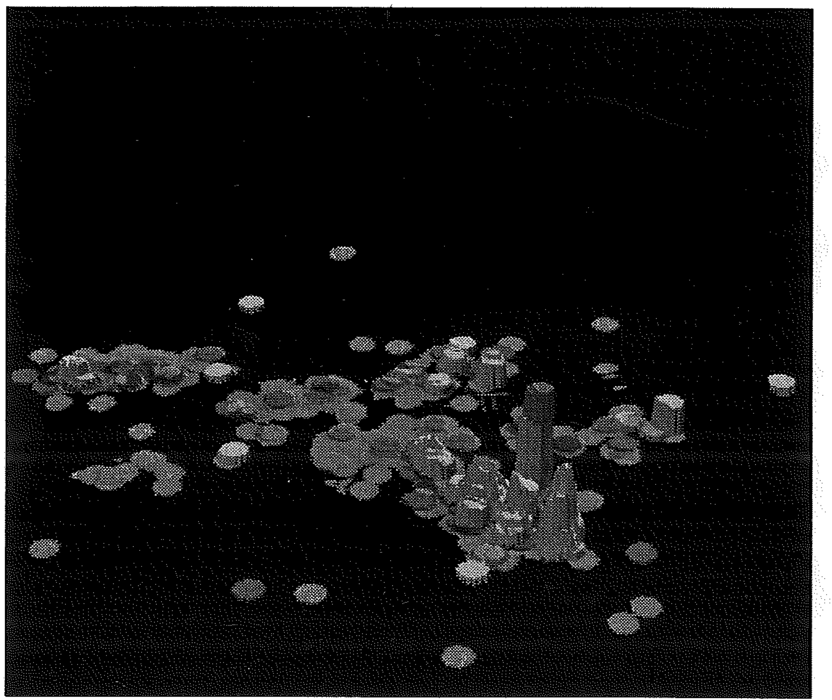

Figure 7 Pseudo-terrain, viewed from the south, created from “daytime” (7:00 AM to 10:00 PM) noise complaints at Denver International Airport for January 1995 through March 1997. Area viewed is approximately 85 miles across.

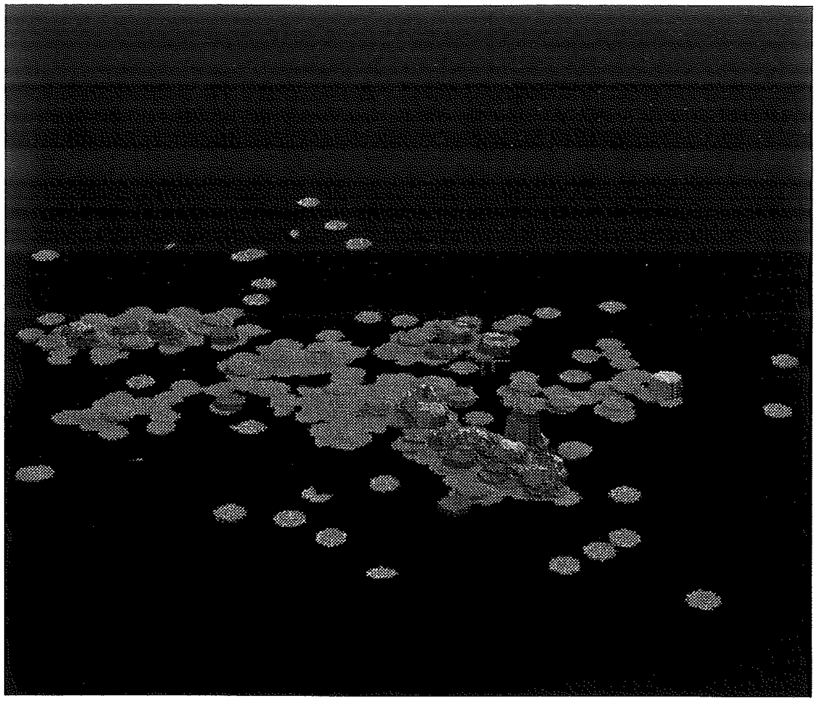

Figure 8 Pseudo-terrain constructed from "nighttime" (10:00 PM to 7:00 AM) noise complaints at Denver International Airport for January 1995 through March 1997.

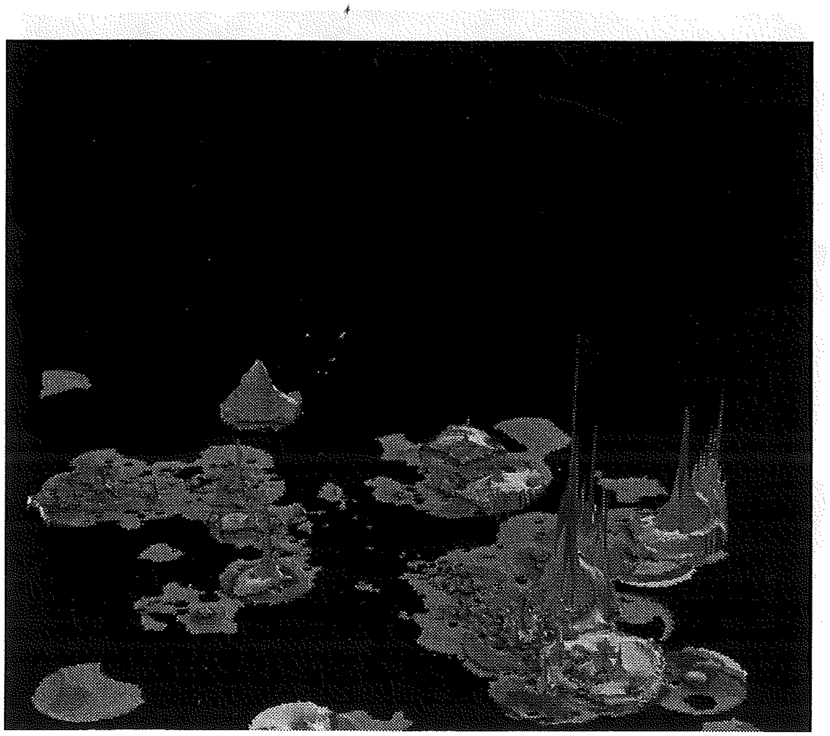

Figure 9 Spot analysis of complaint frequency at Denver International Airport for January 1995 through March 1997. Airport runways are near center of figure.

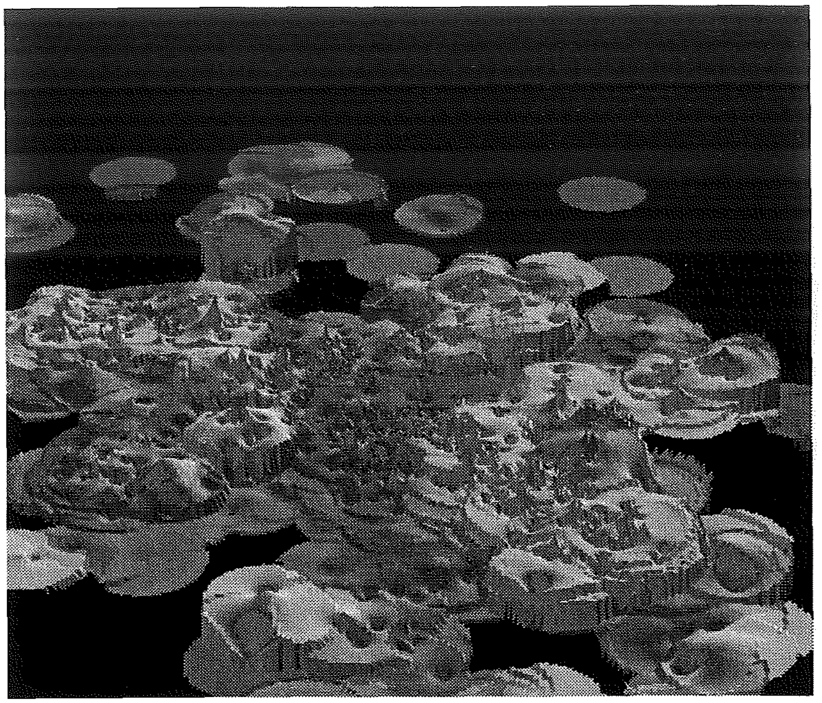

Figure 10 Three dimensional representation of pseudo-terrain constructed from logarithmically transformed complaint information for Denver International Airport for January 1995 through March 1997. Complaint frequencies are encoded by elevation.

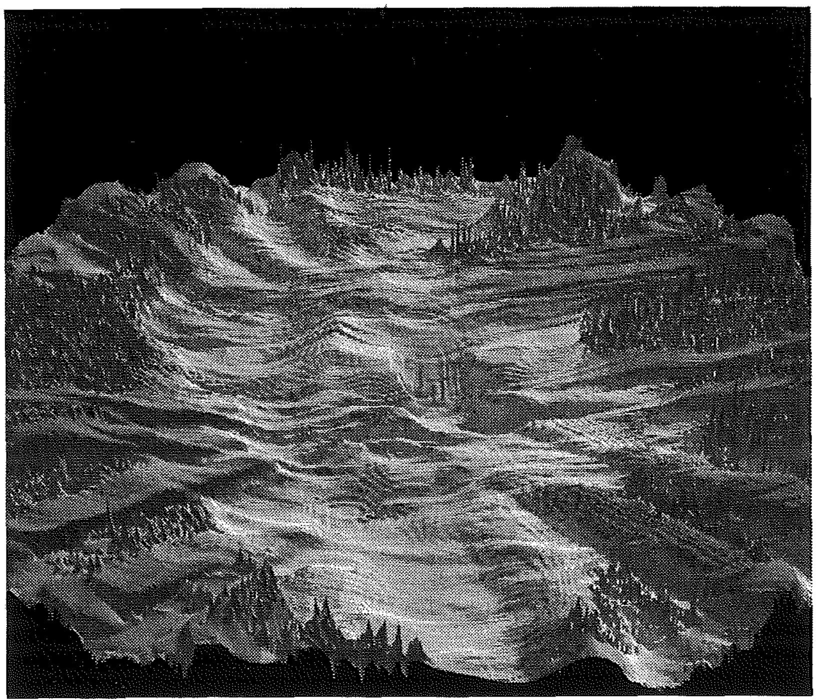

Figure 11 Three dimensional representation of flight tracks approaching and departing Denver International Airport within a 50 mile radius on a single day. Altitude is encoded by elevation. Airport runways are in valley at center of figure.

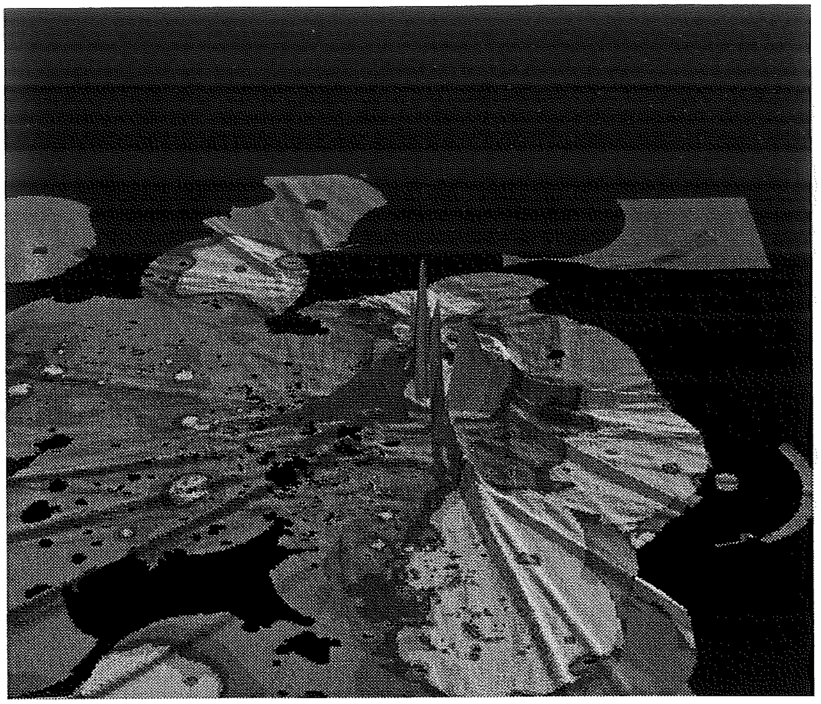

Figure 12 Complaint density draped over elevation-coded flight track density at Denver International Airport.

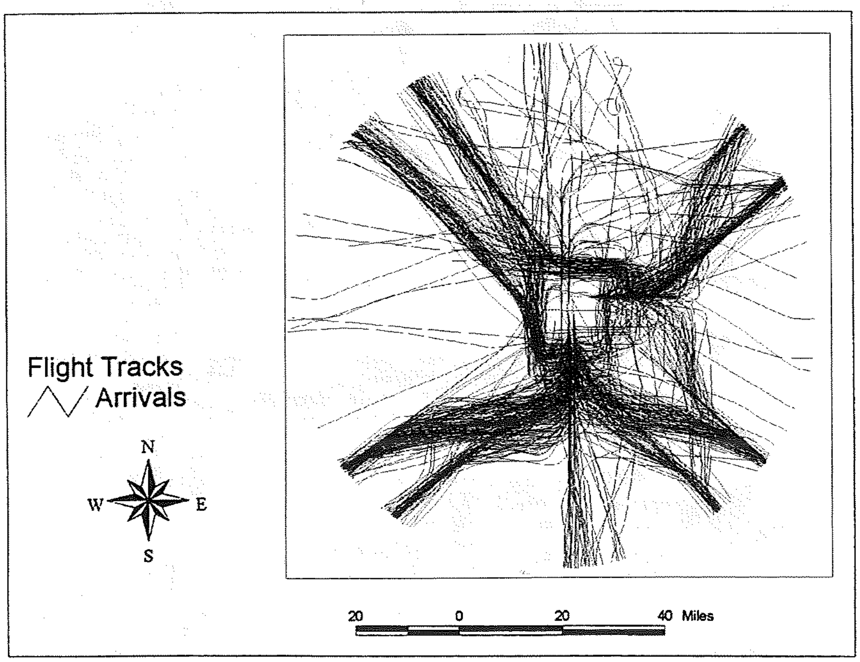

Figure 13 Arrival tracks at Denver International Airport on 1 July 1997.

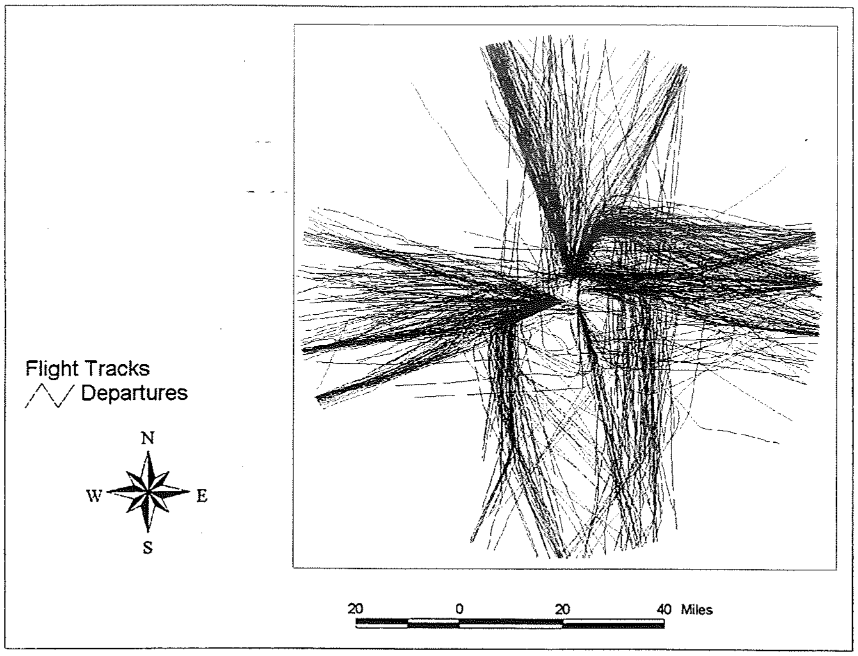

Figure 14 Departure tracks at Denver International Airport on 1 July 1997.

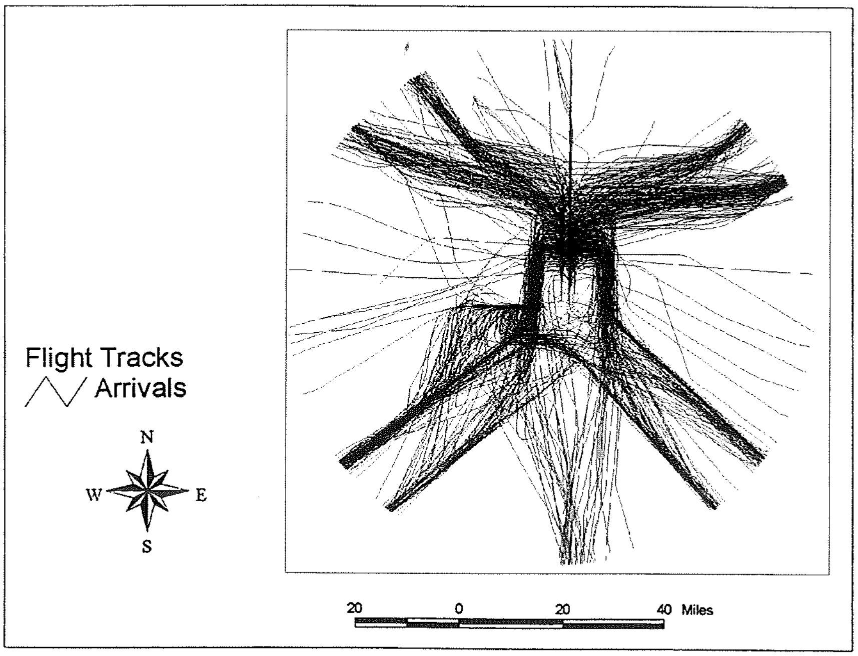

Figure 15 Arrival tracks at Denver International Airport on 15 August 1997.

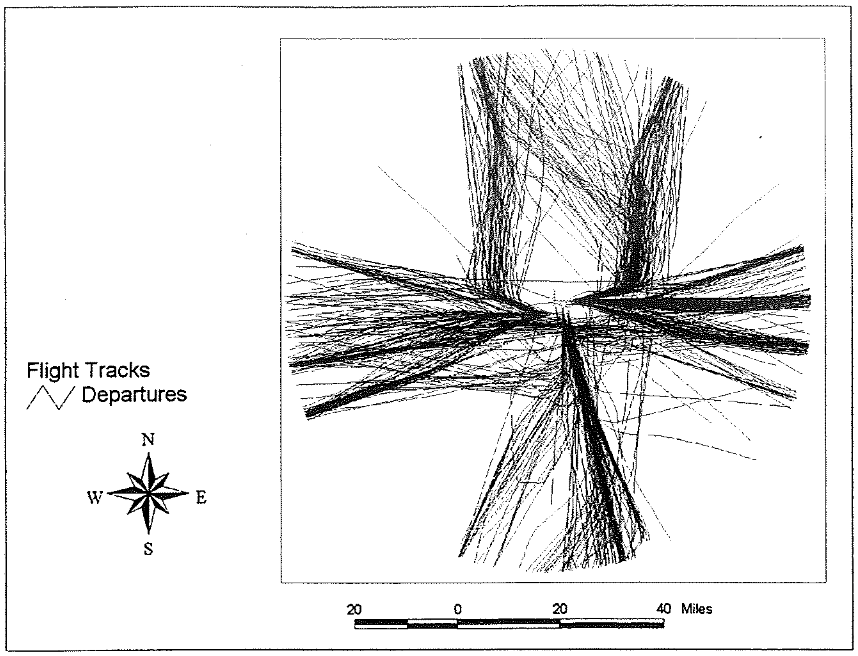

Figure 16 Departure tracks at Denver International Airport on 15 August 1997.

5 AVAILABILITY OF ARCHIVAL NOISE COMPLAINT AND AIRCRAFT OPERATIONAL INFORMATION

Extensive complaint and related operational information is available for analysis from several sources. Perhaps the largest database of airport complaint information in the United States (for Denver International Airport) is accessible through Adams County, Colorado. Adams County has a right of access and use of such information contractually guaranteed by an Intergovernmental Agreement, and has already made such information available for preliminary analyses. The complaint database at this airport is of particular interest for several reasons:

- the unusually large number of complaints apparently associated with airport start-up;
- the extensive spatial distribution of noise monitoring points;
- the great distances from the airport from which complaints have been received;
- the large number of aircraft operations;
- the occurrence of sudden and well-documented shifts in aircraft approach and departure procedures;
- the completeness of the complaint record (commencing with the opening of the airport); and
- the consistency of archiving of complaint information within a single, modern software system.

Phoenix Sky Harbor is another airport at which ready access to a complaint database is known to be available. The Tracor system operational at this airport for the last two years can easily export complaint, noise measurement, and flight track information, and cooperative access to all information collected by the system is available. Permission to analyze complaint data for research purposes can almost certainly be arranged at a number of other airports with modern monitoring systems as well.

6 CONCLUSIONS

Aircraft noise complaint and flight operation information archived in databases created by modern airport monitoring systems can support a range of novel and informative analyses that can advance understanding of community response to aircraft noise. Analyses of such information can provide useful information about several longstanding concerns, including:

- the extent to which complaint rates are driven by objectively measurable aspects of aircraft operations;
- the degree to which changes in complaint rates can be predicted prior to implementation of noise mitigation measures; and
- the degree to which aircraft complaint information can be used to simplify and otherwise improve prediction of the prevalence of noise-induced annoyance in communities.

Both the information and the software tools necessary to perform such analyses on data exported from airport monitoring systems are readily available. Fresh insights into the nature and interpretation of complaint information are especially likely to stem from geoinformation system processing of complaint and flight path information. Improved understanding of relationships between complaints and annoyance can also be expected to clarify the circumstances in which alternate definitions of "community response to aircraft noise" are most appropriate, and to bridge the gap between them.

7 ACKNOWLEDGMENTS

The authors are grateful to the Planning and Development Department of Adams County, Colorado, for providing access to a database of aircraft noise complaints and associated operational information for preliminary analyses.

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APPENDIX A NOISE EVENT CLASSIFICATION PERFORMANCE OF MONITORING SYSTEMS

Classification of the origin of noise events by acoustic means is an example of decision making under conditions of uncertainty and risk. The classic example of such a system is one that attempts to detect a signal embedded in noise. A detection system of this sort may also be thought of as performing a classification task, in which the goal is to correctly classify an observation as due to noise alone or to signal plus noise.

The design and performance of systems undertaking such tasks has been the subject of formal mathematical study for several decades, generally under the rubric of "signal detection theory." As is common in any technical field, certain terms acquire specialized meanings. Use of terminology in this document conforms to that of Green and Swets.[6] This Appendix clarifies several key terms.

A.1 TYPES OF CORRECT AND INCORRECT CLASSIFICATION DECISIONS

As shown in Table 1, two types of "correct" and two types of "incorrect" decisions are possible with respect to classification of the sources of noise events as either aircraft or non-aircraft. It is helpful to distinguish between the two types of correct and incorrect decisions to avoid confusion about the performance of classification algorithms. Some algorithms, for example, may be able to correctly classify an acceptably high proportion of aircraft noise events as aircraft, but may mis-classify an unacceptably high proportion of non-aircraft noise events as aircraft as well.

One way to avoid confusing the different types of correct and incorrect decisions is to consider the decision outcome with respect to the testing of a single hypothesis; for example, the hypothesis that a noise event is produced by an aircraft operation. The corresponding truth table is seen in Table 2.

Table 1 Truth table for classification of noise events.

		True Origin of Noise Event	
		Noise event actually produced by a non-aircraft source	Noise event actually produced by an aircraft
Classification Decision	Origin of noise event classified as non-aircraft	CORRECT DECISION	INCORRECT DECISION
	Origin of noise event classified as aircraft	INCORRECT DECISION	CORRECT DECISION

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[6] Green, D. M., and Swets, J. A. "Signal Detection Theory and Psychophysics," John Wiley and Sons, Inc., New York, 1966.

Table 2 Truth table for decision outcomes defined with respect to testing of a single hypothesis.

		True Origin of Noise Event	
		Noise event actually produced by a non-aircraft source	Noise event actually produced by an aircraft
Action with Respect to Hypothesis that Noise Event is Due to an Aircraft	Reject hypothesis that noise event is caused by an aircraft operation	CORRECT REJECTION	MISS
	Accept hypothesis that noise event is caused by an aircraft operation	FALSE ALARM	HIT

A.2 RECEIVER OPERATING CHARACTERISTIC

Each column and each row of Table 2 is independent of the other. Correct rejections and false alarms can occur only when a noise source is not in fact an aircraft. Misses and hits can occur only when the true source of a noise event is an aircraft. Since the four decision outcomes in Table 2 (correct rejections, misses, false alarms, and hits) have only two degrees of freedom, they may be conveniently plotted on orthogonal axes. By convention, the proportion (or probability) of hits— that is, assertions that a noise event is caused by an aircraft operation when it actually ***is*** caused by an aircraft operation—is plotted on the ordinate, while the proportion (or probability) of false alarms —that is, assertions that a noise event is caused by an aircraft when it is actually caused by a different source—is plotted on the abscissa.

Such a plot is called a Receiver Operating Characteristic, or an ROC curve. An ROC curve is an isosensitivity plot that summarizes the ratio of hits and false alarms that a decision system exhibits when working under different conditions. An ROC plot can also show the limits of performance that a system of fixed sensitivity can achieve. A detection or classification system of fixed sensitivity can exhibit a variety of behaviors (that is, performances characterized by varying ratios of hits to false alarms), but cannot exceed a given maximum ratio of hits to false alarms.

A.3 INDEX OF SENSITIVITY

Although the ratio of hits to false alarms is a useful index of any decision system's performance, the underlying sensitivity that supports performance is most conveniently characterized by a scalar quantity known as d' (pronounced "d-prime"). In mathematical terms, d' is the difference between the means of the distribution of noise alone and the distribution of signal plus noise, divided by the standard deviation of the noise distribution. In inferential statistics, this quantity resembles Student's t-statistic. In acoustic terms, d' is controlled by a bandwidth-adjusted signal to noise ratio.

Thus, it is convenient for some purposes to characterize the performance of a classification system in terms of its sensitivity, in units of d'. Tables have been prepared of d' values corresponding to various ratios of hits to false alarms for certain standard cases, such as equal variance Gaussian distributions of noise alone and signal plus noise. For example, a classification system that exhibits a probability of a hit of 0.90 and a probability of a false alarm of 0.05 has the same sensitivity as a classification system that has a probability of a hit of 0.95 and a probability of a false alarm of 0.10.

APPENDIX B USING COMPLAINT INFORMATION TO INDEPENDENTLY ESTIMATE RESPONSE BIAS

This Appendix reviews methods for predicting "community response" to aircraft noise through empirical and theoretical dosage-response relationships, and the potential role that complaint information could play in improving such predictions. Portions of the text paraphrase that of Green and Fidell (1991).

B.1 PREDICTION OF AIRCRAFT NOISE ANNOYANCE VIA DOSAGE-RESPONSE RELATIONSHIP

Assessment of community response to aircraft noise is generally accomplished with respect to a dosage-response relationship that predicts the prevalence of a consequential degree of annoyance in a community for a given level of noise exposure. Interpretations of land use compatibility and regulations affecting the availability of federal funding for aircraft noise mitigation, for example, are based on the FICON (1992) relationship seen in Figure 17 for predicting the prevalence of annoyance from a long-term average A-weighted measure of noise exposure (Day-Night Average Sound Level). The FICON relationship is a forced curve fit[7] to a data set composed of hundreds of paired observations of the prevalence of self-reported annoyance in residential areas with measured or estimated DNL values.

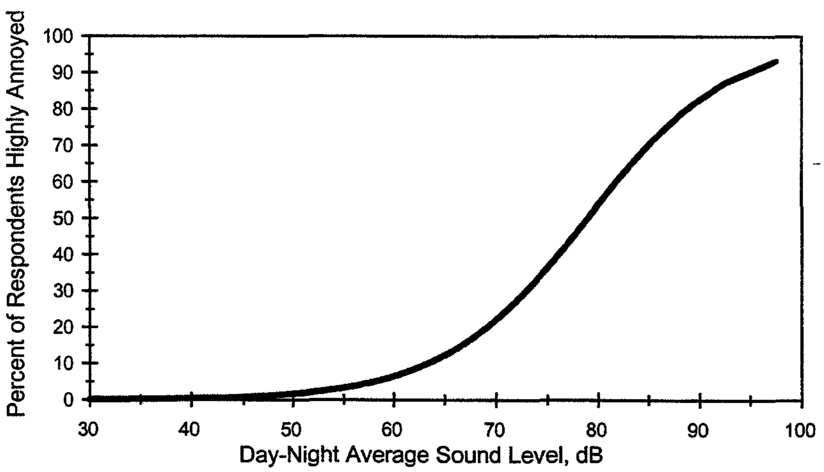

Figure 17 Dosage-response relationship endorsed by FICON for purposes of predicting annoyance produced by (A-weighted) long-term average noise exposure.

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[7] The fit is arbitrary in the sense that its sigmoidal form was assumed *a priori*; that no theory-based justification was offered for preferring this fitting function to a conventional least-squares fit; and that certain data points were intentionally omitted from the analysis.

B.2 THEORY-BASED PREDICTION OF THE PREVALENCE OF ANNOYANCE

Given the fundamental arbitrariness of any dosage-response relationship derived from a curve fitting exercise, not to mention the inability of any useful curve fit to provide a satisfactory account for data with as much variance as is apparent in Figure 2 (page 5), it is not unreasonable to seek an alternate approach to predicting noise-induced annoyance. Fidell, Schultz, and Green (1988) have developed one such approach, in the form of a normative, probabilistic model of the relationship between noise exposure and the observed prevalence of annoyance in communities. The model partitions self-reports of annoyance into two components: one associated with physical noise exposure and one associated with non-acoustic factors. The sole free parameter of the model is the criterion level of noise exposure which individuals adopt when describing themselves as highly annoyed.

B.2.1 Review of Theoretical Model of Prevalence of Annoyance

A basic assumption of the model is that Day-Night Average Sound Level (DNL) provides an adequate description of the integrated noise exposure produced by environmental noise sources such as aircraft and surface traffic. This exposure is regarded as a treatment given to a population of individuals. The reactions of individuals in the community to this exposure are summarized by a random variable, x, assumed to be exponentially distributed with a mean population value of m. This mean parameter, m, is assumed to grow as a power-law transformation of noise exposure, DNL, just as the effective loudness of sounds grows as sound energy raised to the 0.3 power (Stevens, 1972). Thus, noise exposure establishes a distribution of reactions within a community with a mean value that grows monotonically, but nonlinearly, with magnitude of noise exposure.

The model assumes that individuals describe themselves as highly annoyed if their reactions, x, to noise exposure exceed some response criterion, A. Self-reports of annoyance may therefore be treated as outcomes of a decision-making process that is influenced by both acoustic and nonacoustic factors. The net effect of the nonacoustic factors on the decision-making process may be regarded as a form of response bias. The proportion of the population describing itself as highly annoyed can be predicted from the area of the distribution of x that is greater than the value of the criterion adopted for reporting annoyance, A. The model relies on DNL as a sufficient metric of community noise exposure, and assumes that m is a power-law transformation of DNL with an exponent of 0.3. The criterion for reporting annoyance is thus the only free parameter of the model.[8]

The criterion value for reporting annoyance may vary from neighborhood to neighborhood for any number of nonacoustic reasons. The criterion value may differ because the residents of one neighborhood value the commerce or convenience associated with operation of a noise source more highly than residents of another neighborhood; or because greater media or political attention has been focused on environmental problems in one neighborhood than in another; or because non-environmental problems are more pressing to residents of one neighborhood than of another; and so forth.

It is the prescriptive nature of this model that permits it to be used to estimate the relative influences of acoustic and non-acoustic factors on the expressed prevalence of annoyance in a community. Since the acoustically determined component of reaction to noise exposure is asserted to grow as does loudness,

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[8] A more formal derivation of this model may be found in Green and Fidell (1991).

deviations from this predictable growth rate can be attributed to the effects of non-acoustic factors on self-reported annoyance. Using the model predictively, however, requires an independent source of information about the response bias (non-acoustic) parameter.

It is possible that population-weighted complaint rates can serve as such an independent source of information to estimate the degree of response bias in a community without conduct of a social survey. A complaint, after all, is an expression of a complainant's agenda with respect to an airport: not merely his perceptions of aircraft noise, but also his expectations, preferences, and overall tolerance for aircraft noise intrusions.

B.2.2 Estimating the Response Bias Parameter of Theoretical Model

Addition of a response bias parameter permits the Green and Fidell model to account for considerably more variance than FICON's descriptive curve fit. However, truly predictive applications of the Green and Fidell model are not possible without an independent estimate of the response bias parameter for a given community. Complaint rates (adjusted for population size and flight track density) might provide one basis for an independent estimate of response bias within a community. The rate at which a set of aircraft operations generates complaints from a given residential population may reflect a community's overall willingness to consider itself consequentially annoyed by such overflights.

Two hypothetical cases (simplified for purposes of exposition in Tables 3 and 4) illustrate this point. In the first, the population-weighted complaint rate is directly proportional to DNL, while in the second the relationship is inverse. Both cases pertain to a hypothetical single runway airport with a uniform spatial distribution of urban residential development (15,000 people per square mile) beyond the departure end of a runway with 4000 scheduled departures per week.

The rows of both tables are 5 dB intervals bounded by DNL contours. The residential area tabulated in the second column for each noise exposure interval is that within ±½ mile of the extended runway centerline, the assumed heading for all departures. The third column estimates the number of households (at 3.75 people per household) within half a mile to either side of the standard departure heading. The fourth column displays the product of the assumed number of weekly departures (4,000) and the number of households, on the assumption that each household contains no more than a single complainant. (Note that the suggested normalization is to numbers of complainants rather than number of complaints.)

The "Weekly Complaints Received" column shows hypothetical numbers of aircraft noise complaints received from households within each noise exposure contour. The next column normalizes these complaint rates to numbers of overflights of individual households. The final column is simply FICON's prediction of the prevalence of high annoyance (% Highly Annoyed = $100 / 1 + e^{(11.13 - .141 L_{dn})}$, as plotted in Figure 17) at the mid-point of each noise exposure interval.

Table 3 illustrates a case in which complaints and annoyance are both assumed to increase in proportion to noise exposure level, and hence in direct proportion to one another. This is a reasonable (and readily confirmed) assumption with respect to the prevalence of noise-induced annoyance. It is also a common and intuitively appealing assumption with respect to complaints, but it is neither a necessary one nor one that likely to be verifiable in actual airport experience.

Table 4 illustrates a case in which only annoyance is assumed to increase with noise exposure level. Complaint rates are assumed to be inversely proportional to noise exposure levels (a common pattern at operating airports, as described in Section 2.4), and hence, to be inversely related to the prevalence of annoyance.

The basic point of this exercise, however, is not to speculate about the direction of relationships or amounts of shared variance between complaint rates, prevalence of annoyance, and noise exposure. The response bias parameter of Green and Fidell is intended to account for the variance in prevalence of annoyance that is ***not*** related to noise exposure, and complaints are known to be only poorly correlated with cumulative exposure in any event. The point of the exercise is to indicate that however complaint rates vary from one airport neighborhood to another, they may still serve as useful estimators of response bias.

Table 3 Illustration of hypothetical relationships among cumulative noise exposure, complaints, and annoyance: Case 1 — weekly complaint rate directly proportional to noise exposure.

DNL Interval (dB)	Residential Area (square miles)	Households	Weekly Complaint Opportunities (millions)	Weekly Complaints Received	Proportion of Complaints Received to Opportunities	Predicted Prevalence of High Annoyance (%)
50-55	4	4,000	16	25	1.6×10^{-6}	2.4
55-60	3	3,000	12	35	2.9×10^{-6}	4.6
60-65	2	2,000	8	40	5.0×10^{-6}	9.0
65-70	0.5	500	2	50	2.5×10^{-5}	16.6
70-75	0.25	250	1	50	5.0×10^{-5}	28.8

Table 4 Illustration of hypothetical relationships among cumulative noise exposure, complaints, and annoyance: Case 2 — weekly complaint rate inversely proportional to noise exposure.

DNL Interval (dB)	Residential Area (square miles)	Households	Weekly Complaint Opportunities (millions)	Weekly Complaints Received	Proportion of Complaints Received to Opportunities	Predicted Prevalence of High Annoyance (%)
50-55	4	4,000	16	100	6.3×10^{-6}	2.4
55-60	3	3,000	12	50	4.2×10^{-6}	4.6
60-65	2	2,000	8	25	3.1×10^{-6}	9.0
65-70	0.5	500	2	15	7.5×10^{-6}	16.6
70-75	0.25	250	1	10	1.0×10^{-5}	28.8

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY (*Leave blank*)	**2. REPORT DATE** April 1998	**3. REPORT TYPE AND DATES COVERED** Contractor Report

4. TITLE AND SUBTITLE
Use of Airport Noise Complaint Files to Improve Understanding of Community Response to Aircraft Noise

5. FUNDING NUMBERS
C NAS1-20101
WU 538-03-15-01
TA 15

6. AUTHOR(S)
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8. PERFORMING ORGANIZATION REPORT NUMBER
BBN Report 8215

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
National Aeronautics and Space Administration
Langley Research Center
Hampton, VA 23681-2199

10. SPONSORING/MONITORING AGENCY REPORT NUMBER
NASA/CR-1998-207650

11. SUPPLEMENTARY NOTES
Langley Technical Monitor: Kevin P. Shepherd; Final Report - Task 15

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Unclassified - Unlimited
Subject Category 71 Distribution: Nonstandard
Availability: NASA CASI (301) 621-0390

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

This study assessed the feasibility of using complaint information archived by modern airport monitoring systems to conduct quantitative analyses of the causes of aircraft noise complaints and their relationship to noise-induced annoyance. It was found that all computer-based airport monitoring systems provide at least rudimentary tools for performing data base searches by complainant name, address, date, time of day, and types of aircraft and complaints. Analyses of such information can provide useful information about longstanding concerns, such as the extent to which complaint rates are driven by objectively measurable aspects of aircraft operations; the degree to which changes in complaint rates can be predicted prior to implementation of noise mitigation measures; and the degree to which aircraft complaint information can be used to simplify and otherwise improve prediction of the prevalence of noise-induced annoyance in communities.

14. SUBJECT TERMS
Complaint Data Bases; ANOMS; ENOMS; Geocoding; Noise-Induced Annoyance

15. NUMBER OF PAGES
46

16. PRICE CODE
A03

17. SECURITY CLASSIFICATION OF REPORT Unclassified	**18. SECURITY CLASSIFICATION OF THIS PAGE** Unclassified	**19. SECURITY CLASSIFICATION OF ABSTRACT** Unclassified	**20. LIMITATION OF ABSTRACT**