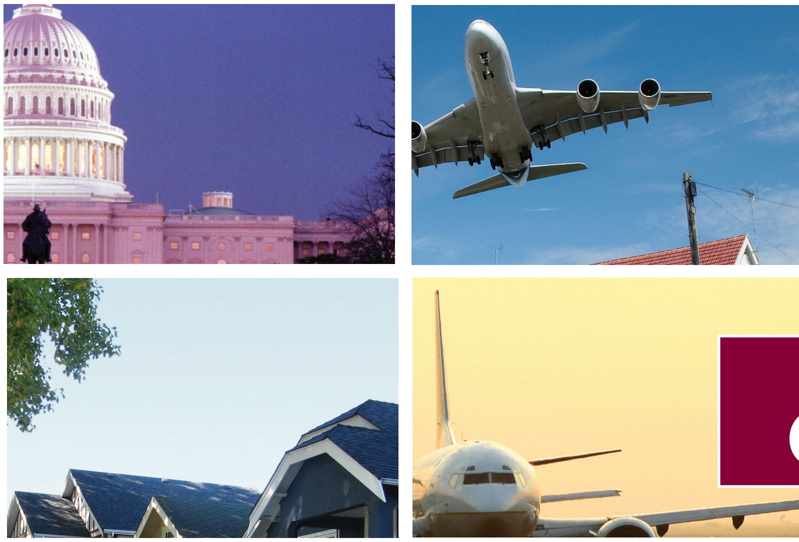
Hawthorne Municipal Airport

Appendix C

Resource Library



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Federal Aviation Noise Regulations

In the early days of commercial aviation, communities close to an airport were not greatly affected by the occasional propeller aircraft overflight. However, in the late 1960s and early 1970s, the problem of aircraft noise became increasingly apparent with the beginning of the jet age. The Deregulation Act of 1978 intensified the issue of airport noise as the act allowed for a more competitive environment between air carriers and the routes that they served. The increased competition brought better and more affordable services, an increase in demand, and an increase in jet noise.

"As air travel expanded, residents living in close proximity to the nation's airports became increasingly concerned."

As air travel expanded, residents living in close proximity to the nation's airports became increasingly concerned. Citizens began to form activist groups and take action against local policy makers and airport operators. With the increasing concerns, complaints and environmental awareness, the airport noise issue became a serious problem amongthe airports, airlines, and the residents living close to the nation's airports.

From a national perspective, federal agencies began studying aircraft noise and developing planning guidelines. In 1970, the National Environmental Policy Act of 1969 (NEPA) was the first federal legislation requiring airport operators to study and analyze aircraft noise impacts before undertaking major development or improvement projects. For airport operators to gain approval for major projects, they had to develop an Environmental Assessment (EA) or Environmental Impact Statement (EIS) that outlined the potential noise impacts of any proposed project on residents surrounding the airport.

After NEPA was passed, the Department of Transportation (DOT) and the Federal Aviation Administration (FAA) adopted the Aviation Noise Abatement Policy (ANAP) in 1976. The ANAP clearly identified aircraft noise responsibilities for the FAA, air carriers, airport operators, and local jurisdictions.

The importance of airport noise impacts was first recognized at a national level in the Aviation Safety and Noise Abatement Act of 1979. This act required the FAA to adopt regulations establishing a single system of measuring aircraft noise and determining the exposure of individuals to noise in the vicinity of airports.

FEDERAL REGULATIONS

Reduction of aircraft noise impacts is a complex issue with several parties sharing in the responsibility: the federal government, state and local governments, planning agencies, the airport proprietor, airport users, airport manufacturers, and local residents. The purpose of this

technical information paper is to provide a summary of the aviation noise regulations and responsibilities at the federal level.

Aviation plays a vital role in interstate commerce. Recognizing this, the federal government has assumed the role of coordinator and regulator of the nation's aviation system. Congress has assigned administrative and regulatory authority to the Federal Aviation Administration (FAA) whose responsibilities include:

- The regulation of air commerce in order to promote its development, safety, and to fulfill the requirements of national defense.
- The promotion, encouragement, and development of civil aeronautics.
- The control of the use of navigable airspace and the regulation of civil and military aircraft operations to promote the safety and efficiency of both.
- The development and operation of a common system of air traffic control and navigation for both military and civil aircraft.

The FAA also administers a program of federal grants-in-aid for the development of airport master plans, the acquisition of land, and for planning, design, and construction of eligible airport improvements. In addition, Congress passed legislation and the FAA established regulations governing the preparation of noise compatibility programs. Laws and regulations were also implemented which required the conversion of the commercial aircraft fleet to quieter aircraft. The following sections summarize these regulations found in Title 14 of the Code of Federal Regulations (14 CFR).

"Reduction of aircraft noise impacts is a complex issue with several parties sharing in the responsibility..."

Part 150 Noise Compatibility Studies

The Aviation Safety and Noise Abatement Act of 1979 (United States Code, Title 49, Sections 47501-47510), signed into law on February 18, 1980, was enacted, "…to provide and carry out noise compatibility programs, to provide assistance to assure continued safety in aviation, and for other purposes." The FAA was vested with the authority to implement and administer the Act.

14 CFR Part 150 (Part 150), the administrative rule promulgated to implement the Act, sets requirements for airport operators who choose to undertake an airport noise compatibility study with federal funding assistance. Part 150 provides for the development of two final documents: the Noise Exposure Maps and the Noise Compatibility Program.

Noise Exposure Maps. The Noise Exposure Maps (NEM) document describes existing and future noise conditions at the airport. It can be thought of as a baseline analysis defining the scope of the noise situation at the airport and including maps of noise exposure for the current year, five-year, and long-range forecasts. The noise contours are depicted on various land use maps to reveal areas of non-compatible land use. Included in the document is detailed supporting information which explains the methods used to develop the maps.

Part 150 requires the use of standard methodologies and metrics for analyzing and describing noise. It also establishes guidelines for the identification of land uses which are incompatible with different noise levels. Airport proprietors are required to update noise exposure maps when changes in the operation of the airport would create any new, substantial non-compatible use. This is defined as an increase in the yearly day-night average sound level (DNL) or community noise equivalent level in California (CNEL) of 1.5 decibels over non-compatible land uses.

A limited degree of legal protection can be afforded to the airport proprietor through preparation of noise exposure maps. Section 47506 of the recodified Aviation Safety and Noise Abatement Act of 1979 (ASNA) provides that:

> A person acquiring an interest in property…in an area surrounding an airport for which a noise exposure map has been submitted… and having actual or constructive knowledge of the existence of the map may recover damages for noise attributable to the airport only if, in addition to any other elements for recovery of damages, the person shows that:
>
> (1) after acquiring the interest, there was a significant
>
> (A) change in the type or frequency of aircraft operations at the airport;
>
> (B) change in the airport layout;
>
> (C) change in flight patterns; or
>
> (D) increase in nighttime operations; and
>
> (2) the damages resulted from the change or increase.

ASNA provides that "constructive knowledge" shall be attributed to any person if a copy of the noise exposure map was provided at the time of property acquisition, or if notice of the existence of the noise exposure map was published three times in a newspaper of general circulation in the area. In addition, Part 150 defines "significant increase" as an increase of 1.5 DNL or CNEL. (See Part 150, Section 150.21 (d), (f), and (g); and Airport Environmental Handbook, Order 5050.4B, 9(n).) For purposes of this provision, FAA officials consider the term "area surrounding an airport" to mean an area within the 65 DNL contour.

Acceptance of the noise exposure maps by the FAA is required before it will approve a noise compatibility program for the airport.

Noise Compatibility Program. A Noise Compatibility Program (NCP) includes provisions for the abatement of aircraft noise through aircraft operating procedures, air traffic control procedures, airport regulations, or airport facility modifications. It also includes provisions for land use compatibility planning and may include actions to mitigate the impact of noise on noncompatible land uses. The program must contain provisions for updates and periodic revisions.

Part 150 establishes procedures and criteria for FAA evaluation of noise compatibility programs. Among these, two criteria are of particular importance: the airport proprietor may take no action that imposes an undue burden on interstate or foreign commerce, nor may the proprietor unjustly discriminate between different categories of airport users.

With an approved noise compatibility program, an airport proprietor becomes eligible for funding through the Federal Airport Improvement Program (AIP) to implement the eligible items of the program.

In 1998, the FAA established a policy for Part 150 approval and funding of noise mitigation measures which stated that the FAA will not approve measures in Noise Compatibility Programs that propose corrective noise mitigation actions for new, non-compatible development, which is allowed to occur in the vicinity of airports after October 1, 1998, the effective date of the policy. Therefore, corrective noise mitigation measures for non-compatible development that occurs after October 1, 1998 is not eligible for AIP funding under the noise set-aside regardless of previous FAA approvals under Part 150. This policy increased the incentives for airport operators to discourage the development of new non-compatible land uses around airports, and to assure the most cost-effective use of federal funds spent on noise mitigation measures.

In December 2003, the Vision 100-Century of Aviation Reauthorization Act was signed in to law. In addition to authorizing FAA programs, Section 189 of Vision 100 amended 49 U.S.C. section 47504(b) by adding new subsection (b)(4). This subsection prohibited FAA from approving NCP measures in Fiscal Years 2004 through 2007 that require the expenditure of AIP funds to mitigate noise of less than 65 DNL or CNEL. Additionally, the legislation precludes FAA approval of recommended NCP measures to mitigate noise outside DNL or CNEL 65 dB if the measures require AIP

"Part 150 establishes guidelines for the identification of land uses which are incompatible with different noise levels."

funds, and unless the local land use planning authority with responsibility for planning in the area surrounding the airport has adopted alternative land use compatibility guidelines.

Additionally, as noted in FAA Order 5190.6B Airport Compliance Manual, FAA encourages a balanced approach to address noise problems and has discouraged unreasonable airport use restrictions. It is FAA policy that airport use restrictions should be considered only as a measure of last resort when other mitigation measures are inadequate to satisfactorily address a noise problem and a restriction is the only remaining option that could provide noise relief. This policy furthers the federal interest in maintaining the efficiency and capacity of the national air transportation system and, in particular, the FAA's responsibility to ensure that federally funded airports maintain reasonable public access in compliance with applicable law.

14 CFR Part 36 Federal Aircraft Noise Regulations

The FAA has required reduction of aircraft noise at the source through certification, modification of engines, or replacement of aircraft. Part 36 prohibits the further escalation of noise levels of subsonic civil turbojet and transport category aircraft and also requires new airplane types to be markedly quieter than earlier models. Subsequent amendments have extended the noise standards to include large and small, propeller-driven airplanes and supersonic transport aircraft.

Part 36 has four stages of certification. Stage 4 is the most recent amendment, having been adopted in July, 2005, and applies to aircraft designs submitted for review after January 1, 2006. Stage 3 applies to aircraft certificated since November 5, 1975; Stage 2 applies to aircraft certificated between December 1, 1969, and November 5, 1975; and Stage 1 includes all previously certificated aircraft.

Stage 4 certification standards for jet aircraft set the noise standard 10 decibels below the Stage 3 standards. These standards apply to all jet aircraft, regardless of weight. Aircraft weight restrictions are addressed in 14 CFR Part 91. The 10 dB reduction for Stage 4 aircraft is the cumulative total of noise reductions for three of the measurement points (approach, flyover, and lateral). The standard requires that aircraft noise is reduced at two of the three measurement points. It is estimated that nearly all currently produced aircraft will be able to meet these requirements and therefore minimal benefits are expected for those communities surrounding airports. There is no planned phase-out of Stage 2 aircraft weighing less than 75,000 pounds or Stage 3 aircraft in this amendment.

14 CFR Part 91 Federal Aircraft Noise Regulations

Part 91, Subpart I, commonly known as the "Fleet Noise Rule," mandated a compliance schedule under which Stage 1 aircraft were to be retired or refitted with hush kits or quieter engines by January 1, 1988. A very limited number of exemptions have been granted by the U.S. Department of Transportation for foreign aircraft operating into specified international airports.

Pursuant to the Congressional mandate in the Airport Noise and Capacity Act of 1990, FAA has established amendments to Part 91 by setting December 31, 1999, as the date for discontinuing use of all Stage 2 aircraft exceeding 75,000 pounds. Stage 2 aircraft over 75,000 pounds utilized for non-revenue flights can operate beyond the December 31, 1999, deadline for the following purposes:

- To sell, lease, or scrap the aircraft;
- To obtain modifications to meet Stage 3 standards;
- To obtain scheduled heavy maintenance or significant modifications;
- To deliver the aircraft to a lessee or return it to a lessor;
- To park or store the aircraft;
- To prepare the aircraft for any of these events; or
- To operate under an experimental airworthiness certificate.

The *FAA Modernization and Reform Act of 2012,* establishes December 31, 2015, as the phase-out date for Stage 2 aircraft weighing less than 75,000 pounds. Additional restrictions or phase-out dates have not been adopted for Stage 3 and Stage 4 aircraft.

Neither Part 36 nor Part 91 apply to military aircraft. Nevertheless, many of the advances in quiet engine technology are being used by the military as they upgrade aircraft to improve performance and fuel efficiency.

14 CFR Part 161 Regulation of Airport Noise and Access Restrictions

Part 161 sets forth requirements for notice and approval of local restrictions on aircraft noise levels and airport access. Part 161, which was developed in response to the Airport Noise and Capacity Act of 1990, applies to local airport restrictions that would have the effect of limiting operations of Stage 2 or 3 aircraft. Restrictions regulated under Part 161 include direct limits on maximum noise levels, nighttime curfews, and special fees intended to encourage changes in airport operations to lessen noise.

In order to implement noise or access restrictions on Stage 2 aircraft, the airport operator must provide public notice of the proposal and provide at least a 45-day comment period. This includes notification of FAA and publication of the proposed restriction in the Federal Register. An analysis must be prepared describing the proposal, alternatives to the proposal, and the costs and benefits of each.

Noise or access restrictions on Stage 3 aircraft can be implemented only after receiving FAA approval. Before granting approval, the FAA must find that the six conditions specified in the statute, and listed below, are met.

(1) The restriction is reasonable, non-arbitrary, and non-discriminatory.

(2) The restriction does not create an undue burden on interstate commerce.

(3) The proposed restriction maintains safe and efficient use of the navigable airspace.

(4) The proposed restriction does not conflict with any existing federal statute or regulation.

(5) The applicant has provided adequate opportunity for public comment on the proposed restriction.

(6) The proposed restriction does not create an undue burden on the national aviation system.

In its application for FAA review and approval of the restriction, the airport operator must include an environmental assessment of the proposal and a complete analysis addressing the six conditions. Within 30 days of the receipt of the application, the FAA must determine whether the application is complete. After a complete application has been filed, the FAA publishes a notice of the proposal in the Federal Register. FAA must approve or disapprove the restriction within 180 days of receipt of the completed application.

Very few Part 161 studies have been undertaken since the enactment of ANCA. **Table 1A** (on the following page) summarizes the studies that have been done to date. Currently, only one Part 161 Study, in Naples, Florida, has been deemed complete by FAA. However, FAA has also ruled that the restriction is a violation of grant assurances Naples signed when accepting federal funds.

Airport operators that implement noise and access restrictions in violation of Part 161 are subject to termination of eligibility for airport grant funds and authority to impose and collect passenger facility charges.

TABLE 1A

SUMMARY OF PART 161 STUDIES

AIRPORT	YEAR STARTED	YEAR ENDED	COST	PROPOSAL, STATUS
Kahului Airport Kahului, Maui, Hawaii	1991	1994	$50,000 (est.)	Proposed nighttime prohibition of Stage 2 aircraft pursuant to court stipulation. Cost-benefit and statewide impact analysis found to be deficient by FAA. Airport never submitted a complete Part 161 study. Suspended consideration of restriction.
Minneapolis-St. Paul International Airport Minneapolis, Minnesota	1992	1992	N.A.	Proposed nighttime prohibition of Stage 2 aircraft. Cost-benefit analysis was deficient. Never submitted complete Part 161 study. Suspended consideration of restriction and entered into negotiations with carriers for voluntary cooperation.
San Jose International Airport San Jose, California	1994	1997	Phase 1 - $400,000 Phase 2 - $5 to $10 million	Study undertaken as part of legal settlement agreement. Studied a Stage 2 restriction. Suspended study after Phase 1 report showed costs to airlines at San Jose greater than benefits in San Jose. Never undertook Phase 2, system wide analysis. Never submitted study for FAA review.
Pease International Tradeport Portsmouth, New Hampshire	1995	N.A..	N.A.	Have not yet submitted Part 161 study for FAA review.
San Francisco International Airport San Francisco, California	1998	1999	$200,000	Proposed extension of nighttime curfew on Stage 2 aircraft over 75,000 pounds. Started study in May 1998. Submitted to FAA in early 1999 and subsequently withdrawn.
Naples Municipal Airport Naples, Florida	1999	2003	Estimated cost of $1.0 to $1.5 million for consulting and legal fees due to litigation	Enactment of a total ban on Stage 2 general aviation jet aircraft under 75,000 pounds. The airport began enforcing the restriction on March 1, 2002.
Bob Hope Airport Burbank, California	2000	2009	Phase 1 - $2 to $4 million (est.) Phase 2 - $1.8 million	FAA denied application stating that other remedies are available that are feasible and cost-effective.
Van Nuys Airport Van Nuys, California	2003	2010	$5 million	Scheduled phase out of noisier aircraft.
Los Angeles International Airport Los Angeles, California	2005	2014	N.A.	FAA denied application because it does not meet the six statutory conditions.

N. A. - Not available.
Sources: Telephone interviews with Federal Aviation Administration officials and staffs of various airports.

FAA Reauthorization Act of 2018

The FAA Reauthorization Act of 2018 (H.R. 302 or Act) is comprehensive legislation prescribing grant funding, passenger facility charges, the airport improvement program, and airport noise and environmental considerations. Title I, Subtitle D, Airport Noise and Environmental Streamlining, specifically addresses community noise concerns and provides grant funding for airport noise compatibility planning, extending grant funding through 2023 for multiple environmental and noise-related issues including updating noise exposure maps, aircraft studies, studies on potential health and economic impact of overflight noise, aircraft noise exposure, and airport noise mitigation and safety studies. H.R. 302 requires the FAA administrator to complete an evaluation of alternative metrics to the current 65 DNL standard. Additionally, the Act requires, in general, that airport operators submit updated noise exposure maps "If, in an area surrounding an airport, a change in the operation of the airport would establish a substantial new non-compatible use, or would significantly reduce noise over existing non-compatible uses, that is not reflected in either the existing conditions map or forecast map currently on file with the FAA." Submission of an updated noise exposure map is required only if relevant changes to airport operations occur during the forecast period.

H.R. 302 requires the FAA to direct focus on community noise concerns and improve community involvement for NextGen projects located in major metropolitan areas. If new area navigation departure procedures are proposed or if an existing procedure is to be amended which could direct air traffic between the surface and 6,000 feet above ground level over noise-sensitive areas, the FAA Administrator shall consider options to address community noise concerns under the following circumstances:

- the affected airport operator submits a request to the FAA administrator;
- the airport operator's request would not conflict with the safe and efficient operation of national airspace; and,
- the effect of a modified departure procedure would not significantly increase noise over sensitive areas.

An important piece to H.R. 302 is that the FAA administrator, within two years of the date of the Act, must submit to congress preliminary recommendations regarding the relationship between aircraft noise exposure and the effects on communities around airports. Such findings shall determine appropriate revisions to land use compatibility guidelines in FAA 14 CFR Part 150.

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Noise and Land Use Compatibility Guidelines

In communities with an airport, noise is a critical factor in the land use planning process. With advancements made in aircraft technology, significant strides have been made in the reduction of noise at its source; however, aviation noise cannot be entirely eliminated. Local, state, and federal agencies, in recognition of this fact, have developed guidelines and regulations to address noise within the land use planning process.

The fundamental variability in the way individuals react to noise makes it impossible to accurately predict how any one individual will respond to a given noise level. However, when considering the community as a whole, trends emerge which relate noise to annoyance. Reasonable evaluations of the average impacts of aircraft noise on a community can be made.

According to scientific research, noise response is most strongly correlated with noise as measured with cumulative noise metrics. In the United States, the most widely used cumulative noise metric is the day-night noise level (DNL). The DNL accumulates the total noise occurring over a 24-hour period, with a 10 decibel penalty applied to noise occurring between 10:00 p.m. and 7:00 a.m. DNL correlates well with average community response to noise.

"Since the 1960s, land use compatibility guidelines based on airport noise levels have been proposed by federal agencies."

In California, the CNEL (community noise equivalent level) metric is used instead of the DNL metric. The two metrics are very similar. While DNL accumulates the total noise occurring during a 24-hour period, with a 10 decibel penalty applied to noise occurring between 10:00 p.m. and 7:00 a.m., the CNEL also adds a 4.77 decibel penalty for noise occurring between 7:00 p.m. and 10:00 p.m. Based on adjacent comparison of the two metrics, there is little difference between the two metrics in practice. Calculations of CNEL and DNL from the same data generally yield values with less than a 0.7 decibel difference (Caltrans 1983, p. 37).

Since the early 1970s, several studies have been conducted to estimate the percent of the population that is, on average, likely to be highly annoyed by aircraft noise. These studies have found that at 65 DNL, the percentage of population highly annoyed ranges from 12 to 26 percent (Miedema and Oudshoorn 2002). Using this information, the DNL or CNEL metric can be a useful planning tool for determining land use compatibility.

LAND USE COMPATIBILITY GUIDELINES

Since the 1960s, land use compatibility guidelines based on airport noise levels have been proposed by federal agencies. This section provides an overview of guidelines from Federal Aviation Administration (FAA), Department of Defense (DOD), Housing and Urban Development (HUD), Veterans Administration (VA), and the Environmental Protection Agency (EPA).

TABLE 1

CHART FOR ESTIMATING RESPONSE OF COMMUNITIES EXPOSED TO AIRCRAFT NOISE 1964 FAA-DOD GUIDELINES

NOISE LEVEL	ZONE	DESCRIPTION OF EXPECTED RESPONSE
Less than 65 DNL	1	No complaints would be expected. The noise may, however, interfere occasionally with certain activities of the residents.
65 to 80 DNL	2	Individuals may complain, perhaps vigorously. Concerted group action is possible.
Greater than 80 DNL	3	Individual reactions would likely include repeated, vigorous complaints. Concerted group action might be expected.

Source: U.S. DOD 1964. Cited in Kryter 1984, p. 616

Federal Land Use Compatibility Guidelines

FAA-DOD Guidelines

In 1964, the Federal Aviation Administration (FAA) and the U.S. Department of Defense (DOD) published similar documents setting forth guidelines to assist land use planners in areas subjected to aircraft noise from nearby airports. These guidelines, presented in **Table 1**, establish three zones and the expected responses to aircraft noise from residents of each zone. In Zone 1, areas exposed to noise below 65 DNL, essentially no complaints would be expected although noise could be an occasional annoyance. In Zone 2, areas exposed to noise between 65 and 80 DNL, individuals may complain, perhaps vigorously. In Zone 3, areas in excess of 80 DNL, vigorous complaints would be likely and concerted group action could be expected.

HUD Guidelines

The U.S. Department of Housing and Urban Development (HUD) first published noise assessment requirements in 1971 for evaluating the acceptability of sites for housing assistance. These requirements contained standards for exterior noise levels along with policies for approving HUD-supported or assisted housing projects in high noise areas. In general, the requirements established three zones: an acceptable zone where all projects could be approved, a normally unacceptable zone where mitigation measures would be required and where each project would have to be individually evaluated for approval or denial, and an unacceptable zone in which projects would not, as a rule, be approved.

In 1979, HUD issued revised regulations which kept the same basic standards, but adopted new descriptor systems which were considered advanced over the old system. **Table 2** summarizes the revised HUD requirements.

TABLE 2

SITE EXPOSURE TO AIRCRAFT NOISE 1979 HUD REQUIREMENTS

ACCEPTABLE CATEGORY	DAY-NIGHT AVERAGE SOUND LEVEL	SPECIAL APPROVALS AND REQUIREMENTS
Acceptable	Not exceeding 65 dB	None
Normally Unacceptable	Above 65 dB but not exceeding 75 dB	Special approvals, environmental review, attenuation
Unacceptable	Above 75 dB	Special approvals, environmental review, attenuation

Source: U.S. HUD 1979

Veterans Administration Guidelines

The Veterans Administration has established policies and procedures for the appraisal and approval of VA loans relative to residential properties located near major civilian airports and military air bases. The agency's regulations, contained within M26-2, Change 15, state that "the VA must recognize the possible unsuitability for residential use of certain properties and the probable adverse effect on livability and/or value of homes in the vicinity of major airports and air bases. Such adverse effects may be due to a variety of factors including noise intensity." **Table 3** contains the VA's noise zones and associated development requirements and limitations.

EPA Guidelines

The U.S. Environmental Protection Agency published a document in 1974 suggesting maximum noise exposure levels to protect public health with an adequate margin of safety. These are shown on the following page in **Table 4.** They note that the risk of hearing loss may become a concern with exposure to noise above 74 DNL. Interference with outdoor activities may become a problem with noise levels above 55 DNL. Interference with indoor residential activities may become a problem with interior noise levels above 45 DNL. If we assume that standard construction attenuates noise by about 20 decibels, with doors and windows closed, this corresponds to an exterior noise level of 65 DNL.

Federal Interagency Committee on Urban Noise

In 1979, the Federal Interagency Committee on Urban Noise (FICUN), including representatives of the Environmental Protection Agency, the Department of Transportation, the Housing and

TABLE 3

VETERANS ADMINISTRATION NOISE GUIDELINES NOVEMBER 23, 1992

NOISE ZONE	CNR (COMPOSITE NOISE RATING)	NEF (NOISE EXPOSURE FORECASTS)	DNL (DAY/NIGHT NOISE RATIO)
1	Under 100	Under 30	Under 65
2	100-115	30-40	65-75
3	Over 115	Over 40	Over 75

Specific Limitations:

1. Proposed or existing properties located in Zone 1 are generally acceptable as security for VA-guaranteed loans.
2. Proposed construction to be located in Zone 2 will be accepted provided:
   a. Sound attenuation features are built into the dwelling to bring the interior DNL of the living unit to 45 decibels or below.
   b. There is evidence of market acceptance of the subdivision.
   c. The veteran-purchaser signs a statement which indicates his/her awareness that 1) the property being purchased is located in an area adjacent to an airport, and 2) the aircraft noise may affect normal livability, value, and marketability of the property.
3. Proposed subdivisions located in Zone 3 are not generally acceptable. The only exception is a situation in which the VA has previously approved a subdivision in zone 3. In such cases, the VA will continue to process loan applications provided the requirements in Table 2 above are met.
4. Existing dwellings in Zones 2 and 3 are not to be rejected because of airport influence if there is evidence of acceptance by a fully informed veteran.

TABLE 4

SUMMARY OF NOISE LEVELS IDENTIFIED AS REQUISITE TO PROTECT PUBLIC HEALTH AND WELFARE WITH AN ADEQUATE MARGIN OF SAFETY - 1974 EPA GUIDELINES

EFFECT	LEVEL	AREA
Hearing Loss	75 DNL and above	All areas
Outdoor activity interference and annoyance	55 DNL and above	Outdoors in residential areas and farms and other outdoor areas where people spend widely varying amounts of time and other places in which quiet is a basis of use.
	59 DNL and above	Outdoor areas where people spend limited amounts of time, such as school years, playgrounds, etc.
Indoor activity interference and annoyance	45 DNL and above	Indoor residential areas
	49 DNL and above	Other areas with human activities such as schools, etc.

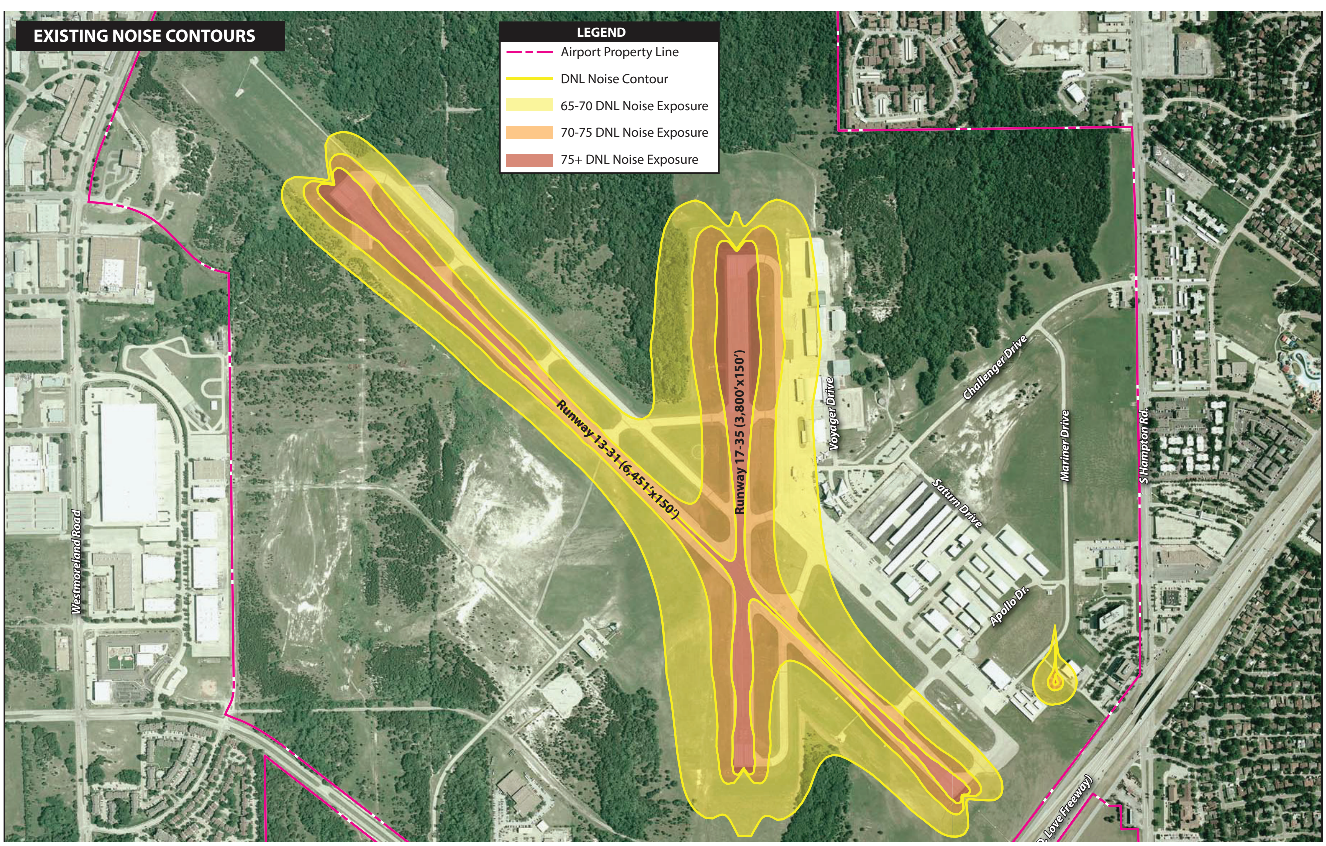
Note: All L_{eq} values from EPA document were converted by FAA to DNL for ease of comparison. (DNL=L_{eq}(24) + 4 dB).
Source: U.S. EPA 1974. Cited in FAA 1977a, p. 26.

Urban Development Department, the Department of Defense, and the Veterans Administration, was established to coordinate various federal programs relating to the promotion of noise-compatible development. In 1980, the Committee published a report which contained detailed land use compatibility guidelines for varying DNL noise levels (FICUN 1980). The work of the Interagency Committee was very important as it brought together for the first time all federal agencies with a direct involvement in noise compatibility issues and forged a general consensus on land use compatibility for noise analysis on federal projects.

The Interagency guidelines describe the 65 DNL contour as the threshold of significant impact for residential land uses and a variety of noise-sensitive institutions (such as hospitals, nursing homes, schools, cultural activities, auditoriums, and outdoor music shells). Within the 55 to 65 DNL contour range, the guidelines note that cost and feasibility factors were considered in defining residential development and several of the institutions as compatible. In other words, the guidelines are not based solely on the effects of noise. They also consider the cost and feasibility of noise control.

14 CFR Part 150 Guidelines

The FAA adopted a revised and simplified version of the FICUN



guidelines when it promulgated Title 14, Part 150 of the Code of Federal Regulations in the early 1980s. (The Interim Rule was adopted on January 19, 1981. The final rule was adopted on December 13, 1984, published in the Federal Register on December 18, and became effective on January 18, 1985.) Among the changes made by FAA include a coarser land use classification system and the deletion of any reference to any potential for noise impacts below the 65 DNL level.

The determination of the compatibility of various land uses with various noise levels, however, is very similar to the FICUN determinations.

Exhibit A (on the following page) lists the Part 150 land use compatibility guidelines. These are only guidelines. Part 150 explicitly states that determinations of noise compatibility and regulation of land uses are purely local responsibilities.

Selected State Land Use Compatibility Guidelines

State of Oregon

The State of Oregon's Airport Planning Rule (APR) establishes a series of local government requirements and rules which pertain to aviation facility planning. These requirements are intended to promote land use compatibility around airports as well as promote a convenient and economic system of airports in the state. To assist local governments and airports in meeting the requirements of the APR, the Oregon Department of Aviation published the Airport Land Use Compatibility Guidebook in January 2003.

The Oregon guidelines contained within the guidebook, as they relate to land use compatibility around airports, are based on administrative regulations of the Department of Environmental Quality, adopted by the Oregon Environmental Quality Commission in 1979 (Oregon Administrative Rules, Chapter 340, Division 35, Section 45). Although the FAA regards the 65 DNL contours and above as significant, the State of Oregon considers the 55 and 60 DNL contours as significant. The state recognizes that, in some instances, land use controls and restrictions that apply to the 65 DNL may be appropriate for applications to areas impacted by noise levels above 55 DNL. For example, a rural area exposed to 55 to 65 DNL noise levels may be more affected by these levels than an urban area. This is because there is typically a higher level of background noise associated with an urban area (Oregon 2003). Air carrier airports are required to do studies defining the airport impact boundary, corresponding to the 55 DNL contour. Where any noise-sensitive property occurs within the noise impact boundary, the airport must develop a noise abatement program.

Part 150 explicitly states that determinations of noise compatibility and regulation of land uses are purely local responsibilities.

An Oregon airport noise abatement program may include many different recommendations for promoting land use compatibility. These include changes in land use planning, zoning, and building codes within the 55 DNL contour. In addition, disclosure of potential noise impacts may be required and purchase of land for non-noise sensitive public uses may be permitted within the 55 DNL contour.

Within the 65 DNL contour, purchase assurance, voluntary relocation, soundproofing, and purchase of land is permitted.

State of California

California law sets the standard for the acceptable level of aircraft noise for persons residing near airports at 65 CNEL (California Code of Regulations, Title 21, Division 2.5, Chapter 6). The 65 CNEL criterion was chosen for urban residential areas where houses are of typical construction with windows partially open. Four types of land uses are defined as incompatible with noise above 65 CNEL: residences, schools, hospitals and convalescent homes, and places of worship. These land uses are regarded as compatible if they have been insulated to assure an

EXHIBIT A

14 CFR PART 150 NOISE COMPATIBILITY GUIDELINES

Land Use	Yearly Day-Night Average Sound Level (DNL) in Decibels					
	Below 65	65-70	70-75	75-80	80-85	Over 85
Residential						
Residential, other than mobile homes and transient lodgings	Y	N[1]	N[1]	N	N	N
Mobile home parks	Y	N	N	N	N	N
Transient lodgings	Y	N[1]	N[1]	N[1]	N	N
Public Use						
Schools	Y	N[1]	N[1]	N	N	N
Hospitals and nursing homes	Y	25	30	N	N	N
Churches, auditoriums, and concert halls	Y	25	30	N	N	N
Government services	Y	Y	25	30	N	N
Transportation	Y	Y	Y[2]	Y[3]	Y[4]	Y[4]
Parking	Y	Y	Y[2]	Y[3]	Y[4]	N
Commercial Use						
Offices, business and professional	Y	Y	25	30	N	N
Wholesale and retail-building materials, hardware and farm equipment	Y	Y	Y[2]	Y[3]	Y[4]	N
Retail trade-general	Y	Y	25	30	N	N
Utilities	Y	Y	Y[2]	Y[3]	Y[4]	N
Communication	Y	Y	25	30	N	N
Manufacturing and Production						
Manufacturing, general	Y	Y	Y[2]	Y[3]	Y[4]	N
Photographic and optical	Y	Y	25	30	N	N
Agriculture (except livestock) and forestry	Y	Y[6]	Y[7]	Y[8]	Y[8]	Y[8]
Livestock farming and breeding	Y	Y[6]	Y[7]	N	N	N
Mining and fishing, resource production and extraction	Y	Y	Y	Y	Y	Y
Recreational						
Outdoor sports arenas and spectator sports	Y	Y[5]	Y[5]	N	N	N
Outdoor music shells, amphitheaters	Y	N	N	N	N	N
Nature exhibits and zoos	Y	Y	N	N	N	N
Amusements, parks, resorts, and camps	Y	Y	Y	N	N	N
Golf courses, riding stables, and water recreation	Y	Y	25	30	N	N

The designations contained in this table do not constitute a federal determination that any use of land covered by the program is acceptable under federal, state, or local law. The responsibility for determining the acceptable and permissible land uses and the relationship between specific properties and specific noise contours rests with the local authorities. FAA determinations under Part 150 are not intended to substitute federally-determined land uses for those determined to be appropriate by local authorities in response to locally-determined needs and values in achieving noise compatible land uses.

See other side for notes and key to table.

interior sound level, from aircraft noise, of 45 CNEL. They are also to be considered compatible if an avigation easement over the property has been obtained by the airport operator.

California noise insulation standards apply to new hotels, motels, apartment buildings, and other dwellings, not including detached single-family homes. They require that "interior noise levels attributable to outdoor sources shall not exceed 45 decibels (based on the DNL or CNEL metric) in any habitable room." In addition, any of these residential structures proposed within a 60 CNEL noise contour requires an acoustical analysis to show that the proposed design will meet the allowable interior noise level standard. (California Code of Regulations, Title 24, Part 2, Appendix Chapter 35.)

In the California Airport Land Use Planning Handbook (Caltrans updated 2011), land use compatibility guidelines are suggested for use in the preparation of comprehensive airport land use plans. The guidelines state that the 65 dB is not acceptable for most new development. However, may be acceptable in noisy urban locations and/or in hot climates where most buildings utilize air conditioning. The 60 dB is suitable for new development or mild climates where windows are often left open. At rural airports, it is noted that 55 CNEL may be suitable for use as a maximum permissible noise level for residential uses.

These guidelines are similar to those proposed in earlier editions of the Airport Land Use Planning Handbook. However, the 2002 handbook provides much more definitive guidance for compatible land use planning around airports.

State of Florida

In 1990, the State of Florida passed legislation which created the Airport Safety and Land Use Compatibility Study Commission. The charge to this commission was to assure that airports in Florida will have the capacity to accommodate future growth without jeopardizing public health, safety, and welfare. One of the Commissions' recommendations was to require the Florida Department of Transportation (FDOT) to establish guidelines regarding compatible land use around airports. In 1994, FDOT responded to this recommendation by publishing a guidance document entitled Airport Compatible Land Use Guidance for Florida Communities (updated in December 2012).

As part of this document's conclusions, it was recommended that all commercial service airports, or airports with significant numbers of general aviation operations, establish a noise compatibility planning program in accordance with the provisions of Part 150. All communities within the airport environs should participate in the preparation of this program. It was requested that each local government prohibit new residential development and other noise-sensitive uses for areas within the 65 DNL contour. Where practical, new residential development should be limited in

areas down to the 55 DNL contour. Currently, many communities use the 55 DNL to restrict noise sensitive development.

State of Wisconsin

Wisconsin State Law 114.136 was established to give local governments the authority to regulate land uses within three miles of the airport boundary. These land use controls supercede any other applicable zoning limits by other jurisdictions that may apply to the area surrounding the airport. To assist airports with the development of land use controls, the Wisconsin Department of Transportation (WisDOT) published a document titled Wisconsin Airport Land Use Guidebook (dated June 1, 2011). Various land use tools such as avigation easements, noise overlay zones, height and hazard zoning, and subdivision regulations are presented within the land use planning guide. WisDOT has recognized that the types of airport compatible land uses depend on the location and size of the airport as well as the type and volume of aircraft using the facility. The 65 DNL contour should be used as a starting point for land use regulations, but lesser contours should be considered if deemed necessary.

The 1985 Wisconsin Act 136 takes State Law 114.136 one step

further by requiring counties and municipalities to depict airport locations and areas affected by aircraft operations on official maps. The law also requires the zoning authority to notify the airport owner of any proposed zoning changes within the airport environs.

State of Washington

In 1996, Washington State Senate Bill 6442 was passed. This bill requires that every city, town, and county having a general aviation airport in its jurisdiction discourage the siting of land uses that are incompatible with airport operations. Policies protecting airport facilities must be implemented within the comprehensive plan and development regulations. Formal consultation with the aviation community is required and all plans must be filed with the Washington State Department of Transportation Aviation Division (WADOT). To assist jurisdictions with establishing appropriate land use planning tools and regulations, WADOT published a revised Airports and Compatible Land Use document in February 1999. Within this planning document, jurisdictions are encouraged to work with airports to ensure that airport noise is factored into land use decisions for the protection of the health, safety, and welfare of its residents.

TRENDS IN LAND USE COMPATIBILITY GUIDELINES

In recent years, citizen activists, anti-noise groups, and environmental organizations have become concerned that the current methods of assessing aircraft noise are not sufficient. Among the concerns is that 65 DNL does not adequately represent the true threshold of significant noise impact. It has been argued that the impact threshold should be lowered to 60 or even 55 DNL, especially in areas of quiet background noise and in areas impacted by large increases in noise (ANR, V. 4, N. 12, p. 91; V. 5, No. 3, p. 21; V. 5, N. 11, p. 82). The purpose of this section is to provide a time line of events which, taken together, indicate a distinct movement toward the consideration of airport noise impacts below the 65 DNL level.

1992

In the 1992 session of Congress, a bill was introduced to lower the threshold for non-compatible land uses from 65 to 55 DNL (ANR, V. 4, N. 11, p. 83). The bill, however, was not passed. In 1995, a bill (HR 1971) was introduced in the House of Representatives to require the Department of Transportation to develop a plan to reduce the number of people residing within the 60 DNL contours around airports by 75 percent by January 1, 2001 (ANR, V. 7, N. 13, p. 101). This bill was not passed either. Nevertheless, these developments indicate concerns about aircraft noise below 65 DNL are coalescing into specific proposals to address the situation.

Also in 1992, an important arbitration proceeding between Raleigh-Durham International Airport and airport neighbors was concluded. Residents residing between the 55 and 65 DNL contours were awarded compensation for noise damages. This was apparently the first time damages had been awarded beyond the 65 DNL contour at any domestic airport (ANR V. 4, No. 14, p. 107). While, strictly speaking, this case sets no legal precedent, it provides further evidence that a change in the definition of the threshold of significant noise impact may be gathering momentum.

After the arbitration was concluded, the Raleigh-Durham Airport Authority developed a model noise ordinance that would require new housing between the 55 and 60 DNL contours to be sound-insulated to achieve an outdoor-to-indoor noise level reduction of 30 dB. Between the 60 and 65 DNL contours, a 35 dB reduction would be required. The model ordinance was proposed for use by local governments exercising land use control. (See ANR, V. 6, N. 3, p. 17.)

In August 1992, the Federal Interagency Committee on Noise (FICON 1992) issued its final report. FICON included representatives of the Departments of Transportation, Defense, Justice, Veterans Affairs, Housing and Urban Development, the Environmental Protection Agency, and the Council on Environmental Quality. FICON was formed to review federal policies for the assessment of aircraft noise in environmental studies. The Committee advocated the continued use of the DNL metric as the principal means of assessing long-term aircraft noise exposure. It further reinforced the designation of 65 DNL as the threshold of significant impact on non-compatible land use. FICON recognized, however, the potential for noise impacts down to the 60 DNL level, providing guidance for analyzing noise between 60 and 65 DNL in reports prepared under the National Environmental Policy Act (NEPA). This includes environmental assessments and environmental impact statements. (It does not include 14 CFR Part 150 studies.) FICON offered this explanation for this action (FICON 1992, p. 3-5).

There are a number of reasons for moving in this direction at this time.

First, the Schultz Curve (See Exhibit A in Coffman Resource Library Effects of Noise Exposure) recognizes that some people will be highly annoyed at relatively low levels of noise. This is further evidenced from numerous public response forums that some people living in areas exposed to DNL values less than 65 dB believe they are substantially impacted (U.S. EPA 1991). Secondly, the FICON Technical Subgroup has shown clearly that large changes in levels of noise exposure (on the order of 3 dB or more) below DNL 65 dB can be perceived by people as a degradation of their noise environment. Finally, there now exist computational techniques that allow for cost-effective calculation of noise exposure and impact data in the range below DNL 65 dB.

The specific FICON recommendation was as follows (FICON 1992, p. 3-5):

If screening analysis shows that noise-sensitive areas will be at or above DNL 65 dB and will have an increase of DNL 1.5 dB or more, further analysis should be conducted of noise-sensitive areas between DNL 60-65 dB having an increase of DNL 3 dB or more due to the proposed airport noise exposure.

FICON further recommended that if any noise-sensitive areas between 60 and 65 DNL are projected to have an increase of 3 DNL or more as a result of the proposed airport noise exposure, mitigation actions should be included for those areas (FICON 1992, p. 3-7). The FICON recommendations represent the first uniform guidelines issued by the federal government for the consideration of aircraft noise impacts below the 65 DNL level. At this time, these remain recommendations and are not official policy.

1995

The Federal Transit Administration (FTA) released a guidance document entitled Transit Noise and Vibration Impact Assessment. Within this document, FTA cites the EPA recommendation of 55 DNL to develop their curve of impact. Further, FTA states that they use the FAA criteria of 65 DNL to define their curve of severe impact.

1996

The American National Standards Institute (ANSI) recommends 55 DNL as the criterion level for housing and similar noise-sensitive land uses within their report ANSI Quantities and Procedures for Description and Measurement of Environmental Sounds - Part 3: Short-Term Measurements with an Observer Present.

The International Organization for Economic Cooperation and Development suggests the following environmentally sustainable transport noise levels: 55 DNL in urban areas and 50 DNL in rural areas.

1998

Within the Federal Railroad Administration's (FRA) High-Speed Ground Transportation Noise and Vibration Impact Assessment, the same criteria used by the FTA is used to assess impacts of new, high-speed trains.

In this same year, the Surface Transportation Board (STB) utilizes 55 DNL as a threshold of impact within the Draft Environmental Impact Statement for the proposed Conrail acquisition by Norfolk Southern Railway Company.

The World Bank Group (WBG) set noise limits for general industrial projects to ensure that projects they fund, such as iron and steel manufacturing and thermal power plants, do not negatively impact noise-sensitive development. The WBG set their threshold of impact at 55 DNL.

1999

The Federal Energy Regulatory Commission adopts a revision to their regulations (Part 157) which states "the noise attributable to any new compressor stations, compression added to an existing station, or any modification, upgrade, or update of an existing station, must not exceed a day-night level (L_{dn}) of 55 dBA at any pre-existing noise-sensitive area."

The World Health Organization's Guidelines for Community Noise recommends a "criteria of annoyance" daytime threshold of 55 DNL and nighttime threshold of 50 DNL for residential areas.

2003

FAA announced the establishment of the Center of Excellence for Aircraft Noise Mitigation. This research center is a partnership between academia, the aviation industry, and the federal government. The Center will focus on studying what level of noise is considered significant, and revisions to noise metrics and alternative aircraft operating procedures that may reduce noise exposure.

2008

The FAA has indicated that a change to address noise outside DNL 65 will be essential to meet both the capacity goals of the Next Generation Air Transportation System and furthering the development of additional noise stringencies in the international arena. FAA identified the following NextGen targets:

- Maintain current target of 4% annual reduction in number of people exposed to DNL 65 or more near-term (compared with 2000 to 2002) and achieve commensurate or greater reduction of the number of people exposed to DNL 55–65.
- Achieve greater reductions mid- and long-term, fi rst bringing DNL 65 primarily within airport boundary and later DNL 55 primarily within airport boundary.

2010

The Continuous Lower Energy, Emissions, and Noise (CLEEN) program is the FAA's fundamental environmental effort to accelerate the development of new aircraft and engine technologies and advance sustainable alternative jet fuels. CLEEN was the principal element for the NextGen strategy to achieve environmental protection allowing for sustainable industry growth.

Dovetailing on CLEEN is the CLEEN II program, initiated in 2015 to continue to 2010 efforts to develop and demonstrate aircraft technology and alternative jet fuels.

AMBIENT NOISE LEVELS

Consideration has also been given to the effects of ambient noise levels and how they relate to annoyance. The U.S. Environmental Protection Agency (EPA) has provided guidelines to address the question of background noise and its relationship to aircraft noise. The EPA has determined that complaints can be expected when the intruding DNL exceeds the background DNL by more than 5 decibels (U.S. EPA 1974). The California Department of Transportation (Caltrans 2000, pp. 7-24-7-25) notes that the level of background (ambient) noise should be used in determining the suitable aircraft noise contour of significance. Specifically, adjustments have been made in areas with quiet background noise levels of 50 to 55 CNEL. In those cases, aircraft CNEL contours are prepared down to 55 or 60 CNEL, and land use compatibility criteria are adjusted to apply to those areas. The State of Oregon Department of Aviation (Oregon 2003) also requires the preparation of noise contours down to the 55 DNL level. This noise contour is used to establish the noise impact boundary for air carrier airports within the state.

The Federal Interagency Committee on Noise (FICON 1992, p. 2-6) examined the question of background noise and its relationship to perceptions of aircraft noise. It reviewed the research in this field, concluding that there was a basis for believing that, in addition to the magnitude of aircraft noise, the difference between background noise and aircraft noise was in some way related to human perceptions of noise disturbance. It noted, however, that there was insufficient scientific data to provide authoritative guidance on the consideration of these effects. FICON advocated further research in this area.

"The difference between background noise and aircraft noise is in some way related to human perceptions of noise disturbance."

CONCLUSIONS

This document has presented information on land use compatibility guidelines with respect to noise. It is intended to serve as a reference for the development of policy guidelines for 14 CFR. Part 150 Noise Compatibility Studies.

There is a strong and long-lasting consensus among various government agencies that 65 DNL represents an appropriate threshold for defining significant impacts on non-compatible land use. Nonetheless, both research and empirical evidence suggest that noise at levels below 65 DNL is often a concern. Increased concern about these lower levels of noise has been registered in public forums across the country. Official responses by public agencies indicate at least a partial acknowledgment of these concerns. Indeed, according to many agencies and organizations as well as in the states of Oregon, Florida, Wisconsin, and California, airport noise analysis and compatibility planning below the 65 DNL level is strongly advised or required.

In urbanized areas with relatively high background noise levels, 65 DNL continues to be a reasonable threshold for defining airport noise impacts. In suburban and rural locations, lower noise thresholds deserve consideration. Given emerging national trends and the experience at many airports, it can be important to assess aircraft noise below 65 DNL, especially in areas with significant amounts of undeveloped land where land use compatibility planning is still possible. Future planning in undeveloped areas around airports should recognize that the definition of critical noise thresholds is undergoing transition. In setting a prudent course for future land use near airports, planners and policy-makers should try to anticipate these changes.

REFERENCES

ANR (Airport Noise Report), selected issues, Ashburn, VA.

ANSI 1980. Sound Level Descriptors for Determination of Compatible Land Use. American National Standards Institute, ANSI S3.23 - 1980 (ASA 22-1980).

Caltrans 1983. Airport Land Use Planning Handbook - A Reference and Guide for Local Agencies. Prepared for California Department of Transportation, Division of Aeronautics by the Metropolitan Transportation Commission and the Association of Bay Area Governments, July 1983.

Caltrans 1993. Airport Land Use Planning Handbook. Prepared for California Department of Transportation, Division of Aeronautics by Hodges & Shutt, Santa Rosa, California, in association with Flight Safety Institute; Chris Hunter & Associates; and University of California, Berkeley, Institute of Transportation Studies, December 1993.

FAA 1977a. Impact of Noise on People. U.S. Department of Transportation, Federal Aviation Administration, May 1977.

FAA 1977b. Airport Land Use Compatibility Planning, AC 150/5050-6. U.S. Department of Transportation, Federal Aviation Administration, Washington, D.C.

FICON 1992. Federal Agency Review of Selected Airport Noise Analysis Issues. Federal Interagency Committee on Noise, Washington, D.C.

FICUN 1980. Guidelines for Considering Noise in Land Use Planning and Control. Federal Interagency Committee on Urban Noise, Washington, D.C.

Finegold, L.S. et al. 1992. "Applied Acoustical Report: Criteria for Assessment of Noise Impacts on People" Submitted to Journal of Acoustical Society of America. June 1992. Cited in FICON 1992.

Kryter, K.D. 1984. Physiological, Psychological, and Social Effects of Noise, NASA Reference Publication 1115.

ODOT 1981. Airport Compatibility Guidelines, Oregon Aviation System Plan, Volume VI, Oregon Department of Transportation, Aeronautics Division, Salem.

Richards, E.J. and J.B. Ollerhead, 1973. "Noise Burden Factor - A New Way of Rating Noise, Sound and Vibration," Vol. 7, No. 12, December.

Schultz, T.J. and McMahon, N.M. 1971. HUD Noise Assessment Guidelines. Report No. HUD TE/NA 171, August 1971. (Available from NTIS as PB 210 590.)

U.S. DOD 1964. Land Use Planning with Respect to Aircraft Noise. AFM 86-5, TM 5-365, NAVDOCKS P-98, U.S. Department of Defense, October 1, 1964. (Available from DTIC as AD 615 015.)

U.S. EPA 1974. Information on Levels of Environmental Noise Requisite to Protect Health and Welfare with an Adequate Margin of Safety. U.S. Environmental Protection Agency, Office of Noise Abatement and Control, Washington, D.C., March 1974.

U.S. EPA 1991. A Review of Recent Public Comments on the Application of Aircraft Noise Descriptors. U.S. Environmental Protection Agency, Office of Noise Abatement and Control, Washington, D.C. Cited in FICON 1992

AIRPORT COOPERATIVE RESEARCH PROGRAM, Report 27, Enhancing Airport Land Use Compatibility, Volume 1: Land Use Fundamentals and Implementation Resources, 2010

AIRPORT COOPERATIVE RESEARCH PROGRAM, Synthesis 16, Compilation of Noise Programs in Areas Outside DNL 65, 2009

Coffman Associates

RESOURCE LIBRARY

The Measurement and Analysis of Sound

Sound is energy — energy that conveys information to the listener. Although measuring this energy is a straight- forward technical exercise, describing sound energy in ways that are meaningful to people is complex. This TIP explains some of the basic principles of sound measurement and analysis.

NOISE - UNWANTED SOUND

Noise is often defined as unwanted sound. For example, rock-and-roll on the stereo of the resident of apartment 3A is music to her ears, but it is intolerable racket to the next door neighbor in 3B. One might think that the louder the sound, the more likely it is to be considered noise. This is not necessarily true. In our example, the resident of apartment 3A is surely exposed to higher sound levels than her neighbor in 3B, yet she considers the sound as pleasant while the neighbor considers it "noise." While it is possible to measure the sound level objectively, characterizing it as "noise" is a subjective judgement.

The characterization of a sound as "noise" depends on many factors, including the information content of the sound, the familiarity of the sound, a person's control over the sound, and a person's activity at the time the sound is heard.

MEASUREMENT OF SOUND

A person's ability to hear a sound depends on its character as compared with all other sounds in the environment. Three characteristics of sound to which people respond are subject to objective measurement: magnitude or loudness; the frequency spectrum; and the time variation of the sound.

LOUDNESS

The unit used to measure the magnitude of sound is the decibel. Decibels are used to measure loudness in the same way that "inches" and "degrees" are used to measure length and temperature. Unlike the linear length and temperature scales, the decibel scale is logarithmic. By definition, a sound which has ten times the mean square sound pressure of the reference sound is 10 decibels (dB) greater than the reference sound. A sound which has 100 times (10 × 10 or 102) the mean square sound pressure of the reference sound is 20 dB greater (10 × 2).

The logarithmic scale is convenient because the mean square sound pressures of normal interest extend over a range of 11 trillion to one.

This huge number (a "1" followed by 14 zeros or 10^{14}) is much more conveniently represented on the logarithmic scale as 140 dB (10 x 14).

The use of the logarithmic decibel scale requires different arithmetic than we use with linear scales. For example, if two equally loud but independent noise sources operate simultaneously, the measured mean square sound pressure from both sources will be twice as great as either source operating alone. When expressed on the decibel scale, however, the sound pressure level from the combined sources is only 3 dB higher than the level produced by either source alone. Furthermore, if we have two sounds of different magnitude from independent sources, then the level of the sum will never be more than 3 dB above the level produced by the greater source alone.

This equation describes the mathematics of sound level summation:

$$S_t=10 \log \sum 10^{S_i/10}$$

where S_t is the total sound level, in decibels, and S_i is the sound level of the individual sources.

A simpler process of summation is also available and often used where a level of accuracy of less than one decibel is not required. **Table 1** lists additive factors applicable to the difference between the sound levels of two sources.

The noise values to be added should be arrayed from lowest to highest. The additive factor derived from the difference between the lowest and next highest noise level should be added to the higher level. An example is shown to the right.

TABLE 1

ADDITIVE FACTORS FOR SUMMATION OF TWO SOUND TYPES

DIFFERENCE IN SOUND LEVEL (DB)	ADD TO LARGER LEVEL (DB)	DIFFERENCE IN SOUND LEVEL (DB)	ADD TO LARGER LEVEL (DB)
0	3.0	8	0.6
1	2.5	9	0.5
2	2.1	10	0.4
3	1.8	12	0.3
4	1.5	14	0.2
5	1.2	16	0.1
6	1.0	> 16	0
7	0.8		

SOURCE: HUD 1985, p. 51.

Logarithmic math also produces interesting results when averaging sound levels. As the following example shows, the loudest sound levels are the dominant influence in the averaging process. In the example, two sound levels of equal duration are averaged. One is 100 dB; the other 50 dB. The result is not 75 as it would be with linear math but 97 dB. This is because 100 dB contains 100,000 times the sound energy as 50 dB.

Another interesting attribute of sound is the human perception of loudness. Scientists researching human hearing have determined that most people perceive a 10 dB increase in sound energy over a given frequency range as, roughly, a doubling of the loudness. Recalling the logarithmic nature of the decibel scale, this means that most people perceive a ten-fold increase in sound energy as a two-fold increase in loudness (Kryter 1984, p. 188). Furthermore, when comparing sounds over the same frequency range, most people cannot distinguish between sounds varying by less than two or three decibels.

Exhibit A presents examples of various noise sources at different noise levels, comparing the decibel scale with the relative sound energy and the human perception of loudness. In the exhibit, 60 dB is taken as the reference or "normal" sound level. A sound of 70 dB, involving ten times the sound energy, is perceived as twice as loud. A sound of 80 dB contains 100 times the sound energy

EXAMPLE OF SOUND LEVEL SUMMATION

59.0 dB
60.0 dB } **Add 2.5 to 60 = 62.5**
66.5 dB } **Add 1.5 to 66.5 = 68**

59 dB+ 60 dB = 66.5 dB = 68 dB

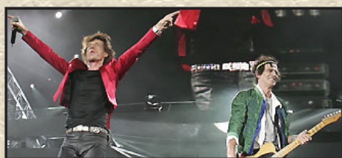
EXHIBIT A

Threshold of Pain

SOUND LEVEL dB (A)	PERCEIVED LOUDNESS	RELATIVE SOUND ENERGY
130	128	10,000,000
120	64	1,000,000
	Deafening	
110	32	100,000
100	16	10,000
	Very Loud	
90	8	1,000
80	4	100
	Loud	
70	2	10
60	1	1
	Moderate	
50	1/2	.1
40	1/4	.01
	Faint	
30	1/8	.001
20	1/16	.0001
	Very Faint	
10	1/32	.00001
0	1/64	.000001

Threshold of Hearing

Military Jet Take-off at 50'



Rock Band

Motorcycle at 25'

Interior of Department Store

Quiet Auto at Low Speed

Country Dwelling Indoors

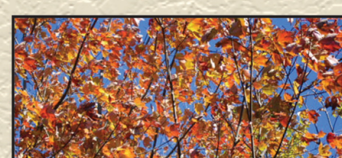
Turbo-fan Aircraft Take-off at 200'

B-737, DC-9-10 at 300' on Approach

Busy Street

Ordinary Conversation at 3'

City Dwelling - Indoors



Rustle of Leaves

and is perceived as four times as loud as 60 dB. Similarly, a sound of 50 dB contains ten times less sound energy than 60 dB and is perceived as half as loud.

FREQUENCY WEIGHTING

Two sounds with the same sound pressure level may "sound" quite different (e.g., a rumble versus a hiss) because of differing distributions of sound energy in the audible frequency range. The distribution of sound energy as a function of frequency is known as the "frequency spectrum." The spectrum is important to the measurement of sound because the human ear is more sensitive to sounds at some frequencies than others. People hear best in the frequency range of 1,000 to 5,000 cycles per second (Hertz) than at very much lower or higher frequencies. If the magnitude of a sound is to be measured so that it is proportional to its perception by a human, it is necessary to weigh more heavily that part of the sound energy spectrum humans hear most easily.

Over the years, many different sound measurement scales have been developed, including the A-weighted scale (and also the B, C, D, and E-weighted scales). A-weighting, developed in the 1930s, is the most commonly used scale for approximating the frequency spectrum to which humans are sensitive. Because of its universality, it was adopted by the U.S. Environmental Protection Agency and other government agencies for the description of sound in the environment.

The zero value on the A-weighted scale is the reference pressure of 20 micro-newtons per square meter (or micro-pascals). This value approximates the smallest sound pressure that can be detected by a human. The average sound level of a whisper at a distance of 1 meter is 40 dB; the sound level of a normal voice at 1 meter is 57 dB; a shout at 1 meter is 85 dB; and the threshold of pain is 130 dB.

TIME VARIATION OF SOUND LEVEL

Generally, the magnitude of sound in the environment varies randomly over time. Of course, there are many exceptions. For example, the sound of a waterfall is steady with time, as is the sound of a room air conditioner or the sound inside a car or airplane cruising at a constant speed. But, in most places, the loudness of outdoor sound is constantly changing because it is influenced by sounds from many sources.

While the continuous variation of sound levels can be measured, recorded, and presented, comparisons of sounds at different times or at different places is very difficult without some way of reducing the time variation. One way of doing this is to calculate the value of a steady-state sound which contains the same amount of sound energy as the time-varying sound under consideration. This value is known as the Equivalent Sound Level (L_{eq}). An important advantage of the L_{eq} metric is that it correlates well with the effects of noise on humans. On the basis of research, scientists have formulated the "equal energy rule." It is the total sound energy perceived by a human that accounts for the effects of the sound on the person. In other words, a very loud noise lasting a short time will have the same effect as a quieter noise lasting a longer time if the total energy of both sound events (the L_{eq} value) is the same.

KEY DESCRIPTORS OF SOUND

Four descriptors or metrics are useful for quantifying sound. All are based on the logarithmic decibel (dB) scale and incorporate A-weighting to account for the frequency response of the ear.

Sound Level

The sound level (L) in decibels is the quantity read on an ordinary sound level meter. It fluctuates with time following the fluctuations in magnitude of the sound. Its maximum value (L_{max}) is one of the descriptors often used to characterize the sound of an airplane overflight. However, L_{max} only gives the maximum magnitude of a sound — it does not convey any information about the duration of the sound. Clearly, if two sounds have the same maximum sound level, the sound which lasts longer will cause more interference with human activity.

Sound Exposure Level

Both loudness and duration are included in the Sound Exposure Level (SEL), which adds up all sound occurring in a stated time period or during a specific event, integrating the total sound over a one-second duration. The SEL is the quantity that best describes the total noise from an aircraft overflight. Based on numerous sound measurements, the SEL from a typical aircraft overflight is usually four to seven decibels higher than the L_{max} for the event.

Exhibit B shows graphs of two different sound events. In the top half of the graph, we see that the two events have the same L_{max}, but the second event lasts longer than the first. It is clear from the graph that the area under the noise curve is greater for the second event than the first. This means that the second event contains more total sound energy than the first, even though the peak levels for each event are the same. In the bottom half of the graph, the SELs for each event are compared. The SELs are computed by mathematically compressing the total sound energy into a one-second period. The SEL for the second event is greater than the SEL for the first. Again, this simply means that the total sound energy for the second event is greater than for the first.

Equivalent Sound Level

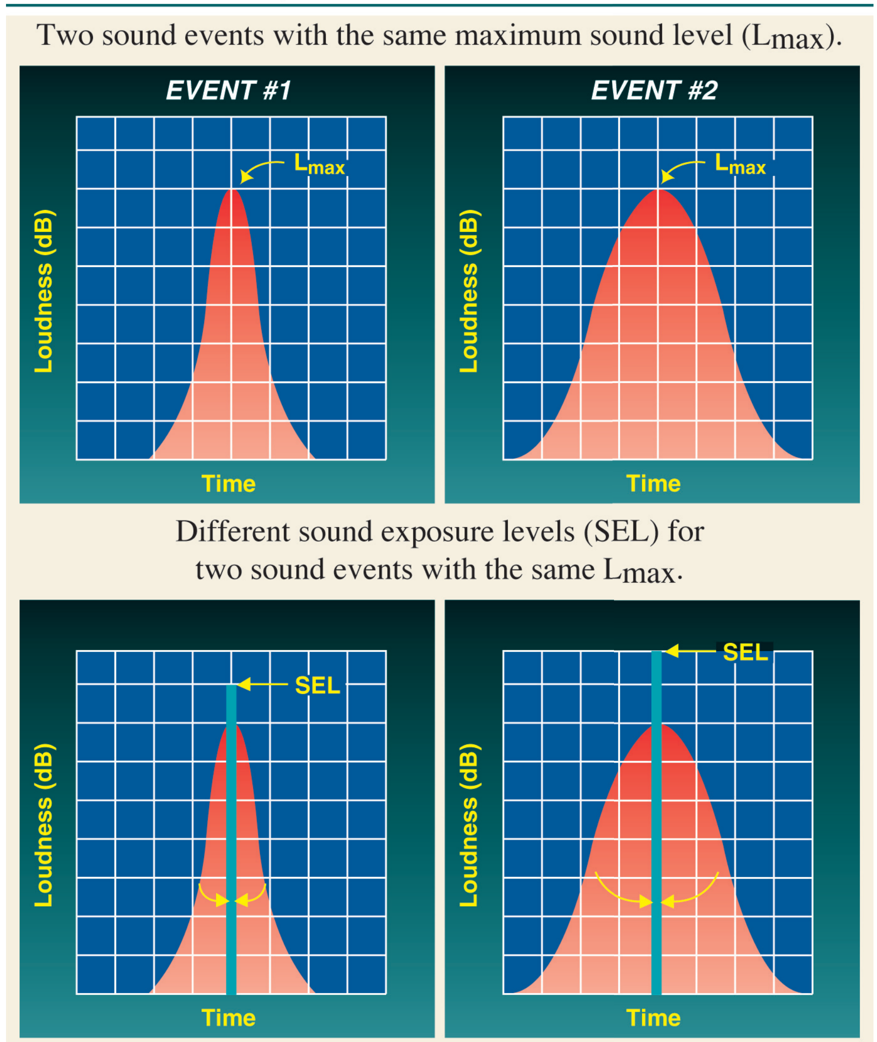
The L_{eq} is simply the logarithm of the average value of the sound exposure during a stated time period. It is typically used for durations of one hour, eight hours, or 24 hours. In airport noise compatibility studies, use of the L_{eq} term applies to 24-hour periods unless otherwise noted. It is often used to describe sounds with respect to their potential for interfering with human activity.

Cumulative Noise Metrics

L_{eq} can be weighted to account for increased annoyance attributed to noise during the evening and nighttime when ambient noise levels are lower. Two weighted noise metrics commonly used for airports are the day-night sound level (DNL) and the community noise equivalent level (CNEL) which is used in the State of California. Both metrics are calculated using similar methodology, DNL is calculated by summing the

EXHIBIT B

COMPARISON OF L_{max} AND SEL



sound exposure during daytime hours plus 10 times the sound exposure occurring during nighttime hours (2200-0700). The sum is averaged by dividing by the number of seconds during a 24 hour day. CNEL includes an additional evening penalty of 4.77 dB for sound events occurring between 1900 and 2200.

Exhibit C shows how the sound occurring during a 24-hour period is weighted and averaged by the DNL or CNEL metrics. In the examples, the sound occurring during the period, including aircraft noise and background sound, yields a DNL or CNEL value of 71. As a practical matter, this is a reasonably close estimate of the aircraft noise alone because, in this example, the background noise is low enough to contribute only a little to the overall DNL or CNEL value during the period of observation.

Where the basic element of sound measurement is L_{eq}, DNL is calculated from:

$$L_{dn} - 10_{log}\ 1/24 \left(\sum_{d=1}^{15} 10^{[L_{eq}(d)]/10} + \sum_{n=1}^{9} 10^{[L_{eq}(n)+10]/10} \right)$$

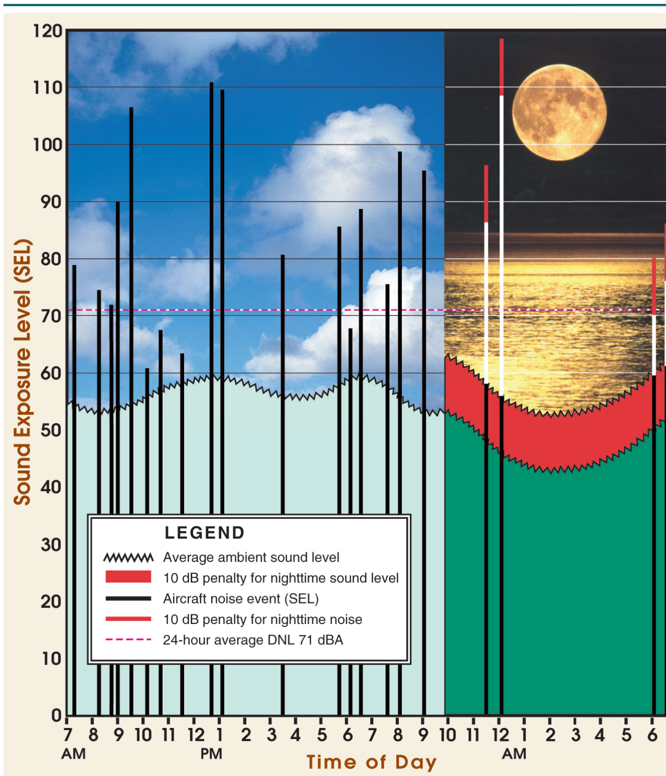
where DNL is represented mathematically as L_{dn}, and $L_{eq}(d)$ and $L_{eq}(n)$ are the daytime and nighttime hour values combined. This expression is convenient where L_{eq} values for only a few hours are available and the values for the remainder of the day can be predicted from a knowledge of day/night variation in levels. The hourly L_{eq} values are summed for the 15 hours from 0700 to 2200 and added to the sum of hourly L_{eq} figures for the 9 nighttime hours with a 10 dB penalty added to the nighttime L_{eq}s.

Use of the cumulative metric to describe aircraft noise is required for all airport noise studies developed under the regulations of 14 CFR Part 150. In addition, DNL and CNEL is preferred by all federal agencies as the appropriate single measure of cumulative sound exposure. These agencies include the FAA, the Federal Highway Administration, Environmental Protection Agency, Department of Defense, and Department of Housing and Urban Development.

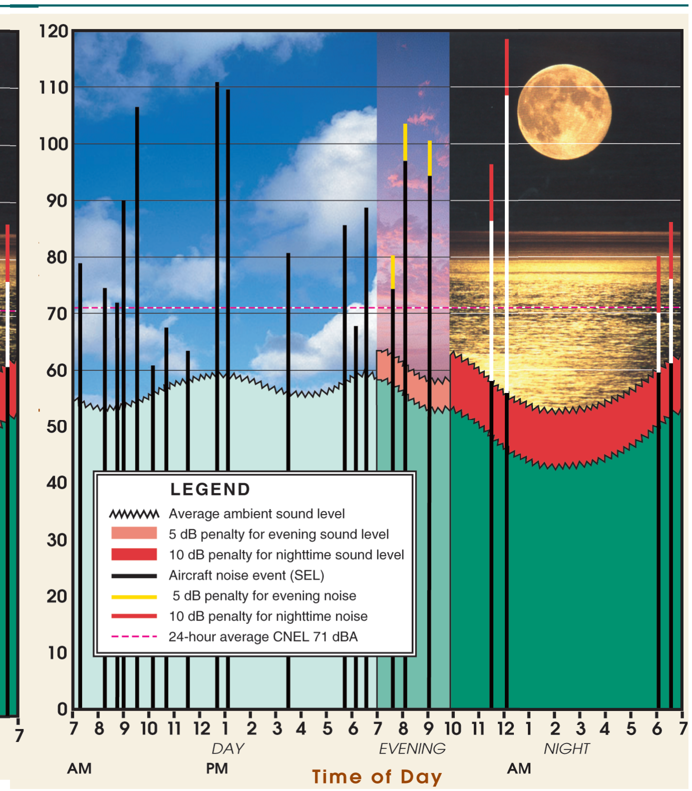
One might think of these metrics as a summary description of the "noise climate" of an area. DNL and CNEL accumulate the noise energy from passing aircraft in the same way that

EXHIBIT C

TYPICAL NOISE PATTERN AND DNL SUMMATION



TYPICAL NOISE PATTERN AND CNEL SUMMATION



Another way of computing DNL is described in this equation:

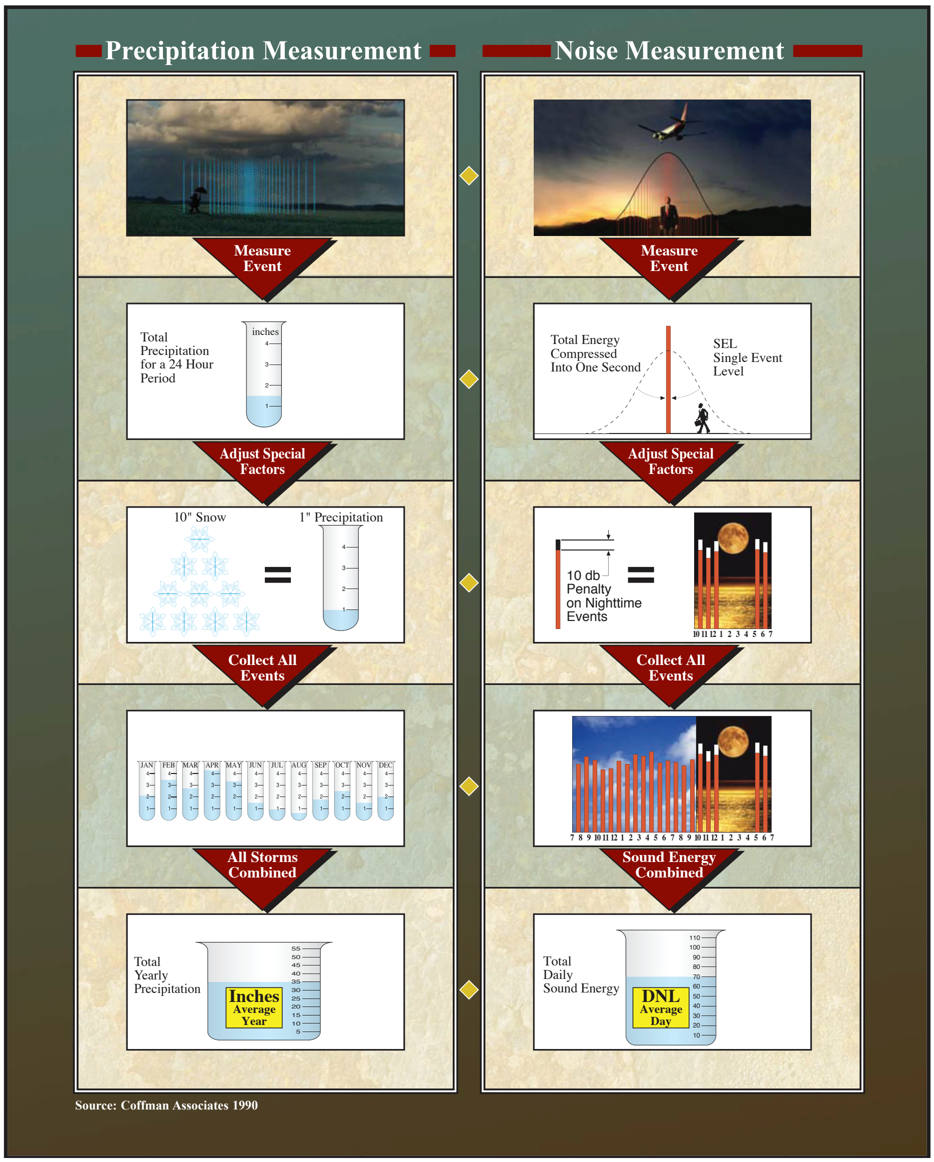
$$L_{dn} = 10\log \frac{1}{86400}\left(\int_{day} 10^{LA/10}dt + \int_{night} 10^{LA+10}dt\right)$$

where LA is the time-varying, A-weighted sound level, measured with equipment meeting the requirements for sound level meters (as specified in a standard such as ANSI SI.4-1971), and dt is the duration of time in seconds. The averaging constant of 86,400 is the number of seconds in a day. The integrals are taken over the daytime (0700 - 2200) and the nighttime (2200 - 0700) periods, respectively. If the sound level is sampled at a rate of once per second rather than measured continuously, the equation still applies if the samples replace LA and the integrals are changed to summations.

a precipitation gauge accumulates rain from passing storms. This analogy is presented in **Exhibit D**. Rain usually starts as a light sprinkle, building in intensity as the squall line passes over, then diminishing as the squall moves on. At the end of a 24-hour period, a rain gauge indicates the total rainfall received for that day, although the rain fell only during brief, sometimes intense, showers. Over a year, total precipitation is summarized in inches. When snow falls, it is converted to its equivalent measure as water. Although the total volume of precipitation during the year may be billions or trillions of gallons of water, its volume is expressed in inches because it provides for easier summation and description. We have learned how to use total annual precipitation to describe the climate of an area and make predictions about the environment.

Aircraft noise is similar to precipitation. The noise level from a single overflight begins quietly and builds in intensity as the aircraft draws closer. The sound of the aircraft is loudest as it passes over the receiver, diminishing as it passes. The total noise occurring during the event is accumulated and described as a SEL. Over a 24-hour period, the SELs can be summed, adding a special 10-decibel factor for nighttime noise, yielding a DNL value and an additional 4.77 dB for CNEL evening events. The DNL or CNEL developed over a long period of time, for example one year, defines the noise environment of the area, allowing us to make predictions about the average response of people living in areas exposed to various DNL or CNEL levels.

EXHIBIT D



HELPFUL RULES-OF-THUMB

Despite the complex mathematics involved in noise analysis, several simple rules-of-thumb can help in understanding the noise evaluation process.

- When sound events are averaged, the loud events dominate the calculation.

- A 10 decibel change in noise is equal to a tenfold change in sound energy. For example, the noise from ten aircraft is ten decibels louder than the noise from one aircraft of the same type, operated in the same way.

- Most people perceive an increase of 10 decibels as a relative doubling of the sound level.

- The DNL metric assumes one nighttime operation (between 10:00 p.m. and 7:00 a.m.) is equal in impact to ten daytime operations by the same aircraft.

- A doubling of aircraft operations results in a three decibel noise increase if done by the same aircraft operated in the same way.

- The CNEL metric assumes one evening operation (7:00 p.m. to 10:00 p.m.) is equal in impact to 4.77 daytime operations by the same aircraft and one nighttime operation (10:00 p.m. to 7:00 a.m.) is equal in impact to ten daytime operations by the same aircraft.

REFERENCES

Kryter, K.D. 1984. Physiological, Psychological, and Social Effects of Noise, NASA Reference Publication 1115.

Newman, Steven J. and Kristy R. Beattie, 1985. Aviation Noise Effects. Prepared for U.S. Department of Transportation, Federal Aviation Administration, Office of Environment and Energy, Washington, D.C., Report No. FAA-EE-85-2, March 1985.

HUD (U.S. Department of Housing and Urban Development) 1985. The Noise Guidebook, HUD-953-CPD Washington, D.C., Superintendent of Documents, U.S. Government Printing Office, March 1985.

United States Central Accounting Office, Aviation and the Environment: FAA's Role in Major Airport Noise Programs. April 2000

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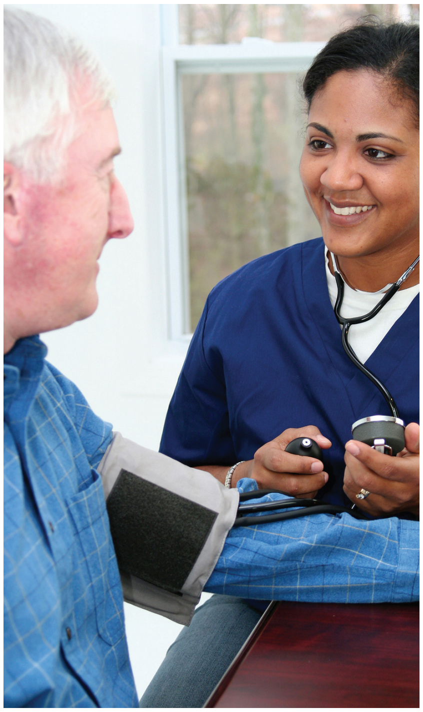
Effects of Noise Exposure

Understanding the effects of noise on people and the physical environment is essential to guiding decisions regarding airport land use compatibility. As noise-related regulations have evolved since the 1970s, so too has the research concerning the effects of noise exposure. Two publications, the Environmental Protection Agency's *Information on Levels of Environmental Noise Requisite to Protect Public Health and Welfare with an Adequate Margin of Safety* (1974) and the Federal Aviation Administration's *Aviation Noise Effects*, Report No. FAA-EE-85-2 (1985), each provide a comprehensive summary of the effects of noise exposure. Since these documents were published, additional research has been conducted on the subject. The Airport Cooperative Research Program (ACRP) has continued to monitor research on noise exposure and published *Effects of Aircraft Noise: Research Update on Selected Topics* in 2008. ACRP's document is intended to update and complement previous publications, primarily focusing on the latest research efforts and conclusions. The following sections summarize recent findings regarding the effects of aircraft noise in the following study areas: health, annoyance, sleep disturbance, children and schools, property values, and vibration.

HEALTH EFFECTS

Hearing Impairment

Hearing loss is the primary health concern related to noise exposure. The EPA's 1974 study found that exposure to noise of 70 L_{eq} or more on a continuous basis, over an extended period of time, at the human ear's most damage-sensitive frequency, may result in a very small but permanent loss of hearing. FAA's *Aviation Noise Effects* cites three studies which examine hearing loss among people living near airports, concluding that under normal circumstances, people in the community near an airport are at no risk of suffering hearing damage from airport noise. More recent research indicates that occupational noise exposure experienced at a person's place of employment or recreation noise exposure such as noise exposure such as a personal music device, concerts, or motorcycles may be greater risk factors for hearing loss. Because aviation and



typical community noise levels near airports are not comparable to the occupational or recreational noise exposures associated with hearing loss, hearing impairment resulting from community aviation noise has not been identified as a community health concern.

Cardiovascular

The study of the effect of noise on cardiovascular conditions has resulted in contradictory conclusions. According to the proceedings of a 2000 World Health Organization task force convened to study the effects of noise on health, a weak association between long-term environmental noise exposure and hypertension was suggested, but no dose-response relationship could be established. The task force concluded that cardiovascular effects may be associated with long-term exposure; however, the associations are inconclusive. The group also suggested that effect of noise is somewhat stronger for ischemic heart disease than for hypertension.

In addition, research published in the Airport Noise Report (Vol 29, No. 20 - June 16, 2017) suggests that nighttime aircraft noise is linked to increased hypertension risk. In contrast, based on a review of cross-sectional studies comparing areas near an airport with areas having lower ambient noise conditions, no differences in systolic and diastolic blood pressure have been found; therefore aircraft noise levels were not a factor affecting hypertension in the subject areas.

In October 2013, a study published in the British Medical Journal titled Residential Exposure to Aircraft Noise and Hospital Admissions for Cardiovascular Diseases: Multi-Airport Retrospective Study surveyed over six million Medicare enrollees in over 2,200 zip codes around 89 airports residing within the 45-dB or greater contour. The results concluded that 2.3 percent of hospitalizations related to cardiovascular disease for Medicare enrollees were attributed to aircraft noise. Twenty-three percent of the study group was exposed to greater than 55 dB contour, which contributed to half of the attributable hospitalizations.

Hospitals and Care Facilities

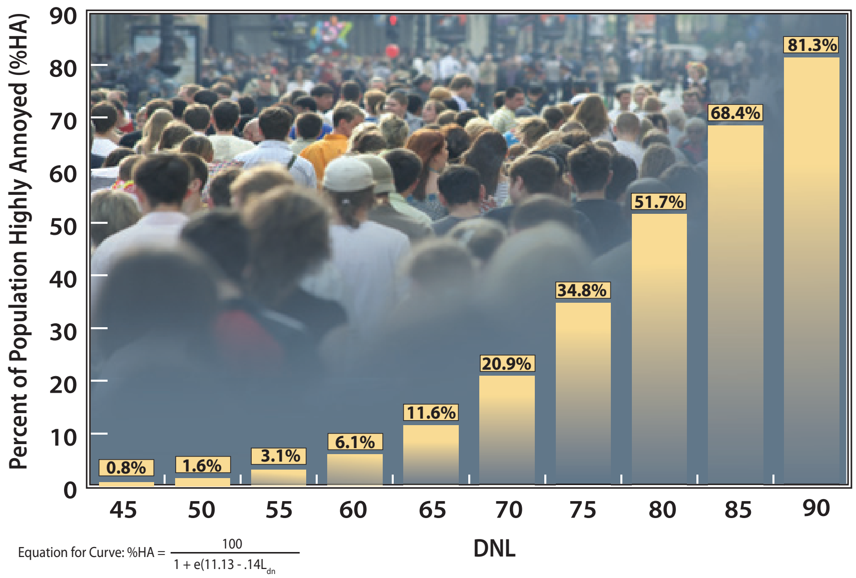
FAA's *Effects of Aircraft Noise* notes that specific research regarding aviation noise and hospitals and care facilities is not available. Although most airport noise and land-use compatibility guidelines include health facilities such as hospitals, convalescent homes, and long term care centers as noise-sensitive uses, there are no studies which identify health effects associated with aviation noise. In comparison, several studies have identified internal medical facility noises as a health risk factor.

Children

The health effects of noise on children has also been widely studied over the past 30 years. Much of the published study results indicate that neither psychiatric disorders nor environmental factors showed any relationship to noise; however, other physical characteristics such as heart

EXHIBIT A

Percent Highly Annoyed at Selected Noise Levels



rate and muscle tension demonstrate a relationship to noise. Additional studies have considered relationships between noise exposure during pregnancy and low birth weights. The results of these studies indicate no correlation between noise exposure during pregnancy and birth weight (Wu et al. 1996; Passchier-Vermeer and Passchier 2000). Additionally, occupational and recreational noise exposure showed no effect on infant birth weights.

ANNOYANCE

The relationship between annoyance and noise exposure is the foundation of many land use compatibility guidelines using the cumulative DNL and CNEL noise metrics. The work of T. J. Shultz published in 1978 reviewed data from social surveys concerning the noise of aircraft, street and expressway traffic, and railroads. Survey responses to noise ratings were translated to Day-Night Average Noise Level (DNL) and has become the most widely accepted interpretation of transportation noise-induced annoyance.

Further research indicates that annoyance increases along an S-shaped or logistic curve as cumulative noise exposure increases. Developed by Fiengold et al., the noise curve is based on data derived from studies of transportation noise. The research shows the relationship between DNL levels and the percentage of people highly annoyed. Known as the "updated Shultz curve," and illustrated in **Exhibit A** above, it represents the best available source of data for the noise dosage-response relationship and was adopted by Federal Interagency Committee on Noise (FICON) in 1992 for use by federal agencies in aircraft noise related environmental impact analyses. In 2006, it was also adopted as part of the American National Standards Institute (ANSI) standard on community responses to environmental noises.

"Day-Night Average Noise Level (DNL)... has become the most widely accepted interpretation of transportation noise-induced annoyance."

SLEEP DISTURBANCE

The British Civil Aviation Authority conducted a study to examine the relationship between nighttime aircraft noise and sleep disturbance near four airports – Heathrow, Gatwick, Stansted, and Manchester (Ollerhead, 1992). A total of 400 subjects were monitored for a total of 5,742 subject-nights. Nightly awakenings were found to be very common as part of natural sleep patterns. The research found that for noise events below 90 SEL, as measured outdoors, there was likely to be no measurable increase in rates of sleep disturbance. Where noise levels ranged

from 90 to 100 SEL, a very small rate of increase in disturbance was detected. Overall, rates of sleep disturbance were found to be more closely correlated with sleep stage than with periods of peak aircraft activity. The research concludes that sleep is more likely to be disrupted from any cause during light stages of sleep rather than heavy stages.

As outlined in FAA's *Effects of Aircraft Noise*, later studies by Horne et al. (1994) document a landmark in-home field study that demonstrated dose-response curves based on laboratory data greatly overestimated the actual awakening rates for aircraft noise events. Additionally, in 1995, Fidell found that SELs of individual noise intrusions were much more closely associated with awakenings than long-term noise exposures. These findings do not resemble those of laboratory studies of noise-induced sleep interference, but agree with the results of other field studies.

Fidell concludes that the relationship observed between noise metrics and behavioral awakening responses suggest instead that noise induced awakening may be usefully viewed as an event-detection process. Put another way, an awakening can be viewed as the outcome of a de facto decision that a change of sufficient import has occurred in the short-term noise environment to warrant a decision to awaken. Additionally, *Effects of Aircraft Noise* states that research may not yet have sufficient specificity to estimate the population awakened for a specific airport environment or the difference in population awakened for a given change in an airport environment.

The ASCENT Aviation Sustainability Center is currently undergoing a multi-year study on aircraft noise and sleep disturbance. The focus of the study is to understand the relationship between aircraft noise and sleep disturbance in the U.S. The preliminary results published in a 2018 report find that nighttime noise (L_{noise}) was associated with diminished sleep quality. L_{night} also increased the probability is sleep troubles due to nighttime awakenings and difficulty staying awake during the day. Neighborhoods with higher L_{night} are more likely to report that sleep was disturbed due to aircraft noise.

CHILDREN AND SCHOOLS

FICAN published the *Position on Research into Effects of Aircraft Noise on Classroom Learning* in 2000 which states that the effects of noise on classroom learning for children suggests that aircraft levels may interfere with multiple aspects of a child's classroom learning experience including memory, speech acquisition, language, motivation, and reading. The position paper indicates that the findings confirm conclusions from earlier studies which indicate a decline in reading performance when exterior noise levels are at an L_{eq} of 65 dB or higher.

Between 2001-2003, a three year study sponsored by the European Commission titled *Road Traffic and Aircraft Noise Exposure and Children's Cognition and Health* studied nearly 3,000 children in schools located near busy roads and airports. The study evaluated the effects of chronic noise exposure on children's reading development. The study suggests that long-term noise exposure can delay a child's reading age up to two months. Additionally, the study found that persistent noise exposure increases the level of annoyance in children. While the effect found to be significant, researchers felt it was small in magnitude and that the long-term effects remain unclear.

The Acoustical Society of America, in 2003, published *Acoustical Performance Criteria, Design Requirements, and Guidelines for Schools.* The guidelines recommend that new classrooms be built with a maximum permissible background-sound level for "typical" classrooms of 35 dBA, with a maximum reverberation time of 0.6 to 0.7 second (depending on room volume). The guidelines are voluntary and are intended to improve the overall learning environment of classrooms.

In November 2013, the Transportation Research Board published Assessing Aircraft Noise Conditions Affecting Student Learning (ACRP 02-26), detailing the results of a multi-year study that examined the relationship between aircraft noise exposure and student performance near 46 major U.S. airports. Student performance measures were based on standardized reading and math test scores for grades three through five at each school. The results found that there was a significant connection between airport noise and student test scores. Sound insulation was installed at 119 of the elementary schools, and the results found that the negative effect from aircraft noise on children's learning diminished. This study was one of the first to quantify the potential impacts of sound insulation on children's learning achievement from aircraft noise exposure.

VIBRATION

Structural vibration from low-frequency noise may also be of concern for airport neighbors. While vibration contributes to annoyance reported by residents near airports, particularly when accompanied by high audible sound levels, it rarely carries enough energy to damage structures constructed in conformance with standard building codes. Although this topic has been studied, there is no accepted methodology for describing the effects of low frequency noise and the effects on communities near airports. FAA and NASA, through the Partner/Center of Excellence, continue to study the effects of low frequency noise and released a report in 2007. As with previous studies on the topic, experts in this field have failed to reach a consensus on the effects.

REFERENCES

"Chronic Airport Noise Found to Impair Children's Reading Skills," Noise Regulation Report, Vol. 32, No. 6, Page 58, 2005.

Airport Cooperative Research Program (ACRP), *Effects of Aircraft Noise: Research Update on Selected Topics,* 2008

Acoustical Society of America, S12.60, *Acoustical Performance Criteria, Design Requirements, and Guidelines for Schools,* 2002.

European Commission, *Road Traffic and Aircraft Noise Exposure and Children's Cognition and Health*, 2003

Federal Interagency Committee on Noise (FICON) 1992. Federal Interagency Review of Selected Airport Noise Analysis Issues.

Federal Interagency Committee on Aviation Noise (FICON) 2000. Position on Research into Effects of Aircraft Noise on Classroom Learning

Fidell, S. et al. 1989. Updating a Dosage-Effect Relationship for the Prevalence of Annoyance Due to General Transportation Noise. HSD-TR-89-009. Cited in FICON 1992.

World Health Organization(WHO) *Guidelines for Community Noise,* 2000.

GLOSSARY OF NOISE COMPATIBILITY TERMS

A-WEIGHTED SOUND LEVEL - A sound pressure level, often noted as dBA, which has been frequency filtered or weighted to quantitatively reduce the effect of the low frequency noise. It was designed to approximate the response of the human ear to sound.

AMBIENT NOISE - The totality of noise in a given place and time — usually a composite of sounds from varying sources at varying distance; no particular sound is dominant.

APPROACH LIGHT SYSTEM (ALS) - An airport lighting facility which provides visual guidance to landing aircraft by radiating light beams in a directional pattern by which the pilot aligns the aircraft with the extended centerline of the runway on the final approach for landing.

ATTENUATION - Acoustical phenomenon whereby a reduction in sound energy is experienced between the noise source and receiver. This energy loss can be attributed to atmospheric conditions, terrain, vegetation, and man-made and natural features.

AZIMUTH - Horizontal direction expressed as the angular distance between true north and the direction of a fixed point (as the observer's heading).

BASE LEG - A flight path at right angles to the landing runway off its approach end. The base leg normally extends from the downwind leg to the intersection of the extended runway centerline. See "traffic pattern."

CFR - Code of Federal Regulation (i.e. 14 CFR Part 150)

CNEL - The 24-hour average sound level, in A-weighted decibels, obtained after the addition of 4.77 decibels to sound levels between 7 p.m. and 10 p.m. and 10 decibels to sound levels between 10 p.m. and 7 a.m., as averaged over a span of one year. In California, it is the required metric for determining the cumulative exposure of individuals to aircraft noise. Also see "L_{eq}" and "DNL".

COMMUNITY NOISE EQUIVALENT LEVEL - See CNEL

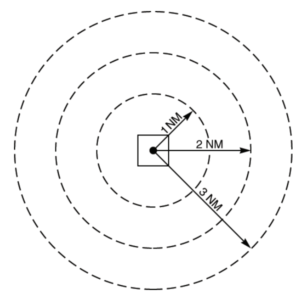
CROSSWIND LEG - A flight path at right angles to the landing runway off its upwind end. See "traffic pattern."

DAY-NIGHT AVERAGE SOUND LEVEL - See DNL.

DECIBEL (dB) - The physical unit commonly used to describe noise levels. The decibel represents a relative measure or ratio to a reference power. This reference value is a sound pressure of 20 micropascals which can be referred to as 1 decibel or the weakest sound that can be heard by a person with very good hearing in an extremely quiet room.

DISPLACED THRESHOLD - A threshold that is located at a point on the runway other than the designated beginning of the runway.

DISTANCE MEASURING EQUIPMENT (DME) - Equipment (airborne and ground) used to measure, in nautical miles, the slant range distance of an aircraft from the DME navigational aid.



DNL - The 24-hour average sound level, in A-weighted decibels, obtained after the addition of ten decibels to sound levels for the periods between 10 p.m. and 7 a.m. as averaged over a span of one year. It is the FAA standard metric for determining the cumulative exposure of individuals to noise. Also see "L_{eq}."

DOWNWIND LEG - A flight path parallel to the landing runway in the direction opposite to landing. The downwind leg normally extends between the crosswind leg and the base leg. Also see "traffic pattern."

DURATION - Length of time, in seconds, a noise event such as an aircraft flyover is experienced. (May refer to the length of time a noise event exceeds a specified dB threshold level.)

EASEMENT - The legal right of one party to use a portion of the total rights in real estate owned by another party. This may include the right of passage over, on, or below the property; certain air rights above the property, including view rights; and the rights to any specified form of development or activity, as well as any other legal rights in the property that may be specified in the easement document.

EQUIVALENT SOUND LEVEL - See $L_{eq.}$

FINAL APPROACH - A flight path in the direction of landing along the extended runway centerline. The final approach normally extends from the base leg to the runway. See "traffic pattern."

FIXED BASE OPERATOR (FBO) - A provider of services to users of an airport. Such services include, but are not limited to, hangaring, fueling, flight training, repair and maintenance.

GLIDE SLOPE (GS) - Provides vertical guidance for aircraft during approach and landing. The glide slope consists of the following:

1. Electronic components emitting signals which provide vertical guidance by reference to airborne instruments during instrument approaches such as ILS, or
2. Visual ground aids, such as VASI, which provide vertical guidance for VFR approach or for the visual portion of an instrument approach and landing.

GLOBAL POSITIONING SYSTEM - See "GPS."

GPS - GLOBAL POSITIONING SYSTEM - A system of 24 satellites used as reference points to enable navigators equipped with GPS receivers to determine their latitude, longitude, and altitude. The accuracy of the system can be further refined by using a ground receiver at a known location to calculate the error in the satellite range data. This is known as Differential GPS (DGPS).

GROUND EFFECT - The attenuation attributed to absorption or reflection of noise by man-made or natural features on the ground surface.

HOURLY NOISE LEVEL (HNL) - A noise summation metric which considers primarily those single events which exceed a specified threshold or duration during one hour.

INSTRUMENT APPROACH - A series of predetermined maneuvers for the orderly transfer of an aircraft under instrument flight conditions from the beginning of the initial approach to a landing, or to a point from which a landing may be made visually.

INSTRUMENT FLIGHT RULES (IFR) -Rules governing the procedures for conducting instrument flight. Also a term used by pilots and controllers to indicate type of flight plan.

INSTRUMENT LANDING SYSTEM (ILS) - A precision instrument approach system which normally consists of the following electronic components and visual aids:

1. Localizer.
2. Glide Slope.
3. Outer Marker.
4. Middle Marker.
5. Approach Lights.

LAAS - Local Area Augmentation System, ground-based antennas whose precisely known locations are used to correct the satellite signals and provide greater positional accuracy as well as integrity of service to aircraft in the air. Represents the next generation of airspace management and aircraft guidance through the National Airspace System using GPS technologies.

L_{dn} - (See DNL). L_{dn} used in place of DNL in mathematical equations only.

L_{eq} - Equivalent Sound Level. The steady A-weighted sound level over any specified period (not necessarily 24 hours) that has the same acoustic energy as the fluctuating noise during that period (with no consideration of a nighttime weighting.) It is a measure of cumulative acoustical energy. Because the time interval may vary, it should be specified by a subscript (such as L_{eq} 8) for an 8-hour exposure to workplace noise) or be clearly understood.

LOCALIZER - The component of an ILS which provides course guidance to the runway.

L_{max} - Maximum Sound Level, the maximum sound level (dB) during a particular noise event.

L_{night} - The equivalent noise level computed for nighttime hours, 10 p.m. to 7 a.m.

LOUDNESS - The attribute of auditory sensation in terms of which sounds may be ordered on a scale extending form soft to loud.

MISSED APPROACH COURSE (MAC) - The flight route to be followed if, after an instrument approach, a landing is not effected, and occurring normally:

1. When the aircraft has descended to the decision height and has not established visual contact, or
2. When directed by air traffic control to pull up or to go around again.

NOISE CONTOUR - A continuous line on a map of the airport vicinity connecting all points of the same noise exposure level.

NONDIRECTIONAL BEACON (NDB) -A beacon transmitting nondirectional signals whereby the pilot of an aircraft equipped with direction finding equipment can determined his bearing to and from the radio beacon and home on or track to or from the station. When the radio beacon is installed in conjunction with the Instrument Landing System marker, it is normally called a Compass Locator.

NONPRECISION APPROACH - A standard instrument approach procedure providing runway alignment but no glide slope or descent information.

PRECISION APPROACH - A standard instrument approach procedure providing runway alignment and glide slope or descent information.

PRECISION APPROACH PATH INDICATOR (PAPI) - A lighting system providing visual approach slope guidance to aircraft during a landing approach. It is similar to a VASI but provides a sharper transition between the colored indicator lights.

PROFILE - The physical position of the aircraft during landings or takeoffs in terms of altitude in feet above the runway and distance from the runway end.

PROPAGATION - Sound propagation refers to the spreading or radiating of sound energy from the noise source. Propagation characteristics of sound normally involve a reduction in sound energy with an increased distance from source. Sound propagation is affected by atmospheric conditions, terrain, and man-made and natural objects.

RESIDUAL NOISE - is ambient noise without specific noise. The residual noise is the noise remaining at a point under certain conditions when the noise from the specific source is suppressed.

RUNWAY END IDENTIFIER LIGHTS (REIL) - Two synchronized flashing lights, one on each side of the runway threshold, which provide rapid and positive identification of the approach end of a particular runway.

RUNWAY USE PROGRAM - A noise abatement runway selection plan designed to enhance noise abatement efforts with regard to airport communities for arriving and departing aircraft. These plans are developed into runway use programs and apply to all turbojet aircraft 12,500 pounds or heavier. Turbojet aircraft less than 12,500 pounds are included only if the airport proprietor determines that the aircraft creates a noise problem. Runway use programs are coordinated with FAA offices as outlined in Order 1050.11. Safety criteria used in these programs are developed by the Office of Flight Operations. Runway use programs are administered by the Air Traffic Service as "Formal" or "Informal" programs.

RUNWAY USE PROGRAM (FORMAL) - An approved noise abatement program which is defined and acknowledged in a Letter of Understanding between FAA - Flight Standards, FAA - Air Traffic Service, the airport proprietor, and the users. Once established, participation in the program is mandatory for aircraft operators and pilots as provided for in Part 150. Section 91.87.

RUNWAY USE PROGRAM (INFORMAL) - An approved noise abatement program which does not require a Letter of Understanding and participation in the program is voluntary for aircraft operators/pilots.

SEL - Sound Exposure Level. SEL expressed in dB, is a measure of the effect of duration and magnitude for a single-event measured in A-weighted sound level above a specified threshold which is at least 10 dB below the maximum value. In typical aircraft noise model calculations, SEL is used in computing aircraft acoustical contribution to the Equivalent Sound Level (L_{eq}), the Day-Night Sound Level (DNL), and the Community Noise Equivalent Level (CNEL).

SINGLE EVENT - An occurrence of audible noise usually above a specified minimum noise level caused by an intrusive source such as an aircraft overflight, passing train, or ship's horn.

SLANT-RANGE DISTANCE - The straight line distance between an aircraft and a point on the ground.

SOUND EXPOSURE LEVEL - See SEL.

SOUND LEVEL METER - An instrument, which is used for the measurement of sound level, with standard frequency weighting and standard exponentially weighted time averaging.

SPL - Sound Pressure Level, measure of the sound pressure of a given noise source relative to a standard reference value (typically the quietest sound that a young person with good hearing can detect).

TACTICAL AIR NAVIGATION (TACAN) -An ultra-high frequency electronic air navigation system which provides suitably-equipped aircraft a continuous indication of bearing and distance to the TACAN station.

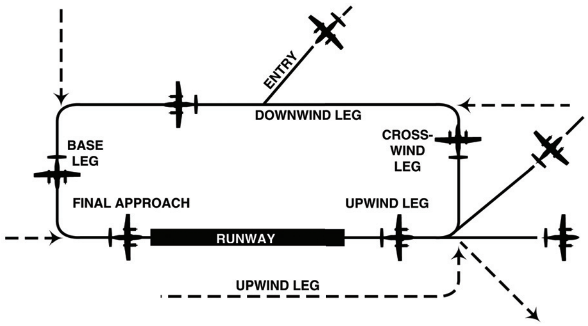
TERMINAL RADAR SERVICE AREA (TRSA) - Airspace surrounding designated airports wherein ATC provides radar vectoring, sequencing, and separation on a full-time basis for all IFR and participating VFR aircraft. Service provided in a TRSA is called Stage III Service.

THRESHOLD - Decibel level below which single event information is not printed out on the noise monitoring equipment tapes. The noise levels below the threshold are, however, considered in the accumulation of hourly and daily noise levels.

TIME ABOVE (TA) - The 24-hour TA noise metric provides the duration in minutes for which aircraft-related noise exceeds specified A-weighted sound levels. It is expressed in minutes per 24-hour period.

TOUCHDOWN ZONE LIGHTING (TDZ) -Two rows of transverse light bars located symmetrically about the runway centerline normally at 100 foot intervals. The basic system extends 3,000 feet along the runway.

TRAFFIC PATTERN - The traffic flow that is prescribed for aircraft landing at or taking off from an airport. The components of a typical traffic pattern are the upwind leg, crosswind leg, downwind leg, base leg, and final approach.



UNICOM - A nongovernment communication facility which may provide airport information at certain airports. Locations and frequencies of UNICOM's are shown on aeronautical charts and publications.

UPWIND LEG - A flight path parallel to the landing runway in the direction of landing. See "traffic pattern."

VECTOR - A heading issued to an aircraft to provide navigational guidance by radar.

VERY HIGH FREQUENCY OMNIDIRECTIONAL RANGE STATION (VOR) - A ground-based electric navigation aid transmitting very high frequency navigation signals, 360 degrees in azimuth, oriented from magnetic north. Used as the basis for navigation in the national airspace system. The VOR periodically identifies itself by Morse Code and may have an additional voice identification feature.

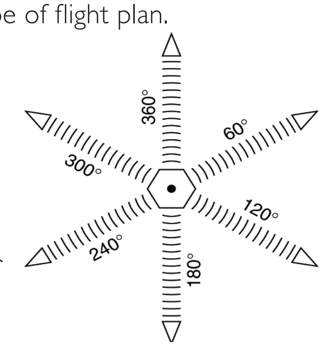
VERY HIGH FREQUENCY OMNIDIRECTIONAL RANGE STATION/TACTICAL AIR NAVIGATION (VORTAC) - A navigation aid providing VOR azimuth, TACAN azimuth, and TACAN distance-measuring equipment (DME) at one site.

VICTOR AIRWAY - A control area or portion thereof established in the form of a corridor, the centerline of which is defined by radio navigational aids.

VISUAL APPROACH - An approach wherein an aircraft on an IFR flight plan, operating in VFR conditions under the control of an air traffic control facility and having an air traffic control authorization, may proceed to the airport of destination in VFR conditions.

VISUAL APPROACH SLOPE INDICATOR (VASI) - An airport lighting facility providing vertical visual approach slope guidance to aircraft during approach to landing by radiating an directional pattern of high intensity red and white focused light beams which indicate to the pilot that he is on path if he sees red/white, above path if white/white, and below path if red/red. Some airports serving large aircraft have three-bar VASI's which provide two visual guide paths to the same runway.

VISUAL FLIGHT RULES (VFR) - Rules that govern the procedures for conducting flight under visual conditions. The term VFR is also used in the United States to indicate weather conditions that are equal to or greater than minimum VFR requirements. In addition, it is used by pilots and controllers to indicate type of flight plan.



VOR - See "Very High Frequency Omnidirectional Range Station."

VORTAC - See "Very High Frequency Omnidirectional Range Station/Tactical Air Navigation."

WAAS - Wide Area Augmentation System, ground-based antennas whose precisely known locations are used to correct the satellite signals and provide greater positional accuracy as well as integrity of service to aircraft in the air. Given the current difficulties with WAAS, LAAS now has higher priority for implementation at U.S. airports.

YEARLY DAY-NIGHT AVERAGE SOUND LEVEL - See DNL.