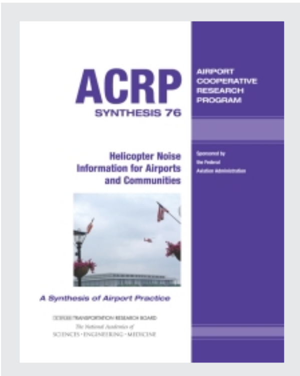

Helicopter Noise Information for Airports and Communities

DETAILS

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AIRPORT COOPERATIVE RESEARCH PROGRAM

ACRP SYNTHESIS 76

Helicopter Noise Information for Airports and Communities

A Synthesis of Airport Practice

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AIRPORT COOPERATIVE RESEARCH PROGRAM

Airports are vital national resources. They serve a key role in transportation of people and goods and in regional, national, and international commerce. They are where the nation's aviation system connects with other modes of transportation and where federal responsibility for managing and regulating air traffic operations intersects with the role of state and local governments that own and operate most airports. Research is necessary to solve common operating problems, to adapt appropriate new technologies from other industries, and to introduce innovations into the airport industry. The Airport Cooperative Research Program (ACRP) serves as one of the principal means by which the airport industry can develop innovative near-term solutions to meet demands placed on it.

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Cover figure: Helicopter over the Kennedy Center in Washington, D.C. *Credit*: Eric Seavey, Landrum & Brown.

FOREWORD

Airport administrators, engineers, and researchers often face problems for which information already exists, either in documented form or as undocumented experience and practice. This information may be fragmented, scattered, and unevaluated. As a consequence, full knowledge of what has been learned about a problem may not be brought to bear on its solution. Costly research findings may go unused, valuable experience may be overlooked, and due consideration may not be given to recommended practices for solving or alleviating the problem.

There is information on nearly every subject of concern to the airport industry. Much of it derives from research or from the work of practitioners faced with problems in their day-to-day work. To provide a systematic means for assembling and evaluating such useful information and to make it available to the entire airport community, the Airport Cooperative Research Program authorized the Transportation Research Board to undertake a continuing project. This project, ACRP Project 11-03, "Synthesis of Information Related to Airport Practices," searches out and synthesizes useful knowledge from all available sources and prepares concise, documented reports on specific topics. Reports from this endeavor constitute an ACRP report series, *Synthesis of Airport Practice.*

This synthesis series reports on current knowledge and practice, in a compact format, without the detailed directions usually found in handbooks or design manuals. Each report in the series provides a compendium of the best knowledge available on those measures found to be the most successful in resolving specific problems.

PREFACE

By Gail R. Staba
Senior Program Officer
Transportation Research Board

Helicopters produce a unique sound that is easily recognizable. While modern light- and medium-weight civil helicopters are much quieter than older helicopters and much quieter than heavy military helicopters they are still the focus of much community concern. They are complex machines that can land and takeoff vertically and are quite flexible in the routes they can take, which makes them useful for law enforcement, fire control, medical evacuation, media, tour operations, personnel transport, and training. Helicopters fly at much lower speeds than fixed-wing aircraft and, as a result, air traffic control separates them from fixed-wing aircraft, usually by altitude with the helicopters assigned altitudes below the fixed-wing aircraft.

A review of the literature and the ten airport survey respondents generally agreed that outreach, helicopter noise management programs, technology, and noise abatement procedures are most effective in managing helicopter noise.

All ten airport survey respondents generally agreed that community outreach was the most important part of their noise management programs. These outreach programs include updated websites, educating the public and operators in person, and notifying the public of changes in helicopter routes either for temporary purposes or permanent changes (and why). Respondents agreed that simply publishing noise mitigation procedures without making operators aware of them is not all that helpful. In the literature as well as from the airport survey helicopter altitude was the next most cited control measure. This is, of course, subject to air traffic control and cannot be mandated by the airport. Noise reduction with increased altitude is most effective directly under the flight track and the noise reduction diminishes to the side with increasing distance. The route structures also were commonly cited in the literature as well as in the airport survey.

Vince Mestre, Landrum & Brown, Irvine, California; and Paul Schomer and Katherine Liu, Paul Schomer and Associates, Inc., Champaign, Illinois, collected and synthesized the information and wrote the report. The members of the topic panel are acknowledged on the preceding page. This synthesis is an immediately useful document that records the practices that were acceptable within the limitations of the knowledge available at the time of its preparation. As progress in research and practice continues, new knowledge will be added to that now at hand.

CONTENTS

Note: Photographs, figures, and tables in this report may have been converted from color to grayscale for printing. The electronic version of the report (posted on the web at www.trb.org) retains the color versions.

HELICOPTER NOISE INFORMATION FOR AIRPORTS AND COMMUNITIES

SUMMARY

This synthesis of practice provides airport operators and their communities with a better understanding of helicopter noise and a description of the current state of effective practices for managing helicopter noise.

In many respects, helicopters are unique aircraft. They are complex machines that can land and takeoff vertically, and are flexible in the routes they can take, which makes them useful for law enforcement, fire control, medical evacuation, media events, tour operations, personnel transport, and training. Helicopters fly at much lower speeds than fixed-wing aircraft and as a result air traffic control (ATC) separates them from fixed-wing aircraft, usually by altitude, with the helicopters assigned to lower altitudes.

Helicopters produce a unique, easily recognizable noise. Under certain flight conditions they create a sequence of sharp, equally spaced impulses at a significantly lower frequency than fixed-wing propeller aircraft and nothing like the broadband (many frequencies) noise from jet aircraft. Helicopter impulsive noise is a complex phenomenon that has two primary causes: The first arises from the very high air flow near the tip of the advancing rotor blade that creates acoustic disturbances that travel outward near the plane of the rotor, called "high speed impulsive" noise and can be a problem for helicopters with high rotor tip speeds in cruise. High-speed impulsive noise can be heard when the aircraft is approaching and not when it is flying away and cannot be heard in the helicopter cabin. The second occurs when the trailing rotor blade interacts with the vortex created by the leading rotor blade and is often called "blade slap" (see Appendix A1 for more details). A portion of this noise can be heard in the helicopter cabin and is often used by the pilot to avoid blade slap flight conditions. Blade slap during landing is generally not a concern for airports as there is usually not a community near the landing pads at airports. However, landing blade slap may be a concern near police or fire helicopter landing pads, hospitals, and commercial or private helipads.

Although modern light- and medium-weight civil helicopters are much quieter than older helicopters and much quieter than heavy military helicopters they are still the focus of community concern. Communities recognize that helicopters fly lower than fixed-wing aircraft, often without knowing there is an air traffic safety reason for these procedures.

There has been discussion and research over the past 40 years about whether helicopters are more annoying than fixed-wing aircraft. There are several schools of thought, supported by research, ranging from the sound characteristics (low-frequency sound, blade slap, or easy to recognize sound) to operational and psychological factors (the low altitudes, the sense of loss of privacy associated with low-flying hovering aircraft, or a sense that if they have such flexibility in flight route that they should be flying somewhere else). Some of these are considered acoustic factors (that can be measured in decibels) and some are considered nonacoustic factors (not related to decibels, but some other judgment about need, control, privacy, etc.). ACRP Project S02-48 includes detailed community surveys to help distinguish acoustic from nonacoustic factors, as well developing a survey technique to determine if decibel-for-decibel helicopters are considered more annoying than fixed-wing aircraft. At the time of this writing, that study was not complete.

As part of this synthesis report a literature search was completed and an annotated bibliography created. In addition to the literature search, a number of airports were contacted and surveyed about their helicopter issues and their helicopter noise management programs. The mitigation strategies that surfaced as effective practices are listed here (and described and discussed in more detail in chapter seven):

- Outreach
  - To both community and operators
  - Flight track monitoring maps to aide discussion with community and operators
  - Establish local or regional forum to address helicopter noise.
- Helicopter noise management program
  - Collect and analyze complaints
  - Flight track monitoring
    - △ Report helicopter compliance
  - Published guides or brochures.
- Technology
  - Quieter aircraft
  - Pilot aides; that is, Global Positioning System-based routes and use of visual landmarks.
- Noise abatement procedures
  - Noise abatement routes
  - Minimum altitudes
  - Reducing high-speed impulse and blade slap
    - △ Reducing speed effect
    - △ Minimizing tight turns.
  - Limiting hovering.
- Media pooling
- Fees based on quiet technology
- Voluntary operational limits and curfews.

The ten airport survey respondents (100% response) generally agreed that community outreach was the most important part of their noise management programs. These outreach programs include updated websites, educating the public and operators in person, and notifying the public of changes in helicopter routes either for temporary purposes or permanent changes (and why). Respondents agreed that simply publishing noise mitigation procedures without making operators aware of them is not all that helpful. In the literature as well as from the airport survey helicopter altitude was the next most cited control measure. This is subject to ATC and cannot be mandated by the airport. Noise reduction with increased altitude is most effective directly under the flight track and noise reduction diminishes to the side with increasing distance. The route structures also were commonly cited in the literature as well as in the airport survey.

Airports can develop and propose voluntary noise abatement procedures that affect the speed, descent angle, or other operational aspects of helicopters, subject to review by FAA to ensure that they can be accomplished safely, do not compromise aircraft performance standards, and do not affect ATC clearance and separation standards.

Note that this synthesis does not address the legal issues associated with control of airspace or helicopter access restrictions at public use airports. The Airport Noise and Capacity Act of 1990 and its implementing Federal Air Regulations Part 161 place constraints on the ability of the airport proprietors to restrict aircraft operations at public facilities, such as heliports at hospitals, police stations, private residences, and commercial buildings that are not subject to these federal laws, and local and state governments are generally able to limit hours of operations, the number of operations, and noise levels through local land use regulations.

CHAPTER ONE

INTRODUCTION

This report provides airport operators and the surrounding communities with an improved understanding of helicopter noise and provides a description of the current state of effective practices for managing helicopter noise impacts. In some areas of the country, helicopter noise has re-emerged as a topic of intense community concern. As can be seen in the literature, many of the helicopter noise research projects date back to the 1970s and 1980s, with more than half of the documents reviewed published before 1990 and an overwhelming number published before 2000.

This Synthesis is one of three ACRP projects on helicopter noise that have been completed or are currently underway. The other two helicopter studies are ACRP S02-44, "Guidance for Helicopter Community Noise Prediction," which has been published as *ACRP Research Results Digest 24: Recommended Community Noise Model Enhancements to Improve Prediction of Helicopter Activity Impacts*, and addresses the improved technical methods to model helicopter noise, and ACRP S02-48, "Assessing Community Annoyance of Helicopter Noise," which was underway at the time this synthesis was produced in 2016. This project was undertaken to investigate acoustical and nonacoustical factors that influence community annoyance to helicopter noise, describing how this compares with community annoyance with fixed-wing aircraft and developing a research method to relate helicopter noise exposure to surveyed community annoyance.

- Chapter two begins with an overview of the unique characteristics of helicopters and helicopter noise and the roles of various stakeholders in helicopter noise management.
- Chapter three describes the community response to helicopter noise, including the direct annoyance associated with the airborne noise created by helicopters and the annoyance associated with so-called secondary emissions, which is the noise produced by rattling created by vibration induced by helicopter noise as well as the response resulting from nonacoustic factors. This chapter also summarizes laboratory and field findings about helicopter-specific noise-induced annoyance and discusses the role of complaints in addressing helicopter noise.
- Chapter four presents a summary of the noise metrics used to describe helicopter noise.
- Chapter five is a summary of the literature review.
- Chapter six describes the purposive survey conducted for this report, which asked ten individuals responsible for managing aspects of helicopter noise about effective practices. The airports and heliport were chosen based on the knowledge that they have a robust helicopter noise management program and that the airport has a history of helicopter noise issues.
- Chapter seven identifies effective helicopter noise abatement and mitigation measures based on the findings of the survey and literature review.

The report concludes with a set of references. Further technical discussion is provided in the appendices.

- Appendix A1 includes a short tutorial on the sources and nature of helicopter noise and an analysis of the correlations among noise metrics commonly used as predictors of community response.
- Appendix A2 presents a discussion of the differences in the various noise metrics that may be used to describe helicopter noise.
- Appendix A3 presents a description of a modern method of identifying the acoustic and nonacoustic effects on annoyance.

- Appendix B is an annotated bibliography on relevant studies on the annoyance of helicopter noise and potential ways to reduce that negative impact in both laboratory and field settings. It is intended as an interpretive guide to the technical literature on the annoyance resulting from helicopter noise and its mitigation. The annotation focuses on the issue of the excess annoyance of rotary-wing aircraft noise.
- Appendix C is a copy of the Helicopter Association International (HAI) Fly Neighborly Guide.
- Appendix D lists the questions used in the airport survey.
- Appendix E provides examples of various airports' helicopter noise brochures.
- Appendix F is an example letter of agreement between the airport operator and the FAA air traffic control.

Superscripts in the text refer to Endnotes that are located at the end of this document.

Note: Within the aviation industry these aircraft are usually called rotary-wing aircraft or rotorcraft, but this report uses the more common term helicopter.

CHAPTER TWO

UNIQUE ROLE OF HELICOPTERS, THEIR COMPLEX NOISE CHARACTERISTICS, AND THE ROLE OF STAKEHOLDERS

Helicopters are unique aircraft in terms of how they fly and how they are used. Because they can lift off and land vertically they do not need a long runway for takeoff and landing. They also can operate at low speeds, hover, make tight turns, and reverse course in mid-air. This operational flexibility is the primary utility of the helicopter and has allowed for their use by a wide range of operators. In the vicinity of civilian airports the helicopters people see and hear on a daily basis may be flown by or for police, medical facilities, news organizations, tour operators, and construction or maintenance, training, or personnel transport.

Helicopters are used for many of the same purposes as fixed-wing aircraft, such as surveillance by law enforcement, air tours, aerial photography, search-and-rescue operations, and crop-dusting; however, in many situations their unique characteristics may make them better suited for these missions. Other missions, such as heavy lifting in construction or utility line projects, cannot be performed by fixed-wing aircraft. Helicopters can also provide an advantage over ground transportation, particularly in congested urban areas or remote wilderness. For example, helicopters have proven effective for medical evacuations and search-and-rescue operations for which other means of transportation cannot compete in terms of minimizing travel time to emergency care and operating without the need of a runway.

For all the benefits that helicopters provide, they also have undesirable characteristics. Helicopters may be seen as a potential invasion of privacy because of their ability to fly and hover at low altitudes. Because helicopters operate at significantly lower speeds than most fixed-wing aircraft, in congested airspace ATC may keep them at a lower altitude to avoid conflicts between the two, and this is readily noticed by the community. This separation of altitudes between helicopters and fixed-wing aircraft is a key safety factor often not well understood by the public. Although the light civilian helicopter is significantly quieter than the heavy military helicopter, people recognize helicopter noise as distinct from fixed-wing aircraft noise and may react more negatively to it. Much of this report is dedicated to explaining the unique noise characteristics of the helicopter, including low-frequency noise from the main and tail rotor, and impulsive noise (“high speed impulsive” noise and blade slap) (see Appendix A1 for a more detailed discussion).

UNDERSTANDING HELICOPTER NOISE IN COMPARISON WITH FIXED-WING AIRCRAFT NOISE

For many reasons community reaction to helicopter noise has not been as thoroughly studied and is less well understood than community reaction to fixed-wing aircraft noise. Most conspicuously, there are far fewer helicopters than fixed-wing aircraft. For example, of 232,567 active aircraft in the domestic U.S. fleet, including commercial and general aviation aircraft, only 11,245 are helicopters (FAA 2011). Despite the smaller numbers of helicopters, people affected by exposure to helicopter noise nonetheless may find it to be distinctive and annoying.

The noise emissions of helicopters are more complex, variable, and more unpredictable than those of fixed-wing aircraft. Appendix A1 provides a brief tutorial on the sources and characteristics of helicopter noise in various flight regimes. Helicopter noise emissions vary considerably between approach, departure, hover, and overflight. Rotor High Speed Impulsive noise is concentrated in the plane of the rotor disk and in the direction of forward flight. Blade Slap Impulsive noise radiates more out of plane and is most intense in the direction of forward flight. Tail rotor harmonic noise has the same physical origins as the main rotor and can be a notable noise source with its radiation pattern rotated by 90 degrees. Broadband emissions of rotary-wing aircraft are typically greater on the side of the aircraft. Furthermore, the low-frequency noise emissions of helicopters can cause more indoor rattle and vibration in residences than fixed-wing aircraft. This vibration is caused by the helicopter noise interacting with the structure of the home and is a result primarily of the lower frequency content of helicopter noise.

Fixed-wing aircraft noise increases as an aircraft flies toward an observer, reaches a peak at about the time that the aircraft is directly overhead, and then decreases as it flies away from the observer. In contrast, helicopters typically operate at lower altitudes and at slower speeds than fixed-wing aircraft and may hover or fly in tight circles over a given area. Banking, turning, and changing flight speeds can substantially change noise radiation. These flight characteristics can render individual helicopter operations more variable and more audible for longer periods of time than fixed-wing aircraft overflights.

In areas within a few miles of runway ends, high-speed, fixed-wing aircraft usually follow predictable paths and distribute their noise emissions symmetrically with respect to the flight path. In contrast, helicopters may approach and depart a landing pad at low speeds and to and from more than one direction. In addition, the spatial distribution of helicopter noise varies based on source directivity, dependence of emissions on operation (takeoff, approach, hover, overflight), and the operational flexibility of rotary-wing flight.

The location, timing, and duration of helicopter noise are less predictable than that of fixed-wing aircraft. For example, at an air-carrier airport airlines tend to have busy periods in the morning and late afternoon/evening, with busy Fridays and Mondays and slow Saturdays. Helicopters are used for a number of different activities, many of which do not follow a predictable pattern.

For these reasons, researchers have theorized that helicopter noise may be more annoying on a per-event basis than fixed-wing aircraft noise of comparable sound level. It is also theorized that the repetitive impulsive nature of helicopter noise is its most annoying characteristic. Neither of these interpretations has been conclusively proved by research. In particular, it remains unclear whether the supposed “excess” annoyance of helicopter noise (vis-à-vis that of fixed-wing aircraft noise) is acoustic or nonacoustic in origin or is a combination of both.

A compounding factor is the age of the helicopter fleet. The United States has phased out older jet aircraft; however, there is no mandatory retirement of older helicopters. A recent study estimates that 60% of the helicopters built 40 years ago (1975) and 95% of helicopters built 20 years ago are still in the fleet (see http://www.ascendworldwide.com/2014/03/what-factors-influence-helicopter-values.html). This compares with the U.S. commercial jet aircraft fleet, where the average aircraft is retired at 27 years (http://www.airfinancejournal.com/Article/3341243/Aircraft-Retirement-Trends-and-Outlook.html).

ROLE OF STAKEHOLDERS

FAA plays several different roles in helicopter noise management. It sets noise certification standards through Federal Air Regulation Part 36. These are noise levels set at defined measurement locations and tested under specified conditions, as part of FAA certification of the helicopter type prior to its sale in the United States. Each noise certification standard is designated as a different “stage,” with Stage 1 being the loudest. Helicopters are certified as Stage 1, Stage 2, or Stage 3.

FAA manages the airspace in which helicopters operate and is responsible for the safe operations of aircraft. The *Report on the Los Angeles Helicopter Noise Initiative* (FAA 2013) describes airspace management and safety considerations in greater detail. It is described in the annotated bibliography (Appendix B) and available on the FAA website:

> http://www.faa.gov/regulations_policies/policy_guidance/envir_policy/media/la_helicopter_noise%20report_final_053113.pdf.

FAA also licenses pilots; there are a relatively small number of licensed helicopter pilots compared with fixed-wing pilots (in 2011, 37,000 helicopter pilots out of a total of 619,000 pilots, including commercial aircraft pilots: http://www.aopa.org/About-AOPA/General-Aviation-Statistics/FAA-Certificated-Pilots). This is a benefit because voluntary noise abatement measures are easier to communicate to the smaller helicopter pilot population.

States play varying roles in managing helicopter noise. They generally have statewide aviation system plans that in some cases include helicopter forecasts and facility needs. An important role that states play in managing helicopter noise is through enabling local land use legislation. This can vary widely from state to state, but includes the ability for local jurisdictions to allow for zoning or land use restrictions on private heliports or helipads. State restrictions on helicopter operations may be preempted at public use airports or heliports.

Local government has control over private use heliports and helipads through zoning and land use restrictions, but may have more limited control over helicopter operations at public use facilities. The restrictions may include limits on the number of operations, time of operations, size of helicopters, and noise levels. These kinds of restrictions are often found as part of conditional use permits or zoning restrictions for hospitals or other private heliports or helipads.

Local government is also responsible for compatible land use planning. Only local government can adopt policies that ensure compatible land uses around airports and heliports pending the existence of enabling state land use legislation. Currently, there are no unique noise/land use compatibility guidelines for helicopter noise and further research is needed to determine if such policies are needed or warranted.

The airport operator is generally a part of local government and is responsible for the operation of the airport. Members of the community often confuse the role of the airport operator and FAA. Although the airport operator is responsible for maintaining and operating the airport facilities and can develop and propose voluntary noise abatement procedures, FAA has exclusive control over aircraft in flight. Although an airport operator can make requests to FAA, only that agency may chart flight routes and altitudes.

CHAPTER THREE

COMMUNITY RESPONSE TO HELICOPTER NOISE

ANNOYANCE

The adverse impact of aircraft noise is usually expressed in terms of annoyance (that is, a subjective response to a particular sound). Annoyance is gauged by the self-report of reactions in community-wide social surveys, which typically ask residents about their level of annoyance with aircraft noise, ranging from "not at all" to "highly annoyed." Schultz (1978) and his successors have produced several quantitative dosage-response relationships to predict the prevalence of a consequential degree of aircraft noise-induced annoyance attributable to cumulative noise exposure. The most commonly cited measure of community annoyance response to noise is the Schultz Curve, which plots the percentage of the population that is highly annoyed as a function of Day-Night Average Noise Level (DNL). The Schultz Curve was based on aircraft, rail, and road noise. Very little information is available concerning the annoyance produced by helicopters rather than fixed-wing, rail, or road operations.

Dosage-response relationships, such as the Schultz Curve, attempt to predict the prevalence of annoyance in communities from cumulative noise exposure such as DNL. The Schultz Curve accounts for less than half of the variance in the association between noise exposure and annoyance. In other words, there is a wide range in the reported annoyance for a given noise level, indicating that community annoyance is dependent on more than just the DNL. Only in recent years has a practical, quantitative method emerged for incorporating an additional variable into predictions of annoyance prevalence rates. This is described in the next section, where the annoyance prediction accounts for *non*acoustic influences on annoyance.[1] In the literature, a number of "correction factors" have been suggested for interpreting helicopter noise based on the impulsive nature and/or induced rattle caused by helicopter noise. These factors range from 3 to 12 dB with no clear consensus.

Even if it is assumed that the annoyance of exposure to noise produced by helicopters is best understood in entirely acoustic terms, a further question remains: whether that annoyance is produced solely by the airborne acoustic energy that helicopters produce or also by secondary emissions (rattling noises and vibration) induced by helicopter noise in residences.

DIRECT ANNOYANCE OF AIRBORNE NOISE CREATED BY HELICOPTERS

There is an outstanding question in the research field as to whether a noise metric such as DNL accounts for the way people respond to helicopter noise. In the annotated bibliography (Appendix B) there is discussion of correction factors considered for helicopter noise. Appendix A2 shows that even if other noise metrics such as those that are affected by low-frequency noise are considered, most metrics are highly correlated (note that none of the existing metrics account for impulse type noise). Leverton (2014; see also Leverton and Pike 2007, 2009) suggests that helicopters are perceived differently and that nonacoustic factors play a role. Fidell et al. (2011) published a way of measuring the nonacoustic response by comparing communities and identifying the acoustic and nonacoustic part of annoyance response (Appendix A). The Final Draft International Standard of the revised ISO Standard 1996-1[2] (ISO 1996) adopts this concept of a correction factor by noise source, but does not directly address helicopter noise correction factors. If helicopter noise is more annoying, decibel for decibel, than fixed-wing aircraft noise, perhaps a helicopter-specific annoyance dosage-response curve may be developed and an ISO 1996-1 type correction for helicopters may be developed; however, to date no such relationship is known. This is an area where additional research is needed.

FAA's review of the technical literature on the annoyance of helicopter noise in its Nonmilitary Helicopter Urban Noise Study (FAA 2004) cites eight (mostly laboratory) studies supporting the imposition of a blade slap penalty on A-weighted measurements of helicopter noise and seven suggesting that such a penalty is not justified. The FAA report also cites two studies of heightened reaction to helicopter noise—presumably not associated with blade slap—by Schomer (1983) and Atkins et al. (1983). Based on the inconsistency and ambiguity of these findings, the study concluded that the annoyance of helicopter noise had not been fully substantiated by a well-correlated metric. As a result, FAA continued to rely on DNL as its primary noise descriptor for airport and heliport land use planning and also continued to use supplemental noise descriptors for evaluation of helicopter noise issues.

ANNOYANCE RESULTING FROM SECONDARY NOISE EMISSIONS

Inside homes near helipads and helicopter flight paths helicopter operations can induce a noticeable vibration in addition to the noise that penetrates the structure. These are called structural vibrations or secondary emissions, because the vibration is the product of sound waves from the helicopter interacting with the structure of the home. A portion of the energy contained in the sound waves is transferred to the structure and, as a result, the home vibrates. Even modest levels of structural vibration, which might escape direct notice, can cause lightweight or suspended architectural elements that are mounted vertically [e.g., windows, doors, pictures on walls, heating, ventilation, and air conditioning (HVAC) ducts, and other vertically mounted household paraphernalia] to rattle audibly.[3] Such rattling noises can be annoying in their own right, whether or not accompanied by noticeable vibration or by audible helicopter noise. This is more likely to be a problem with helicopters rather than fixed-wing aircraft, because of the low-frequency content of helicopter noise that is not usually a part of fixed-wing aircraft noise.

Research has attempted to quantify the increase in annoyance associated with the induced rattle. Fidell et al. (2002a) showed a relationship between the prevalence of annoyance resulting from aircraft noise-induced rattle and a single event measure of low-frequency noise. In other words, if the helicopter noise induces a rattle, the annoyance response is increased as though the noise were louder than it is. The annotated bibliography (Appendix B) cites a number of papers where this is discussed, and there is general agreement that induced rattle causes higher reported annoyance than if no rattle were to exist at the same noise exposure; however, there is no consensus on the correction factor that may be associated with this induced rattle.

The presence of secondary emissions is affected by the type and quality of the home construction as well as maintenance. Aluminum sliding windows of the 1960s are well known for their lightweight, poor fit, and predisposition to rattle. Recent building codes, instituted to reduce home energy consumption, have contributed to much higher quality, better fitting windows, with far less tendency to rattle.

LABORATORY VERSUS FIELD STUDIES OF HELICOPTER ANNOYANCE

Studies of the annoyance of helicopter aircraft noise have been conducted under both laboratory and field conditions. Laboratory studies offer greater control over listening conditions than field studies, but lack the context of field studies. It is also difficult to accurately reproduce recorded or synthesized helicopter sounds under laboratory conditions, while preserving the dynamics of helicopter noise emissions. On the other hand, although field studies provide the appropriate context for annoyance judgments, they lack the precision of control over acoustic conditions of laboratory studies.

It follows that questions about potential nonacoustic influences on the excess annoyance of helicopter noise are not readily answered in laboratory studies and that questions about the detailed acoustic origin of excess annoyance are not readily answered in field settings.

Schomer and Wagner (1995b) captured many of the benefits of both methods with their laboratory and field studies in which subjects in real houses compare two real sound sources. One is the source under test, such as a helicopter flyby, and it is compared with the noise of five or six different sizes of passing motor vehicles. The authors also found "that the rate of notice of helicopter noise was three times as great as the rate of notice of fixed-wing aircraft noise." They speculate that the greater rate of notice of helicopter noise was due to the "distinct sound character" of rotary-wing aircraft. Because the participants were exposed to notably fewer helicopter than fixed-wing overflights, it is also possible that they were less habituated to helicopter noise than to fixed-wing aircraft noise.

NONACOUSTIC CONTRIBUTIONS TO COMMUNITY REACTION TO HELICOPTER NOISE

FAA, in its *Report to Congress: Nonmilitary Helicopter Urban Noise Study* (2004) has summarized many operational, situational, and other nonacoustic factors that contribute to the adverse community response to helicopter noise, including low flight altitudes; long hover durations; and the times, numbers, and frequencies of operations, fear of crashes, and attitudes of misfeasance and malfeasance. With the exception of hover times, these factors similarly affect the annoyance derived from fixed-wing aircraft noise. Helicopters hovering over residences or operating at low altitudes may prompt concerns about the privacy or fear of crashes, which can affect annoyance.

Perceptions of the necessity for flight operations can also affect the response to helicopter noise. The necessity of medical evacuation, search and rescue operations, and firefighting is widely acknowledged and may make noise from helicopters conducting these missions more acceptable to the communities they serve. In contrast, private transportation of individuals by helicopter is widely viewed as a luxury (for example, rich people avoiding road traffic), which may contribute to an increase in annoyance.

The ability of helicopters to takeoff from and land at nearly any flat area and to fly on nonlinear routes likewise can affect the level of annoyance. Fixed-wing aircraft near airports necessarily approach and depart runways on flight paths corresponding to runway alignments. Helicopters are not as predictable in their flight paths and the reason for their operation in a particular area is not always apparent. For example, helicopters may be directed by ATC to hover at a distance from an airport to avoid conflict with a faster-moving jet aircraft or may be flying at a lower altitude to remain below cloud cover. Because helicopters are slower than fixed-wing, aircraft ATC separates helicopters from fixed-wing aircraft primarily by keeping helicopters at altitudes below the altitudes of fixed-wing aircraft. Given their flexibility of flight, people may wonder why a helicopter is flying close to their homes rather than over water or at a higher altitude.

The most common nonacoustic factor discussed in the literature, both for fixed-wing aircraft and helicopters, is fear of an accident. Other factors include the perceived necessity of the operation, predictability of the noise, and habituation and past experience (Harris 1979). Helicopters add a unique nonacoustic factor, which can be perceived as a loss of privacy. It is possible that because helicopters have the ability to hover and are typically kept at lower altitudes than fixed-wing aircraft the effect of fear and loss of privacy is exacerbated. In the airport surveys done as part of this synthesis, interviewees reported that communities commonly request that helicopters be flown at higher altitudes. There may be both acoustic and nonacoustic reasons behind this request.

COMPLAINTS

Complaints are one means through which the community communicates its annoyance with helicopter noise. It is important to distinguish between complaints and annoyance. In the field of psychoacoustics annoyance is considered an attitude and a complaint is considered a behavior. Community attitudes; that is, annoyance, are determined through complicated and expensive social surveys of randomly selected individuals in the community. Community complaints are usually recorded by the local airport. A novel approach to helicopter noise has recently been instituted in Los Angeles and is based on collecting helicopter complaints correlated with flight tracks to help identify patterns and trends in helicopter operations, improve understanding of community reaction to helicopter noise, and inform future efforts to develop and implement noise abatement measures (see http://heli-noise-la.com/). Whether collected regionally or by airport complaint tracking is one measure of community response that many airports find useful. Interpreting the complaint data can be complicated by a number of prolific complainers; therefore, complaint data are often reported and mapped as the total number of complaints and total number of complainers. A recent report identifies interesting patterns in complaints that appear to be common to all airports and that is that for nonprolific complainers there is a fixed ratio of the number of people who complain once, versus twice, three times, etc. (Fidell et al. 2012).

In 2007, in response to community concerns, FAA designed a visual flight rules (VFR) helicopter route to reduce noise over communities along the north shore of Long Island by moving flights offshore and establishing a minimum altitude. FAA published the route on the Helicopter Route Chart for New York, effective May 8, 2008. Subsequently, New York public officials advised FAA that they continued to receive noise complaints in this area even with the voluntary North Shore Helicopter Route in place. In 2012, FAA adopted a rule that made the route mandatory for a trial period of 2 years, on the basis that increasing use of the route by making it mandatory would further reduce noise impacts from helicopters operating along the north shore of Long Island (the rule was subsequently extended for an additional 2 years). In July 2013, the Federal Court of Appeals for the District of Columbia found that the rule was supported by substantial evidence. The ruling appears to rely considerably on evidence of a high number of noise complaints rather than any specific acoustic measure.

CHAPTER FOUR

NOISE METRICS FOR QUANTIFYING HELICOPTER NOISE

Measuring noise is complex. It is not the intent of this synthesis to delve into this topic in great detail, but to provide a broad overview. When discussing noise metrics it is common to talk about weighting factors. The two most common weighting factors are “A” and “C” weightings. These are frequency weightings used to adjust measured sound levels to how the individual perceives loudness at different frequencies. Frequency is measured in hertz (Hz) and it represents the sound frequency in cycles per second. Middle C (the centermost key on a piano) is approximately 250 Hz. People hear very well in the so-called middle frequencies (centered at 1,000 Hz) and poorly at low frequencies; for example, sound at 125 Hz would have to be approximately 16 decibels (dB) louder than a sound at 1,000 Hz for an individual to perceive them as having the same loudness. The commonly used DNL metric used for noise policy is based on the A-weighted decibel. The C-weighted decibel does not adjust the low-frequency sounds in such a significant way until the frequency is less than 25 Hz. For helicopter noise, the measured C-weighted level is significantly higher than the measured A-weighted level; on the order of 10 dB (Schomer 1987).

Note that this discussion of the frequency weightings is based on perceived loudness. There are other scales for measuring human response to noise based on perceived noisiness. Aircraft noise certification tests are based on Perceived Noise Level (PNL). The differences between the two systems resulted from psychoacoustic studies where people were asked to rate different noises; some studies were based on ratings in terms of loudness and others based on ratings according to noisiness.

To the extent that excess annoyance of helicopter noise is attributable to the annoyance of rattle and vibration (to which A-weighted noise metrics are insensitive), A-weighted noise metrics are unlikely to adequately predict the overall annoyance of helicopter overflights of residential populations.

The two frequency weighting networks and families of noise metrics are commonly employed in the United States to express sound levels of both fixed-wing aircraft and helicopters. For aircraft noise certification purposes, FAA’s required frequency weighting is the Tone-Corrected Perceived Noise Level, abbreviated PNLT, developed in the 1950s. For predicting and assessing environmental impacts of aircraft noise exposure, FAA endorses the A-weighting network, which dates to the 1930s, and is the weighting used in DNL that forms the basis of current FAA noise policy.[4] Each metric such as Sound Exposure Level, DNL, or Maximum Noise Level, can be expressed in terms of A or C weighting and from instantaneous through annual time frames.[5]

Concern about the appropriateness of noise metrics for predicting annoyance derived from exposure to helicopter noise has arisen several times since the 1950s. As discussed in Appendix B, a 1982 literature review by Molino (1982) compares the findings of 34 earlier analyses of the annoyance of helicopter noise, the earliest of which date to the 1960s (cf. Crosse et al. 1960; Robinson and Bowsher 1961; and Pearsons 1967). The findings of these early studies are neither consistent nor definitive. They and other studies (e.g., Powell 1982) do not fully support Molino’s conclusion that there is “no need to measure helicopter noise any differently from other aircraft noise.”

The common belief that rotary-wing aircraft noise is more annoying, on a decibel-for-decibel basis, than fixed-wing aircraft noise has led to the practice of imposing decibel-denominated penalties on A-weighted (but not PNL-weighted) measures of helicopter noise for purposes of assessing environmental impacts of helicopter noise.

The tactic of assigning penalties treats the assumed excess of annoyance of helicopter noise as a simple problem of measurement, while ignoring the underlying causes of the supposed excess annoyance. However, since the evidence supporting the assumption of excess annoyance is not definitive, the issue may not simply be one of physical measurement. The supposed excess could be attributable to operational factors (the characteristic shorter slant ranges and relatively longer duration of helicopter flyovers vis-à-vis fixed-wing aircraft operations) rather than inherent differences in noise-induced annoyance. The supposed excess could also be entirely attributable to nonacoustic factors. Although much has been learned about the mechanisms that generate rotary-wing aircraft noise in different flight regimes since Molino's 1982 review, it is only recently that systematic means have become available to focus more closely on potential nonacoustic factors that influence annoyance judgments (Appendix A3 provides greater detail).

CHAPTER FIVE

SUMMARY OF FINDINGS OF LITERATURE REVIEW

The literature review started with the review that had already been completed for ACRP S02-48 ("Assessing Community Annoyance of Helicopter Noise") and expanded to cover documents identified in the references to that document and documents recommended by panel members, recommended by surveyed airports, and suggested by the authors of this report. A search of helicopter noise studies in general uncovered a large number of documents; the majority of helicopter noise studies that address the technical aspect of measuring, predicting, or controlling helicopter noise through helicopter design. These technical documents address the aero-acoustics, physics, and study of helicopter noise generation and control. The technical documents that form the primary body of existing research are important but are not as useful as a practical guide on managing helicopter noise except to the extent they can be referenced as progress being made in the field of producing quieter helicopters. The literature review focused on those studies that addressed human response to helicopter noise, mitigating helicopter noise, or managing helicopter noise, generally favoring peer-reviewed journal articles, government agency reports, and industry studies.

The literature review for this project, as well as prior literature reviews such as those conducted by Molino (1982), Ollerhead (1985) and FAA (2004), documents research undertaken in the last half century to quantify and predict the individual and community annoyance of helicopter aircraft noise and evaluate ways to manage the impacts of helicopter noise. An annotated bibliography is presented in Appendix B. The reader is encouraged to review this material for a more detailed view of helicopter noise response research.

The literature is most prevalent in the 1970s and 1980s, and appeared to peak in the 1990s, with most research done by government agencies in the United States and Europe, particularly by the military. After the year 2000 the research was focused more on the technical issues of aero-acoustics and design of quieter helicopters and tilt-rotors.

Whether conducted under laboratory or field conditions, much of this research was intended, directly or indirectly, to inform decisions about aircraft noise regulatory policy. The early research searched for a noise metric that would correlate helicopter noise to response and create in effect a helicopter dosage-response relationship much like the fixed-wing, dosage-response relationship endorsed by the Federal Interagency Committee on Noise (FICON 1992). The reviewed literature did not identify any such "magic bullet" approach to assessing helicopter noise. A number of approaches were found that used helicopter "corrections" to account for the differences in response to helicopter noise; however, these generally were studies directed at large military aircraft or a single type of civilian helicopter.

The findings of individual studies of the annoyance of helicopter noise disagreed about as often as they agreed. The main point of agreement in the technical literature is that helicopter noise is much more variable and complex than fixed-wing aircraft noise. This variability and complexity make it more difficult to accurately and credibly model helicopter noise exposure (other than under idealized conditions[6]), particularly in the vicinity of helipads. It follows, in turn, that predictions of the prevalence of annoyance of exposure to helicopter noise are likely to be more uncertain than predictions of the annoyance of exposure to fixed-wing aircraft noise.

A main point of disagreement is the degree to which main rotor impulsive noise controls the annoyance of helicopter noise. Some studies conclude that impulsiveness corrections are appropriate for predicting this annoyance; others found that conventional A-weighted noise measurements suffice for predicting the annoyance of helicopter noise.

There were no studies done by countries, organizations, manufacturers, or communities that comprehensively examined the rates of reported high annoyance with noise exposure for a variety of helicopter types. The lack of an accepted dosage-response relationship for helicopter noise is the single largest gap in the knowledge base for understanding helicopter noise response. Some of the findings of this literature review included:

- Neighborhood opinions about the difference in annoyance owing to helicopter and fixed-wing aircraft noise exposure likely differ for nonacoustic reasons and these differences may differ from community to community. Unless analytic means are employed to account for such community-specific differences, it may not be possible to reliably identify differences in opinions about fixed- and rotary-wing annoyance per se.
- The flexibility of helicopter flight lends itself to much more complex and widely varying flight paths than those of fixed-wing aircraft. The directivity of helicopter noise emissions and changing noise levels during turns and acceleration and deceleration further complicate noise exposure predictions based on flight tracks alone. These factors contribute to the unpredictability of the noise, which is one cause of increased level of annoyance.
- Extensive efforts to confirm the utility of impulse noise adjustments have proved contradictory and inconclusive. Resolving how to account for the impulse characteristics and low-frequency characteristics is an area in need of research. One issue is that much of the early research on this topic was done based on noise from heavy military helicopters that do not have the same noise signature as lightweight civilian helicopters.
- Correlation analyses have shown that most of the noise metrics commonly used to quantify helicopter noise are so highly correlated that no one metric differs meaningfully from others in its ability to predict the prevalence of annoyance with helicopter noise.
- Questions about potential nonacoustic influences on the “excess” annoyance of helicopter noise are not readily answered in laboratory studies, whereas questions about the detailed acoustic origin of excess annoyance are not readily answered in field settings. Understanding the role of nonacoustic factors, including identifying the more relevant nonacoustic factors, is an important research need.
- Industry-developed noise mitigation measures focus on altitude, avoiding blade slap through control of forward speed and descent or climb rate, and avoiding the overflight of residential areas. The *HAI Fly Neighborly Guide*, while providing guidance to operators not airports, is a very useful summary of effective practices on operating the helicopter (subject to the limitations described later in the section on reducing high-speed impulse and blade slap noise).
- Air traffic issues can complicate the development and implementation of altitude or route restriction most identified by complaining communities, as described in the FAA report on the Los Angeles Helicopter Noise Initiative.

CHAPTER SIX

AIRPORT HELICOPTER NOISE SURVEY

Staff at eight airports, one helipad, and a regional office of FAA was interviewed about helicopter noise issues and noise management approaches. The survey sites were chosen based on author knowledge of helicopter noise management programs, the LA Helicopter Noise Initiative, and input from the ACRP panel members. Interviews were conducted by using a semi-structured format that consisted of a series of open-ended questions. Detailed notes were kept and responses recorded, and copies of any brochures or other printed guidance that was not available on the organization's website were requested. The questionnaire is reproduced in Appendix D along with a summary table of responses to each question.

The responding organizations were:

- Austin–Bergstrom International Airport (Austin, Texas)
- Representative for PlaneNoise, Inc., for helicopter operations on Long Island, New York
- FAA (Western Pacific Region)
- Long Beach Airport (Long Beach, California)
- Los Angeles International Airport (Los Angeles, California)
- McCarran International Airport (Las Vegas, Nevada)
- Oakland International Airport (Oakland, California)
- UCSF Benioff Children's Hospital Helipad (San Francisco, California)
- San Francisco International Airport (San Francisco, California)
- Van Nuys Airport (Los Angeles, California).

All respondents noted that they had a program in place to help manage the noise impact of helicopters, although these varied in degree of formality and specificity from a city ordinance to voluntary fly quiet programs. Those programs often included recommended flight paths that avoid residential areas, with recommended altitudes being less common because of issues of safety and regulation by FAA. A few airports monitored adherence to routes through setting up gates or by tracking the helicopters by call sign using their airport noise monitoring system that included a flight tracking system. Some of the survey respondents also limited training operations by restricting time of day or the location of those operations. All of these measures, as well as general information about the helicopter noise management programs, were generally accessible online.

Each respondent dealt with different combinations of types of helicopter operations, with the most common categories being transport, law enforcement, fire department, medical, tour, and media. Between the various airports and heliports, the number of operations per day ranged from one to 300; a significant difference in the level of activity. Just as the number of operations varied, so did the number of complaints; anywhere from a few per month to about 2,000. Most of these were triggered by noise, with many people complaining about the noise in general, frequency of flights during certain times of day, low altitudes, and deviations from routes, whereas factors such as fear of crashes and loss of privacy were rarely cited as concerns.

In terms of helicopter noise management, most respondents reported that outreach was most effective, including maintaining a flow of information through websites, educating the community and operators in person, or notifying people if helicopter routes were created that passed over their property. It is important to note that outreach in this context meant outreach to the community and to helicopter operators. Higher altitudes, route compliance, and diversifying route structures were also mentioned as important measures. Respondents noted that simply publishing noise mitigation procedures without making operators aware of them is not effective. To improve their helicopter noise management, most respondents regularly hold formal or informal meetings with helicopter operators. However, respondents recognized that airports and public use heliports are limited in their ability to control helicopter operations or restrict their access.

Some respondents suggested that the FAA could make the Integrated Noise Model easier to use, make it easier to track individual helicopters, keep the community and operators informed, and remain aware of repeat caller impact when analyzing complaint data. The air traffic control tower staff was viewed as supportive by all of the airports interviewed, and respondents reported that the controllers usually tried to assist with implementing the noise abatement procedures in place at each airport. Ultimately, even as they saw the potential for further improvement, many believed that their helicopter noise management programs were already satisfactory; however, all agreed that a guidebook of effective practices would have an overall positive effect.

CHAPTER SEVEN

EFFECTIVE PRACTICES AND MITIGATION OF HELICOPTER NOISE

The following list of potential strategies was developed from the literature review (in particular the *HAI Fly Neighborly Guide* and the *Los Angeles Helicopter Noise Initiative Report*), and the airport survey. The list is followed by relevant discussion of each strategy. As noted in the *Los Angeles Helicopter Noise Initiative Report*, ensuring safety is the FAA's primary mission and none of the potential measures should be considered where such a measure might compromise safety.

LIST OF POTENTIAL STRATEGIES FOR USE BY AIRPORT AND HELIPORT OPERATORS

- Outreach
  - To both community and operators
  - Flight track monitoring maps to aid discussion with community and operators
  - Establish local or regional forum to address helicopter noise.
- Helicopter noise management program
  - Collect and analyze complaints
  - Flight track monitoring
    - △ Report helicopter compliance
  - Published guides or brochures.
- Technology
  - Quieter aircraft
  - Pilot aides; that is, Global Positioning System-based routes and use of visual landmarks.
- Noise abatement procedures
  - Noise abatement routes
  - Minimum altitudes
  - Reducing high-speed impulse and blade slap
    - △ Reduced speed effect
    - △ Minimize tight turns
  - Limit hovering.
- Media pooling
- Fees based on quiet technology
- Voluntary operational limits and curfews.

DISCUSSION OF NOISE MITIGATION STRATEGIES

Outreach

The airport operators responding to the survey universally identified outreach as the number one component of their programs. The outreach refers to both outreach to the community and outreach to helicopter operators. Airports that have flight track monitoring systems use the flight track maps as a means of communication with both the community and operators. Because the establishment of helicopter routes and altitudes must be integrated with the safe separation of helicopters from fixed-wing aircraft it is imperative that the community understand the constraints and also understand that FAA, not the airport, controls all aircraft in flight. Some airports have been successful in establishing community noise forums (San Francisco International Airport, Oakland International Airport, and Los Angeles International Airport) and these forums have been useful in bringing the airport operator, the community, FAA, and the aircraft operators into a forum or round table for discussing issues and developing noise management programs.

Helicopter Noise Management Program

A noise management program is a means to implement the goals of reducing helicopter noise in the community and track the progress toward meeting that goal. It is not possible here to develop a universal noise management program that will fit all airports. Effective noise management programs require input from all stakeholders. The roundtable/noise forum structure described previously may be useful for complex situations or developed as part of another community outreach or public forum that the airport may already have in place. The keys to establishing a program are setting goals, developing implementation programs, and monitoring progress on meeting those goals. Periodically, new goals or modified goals and implementation measures may be needed.

A helicopter noise management program that recommends routes and altitudes will have to be developed with FAA as only this agency may set routes and minimum altitudes. It may be possible in noncongested airspace for an airport to suggest voluntary routes and minimum altitudes; however, in congested airspace this program will need to be coordinated with FAA and only FAA can publish these routes and altitudes on official aeronautical charts. It is generally considered poor noise management practice to move noise from one community to another; therefore, establishing route structures requires looking for potential impacts created by new routes.

Suggested means to monitor progress include tracking noise complaints and monitoring flight tracks. A good example of complaint tracking is the program designed for the Long Island (New York) area. Analyzing trends in noise complaints can identify progress or regression in terms of trends in the number and location of complaints. Complaint tracking is enhanced when complainers provide their location so that complaints can be mapped. The Los Angles Helicopter Noise Initiative's Automated Complaint System is the first county-wide system dedicated to helicopter noise and uses flight track monitoring to correlate complaints with specific helicopter operations. Flight track monitoring is common at airports with noise monitoring systems and less common at smaller airports. There are multiple vendors that provide flight tracking systems and they can be costly. A relatively new feature of flight tracking systems is providing a web portal so that community members and operators can visually see aircraft flight tracks in near real time or historical data, although the ability to accurately identify helicopters varies with the system capabilities and the data feed. Some of these systems allow for online noise complaint entry. Examples of flight tracking web portals for the community can be found at the following airports websites:

http://www.flysfo.com/flight-info/flight-tracker
http://webtrak5.bksv.com/oak
www.planenoise.com
http://www.ocair.com/communityrelations/flighttracking/
http://www.portseattle.org/Environmental/Noise/Noise-Abatement/Pages/Aircraft-Monitoring-System.aspx
http://heli-noise-la.com/.

Note that these websites provide an example from each of the vendors of flight tracking systems.

Flight track monitoring is a useful tool for communicating with the public and with the operators. It clearly demonstrates where the helicopters actually are and at what altitudes. Sometimes helicopters are difficult to identify on these systems because they do not always broadcast their unique identity. As part of the Los Angeles Helicopter Noise Initiative, FAA now has helicopters broadcasting a unique code identifying them as helicopters. Las Vegas and Washington D.C. also have helicopters that broadcast a unique code for easy identification. It might be useful for FAA to adopt this program throughout the country so that helicopters would be easier to identify in flight tracking systems. For example, currently when any aircraft is flying under Visual Flight Rules it broadcasts the common identifying number, 1200. This includes fixed-wing aircraft and helicopters. The new program in

Los Angeles has the helicopters broadcasting 1205 or 1206, which makes them distinguishable from fixed-wing aircraft.

Where airports or FAA have established voluntary or mandatory helicopter routes, the flight tracking system can monitor and report adherence. An example of a helicopter flight track map used as part of helicopter noise management program is shown in Figure 1.

The dissemination of the recommended noise management program is a key part of implementation. Published guides or brochures are a common tool, as well as the Internet to distribute information on helicopter noise management programs. Appendix E contains a few examples of helicopter brochures. Brochures are now more commonly published on the web; however, some airports use printed versions to distribute to the operators. The brochures, while intended for helicopter operators, are also useful in communicating with the community. The community can observe what efforts are being made by the airport to manage helicopter noise and may contribute to a better understanding of helicopter patterns. There is an additional tool available to airports. A commercial firm is providing a noise abatement program dissemination service to airports. This is relatively new and requires the airport to subscribe to the service, which provides a basic service for free and more advanced services for a fee. In addition, the Boeing Aircraft Company operates a very detailed website that publishes noise abatement programs from airports worldwide. Each airport provides the information to Boeing, and Boeing manages the database (information from this database should be confirmed with the airport in case of any updates): http://www.boeing.com/commercial/noise.

Technology

The important contribution of technology in reducing helicopter noise comes from designing and producing quieter helicopters. This is not under the control of the airport or heliport operator. The

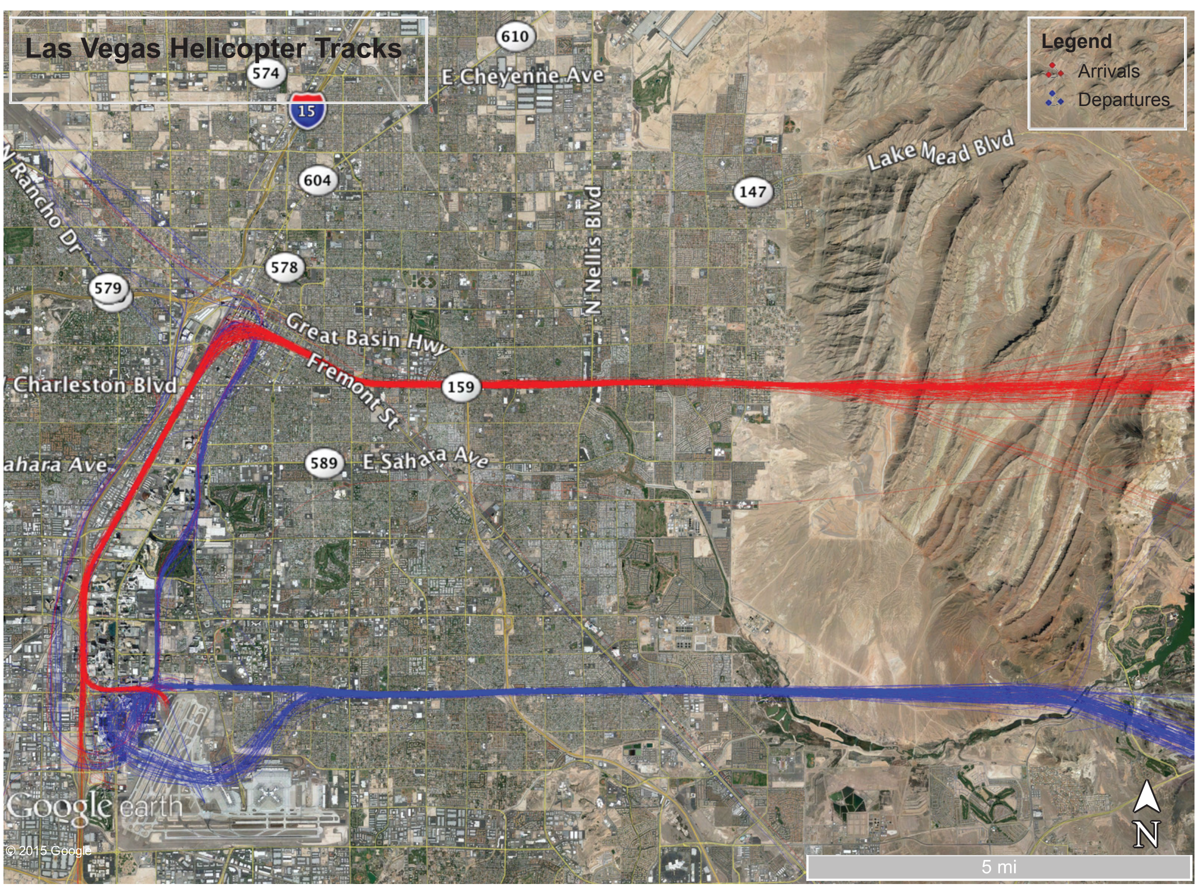

FIGURE 1 A plot of Las Vegas helicopter tracks for 1 week, September 2015. (*Source*: Track data courtesy of Las Vegas Department of Aviation, plotted in Google Earth Pro by L&B.)

literature search for this synthesis found research from agencies such as NASA, university consortiums, and industry about how to design helicopters to reduce noise. However, there is a complicating factor when it comes to quieter helicopter technology. Helicopters remain in the fleet much longer than fixed-wing air-carrier aircraft and there is no mandatory phase-out of older, noisier helicopters.

Another technology development that may affect helicopter noise is the introduction of advanced navigation aids and the modernization of ATC systems. Helicopters are generally flown under visual flight rules and adherence to recommended or mandatory routes is generally by visual landmarks. The much-publicized FAA Next Generation (NextGen) ATC system has to date focused on fixed-wing aircraft; however, eventually Global Positioning System-based navigation may be used to improve adherence to helicopter flight routes. It can be noted that this program is not under the control of the airport or heliport operators; rather, it is solely the responsibility of FAA.

The technology approach that is available to airport and heliport operators has already been described in terms of flight tracking technology and noise complaint tracking.

Noise Abatement Procedures

An airport or heliport operator has a role in the development of noise abatement procedures. Noise abatement procedures as used here specifically imply operating the helicopter in a way that reduces noise. Operational limits in terms of time, numbers, and type of aircraft are discussed later in this section. There are a number of resources available to help the airport operator develop recommendations for a noise abatement program. It is important for airport operators to note that it is beyond their role to tell operators how to fly an aircraft and that any such noise abatement recommendations must be consistent with the safe operation of the aircraft. The *HAI Fly Neighborly Guide* and the report on the Los Angeles Helicopter Noise Initiative are useful for this purpose. In addition, an airport operator can review programs at other facilities; a prominent example of such a program is the Las Vegas helicopter noise management program (see brochure in Appendix E).

This closing discussion of noise abatement programs is divided into the following four procedures:

- Noise abatement routes
- Establishing minimum altitudes
- Reducing high-speed impulse and blade slap noise
  - Reduced speed effect
  - Minimize tight turns
- Limiting hovering activity.

Noise abatement routes are an important component of any noise abatement program, but are impossible to generalize for all airports or heliports. The development of recommended helicopter routes is unique to each facility and must take into account the land use patterns, runway and flight corridors, airspace structure and congestion, local topography, and the missions of the helicopters using the facility. As expressed in the *HAI Fly Neighborly Guide*, as well as most literature on the subject, the goal is to avoid or minimize overflying noise-sensitive land uses whenever possible. The opportunity to do this is highly dependent on the land use patterns and geography surrounding any facility. A common approach is to recommend that helicopters overfly freeways or major highways. A note of caution regarding this strategy; if there is two-way traffic on this recommended route ATC will keep aircraft flying in one direction to one side of the road, and traffic in the other direction will be kept to the other side of the road, separating the two by at least several hundred feet. In effect, this keeps the airspace above the road free of helicopter noise. Instead, the noise is directed to the properties that are to either side of the road. The effect on this procedure's efficacy is dependent on how much helicopter traffic is using the route. Too much traffic will render the route significantly less effective than expected. In Las Vegas, the roads are generally overflown by one-way helicopter traffic only. The result is twofold, a tighter concentration of flight tracks over the roads and fewer flights over any particular road, and a concomitant use of additional roads to accommodate the one-way overflights. In Las Vegas this has been quite successful.

Establishing minimum altitudes can reduce helicopter noise. The altitude of the helicopter has a direct effect on the noise level experienced on the ground. It is common for communities with helicopter noise issues to request higher minimum altitudes. Where altitudes can be raised the level of annoyance may be reduced as a result of both acoustic and nonacoustic factors. The noise may be diminished with higher altitudes and the concern over possible accidents or a sense of an invasion of privacy may also be reduced, particularly where the existing routes are on the order of 500 feet above ground level. However, safety concerns frequently limit the altitude at which helicopters are permitted to fly. The *Los Angeles Helicopter Noise Initiative Report* discusses the issues with raising helicopter altitudes in more detail:

> Due to their special operating characteristics, helicopters are allowed under federal regulations to operate at lower altitudes than fixed-wing aircraft. When establishing altitudes for helicopter routes, the FAA will consider the speed compatibility of aircraft operating in the same airspace. Despite the advancements in situational awareness technology, VFR [visual flight rule] pilots must abide by the see-and-avoid concept of flight. For safety reasons, helicopter routes are generally designed to be flown at altitudes below arrival and departure routes for fixed-wing aircraft to segregate the slower helicopter traffic to the extent possible. Having slower helicopters operate at the same altitude as fixed-wing aircraft that are two to three times faster increases the risk of evasive maneuvers occurring over congested areas and would create an unsafe environment.
>
> In addition, vertical separation must be maintained between aircraft due to the dangers of wake turbulence, which has been identified as the cause of numerous injuries to crew and passengers as well as a contributing factor in many fatal accidents. Wake turbulence is most dangerous at low altitudes and increases in strength depending on the size of the aircraft generating the wake.
>
> The Terminal Collision Avoidance System (TCAS) is another consideration. TCAS is deployed in air carrier aircraft and is designed to alert pilots to possible collisions with other aircraft. Takeoff and landing are considered critical phases of flight, and it is important to avoid unnecessary TCAS alerts and potential resulting evasive actions that could result from increasing the numbers and types of aircraft operating within the same area.
>
> The FAA would subject any proposed altitude changes to an FAA Safety Risk Management Panel prior to publication on the VFR Helicopter Chart.

This discussion from the FAA report shows that the ability to raise helicopter altitudes will be dependent on several complex airspace factors. The difference in speed between fixed-wing aircraft and helicopters presents a significant obstacle to having both types of aircraft at a common altitude. Within any given region there may be places where altitudes can be raised and others where they cannot. The inability to raise altitudes may be more difficult near airports and less constrained at farther distances. There are no simple guidelines that can be used to determine if altitudes can be raised. The airport operator will need to work with FAA and assess each situation on a case-by-case basis.

Reducing high-speed impulse and blade slap noise is a major goal of the HAI Fly Neighborly program (HAI 2009). There is the so-called “fried egg” diagram that relates the aircraft forward speed to descent rate and the potential to cause blade slap. Although multiple reports showed an example of such a plot, the plot was generally shown only for one aircraft type; the variables change by aircraft type. The HAI program provides specific procedures for a list of aircraft. Unfortunately, the list is not complete and has not been updated since 2009. The Fly Neighborly Program is well-established; however, an army study measured the noise generated by a helicopter abiding by those landing procedures and offered evidence that the glide slopes and landing approach speeds that made for the quietest approaches did not always match those recommended in the Fly Neighborly guidelines. This could be the result in part to a discrepancy this study highlighted between the measurements of sound levels from aboard and outside of the helicopter of focus, with the former being what was used in the creation of the Fly Neighborly recommendations, even though the latter would better reflect the surrounding community’s experience of helicopter noise. It is also unclear how definitive the “Fly Neighborly” charts are. Because they were gathered in near ideal conditions, it raises the question of whether they adequately predict the likely occurrence of blade slap during turbulence or maneuvering flight. Although the Fly Neighborly program is a good reference, additional work for each helicopter type under a variety of conditions would be a useful expansion of the program. This would require substantial additional research and measurements.

The state of the art of helicopter noise abatement could benefit from helicopter manufacturers publishing clear procedures for each aircraft type, at which time HAI could update its recommendations. There are two other variables that may be used to reduce helicopter noise. Reduced helicopter speed effect, by even a few knots, can have a significant effect on the noise experienced on the ground. Also, tight turns can focus increased noise on a particular location. Again, the ranges of speed and tightness of turn may be helicopter type dependent. More work by helicopter manufacturers on these topics, along with an effective method for transferring this technology to airports and helicopter operators is essential.

Limiting hovering activity is a method of reducing helicopter noise. Hovering not only increases the length of the noise event, the turn radius and directionality of the noise may increase noise and annoyance. However, hovering activity associated with law enforcement activity may be difficult to limit. Airports and heliports can work with the news media, photographers and paparazzi, air tours and other commercial operators to avoid extended hovering or circling and raise the altitudes of the their activity voluntarily.

Media pooling is a recent effort to avoid having multiple news outlets covering the same event with multiple helicopters. The high cost of operating helicopters has contributed to a trend in news outlets of subscribing to a single-source helicopter service to provide video coverage of events of interest. This program reduces the number of helicopters in a given area at any given time and with less congestion the potential to remain over less noise-sensitive areas is improved.

Fees based on quiet technology are being used in one location; however, this may be difficult to implement elsewhere. Tour operators that fly over the Grand Canyon must pay a fee for each flight. FAA and the National Park Service have implemented a reduced fee program for tour operators that use newer, quieter technology helicopters. However, this measure is not available to public airports or heliports. FAA in its *Report on the Los Angeles Helicopter Noise Initiative* summarizes the legal problem with a public airport attempting to implement a fee based on noise:

> The FAA is specifically prohibited from imposing any new aviation user fees (Consolidated and Continuing Appropriations Act of 2012, Pub. L.112-55). Airport proprietors who have accepted federal funds are bound by the terms of their grant assurances, which require them to make the airport available as an airport for public use on reasonable terms and without unjust discrimination to all types, kinds and classes of aeronautical activities, including commercial aeronautical activities offering services to the public at the airport (FAA Airport Grant Assurance 22 (a)). In addition, charges or fees that are designed to, or have the effect of, controlling noise or restricting access to the airport must comply with the requirements of ANCA and 14 CFR part 161.

Voluntary operational limits and curfews are always available to an airport or heliport operator. Working with the helicopter operators and understanding their needs and looking for opportunities to reduce noise impacts by voluntarily limiting the number of daily operations; requesting use of quieter aircraft types, approaches, or departures to or from advantageous directions (wind permitting); or voluntary night time restrictions may achieve at least some of the goals that the community desires in terms of reduced helicopter noise impact.

Note that some airports have a letter of agreement (LOA) with ATC describing the procedures that ATC will use to manage helicopters in the vicinity of the airport. An example letter of agreement is provided in Appendix F.

In conclusion, although modern light- and medium-weight civil helicopters are much quieter than older helicopters and much quieter than heavy military helicopters they are still the focus of much community concern. This synthesis provides information to airports and communities in a concise and readable format on helicopter noise acoustics and helicopter operational attributes. It also provides helicopter noise mitigation strategies that have been used effectively by airports, pilots, and effected communities with approval by FAA to ensure aviation safety. The appendices include additional resources, as do two additional research projects that will be published through ACRP and available on the FAA website.

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APPENDIX A1

Technical Discussion of Helicopter Noise

This appendix discusses two distinct matters: the nature of helicopter noise emissions (Section A1) and the relationship among various measures of helicopter noise levels (Section A2). The former discussion provides insight into some of the constraints of on-site selection for subsequent field studies. The latter discussion, which presents the results of an analysis of the relationships among various helicopter noise measurements, can help with the design of field measurements.

SECTION A1: CHARACTERISTICS OF HELICOPTER NOISE IN VARIOUS FLIGHT REGIMES

Helicopter noise is an unavoidable by-product of creating the lift necessary to make helicopters and other vertical lift machines fly. When rotating and translating through the air, rotor blades displace the air because of their finite thickness. When these spatial disturbances of the fluid are added at a far-field observer location (keeping track of retarded time), they create harmonic "thickness noise." The rotating and translating rotor also accelerate air to cause net forces (lift and drag) on the blades. This acceleration of the air, caused by the lift and drag forces, causes small compressible waves that, when added together at the correct retarded time, radiate harmonic noise to an observer far from the noise source. Heavier vehicles produce more noise, as shown in Figure A1, for a series of older military helicopters. Although there is some deviation about the trend line as a result of design characteristics unique to each model, the trend is readily apparent. Other unsteady aerodynamic sources dependent on design details of particular vehicles can add to the noise. The basic physics of these phenomena has been known for more than six decades—and even longer for propellers.

Major Helicopter Noise Sources

Before addressing the origins and mechanisms of helicopter external noise it is useful identify the most noticeable, even if not necessarily the most annoying, sources. The order of importance for producing an acceptably quiet helicopter is shown in Figure A2 for a generic single rotor helicopter of the light to medium weight class—up to 10,000 lb.

Impulsive harmonic noise sources generally dominate helicopter detectability, and are often thought to be the main source of annoyance, for both the main rotor and tail rotor. The tip region on the advancing side of the rotor near the 90-degree azimuth angle of the rotor disk produces most of the radiated harmonic noise. The thickness and loading noise sources on each blade element are amplified by the high advancing Mach numbers in this region.

At high advancing-tip Mach numbers, thickness noise often becomes more dominant as Mach number increases. At very high advancing tip Mach numbers, High Speed Impulsive (HSI) noise develops. The local transonic flow around the rotor blade often couples with this radiating acoustic field causing acoustic "delocalization" that radiates local shock waves to an observer in the far field. When this occurs, the noise produced is nearly always highly annoying and dominates the acoustic signature of the helicopter. This type of noise tended to dominate the main rotor noise of the Huey helicopter of the Vietnam War era. When it occurs, HSI noise clearly dominates the acoustic radiation near the plane of the rotor. Most modern helicopters are designed so that delocalization does not occur in normal cruising operations. However, thickness noise remains a main contributor to in-plane noise levels in cruising flight even for modern helicopters. It is also interesting to note that main rotor HSI noise cannot be heard in the helicopter cabin because the radiating waves originate near the tip of the rotor and radiate in the direction of forward flight.

Most helicopters also produce a second impulsive noise caused by sudden, rapid pressure changes occurring on the lifting rotor blades. These pressure changes occur when the rotors pass in close proximity to their previously shed or trailed tip vortices. They normally occur when the helicopter is operating in descending, turning, or decelerating flight, at times when the rotor blades are passing through or near their own wake system. A typical one-revolution period for this type of noise signature radiated from a single main rotor helicopter is shown in Figure A3. This "wop-wop" sounding impulse stream, called Blade-Vortex-Interaction, BVI, is often the characteristic sound that distinguishes helicopter operational noise from other transportation noise sources in terminal operating areas.

The noise produced by the anti-torque device of a single rotor helicopter can also be a major noise source. When tail rotors are used as the anti-torque device, the dominant sources are fundamentally the same as

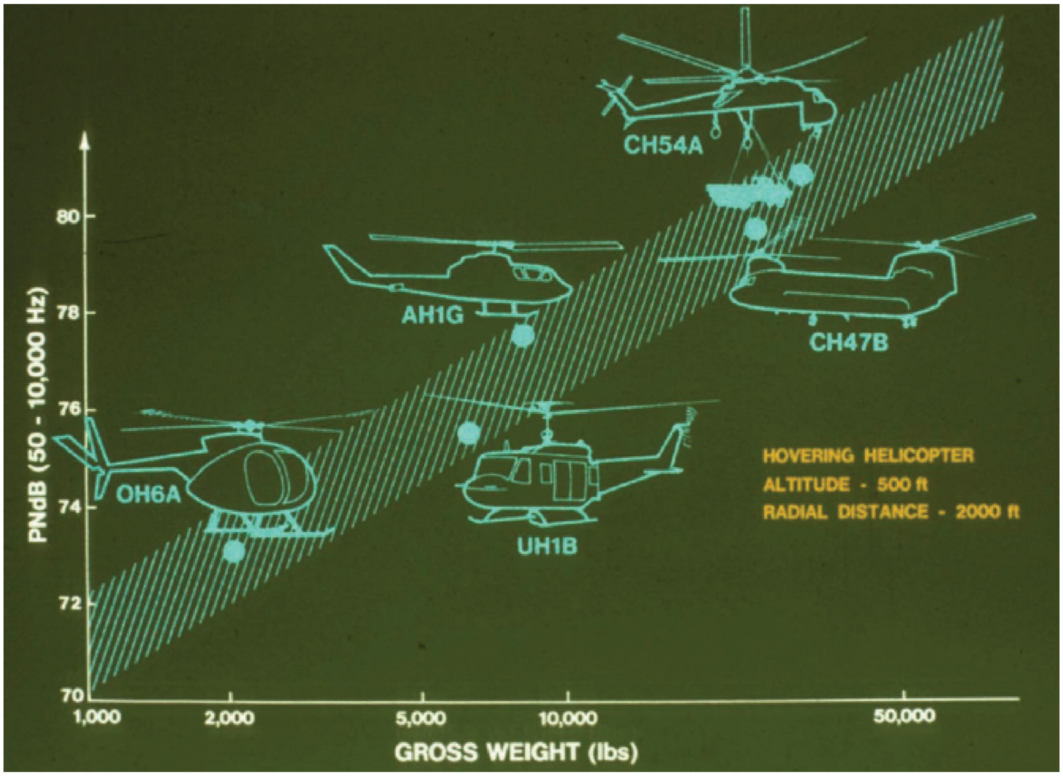

FIGURE A1 Relationship between helicopter weight and Perceived Noise Level.

the main rotor. However, the higher operating rpms of the tail rotor make the lower and mid-frequency tail rotor harmonic noise more noticeable and objectionable to a far-field observer. Because the tail rotor is often unloaded in forward flight, tail rotor thickness noise can often be the first sound heard by a far-field observer.

On some helicopters, the main rotor wake can pass in close proximity to the tail rotor disk in some operating conditions and increase noise emission level. The problem is aggravated by helicopters that operate with "top forward rotating" tail rotors. The problem has been minimized by more careful design and operation.

Aérospatiale introduced a lifting fan for directional control on many of its single rotor helicopters to mitigate tail rotor noise and reduce tail rotor drag in forward flight. The many-bladed fan (the "Fenestron")

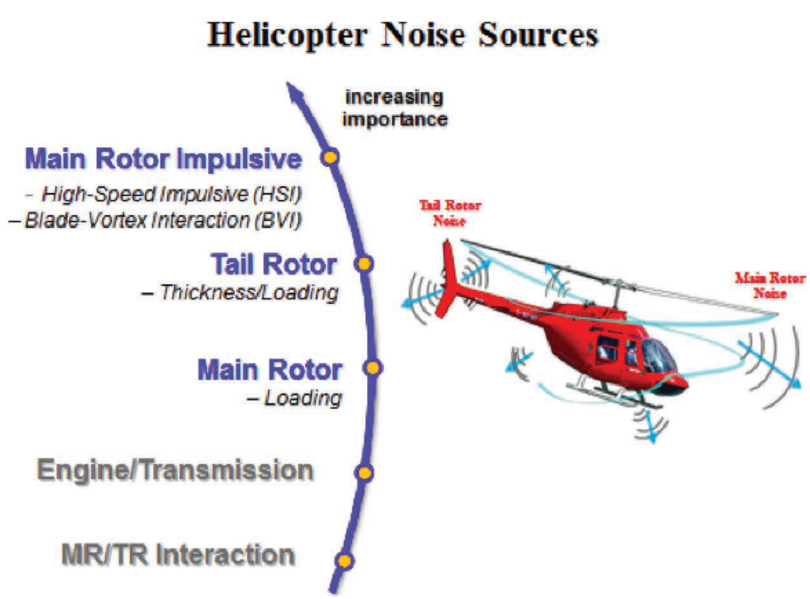

FIGURE A2 Prioritized contributions of helicopter noise sources to overall emissions.

Dominant Acoustic Waveform Features, M ~ .85

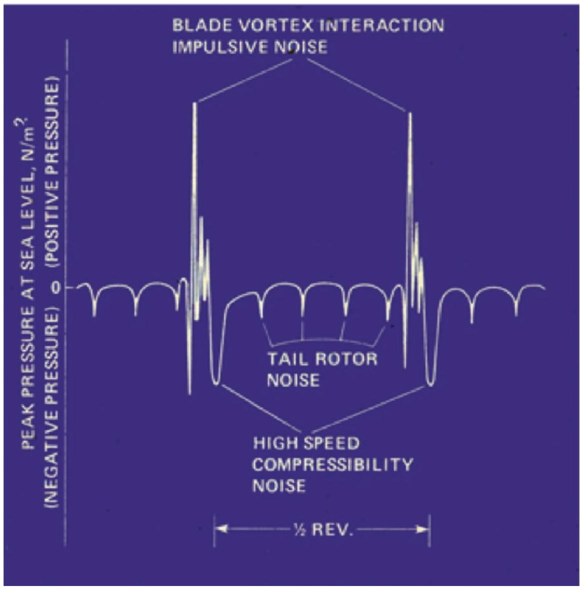

FIGURE A3 A typical one-revolution period for "wop-wop" of noise signature radiated from a single main two-bladed rotor helicopter.

creates somewhat lower levels of harmonic noise, but at higher frequencies, and can be quite annoying. However, noise at these frequencies is reduced with distance from the source as a result of atmospheric absorption effects. Fenestron noise therefore contributes little to helicopter noise at long ranges.

Lower frequency harmonic loading of the helicopter is next in order of acoustic importance. This sound is a direct result of the lift and drag (torque) produced by helicopters. It tends to be most important for civil helicopter operations directly underneath the helicopter. Although it is low frequency in character, it has substantial energy and is partially responsible for the excitation of "rattle" in many instances. For military helicopters, however, the low- to mid-frequency radiated noise near the plane of the rotor is of prime concern, because it often sets the aural and electronically aided detection range of helicopters. This noise is determined by the in-plane drag time history of the rotor and by the thickness of the blades, as noted earlier.

Engine noise can also be an important noise source. It is controlled by engine choice and on-board installed acoustic treatment. Transmission noise is important in close proximity to the helicopter or internally, but unless excessive, is not usually an external noise problem.

Last on the list of noise sources is Broadband noise. It is caused by changes in localized blade pressures caused by aperiodic and/or unsteady disturbances. It is normally of lower level on light to medium weight helicopters with normal operational tip speeds, but becomes more important on heavy helicopters as design tip speeds are lowered and the numbers of rotor blades are increased. It is also influenced to a great extent by the local inflow through the rotor system. Higher positive or negative inflow tends to reduce the noise by carrying the disturbed unsteady flow away from the rotor, thus avoiding additional unsteady blade loading and hence additional noise.

Because of their ability to carry large loads and more easily handle the center of gravity issues associated with these large loads, tandem rotor helicopters have also become a workhorse helicopter for the military. The lack of conventional tail rotors on these machines reduces the noise to a degree; however, their large overlapped rotor systems often create unsteady inflow to the rotors, making large harmonic noise levels commonplace for such vehicles. Because of their high tip Mach numbers, tandem rotors also produce large amounts of thickness noise. Tandem rotors also produce large amounts of thickness noise. For a variety of reasons, most tandem rotor helicopters do not operate in commercial airspace in or around noise sensitive areas.

The TiltRotor is another type of dual rotor rotorcraft that was also developed by the military. It is being proposed for civilian operations in a scaled down version for executive travel (Agusta 609) to combine a vertical lift capability with conventional turboprop airspeeds. In helicopter mode, the net inflow through the rotor can be controlled, thus controlling BVI noise in the terminal area. Thickness noise at cruise speeds is minimized by converting to aircraft mode at reduced rotor rpm. The reduced rpm in cruise decreases the noise level. Lower frequency noise is still present because the disturbance field of the wings induces periodic loading on the blades, creating far-field noise.

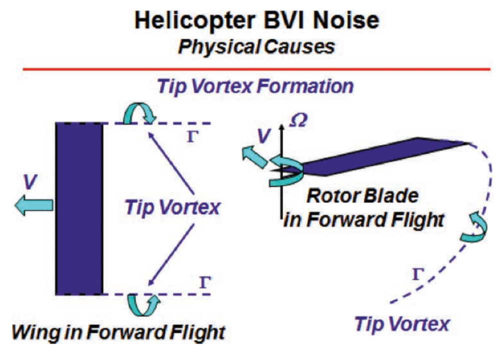

FIGURE A4 Physical causes of helicopter blade-vortex interaction noise.

Controlling BVI Noise in the Terminal Area

As discussed previously, BVI impulsive noise occurs when the rotor operates near its own shed wake. Figure A4 shows that a vortex is shed from the tip of each rotor blade just as it does for a fixed-wing aircraft. The tip vortex trailed behind each blade interacts with the following blades to create sharp changes in local blade pressure (and thus lift.) The pressure changes push on the fluid and radiate BVI noise. Figure A5 is a sketch of the geometry of the BVI interaction process. The top view shows the geometry of the interaction process, whereas the side view illustrates the closeness of the shed tip-vortices to the top tip-path-plane.

Figure A6 shows that this closeness can be controlled to some degree by the choice of the helicopter operating condition. In level flight, the helicopter's shed tip vortices pass under the rotor's tip-path-plane and radiate small to moderate amounts of BVI noise. However, as the helicopter descends, the rotor's wake is forced to remain near the rotor's tip path plane, causing the rotor to closely interact with the shed tip vortices of preceding blades. These strong changes in lift cause large levels of BVI noise radiation. Increasing the descent rates further causes most of the shed tip vortices to pass above the rotor's tip-path-plane, which reduces BVI noise levels. Vehicle acceleration and deceleration and turning flight also can influence the location of the tip vortices with respect to the rotor tip-path-plane and hence dramatically change the radiated blade-vortex interaction noise.

Figure A7 shows in-flight measurements of BVI noise, taken on a microphone about 30 degrees below the plane of the rotor. A rapid series of positive pressure pulses are seen to occur that reach

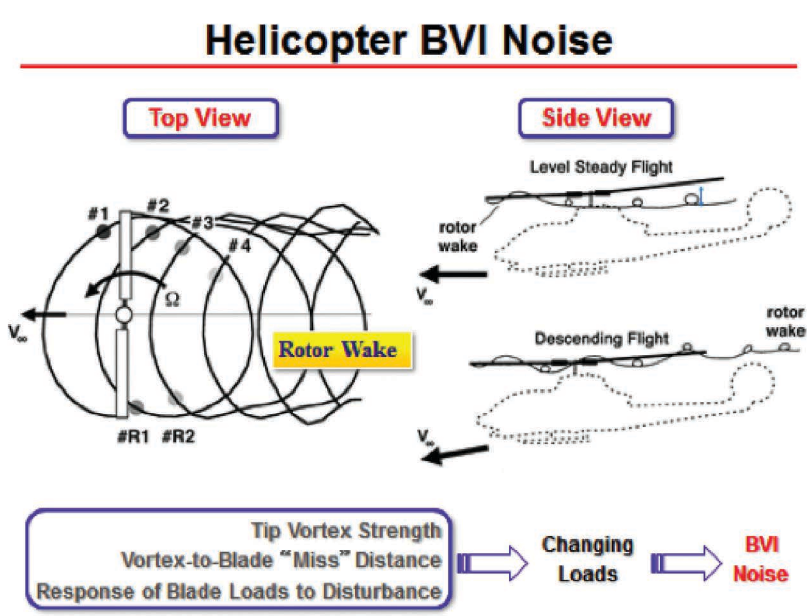

FIGURE A5 Geometry of the BVI interaction process.

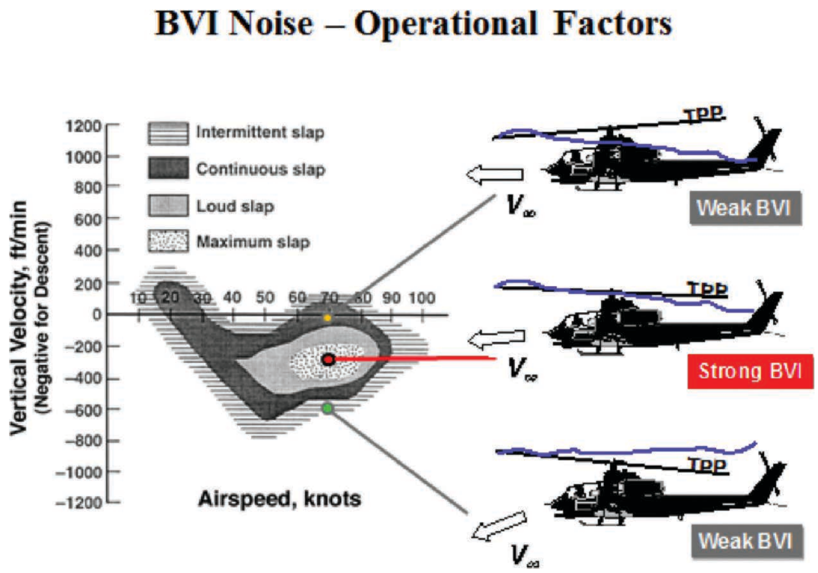

FIGURE A6 Effect of operating condition on blade slap.

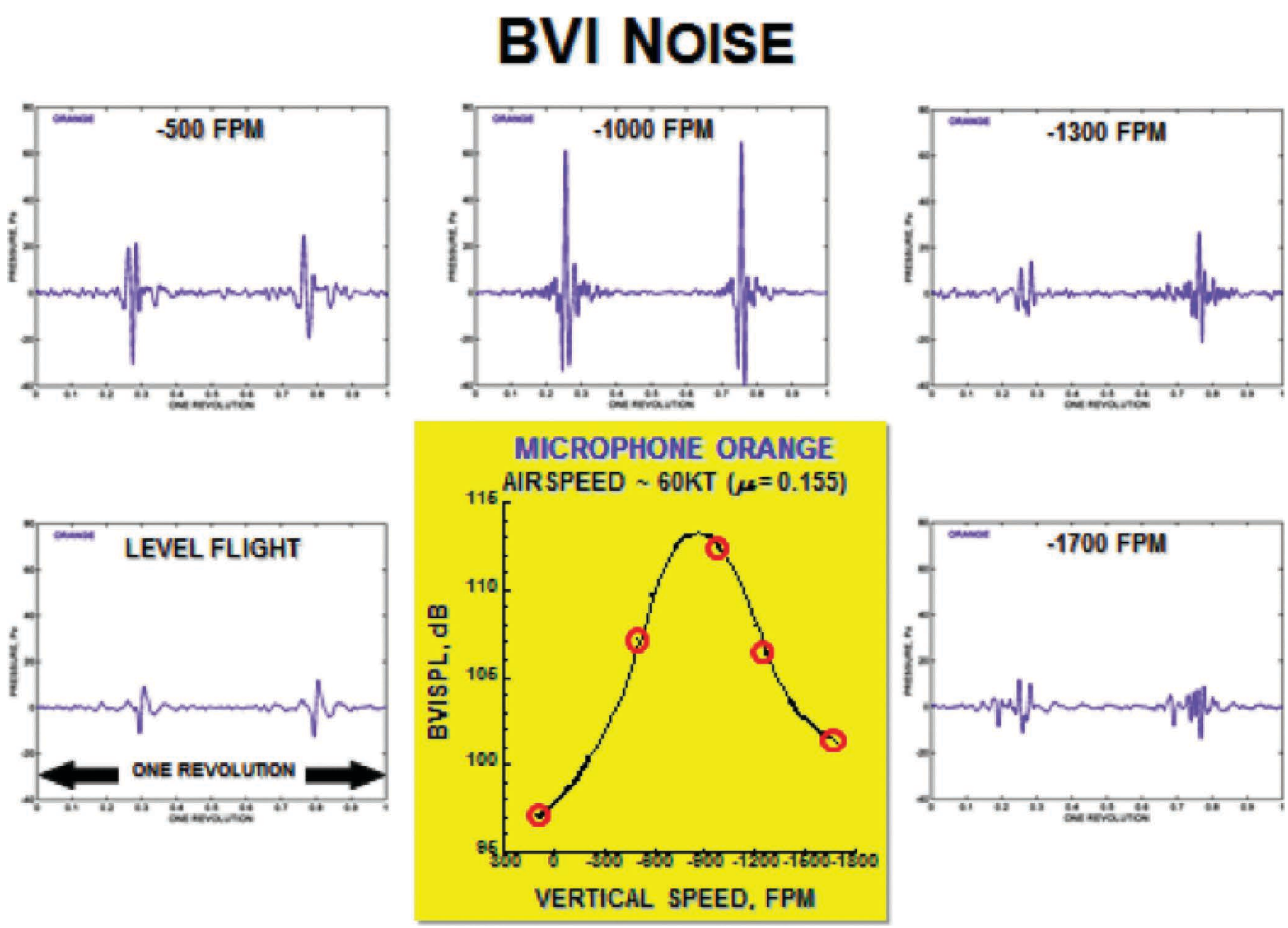

FIGURE A7 BVI noise as a function of descent rate and level flight.

a peak and then decrease with increasing rates of descent at approach air speeds. Because these pressure pulses are very narrow they radiate most, but not all, of their energy in the mid- to high-frequency range and can easily annoy and disturb a far-field observer. A narrow band FFT of the pulse time histories illustrates the moderate to high frequency nature of the resulting BVI noise (Figure A8).

Because radiated BVI noise levels can be controlled by changing the helicopter flight path has not gone unnoticed by the rotorcraft operational community. Helicopter International Association (HAI) has developed a "Fly Neighborly Program" to make pilots aware that helicopters can be flown quietly near high density and/or sensitive population zones. Research has also shown that X-Force control (acceleration/deceleration and drag/thrust control) can also be effective at minimizing BVI noise; a 0.1 g deceleration is equivalent to a 5.7 degree change in descent angle. A sketch of the use of such techniques is shown in Figure A9.

Use of operational parameters to minimize noise exposure is well documented. One such example is shown in Figure A10, in which a Sikorsky S-76 helicopter was flown to minimize ground noise exposure. High rates of descent and deceleration were both used to substantially reduce radiated BVI noise levels.

Source noise reductions depicted in Figures A9 and A10 are not always achievable in normal operations. Weather, winds, other flight traffic, and maneuvering flight can substantially change BVI noise levels. In addition, the BVI noise may become intermittent—occurring for a few seconds (seemingly disappearing) and then reappearing randomly. This often happens in near level flight operations in "bumpy" air, creating intermittent BVI.

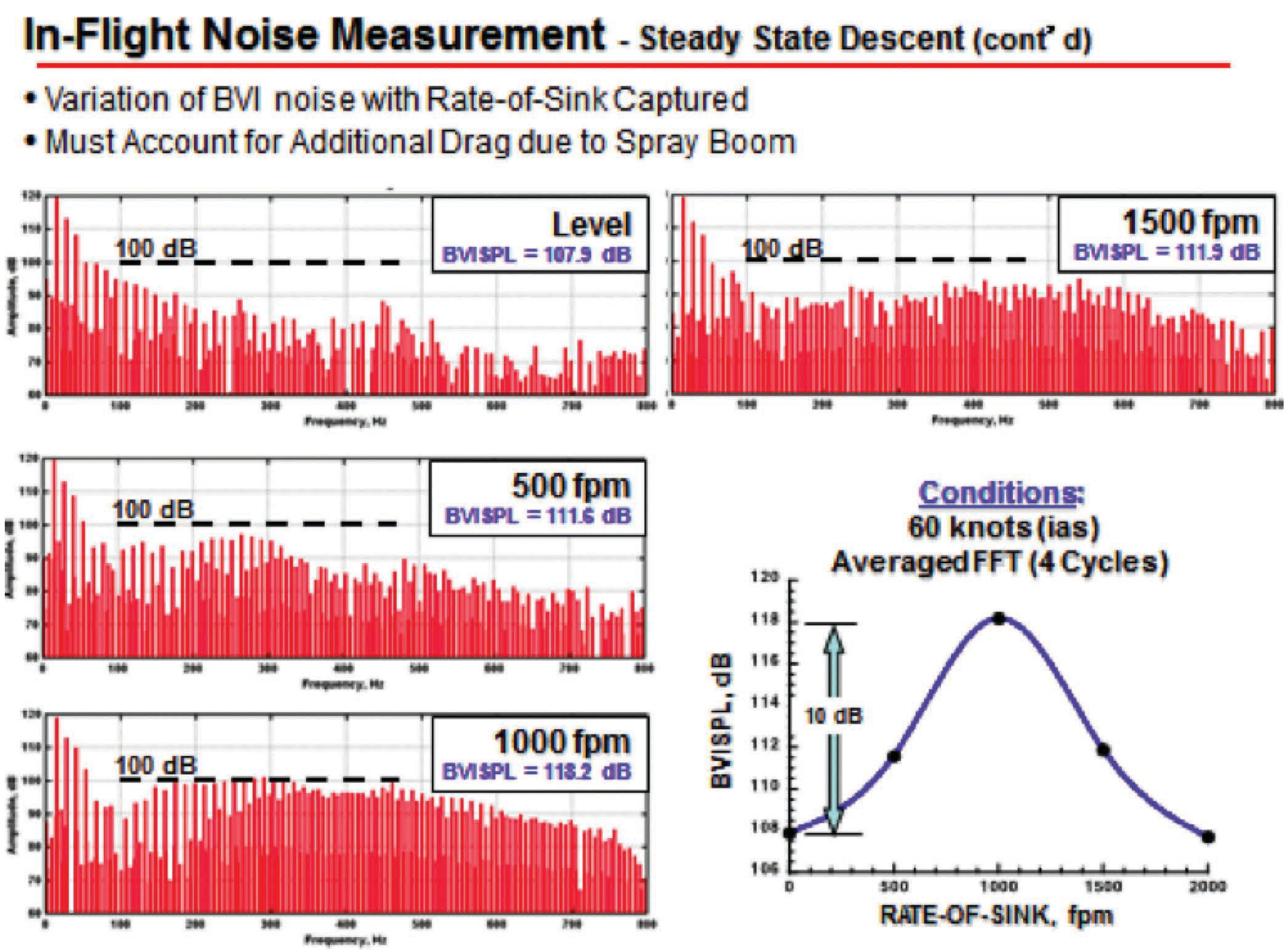

FIGURE A8 Sound frequency as function of climb rate and level flight.

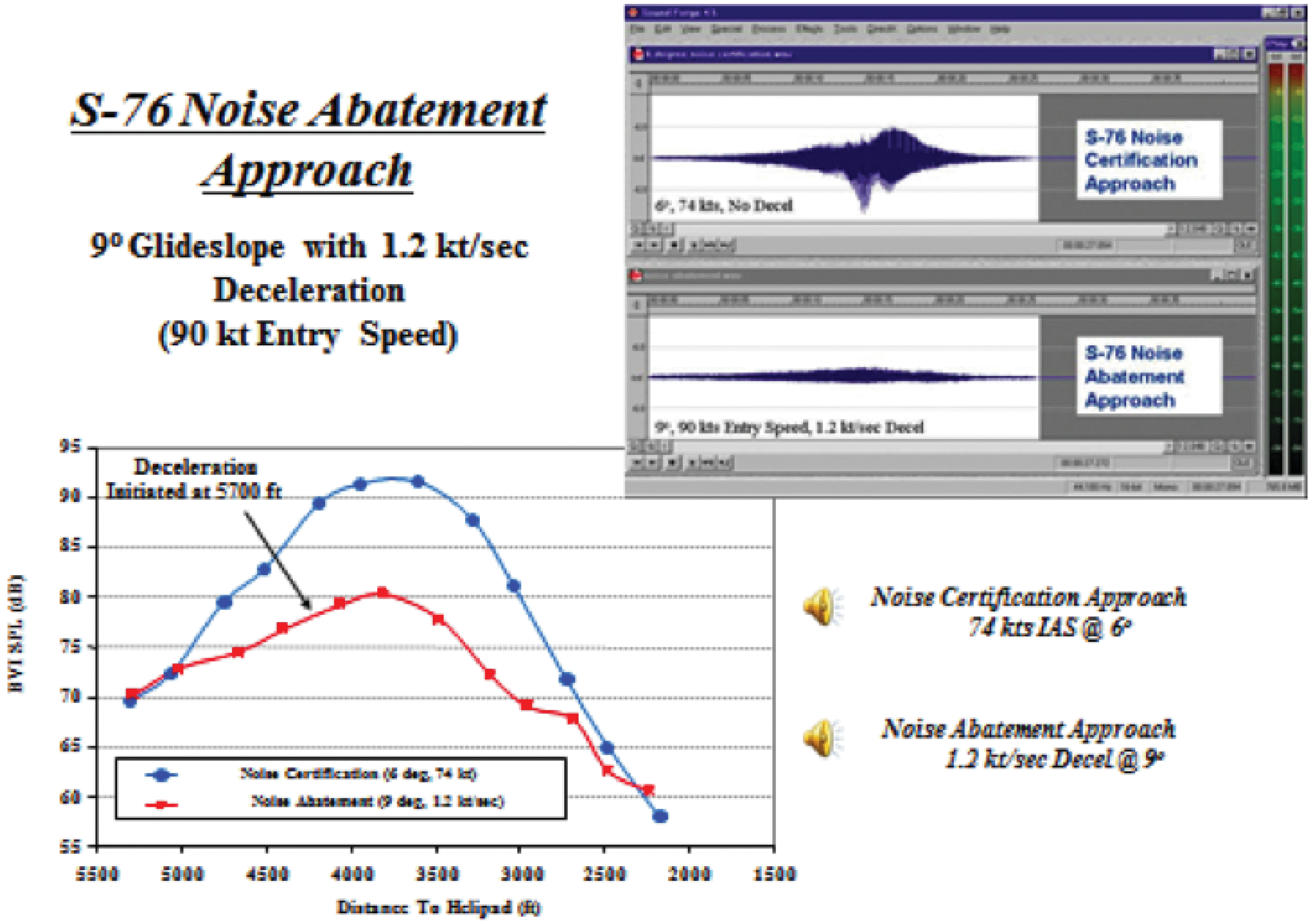

FIGURE A9 S-76 noise abatement approach.

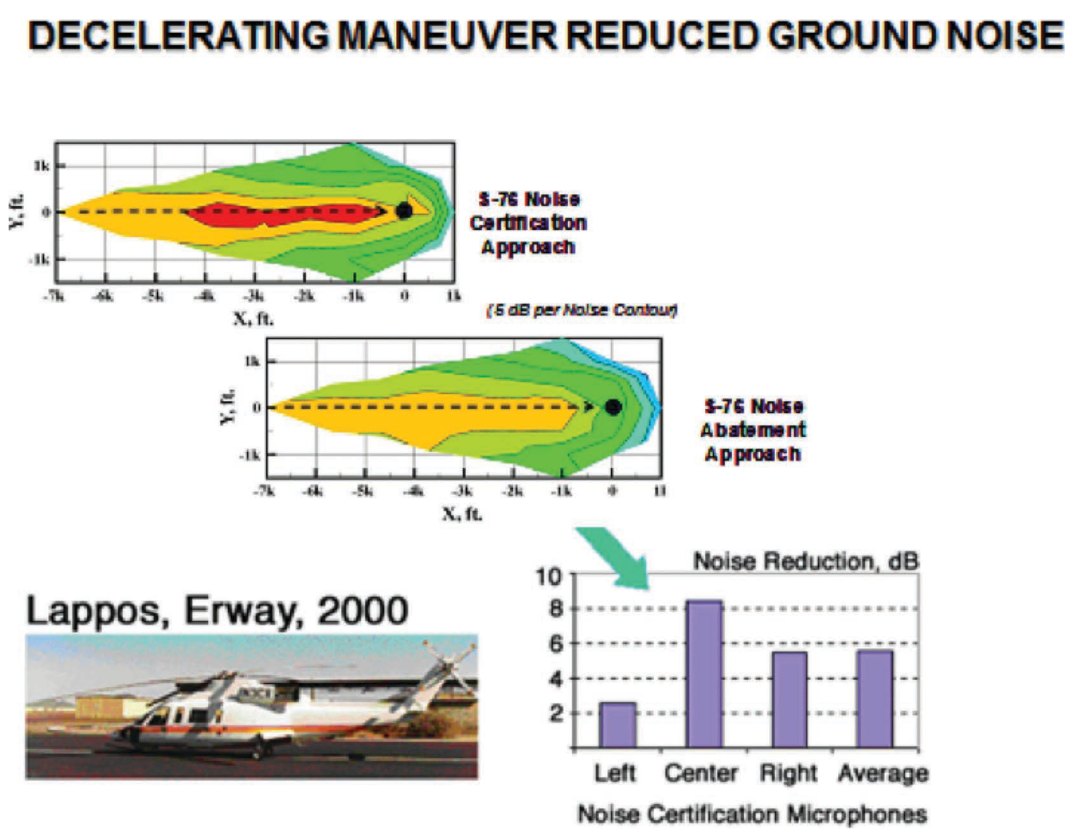

FIGURE A10 Reduced ground noise with modified approach procedure.

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APPENDIX A2

Correlational Analysis of Helicopter Noise Metrics

Version 7.0d [INM version 7.0d (FAA 2013)] was replaced by the Airport Environmental Design Tool (AEDT) Version 2b in May 2015. The helicopter noise modeling methodology in AEDT2b is consistent with INM version 7.0d. Prior to Integrated Noise Model (INM) Version 6, helicopter noise was modeled with Helicopter Noise Model (HNM) (Volpe Transportation Systems Research Center 1994). The helicopter noise computation model from HNM was incorporated into INM beginning with INM Version 6. FAA's INM allows users to predict helicopter noise exposure in a range of units (noise metrics). INM's databases contain information for a variety of helicopter types that include physical descriptions of aircraft; noise-power-distance curves; standard arrival, departure, and level flight profiles; and for some helicopters hover-in-ground-effect profiles, directivity profiles for each operating mode, and spectral class data for some helicopters. The noise power distance curves include A-weighted metrics Maximum Noise Level ($L_{\max}$ or L_{Amax}) and sound exposure level (SEL), and for some aircraft Tone Corrected Perceived Noise Level (PNLT) and Effective Perceived Noise Level (EPNL). INM uses spectral class data to compute C-weighted metrics, C-weighted Maximum Noise Level ($LC_{\max}$), C-weighted Sound Exposure Level (CEXP), and Time Above C-weighted threshold.

Table A1 lists the helicopters that are currently included in the INM database. Note that FAA has published a long list of substitutions for helicopters not included in the database and a recommended helicopter from the database to use as a surrogate for that helicopter.

HELICOPTER SPECTRAL CLASSES

INM helicopter spectral classes are representations of average spectra for groups of helicopters with common characteristics. Figures A11 and A12 show two of INM's spectral class charts; for the B212, BO150, and S70 helicopters (Figure A11) and the SA355, S65, and H500D helicopters (Figure A12). Note that the spectral class data are unavailable for frequencies lower than the one-third octave band centered at 50 Hz. The database structure in AEDT2b allows for lower frequency information; however, no data are currently available.

Correlations Among Helicopter Noise Metrics

A hypothetical helicopter exposure case was constructed to examine the relationships among the noise metrics that INM computes. The purpose of the exercise was to inform the selection of noise metrics for the field measurements of this research project. The numbers and types of measurements required for the social survey and subsequent analyses can directly affect the cost and design of the research.

The hypothetical case modeled noise exposure for a generic heliport with a large number of operations. The first case studied featured simple straight-in and straight-out departure flight paths, using the standard profiles built into INM for the nine helicopters that have both A-weighted and PNL-based NPD data. One hundred arrivals and 100 departures were evaluated using an equal distribution of the following helicopter types: B206B3, B407, B427, B429, B430, EC130, R22, R44, and SC300C.

Figure A13 shows the 55 through 75 DNL contours for this generic helicopter test case. The grid points shown are 0.1 nautical miles apart (approximately 608 ft). The resulting DNL contours are relatively small, even with 200 daily helicopter operations.

Figures A14 and A15 compare the noise metrics that INM can compute relative to the DNL value at each of the grid points within a 4 nautical mile square grid with 0.1 nautical mile spacing. Figure A14 shows the traditional level-based metrics, whereas Figure A15 shows the time above metrics. Table A2 supplies the variance accounted for (coefficients of determination) for each of the noise metrics with DNL. All of the metrics other than the time above metrics are highly correlated with DNL. For all practical purposes, if one of the equivalent energy metrics is known, all of the other equal energy metrics are also known (except for constants and scale factors.) These results are similar to the results for fixed-wing aircraft (Mestre et al. 2011).

The R^2 values between DNL and individual metrics displayed in Table A2 demonstrate that essentially all of the metrics modeled by INM are highly correlated with DNL. Note that in each case in Table A2 the correlation of determination was based on a linear fit except for the time above metrics. For the time

TABLE A1
HELICOPTERS INCLUDED IN INM V7.0d DATABASE

Helicopter INM Name	Description
A109	Agusta A-109
B206L	Bell 206L Long Ranger
B212	Bell 212 Huey (UH-1N) (CH-135)
B222	Bell 222
B206B3	Bell 206B-3
B407	Bell 407
B427	Bell 427
B429	Bell 429
B430	Bell 430
BO105	Bölkow BO-105
CH47D	Boeing Vertol 234 (CH-47D)
EC130	Eurocopter EC-130 w/Arriel 2B1
H500D	Hughes 500D
MD600N	McDonnell Douglas MD-600N w/ RR 250-C47M
R22	Robinson R22B w/Lycoming 0320
S61	Sikorsky S-61 (CH-3A)
S65	Sikorsky S-65 (CH-53)
S70	Sikorsky S-70 Blackhawk (UH-60A)
S76	Sikorsky S-76 Spirit
SA330J	Aérospatiale SA-330J Puma
SA341G	Aérospatiale SA-341G/342 Gazelle
SA350D	Aérospatiale SA-350D AStar (AS-350)
SA355F	Aérospatiale SA-355F Twin Star (AS-355)
R44	Robinson R44 Raven / Lycoming O-540-F1B5
SC300C	Schweizer 300C / Lycoming HIO-360-D1A
SA365N	Aérospatiale SA-365N Dauphin (AS-365N)

Source: INM 7.0d database, FAA.

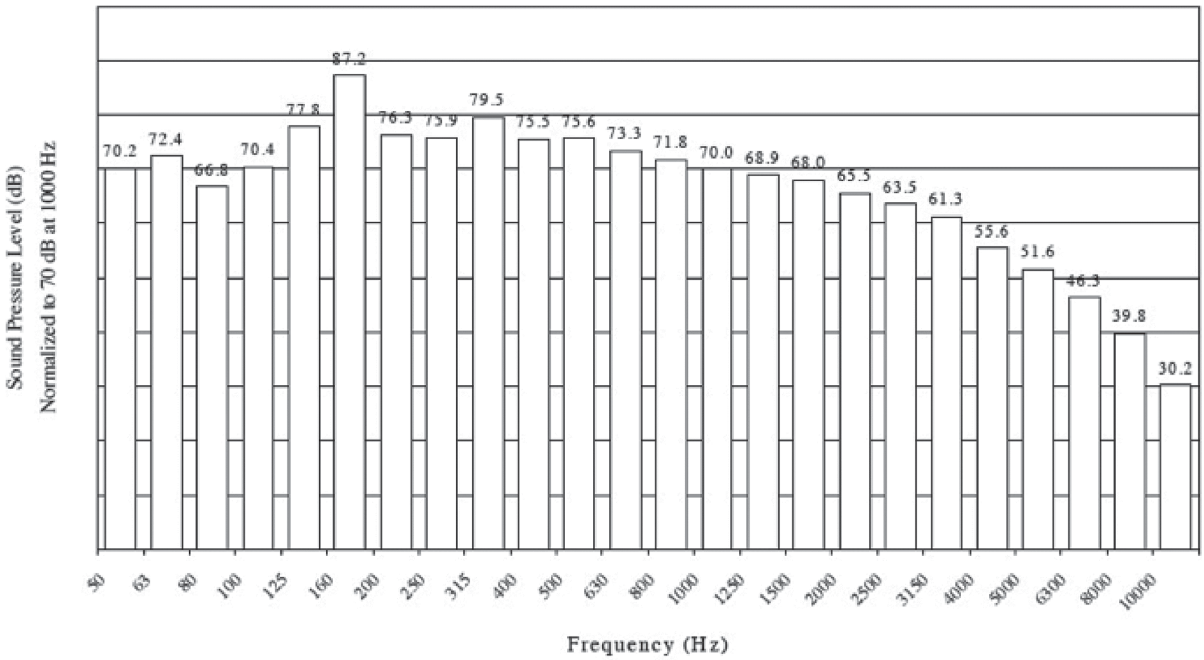


FIGURE 14. DEPARTURE SPECTRAL CLASS 114

INM Aircraft Descriptions:	Helicopter
INM Aircraft ID:	B212 BO150 S70

FIGURE A11 Spectral Class Example 1.

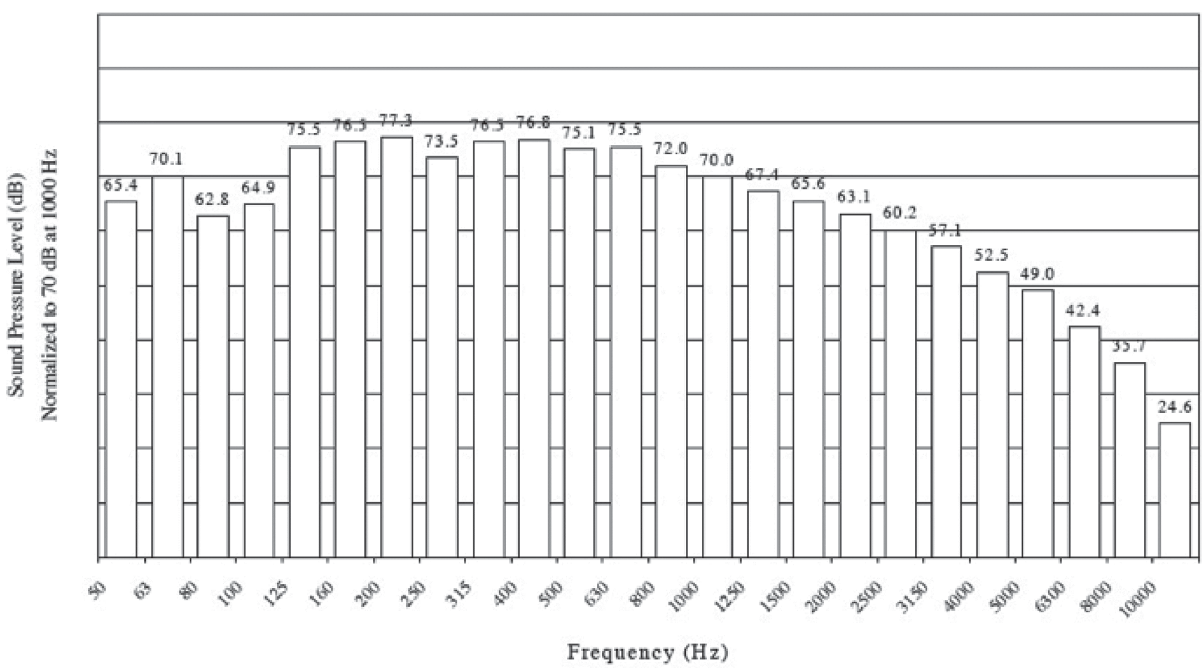


FIGURE 16. DEPARTURE SPECTRAL CLASS 116

INM Aircraft Descriptions:	Helicopter
INM Aircraft ID:	SA355 S65 H500D

FIGURE A12 Spectral Class Example 2.

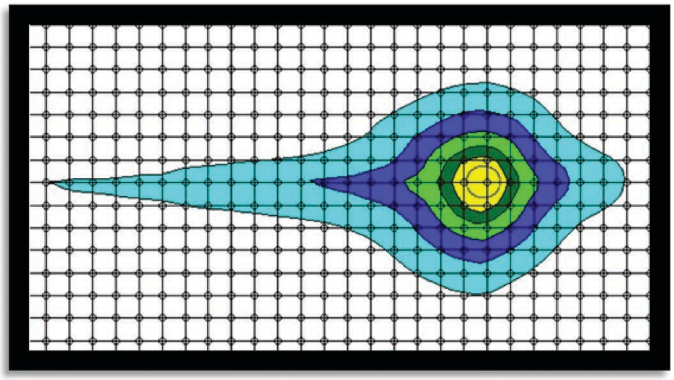


FIGURE A13 DNL contours for test case operations.

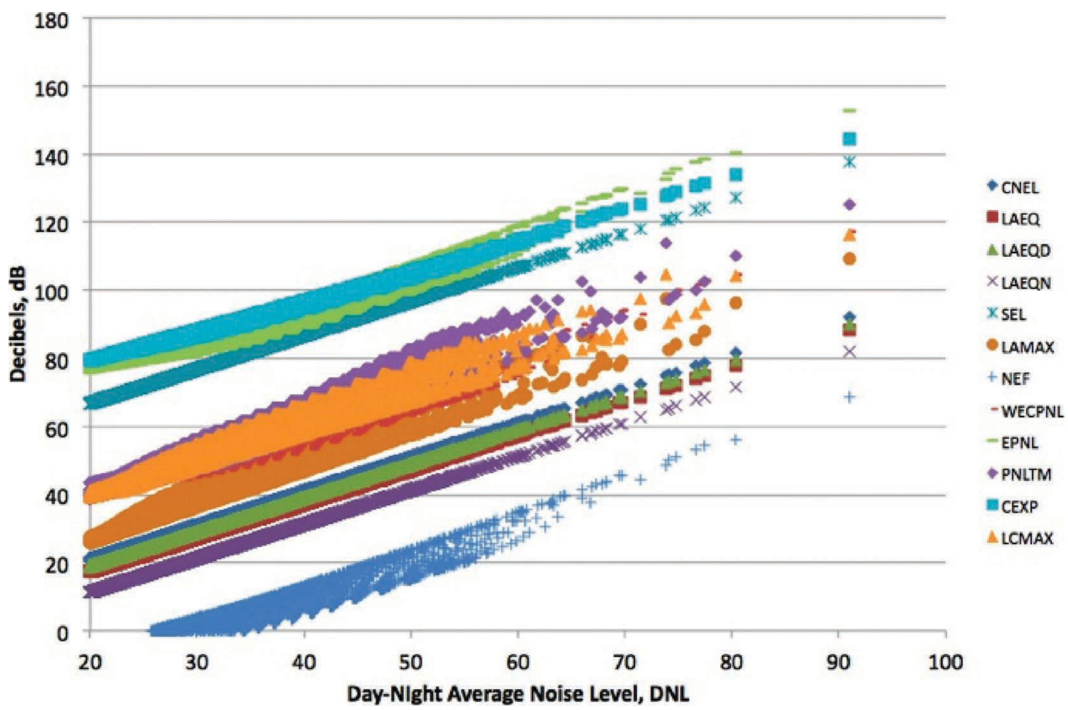


FIGURE A14 Relationship of Traditional Level-Based Noise Metrics to Day-Night Average Noise Level for an example heliport.

above metrics a second order polynomial fit was used. The choice of linear or second order fit of DNL to the individual metrics was based on the shape of the data plot and the method that provided the best correlation. TAPNL is the metric most independent from DNL, albeit in a not particularly useful manner. Figure A15 shows that the TAPNL data have a very narrow dynamic range, with a nearly vertical slope between DNL 75 and DNL 80. Time above 95 PNL goes from nearly zero to 1,400 minutes within a range of only *Ldn* = 5 dB.

Note that none of the metrics, the traditional level based metrics or time above metrics, include any corrections or adjustments for impulse type noise that occurs as part of some helicopter operating modes. Note also that the spectral data used by INM to compute C-weighted and PNL metrics do not contain any information below the one-third octave band centered at 50 Hz.

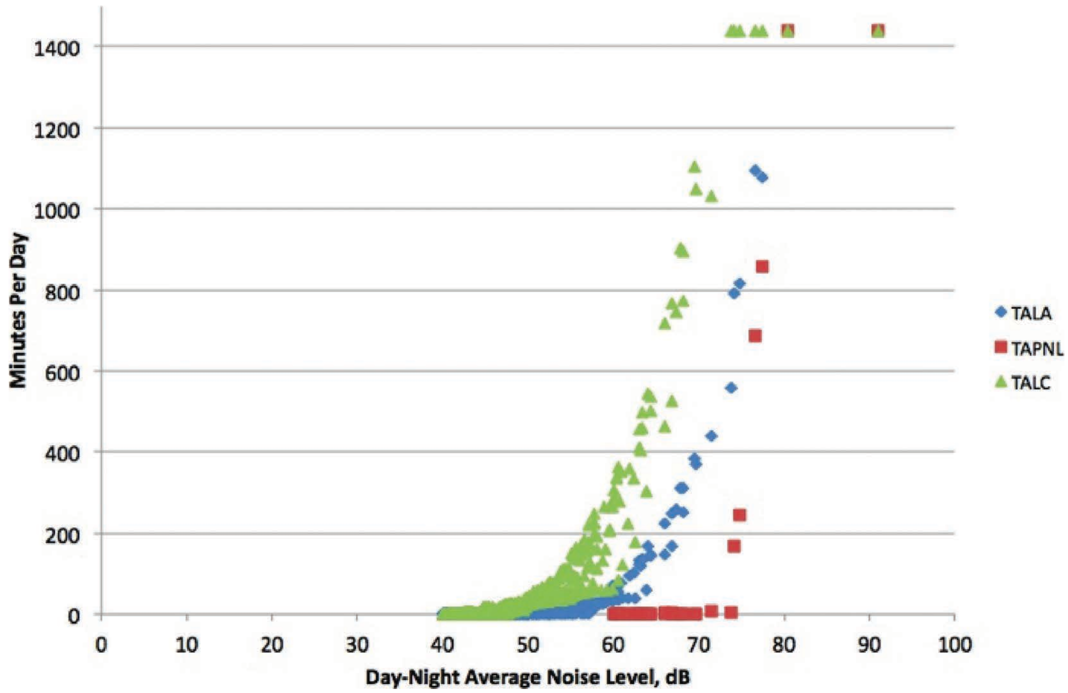


FIGURE A15 Correlation of Time Above Metrics to Day-Night Average Noise Level for an example heliport (threshold 65 dB for TALA and TALC and 95 dB TAPNL).

TABLE A2
COEFFICIENTS OF DETERMINATION (R^2) OF NOISE METRICS WITH DNL

Noise Metric	R^2 Relative to DNL
CNEL	0.99997
LAEQ	1
LAEQD	0.99997
LAEQN	0.99997
SEL	0.99998
LAMAX	0.95152
NEF	0.92129
WECPNL	0.92128
EPNL	0.92126
PNLTM	0.92887
CEXP	0.99538
LCMAX	0.95927
TALA	0.86722
TALC	0.86848
TAPNL	0.6641

Source: L&B.

APPENDIX A3

Community Tolerance Level, Accounting for Nonacoustic Effects on Annoyance

Figure A16 compares several dosage-response relationships between cumulative aircraft noise exposure and the prevalence of aircraft noise-induced annoyance in average communities. The solid black Community Tolerance Level (CTL) relationship is the one recommended by the Final Draft International Standard of the revised ISO Standard 1996-1. (The lowermost curve is FICON's dosage-response relationship for the prevalence of annoyance for all forms of transportation noise. The Miedema and Vos (1998) curve is that of the European Noise Directive.) If helicopter noise is more annoying, decibel-for-decibel, than fixed-wing aircraft noise, the CTL curve in Figure A16 (developed for fixed-wing aircraft) will be shifted toward the left side of the graph.

Figure A17 illustrates a family of dosage-response relationships corresponding to increases in the annoyance of helicopter noise exposure by amounts ranging from 3 to 10 dB. For example, if helicopter noise proves to be 3 dB more annoying than fixed-wing aircraft noise analyses of survey data may be expected to produce a dosage-response relationship similar to the dashed curve to the left of the one seen in Figure A16. Note that the curves in Figure A17 differ both in positions on the abscissa, and in their slopes, for reasons discussed in Appendix C. The shapes of the curves are identical no matter where they lie horizontally. However, the horizontal position affects the slope of a given curve at a particular dose (i.e., day-night average noise level value), and hence the rate at which annoyance grows with increasing dose at that level.

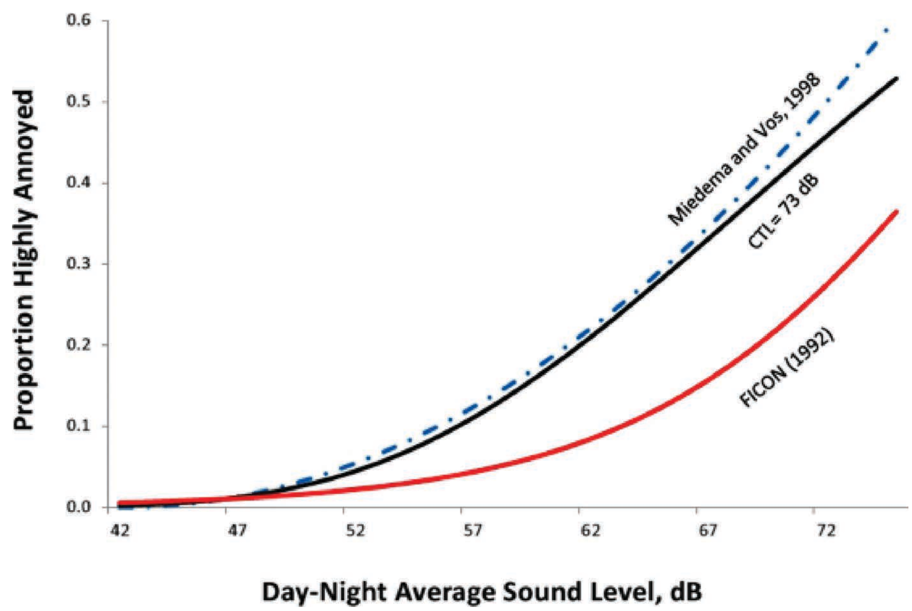


FIGURE A16 Comparison of revised ISO Standard 1996-1 dosage-response curve with earlier curves derived by regression analyses.

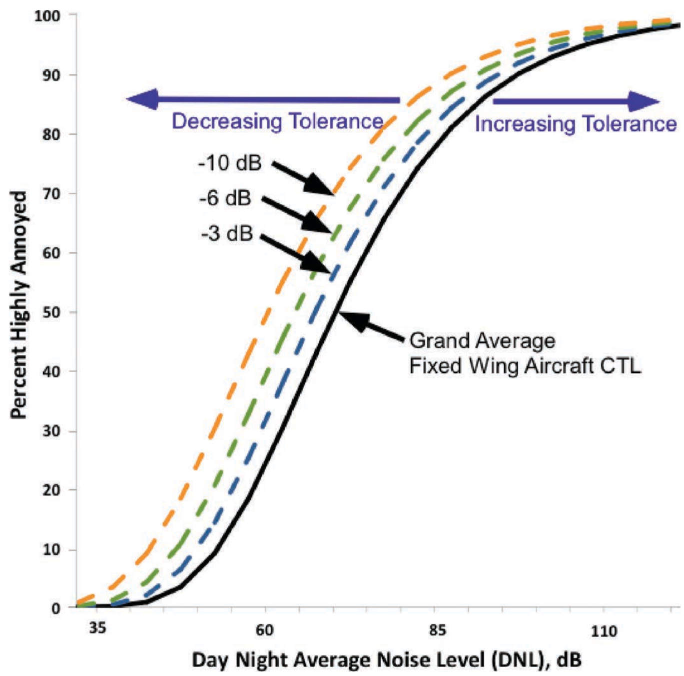


FIGURE A17 Family of dosage-response curves for differing levels of community sensitivity.

APPENDIX B

Annotated Bibliography

The entries in the following bibliography are not intended to be comprehensive, but rather to summarize interpretations of findings of some of the better known studies of the annoyance of helicopter noise. They exclude studies intended mostly to measure helicopter noise emissions and some laboratory studies of rotor noise whose findings have little direct bearing on the design of social surveys of the annoyance of helicopter noise. Although preference was given to annotating peer-reviewed studies, a number of technical reports are annotated as well.

Ahuja, K., M. Benne, M. Rivamonte, R. Funk, J. Hsu, and C. Stancil, *Operation Heli-STAR—Helicopter Noise Annoyance Near Dekalb Peachtree Airport*, Georgia Tech Research Institute Report A5146-110/2, DOT/FAA/ND-97/11, 1997.

This report describes the conduct of a small scale social survey of the annoyance of a temporary increase in helicopter noise exposure near a regional airport at the time of the 1996 Olympics in Atlanta, Georgia. Only 142 interviews were completed with neighborhood residents living in households with noise exposures in the range $56 \leq L_{dn} \leq 64$ dB.

Table 4.5 of this report notes the following observations of the noise exposure and percentage of respondents highly annoyed by helicopter noise. The numbers of interviews in the noise exposure categories shown here were as few as ten in some cases:

DNL, dB	% highly annoyed by helicopter noise
56	20.7
61	39.4
62	13.5
63	23.1
64	43.8

The small number of interviews led to confidence intervals for the percentages of the highly annoyed that were too wide to infer any systematic relationship between helicopter noise exposure and annoyance prevalence rates. Figure B1 plots the field observations, along with an a priori dosage-response relationship described by Fidell et al. (2011).

Although the findings of this study are suggestive at best, they provide weak support for the hypothesis that people are (about 3 dB) less tolerant of helicopter noise than of fixed-wing aircraft noise.

Atkins, C., P. Brooker, and J. Critchley, *1982 Helicopter Disturbance Study: Main Report*, Civil Aviation Authority/Department of Transport/British Airports Authority, 1983.

The authors report the results of a large-scale field study that intended to evaluate the attitudinal differences between fixed- and rotary-wing aircraft. Six interviewing areas were chosen with differing proportions of the two aircraft types, from none to exclusive. Areas near military installations were avoided in the belief that attitudes near such installations might differ from those of the general population. Each potential site received considerable pre-study qualification, including site visits to some and consultations with air traffic control and airport personnel. Exclusive helicopter exposure was found in areas where aircraft served North Sea oil platforms and helicopter passenger service.

Interviews were conducted in person. Interview areas were sized to encompass cumulative exposure ranges no greater than 5 dB. (All respondents within such areas were assumed to receive the same dose.) Questionnaire completion rates across interviewing areas ranged from 61% to 82%. Continuous sound level measurements were conducted for 10 or more days in each area. The measurements were largely unattended except in areas where varying source contributions or complex flight procedures were anticipated.

The survey instrument was quite lengthy, as it sought information about a large number of variables that might relate to respondent attitudes. The main questionnaire item about bother or annoyance used a four-point category scale. This question was asked only of those respondents who responded positively that they heard aircraft noise in an earlier question. An average of 30% of respondents expressed fear that

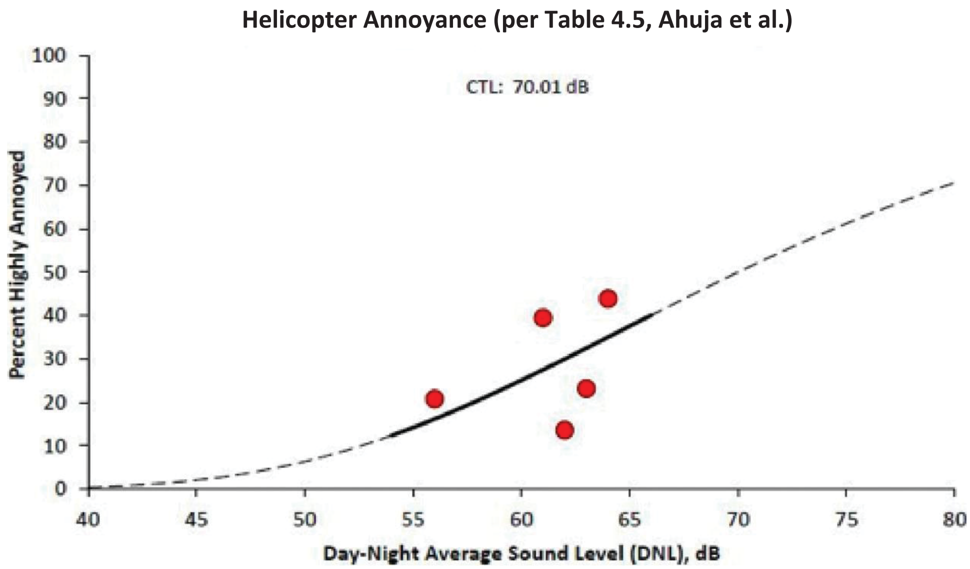


FIGURE B1 Field observation and a priori dosage-response relationships. *Source*: Fidell et al. (2011).

an overhead aircraft might crash. The attitudinal response of bother or annoyance to aircraft noise was found to be positively correlated with crash fear: "On the whole, residents who feared a crash were more annoyed by aircraft noise than those who did not."

The authors noted that the scatter of dose-response points about their trend line exhibited greater scatter than expected by chance alone. This scatter was somewhat reduced when the respondent socio-economic group factored into the analysis of the scatter was measurably reduced. Some neighborhoods differed markedly in the age of the population; however, no age effect was found in the dose-response analysis.

Austin-Bergstrom International Airport, "Helicopter Air Taxi Analysis, 2013 Formula 1," City of Austin, Jan. 20, 2014.

The city of Austin prepared a report on the helicopter operations and associated air traffic and noise associated with the year 2013 Formula 1 Gran Prix held in Austin. The report is interesting for those looking for information on the effect of a major sporting event in terms of helicopter demand and operations, how preferred routes (Fly Friendly Corridors) were established and used and how coordination was handled between the airport and the event organizer. The 2013 event generated three noise complaints, while the 2012 event had generated 116 complaints. Flight track maps are provided for the 2012 event and the 2013 event, and the result of the Fly Friendly Corridors is clearly seen as confining the tracks to a desired route over less sensitive areas.

Edwards, B., *Psychoacoustic Testing of Modulated Blade Spacing for Main Rotors*, NASA Contractor Report 2002-211651, 2002.

Edwards reports the results of laboratory studies on the annoyance of noise created by a simulated 5-bladed main rotor with unevenly spaced rotors. Forty subjects assigned numeric ratings to the annoyance of various simulated blade configurations and 40 provided paired comparison ratings. Edwards concludes that "No strong subjective differences among the predicted helicopter test sounds were found in either test . . . ," and that A-weighted measures of helicopter rotor noise are "not strongly indicative of subjective response."

Federal Aviation Administration, *Report to Congress: Nonmilitary Helicopter Urban Noise Study*, Report of the Federal Aviation Administration to the United States Congress Pursuant to Section 747 of the Wendell H. Ford Aviation Investment and Reform Act for the 21st Century (AIR-21), Washington, D.C., 2004.

Human Response

FAA's review of the technical literature on the annoyance of helicopter noise in its Report to Congress cites eight (mostly laboratory) studies supporting the imposition of a blade slap "penalty" on A-weighted measurements of helicopter noise, and seven suggesting that such a penalty is not justified. The FAA report also cites two studies of "heightened reaction" to helicopter noise—presumably not associated with blade slap—by Schomer (1983) and Atkins et al. (1983). Despite the inconsistency and ambiguity of these findings, the report repeats the common assertion that "Helicopter noise may be more noticeable because of its periodic impulsive characteristic." The report also cites "the possible phenomena (*sic*) of 'virtual noise'" (see annotation for Leverton 2014), which it suggests may be the result of attitudes and beliefs about the necessity of helicopter operations and fear of crashes.

The FAA report also includes brief discussions in Sections 3.5.5 through 3.5.8 of contentions that "Helicopter noise is more annoying than fixed-wing aircraft noise"; that "Helicopter sounds may be more readily noticeable than other sounds"; that attitudes such as fear of danger, beliefs about the importance of the noise source, and invasions of privacy may influence the annoyance of helicopter noise; and that rotary-wing flight capabilities such as prolonged hovering and proximity to residences may also heighten the annoyance of helicopter noise.

The primary conclusion of FAA's Report to Congress is that "models for characterizing the human response to helicopter noise should be pursued." The report also includes a wide range of recommendations, including some that are reflected in the current effort. For example, FAA recommends study of "non-acoustical effects," among which it includes vibration and rattle, and "virtual noise," as described informally by Leverton (2014) and systematically by Fidell et al. (2011). The report also suggests that unique characteristics of helicopter noise emissions (notably including blade slap) may heighten community annoyance with helicopters; that evaluation of noise metrics other than DNL should be undertaken; and that "operational alternatives that mitigate noise should be examined." The latter specifically include higher altitude flight and route planning to avoid noise-sensitive areas.

Noise Impact Mitigation

Despite technological improvements that have allowed aircraft noise in general to decrease, the noise generated by nonmilitary helicopters has increasingly become a point of concern, particularly in densely populated communities. To address this, FAA carried out a study that investigated the impacts of helicopter noise and offered recommendations as to how to reduce those effects on the quality of life, all on the behalf of the Secretary of Transportation, who was in turn operating under a mandate of the United States Congress.

FAA began by reviewing the available literature relevant to determining what effects noise could have on people. The major consequences regarding health were identified in a report by the World Health Organization (WHO), and these included hearing impairment; interference with speech communication or performance; general physiological, cardiovascular, behavioral, and mental health effects; sleep disturbance; and annoyance. FAA also took into consideration the possibility of helicopters in particular causing more annoyance resulting from impulsivity, lower frequency (which in turn can cause vibrations and rattles), or general heightened awareness of its noise.

The next step taken by FAA was to seek public input through *Federal Register* notices as well as two public workshops in Washington, D.C. Together, these forms of outreach allowed for the compilation of comments from a variety of parties; private citizens, elected officials, civic group representatives; and the helicopter industry. In terms of the types of operations that sparked the most concern, Electronic News Gathering (ENG) and sightseeing were seen as causing the most problems with the least justification. These comments were then divided into two categories: operational and nonoperational issues.

The most frequently indicated operational issues included a minimum altitude in Above Ground Level (AGL) or maximum Sound Pressure Level (SPL) for overflight and hover, the improvement of operational routes and routing design guidelines through more in-depth analysis of noise-sensitive areas, a limit on hover duration time, the retirement of the noisiest helicopters, and the marking of helicopters with visible identification. Also among the operational issues and suggestions mentioned were controlling the frequency of helicopter operations (sometimes by operation type), restricting the time frame of helicopter operations, limiting the operations of helicopters on heliport or airport property, general noise abatement procedures, noise certification limit stringency, and the implementation of noise reduction technology; facing the problem at its source.

In addition, a large number of issues fit into the nonoperational category. The effectiveness of voluntary noise mitigation programs that ENG flights should pool their operations more often, the exemption of public service helicopter operations from limits, and the improvement of VFR corridors and IFR access for helicopters were all nonoperational concerns. The empowerment of local municipalities with airspace control, the inclusion of military helicopter impact, the need for a socio-acoustic study relating medical and health effects, flight tracking and noise monitoring systems, the utilization of differential Global Positioning Systems (dGPS), and a better helicopter noise metric were brought up as well.

Through the assistance of the Volpe Center, FAA then acquired measurements of helicopter noise at the urban center of New York City, chosen in order to quantify the noise levels in a densely populated metropolitan community. Among the locations of focus were the New Jersey Liberty State Park and the vicinity of downtown heliports. Data were collected using microphones, a video-based tracking system, camera-based photo scaling methods, and laser range-firing devices before they were analyzed. Their measurements matched those in the New York City Master Plan Report, as well as suggested that there should be a +2 dB adjustment for urbanization. Through modelling by the FAA's INM, these data also showed that flying at higher altitudes reduced the noise inhabitants were exposed to; supporting the validity of the voluntary helicopter industry recommendation of operating at higher altitudes.

Taking into account the information gleaned through the study, FAA came up with a set of conclusions and recommendations. They believed that additional socio-acoustic studies about the annoyance effects of low-frequency and impulsive noise specific to helicopters could improve the measurement and evaluation of helicopter noise and lead to better mitigation. Operational mitigation measures that do not affect safety could also be beneficial, such as higher altitudes, better route planning, the incorporation of more precise technologies such as dGPS into helicopter approaches and departures, and advocating noise abatement among both operators and the ATC. FAA further suggested that communities and operators should come up with voluntary agreements for noise mitigation and that, in general, public service helicopters such as law enforcement, firefighters, and EMS should be exempt from any restrictions relating to noise.

Federal Aviation Administration (FAA), "The New York North Shore Helicopter Route, Final Rule," 14 CFR Part 93, U.S. Department of Transportation, Washington, D.C., July 26, 2012.

FAA published a mandatory helicopter route in response to noise complaints associated with helicopter operations in the vicinity of Long Island. This rule is of interest to the reader because it contains a detailed history of the noise issue, the complex process of converting the existing voluntary route to a mandatory route, and the associated analyses. The rule includes a discussion of the benefit of route and the economic cost to operators of implementing the route. FAA identified five reasons that the situation in Long Island was unique enough to warrant a mandatory route:

1. Because Long Island is surrounded by water, it was possible to develop a route that took helicopters a short distance off the shoreline. Thus, the North Shore Helicopter Route does not negatively impact other communities and operators can use the route without significant additional costs.
2. There are disproportionately more multi-engine helicopters flying in Long Island than the national averages (approximately 65% versus 10%–15% nationally.) This allows for greater use of the off-shore route.
3. There are visual waypoints along the route that allow pilots to fly along the route with no additional equipment during good weather.
4. The helicopter traffic along the north shore of Long Island is largely homogenous, in that it is primarily point-to-point transit between New York City and the residential communities along the northern and eastern shores of Long Island.
5. The population corridor along the north shore of Long Island is significant and, coupled with the number of airports/heliports on the island, FAA found it reasonable to develop a route to mitigate noise impacts.

In addition to the rule, FAA published the Long Island North Shore Helicopter Route Environmental Study that describes the route, number of operations, and noise levels along the route.

The route was to sunset in 2 years from initiation unless FAA chose to extend the time. FAA extended the time for another 2 years in 2014.

Federal Aviation Administration (FAA), *Report on the Los Angeles Helicopter Noise Initiative*, May 31, 2013, FAA, Washington, D.C.

FAA, in response to a request from members of the California Congressional Delegation, formed the Los Angeles Helicopter Noise initiative in response to long-term citizen concerns over helicopter noise in the Los Angeles area. This report documents the work done as part of public workshops, with suggestions from private citizens, elected officials, civic group representatives, and the helicopter industry.

The report states that "there is no single remedy that can be implemented on a large-scale basis throughout the Los Angeles Basin. The airspace over Southern California is among the most congested and complex in the world. For safety reasons, helicopter traffic must be separated by altitude from higher-performing and faster-moving fixed-wing aircraft. The density of land use in the area, as well as the complexity and diversity of airspace users present challenges to identifying optimal helicopter routes that are safe, efficient, and serve noise abatement purposes."

FAA grouped the approaches for addressing the noise issue that were gathered from all stakeholders into 10 groups and the report presents technical discussions relative to each approach:

- Ensure Safety of Helicopter Operations
- Establish Noise Abatement Helicopter Routes
- Keep Helicopters at Higher Altitudes
- Limit Hovering
- Reduce Helicopter Source Noise
- Reduce Flights by Electronic News Gathering (ENG) Operations
- Restrict Helicopter Flights
- Charge Fees for Helicopter Operations
- Improve Information on Helicopter Operations and Noise Abatement Practices
- Establish a Forum for Addressing Helicopter Noise Issues.

FAA committed to undertaking and supporting the following actions:

- Evaluate existing helicopter routes to identify feasible modifications that could lessen impacts on residential areas and noise-sensitive landmarks. Any new routes intended to provide noise relief will be evaluated to avoid simply shifting noise from one residential neighborhood to another. Safety Risk Management studies would be required to ensure that helicopters can transition airspace safely and efficiently.
- Analyze whether helicopters could safely fly at higher altitudes in certain areas along helicopter routes and at specific identified areas of concern. Any proposed altitude changes would be required to go through an FAA Safety Risk Management Panel prior to adoption.
- Develop and promote effective practices for helicopter hovering and electronic news gathering. Hover times are site-specific and event-specific. FAA will continue to issue Advisory Notices to Airmen (NOTAMs) for large events and encourage helicopter operators and news organizations to employ practices that reduce noise.
- Conduct outreach to helicopter pilots to increase awareness of noise-sensitive areas and events. A collaborative effort among FAA, pilot groups, and communities has identified noise "hot spots" within the Los Angeles Basin. FAA seeks to increase pilots' situational awareness of noise problems on the ground and of community issues with noise.
- Explore a more comprehensive noise complaint system. A centralized system that provides a single repository for helicopter noise complaints in Los Angeles County may be more advantageous than current individual systems, with differing geographic and jurisdictional coverage. FAA will support the assessment of the prospects for developing such a system with homeowners' associations and operator groups.
- Continue the collaborative engagement between community representatives and helicopter operators, with interaction with FAA. A significant positive result of the Los Angeles Helicopter Noise Initiative is that community representatives and helicopter operators plan to meet regularly, with input from FAA, to identify specific noise-sensitive locations and helicopter operating practices that contribute to noise concerns. The group is committed to identifying measures that will provide noise relief without degrading safety or eroding business opportunities.

The report goes on to describe federal efforts on the national level to reduce helicopter noise including sponsoring research on aircraft noise. FAA is currently creating a research roadmap to identify new areas of aircraft noise research, including helicopters, and will be preparing additional studies pending availability of funding and resources. FAA is also in the process of rulemaking to implement a Stage 3 helicopter noise standard in the United States. The Stage 3 helicopter noise standard will apply to all new helicopters types certified after the implementation date of the rule. As older helicopters are retired and new helicopters are purchased, the percentage of quieter Stage 3 helicopters in the U.S. fleet will increase.

The report concludes that "the most satisfactory and widely accepted noise abatement measures are those that are collectively discussed by engaged stakeholders and FAA at the local level and are supported by local consensus. As explained in the conclusion of the report, a federal regulatory process is not well suited to the helicopter noise situation in Los Angeles and could reduce community and other stakeholder involvement, as well as delay other remedies for an indefinite period of time" and that "the FAA recommends the engagement of a robust local process and is prepared to support such a process to pursue remedies that reduce helicopter noise, are responsive to community quality-of-life and economic interests, and are consistent with National Airspace System safety and efficiency."

Generally the report is an excellent resource for understanding how FAA manages airspace and separates helicopters from fixed-wing aircraft and gives a detailed explanation of how the airspace is structured and why helicopters are kept at altitudes below fixed-wing aircraft. Graphical presentation of helicopter routes in the vicinity of specific airports illustrates the problem of separating helicopters from fixed-wing aircraft. Specific areas of concerns such as the Hollywood Bowl and Getty Center, as well as communities where helicopters are an issue are described.

Fidell, S. and R. Horonjeff, "Detectability and Annoyance of Repetitive Impulse Sounds," ***Proceedings of the 37th Annual Forum*****, American Helicopter Society, New Orleans, La., 1981, pp. 515–521.**

The audibility of low-frequency rotor noise is of concern not only in residential settings, but also in military applications (where the element of surprise can be mission-critical) and in airspace subject to special federal aviation regulations intended to protect natural quiet. In such applications, the main concern is prediction of the audibility of wave trains of repetitive acoustic impulses, rather than of individual impulses. Fidell and Horonjeff (1981) demonstrated that over a range of observation intervals (0.25 to 2.00 s) and repetition rates (5 Hz to 40 Hz, corresponding to the range of fundamental and harmonics of blade passage rates of present interest) the audibility of impulse wave trains is very closely predictable from the audibility of a single impulse. Under highly controlled listening conditions, participants determined when impulse wave trains of varying repetition rate and observation interval duration were just audible in white noise. The impulse was a 1000 Hz sinusoid. Test participants also listened for a single impulse randomly placed within a 500 ms observation interval.

Equation 1 shows a derived relationship between the energy ratio of a wave train divided by single impulse (left side of equation) and the repetition rate and observation interval (right side).

$$10 \log_{10}(E_{ri}/N_0) - 10 \log_{10}(E_{si}/N_0) = 5 \log_{10}(RR) + 8 \log_{10}(D) + 1.5 \qquad \text{Eq. 1}$$

where:

E_{ri}/N_0 = signal energy to noise power density ratio of impulse wave train,
E_{si}/N_0 = signal energy to noise power density ratio of a single impulse,
RR = impulse repetition rate (Hz), and
D = observation interval (seconds).

Figure B2 shows the resulting clustering of data points (each an average over all test subjects) when the energy ratio is plotted against repetition rate and the energy ratios have been adjusted for the duration term, 8 Log10(D) in Equation 1.

The tight fit of the data points about the line (±0.3 dB) suggests a strong predictive relationship between repetition rate and observation interval (all for the same waveform) and the energy ratio of the wave train

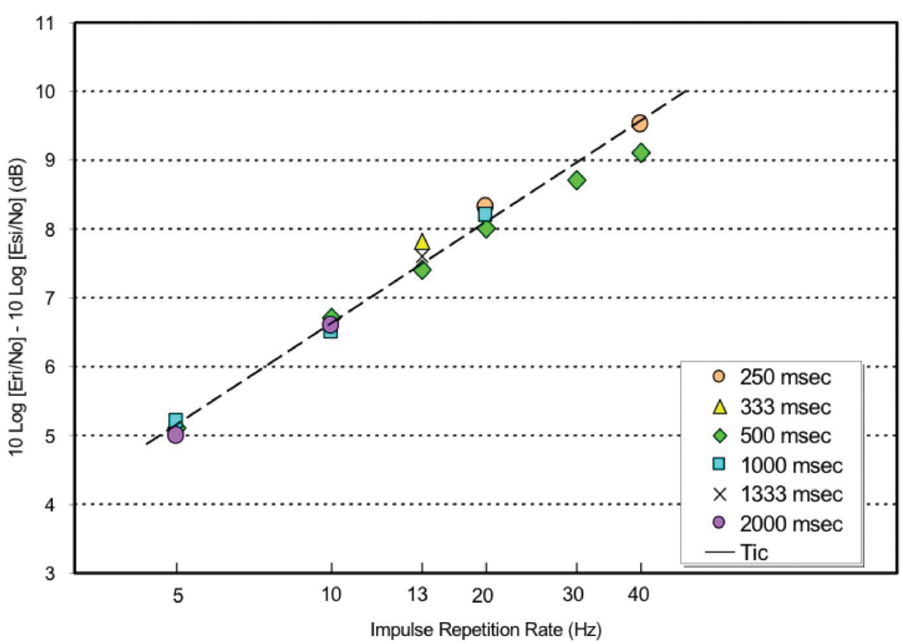


FIGURE B2 Observed relative signal-to-noise ratios (10 $\log_{10}[E_{ri}/N_0]$ – 10 $\log_{10}[E_{si}/N_0]$) of equally detectable impulse wave trains as a function of impulse repetition rate collapsed over observation interval duration by 8 $\log_{10}[D]$.

and single impulse. The positive slope of about 1.5 dB per doubling of repetition rate (or 5 dB/decade) indicates that greater signal energy is needed at increasing repetition rates to maintain constant detection performance, and that these slopes are effectively independent of observation interval duration over the investigated range.

Fields, J. and A. Powell, "Community Reactions to Helicopter Noise: Results from an Experimental Study," *Journal of the Acoustical Society of America*, Vol. 82, No. 2, 1987, pp. 479–492.

Noting the characteristically small numbers of helicopter overflights in many residential exposure settings, Fields and Powell focus on "the applicability of the equivalent energy assumptions about the relative importance of noise level and number of noise events." They devised a controlled listening field study in which the same 330 respondents were paid $40 to complete repeated interviews on the evenings of 22 days about their annoyance with late morning and early afternoon weekday helicopter noise.

The study area, in close proximity to an army helicopter training base, was a strip 500 m long, containing 861 dwellings, in a "quiet, well-maintained, middle-class suburban area" with high military employment. The residents were thoroughly habituated to helicopter overflight noise. Large percentages of respondents considered helicopters "very important" (64%), believed that "pilots or other authorities" could not do anything to reduce helicopter noise (62%), and were not afraid that a helicopter might crash nearby (67%).

The daily interview lasted only about 4 minutes and was confined to determining the times at which respondents were at home during the day, what noise sources they heard, and how annoyed they were by them. Noise measurements were limited to those made at one fixed site at the end of the exposure area, and two roving mobile sites.

Fields and Powell found that respondents' annoyance ratings of helicopter noise increased with both number and level of noise exposure. The average annoyance scores were almost all below 4 on a 10-point scale indicating that few, if any, respondents were highly annoyed by helicopter noise in the target population. They also found only minor differences in annoyance scores for long-term exposure to more or less impulsive noise: "annoyance, in general, was slightly higher" for exposure to more impulsive (UH-1H). Correlations between noise exposure levels and annoyance scores accounted for less than 10% of the variance in the relationship.

Helicopter Association International, "Fly Neighborly Guide," Third Edition, 2009 [Online]. Available: http://www.rotor.com/Resources/NoiseAbatementTrainingCD.aspx.

The Helicopter Association International (HAI) has published a number of materials that are of interest for managing helicopter noise. Included is a downloadable CD (see URL), which includes the "Fly Neighborly Guide." This document is of sufficient relevance to this synthesis that it is included here as Appendix C.

The guide is divided into eight chapters that include general information and background materials, how helicopters generate sound, guidelines for helicopter operators on noise abatement, how to operate helicopters quietly, pilot training issues, guidelines for helicopter operators (companies) on noise abatement, managing public acceptance, and the "Fly Neighborly Program—What Can be Achieved?" The guide is written for helicopter operators not airport operators; however, much of the material is useful and informative both to the airport operator and the general public. The training program is designed to help helicopter operators:

- Recognize the impact operations have on noise
- Understand the dangers of not addressing noise concerns
- Recognize the main noise generators on a helicopter
- Recognize which noise sources dominate each helicopter flight regime
- Recognize the effect that distance has on sound
- State the effect of temperature, humidity, and wind on sound
- Recognize the impact of terrain on sound
- Recognize the steps manufactures have taken to reduce helicopter noise
- Recognize new design features being examined for future noise reduction
- Recognize the need for noise abatement
- Recognize how pilot attitude factors into noise abatement
- Relate general guidelines for reducing helicopter noise
- Recognize the role of associations in establishing and enforcing noise abatement procedures.

The HAI website also includes specific guidance on noise abatement procedures for specific aircraft and can be found at: http://www.rotor.com/Resources/NoiseAbatementProcedures.aspx.

It is interesting to note that the guidelines generally recommend that helicopters stay 1,000 ft above noise-sensitive areas. The following aircraft are included in the noise abatement procedures document and, while it appears comprehensive, it is from 2009 and should be updated as some of the guidance for some of the aircraft listed is quite general and not as aircraft-specific as that done for other aircraft in the list:

Agusta
 A109A, A109A II, and A109C
Bell Helicopter
 204, 205, 212, UH-1, AH-1 Series Helicopters
 206A, 206B, 206B-3, 206L, 206L-1, 206L-3, 206L-4, and 206LT
 427, 429
 407
 430
Boeing
 234 and CH-47A
 [*Note:* Some information also applies to 107 and CH-46.]
Enstrom
 F28F and 280FX
Airbus Helicopters (Eurocopter)
 EC120, EC130, AS350BA, AS350B2, AS350B3, AS355F1, F2, N, NP
 EC135T1,T2,T2+, EC135P1, P2, P2+, BK117B1, C1, C2, EC145, BO105 all models
 SA 365N (formally Aerospatiale)
MD Helicopters
 MD500N, MD500D, and MD500E (formerly McDonnell Douglas)
 MD530F PLUS (formerly McDonnell Douglas)
 MD 600N (formerly McDonnell Douglas)
 MD 900 (formerly McDonnell Douglas)
Robinson
 R22
 R44
Rogerson Hiller
 UH12 and RH1100
Schweizer
 300C
Sikorsky
 S-76A/A+/A++/B/C/C+
 S-92

Leverton, J., "Helicopter Noise: What Is the Problem?" *Vertiflite*, Vol. 60, No. 2, March/April 2014, pp. 12–15. (See also Leverton and Pike 2007, 2009.)

The standard measure of adverse public reaction to transportation noise exposure is the prevalence of a consequential degree of noise-induced annoyance (FICON 1992; ISON 1996-1). Leverton (2014) asserts that vigorous adverse community reaction to helicopter noise "is a little difficult to understand because most helicopters generate less noise than the noise certification standards [*for fixed-wing aircraft*]. . . ."[i] He infers from this observation that "there appears to be something different about the way in which helicopters are perceived."

Leverton expands the concept of "something different" about the perception of helicopter noise into the concept of "virtual noise." However, he offers somewhat contradictory definitions of virtual noise. On the one hand, Leverton states that virtual noise is nonacoustic in nature. This is a plausible belief, since the annoyance of an unwanted noise intrusion is, after all, a property of an unwilling listener, not of a noise source per se. A sound level meter measures sound pressures, not annoyance. Absent a reliable dosage-response relationship, useful inferences cannot be drawn from noise levels alone about the prevalence of annoyance with transportation noise in noise-exposed communities.

On the other hand, Leverton believes that even though virtual noise is not directly related "either to the absolute level or to the character of the noise generated by helicopters," it is nonetheless "triggered by the direct acoustic signal." As Leverton puts it, "Virtual noise is dependent on a wide range of inputs, but is triggered initially by any distinctive feature of the acoustic signature and, to a far lesser extent, the absolute noise level." In other words, adverse community reaction to helicopter noise is conditioned on

[i]This assertion tacitly assumes that compliance with ICAO standards for fixed-wing aircraft noise certification precludes vigorous adverse reactions in aircraft noise-exposed communities near airports. ICAO's recommendations are merely consensus standards for noise levels that may not be exceeded by aircraft offered for sale in those member states that chose to adopt ICAO's recommendations. ICAO's noise certification standards are not intended to, and do not in fact, preclude adverse community reaction to aircraft noise exposure. Indeed, it is commonplace for communities near airports served by large fleets of ICAO-compliant aircraft to vigorously oppose continued, unmitigated airport operation and expansion.

two sets of factors other than the conventionally measured, A-weighted, acoustic energy of helicopter noise emissions. The first component of virtual noise is the noticeability of distinctive features of helicopter noise emissions, such as high-speed impulsive noise (HSI), tail rotor noise (TR), main rotor/tail rotor interaction noise (TRI), and blade/vortex interaction noise (BVI). In Leverton's view, the second component of "virtual noise" is entirely nonacoustic.

Leverton's concept of virtual noise has several limitations. First, it does not consider the possibility that certain characteristics of helicopter noise could be highly annoying at levels that do not control a helicopter's total A-weighted noise emissions. Second, it does not clearly distinguish between the influences of acoustic and nonacoustic factors on the annoyance of helicopter noise, nor offer any quantitative guidance about the relationships between them. Third, it does not provide any operational definition or methods of quantifying the nonacoustic aspects of virtual noise.

The major contribution of this publication is that it reinforces the notion that factors other than those that can be measured with a sound level meter may somehow affect the annoyance of helicopters.

Magliozzi, B., F. Metzger, W. Bausch, and R. King, *A Comprehensive Review of Helicopter Noise Literature*, FAA-RD-75-79, 1975.

The "comprehensive review" of Magliozzi et al. is more of a summary of early field measurements of helicopter noise than a critical review. It focuses more on noise emissions and noise control concerns than on the subjective effects of helicopter noise on individuals or communities, and includes little novel analysis. Some of the reasoning is specious, as for example, when the authors conclude "Spectrum analyses of helicopter noise show that the main rotor, tail rotor, and engine sources contribute significantly to annoyance." Merely because rotating noise sources contribute conspicuously to a spectrogram does not mean that they are "significant" sources of annoyance.

Likewise, Magliozzi et al. simply repeat others' views that a need for "a new noise unit" for measuring helicopter noise is required, and assert that a "modification of the Day-Night Noise Level (*sic*) . . . shows promise" for assessing community acceptance of helicopter noise.

Maryland Aviation Administration and Metropolitan Washington Council of Governments, "Regional Helicopter System Plan For the Maryland and Metropolitan Washington Area," June 2005.

The Maryland Aviation Administration and Metropolitan Washington Council of Governments contracted for a helicopter systems plan for the Washington D.C. area. The report is in the form of an aviation system plan that presents aviation forecasts and facility requirements for anticipated helicopter demand in the D.C. area. The report also includes a section on environmental impact including noise. The noise section includes background material on helicopter noise, measuring helicopter noise, and modeling helicopter noise. The report goes into detail and existing and preferred routes for helicopters and noise contours for those routes. The noise mitigation section discusses a number of regulatory issues that describe what is under federal authority, the limits of what the state can do, and local land use controls. The report lists the Helicopter Fly Neighborly Program, published by the Helicopter Association International, suggestions for managing helicopter noise:

Routes and Airspeeds:

- Fly highest practical altitude
- Routes to heliport/helistop should fly over least populated area
- Follow major thoroughfares or railway beds
- Avoid flying over densely populated areas
- If flying over populated areas, use a 95 knot cruise speed
- Select a final approach route avoiding noise-sensitive areas.

Approach and Landing:

- Use one of two procedures when commencing an approach:
  - Establish a 500 ft/minute rate of descent
  - Reduce airspeed and increase descent to 800 ft/minute.
- Hold rate of descent to less than 200 ft/minute while reducing airspeed to 57 knots
- Increase rate of descent to 800 ft/minute
- Use convenient airspeed between 50 and 80 knots and an 800 ft/minute descent on glide slope
- Reduce airspeed to 60 knots when approaching the flare
- Execute a normal flare.

Takeoff

- Use a higher rate of climb to reduce overall area exposed to noise.

Miller, N., "Technical Memorandum, Review of Studies that Address Effects of Helicopter Noise," HMMH, Feb. 2015 (for the Town of East Hampton) [Online]. Available: http://www.htoplanning.com/docs/Town%20Documents/150203%20HMMH%20Memorandum%20re_%20Review%20of%20Studies%20that%20Address%20Effects%20of%20Helicopter%20Noise.PDF.

This technical memorandum was developed for the town of East Hampton and describes the background on noise and human annoyance response to aircraft noise. The memorandum goes in to some detail showing where previous studies have shown that people are more highly annoyed by helicopter noise of the same level of other sources of noise. The report goes through current theory on noise annoyance in detail. The following summary of current noise annoyance theory is a quoted from the report:

- "Except for Luz, all studies reviewed were focused on annoyance reactions and associated variables that could affect annoyance.
- Annoyance may be correlated with L_{eg}, DNL.
- Some adjustment to SEL-based metrics may be appropriate if surveyed helicopter noise annoyance is to be predicted in terms and with metrics used to estimate the annoyance of fixed-wing aircraft noise.
- Annoyance reactions (e.g., complaints), although not the degree of annoyance may be triggered by noticing the event rather than by the loudness of an event.
- Helicopter noise may contain aspects that increase probability of noticing:
  - Low-frequency modulation of broad-band noise and
  - Slow travel speed and relatively low and constant altitudes that may lend to long audibility of approaches. Fear reactions to approaching sounds may be endemic to humans.
- SEL or SEL-based metrics are not likely the entire answer as far as complaints are concerned; they may depend upon noticeability as well."

The town of East Hampton has included on the town website a number of reports, studies, and proposals for managing helicopter noise. These may be of interest to the reader and is available here: http://ehamptonny.gov/HtmlPages/AirportInterimNoiseAnalysis.html.

Molino, J.A., *Should Helicopter Noise Be Measured Differently from Other Aircraft Noise?—A Review of the Psychoacoustic Literature*, NASA Contractor Report 3609, 1982.

Molino's review describes the many differences between fixed and rotary-wing aircraft noise, but pays most attention to the impulsive nature of helicopter blade-vortex interaction noise ("blade slap"). He reviewed 34 studies of the noisiness of helicopter blade slap, many of which were non-peer reviewed conference papers or technical reports, which yielded conflicting if not contradictory findings. His conclusion that "there is apparently no need to measure helicopter noise any differently from other aircraft noise" is based largely on the lack of consistent empirical findings about the "excessive" (with respect to the annoyance of fixed-wing aircraft noise) annoyance of impulsiveness per se.

The zeitgeist of the early 1980s, particularly ISO's attempts to recommend noise metrics appropriate for certification of helicopter noise, appears to have influenced Molino's analyses. Several national helicopter industries had proposed methods for assessing the annoyance of helicopter noise. Each disproportionately penalized the noise emissions of competitors' products. Aérospatiale, for example, proposed a "correction" to helicopter noise that heavily penalized even slight short-term temporal variation in noise levels. "Corrections" proposed by British sources, on the other hand, heavily penalized tonal components of helicopter noise, such as those produced by Sud Aviation's (subsequently Aérospatiale, Eurocopter, and now Airbus Helicopters) high-speed, ducted fan ("Fenestron") tail rotor.

Molino's report goes into considerable detail about the acoustic characteristics of helicopter noise emissions, and into variability in noise emissions associated with various helicopter types and operating conditions. He notes that relationships between operating mode, engine power, and airspeed in helicopters are not as straightforward as they are for fixed-wing aircraft. For example, Molino observes that unlike fixed-wing aircraft, "helicopters generally produce a minimum sound level at some intermediate airspeed, with higher sound levels at lower and higher airspeeds." He also observes that "for the same airspeed, helicopters often exhibit different sound spectra for approach versus level flight."

The psychoacoustic research reviewed by Molino consists mostly of 1970s-era studies, with a smattering of earlier and later studies. A major part of Molino's review addresses the methodological advantages and disadvantages of varying forms of signal presentation, listening contexts, and annoyance rating scales for controlled listening tests. He ultimately speculates (1) that "the source of . . . [*discrepancies among empirical findings*] . . . may lie in the methodologies and approaches selected by the experimenters," rather than in bona fide differences in the annoyance of helicopter noise; and (2) that inadequate experimental treatment of the complexity of helicopter noise may obscure the annoyance of helicopter noise. For example, Molino notes "The presence of blade slap, in and of itself recognized as contributing to increased annoyance, produces changes in other acoustic parameters that can compensate for or account for the increased annoyance cause by the presence of blade slap."

Molino concludes from the contradictory and inconclusive nature of the findings of laboratory studies about the annoyance of helicopter noise that "there is apparently no need to measure helicopter noise any differently from other aircraft noise." The logic and universality of Molino's conclusion are open to question, given the limited nature of comparisons that Molino describes among the findings of different forms of laboratory studies of the annoyance of helicopter noise.

Another major limitation of Molino's review is that he confines his review to the direct annoyance of airborne acoustic energy produced by helicopters, and ignores the potential contributions to annoyance of secondary emissions (audible rattle and sensible vibration) produced by helicopter flight operations inside residences. To the extent that any excess annoyance of helicopter noise is related to the annoyance of secondary emissions, Molino's conclusion about the sufficiency of A-weighted measurements is premature.

More, S.R., *Aircraft Noise Characteristics and Metrics*, Purdue University Doctoral Thesis and Report No. PARTNER-COE-2011-004, West Lafayette, Ind., 2011.

More's thesis reports the findings of laboratory studies of second-order effects, such as "sharpness" (spectral balance of low- and high-frequency energy), tonality (presence of prominent tones), slow fluctuations in loudness (fluctuation "strength"), and "roughness" (rapid fluctuations in loudness) on absolute judgments of the annoyance of single-event, fixed-wing aircraft noise presentations. (The reported work does not address the effects of rattle and vibration or the annoyance of cumulative noise exposure.) Although More's interests did not specifically extend to the annoyance of helicopter noise, some of the factors that he studied are more characteristic of complex rotary-wing noise emissions than those of simpler, broadband fixed-wing aircraft.

The laboratory judgments failed to demonstrate any clear contributions of sharpness, roughness, and fluctuation strength to judgments of the annoyance of aircraft noise. Loudness remained the major determinant of judged annoyance, with a clear contribution of tonality.

Munch, C. and R. King, *Community Acceptance of Helicopter Noise: Criteria and Application*, National Aeronautics and Space Administration, NASA-CR-132430, 1974.

Because assumptions made by the authors have not withstood the passage of time, the reasoning in this 40-year old study—dating from the era prior to FICON's recognition of the prevalence of a consequential degree of annoyance as a preferred measure of adverse impact of transportation noise—is largely irrelevant to modern analyses of the effects of helicopter noise exposure on communities.

For example, the authors loosely define "community noise acceptance criteria" in terms of "a noise exposure acceptable to the average member of the community." Further, they interpret EPA's recommendation of a DNL of 60 dB as a level consistent with "requirements for human compatibility in the areas of annoyance, speech interference, and hearing damage risk" as a basis for regulating aircraft noise. They also assume that A-weighted noise levels 2 dB lower than ambient levels are completely acceptable and that ambient noise levels in inhabited places will decrease "over the years as a result of stricter controls on noise sources other than aircraft." Neither assumption is correct. The audibility of aircraft noise cannot be reliably predicted from A-weighted noise levels, and Schomer et al. (2011) has shown that the slope of the relationship between population density and cumulative noise exposure has remained unchanged for 40-odd years.

The authors also report an informal study of the noticeability of blade slap, from which they estimate that notice of blade slap occurs at a crest factor of 13 dB. This figure is little greater than the crest factor of many urban ambient noise environments. Although the authors repeatedly emphasize that understanding of the annoyance of blade slap is "sketchy," "inadequate," "very limited," "inconsistent," etc., they nonetheless conclude that a "penalty" is required to account for the annoyance of repetitive impulsive aircraft noise. The magnitude of the recommended penalty in units of Perceived Noise Level is 4 to 6 dB, or 8 to 13 dB in A-weighted units.

Namba, S., S. Kuwana, and M. Koyasu, "The Measurement of Temporal Stream by Hearing by Continuous Judgments—In the Case of the Evaluation of Helicopter Noise," *Journal of the Acoustical Society of Japan*, Vol. 14, No. 5, 1993.

Namba et al. suggest that the practice of calculating equivalent energy metrics for time-varying environmental noises (such as those produced in the course of helicopter flight operations) can misestimate their annoyance because they do not take into consideration the temporal context of noise intrusions.[ii] They propose instead a method of continuous judgment, such that the annoyance of helicopter and other ". . . fluctuating sounds [can be measured] by pressing a key on a response box . . . ," in real time. The authors found marked differences in the momentary annoyance of helicopter takeoffs, overflights, and landings.

Ollerhead, J., *Laboratory Studies of Scales for Measuring Helicopter Noise*, NASA Contractor Report 3610, 1982.

Ollerhead solicited absolute judgments from scores of test subjects of the annoyance of tape-recorded helicopter sounds presented both over headphones and by loudspeaker in a series of laboratory studies. A set of preliminary investigations was conducted to pilot-test the annoyance rating and signal presentation methods. A set of "main" tests followed, in which six undergraduates at a time rated the annoyance of the sounds of 89 helicopters (mostly level flyovers) and 30 fixed-wing aircraft heard through headphones. The headphone presentation results were generally replicated in subsequent free-field testing at NASA LaRC.

Ollerhead concludes that tone-corrected effective (that is, duration-adjusted) Perceived Noise Level predicts the annoyance of helicopter noise better than does A-weighted sound pressure level, and that any putative effects of impulsiveness per se may be equally attributed to increases in helicopter noise level and duration.

Ollerhead, J.B., *Rotorcraft Noise*, Loughborough University of Technology, Leicestershire, England, 1985.

Ollerhead's review addresses "subjective impact" (individual and community response to exposure to helicopter noise), mechanisms of helicopter noise generation, and potential helicopter noise control measures, with greater emphasis accorded to the latter two topics.[iii] Like most other review articles, Ollerhead's dwells at length on differences between rotary- and fixed-wing noise emissions. Among other salient differences, Ollerhead notes that unlike fixed-wing aircraft, "helicopters are usually confined to low altitudes," and that "many helicopters radiate maximum noise in a forward direction," so that "an approaching helicopter can often be heard for as long as five minutes."

Ollerhead's review of subjective impacts of helicopter noise consists in large part of re-statements attributed to Molino (1982). Like Molino, Ollerhead draws attention to contradictory findings and to apparent discrepancies between the findings of field studies and laboratory studies. Ollerhead notes, for example, that his own 1971 finding "that the very long attention-arresting sound of an approaching helicopter did not affect annoyance responses in the laboratory experiments" conflicts with "hearsay evidence of complainants near heliports that [*duration of audibility*] may be a particular source of aggravation to people at home."

Pater, L. and R. Yousefi, "Hangars as Noise Barriers for Helicopter Noise," National Conference on Noise Control Engineering, Williamsburg, Va., NOISE-CON, 1993, pp. 241–246.

In their effort to reduce the noise effects of military activities on communities in the vicinity of army airfields, the U.S. Army Construction Engineering Research Laboratories studied the effectiveness of the expedient use of potential large noise barriers such as hangars to shield the community from engine run-up or in ground effect hover noise.

A UH-1H helicopter was measured at two locations, one with and one without a hangar separating it from the microphones, and in six orientations relative to a marker. Shielded and unshielded microphones were placed at various distances and heights to keep track of sound level using the *Leq* sound metric, and noise samples were recorded as well. In the hangar measurements, the helicopter was 49 ft from the nearest side of the hangar.

Both flat and A-weighting were used to analyze the data to take into account both possible indoor and outdoor experiences of helicopter noise. The data show that helicopter noise levels were clearly higher than the ambient noise and this allows the experimenters to measure the actual insertion loss, in addition to theoretical calculations. These measurements and calculations were compared with one another. Researchers concluded that for helicopter operations close to or on the ground, large physical barriers such as buildings can help mitigate noise.

[ii] The influence of meaning on annoyance judgments was also demonstrated by Fidell et al. (2002b), who solicited annoyance judgments under highly controlled listening conditions to sounds with identical duration and power spectra, but differing phase spectra. Large differences were documented between meaningful sounds and the same sounds with scrambled phase spectra.

[iii] For example, Ollerhead's conclusions include no mention of the subjective impact of helicopter noise.

Pater, L., R. Yousefi, and J. Burnett, "Measurement of the Effect of Helicopter Landing Approach on Community Noise Level," 24th International Congress and Exposition on Noise Control Engineering, Newport Beach, Calif., INTER-NOISE, 1995, pp. 767–770.

As more measures are implemented to reduce the noise impact of helicopter landings on nearby communities, it has become a subject of debate what the most effective procedures are. Pater et al. decided to measure whether noise-reducing benefits were achieved when a UH-H1 helicopter followed Fly Neighborly landing procedures.

In this study, aircraft pilots were asked to fly what is essentially a missed approach in accordance with the Fly Neighborly descent, beginning at an altitude of 300 m. The pilot tried to maintain constant airspeed and glide slope with help of visual approach slope indicator (VASI), until 15 m, where they pulled out of landing and turned off noise instruments. A range of landing approach speeds and glide slopes were used, these being 75–185 km per hour and 2–10 degrees, respectively. Measurements were taken from both on aboard the helicopter and on the ground, the latter being from 16 sound measurement sites over 4 square kilometers of flat and sandy land that had the landing site as its center. Researchers kept track of data in ASEL, SEL, MXA, and MX noise metrics, as well as recorded meteorological data, specifically humidity, temperature, barometric pressure, wind speed, and wind direction.

For purposes of comparison, normalized data from each of the 16 sites were averaged to get a single number descriptor for each helicopter run. This paper considered unweighted noise data because A-weighting does not sufficiently factor in low frequency, and based on this noise metric a steeper glide slopes lowers noise level. The data were A-weighted as well, to predict community response, and the results suggested that the combination of a speed of 120 km/h or slower and a 2–5 degree glide slope made for the quietest landings. However, measurements made on the helicopter found that 3 degree glide slope landings were the loudest, suggesting that data collected from on board are not indicative of the actual community exposure.

As described in the paper, it was very difficult for the pilots to fly these procedures for landing. Another finding was that blade slap occurred intermittently during most flights as a result of the blade-vortex interaction (BVI) caused by the pilot holding glide slope constant when there were thermal updrafts, ultimately resulting in an increase of the noise over standard arrivals. Although perhaps not widely known, it is this researcher's understanding that the original blade-slap regions and quiet regions were developed by descents from say 2,500–2,000 ft AGL and that the measurements were primarily internal to the aircraft, casting doubt onto the effectiveness of Fly Neighborly procedures.

Unfortunately, this InterNoise paper is the only publication I know of that was made about these measurements. To my knowledge, they have never been replicated and, also, this was the first real test of the Fly Neighborly procedure. Basically what they found was only if the pilot went slow enough and shallow enough, would you get any quieting, but the basic procedure did not work. Regardless of what the actual best practices may be, the total 7 dB data spread reveals what a big difference varying landing procedures could make in terms of noise reduction.

Patterson, J., B. Mozo, P. Schomer, and R. Camp, *Subjective Ratings of Annoyance Produced by Rotary-Wing Aircraft Noise*, USAARL Report No. 77-12, Bioacoustics Division, U.S. Army Aeromedical Research Laboratory, Fort Rucker, Ala., May 1977.

Patterson et al. describe an outdoor noisiness magnitude estimation test in which a panel of 25 audiometrically screened participants rated the sounds of actual rotary-wing aircraft passbys relative to that of a fixed-wing C-47 propeller driven aircraft. The goals of the study were fourfold with regard to determining a metric that would best predict subjective annoyance: (1) Which spectral weighting function(s) are most appropriate?, (2) What type of temporal integration should be used?, (3) Is an impulsive blade slap correction factor necessary?, and (4) Do present fixed-wing annoyance predictors underestimate annoyance from rotary-wind aircraft?

To evoke differing spectral and temporal characteristics the listening test involved nine different rotary-wing aircraft each flying six different flight maneuvers: (1) level flyover, (2) nap-of-the-earth, (3) ascent, (4) decent, (5) left turn, and (6) right turn. During each passby the sound pressure level signature was FM-recorded on magnetic tape for subsequent analysis into one-third octave bands. Observers recorded their noisiness rating relative to the C-47 at the end of each passby.

In the subsequent analysis five broadband frequency-weighted metrics were considered, A-weighted sound level, B-weighted sound level, C-weighted sound level, and tone-corrected perceived noise level (per FAR Part 36). For each, four different temporal treatments were examined: the maximum sound level, the peak sound level, the average sound level over the passby, and the time-integrated level over the passby. The Pearson product moment correlations (r), relating noisiness to all frequency weightings

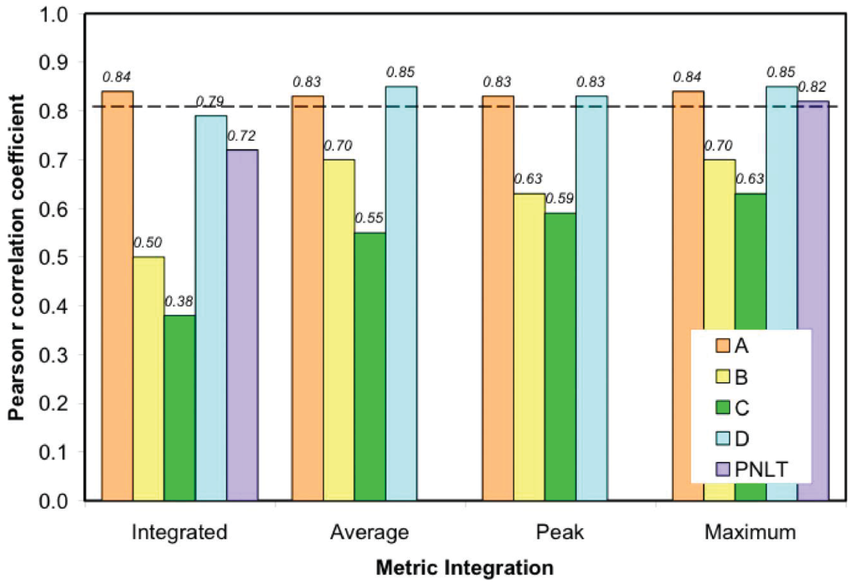


FIGURE B3 Subjective noisiness correlations with four frequency weighting functions and four temporal integration measures. *Source*: Powell (1981).

and temporal considerations, are shown in Figure B3. This figure plots the correlations in four groups of differing temporal considerations. Within each group the four different frequency weightings are shown.

The figure reveals that the A-weighted and D-weighted sound levels and the tone-corrected perceived noise level all performed equally well as noisiness predictors regardless of the time integration method employed. The dashed horizontal line plots the average value of all the coefficients for these metrics (0.81). In addition, the figure shows that B-weighted and C-weighted sound levels performed demonstrably more poorly. It is interesting to note, however, that the maximum level was a better predictor of annoyance for both the C-weighted sound level and tone-corrected perceived noise level than was a temporal integration of these measures. These correlations notwithstanding, the authors found that on average the rotary-wing aircraft were rated an equivalent of 2 dB more annoying than the fixed-wing C-47. This difference represents only about one-third of the scatter in sound level observed for any given relative annoyance rating, but is probably significantly different from zero (not determined by the authors).

The authors note that the similar performance of the A, D, and tone-corrected metrics was largely the result of the high correlation between the metrics themselves. The correlations (r) were largely independent of temporal consideration and ranged from 0.91 to 0.98. The authors thus concluded that "The high correlation among these predictors of annoyance makes any attempt to show the superiority of one over another unlikely to succeed."

The authors also explored two measures of impulsivity to determine whether either improved the correlation. These were (1) the crest factor (peak minus rms), and (2) a novel adjunct to crest factor that measured the rms level between blade slaps and subtracted this value from the peak level. No improvement was found using crest factor. However, some modest improvement was found using the second method, but the authors concluded the method was too cumbersome to be used in practice.

Powell conducted two controlled-listening studies in which 91 test participants located both indoors and outdoors judged the noisiness of 72 helicopter and propeller-driven, fixed-wing aircraft flybys. After noting the "very diverse" character of helicopter noise, Powell comments on the inconclusiveness of studies intended to ascertain whether an impulsiveness correction is useful for predicting the noisiness of helicopter noise. One purpose of the current investigation was to determine whether highly impulsive helicopter overflights are judged to be noisier than less impulsive helicopter overflights at constant EPNL values. The other purpose was to determine the utility of ISO's then recent suggestion of an impulsiveness correction to EPNL.

Powell's findings were counterintuitive, and in direct contrast to the common assumption (*cf.* Sternfeld and Doyle 1978) that the impulsiveness of helicopter noise accounts for much of its annoyance. Powell found that "at equal effective perceived noise levels (EPNL), the more impulsive helicopter was judged less noisy than the less impulsive helicopter." Powell also found that ISO's proposed impulsiveness correction, based on measurements of A-weighted crest factors, failed to improve the ability of EPNL to predict helicopter noisiness judgments. Powell concluded that ". . . some characteristic [*of helicopter* *noise*] related to impulsiveness is perceivable by subjects but is not accounted for by either EPNL or [*ISO's*] proposed impulsiveness correction."

Schomer, P.D., B.D. Hoover, and L.R. Wagner, *Human Response to Helicopter Noise: A Test of A-weighting*, USACERL Technical Report N-91/13, U.S. Army Corps of Engineers, 1991; and

Schomer, P.D. and R.D. Neathammer, "The Role of Helicopter Noise-Induced Vibration and Rattle in Human Response," *Journal of the Acoustical Society of America*, Vol. 81, No. 4, 1987, pp. 966–976.

Schomer et al. (1991) describe this study as a continuation of a field study ("jury test") conducted by Schomer and Neathammer (1987). The former study solicited individual paired-comparison judgments of the annoyance of helicopter flybys with respect to a single broadband noise from groups of paid test participants seated in a house, a tent, and a mobile home. Schomer and Neathammer (1987) concluded that A-weighted measurements of helicopter flyby noise did not adequately predict differences in annoyance between the flyby noise and the control signal, and that the level of secondary emissions (helicopter-induced rattle) in the listening environment influenced the annoyance judgments. The annoyance judgments were solicited in a field setting rather than in a laboratory because "the very low-frequency sounds, the rattles, and the vibrations characteristic of helicopter noise would be too hard to simulate realistically in a laboratory. . . ."

Neither A-weighted nor C-weighted measurements of helicopter noise were able to predict offsets between objective measurements of sound levels produced by helicopter flybys and the comparison sounds when heard at subjectively equally annoying levels. The differences between A-weighted and C-weighted levels of helicopters and equally annoying broadband noise varied from 10 dB (for helicopters with two bladed main rotors) to 8 dB for helicopters with greater numbers of rotor blades.

In other words, Schomer et al. (1987, 1991) found that that exposure to helicopter noise depended in part on its impulsive characteristics (blade passage frequency and/or repetition rate) and the rattle induced by repetitive impulsive signals in residences. This finding directly contradicts Molino's interpretation a decade earlier of the (largely laboratory-based) research findings that "there is apparently no need to measure helicopter noise any differently from other aircraft noise." Note, however, that the Schomer et al. studies included no direct comparisons of the annoyance of exposure to rotary- and fixed-wing aircraft sounds. Because these studies included no direct empirical comparisons of helicopter noise with fixed-wing aircraft noise, they do not clarify whether the observed "excess" (that is, greater than A-weighted) annoyance of helicopter noise also holds with respect to fixed-wing aircraft noise.[iv]

Schomer, P. and L. Wagner, "On the Contribution of Noticeability of Environmental Sounds to Noise Annoyance," *Noise Control Engineering Journal*, Vol. 44, No. 6, 1995a, pp. 294–305.

Schomer and Wagner provided modest numbers of paid volunteers at three locations with portable (palm-top) computers to self-report prompt annoyance judgments for naturally occurring outdoor noises that they noticed while at home. The computers administered a brief questionnaire that asked respondents to identify the source of the annoying sound (e.g., rotary- or fixed-wing aircraft) and their degree of annoyance with it). Unattended outdoor noise measurements were made at locations near the test participants' homes.

The authors analyzed both the per-event annoyance ratings and the rate of notice of noise events. They found only minor differences in the per-event annoyance ratings of fixed- and rotary-wing aircraft noise of comparable A-weighted sound exposure levels. For some of the test participants, the annoyance ratings varied little with sound exposure levels. Mere detection of noise events appeared sufficient to annoy these participants.

However, the authors also found that the rate of notice of helicopter noise was three times as great as the rate of notice of fixed-wing aircraft noise. They speculate that the greater rate of notice of helicopter noise was the result of the "distinct sound character" of rotary-wing aircraft. Because the participants were exposed to notably fewer helicopter than fixed-wing overflights, it is also possible that they were less habituated to helicopter noise than to fixed-wing aircraft noise.

Sternfeld, H. and L.B. Doyle, *Evaluation of the Annoyance Due to Helicopter Rotor Noise*, NASA Contractor Report 3001, NASA Langley Research Center Contract NAS1-14192, 1978.

Sternfeld and Doyle conducted controlled (laboratory environment) listening tests in which 25 volunteer listeners adjusted the annoyance of three degrees of rotor impulsiveness, heard at four blade passage

[iv] It is possible, for example, that rattle and vibration produced by fixed-wing aircraft at the relatively short ranges of the controlled helicopter flybys would also have created "excess" annoyance.

(repetition) rates, to the annoyance of a single broadband noise. As with virtually all other publications in this research area, Sternfeld and Doyle characterize helicopter noise as "unusually complex." They assert, however, without further elaboration, that "It is the more impulsive types of rotor noise which are responsible for most of the noise complaints against helicopters." Sternfeld and Doyle made no effort to match the annoyance of broadband noise with that of fixed-wing aircraft noise.

The experimentation conducted by Sternfeld and Doyle was premised on the assumption that main rotor impulsiveness controls the annoyance of helicopter noise. The authors therefore made no effort to study the potential contributions of other sources of helicopter noise to annoyance judgments. Sounds presented to test participants for annoyance judgments were reproduced by headphones, rather than in free-field settings, and consisted entirely of synthesized signals. On the continuum of compromise between face validity and precision of control, the work of Sternfeld and Doyle sacrifices nearly all claims to face validity to a desire for very high precision of control of signal presentation.

The authors concluded that their findings permit designers of helicopter rotor systems "to trade off rotor design parameters" to minimize their annoyance, but note certain limitations of the generalizability and practicality of their findings. They were also puzzled (1) by an "apparent inconsistence that when different rotor sounds were adjusted to be equally annoying as a broadband reference sound, subsequent subjective ratins of the rotor sounds were not equal to each other, or to the broadband reference sound"; and (2) about "the apparent relative insensitivity to the rotor blade passage period." They conjecture that headphone presentation of signals for annoyance judgments deprived test participants of the sensations of high-level, near-infrasonic harmonics on body surfaces.

Sternfeld, H., R. Spencer, and P. Ziegenbein, *Evaluation of the Impact of Noise Metrics on Tiltrotor Aircraft Design*, NASA Contractor Report 198240, 1995.

Sternfeld et al. (1995) introduce their indoor, controlled listening study of the judged annoyance of simulated rotor noise by re-capping the inappropriateness of the A-weighting network as applied to rotary-wing aircraft noise, which characteristically includes large amounts of low-frequency, if not infrasonic, acoustic energy associated with the fundamental blade passage frequency of a main rotor and its harmonics. Although the work is motivated by concerns about noise produced by a hovering tiltrotor, the arguments apply generally to other rotary-wing aircraft.

Forty test subjects rated the annoyance of 145 outdoor and 145 indoor simulated rotor noise sounds. The sounds varied in A-weighted and overall sound pressure level from 72 to 96 dB, and in fundamental blade passage rates from 15 to 35 Hz. The spectra and presentation levels of the test sounds were arranged such that the overall sound pressure levels of the test sounds always exceeded A-weighted levels by 6 dB. Sounds intended to represent indoor listening conditions were accompanied by a projection of an indoor scene, whereas sounds intended to represent outdoor listening conditions were accompanied by a projection of an outdoor scene.

Sternfeld et al. concluded that A-weighted measurements of the sounds rated by the test subjects were inferior predictors of the annoyance ratings because they were insufficiently sensitive to low-frequency rotor harmonics. They also concluded that:

1. A combination of A-weighted and overall sound pressure level measurements provided improved prediction of the annoyance ratings;
2. Annoyance predictions based on a combination of the two metrics were at least as good as, if not superior to, predictions made from the Stevens Mark VII method of predicting perceived sound levels; and
3. Including blade passage frequency as a predictor of annoyance judgments improves matters yet further.

The differences in correlations between predicted and observed ratings for the various prediction schemes were quite small in some cases. For example, adding blade passage frequency to perceived level increased the variance accounted for in outdoor judgments by only 2%, from $R^2 = 0.87$ to $R^2 = 0.89$. Considering the marginal size of many of the observed differences, and that the ISO standard for low-frequency equal loudness curves has changed since the conduct of the Sternfeld et al. analyses, the authors' conclusions are best regarded as suggestive rather than definitive.

Sutherland, L. and R. Burke, *Annoyance, Loudness, and Measurement of Repetitive Type Noise Sources*, EPA 550/8-79-103, 1979.

This report evaluated "subjective and objective aspects of moderate levels of noise from impulsive sources," such as truck-mounted garbage compactors, drop hammers, two-stroke motorcycle engines, and rock drills. The report specifically excludes consideration of high energy impulses (sonic booms, weapons fire, and quarry blasting), and treats helicopter blade slap as a special case. Sutherland and Burke's summary of early findings about the annoyance of blade slap may be paraphrased as follows:

- The mean observed blade slap correction or penalty factor was 3.3 ± 2.7 dB for 11 (laboratory) studies that measured this quantity directly. However, three of these 11 studies found essentially a zero or negative correction. The maximum correction for moderate blade slap (i.e., crest level of 10 to 15 dB) was about 6 dB. The maximum correction for severe blade slap (i.e., crest level about 20 dB) was 13 dB, comparable to the values measured for a variety of nonhelicopter sounds.
- The methods proposed (by ICAO in the late 1970s) to objectively compute a blade slap correction factor do not appear to agree consistently with the correction factors measured subjectively to account for annoyance of blade slap.
- Improved results are obtained if (ICAO's proposed methods) are modified to account for variations in the frequency of the blade slap. Adjustments of 2 dB (for a blade slap repetition rate of 10 Hz) to 7 dB (for a blade slap rate of 30 Hz) might be appropriate. [These findings are discussed in the annotation for the Fidell and Horonjeff (1981) findings.] The dependency on repetition rates in this frequency range suggests that a blade slap "correction factor" may arise from inherent errors in perceived noise level computations for signals with significant energy below 50 Hz.
  The latter inference is not fully consistent with the observations of Fidell and Horonjeff (1981).
- ICAO's proposed methods for predicting a subjective correction factor depend on some means of measuring the relative impulsiveness. These methods vary from a simple measurement of the crest level of A-weighted noise levels to more complex procedures involving sampling the detected signal (e.g., instantaneous A-weighted level) at a high rate (~5000 Hz) and computing a measure of mean square fluctuation level from these samples.

Transportation Research Board, Annual Meeting Presentations, 2014

There were three presentations made at the 2014 TRB Annual Meeting that addressed helicopter noise. These presentations can be found on the TRB website as referenced here:

Pagnano, G., "Clean Sky Green Rotorcraft Project" [Online]. Available: http://onlinepubs.trb.org/onlinepubs/sp/airport/ACRP11-03-S02-13NASARotaryWingResearch.pdf.

This presentation describes the European Union efforts in managing helicopter noise. It is generally quite technical regarding helicopter and tilt rotor noise generation and efforts to design quieter aircraft. The efforts on managing helicopter noise in terms of operational procedures in the presentation described the following:

FRIENDCOPTER: noise abatement procedures, improved engine integration, active rotor blades with distributed actuation for lower noise, and reduced power loss.
OPTIMAL: airport approach procedures specific to rotorcraft for noise abatement and integration in the general ATM.
NICETRIP: developing the ERICA tilt rotor aircraft and previous projects addressing noise impact and power demand.

Gorton, S., "Overview of Rotary Wing Research in NASA" [Online]. Available: http://onlinepubs.trb.org/onlinepubs/sp/airport/ACRP11-03-S02-13NASARotaryWingResearch.pdf.

This presentation describes the NASA program to reduce noise associated with helicopters. These include a description of which facilities are involved in NASA helicopter research and the programs. Much of the material describes very technical programs on researching low noise helicopter design, but also lists a project on human response to helicopter noise. In general, the NASA presentation describes its goals as

Vision:

- Improve capabilities, performance, and acceptance of existing and future rotorcraft configurations for civil and dual-use military missions!
- Explore and develop new capabilities for rotorcraft use as commercial transportation in national airspace.

Scope:

- Conventional and nonconventional light, medium, heavy, and ultraheavy rotorcraft.
- Technologies that address performance, noise, efficiency, safety, passenger acceptance, and affordability.

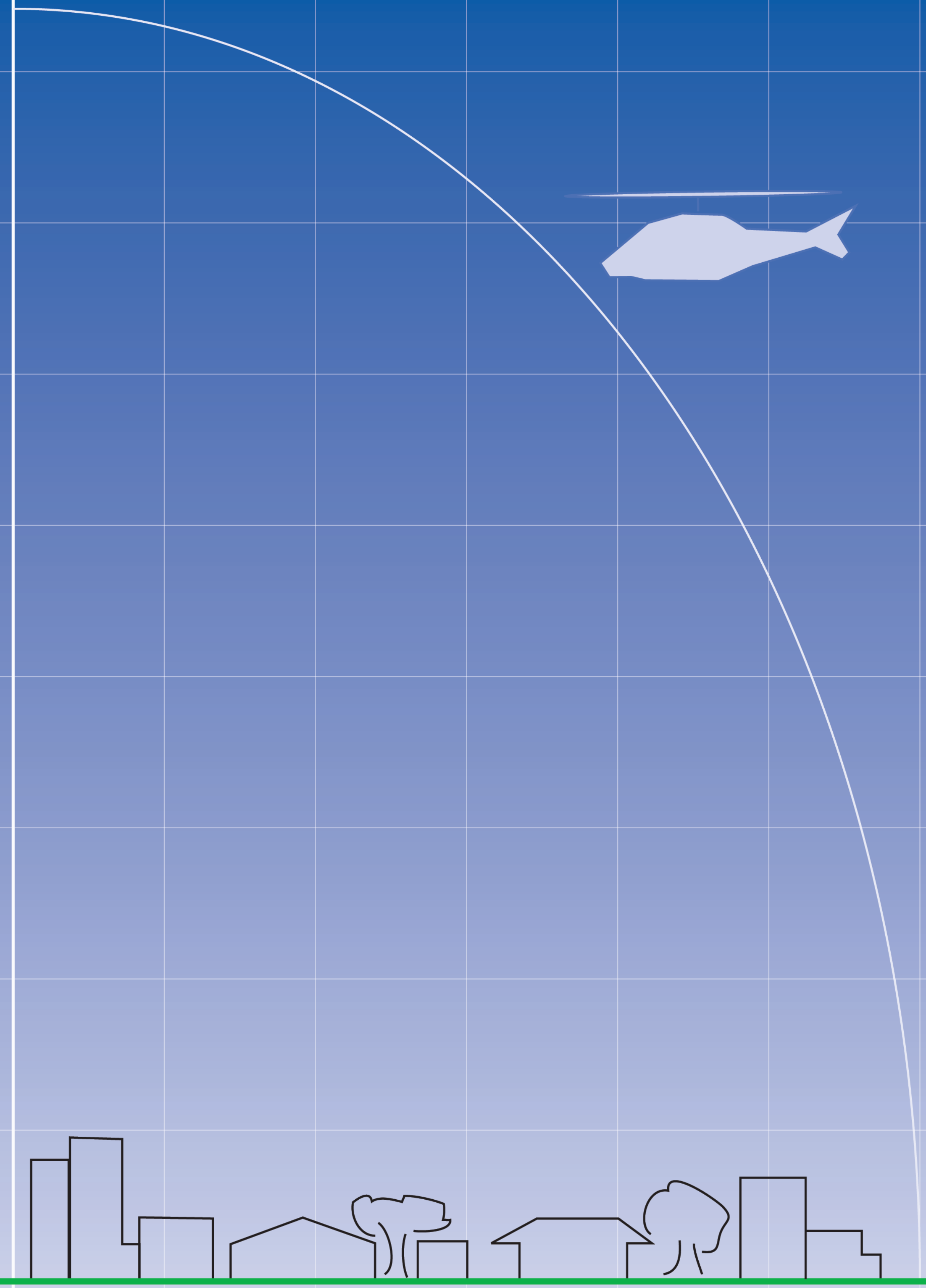
Brentner, K., "Rotor Source Noise Prediction and the Challenges of Rotor Noise Abatement," Pennsylvania State University, 2014 [Online]. Available: http://onlinepubs.trb.org/onlinepubs/sp/airport/ACRP11-03-S02-13TRB2014-RotorNoisePredictionandAbatement-Brentner.pdf.

This presentation provides background information on helicopter noise sources similar to Appendix A1 and then goes on to describe technical details of helicopter noise generation and the methods to try to reduce rotor noise. The presentation does summarize best efforts to manage helicopter noise and includes the following recommendations:

- Fly higher!
- Avoid over flying neighborhoods, outlying residential areas, and noise-sensitive areas.
- Follow high ambient noise routes such as major roadways or highways to mask the sound of the helicopter.
- Fly at an altitude that is as high as practical.
- Identify noise-sensitive areas and adjust routes to avoid them to the extent possible.
- Fly normal cruising speed or slower and observe low-noise speed and descent recommendations per the manufacturers recommendations.
- Avoid sharp maneuvers, use takeoff and descent profiles consistent with the *Pilot Operating Handbook*, and vary the route since repetition contributes to annoyance.
- Avoid late night/early morning flights.

APPENDIX C

HAI Fly Neighborly Guide



Fly Neighborly Guide

produced by the **Helicopter Association International** Fly Neighborly Committee

Preface

This is the third edition of the Helicopter Association International (HAI) *Fly Neighborly Guide*. The initial guide was issued in 1981 and again with a change to the title page in 1983. A second edition was issued in 1993. This guide is based on the second edition and was edited and revised by Charles Cox and Dr. John Leverton on behalf of the HAI Fly Neighborly Committee.

The Fly Neighborly Program is a voluntary noise abatement program developed by the HAI Fly Neighborly Committee. The program is designed to be implemented worldwide by large and small individual helicopter operators. This program applies to all types of civil, military and governmental helicopter operations.

Fly Neighborly Noise Abatement procedures for specific helicopter models are available on the HAI Web site www.rotor.com.

Additional pilot training information, discussion of helicopter noise sources, noise propagation and general information on how to operate helicopters to minimize the noise impact is also available on an associated interactive Noise Abatement Training CD developed for pilots by the HAI Manufacturers Committee. Copies of this CD can be obtained from HAI .

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List of Figures

Foreword

In the late 1970s, concern was being expressed about helicopter noise by the general public and national authorities in a number of nations, including the USA. As a result, a number of Helicopter Association International (HAI) committees, including the Heliport and Airways Committee (now known as the Heliports Committee), started to research how this concern should be addressed. At the same time, the International Civil Aviation Organization (ICAO), with active support of the United States Federal Aviation Administration (FAA) and most European nations, established a working group to develop helicopter noise certification standards. In addition, the FAA issued a Notice of Proposed Rulemaking (NPRM) outlining proposed noise certification procedures and limits.

The industry, and HAI in particular, felt that a better approach would be for the industry to develop voluntary guidelines to control the noise impact by operational means. After a number of FAA/industry meetings, the FAA, in the fall of 1981, agreed to withdraw its initial NPRM related to helicopter noise certification while additional technical data were acquired. This was done with the understanding that the helicopter industry would develop new technology - creating quieter, more advanced equipment, and implement a voluntary noise abatement program. This resulted in the establishment of the HAI Fly Neighborly Program based on an earlier program developed by Bell Helicopter Textron.

ICAO initially issued international noise standards in 1981, as a part of the International Standards and Recommended Practices, “Environmental Protection,” Annex 16 to the Convention on International Civil Aviation. These were not adopted by many nations before they were relaxed in 1985. Since that time, the standards have been amended a number of times. The FAA subsequently issued helicopter noise certification standards in 1988. These have been revised over the years. They are defined in 14 CFR Part 36. The Fly Neighborly Program offers the technical information necessary for helicopter operators to fly both current and new advanced helicopters as quietly as practical, and to make helicopter operations compatible with nearly all land uses. The program also discusses how to communicate to the public the gains from using such procedures. In addition, the program provides general information related to helicopter noise and public acceptance.

1 General Information

1.1 Background

HAI's Heliports and Airways Committee (HAC) originally organized the Fly Neighborly Program through its Fly Neighborly Steering Committee. This committee was composed of members of HAI and governmental representatives, including the FAA, members of the military and other associations. Officially launched by HAI in February 1982, the program gained U.S. and international acceptance. Subsequently, the work related to the Fly Neighborly Program was considered sufficiently important by HAI that a separate Fly Neighborly Committee was formed to promote the program and ensure that the *Fly Neighborly Guide* and associated material are updated as appropriate.

In the U.S., the program has gained the full support of helicopter operators, regional associations, manufacturers, pilots and communities throughout the country. Federal, state and local government agencies have embraced the program, and taken an active part in sponsoring Fly Neighborly presentations in conjunction with safety seminars and other activities. Worldwide, the helicopter industry and its related communities are kept informed on the Fly Neighborly Program. Companion programs have been developed in a number of countries including Germany, France, and the United Kingdom.

1.2 Objectives

The Fly Neighborly Program addresses noise abatement and public acceptance objectives with guidelines in the following areas:

- pilot and operator awareness
- pilot training and education
- flight operations planning
- public acceptance and safety
- sensitivity to the concerns of the community

1.3 About This Guide

The *Fly Neighborly Guide* is published under the auspices of HAI to promote helicopter noise abatement operations. It addresses general issues only and is, by no means, comprehensive.

1.4 Purpose

These guidelines are intended to assist pilots, operators, managers, and designated Fly Neighborly officers to establish an effective Fly Neighborly Program. The concepts and flight operations outlined, herein, must be further tailored to suit local needs, and to ensure local or regional organizations cooperate to develop a strong, well-organized and disciplined approach to achieving Fly Neighborly objectives.

1.5 Organization

This guide is divided into seven main sections. Section One covers general information. Section Two addresses helicopter sound generation. Section Three gives guidance for noise abatement operations. Section Four discusses how to operate helicopters quietly. Section Five covers pilot training. Section Six describes the operator program which provides a broad outline of the possible actions helicopter operators can take, including flight operations planning. Section Seven deals with community concerns and issues of public acceptance and Section Eight answers the question of what the Fly Neighborly Program can achieve. Three appendices present a comparison of sounds, the Advisory Circular (AC) 91.36D, and an example of a public heliport noise abatement program. In addition, a glossary is provided to help define the acronyms used or referred to in this Guide.

1.6 Administration

HAI solicits new ideas, comments, and recommendations to improve the program. HAI's Fly Neighborly, Safety and Heliport Committees are focal points for the development of new technical material in their respective areas. Additional guides can be obtained from HAI.

The Fly Neighborly Committee monitors the Fly Neighborly Program, and distributes new information to participants. Individuals, operators, or agencies desiring additional information should contact the HAI Fly Neighborly Program staff liaison at:

Helicopter Association International
1635 Prince Street
Alexandria, VA 22314 USA

Phone: (703) 683-4646
Fax: (703) 683-4745
Web site: www.rotor.com
Email address: flyneighborly@rotor.com

2 Helicopter Sound Generation

2.1 The Source of the Sound

The external sound produced by a helicopter is made up of acoustical sources from the main rotor, the anti-torque system (tail rotor), the engine(s), and drive systems. For turbine-powered helicopters, the main rotor and anti-torque system dominate the acoustical signature. Engine and gearing noise are generally of significance only when up close to the helicopter. The same is true for piston-powered helicopters, although muffling of the engine is usually necessary.

The most noticeable acoustical characteristic of all helicopters is the modulation of sound by the relatively slow-turning main rotor. This modulation attracts attention, much as a flashing light is more conspicuous than a steady one. The resulting modulated sound can become impulsive in character and is referred to as BVI (Blade Vortex Interaction Noise), *blade slap*, or more generally, as *impulsive noise.* In some flight conditions, the main rotor noise can become quite impulsive in character (*blade slap*, or more generally *impulsive noise*), which can increase the annoyance of the helicopter to people on the ground.

Impulsive noise occurs during high-speed forward flight as a result of blade thickness and compressible-flow on the advancing blade. This latter source causes the blade's airloads to fluctuate rapidly. These fluctuations result in impulsive noise with shock waves that can propagate forward. High tip-speed rotor designs flown at high airspeeds are the worst offenders.

At lower airspeeds, and typically during a descent, rotor impulsive noise can occur when a blade intersects its own vortex system or that of another blade. This type of noise is referred to as Blade Slap or (BVI) noise. When this happens, the blade experiences locally high velocities and rapid angle-of-attack changes. This tends to produce a sound that is loud and very annoying in character.

There are three basic types of anti-torque systems used in current helicopters: the conventional open tail rotor, the ducted tail rotor/fan (e.g., the Fenestron), and the Coanda-effect/ blown-air system (e.g., the NOTAR). Each system has its own unique acoustical characteristics. The conventional open tail rotor generates a fluctuating low pitch whine or drone. The ducted tail rotor/fan produces a high pitch, sometimes fluctuating shrill. The blown-air, directional-vane system generates a broadband, 'compressed-air' hissing.

The noise of both the open tail rotor and the ducted tail rotor/fan increases with airspeed and in high-rate climbs and turns. Interaction between the main rotor and either type of anti-torque system can, and often, exacerbates the anti-torque system's sound output. In addition, the proximity of the vertical fin and tail boom influences the sound output of an open tail rotor. Somewhat similarly, the presence of vanes/stators and support struts, plus inflow/outflow turbulence, exacerbate the sound output of ducted tail rotor/fan systems. Turbulent flows off the pylon and fuselage also tend to increase the level and the sound fluctuations of both these types of anti-torque systems.

The Fenestron has some advantages over an open rotor at distance since it generates a higher frequency sound, which is more easily attenuated by the atmosphere. On many helicopters, the main source of noise heard at distance, particularly if a high tip-speed tail rotor is used, is associated with the tail rotor blade thickness. 'Quiet open tail rotors' tend, therefore, to use lower tip speeds, thinner blade sections and, to provide adequate thrust, an increase in the number of blades.

With regard to the noise generated, the NOTAR has advantages in many respects because it is independent of the increase associated with the other two types of anti-torque systems. The NOTAR is, however, only available at the current time on designs manufactured by one company.

The general relationship between sound level and helicopter weight, and a comparison of the sound generated by a helicopter and other common noise sources are given in Appendix 1.

2.2 Impact of Operations

For a typical small/light helicopter, the most annoying noise mechanism impulsive noise (BVI) occurs during partial power descents and in sharp/high-rate turns. For a typical medium or large/heavy helicopter, they can occur in low-speed level flight, during partial power descents, and in sharp/high-rate turns. Figures 1, 2 and 3 show the flight conditions under which you can expect main rotor impulsive noise to occur.

The impulsive noise boundary for your particular helicopter may be somewhat larger than that shown in Figures 1 and 2 because the main rotor may generate impulsiveness intermittently when it encounters wind gusts, or during a rapid transition from one flight condition to another. Although the sound produced at these descent rates is not extremely loud to crewmembers inside the helicopter, they can, in most cases, recognize it and, thereby, define the impulsive noise boundaries for their particular helicopter. However, in some cases, the impulsive BVI noise cannot be detected in the cockpit. Of course, people on the ground hear impulsive noise grow more intense as the helicopter descends.

Figure 1

High-Noise Flight Operations – Small/ Light Helicopter

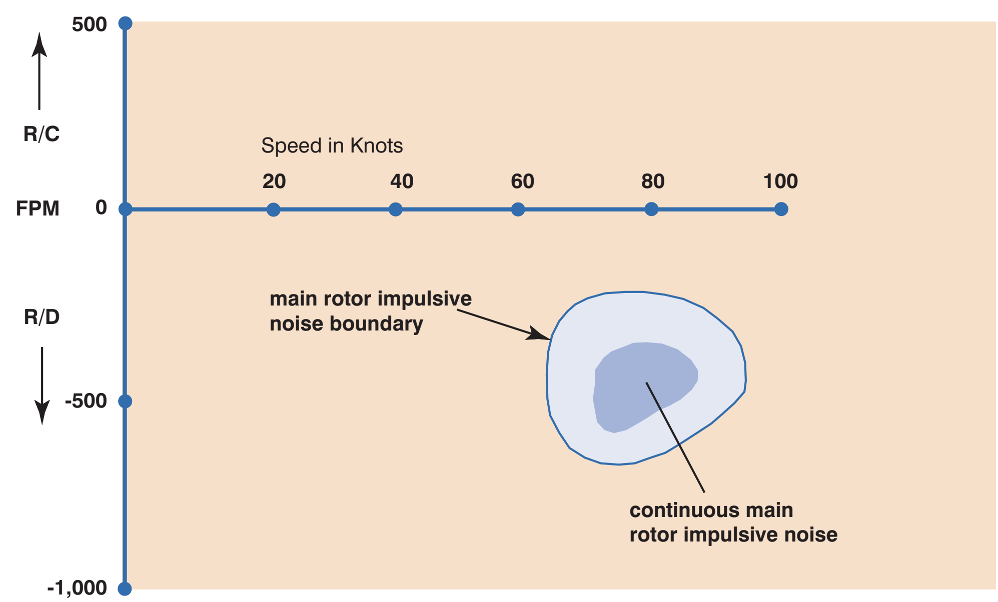
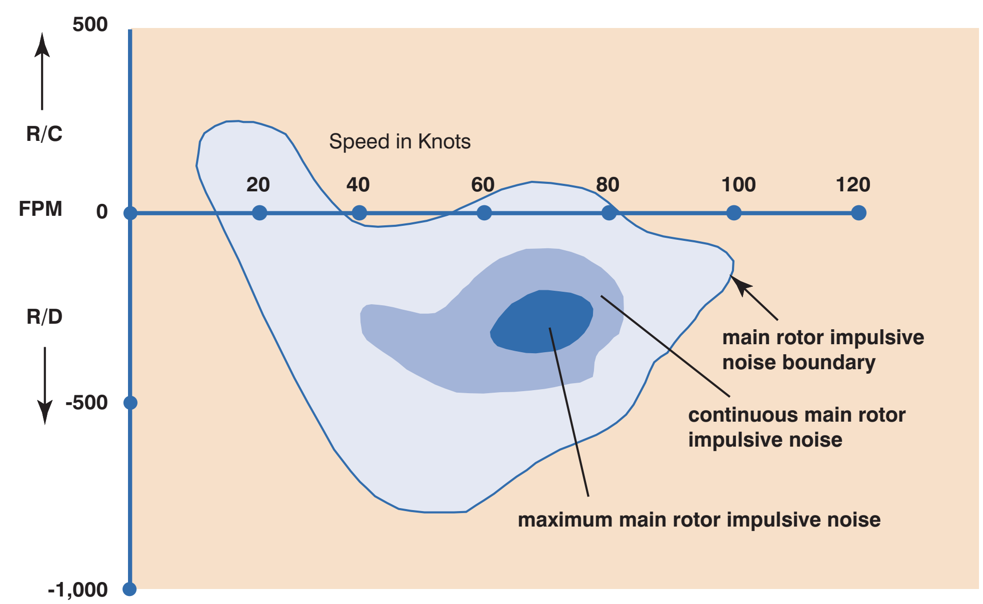


Figure 2

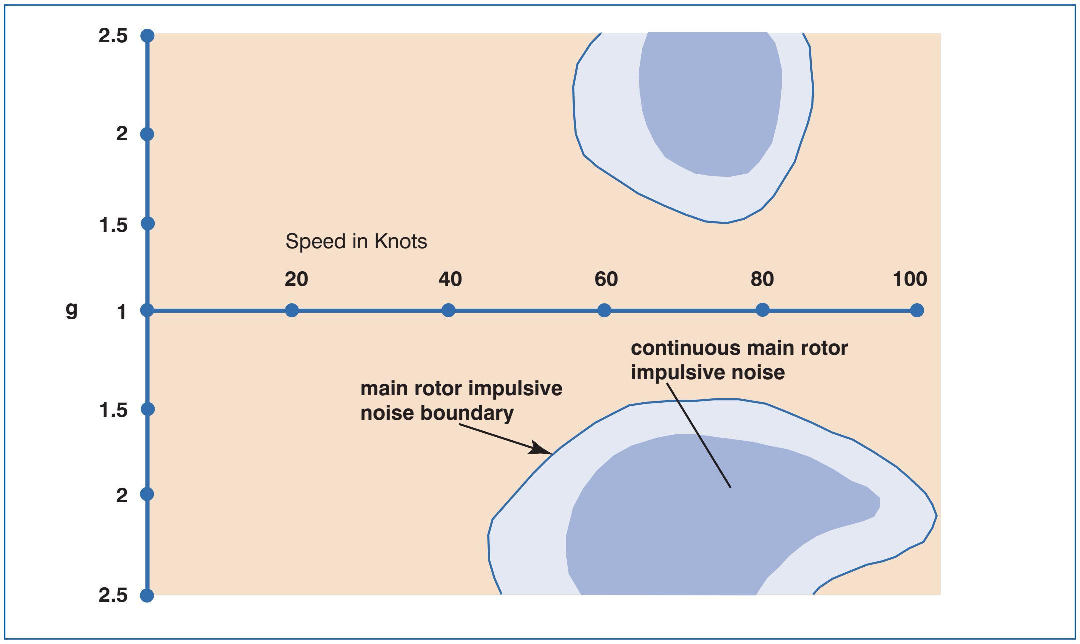
High-Noise Flight Operations – Medium/ Heavy Helicopters



Main rotor impulsive noise also occurs during maneuvers (i.e. in constant speed turns, if turn rates are too high. Here, the main rotor blade and wake interact in much the same manner as in partial power descents. As Figure 3 shows, for a medium helicopter with a two-bladed main rotor, main rotor impulsive noise occurs in turns that exceed 1.5g, with airspeeds between 50 and 90 knots in a left turn, and between 40 and 100 knots in a right turn. There is little difference in the intensity of the noise in right or left turns once the 'critical g' is reached. The crew can normally hear this impulsiveness. These characteristics also generally apply to other helicopters. Unfortunately, specific information on the increase in the level of impulsive noise, in terms of 'g' or bank angle, is not generally available.

Figure 3

High-Noise Maneuvers – Medium Helicopters



In addition to the general characteristics discussed above, it should be noted that the various sound sources exhibit specific directivity characteristics. These are not discussed in detail in this document, but it is worth noting that, in general, the main rotor sound is focused towards the front and on the advancing blade side of the helicopter. The tail rotor noise is similarly focused forward and it is also radiated downward under the helicopter. As a result, the sound – in particular from the main rotor impulsive sources - is generally detected well in advance of the helicopter flying over. Fortunately, these aspects are normally taken into account when noise abatement procedures are developed by the manufacturer. Even so, they should not be ignored when planning flight operations.

3 General Guidelines for Noise Abatement Operations

This section offers a number of noise abatement techniques for use in daily operations. A few general guidelines are given below.

- Avoid noise-sensitive areas altogether, when possible. Follow:
  - high ambient noise routes such as highways, or
  - unpopulated routes such as waterways.

If it is necessary to fly near noise-sensitive areas:

- maintain an altitude as high as possible in line with the HAI *Fly Higher Chart* (Fig. 4)
- fly normal cruising speed or slower
- observe low-noise speed and descent recommendations
- avoid sharp maneuvers
- use steep takeoff and descent profiles, and
- vary the route, since repetition contributes to annoyance

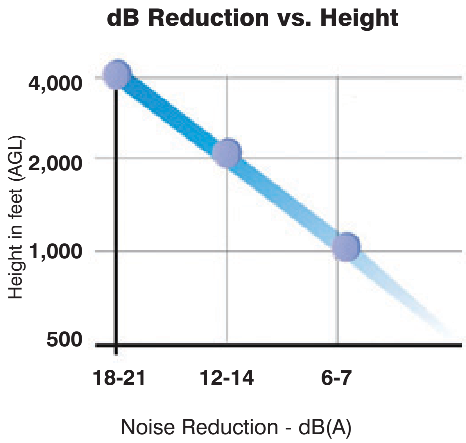
Flights conducted over roads (particularly interstates), railways and rivers in noise-sensitive areas are less likely to generate complaints than routes that acoustically and visually intrude on peoples' privacy, such as those that cross, or can be heard from, residential backyards.

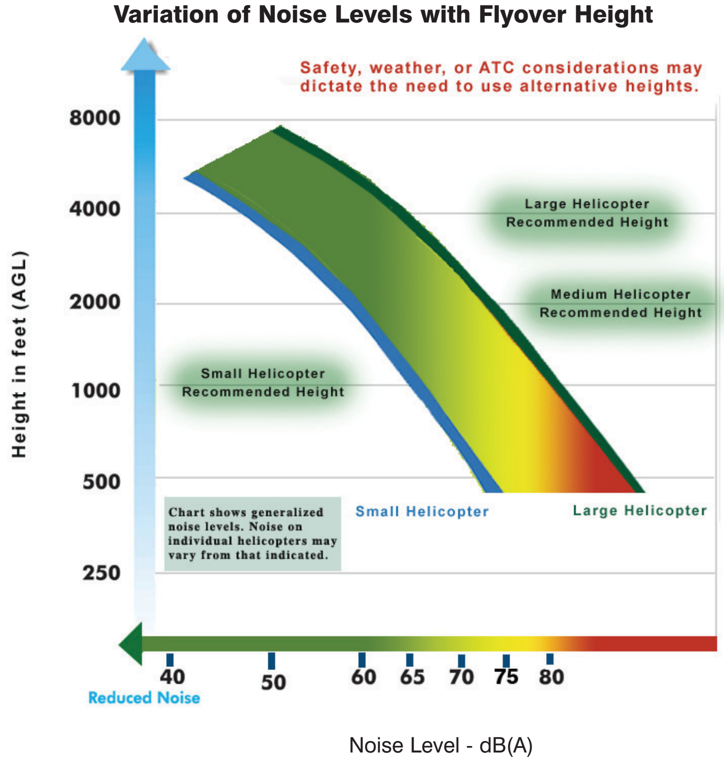
3.1 Flyover Height

Maintaining an altitude as high as possible above the ground and flying at airspeeds consistent with minimum noise output, flight safety and ATC constraints is essential. Height and distance have a major impact on the noise level observed under the helicopter, as illustrated in the HAI *Fly Higher Chart*, shown in Figure 4. It shows the relationship of flyover height and noise exposure at ground level for different-sized helicopters. A doubling of height or distance reduces the level by six to seven dB(A). If the height/distance is increased by a factor of three, the maximum level is decreased by approximately 10 dB(A), which is equivalent to reducing the loudness by half. The chart can be used to decide what height should be flown so that the helicopter's noise output is compatible with community noise exposure criteria. For example, to be compatible with the generally accepted criterion of 65 dB(A) max for flyover of noise-sensitive areas, light/small helicopters should fly at altitudes no less than 1,000 feet AGL. For medium helicopters, the recommended height is 2,000 feet AGL, and, for heavy/large helicopters, 4,000 ft AGL.

Figure 4

Fly Higher Chart





3.2 FAA Guidance - VFR Flight Near Noise Sensitive Areas

The FAA has published guidance when flying near noise-sensitive areas for a number of years. It was updated in 2004 and issued as Advisory Circular AC91.36D. A copy of this document is reproduced in Appendix 2. This voluntary practice recommends:

- the avoidance of flights over noise sensitive areas, if practical.
- When not possible, pilots flying VFR flights over noise-sensitive areas should make every effort to fly at not less than 2,000 feet above the surface, weather permitting, even though flight at a lower level may be consistent with the provisions of FAR 91.79, Minimum Safe Altitudes.

Typical of noise-sensitive areas in this Advisory Circular are defined as: outdoor assemblies of persons, churches, hospitals, schools, nursing homes, residential areas designated as noise-sensitive by airports or by an airport noise compatibility plan or program, and National Park Areas (including Parks, Forest, Primitive Areas, Wilderness Areas, Recreation Areas, National Seashores, National Monuments, National Lakeshores, and National Wildlife Refuge and Range Areas). It is also recommended that, during departure from, or arrival at an airport, climb after takeoff and descent for landing should be made so as to avoid prolonged flight at low altitudes near noise sensitive areas. It should be mentioned, however, that such procedures should not apply where it would conflict with ATC clearances or instructions, or where an altitude of less than 2,000 feet is considered necessary by a pilot in order to adequately exercise his or her primary responsibility for safe flight.

It should be noted that FAA guidance recommends a height of 2,000 ft AGL be used for general over flight of noise-sensitive areas. This is somewhat different than the guidance developed by HAI's Fly Neighborly Committee, discussed previously and illustrated in Figure 4, which recommends 1,000 ft for small helicopters. For medium helicopters, HAI recommends 2,000 ft, the same as the FAA, but for large helicopters, HAI recommends 4,000 ft. Although FAA guidance should be followed when practical, HAI considers use of the heights in Figure 4 will ensure acceptable noise disturbance to persons on the ground.

3.3 Flyover Speed

The airspeed of the helicopter has an important effect on both noise exposure impact and the impulsive character of your helicopter. Generally, it is best to fly at, or somewhat below, normal cruise speeds when over-flying noise-sensitive areas. Airspeeds above normal cruise can dramatically increase your helicopter's noise levels and the impulsive character to the extent that, even if you maintain the suggested minimum flight altitudes, your over-flight is no longer compatible with generally accepted noise exposure criteria.

4 How to Operate Helicopters Quietly

In this section, general information is presented on how to fly a helicopter more quietly. Such information applies to the operation of all helicopters. The flight techniques given in this section are also general in nature and vary somewhat according to the actual helicopter being flown. Manufacturers have developed recommended noise abatement procedures for specific models and, when available, these should be followed. The information on HAI's Web site, www.rotor.com, represents data currently available from the manufacturers. As new data becomes available, HAI will periodically update the Web site. In some cases, the noise abatement information is also available in the specific *Rotorcraft Flight Manual*. When noise abatement information is not available for a specific helicopter model, the flight techniques in the following sections should be followed. This information is also helpful to supplement the information supplied by a manufacturer.

4.1 General

Increasing the distance/separation from noise-sensitive areas is the most effective means of noise abatement.

4.2 Ground Operations

Although startup and shutdown procedures are relatively quiet and are usually shielded from noise-sensitive areas, it is good practice to reduce the amount of time spent on the ground with the rotor turning. This reduces the noise exposure to ground handling crews and heliport/airport personnel.

Minimize the duration of warm-up or cool-down periods (typically two to three minutes, although, on some engines it can be as short as 30 seconds). Do not idle at the heliport for extended periods of time.

When feasible, park with the rotors running with the nose of the helicopter directed into the wind to minimize noise. If the wind speed is above 5 knots, avoid parking with the nose 15 degrees or more from the approaching wind. This will minimize tail rotor noise.

4.3 Hover / Hover Taxi /Ground Taxi

When hover turning, make the turn in the direction of the main rotor rotation. This minimizes the anti-torque thrust required and, therefore, minimizes the level of noise generated by the anti-torque system. Keep the turn rate to as low as practical.

4.4 Takeoff and Climb (Departure)

Takeoffs are reasonably quiet operations, but you can limit the total ground area exposed to helicopter sound by using a high rate-of-climb and making a smooth transition to forward flight. The departure route should be over areas that are least sensitive to noise.

4.5 Enroute and Cruise Flyover

- Fly at least at the heights recommended in the *Fly Higher Chart* (Figure 4).
- Fly at the highest practical altitude when approaching metropolitan areas.

- Select a route into the landing area over the least populated area.
- Follow major thoroughfares or railway tracks.
- Avoid flying low over residential and other densely populated areas.
- If flight over noise-sensitive areas is necessary, maintain a low to moderate airspeed.
- Select the final approach route with due regard to the type of neighborhood surrounding the landing area, and the neighborhood's sensitivity to noise. Assess this sensitivity beforehand for each landing area. Some guidelines are:
  - Keep the landing area between the helicopter and the most noise-sensitive building or area on approach.
  - If the landing area is surrounded by noise-sensitive areas, approach using the recommended noise abatement approach procedure or at the steepest practical glideslope.
  - Avoid flying directly over hospitals, nursing homes, schools, and other highly noise-sensitive facilities.

4.6 Turns (Maneuvers)

As a general rule, avoid rapid, 'high g'/high bank angle turns. When the flight operation requires turns, perform control movements smoothly.

4.7 Descent/Approach and Landing

The approach techniques presented below are designed to avoid the impulsive (BVI) noise generated by the main rotor. These techniques typically use a glideslope that is a few degrees steeper than a normal approach. In addition to avoiding high BVI regimes, steep approaches ensure a greater height over the noise-sensitive area. Once the transition from cruise to the approach glideslope has been made, the airspeed and rate of descent can be 'tailored' to fit local conditions, avoid unsafe regimes, and still guarantee minimum noise.

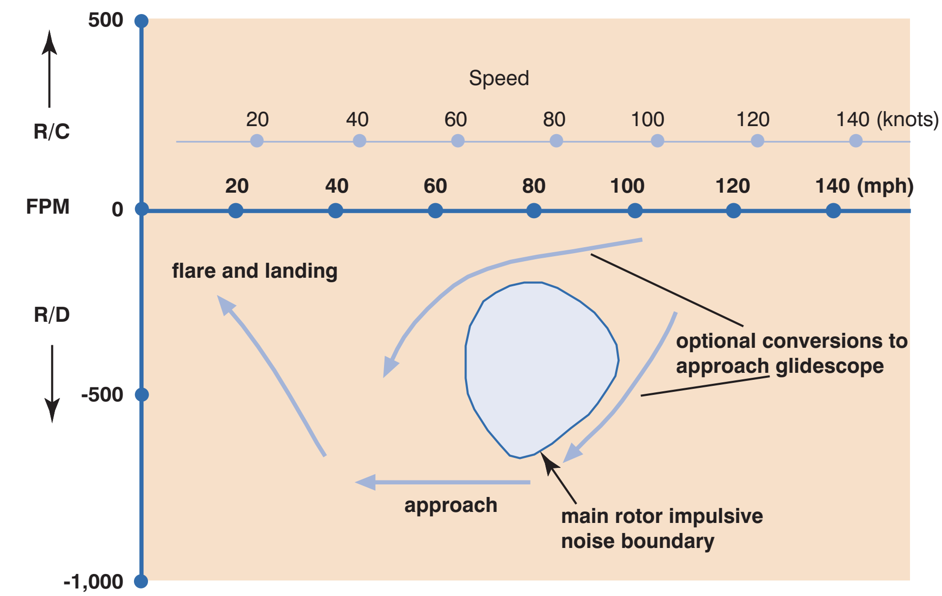
4.7.1 Small/light helicopters

Follow one of the noise abatement flight techniques given below and illustrated in Figure 5.

- When commencing approach, first establish a rate-of-descent of at least 500 fpm, then reduce airspeed while increasing the rate-of-descent to 700-800 fpm.
  - Hold the rate-of-descent to less than 200 fpm while reducing airspeed to 50-60 knots/60-70 mph, then increase the rate-of-descent to 700-800 fpm.
- At a convenient airspeed between 45 and 60 knots/50-70 mph, set up an approach glideslope while maintaining the 700-800 fpm or greater rate-of-descent.
- Increase the rate-of-descent if main rotor BVI noise is heard, or if a steeper glideslope is required.
- Just prior to the 'flare,' reduce the airspeed below 50 knots/60 mph before decreasing the rate-of descent.
- Execute a normal flare and landing, decreasing the rate-of-descent and airspeed appropriately.

Figure 5

Noise Abatement Approach Techniques for Small/Light Helicopters



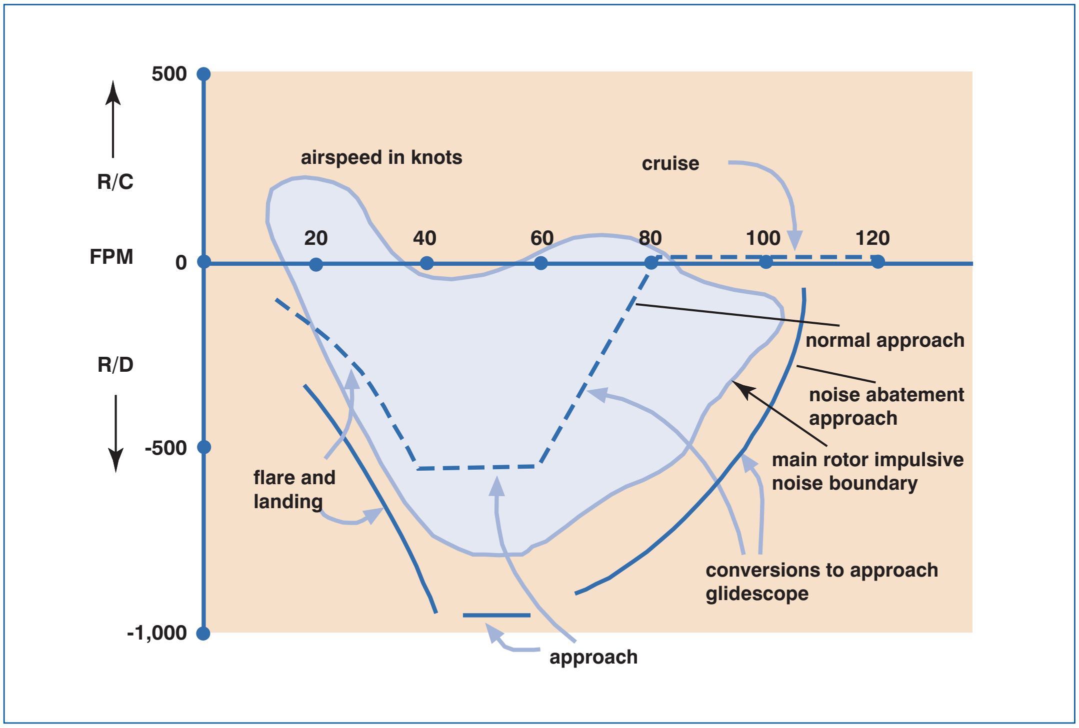
4.7.2 Medium and heavy helicopters.

Follow the noise abatement flight technique given below and illustrated in Figure 6.

- When commencing approach, begin descent at a rate of at least 200 fpm before reducing airspeed, then reduce airspeed while increasing the rate of descent to 800-1000 fpm.
- At a convenient airspeed between 50 and 80 knots, set up an approach glideslope while maintaining the 800-1000 fpm rate of descent.
- Increase the rate-of-descent if main rotor BVI noise is heard, or a steeper glideslope is required.
- Just prior to the approach to the ‘flare,’ reduce the airspeed to below 50 knots before decreasing the rate-of-descent.
- Execute a normal flare and landing, decreasing the rate of descent and airspeed appropriately.

Figure 6

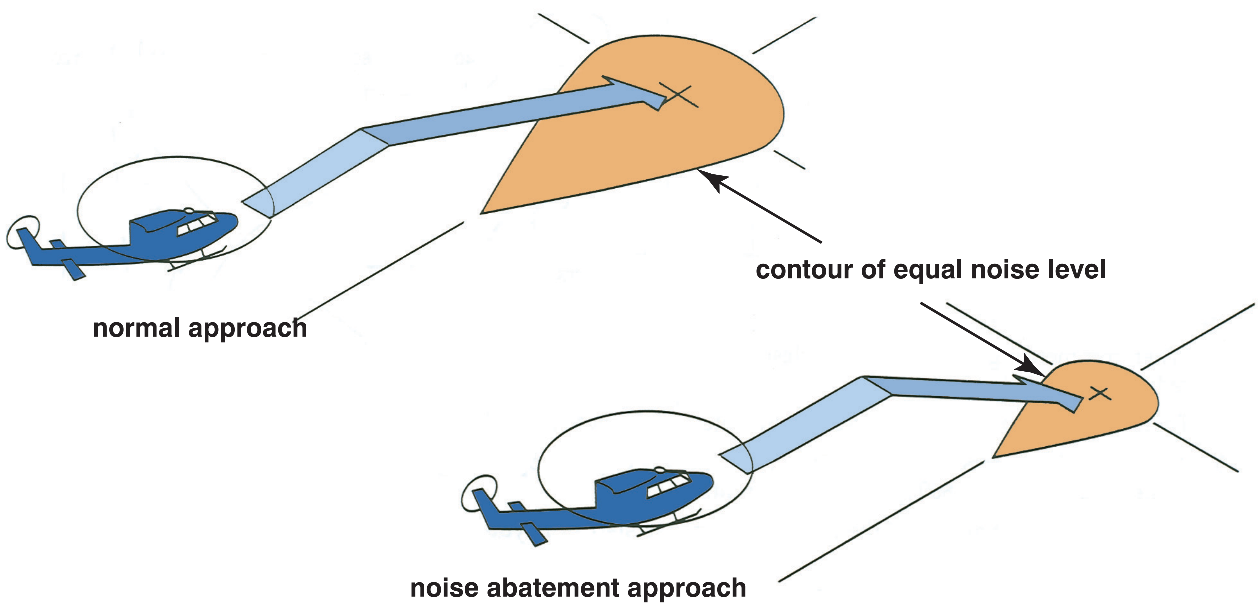
Noise Abatement Approach Technique for Medium and Heavy Helicopters



The noise abatement flight techniques discussed above for small/light and medium helicopters reduce the ground area exposed to a given noise level by as much as 80 percent. Figure 7 illustrates the potential noise benefits when compared to a normal approach.

Figure 7

Ground Noise Exposure Footprint



4.8 Other Factors to be Considered

It is important to mention that the sound environment on the ground and weather have much to do with how offensive helicopter sound is judged. The background noise of residential areas reaches its lowest level between late evening and early morning. In warm weather, people are apt to be relaxing outdoors in the evening and on weekends. At these times, they are most conscious and resentful of noise intrusion. Therefore, flight over or near residential areas should be avoided, if possible.

Although the weather cannot be controlled, it may be possible to adapt the planned flight schedule to take advantage of meteorological conditions to help minimize noise. The two weather factors most useful in this respect are wind and temperature. They are helpful because they affect the propagation of sound, and vary throughout the day, in a more or less predictable manner.

Wind carries sound in the direction towards which it is blowing, and it makes a background noise of its own that, in high winds, tends to reduce the intrusion of helicopter sound. In inland areas, surface winds are generally stronger during the day, reaching a maximum in mid-afternoon and weaker at night. In coastal regions, land and sea breezes give a different diurnal pattern, beginning to blow shortly after sunrise (sea breeze) and sunset (land breeze). These winds can be used to increase the acceptability of the helicopter by flying downwind of densely populated areas and by scheduling the majority of flights after noon near especially noise-sensitive areas.

Temperature has two effects upon sound. One is the tendency of warm air to be more turbulent than cold air, and, therefore, to disperse sound and decrease its nuisance effect. The other is temperature gradient - the change in temperature with altitude. The normal gradient is negative: temperature decreases with altitude. A negative gradient reaches a maximum in the late morning or just after noon, and is more intense during summer months. This means that it is of some value to schedule flights to and from noise-sensitive areas during the warmer parts of the day. Also, lower temperatures lead to higher advancing main rotor and tail rotor tip speeds which increase the magnitude of the impulsive noise.

At certain times, however, there may be an inversion in the atmosphere - a layer of air from a few hundred to a few thousand feet thick in which the temperature increases with altitude. The inversion reverses the normal curvature of sound propagation, turning an abnormally high portion of the sound energy back toward the ground. The most severe inversions usually occur at night and in the early morning. These, then, are times when the sound of the helicopter will have the most adverse effect upon people on the ground.

In terms of helicopter noise, the worst possible combination of atmospheric conditions is a windless, cold, overcast morning. At such times, it is important that even more emphasis is placed on using noise abatement procedures.

NOTE: *The noise abatement flight techniques described above and detailed on the HAI Web site permit flight crews to fly helicopters in the quietest manner possible. They are to be construed as advisory guidelines only. If flying according to these noise abatement flight techniques conflicts with operating the aircraft in a safe manner, then all safety-related procedures take precedence.*

5 Pilot Training

The basic scope of the recommended pilot training program and an outline of the requirements for such a program are outlined in this section. The information embodied in other sections of the Guide is also relevant. In addition, HAI has issued an interactive Noise Abatement Training CD for Pilots which covers all the aspects a pilot should be aware of. This CD, developed by the HAI Manufacturers Committee, and initially issued in 2006, is available from HAI. It is recommended that this CD be used as a part of any pilot noise abatement training program.

5.1 Scope

The scope of a pilot training program should include:

- initial and recurrent flight training for pilots
- preparing and distributing recommended noise abatement procedures
- organizing and holding operator and manufacturer seminars
- providing environmental and supervisory personnel training courses.

5.2 Basic Guidelines for Pilot Training

Public acceptance for helicopter operations can be obtained in several ways. One is noise abatement. Crew training to ensure that pilots are fully familiar with the noise abatement procedures is, therefore, vital. The following guidelines for noise abatement training are suggested:

- Select training teams for ground and flight training, usually two or three people who have extensive metropolitan operations experience.
- Standardize presentations.
- Maintain complete files of all persons trained.
- Circulate comment sheets at all meetings or training sessions, and stress that all suggestions, ideas and comments will be taken into consideration.
- Make the necessary changes in training and publications that result from the feedback.
- Maintain an open-door policy to all participants, flight crews and the public.
- Determine the effect of this training on the public. Has it been positive or negative?
- Record all complaints and include all relevant details, such as the time, date, location, altitude, and weather.
- Follow up with proficiency training every six months. Emphasize the importance of public contacts, and the necessity of good community relations.
- Expand the guidelines given in this document to cover local needs.

6 Operator Program

When operating a helicopter in a new area, a new spectrum of sound is added to the usual noise environment. If that area is a municipality, thousands of people will hear the new sounds and know a helicopter is operating. How they react depends not only on the noise you generate but upon physical, economic, and psychological factors. One thing is certain: they will react strongly, adversely, and actively if the sound is too irritating, if it represents something that seems to threaten their safety and well-being, or if they cannot see how the noisemaker (the helicopter) benefits them. Although it is up to operators to educate the public about the safety and usefulness of the helicopter, pilots can make the public less hostile to the helicopter (and to the operator's arguments about its safety and community service) by flying in such a way as to make the sound of the aircraft as non-intrusive as possible.

6.1 Introduction

The Fly Neighborly Program attacks the problem of helicopter noise on three fronts: pilot training, flight operations planning, and public education and acceptance. These three areas are interrelated. Planning flight operations with an eye to noise abatement can have a major positive impact on both the pilot training program and public acceptance.

The information presented in this section provides only a broad outline of the possible actions helicopter operators can take. Operators are encouraged to expand this outline by applying knowledge of their own geographical area of operations, the nature of their businesses, and the local climate of opinion with regard to helicopter operations.

6.2 Company Policy

Implement a company policy aimed at reducing the sound levels produced by the operation of your aircraft or other equipment. As part of this policy, implement a broad-based complaint prevention program. Such a voluntary program is necessary to preclude the eventual implementation of restrictive and mandatory federal, state or local laws, regulations, or ordinances.

To formulate this policy, identify and evaluate current and anticipated problems. To assure its acceptance and success, make your commitment to your policy clear, in order to generate such change as may be necessary in the attitudes of pilots and other personnel. In order for company policy to have any meaning, companies should formulate and implement specific guidelines.

6.2.1 Formulate Guidelines

Guidelines are intended to assist flight crews and flight operations personnel to formulate responsible mission profiles without infringing on operational reality. They are not, however, provided as a substitute for good judgment on the part of the pilot. They must also not conflict with federal aviation regulations, air traffic control instructions, or aircraft operating limitations. The noise abatement procedures outlined by these guidelines should be used when consistent with prudent and necessary mission requirements. The safe conduct of flight and ground operations remains the primary responsibility.

- Enroute operations:
  - Maintain a height above the ground consistent with the HAI *Fly Higher Chart* (see Figure 4), or higher, when possible. Complaints are significantly reduced when operating above these altitudes. The reverse is also true.
  - Vary routes in order to disperse the aircraft sound.
- Heliport (Terminal) operations:
  - Restrict hours or frequency of operations as appropriate. Minimize early or late flights, especially on holidays and weekends.
  - Limit ground idling in noise-sensitive areas.
  - Minimize flashing landing lights in residential areas at night.
- Establish procedures for each sensitive route or terminal.
- Provide flight crews with noise abatement procedures for each model of aircraft.

6.2.2 Implement Guidelines

- Publish all guidelines and procedures in a flight operations manual or similar document.
- Train flight crews and flight operations personnel as appropriate:
  - Educate regarding basic attitudes in ground school.
  - Train in noise abatement procedures for each model of aircraft to be flown.
  - Emphasize awareness and recognition of sensitive routes and terminals.
  - Establish a requirement that noise abatement procedures must be considered in recurrent company flight checks.
- Assign responsibility and authority for the company program to an appropriate person.

6.2.3 Review and Revise

- Establish periodic reviews of company policy and programs to respond to changes in the regulatory climate or operational conditions.
- Revise your policy and programs as necessary.

7 Managing Public Acceptance

7.1 Scope

The scope of the public acceptance program includes:

- engendering media support
- promoting positive public relations
- enacting a program to prevent or resolve complaints from the public

7.2 Media Support

The purposes of engendering media support are to:

- develop favorable and active helicopter-related media coverage
- provide valid information concerning helicopter operations as necessary

Media sometimes concerned with news of helicopter-related activities include general circulation newspapers, television and radio news, trade journals, and the magazines or newsletters of international, national, state, and regional helicopter associations.

To engender awareness and support in these media, a number of actions can be taken:

- Provide press releases to trade journals and local newspaper, radio, and television news editors concerning any Fly Neighborly seminars that may be sponsored by the local helicopter operator association.
- Support a continuing campaign with the trade journals to keep the rotary-wing community aware of the Fly Neighborly Program.
- Support a continuing campaign with the general press to make the public aware of the Fly Neighborly Program, and the benefits of helicopter transport.
- Stage demonstrations and press conferences addressing specific local issues such as heliports, high-rise evacuation, police services, search and rescue services, emergency medical evacuation, fire-fighting, and the benefits of helicopter transportation to the general public.

7.3 Public Relations

The purposes of engaging in public relations activities are to:

- Develop awareness in the community of the benefits of helicopter transportation
- Develop awareness of the Fly Neighborly Program
- Develop support for the voluntary Fly Neighborly Program, as administered by the helicopter community, in lieu of governmental regulation

In order of their general importance and effectiveness, public relations activities can be undertaken in conjunction with:

- governmental agencies concerned with aviation such as federal, state, or local agencies, the FAA, or state aeronautics commissions
- other governmental agencies not particularly concerned with aviation, such as regional planning commissions, economic development commissions, the National League of Cities, or the U.S. Council of Mayors

- local civic and professional organizations such as Rotary or Kiwanis Clubs, the National Association of Aviation Officials, the Airport Operators Council International, or the National Fire Protection Association. Provide speakers for their local meetings. Solicit their sponsorship of heliports based on the Fly Neighborly Program as a civic project to promote public service.
- nongovernmental economic development agencies such as chambers of commerce, regional economic development councils, or merchant associations. Demonstrate to economic development agencies how helicopter transportation benefits the community, and present data to show the economic viability of helicopter transportation.
- direct public contact
- environmental organizations such as Greenpeace, the Sierra Club, or federal or state environmental protection agencies. Provide information. Do not immediately assume they are hostile to the planned operations. Instead, emphasize the positive environmental aspects of helicopter operations, such as the fact that they are involved in search and rescue operations for hikers or workers injured in remote areas, and that they provide access to such areas without the need to pave over ground for landing strips.

Public relations can be improved by influencing government agencies concerned with aviation in the following ways:

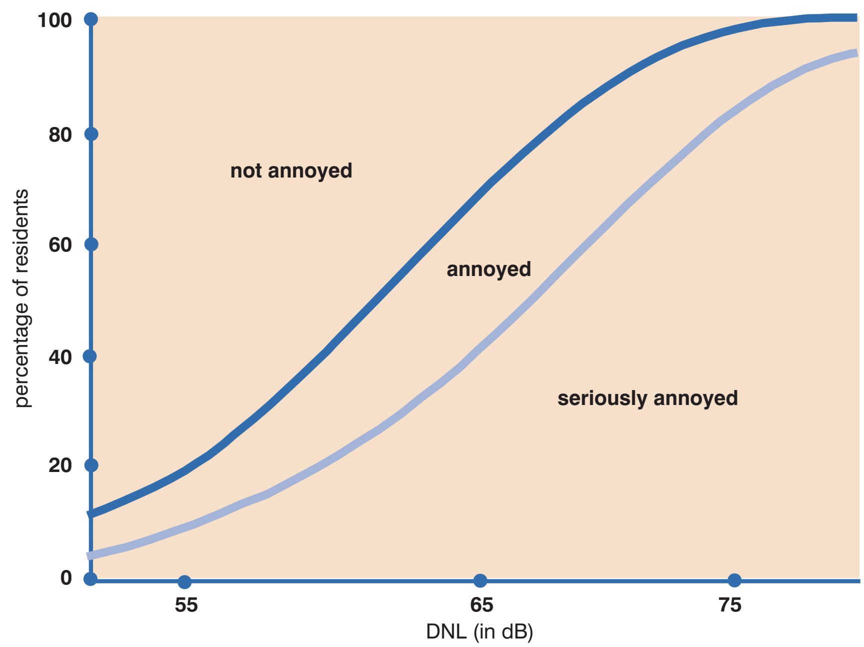
- Participate in public hearings
- Provide professional testimony as appropriate
- Conduct flight demonstrations
- Conduct one-on-one campaigns
- Submit petitions and letters

7.4 Preventing and Responding to Complaints

Helicopter operations are undeniably noisy, and this guide is concerned with a program designed to minimize the problem. Figure 8 shows the relationship between the amount of noise people are exposed to, and how annoyed they are likely to get. In the figure, the amount of noise exposure is expressed as DNL (day-night sound level).

Figure 8

Relationship between Noise Exposure and Annoyance



7.4.1 Complaint Prevention

A significant number of noise-related complaints can be prevented in the first place, given a certain degree of sensitivity, foresight, and commitment. Prevent complaints by assessing the environmental compatibility of potential landing facilities. Select those most suitable from a safety, operational, and environmental point of view.

Implement a public acceptance program.

- When contemplating site licensing, identify, contact, and try to influence potential sources of opposition before the hearing.
- Initiate or support presentations, seminars, or displays to educate the public about the value of helicopter transport.

Educate customers about noise abatement procedures, in order to prevent or minimize conflicts between their expectations and company policy.

Coordinate operations personnel and flight crews, so that flights that would unnecessarily violate company policy are not assigned.

7.4.2 Handling Noise Complaints

Although earlier sections of this guide offer information concerning noise abatement techniques, it is unlikely all noise complaints can be avoided. Since some complaints are inevitable, how they are handled is also important to the success of the Fly Neighborly Program.

The resulting problem is not simple. A helicopter can annoy people simply by being over, or too near, certain noise-sensitive areas. If someone calls the FAA, or a state agency, and offers routine information such as the aircraft registration number, colors, or type, it is likely that he or she will be told the aircraft was not in violation of any regulation, and that, therefore, nothing can be done. The result can be an angry, frustrated member of the community who will probably not be particularly supportive of any current or future helicopter or heliport related issue.

The helicopter user community has a real interest in assuring all complaints are appropriately addressed. Conventional channels for complaints are demonstrably insufficient. Therefore, a number of regional helicopter associations have started to operate their own complaint lines. These lines offer state, federal and local agencies another option when they receive complaint calls about legal and proper operations. The agencies can pass the complaint along to the regional association, or provide the complainant with the telephone number of the complaint line.

Such programs offer a number of benefits:

- Regional associations can often identify an aircraft with much less information than other agencies require.
- Associations can ensure that each issue is addressed and, when possible, satisfy the complainant.

When a complaint is received, how should it be addressed?

- The most effective way to deal with the complaint is to contact the complaining party personally. When you do, avoid being defensive, argumentative, or opinionated. Sincerely try to understand the other person's point of view, and avoid hostile confrontations. Sometimes merely listening politely can improve the situation.
- Furthermore, evaluate the problem thoroughly, and follow through. Was the pilot aware of the problem? Was there something the pilot could have done to avoid it? Is it likely to recur? Contact the pilot or the operator to determine the facts. Consult this guide, and other sources of noise abatement information, to determine how to improve the situation.
- Finally, respond to the caller. Tell him or her what has been learned, and what is being done to prevent the situation from recurring.

Of course, the best way to handle complaints is to avoid them in the first place. If a problem with a certain operation can be anticipated, contact the likely complainant, or members of the public to be impacted, before the operation begins. Explain to him or her, the purpose, timing, and duration of the operation, and its likely impact upon the area. People like to feel they have some control over their lives. Often, just a simple courtesy call in the beginning can save hours of trouble and nuisance later.

An example is given in Appendix 3 of a noise abatement program established at a heliport in a downtown area. The noise abatement program that was put into effect to solve the situation is described.

8 Fly Neighborly Program– What Can be Achieved?

The Fly Neighborly Program outlined in this guide, together with the information on HAI's Noise Abatement Training CD for Pilots, and use of the noise abatement procedures which are available on HAI's Web site, provide the basis for lowering the noise generated by helicopters in day-to-day operations. In addition, the noise abatement procedures offer a way of reducing the impulsive noise characteristic of helicopters which occur during normal operations and often cause complaints. By adopting and following the Fly Neighborly Program, a high level of public acceptance can be obtained.

It should also be noted that current public acceptance of helicopters is, in general, poor and, unless the program outlined in this guide is adopted, further international, national, and local regulations will be enacted to limit helicopter operations. Therefore, HAI strongly recommends that its members introduce a Fly Neighborly Program as outlined in this guide.

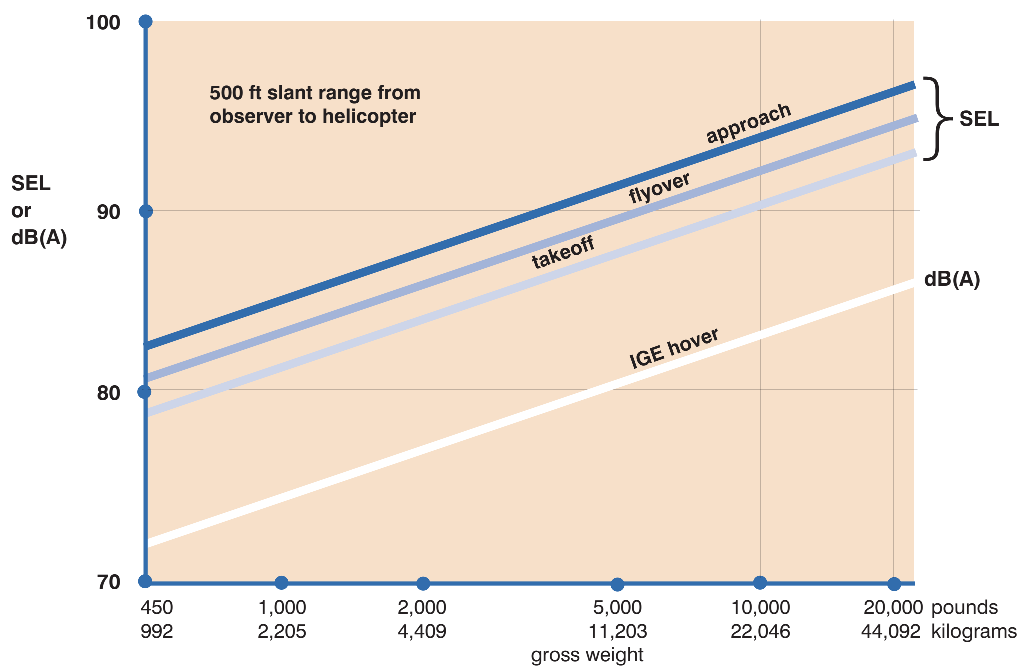
If the procedures given in this guide are followed, public acceptance will be improved and the rotorcraft segment of the aviation industry will be able to flourish and grow, without being restricted by the burden of new noise regulations and operational restrictions.

Sound Comparisons

The general relationship between sound level and helicopter weight is shown in Figure A1 reproduced from the HAI Helicopter Noise Prediction Method. Smaller helicopters are generally quieter than larger ones and sound levels tend to increase approximately three decibels per doubling of helicopter weight.

Figure A1

Relationship between Sound Level and Helicopter Weight



Appendix 1

What do these sound levels mean? Table A1 provides sound levels for illustrative noise sources heard both outdoors and indoors. Human judgment of the relative loudness (relative to a reference level of 70 dB(A) of different sound levels is also given.

Table A1

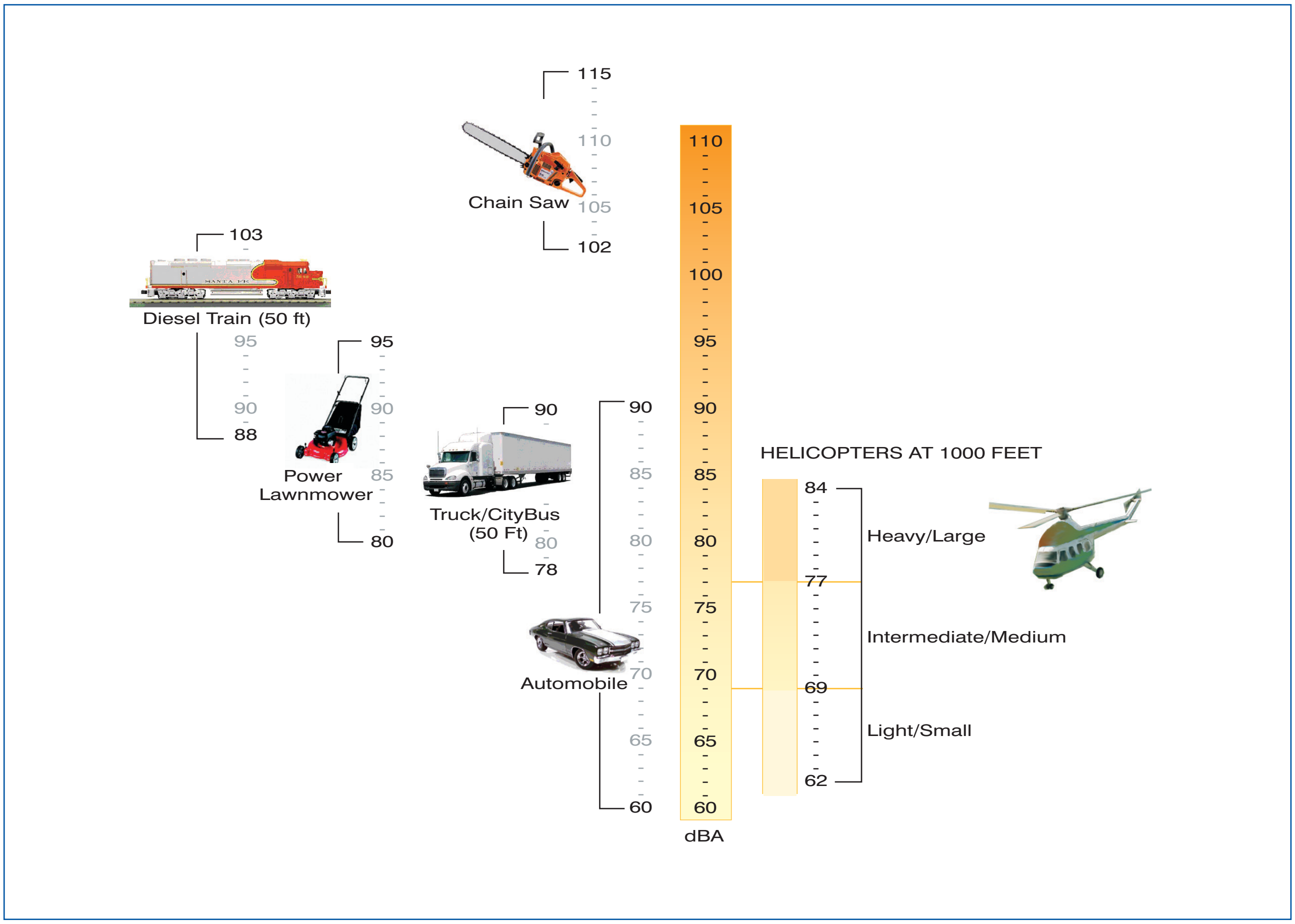
Illustrative Noises

dB(A)	Overall Level	Community (Outdoors)	Home or Industry (Indoors)	Human Judgment of Loudness
130	uncomfortably loud	military jet takeoff from aircraft carrier at 50ft (130)		
120			Oxygen Torch (121)	120dB(A) 32 times as loud
110	very loud	turbofan aircraft takeoff at 200ft (118)	riveting machine (110) rock-and-roll band (108-114)	110 dB(A) 16 times as loud
100		Jet flyover at 1,000 ft (103)		100dB(A) 8 times as loud
90		Power mower (95)	newspaper press (97)	90dB(A) 4 times as loud
80	moderately loud	car wash at 20 ft (89) diesel truck at 40mph at 50ft (84) high urban ambient sound (80)	food blender (88) milling machine (85) garbage disposal (80)	80dB(A) twice as loud
70		car at 65mph at 25ft (77)	living room music (76) TV audio, vacuum cleaner (70)	70dB(A)[reference]
60		A/C unit at 100ft (60)	electric typewriter at 10ft (64) dishwasher (rinse) at 10ft (60) conversation (60)	60dB(A) half as loud
50	quiet	large transformer at 100ft (50)		50 dB(A) 1/4 as loud
40		bird calls (44) lower limit of urban ambient sound (40)		40dB(A) 1/8 as loud
10	just audible			
0	threshold of hearing			

Figure A2 provides some basis for comparing helicopter sound levels to other familiar sounds. Comparisons are made at representative distances from each sound source.

Figure A2

Comparison of Sounds



The sound level is, however, only one of the aspects to be considered since the character of the sound - or the impulsive character of the sound - can be equally important. Fortunately, the impulsive character of the sound, as well as the actual level, can be controlled by using noise abatement procedures.

FAA Advisory Circular AC 91.36D

Date: September 17, 2004 AC No: 91-36D

Subject: VISUAL FLIGHT RULES (VFR) FLIGHT NEAR NOISE-SENSITIVE AREAS Initiated by: ATO-R

1. PURPOSE. This Advisory Circular (AC) encourages pilots making VFR flights near noisesensitive areas to fly at altitudes higher than the minimum permitted by regulation and on flight paths that will reduce aircraft noise in such areas.

2. EFFECTIVE DATE. This advisory circular is effective on September 17, 2004.

3. CANCELLATION. Advisory Circular 91-36C, Visual Flight Rules (VFR) Flight Near Noise Sensitive Areas, dated October 19, 1984, is cancelled.

4. AUTHORITY. The FAA has authority to formulate policy regarding use of the navigable airspace (Title 49 United States Code, Section 40103).

5. EXPLANATION OF CHANGES. This AC has been updated to include a definition of “noisesensitive” area and add references to Public Law 100-91; the FAA Noise Policy for Management of Airspace Over Federally Managed Lands, dated November 1996; and the National Parks Air Tour Management Act of 2000, with other minor wording changes.

6. BACKGROUND.

a. Excessive aircraft noise can result in annoyance, inconvenience, or interference with the uses and enjoyment of property, and can adversely affect wildlife. It is particularly undesirable in areas where it interferes with normal activities associated with the area’s use, including residential, educational, health, and religious structures and sites, and parks, recreational areas (including areas with wilderness characteristics), wildlife refuges, and cultural and historical sites where a quiet setting is a generally recognized feature or attribute. Moreover, the FAA recognizes that there are locations in National Parks and other federally managed areas that have unique noise-sensitive values. The Noise Policy for Management of Airspace Over Federally Managed Areas, issued November 8, 1996, states that it is the policy of the FAA in its management of the navigable airspace over these locations to exercise leadership in achieving an appropriate balance between efficiency, technological practicability, and environmental concerns, while maintaining the highest level of safety.

b. The Federal Aviation Administration (FAA) receives complaints concerning low flying aircraft over noise sensitive areas such as National Parks, National Wildlife Refuges, Waterfowl Production Areas and Wilderness Areas. Congress addressed aircraft flights over Grand Canyon National Park in Public Law 100-91 and commercial air tour operations over other units of the National Park System (and tribal lands within or abutting such units) in the National Parks Air Tour Management Act of 2000.

c. Increased emphasis on improving the quality of the environment requires a continuing effort to provide relief and protection from low flying aircraft noise.

d. Potential noise impacts to noise-sensitive areas from low altitude aircraft flights can also be addressed through application of the voluntary practices set forth in this AC. Adherence to these practices is a practical indication of pilot concern for the environment, which will build support for aviation and alleviate the need for any additional statutory or regulatory actions.

7. DEFINITION. For the purposes of this AC, an area is “noise-sensitive” if noise interferes with normal activities associated with the area’s use. Examples of noise-sensitive areas include residential, educational, health, and religious structures and sites, and parks, recreational areas (including areas with wilderness characteristics), wildlife refuges, and cultural and historical sites where a quiet setting is a generally recognized feature or attribute.

8. VOLUNTARY PRACTICES.

a. Avoidance of noise-sensitive areas, if practical, is preferable to overflight at relatively low altitudes.

b. Pilots operating noise producing aircraft (fixed-wing, rotary-wing and hot air balloons) over noisesensitive areas should make every effort to fly not less than 2,000 feet above ground level (AGL), weather permitting. For the purpose of this AC, the ground level of noise-sensitive areas is defined to include the highest terrain within 2,000 feet AGL laterally of the route of flight, or the uppermost rim of a canyon or valley. The intent of the 2,000 feet AGL recommendation is to reduce potential interference with wildlife and complaints of noise disturbances caused by low flying aircraft over noise-sensitive areas.

c. Departure from or arrival to an airport, climb after take-off, and descent for landing should be made so as to avoid prolonged flight at low altitudes near noise-sensitive areas.

d. This advisory does not apply where it would conflict with Federal Aviation Regulations, air traffic control clearances or instructions, or where an altitude of less than 2,000 feet AGL is considered necessary by a pilot to operate safely.

9. COOPERATIVE ACTIONS. Aircraft operators, aviation associations, airport managers, and others are asked to assist in voluntary compliance with this AC by publicizing it and distributing information regarding known noise-sensitive areas.

Signed

Sabra W. Kaulia

The Portland Public Heliport Noise Abatement Program

In 1989, the city of Portland, Oregon and the Northwest Rotorcraft Association decided to build a heliport to provide direct air access to downtown Portland. During hearings to approve the facility, concern was expressed about the resulting noise increase in the area surrounding the heliport. In response to this concern, the following noise abatement program was put into effect:

Noise Abatement

Pilots are requested to utilize the following noise abatement procedures, whenever possible. Of course, it is the pilot's responsibility on each flight to determine the actual piloting techniques necessary to maintain safe flight operations.

1. *Flight Paths:* Maintain approach and departure paths over rivers and freeways. Avoid residential neighborhoods, the McCormick Pier Apartments, the convention center towers, and the piers for the Steel Bridge. Approach and depart over the Morrison, Broadway, and Grand Avenue bridges. [A map is provided with those features marked.]

2. *Steep Departure:* Depart at Vy (best rate of climb) when possible.

3. *Steep Approach:* Use steep approach angle when possible (PLASI is set for a 10º approach).

4. *Night Operations:* Avoid night approach from the north, as it passes near the McCormick Pier Apartments.

5. *Minimize Ground Operations:* Minimize the duration of warm-up or cool-down periods (typically two to three minutes). Do not idle at the heliport for prolonged periods.

6. *Avoid High Noise Regime:* Most helicopters have a high noise regime near a descent profile of 70 knots at 300 fpm. Pilots can avoid descending through this area by initiating the descent at a higher speed than normal.

7. *Gradual and Smooth Control Inputs:* Gradual and smooth control inputs result in reduced noise impact.

8. *Avoid Steep Turns:* Avoidance of steep turns result in reduced noise impact.

9. *Enroute Altitude:* Whenever possible, maintain 2,000 feet above ground level over residential neighborhoods and other noise-sensitive properties, as per FAA AC 91-36 "VFR Flight Near Noise-Sensitive Areas."

10. *Fly Neighborly:* Refer to the HAI Fly Neighborly Program for additional information on how to minimize helicopter noise impact.

Citizen concerns about helicopter noise emanating from the Portland Heliport should be brought to the attention of the Northwest Rotorcraft Association by calling 503-286-0927. All noise complaint calls will be logged. If the caller can identify the helicopter involved, follow-up calls will be made to the involved helicopter pilot and then back to the concerned citizen.

The Bureau of General Services maintains a Portland Heliport Noise Abatement Committee. When noise issues at the heliport cannot be easily resolved, the committee will be convened to assist in the resolution process, and the logs reviewed for pertinent information.

As concerns noise abatement of helicopter traffic in other parts of the city, it is noted that the Port of Portland has developed a plan of preferred helicopter flight routes for use in the greater Portland metropolitan area, especially as concerns helicopter traffic to and from Portland International Airport and Portland Hillsboro Airport. This program has been very successful and the heliport is still operating today.

The acronyms used in this Guide are defined below.

AGL Above Ground Level

BVI Blade-Vortex Interaction

dB Decibels, the basic unit for measuring the level of sounds.

dB(A) A-weighted sound level. A sound pressure level that has been weighted to approximate human hearing response to sound of different frequencies. Weighted sound pressure levels, such as the "A" weighting, are currently used for noise certification of light helicopters and small propeller-driven aircraft. In FAA Advisory Circular 36-3C, they are used as the basis for airport access restrictions that discriminate solely on the basis of noise level.

DNL Day-night sound level. A single-number measure of community noise exposure (expressed in the unit Ldn), introduced to help predict the effects on a population of the average long-term exposure to environmental noise. It is based on the equivalent sound level (Leq), but corrects for night-time noise intrusion. A ten-decibel correction is applied to noises heard between 10 P.M. and 7 A.M. to account for the increased annoyance of noises heard at night.

DNL uses the same energy equivalent concept as Leq. The specified time integration period is 24 hours. For assessing long-term exposure, the yearly average DNL is the specified metric in the FAA 14 CFR Part 150 noise compatibility planning process.

EPNL Effective perceived noise level. A measure of complex aircraft noise, expressed in decibels, that approximates human annoyance responses. It corrects for the duration of the noise event and the presence of audible pure tones and discrete frequencies such as the whine of a jet aircraft. The EPNL is used by the FAA as the noise certification metric for large transport and turbojet airplanes, as well as for helicopters.

fpm Feet per minute. A measure of speed used for the rate-of-climb or rate-of-descent of an aircraft.

KIAS Knots indicated airspeed. A measure of the speed of an aircraft.
[1 knot = 1.69 ft/sec =101.3 ft/min = 1.15 mile/hour]

Leq Equivalent sound level expressed in decibels. The energy average noise level (usually A-weighted) integrated over some specified time. The purpose of Leq is to provide a single-number measure of noise level averaged over a specific period of time. When use for assessing community noise, Leq is normally defined over a 16 or 24 hour period.

mph Miles per hour. A measure of speed. [1 mph = 0.87 Knots]

PNL Perceived noise level. A rating of noisiness used in assessing aircraft noise, expressed in decibels. PNL is computed from sound pressure levels measured in octave or one-third octave frequency bands. An increase of ten decibels in PNL is equivalent to doubling the perceived noisiness. Currently, this measure is used by the FAA and foreign governmental agencies in the noise certification process for all turbojet-powered aircraft, and large propeller-driven transports.

R/C Rate of climb. The speed at which an aircraft is ascending.

R/D Rate of descent. The speed at which an aircraft is descending.

RPM Rotor revolutions per minute. The rotational speed at which an aircraft rotor is turning.

SEL Sound exposure level. A measure, expressed in decibels, of the effect of duration and magnitude for a single event. In typical aircraft noise model calculations, SEL is used in computing aircraft acoustical contribution to the equivalent sound level (Leq) and the day-night sound level (DNL).

Fly Neighborly Guide

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APPENDIX D

Airport Survey Questions

Questionnaire

The questionnaire that was used is a simple one consisting of a series of open ended questions. The surveyor kept detailed notes and recorded the of responses and requested copies of any brochures or other printed guidance that is not available on the airports website. The reason this format was chosen rather that a list of specific questions was that programs will vary considerably as we do not expect a common thread to run through each program and we want to make the survey efficient and not ask a lot of questions that are not applicable to the airport. The following is the questionnaire:

1. Introduction: Hello, my name is _________ and I am conducting a survey of helicopter noise management programs at select airports and heliports in the US. I received your name and contact information from Vincent Mestre at Landrum & Brown. This survey is being conducted for the Airport Cooperative Research Program of the National Academies as part of a synthesis study funded by the FAA. The research work is being done by Landrum & Brown under contract to the ACRP. I have a few questions that I would like ask. Is this a good time for you or is there a better time to call back? [proceed or make appointment to call back]
2. Before we start I just want to make you aware that I have two coworkers listening to your responses as well. Would you allow us for note taking purposes to use a handheld voice recorder to ensure we capture your responses accurately?
3. Do you have a helicopter noise management program? [If not, skip to 5]
4. Is the program described in a brochure, SOP, NOTAM, on your website, or by some other communication's vehicle?
    a. [if not on website ask for a copy, if on website ask for the URL]
5. Can you describe your helicopter program?
6. Do you have recommended helicopter routes?
    a. If yes, ask if they are published on aeronautical charts
    b. What is evaluation of the adherence to the routes?
7. Do you have recommended minimum altitudes?
    a. If yes, ask if they are published on aeronautical charts
8. Do you have any other operational mitigation measures such as restrictions on helicopter training operations or time of day?
9. What kinds of helicopters use your facility and approximately how many daily or annual operations are there?

10. How many noise complaints do you get per year or per month?
11. What is the issue or issues that most complainants are concerned about?
12. Would you say that noise is the cause of most complaints and if so what are the roles of fear or loss of privacy concerns to the complainers?
13. Do you feel that there are a few operators that cause the most problems or are the community concerns applicable to all operators?
14. Do you hold regular or occasional meetings with helicopter operators?
15. Does the tower support your efforts in managing helicopter noise?
16. What are the most effective and ineffective parts of your noise management program?
17. What would like to do to improve your helicopter noise management program?
18. What could the industry, including the FAA, do to help improve your noise management programs?
19. Would you find a guidebook of best practices useful at your airport or heliport?
20. That's the end of our formal survey questions. Thank-you very much for your cooperation, this information will be most useful in the compilation of our research. If you would like to contact me with additional information I can be reached at: (redacted)
21. We just have a couple more follow up questions. First, would you like to see a copy of what we write up to check it for accuracy?
22. If we have any questions or need to clarify something, is it okay to call you back?
23. Is it acceptable if our report identifies this airport, or would you prefer to remain anonymous?

Summary Table of Responses To Survey

(paraphrased from telephone survey responses)

Question 1: Do you have a helicopter noise management program?

The answers were five "yes" answers and four "sort-of"'s. The 'yes' programs were all voluntary and mainly consisted of asking pilots to fly certain routes.

Austin	Kind of: city ordinance about heliports that limits number of operations by category
East Hampto n	Yes: Plane Noise Inc. has an automated system that monitors aircraft noise complaints in real time and then analyzes those.
FAA	Kind of: there's an LA helicopter noise initiative that used stakeholder feedback to identify six actions to focus on.
LAS	Yes: voluntarily Fly Quiet program with meetings and routes which are monitored for compliance.
LGB	Yes: It is incorporated into helicopter flight guide. The guide contains suggested flight paths and altitudes.
OAK	Yes: established in 1970s. Try to get helicopters to fly over freeway as much as possible, avoid hotels & residential areas.
UCSF Hospital	Kind of: had one planned but became unnecessary. Complaints system active.
SFO	Kind of: more of a general aircraft noise management program with preferential runways and trying to use routes over water.
VNY/LAX	Yes: voluntary program that asks pilots to fly specific routes.

Question 2: Is this program published? Where?

To the question "Is this noise management published and if so where?", the answers are generally "yes" but there but there is a wide disparity in the accessibility of these publications, ranging from a direct website location to some rather vague references.

Austin	City ordinances, chapter 13-1 under helicopters
East Hampto n	planenoise.com
FAA	May 2013 report about the LA helicopter noise initiative on the FAA webpage
LAS	Partially in a Fly Quietly brochure, partially in the FAR Part 150 program

LGB	Guide is published and available to operators, as well as on website (http://www.lgb.org/)
OAK	Yes, pilot brochure and on third party website with monthly subscription--whispertrack from flyquietoak.com. Has description of program with airport contact information and diagrams of noise-sensitive areas.
UCSF Hospital	Not in use, but being sent to us
SFO	On the website (http://www.flysfo.com/)
VNY/LAX	Look at website, lawa.org then go from there

Question 3: Recommended helicopter routes?

To the question "Are there recommended helicopter routes?" the answers were generally yes with one "no" and one "don't know".

Austin	Yes, during major events, mainly Formula 1 race. Create routes that avoid noise-sensitive areas that must be approved for operator to have temporary permit--if pass over private property must alert and ask for permission.
East Hampto n	Not really; maybe East Hampton doeswe are only involved with compiling the complaints. Try to maximize altitude.
FAA	Have a few, still in the process of creating them
LAS	Yes, worked with FAA and operators to come up with routes, which in the end must be approved by the FAA
LGB	Yes, 8 visually identifiable flight paths, usually over large streets, mainly for arrival/departure, Also have helicopter training flight paths that are designed to avoid residential areas.
OAK	Yes: brochure has fixed-wing routes/paths on diagrams and one is labeled Heli as well, basically recommended to follow freeway
UCSF Hospital	Have primary route, and 3 other ones
SFO	The tower decides/controls these
VNY/LAX	Yes, but they're all voluntary and generally are for when helicopters are on airport property

Question 4: Are these routes published?

To the question "Are these routes published?" four responded that their routes were readily available affirmatively; four others responded that they thought they had something, but it was not readily available, and the ninth was a "don't know".

Austin	Temporary and not in the ordinance, but may be somewhere else published by FAA or with the operators

East Hampton	N/A
FAA	Helicopter aeronautical chart for LA basin has some, but again, in the process of making more
LAS	Fly Quietly brochure and letter of agreement with ATC.
LGB	Helicopter Flight Guide
OAK	Brochure on whispertrack
UCSF Hospital	Contour routes were drawn, exist, being sent to us
SFO	unknown
VNY/LAX	Also on the site

Question 5: Is there an evaluation to the adherence of routes?

To the question “Evaluation of the adherence to the published routes” four did evaluations. Two did this all the time, one did this on the basis of complaints, and one was rather *ad hoc*.

Austin	Routes must be pre-approved
East Hampton	N/A
FAA	None: routes are voluntary, recommended, VFR
LAS	Although voluntary, evaluate using Exelis Environmental Vue Application, a radar analysis package, to track each individual operator by their call sign and see if they pass through narrow gates on the preferred route
LGB	Yes: We periodically evaluate the dispersion and altitudes via gates in ANOMS. The gates are located along the recommended routes. This information is communicated to operators.
OAK	case by case basis using flight tracking system
UCSF Hospital	Seems like helicopters follow except due to weather etc. since so few/specific routes
SFO	unkown
VNY/LAX	Used to monitor and still do occasionally based on complaints, but they're voluntary and basically only about airport property. In general adherence is pretty good

Question 6: Is there a minimum altitude requirement?

To the question “Are there minimum altitude requirements?” the answers were generally no, with one airport suggesting that media aircraft stay above 1000 feet. One had minimum altitudes over the airfield.

Austin	No, just based on FAA standards
East Hampton	unknown
FAA	Some published on helicopter/hybrid routes, in the works and specific to airport. Voluntary for the LA helicopter noise initiative
LAS	No, for safety reasons since terrain drops. Do ask them to fly as high as possible
LGB	Maximum: recommended to be below 500 ft within 1.5 miles of airport, below 700 ft within 5 miles.
OAK	Ask most helicopters, especially media to stay above 1000 ft but don't recommend anything to law enforcement, medevac since that has to do with safety, health; people's lives. Brochure says 600 ft for fixed-wing
UCSF Hospital	unknown
SFO	No
VNY/LAX	1300ft MSL/500ft AGL, on airport property. And 1500ft MSL maximum

Question 7: Are the minimum altitudes published?

The question "Are the minimum altitudes published" is **not applicable** because nobody has minimum altitudes (except for the one on-field minimum, which certainly is published).

Austin	N/A
East Hampton	N/A
FAA	See above
LAS	N/A
LGB	No: Maximum altitudes are prescribed.
OAK	LOA between FAA and operators
UCSF Hospital	N/A
SFO	N/A
VNY/LAX	Yes, probably on the site

Question 8: What other mitigation measures?

To the question "What other mitigation methods do you use?", the answers largely repeated the responses dealing with preferred route (questions 3/4/5) but expanded to preferred areas for such things as training. One airport restricted training by time of day.

Austin	Basically only during specific events, identifying noise-sensitive areas
East Hampto n	We just collect complaints
FAA	Possibly limiting time of day and requesting camera pooling for news helicopters
LAS	No
LGB	As mentioned above, training flight paths over compatible land uses
OAK	It's a 24/7 airport, but do try to minimize noise, follow noise abatement procedures 10PM-6AM by avoiding Bay Farm Island, especially have helicopters fly along San Leandro Bay
UCSF Hospital	Restrictions on which patients are transferred reduces number of flights and thus amount of noise
SFO	No.
VNY/LAX	Ensure helicopter training ops aren't repetitive and usually restrict time of day

Question 9: What kind of helicopters use your facility?

To the question "What kind of helicopters use your facility" almost everyone mentioned emergency services of one kind or another and included police, fire, medical, and coast guard. Other than the emergency services, the uses were whatever was local to that facility (passenger transport, tours, news media, etc.)

Austin	Transporting people during special events, police, fire, EMS
East Hampto n	Lots of tour helicopters in NYC, transport and Manhattan and Wall St both passenger and corporate, and probably transport in East Hampton since there's often transport between these places. Also fractional share model: Blade
FAA	(Use the LA area) mostly single engine aircraft, definitely news and transport
LAS	7-8 seat helicopters, e.g. A Star 350, A Star 135, R22, R44. Tours of Grand Canyon, local police department, media
LGB	R22's, R44's. Also A Star 350's and A Star 330 Pumas for search and rescue belonging to LA county sheriff's department. Island Express (S76) that shuttles from airport to Catalina and Queen Mary. Law enforcement in general
OAK	Media, law enforcement (Oakland police department), medevac turboprops, training operations for Coast Guard at North Field

UCSF Hospital	hospital-to-hospital transport
SFO	Coast Guard, tours
VNY/LAX	Training operations, transport, helicopters that need service/repair, LAPD

Question 10: How many operations?

To the question "how many operations?" the numbers given varied a lot, ranging from about 400 operations per year to 100,000 operations per year.

Austin	A couple hundred per weekend, three thousand the weekend of Formula 1
East Hampton	100,000/year at Manhattan heliport. When it comes to East Hampton, doesn't know. For use in a hypothetical, says 1667/month (1/3 of 5000) but also says 1 complaint/op and 25000 complaints so possibly ~25000 ops
FAA	unknown
LAS	About 300 per day, mostly tour
LGB	Approximately 25,000/year
OAK	1300 annually: 598 departures 709 arrivals
UCSF Hospital	88-104 in 3 months (not sure if 16 night operations included in the 88)
SFO	Fewer than 10/day
VNY/LAX	100/day

Question 11: How many complaints do you receive?

To the question "how many noise complaints do you receive?" the number of complaints varied a lot, ranging from less than a dozen per year to twenty five thousand per year.

Austin	Only a few/year, except during Formula 1 up to 220/230, though recent years closer to 120
East Hampton	About 1/op at East Hampton. Also says 25000/year but not sure if this is for only helicopters or all aircraft
FAA	About a dozen/year
LAS	81 total/year, 36-37 if don't count repeat households
LGB	About 200 complaints/year (2 percent of 10000)
OAK	937 in 2014 which is about 78 per month
UCSF Hospital	2 or 3 complaints between February 1 (when hospital opened) and when interview was conducted
SFO	2/month

VNY/LAX	Quite a few and it varies. Also, if one person marks multiple issues in their complaint, each one counts as a separate complaint

Question 12: What is the issue/what are the issues most are concerned about?

To the question "What are the issues most are concerned about" *noise* is the greatest concern (8/9), followed closely by *altitude* (4/9). Also mentioned were *time of flights, frequency of flights* (especially tour aircraft), and *routes.*

Austin	Noise, but in terms of time of day and when different populations feel most disrupted as well as number of activities and level of noise per activity; intensity.
East Hampto n	In East Hampton, it seems that the majority are noise complaints, but he thinks that their true cause/motivation is that the very rich create the problem. ? In NYC, high-volume frequency during peak hours
FAA	Noise due to low-flying, hovering aircraft
LAS	Frequency, especially of tour helicopters
LGB	Vary by location, but include veering off the routes over major streets and low altitudes. Noise probably triggers a lot of complaints; makes people notice
OAK	Mostly about noise, vary by location. Berkeley and Oakland: media covering protests leads to low-flying and hovering as well as just high quantity due to addition of law enforcement at protests. Davis West: veering off the path, over residential area
UCSF Hospital	Noise, definitely
SFO	Noise and low-altitude flights
VNY/LAX	Noise, vibration, and low altitudes.

Question 13: What about fear or loss of privacy--are these concerns?

To the question "Are fear or loss of privacy concerns?" There was again a wide range of responses. The most common answer was "not really" (6/9) ; three indicated that fear is a problem.

Austin	Not really
East Hampto n	I think no because he went on to describe actual issues in East Hampton, but never explicitly said fear or privacy.
FAA	Not loss of privacy but maybe fear of helicopters crashing wherever they're located; safety
LAS	Not really, since helicopters usually fly pretty high

LGB	Fear is yes due to flying over elementary school, loss of privacy isn't explicitly expressed but alluded to and about law enforcement.
OAK	Fear helicopters being too close to ground, crashing (corrected by interviewer to say not that much fear of crashing?) Paranoia about law enforcement spying on them, and about their aircraft circling around fields/crops looking for marijuana
UCSF Hospital	Not really
SFO	Not really
VNY/LAX	Very few; 1-2 in 14 years

Question 14: Are there a few operators that cause the most problems?

To the question "are there a few operators that cause the most problems?" it appears that the answers addressed a slightly different question. The few that answered our question answered the question "what type of **operations** gave rise to the most problems" rather than the question "what **operators** cause the most problems". The answers were that tour helicopter, transportation helicopters, and media helicopters were the type of operations that caused the most problem. The three airports that used the term *operator* said that all their operators were about equal.

Austin	During the year, EMS and police, although people often retract complaints once they know who it is. Also banner-towing aircraft.
East Hampton	In NYC, people are concerned about the idea of Blade (a helicoptor transport service to NYC), but in general it seems to be passenger transport for both East Hampton and NYC
FAA	Depends. Based on location: some places have more surveillance so public service helicopters cause many complaints. If operations based at airport, then ingress/egress causes a lot of issues.
LAS	No, in recent years all about the same since all are aware of the concerns--they meet and discuss these.
LGB	Not really, about equal for each operator
OAK	No, applicable to all
UCSF Hospital	There's only really one kind of operator
SFO	Tour and Coast Guard, but out of the two, tours. Also occasion-specific news copters
VNY/LAX	Tours over people's houses, police flying low for surveillance especially if there's no crime, and news copters hovering so low for so long

Question 15: Do you hold regular or occasional meetings with operators?

To the question "do you hold regular meetings?" 4 responded "yes", 1 was a qualified "yes", 2 were "Semi-yes", and 1 was "no".

Austin	Kind of; meet before Formula 1. During the year, informally with police/fire department. Also meet when heliport/helistop needs to be approved, etc.
East Hampton	No.
FAA	Yes, as part of the LA helicopter initiative
LAS	Yes, quarterly or biannual meetings talking about route compliance, noise areas, general issues, and growth of the operators. Meet with FAA Air Traffic Control, local police department, FSDO, and operators
LGB	Not exactly, but quarterly meeting with airport noise abatement committee that includes helicopter operators. Might form helicopter-specific committee
OAK	Yes, annual meetings
UCSF Hospital	Community advisory board that will meet quarterly, with representatives from the community, community/government relations, and the transport manager.
SFO	No
VNY/LAX	Informal: sometimes they go and sit in on professional helicopter pilot association meetings that happen once a month, sometimes talk afterwards in office

Question 16: Does the tower support your efforts?

To the question "does the tower support your efforts" the answers were 7 "yes", and 2 "don't know".

Austin	Yes, provide separation for aircraft during the year and even a special division of FAA comes in to help with Formula 1
East Hampton	unknown
FAA	Yes, with routes, altitudes, operating practices--
LAS	Yes generally, and tower has also supported them in trying to hold onto the radar feed
LGB	Yes, very much.
OAK	Of course safety is priority, but try to assist and adhere to noise abatement procedures
UCSF Hospital	N/A
SFO	Generally yes. Sometimes helicopter placement decided by tower causes disruption, but placement choice is out of necessity

VNY/LAX	Kind of. Clears helicopters to fly route but doesn't monitor them after that. Then talks about FAA, saying they issued letter agreements in the past that were helpful

Question 17: What are the most effective and ineffective parts?

To the question "What are the most effective and ineffective parts?" the response to effective was pretty clear, and listed communications/outreach as the best method, with minimum altitudes and routing also being strong, effective parts of a plan. Ineffective was mentioned by a minority and it consisted mainly of methods that had the effect of controlling how the pilot flies the plane.

Austin	Outreach in working with the stakeholders and always notifying property owners about applications, especially during Formula 1: it's the most effective as in it works well, but ineffective as well in how much labor is involved in this depth of involvement
East Hampton	Doesn't say what's most effective/ineffective for East Hampton/NYC, only talks about opinions/knowledge: believes that maximizing altitudes would be/is generally effective, and believes in diversifying route structures.
FAA	N/A
LAS	Most effective is communication, making operators challenge each other/compete to fly quietly. Also higher altitudes, route compliance, and quieter helicopters. Ineffective is trying to control how a pilot flies; speed, rotation angle, etc. during arrival/departure, because that can become a safety issue.
LGB	Least ineffective is just publishing flight guide, establishing procedure. Need personal follow-up with individual operators to ensure they're aware of community concerns, and then becomes effective
OAK	Most effective is outreach: educating pilots and community on what airport can/cannot do. Ineffective is same as what they need to improve
UCSF Hospital	N/A
SFO	Website and Fly Quiet program are most effective, as well as general good flow of information
VNY/LAX	Recommended routes are effective; good compliance. Possibly in the past, deviation monitoring program was effective. Ineffective is how agencies like police and fire dept. deal with complaints

Question 18: What would you like to do to improve it, if anything?

To the question "What would you like to do to improve it?" four want to do things to improve communications and outreach, two say it's fine the way it is, two don't answer the question, and one says maximize altitudes and diversify route structure.

Austin	Not much, it's really good the way it is. The things that really disrupt people, like EMS, are life-saving so no real debate
East Hampton	Maximizing altitudes and diversifying route structures
FAA	No comments.
LAS	Recognize and support the efforts operators are making to Fly Quietly, both on a community and national level; positive reinforcement
LGB	Make community understand what airport can/cannot restrict, instead of just blaming /complaining. Also establishing specific helicopter noise abatement committee to improve outreach mentioned above; keeping helicopter operators informed, especially in terms of training operations where operators are continually changing
OAK	Work on brochure and make pilots/operators aware of noise abatement procedures before they arrive at Oakland Airport
UCSF Hospital	Nothing, it's pretty good
SFO	Improve complaint page, keep lines of communication open
VNY/LAX	Not explicitly answered.

Question 19: Is there anything the industry including the FAA could do to improve it?

To the question "What would you like the FAA to do to improve it, if anything?" four specified a desire for more communication/outreach from the FAA. The other four are very short and specific.

Austin	FAA could make Integrated Noise Model easier to use, so that it took less training
East Hampton	Same as above; work with FAA/Industry to accomplish those things
FAA	They've already done a lot
LAS	FAA could help with openness with radar data: get rid of 1200 codes, create local call sign so operators are identifiable. Also, generally create brochure/guidance document talking about what has been done to reduce noise impact. Finally, being aware of repeat caller impact when analyzing data
LGB	Communicating to operators how important noise is and making noise abatement measures simpler/more comprehensible to transient pilots
OAK	The FAA could attend more research meetings and offer their expertise in explaining to the community why things are done the way they are in the tower

UCSF Hospital	N/A
SFO	FAA could work with media, create media bill of rights.
VNY/LAX	Industry (pilots association) has been slowly improving, in the sense that they've become aware that they need to do more. And FAA could encourage transponder code use, possibly restart monitoring deviation from routes?

Question 20: Would you find a guidebook of best practices useful at your airport/heliport?

To the question “Would you find a guidebook useful?” we were greeted with four “yes” answers, two “maybe” answers, and three “not-really” answers.

Austin	They already have noise abatement procedures, he thinks it might be more useful in a place where there's more helicopter activity.
East Hampton	No comment.
FAA	N/A
LAS	Yes, especially if it had specific examples of what airports have done
LGB	Yes, but possibly more useful at airports without a good noise abatement program
OAK	Yes!
UCSF Hospital	Possibly
SFO	Wouldn't turn it away
VNY/LAX	Always, and something similar is in the works by helicopter pilots association

APPENDIX E

Sample Airport Helicopter Brochures

PORT OF PORTLAND

HIO FLY FRIENDLY

Helicopter Operator's Guide

NOISE
MANAGEMENT
PORT OF PORTLAND

7200 NE Airport Way Portland, OR 97218
OR: 503.460.4100 WA: 800.938.6647
Pilot Information Line: 800.938.5167
Email: PDXNoise@portofportland.com

www.portofportland.com

HIO FLY FRIENDLY

The Fly Friendly program was developed in collaboration with the Federal Aviation Administration, airport tenants and aircraft operators who utilize the Hillsboro Airport.

We are asking for your help in minimizing noise impacts in communities surrounding the Portland Hillsboro Airport.

As pilots, you serve as ambassadors for the industry and the manner in which you operate your aircraft reflects on the larger aviation community.

With this in mind, we ask that you be proactive by applying the elements of the Fly Friendly Program described in this brochure. Your participation with our noise abatement program is extremely important and helps us maintain goodwill with the communities surrounding the airport.

We appreciate your support and welcome your feedback about the program and how we can make it better.

Thank you for "flying friendly."

BT/500/10.13/AVA13_025

GENERAL NOISE ABATEMENT GUIDE

HELICOPTERS

The recommendations described in this brochure are not intended to preempt the responsibilities of the pilot-in-command or FAA/air traffic control.

HIO is bordered by noise sensitive areas to the west, south and east.

Minimize overflight of residential areas (highlighted in red on the map) whenever possible. When overflight of residential areas is unavoidable, please remain as high as possible.

Please follow these procedures (as long as conditions and air traffic control instructions permit):

- When departing, ascend as quickly as possible while over airport property. When arriving, remain as high as possible until reaching the airport. Remember: flying higher = flying quieter.
- For noise abatement, pilots are encouraged to overfly major roadways and non-residential areas whenever possible and to use established reporting points when entering or exiting the airport.
- Pilots are enouraged to use the noise abatement procedures published by Helicopter Association International or comparable procedures published by their aircraft manufacturer.

For more information please visit the Helicopter Association International website at www.rotor.com or contact the Port of Portland Noise Management Department.

HELICOPTER NOISE ABATEMENT PROCEDURES

- Residential/noise sensitive areas border the airport to the west, south and east. Please avoid overflight of residential communities whenever possible, especially during nighttime and early hours.
- In an effort to reduce community noise impacts, pilots are encouraged to overfly major roadways and non-residential areas whenever possible.
- The preferred ingress/egress routing is from/to the northeast overflying Highway 26. When possible, use established reporting points (shown in yellow) when entering or exiting the airport
- Due to the community noise impacts, training operations are discouraged between 2200L and 0600L daily.

HILLSBORO AIRPORT – HIO

General Information

Latitude: .... 45º 32'26.20" (45.540611º) North
Longitude: .... 122º 57'00.70" (122.950194º) West
Elevation:.............................. 208 ft./63.4 m (surveyed)
Variation: 16E (2010)
Location:...................................... 15 miles SW of PDX
Time Zone: .... UTC-8 (UTC-7 during DST)

Airport Operations

Sectional Chart: .... Seattle
ARTCC: .... Seattle Center
FSS:.. McMinnville
NOTAM Facility:........ HIO (NOTAM-D service available)
Control tower: .... Hours (0600-2200)
Pattern altitude: ....1,208 ft. MSL

Airport Communications

ATIS: 127.65
CTAF:.. 119.30
UNICOM: 122.95
Ground: 121.70 (0600-2200)
Tower: 119.30 (0600-2200)
Approach: 126.0
Departure:... 126.0

Runway Information

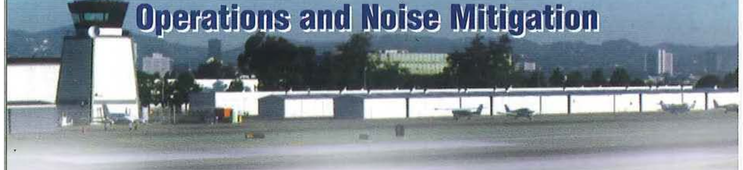
Rwy 13/31

Dimensions: .... 6,600 x 150 ft. (2,012 x 46 m.)
Surface: .... Asphalt
Rwy edge lights: .... High intensity

Rwy 2/20

Dimensions: .... 4,050 x 100 ft. (1,234 x 30 m.)
Surface: .... Asphalt
Rwy edge lights: ....Medium intensity

Santa Monica Airport
(SMO)
Operations and Noise Mitigation



HELICOPTERS

Santa Monica Airport is the oldest continuously operated airport in Los Angeles County and is one of the busiest single-runway general aviation airports in the nation. The Airport is closely surrounded by noise sensitive residential areas, with over 130,000 residents within 2 miles of the Airport. In order to mitigate potential negative impacts from aircraft operations and enhance compatibility with the surrounding communities, Santa Monica Airport maintains a proactive and extensive noise mitigation program which includes a maximum allowable noise level, limited aircraft operating hours and requested VFR noise mitigation flight paths.

This brochure introduces you to Santa Monica Airport's **Fly Neighborly Program** and will help you operate your aircraft in the quietest manner possible consistent with safety. The Airport recognizes that pilots truly are the key to a successful noise mitigation program and greatly appreciates your cooperation.

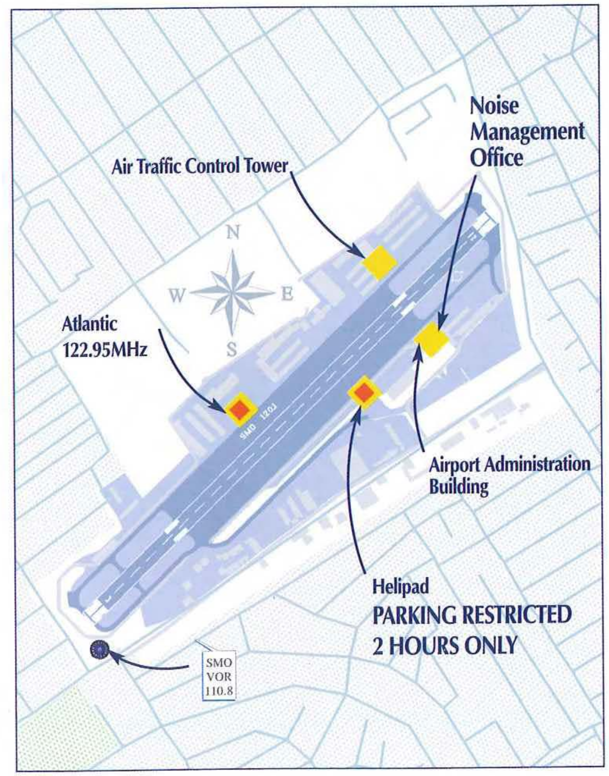
DISCLAIMER

The procedures described on the reverse side are not intended to pre-empt the prerogatives or responsibilities of the pilot-in-command, conflict with safe aircraft operations, or interfere with ATC instructions or any domain that is the exclusive authority of the FAA.

Fly Neighborly Program

HELICOPTER LANDING LOCATIONS

There are two approved landing locations for helicopters at Santa Monica Airport: the City's helipad on the south side and the Atlantic Aviation ramp on the north side.



The Helipad is located mid-field on the south side of Runway 03/21. When landing on the Helipad, please avoid flying over the Airport Observation Deck at the Airport Administration Building and stationary or taxiing aircraft to minimize rotor wash. Remain clear of the active Runway at all times unless approved by ATC.

NOISE MITIGATION

ARRIVAL & DEPARTURE PROCEDURES

The helicopter procedures described below are derived from a Letter of Agreement between the City of Santa Monica and the FAA. The procedures were developed by involving helicopter pilots (PHPA) airport neighbors, the FAA and City Staff.

VFR DEPARTURES

RUNWAY 21

Helicopters will depart via the Runway (over the Runway, not the Taxiway) and execute a left turn at the end of the Runway to over-fly the Penmar Golf Course. Helicopters departing the area are requested to turn at the shoreline.

RUNWAY 03

Helicopters will proceed straight out to the 405 Freeway before executing a left or right crosswind departure.

Helicopters will be sequenced with the flow of fixed-wing aircraft and no crosswind turns are permitted prior to the 405 Freeway.

VFR ARRIVALS

Arrivals can expect to enter mid-field at or above 900 feet MSL and execute a descending turn to the North Taxiway. Descent from 900 feet MSL should be made over the Airport or business park to the taxiway.

All helicopters will remain north of Runway 21 and avoid the flow of other arriving fixed-wing aircraft unless cleared to use the Runway.

SPECIAL REQUEST

Prior to visiting SMO, please contact Atlantic Aviation at 310-396-6770 for advance accommodations, as the City's only helipad on the south side may be occupied at different times of the day. **PARKING RESTRICTED 2 HOURS ONLY**

PROXIMITY TO THE COMMUNITY

The Airport is in close proximity to residential areas. Helicopters are requested to maintain at or above 900 feet MSL while in the Class D Airspace. (see noise mitigation procedures on reverse side)

PHOTO COURTESY OF: AERIAL FOTOBANK INC.

MAXIMUM NOISE LEVEL

As a result of an agreement between the City of Santa Monica and the FAA, an Airport Ordinance was established setting a maximum noise level of **95.0 dBA Single Event Noise Exposure Level (SENEL)** measured at noise monitor sites 1,500 feet from each end of the runway. Santa Monica Airport's **Fly Neighborly Program** focuses on pilot education and cooperation. However, repeat violators of the noise limit may be fined or suspended from using the Airport. Pilots are encouraged to contact the Noise Management Office for additional details.

PHOTO COURTESY OF: MICHAEL BURR

Compliance with the Airport Ordinance is mandatory unless deviations are made necessary by weather, ATC instructions or clearances, an in-flight emergency or other safety considerations.

NIGHT DEPARTURE CURFEW

No takeoffs or engine starts are permitted between 2300 hours and 0700 hours local time Monday through Friday, or until 0800 hours on weekends. Exceptions are allowed for bona fide medical or public safety emergencies if prior approval is obtained from the Santa Monica Police Watch Commander (310) 458-8426 or the Airport Manager (310) 458-8591. **Curfew violators are subject to misdemeanor criminal prosecution and a $2,000 fine.**

NIGHT ARRIVAL CURFEW

Although arrivals are permitted 24 hours a day, a voluntary curfew for arrivals is in effect between 2300 hours and 0700 hours local time Monday through Friday, or until 0800 hours on weekends. Night arrivals between 2100 local hours and 0700 local hours are strongly discouraged.

PHOTO COURTESY OF: MICHAEL BURR

FORMATION FLYING

Formation takeoffs and landings are prohibited. Formation flying within the Class D Airspace is highly discouraged unless necessary for an emergency.

HELICOPTER FLIGHT TRAINING

Helicopter flight training operations at the Airport are prohibited at all times.

NOISE MANAGEMENT OFFICE

3223 Donald Douglas Loop South
Santa Monica, CA 90405-3279

Tel: (310) 458-8692
Fax: (310) 572-4495
www.santamonicaairport.org

BUSINESS HOURS

Mon-Fri 0730-1730 LCL
Closed Weekends / Open every other Friday 0800-1700 LCL

AIRFIELD INFORMATION

FIELD ELEVATION	177 feet MSL
Runway 21	177 feet MSL
Runway 03	118 feet MSL
RUNWAY LENGTH/WIDTH	4,973 FEET X 150 FEET (ASPH)
Runway Slope	1.2% down SW
Runway Lighting	MIRLs, VASI R03, REIL & PAPI R21
Maximum Weight (PPR)	60,000 lbs. Maximum Certified Landing Weight (dual wheel)

TRAFFIC PATTERN

Left Traffic	Runway 21
Right Traffic	Runway 03
Pattern Altitude	1,400 feet MSL Single-Engine 1,900 feet MSL Multi-Engine

AIRPORT MANAGEMENT

Airport Administration	(310) 458-8591
Noise Management Office	(310) 458-8692
Airport Police (Airport Service Officers)	(310) 458-2253

AIRPORT FREQUENCIES

Noise Management Office	122.85 MHz
ATIS	119.15 MHz or (310) 450-4620
Tower	120.1 MHz (0700 to 2100 local)
Ground Control	121.9 MHz (0700 to 2100 local)
Unicom	122.95 MHz (after hours)
VOT	113.9 MHz
SMO VORTAC	110.8 MHz
Flight Services (Lockheed Martin)	(800) 992-7433

FIXED BASE OPERATORS

Atlantic 122.95 MHz	American Flyers 123.3 MHz
(310) 396-6770 AIRINC 129.375	(310) 390-4571
Chevron 100LL & Jet A	BP Fuels 100LL

INSTRUMENT APPROACH PROCEDURE

VOR or GPS-A Runway 21

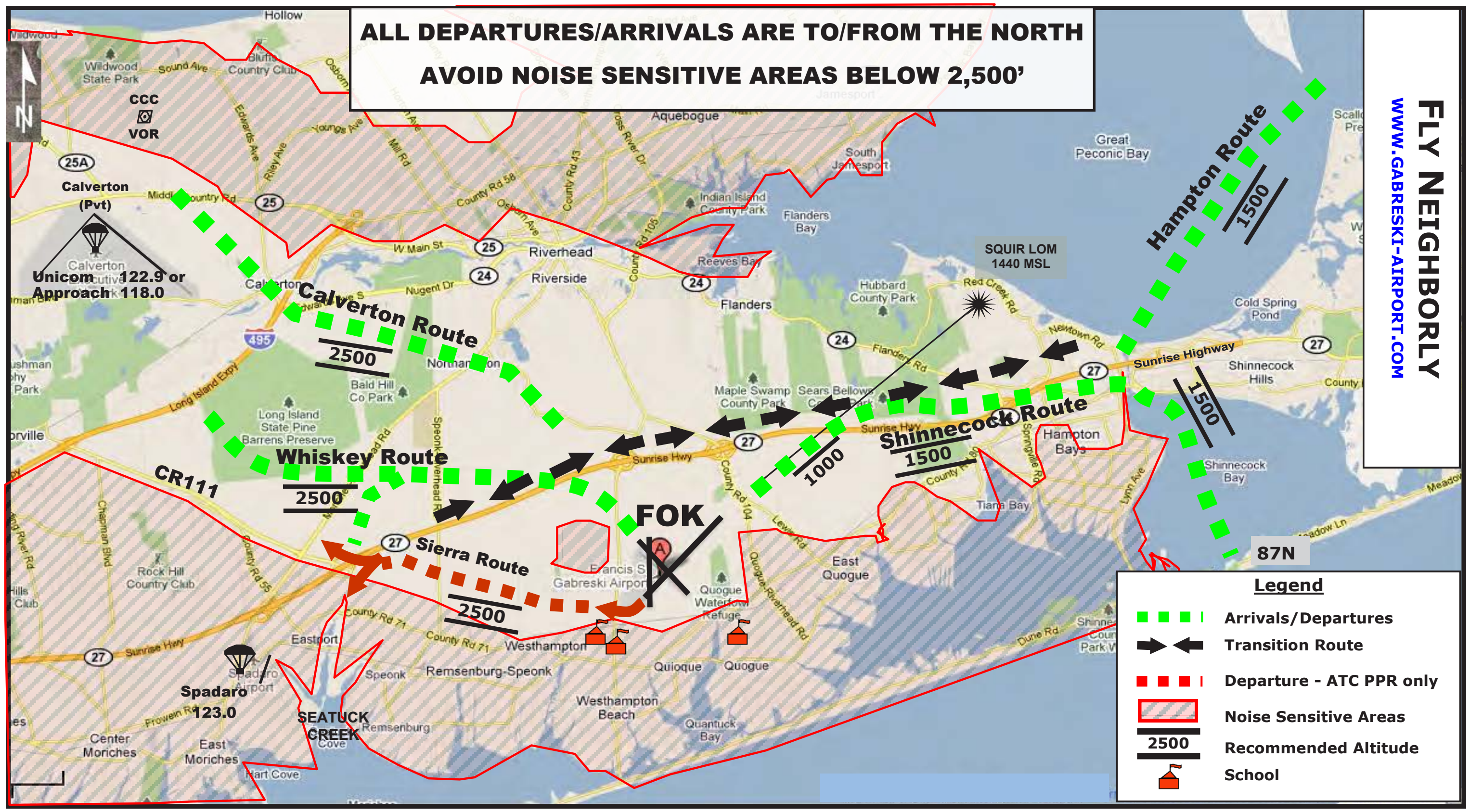
Thank you for flying neighborly . . .

BACKGROUND PHOTO COURTESY OF: AERIAL FOTOBANK INC.


HELICOPTER
VFR OPERATIONS ONLY
NOT FOR NAVIGATIONAL USE
Pacific Palisades
Pacific Ocean
Pacific Coast Highway
Sepulveda Pass
Veteran's Hospital
UCLA
For Noise Mitigation Purposes Cross the Airport Boundary at or Above 900' MSL
Santa Monica Pier
Lincoln Blvd
North Arrival
Century City
Twin High-Rise
Right and Left turns permitted after shoreline.
3
21
No left turns prior to Lincoln Blvd
SMO VOR 110.8
South Arrival
Venice Pier
Venice Blvd
Marina del Rey
Sony Studios
405
10
1
Runway 21 Departures -
Offset at the END of the runway abeam the VOR to overfly the golf course.
Noise Monitor Sites (Six)
Runway 3 Departures -
Fly straight out.
No turns prior to 405 Freeway.
Information Systems Department Geographic Information Systems, David Mrak June 1, 1999
© City of Santa Monica. All rights reserved.

Gabreski Airport (FOK) Fly Neighborly Voluntary Noise Abatement Program

Helicopter Routes



ARRIVALS: Enter Class D airspace from ***NORTH*** of ***Sunrise Hwy*** via the ***WHISKEY***, ***CALVERTON, or Shinnecock*** routes. Fly over wooded area between the LIE (495) and Sunrise Highway (27).

DEPARTURES: Depart northbound climbing to 2500 ft on the WHISKEY or CALVERTON routes. Use southbound SIERRA route only at ATC direction due to traffic or weather.

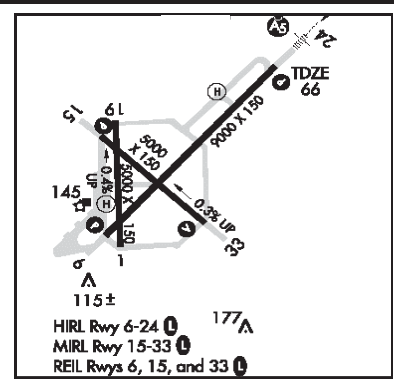
Do not fly south of AIRPORT unless directed by ATC or the Tower. Remain at 2500 ft. until one (1) mile from the airport.

Note: The Transition can also be used to access other East End airports. Use the Transition Route to access the Hampton or Shinnecock Route.

Frequencies

ASOS:	119.925
GROUND:	121.8
TOWER:	125.3
APPROACH:	
EAST:	125.97
WEST:	118.0
UNICOM:	
SheltAir	130.20
Malloy	122.95

Not to be used for navigation



RECOMMENDED VFR
DEPARTURE PROCEDURES

Note: All departures should be flown *Northbound* whenever possible.

- **North - Use the Whiskey Route -** Climb to 2500 ft. Turn on course after crossing Sunrise Highway or as directed by Tower.
- **South (only if traffic or wind conditions require) - Use Sierra Route -** Helicopter departures to the south should expect RWY 24. Fly RWY heading to airport boundary or railroad tracks. Turn right to 270 degrees and climb to 2500 ft. Turn south over Seatuck Creek (see map).
- **To Southampton Heliport (87N): Use Shinnecock Route** (see map) - Fly northeast bound. Climb to 1500 ft.
- **Police Helicopter Operations:** During non-emergencies, Police helicopters should plan to follow all helicopter noise abatement procedures whenever possible.

Suffolk County
Francis S. Gabreski Airport
Westhampton Beach, New York
(631) 852-8095
WWW.GABRESKI-AIRPORT.COM

TRANSITION PROCEDURES

- **DO NOT ENTER GABRESKI AIRSPACE FROM THE SOUTHWEST OR WEST. *These locations contain noise sensitive areas.***
- Helicopter transitions through the Class D airspace will be granted via north of Sunrise Highway at 1600 ft. (see transition route on map). Do not request to over-fly the airport.
- Flight crews departing the New York Metropolitan area should brief the route into the wooded areas north of Sunrise Highway prior to departing the city to avoid over-flying noise sensitive areas. This will be especially important during MVFR conditions when the requested cruise altitude of 2500 ft. AGL cannot be flown.
- **Follow Eastern Region Helicopter Council's recommended flight paths into the wooded areas north of Sunrise Highway. http://www.erhc.org**
- **SOUTH SHORE ROUTE - If landing at FOK** Helicopters using the South Shore Route should transition into the wooded areas north of Sunrise Highway west of Gabreski Airport. Enter Class D Airspace north of Sunrise Highway. Use one of the many sparsely populated areas along the south shore for access. If continuing on to Southampton Heliport (87N) or East Hampton Airport, continue along FAA published South Shore Route.
- **NORTH SHORE ROUTE** - Helicopters using the North Shore Route should transition to the airport northwest of Gabreski using the Calverton or Whiskey Route. There are a number of open space and sparsely populated areas to cross into the wooded areas north of Sunrise Highway.
- **FROM THE WEST** - Use Whiskey Route - Follow the LIE East into the wooded areas north of Sunrise Highway. Stay north of Sunrise Highway until directed by Tower.
- **FROM THE EAST**, - Use Hamptons or Shinnecock Route. Fly north of Sunrise Highway to the airport - enter as directed by Tower. Plan on flying south of the RWY 24 final approach path or as directed by Tower.

GABRESKI AIRPORT - KFOK
VOLUNTARY
NOISE-ABATEMENT PROCEDURES
HELICOPTERS

THIS BROCHURE HAS BEEN PREPARED TO HELP HELICOPTERS OPERATE IN THE QUIETEST MANNER POSSIBLE CONSISTANT WITH SAFETY, AND HELP THE AIRPORT BE A GOOD NEIGHBOR TO ITS SURROUNDING COMMUNITIES.

- Voluntary **night curfew** - 11PM to 7AM.

RECOMMENDED VFR
ARRIVAL PROCEDURES

Runway 6/24 in use:

- **From northwest** - Use Whiskey or Calverton Route. Expect to make an initial approach from north of Sunrise Highway to the numbers of RWY 15.
- **From northeast** - Use Hampton/ Shinnecock Route. Remain east of the extended centerline of RWY 6/24 until directed by Tower.
- **From Southampton Heliport (87N):** Use Shinnecock Route. Fly North to Shinnecock Canal - climb to 1500 ft. Turn west and remain north of Sunrise Highway. Follow Tower instructions. Descend to 1000 ft. by Sunrise Highway as you approach the airport from the northeast. Remain south of the RWY 24 final approach path unless directed by Tower (see map).

Runway 15/33 in use:

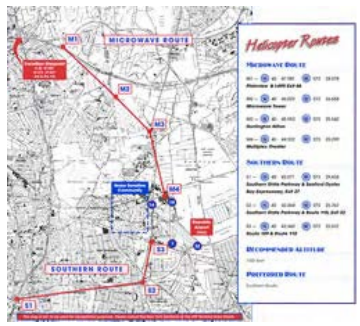
- **From northwest** - Remain north of Sunrise Highway and follow Tower instructions.
- **From northeast -** Make an initial approach to the numbers of RWY 24.

These procedures are not intended to pre-empt the responsibilities of the pilot-in-command for safe aircraft operations. Recommended procedures are not intended to conflict with instructions from ATC or those which are the exclusive authority of the FAA.

REPUBLIC
Long Island's Executive Airport

Pilot Infomation

- **Pilot Shops**
- **Approach & Departure Procedures**
- **Republic Tower Letter to Airmen 10-1**
- **Rates and Charges**
- **FRG Airport Diagram**
- **Noise Abatement Procedures**
  - Light General Aviation Noise Abatement Procedures
  - Jet Noise Abatement Procedures
  - Helicopter Noise Abatement Procedures
- **Aircraft Owner Operator Meeting Information**
- **2009-10 New York State Airport Directory**
- **Federal Aviation Administration (FAA)**
- **New York State Department of Transportation**
- **Garden of Remembrance**
- **Wildlife**
  - Wildlife Hazard Assessment Presentation - 2012



Helicopter Noise Abatement Procedures

MICROWAVE ROUTE:

Arrival: Enter the Route at the Long Island Expressway. Proceed directly to the Microwave Tower. Then, fly heading 140° until reaching the Huntington Hilton and Route 110. Follow Route 110 South until reaching the airport.

Departure: Fly northbound and parallel Runway 01/19 until reaching the National Amusements Multiplex Theater. Follow Route 110 north until reaching the Huntington Hilton. Then, fly 320° to the Microwave Tower, intercept the Long Island Expressway and proceed on course.

SOUTHERN ROUTE:

Arrival: Join the Southern State Parkway at the Seaford Oyster Bay Expressway. Fly heading 90° until reaching Route 110. Then, fly northbound to the intersection of Route 109.

Departure: Fly southbound and parallel Runway 01/19 until reaching the intersection of Route 109 and Route 110. Then, overfly the Southern State Parkway until reaching the Seaford Oyster Bay Expressway and proceed on course.

TRANSITION ROUTE:

Use the Seaford Oyster Bay Expressway, Route 135 when moving from The Microwave Route to the Southern Route or vise versa to avoid flying over noise-sensitive communities.

PARKWAY ROUTE:

Available only to helicopter operators who are signatories to the Letter of Agreement for Special VFR Operations with the Air Traffic Control Tower.

TRANSITIONS FROM THE NEW YORK CITY HELICOPTER ROUTE

NYC Routing to Microwave Route:

TRACK — From Mineola proceed to M1.

THROGS — Join the Long Island Expressway and proceed to M1.

NYC Routing to Southern Route:

SHORE — Join the Meadowbrook Route and proceed to the Southern State Parkway at N 40 41.457' W 073 34.530' and proceed to S1.

MEADOWBROOK — Join the Southern State Parkway at N 40 41.457' W 073 34.530' and proceed to S1.

NOISE ABATEMENT PROGRAM
The Helicopter Routes were established in 1993 to reduce sound levels in the vicinity of the airport. When practical, possible and feasible, operators are also encouraged to:

- Avoid Approaching The Airport Directly From The West Due To Noise Sensitive Area One Mile West Of The Airport.
- Avoid Flying Between 10:00 pm and 7:00 am
- Follow Republic Airport Noise abatement procedures.
- Use Manufacturer's Suggested Noise Abatement Techniques.
- Use Helicopter Association International Fly Neighborly Guide.
- Consult The Airport Facility Directory.

These measures are recommended practices in an effort to reduce sound levels. In all cases, safety and air traffic control instructions take precedence.

AIRPORT FREQUENCIES

Remote Transmitter Receiver (RTR)	128.25 (2300 – 0700 Local)
Clearance Delivery	128.25
Tower	118.8 (0700 – 2300 local)
CTAF	118.8 (2300 – 0700 Local)
Ground Control	121.6
ATIS	126.65
UNICOM/Airport Operations	122.95
Emergency	121.5
NY Approach Control	125.7
FSS	122.2/122.6

AIRPORT INFORMATION

Airport Operations Office	631.752.7707 ext. 108
Air Traffic Control Tower	631.454.2331
ASOS	631.752.8129
Snow Desk	631.752.7992
New York FSS	1.800.WX.BRIEF
New York Tracon	516.683.2984
Runway 01/19	5,516' X 150' (ASPH)
Runway 14/32	6,827' X 150' (ASPH)

Republic Airport (FRG) E. Farmingdale, NY 11735 / Phone: 631.752.7707 / info@republicairport.net

Town of East Hampton Airport
P.O. Box 836
East Hampton, NY 11937
631.537.1130

April 30, 2015

Helicopter Noise Abatement

The following Helicopter Noise Abatement Procedures have been developed in collaboration with the East Hampton Control Tower, the Eastern Region Helicopter Council (ERHC), and East Hampton Airport Operations. These routes are strongly recommended in order to mitigate the noise associated with helicopter operations at HTO.

This plan has been selected to best relieve communities surrounding East Hampton Airport from the noise produced from Arriving and Departing helicopter traffic. While noise mitigation is extremely important, these procedures should in no way supersede the safe operation of aircraft. These procedures will be monitored for compliance at all checkpoints for accuracy of the route and recommended altitudes. The ERHC will receive weekly compliance reports.

ARRIVALS

November: (figure 1)

Arrivals from the west proceed to "November 1" (N40.59.5.48 W072.25.58.48) at or above 3500 feet, continue to "November 2" (N40.58.15.10 W072.20.26.56) at or above 3000 feet, to "November 3" (N40.58.2.70 W072.17.31.67) at or above 2500 feet, then to the airfield.

Sierra Inbound: (figure 2)

Arrivals from the south fly along the south shore approximately half a mile offshore, via S1 (N40.52.56.30 W072.20.8.26) at or above 3000 feet until passing S2 (N40.53.55.90 W072.17.11.03) which is a point of converging traffic departing East Hampton Airport (HTO) on the Sierra Route.

Proceed past the mouth Georgica Pond to S3 (N40.55.52.92 W072.12.35.84) which is a flyover fix and enter a left base for Runway 28 or the parallel taxiway depending on the traffic at the airport and the direction of the air traffic controller.

Please hold your altitude as high as possible. Please look for fixed wing traffic in the traffic pattern or on approach to the airport. Overhead Georgica arrivals with spiraling descents on the north side of the airport are no longer expected and impede the safe flow of traffic on the north side of the airport.

DEPARTURES

Echo: (figure 3)

Depart heading northwest over the power lines to “Echo 1” (N40.58.02.0 W072.16.16.5). Turn right, remaining well east of Town Line Road and proceed to the East side of Barcelona Neck “Echo 2” (N41.00.47.5 W072.15.44.3). “Echo 2” is a mandatory flyover point. Please keep your tracks away from the village of Sag Harbor. Use max performance climb so as to cross Barcelona Neck at or above 3000 ft. MSL. Proceed then to “Echo 3” (N41.02.55.9 W72.17.81.4) and then to “Echo 4” (N41.01.73.5 W72.22.75.4). Please avoid any over flight of Shelter Island and North Haven.

Sierra Outbound: (figure 2)

Depart the airport via runway heading until passing 1,500 feet in the vicinity of O1 (N40.57.25.83 W072.17.6.39) then turn left to S2 (N40.52.56.30 W072.17.11.03) climbing to 3,000 feet BROC. After reaching S2, proceed westbound approximately a half mile off shore.

PLEASE NOTE:

The success of noise abatement depends on the requested routes and altitudes being observed with precision to the greatest extent possible.

East Hampton Airport Curfew: 11pm to 7am Daily

Pathways depicted on the map are for illustration only and may not conform precisely to coordinates.

The Control Tower will advise pilots of traffic conflicts on each of the voluntary helicopter routes and will retain the option of issuing arrival and departure instructions as traffic permits.

Ramp Operations

All arrivals and departures to HTO should be to and from active runways or parallel taxiways so as not to interfere with fixed wing traffic. Approaches and departures directly to and from the **Terminal Ramp** area are **prohibited.**

No part of a helicopter, **including rotor tips**, is to come closer than **100 feet** to the Terminal building. Parking spot 1 in front of the Terminal Building is reserved for fixed wing aircraft only.

Boarding and deplaning a helicopter with the rotors turning should be avoided. Use of a rotor brake, if installed is encouraged.

Operating rotors for an extended period of time on the ramp is discouraged. **More than five (5) minutes is considered excessive.** Your cooperation with this limit is for noise and environmental considerations. Passengers who demand rotors turning when they arrive should be informed of this limit. If it is necessary to operate engines and/or rotors for extended periods of time, please move to one of the transient helicopter pads or as far from the Terminal Building as possible.

Other Considerations

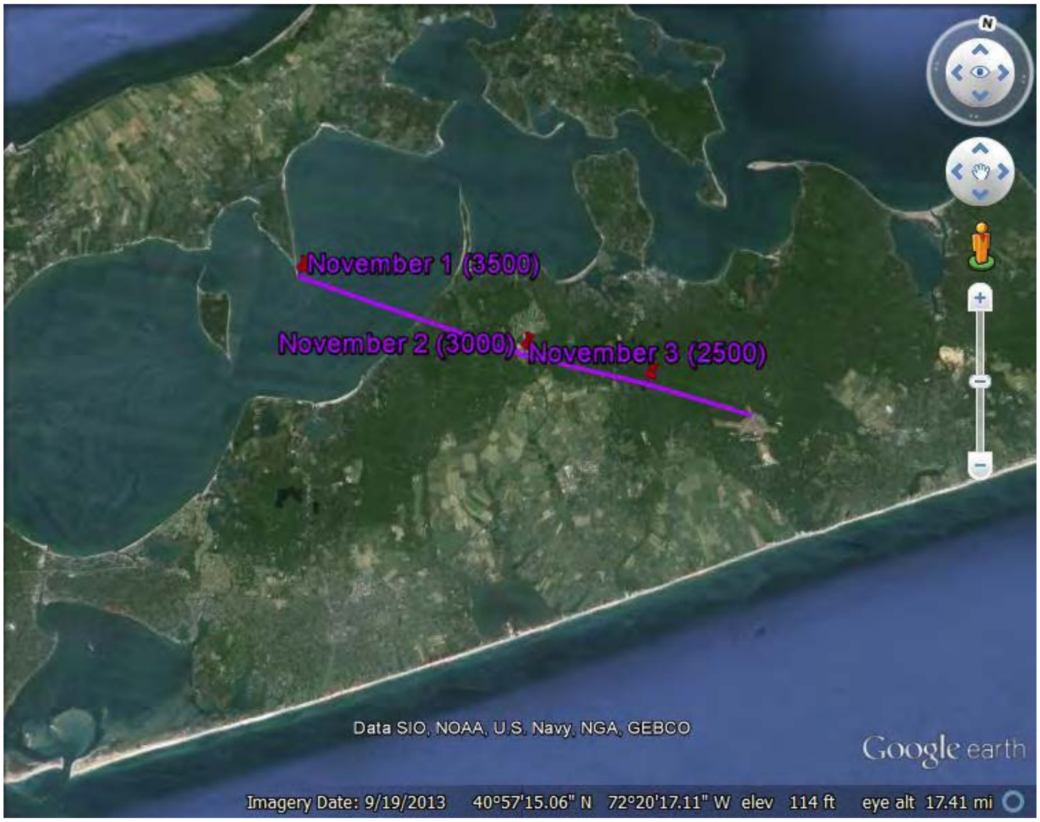
Helicopter operations are the most serious environmental challenges we have at HTO. Anything you can do to mitigate the environmental impact of your operations will be greatly appreciated by this office and the surrounding communities.

Noise complaints increase dramatically during periods of inclement weather because of aircraft flying below a broken or overcast layer. While such operations are strongly discouraged (and may violate FAR 91.13), adherence to suggested routes is even more important.

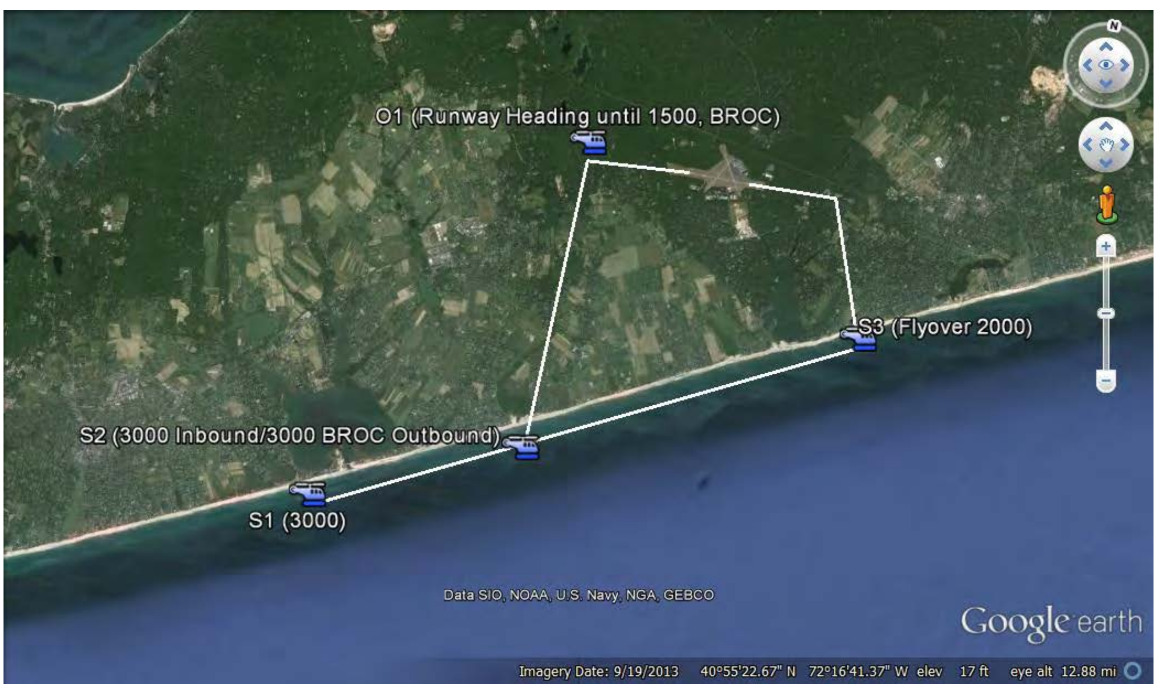
The area surrounding HTO has substantial air traffic during the summer months some of which may have neither a radio nor transponder. Adherence to the suggested routes reduces the potential for conflicts but does not eliminate it. Frequent announcements of position, altitude and intended route are strongly encouraged. ***See and Avoid*** is paramount, all available aircraft lights should be illuminated day or night. Coordination with or monitoring of New York approach frequency is recommended to help avoid IFR traffic that may otherwise appear suddenly from IMC conditions. Operators are reminded that merely because an operation may be legal does not necessarily make it safe.

Sincerely,

Jémille R. Charlton
Airport Director



November Route (figure 1)



Sierra Route (figure 2)

Echo Route (figure 3)

APPENDIX F

Example Letter of Agreement

SANTA MONICA AIRPORT - SANTA MONICA TOWER

LETTER OF AGREEMENT

Effective: August 10, 2006

SUBJECT: Noise Management Procedures for Helicopter Operations

1. **PURPOSE:** In an effort to minimize helicopter noise, this Agreement establishes procedures for the operation and control of helicopters landing, departing, and transitioning within the Santa Monica Class D Surface Area.

2. **CANCELLATIONS:** Santa Monica Helicopter Operations Letter of Agreement between Santa Monica Tower and Santa Monica Airport dated **October 22, 1998.**

3. **SCOPE:** These procedures apply to all helicopters landing, departing or over-flying Santa Monica Airport that are operating under VFR conditions in the Santa Monica Class D Surface Area. They are supplementary to those procedures contained in the Federal Aviation Administration Air Traffic Control (ATC) Handbook, and shall not be construed as approval or permission to violate any Federal Aviation Regulation (FAR) or any other regulation. The City and the FAA acknowledge and agree that vis-à-vis third parties, each of them is responsible for the enforcement of their own respective regulations and that neither of them has any responsibility for or authority to enforce any regulations established by the other. However, both the City and the FAA recognize that it is in their mutual interest to cooperate and exchange relevant information necessary to the successful implementation of the Agreement.

4. **PROCEDURES:**

   A. The City of Santa Monica will disseminate this Letter of Agreement to rotary-wing pilots concerning the provisions herein, including attachments.
   B. VFR helicopter operations will be conducted using the traffic patterns, areas, altitudes, routes and procedures specified in attachments to this Agreement.
   C. For noise abatement, pilots shall operate at a minimum altitude of 900 feet MSL when approaching Santa Monica Airport. ***Do not begin descent until over the airport boundary.***
   D. Departing helicopters are requested to avoid low altitude flight over the homes adjacent to the Airport.

E. All VFR helicopters landing at Santa Monica will report at one of the following reporting points:

Arrival - Reporting Points

North - Report Getty Center
NE - Report Blue Whale
East - Report Sony
South - Report Hughes Center
SW - Report Marina Del Rey
NW - Report Gladstone's

F. Arrival and Departure Procedures - Runway 21 in use.

(1) Arrivals (see attachment 1)

(a). Arrivals from the south will be asked to report Venice Blvd. mid field. When advised, cross the airport boundary and runway to the business park north of the airport remaining at or above 900' MSL. Execute a descending turn within the airport boundary east of the control tower to a landing point midway down the runway (to the extent possible) or to the north taxiway.

(b). Arrivals from the north will be asked to report over the 10 Freeway mid field. When advised, cross the business park north of the airport and the airport boundary remaining at or above 900' MSL. Execute a descending turn within the airport boundary east of the control tower to a landing point midway down the runway (to the extent possible) or to the north taxiway.

(c). All helicopters will remain North or South of Runway 21 and avoid the flow of other arriving fixed-wing aircraft until cleared to use the runway or north taxiway.

(2) Departures

(a). Overfly the Penmar Golf Course west of SMO. This procedure requires an initial left 10 degree turn at the end of the runway, and then a right turn to heading of 225 degrees to maintain a flight track over the golf course. Do not initiate the left 10 degree turn prior to end of runway. Helicopters will be sequenced with the flow of fixed-wing departures - no left crosswind turns permitted prior to Lincoln Boulevard. Helicopters departing the area to the north and east are requested to turn at the shoreline.

G. Arrival and Departure Procedures - Runway 03 in use.

(1) Arrivals (see attachment 2)

(a). Arrivals from the south will be asked to report Venice Blvd. mid field. When advised, cross the airport boundary and runway abeam the tower to the business park north of the airport remaining at or above 900' MSL. Execute a descending turn around Supermarine to a landing point midway down the runway (to the extent possible) or to the north taxiway.

(b). Arrivals from the north will be asked to report over the 10 Freeway mid field. When advised, cross the business park abeam the tower north of the airport and the airport boundary remaining at or above 900' MSL. Execute a descending turn around Supermarine to a landing point midway down the runway (to the extent possible) or to the north taxiway.

(c). All helicopters will remain North or South of RY03 and avoid the flow of other arriving fixed-wing aircraft until cleared to use the runway or north taxiway.

(2) Departures

(a). Proceed straight out to the San Diego Freeway before executing a left or right crosswind turn. Helicopters will be sequenced with the flow of fixed-wing aircraft.

H. Regardless of route of flight, avoid flying over stationary or taxiing aircraft to minimize rotor-wash. Remain clear of the RY in use at all times unless approved by ATC.

I. Attachment 1(a). Helicopter Route Diagram - RY21 Procedures-North.

J. Attachment 1(b). Helicopter Route Diagram - RY21 Procedures-South.

K. Attachment 2(a). Helicopter Route Diagram - RY03 Procedures-North.

L. Attachment 2(b). Helicopter Route Diagram - RY03 Procedures-South.

5. **SIGNATURES**: This LOA agreed to by both parties as set forth herein:

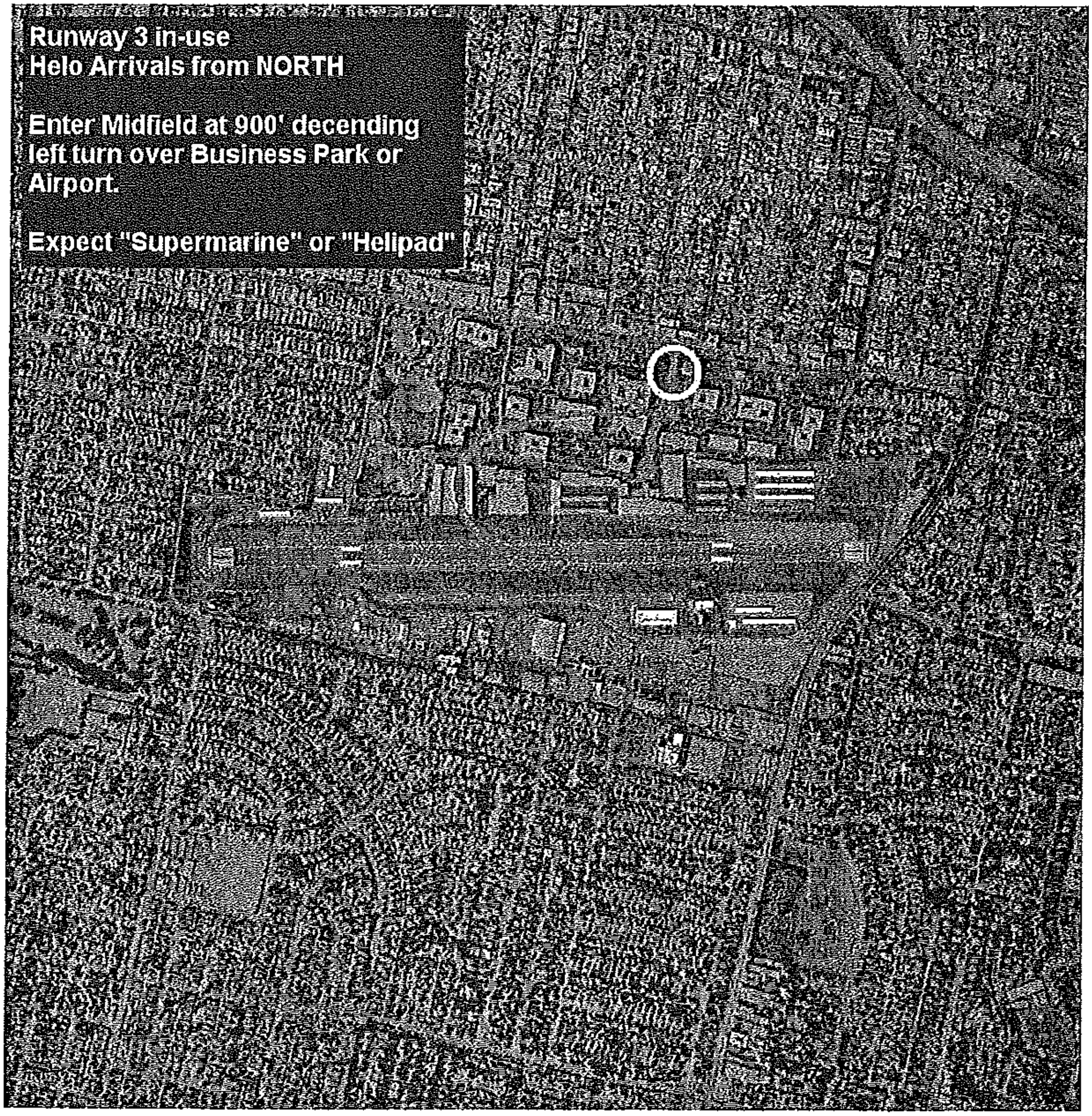
For Robert D. Trimborn
Airport Manager
Santa Monica Airport
City of Santa Monica

Michael Evangelista
Acting Air Traffic Manager
Santa Monica Control Tower
Federal Aviation Administration

Attachment 1(a)
Helicopter Route Diagram
RY21 Procedures – ARRIVALS FROM NORTH

Attachment 1(b)
Helicopter Route Diagram
RY21 Procedures – ARRIVALS FROM SOUTH

Attachment 2(a)
Helicopter Route Diagram
RY03 Procedures – ARRIVALS FROM NORTH



Attachment 2(b)
Helicopter Route Diagram
RY03 Procedures – ARRIVALS FROM SOUTH

ENDNOTES

1. Note that these nonacoustic influences are most productively addressed at the community rather than individual level. As described in the paper on Community Tolerance Level (CTL) (Fidell 2011), communities form unique attitudes about noise. Decades of efforts (e.g., Job 1988; Fields 1993) to quantify individual differences in sensitivity to aircraft noise have produced little information useful for prediction of annoyance prevalence rates or for regulation of aviation noise.
2. The ISO 1996-1 revision was, at the time of this writing, in the final publication stages at ISO after having been approved by the ISO committee and was pending publication.
3. In contrast, *horizontally* mounted objects (e.g., bric-a-brac on shelves or crockery in cupboards) must overcome gravity before they can rattle; in other words, rattle can only occur when the surface they are on accelerates at greater than 1 G.
4. FAA's endorsement of A-weighted noise measurements for assessment of community noise impacts is in large part based on limitations of field-portable, analog-era sound level meters. Lacking the capacity for combining one-third octave band sound level measurements and identifying tonal signal components, it was not possible decades ago to directly measure PNL(T) values in the field.
5. Readers interested in additional detail about these frequency-weighting networks and noise metrics are referred to Mestre et al. (2011).
6. Idealized conditions include a stable and still atmosphere, close adherence to published flight paths and procedures, and ideal pilot technique. Because relatively few helicopter operations are likely to occur under all of these conditions, and because of the great sensitivity of helicopter noise emissions to minor changes in operating conditions, actual noise emissions in the vicinity of helipads may diverge considerably from predicted noise emissions.

Abbreviations and acronyms used without definitions in TRB publications:

A4A	Airlines for America
AAAE	American Association of Airport Executives
AASHO	American Association of State Highway Officials
AASHTO	American Association of State Highway and Transportation Officials
ACI–NA	Airports Council International–North America
ACRP	Airport Cooperative Research Program
ADA	Americans with Disabilities Act
APTA	American Public Transportation Association
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
ATA	American Trucking Associations
CTAA	Community Transportation Association of America
CTBSSP	Commercial Truck and Bus Safety Synthesis Program
DHS	Department of Homeland Security
DOE	Department of Energy
EPA	Environmental Protection Agency
FAA	Federal Aviation Administration
FAST	Fixing America's Surface Transportation Act (2015)
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
HMCRP	Hazardous Materials Cooperative Research Program
IEEE	Institute of Electrical and Electronics Engineers
ISTEA	Intermodal Surface Transportation Efficiency Act of 1991
ITE	Institute of Transportation Engineers
MAP-21	Moving Ahead for Progress in the 21st Century Act (2012)
NASA	National Aeronautics and Space Administration
NASAO	National Association of State Aviation Officials
NCFRP	National Cooperative Freight Research Program
NCHRP	National Cooperative Highway Research Program
NHTSA	National Highway Traffic Safety Administration
NTSB	National Transportation Safety Board
PHMSA	Pipeline and Hazardous Materials Safety Administration
RITA	Research and Innovative Technology Administration
SAE	Society of Automotive Engineers
SAFETEA-LU	Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (2005)
TCRP	Transit Cooperative Research Program
TDC	Transit Development Corporation
TEA-21	Transportation Equity Act for the 21st Century (1998)
TRB	Transportation Research Board
TSA	Transportation Security Administration
U.S.DOT	United States Department of Transportation

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