Federal Aviation Administration

REPORT TO CONGRESS

Nonmilitary Helicopter Urban Noise Study

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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)

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NONMILITARY HELICOPTER URBAN NOISE STUDY

* Note: The following information given in the List of Appendixes is available for reference only on the FAA website located at: http://www.aee.faa.gov under the topic entitled "Sec.747-Nonmilitary Helicopter Noise."

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LIST OF ABBREVIATIONS

AGL	Above Ground Level
ANCA	Airport Noise and Capacity Act
ANSI	American National Standards Institute
ASEL	A-weighted Sound Exposure Level
ASNA	Aviation Safety and Noise Abatement Act
AStar	Eurocopter (former Aerospatiale) helicopter
ATC	Air Traffic Control
BVI	Blade Vortex Interaction
B206	Bell 206 Helicopter
B&K	Brüel & Kjær
CAEP	Committee on Aviation Environmental Protection
CFR	Code of Federal Regulations
CPA	Closest point of approach
dB	Decibel
dGPS	Differential Global Positioning System
DAT	Digital Audio Tape
DNL	Day-Night Sound Level
DOT	Department of Transportation
EC	Eurocopter Corporation
EGA	Excess Ground Attenuation
EMS	Emergency Medical Services
ENG	Electronic News Gathering
EPA	Environmental Protection Agency
EPNL	Effective Perceived Noise Level
FAA	Federal Aviation Administration
FAR	Federal Aviation Regulations
FICAN	Federal Interagency Committee on Aviation Noise
GPS	Global Positioning System
HNM	Helicopter Noise Model
HP	Hewlett Packard
HSI	High Speed Impulsive noise
ICAO	International Civil Aviation Organization
IFR	Instrument Flight Rules
INM	Integrated Noise Model
INMrv	INM Research Version
LAAS	Local Area Augmentation System
LEQ	Equivalent Sound Level
Lmax	Maximum A-Weighted Sound Level
LSP	Liberty State Park, New Jersey
MD	McDonnell Douglas
MDHI	McDonnell Douglas Helicopters Incorporated
NAS	National Airspace System
NASA	National Aeronautics and Space Administration

NEPA	National Environmental Policy Act
NOTAR	No Tail Rotor
NRTC	National Rotorcraft Technology Center
NYC	New York City
PNLT	Perceived Noise Level Tone Corrected
R&D	Research and Development
RITA	Rotorcraft Industry Technology Association
SAE	Society of Automotive Engineers
SEL	Sound Exposure Level
SIL	Speech Interference Level
SPL	Sound Pressure Level
SS	Sight Seeing
S-76	Sikorsky Model S-76 Helicopter
TSPI	Time Space Position Information
UNC	Uncontrolled Condition
UTC	Universal Coordinated Time
VFR	Visual Flight Rules
VOR	Very High Frequency Omni-directional Range
VTOL	Vertical TakeOff and Landing
vTSPI	Video Time Space Position Information
WAAS	Wide Area Augmentation System
WHO	World Health Organization

1.0 Executive Summary

In response to public concerns about nonmilitary helicopter noise impact on densely populated communities, the United States Congress directed the Secretary of Transportation to investigate and develop recommendations on reducing helicopter noise effects. Legislative guidance was developed and specified in the FAA authorization act entitled "Wendell H. Ford Aviation Investment and Reform Act for the 21st Century" (Public Law 106-181) under Section 747 - Nonmilitary Helicopter Noise. The Federal Aviation Administration (FAA) carried out this study on behalf of the Secretary.

The FAA outlined a three-step approach to perform this study. The first step of the FAA approach was a comprehensive literature review of current noise effects on human beings. The review identified several socio-acoustic concerns addressed in the report. These were:

- Noise-induced hearing impairment;
- Interference with speech communication;
- Effects of noise on performance;
- Sleep disturbance;
- Cardiovascular and physiological effects;
- Mental health effects; and
- Effects of noise on residential behavior and annoyance.

Second, FAA solicited public input through Federal Register notices and two public workshops.[1] This generated numerous comments from private citizens, elected officials, civic group representatives, and the helicopter industry. The comments were categorized into operational and non-operational issues. The operational issues most frequently expressed were:

- Minimum altitude for overflight and hover;
- Operational routes & routing design guidelines;
- Hover duration time;
- Retirement of noisiest helicopters;
- Visible identification markings;
- Frequency of helicopter operations (number of flights);
- Time frame of helicopter operations (hours of operation);
- Heliports/airports operations (i.e., ground run-up duration);
- Noise abatement procedures;
- Noise certification limit stringency; and
- Implementation of noise reduction technology (i.e., helicopter "hushkits").

The nonoperational issues most frequently expressed were:

- Effectiveness of voluntary "Fly Neighborly" program;
- Redundancy of Electronic News Gathering (ENG) flights;

[1] 65 FR 39220 (June 23, 2000) and 65 FR 49630 (August 14, 2000).

- Acceptance of public service helicopter operations; i.e., law enforcement, emergency medical services (EMS), and fire fighters;
- Visual Flight Rule (VFR)/Instrument Flight Rule (IFR) Air Traffic Control (ATC) operations access for helicopters;
- Empowerment of local municipalities with airspace control;
- Accounting for military helicopter impact;
- Need for a socio-acoustic (psychoacoustic) study relating medical and health effects;
- Tracking of helicopter traffic growth and noise measures to quantify impact of noise sensitive community sites (parks, hospitals, neighborhoods, etc);
- Utilization of differential Global Positioning Systems (dGPS) approach/departure for noise abatement operations; and
- Insensitivity of A-weighted measurements in accounting for low-frequency noise impact of helicopters.

The third part of the FAA approach involved the acquisition of helicopter noise measurements to quantify noise levels in a densely populated metropolitan area. This was done by taking sets of noise measurements within the urban center of New York City. The FAA's preliminary *in-situ* noise measurements showed that increasing operational altitude does reduce noise from helicopters (see Section 7.2 and Appendix G), corroborates operational noise measurements reported in the New York City Master Plan Report, and supports the industry's voluntary operational guidance to "fly higher" altitudes.

<u>Conclusions and Recommendations</u>:

The FAA offers the following conclusions and recommendations based upon the study:

- <u>Additional development of models for characterizing the human response to helicopter noise should be pursued</u>. Civil helicopter annoyance assessments utilize the same acoustic methodology adopted for airplanes with no distinction for a helicopter's unique noise character. As a result, the annoyance of unaccustomed, "impulsive" helicopter noise has not been fully substantiated by a well-correlated metric. Comments from both the helicopter industry and the public strongly recommended that further socio-acoustic investigations be pursued. Additional civil helicopter annoyance studies may help refine current noise measurement analysis methodology that would lead to improved noise mitigation effectiveness. The Federal Interagency Committee on Aviation Noise (FICAN) should charter a technical study to focus on low frequency noise metric to evaluate helicopter annoyance, including performance of multi-year socio-acoustic (noise) studies to correlate helicopter annoyance and health effects of urban helicopter operations. In the meantime, the FAA will continue to rely upon the widely accepted Day-Night Sound Level (DNL) as its primary noise descriptor for airport and heliport land use planning. The FAA will also continue the use of supplemental noise descriptors for evaluation of helicopter noise issues.

  To date, this recommendation has been incorporated into the Rotorcraft Research and Development Initiative for Vision 100 – Century of Aviation Reauthorization Act (Public Law 108-176) under Sec. 711. For Sec. 711, NASA, FAA, and the rotorcraft industry defined a 10-year rotorcraft research and development (R&D) plan that included the study of Psychoacoustics. The research proposes to determine human annoyance levels due to helicopter noise, both in its native condition and synthetically modified. Studies would be conducted to uncover neglected characteristics of noise and develop a refined metric more representative of the true human response.

- Further operational alternatives that mitigate noise should be explored. A number of operational alternatives, proposed by the public and industry, have the potential to mitigate urban nonmilitary helicopter noise and preserve the safe and efficient flow of air traffic. In particular, the FAA found:

  - Noise reduction benefits can be achieved with higher altitude flight. With more conclusive demonstrations addressing safety, such noise mitigation approaches could be integrated within the ATC design planning in specific urban airspaces;

  - Optimal helicopter route planning to avoid noise sensitive areas will require comprehensive evaluation for each specific region of concern;

  - The promotion of noise abatement procedures should be pursued on two fronts – with helicopter pilots and air traffic control personnel. The FAA will continue training ATC personnel to increase awareness of noise abatement procedures that best mitigate noise over communities; and

  - The use of advanced technologies, such as dGPS, aids in helicopter approach and departure procedures do show to be beneficial for noise abatement operations. Preliminary dGPS/noise research sponsored by the National Rotorcraft Technology Center (NRTC)/ Rotorcraft Industry Technology Association (RITA) has indicated promising noise reductions using more precise procedures.

  The implementation of any of these alternatives would require comprehensive evaluation, and demonstration where appropriate on a case-by-case basis, in accordance with all applicable FAA orders and regulations. Also, careful consideration would have to be taken of any ATC changes to an urban segment of the National Airspace System (NAS) that could impact the heavily utilized and highly burdened large commercial transport sector. Finally, funding levels required to develop and explore the technology and procedures listed above will be significant.

  Similarly under the 2004 Vision 100 Rotorcraft R&D plan, operational noise reduction studies were defined to aid in the noise mitigation of legacy helicopters, such as the Sikorsky S-76 and Bell helicopter products. The expansion of noise abatement flight techniques would be tested for consistency with safety and passenger comfort for several classes of rotorcraft: light, medium and advanced configurations. At the R&D program conclusion, the compilation of noise mitigation technology and abatement operational procedures is to be integrated and demonstrated in a selected single flight vehicle for noise and system validation.

Also, under the Vision 100 plan, there is the "Zero ceiling/Zero visibility" operational goal that addresses advances in navigational system such as wide area augmentation system (WAAS) and local area augmentation system (LAAS) and moving to a comprehensive differential global position system (dGPS) precision navigation capability. Such research applications have proven beneficial to noise mitigation and are expected to enhance the noise abatement operational procedures development.

- Emergency helicopter service should be exempt from restrictions. A key outcome of the FAA-hosted workshops was the mutual agreement among public and industry participants that emergency helicopter service (air medical, law enforcement, fire-fighting, public services, etc.) should be exempted from any proposed limitations or restrictions considered by Congress following this study. These services are time-critical and provide a "noise-excusable" public service.
- Helicopter operators and communities should develop voluntary agreements to mitigate helicopter noise. Federal, state, and local governments encourage voluntary mutual cooperation by helicopter operators, the community, and local authorities in the establishment of a "noise response" process. Federal, state and local governments establish business incentives that encourage the "pooling" of helicopter operations, especially for redundant ENG operations.

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2.0 Introduction

Helicopters serve specialized functions and important roles in the Nation's commerce and transportation system. Helicopters are a versatile and valued segment of the multimodal transportation infrastructure. The helicopter's unique hovering, vertical takeoff and landing capabilities fulfill a broad range of missions. Helicopters support vital roles including air ambulance services; Federal, state, and local law enforcement patrol; flexible corporate shuttle services; news coverage; parcel distribution; aerial tourism; firefighting; and heavy lift capability.

Over the past several decades, significant technological advances have been made in aviation noise reduction. However, research and development activities have succeeded primarily in reducing the noise levels associated with commercial transport jet airplanes. Much of the scientific investments for rotorcraft has benefited in physical understanding and phenomenon modeling, such as Blade Vortex Interaction (BVI) and High Speed Impulsive (HSI) noise during approach and high speed cruise, respectively. A Congressional Report on "Quiet Aircraft Technology for Propeller-Driven Airplanes and Rotorcraft" identified the technical status of the United States Research and Technology (R&D) for the rotorcraft sector. The 1996 report concluded that, in general, quiet rotorcraft technology was immature and too slow to market.

A notable "low noise" technological success was achieved with the non-conventional NOTAR (NO TAil Rotor) anti-torque design by MDHI (formerly McDonnell Douglas Helicopters Incorporated). Yet, a major challenge continues to exist in balancing cost to implement low noise technology within an overall affordable market cost to users and operators.

The FAA and the International Civil Aviation Organization (ICAO) continue to assess and revise rotorcraft noise certification requirements for increased noise stringency that are based upon reasonably achievable noise reduction technology. The noise certification process establishes reference conditions for the manufacturer to demonstrate that a design complies with the standard.

In the New York City metropolitan area, there has been an ongoing dispute over helicopter noise. Communities there are concerned that helicopter noise impacts their quality of life. Consequently, New York City launched a comprehensive master plan analysis that studied: 1) the City's heliport "needs", 2) heliport guidelines taking into consideration the environment and socioeconomic issues of the community, 3) future heliport planning, 4) present and future airspace integration issues, and 5) proposed financial planning and implementation schedule.[2]

2.1 Mandate

In response to public concerns about nonmilitary helicopter noise impact on densely populated communities, the U.S. Congress directed the Secretary of Transportation to investigate the effects of helicopter noise and to develop recommendations for reducing the effects.

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[2] Edwards and Kelcey Engineering, Inc., "Heliport and Helicopter Master Plan for the City of New York," Final Report, March 1999.

This mandate was specified in Section 747 (Public Law 106-181) of the FAA authorization act entitled “Wendell H. Ford Aviation Investment and Reform Act for the 21st Century.” It states:

Section 747. - Nonmilitary Helicopter Noise

(a) IN GENERAL- *The Secretary shall conduct a study - (1) on the effects of nonmilitary helicopter noise on individuals in densely populated areas in the continental United States; and (2) to develop recommendations for the reduction of the effects of nonmilitary helicopter noise.*

(b) FOCUS- *In conducting the study, the Secretary shall focus on air traffic control procedures to address helicopter noise problems and shall take into account the needs of law enforcement.*

(c) CONSIDERATION OF VIEWS- *In conducting the study, the Secretary shall consider the views of representatives of the helicopter industry and organizations with an interest in reducing nonmilitary helicopter noise.*

(d) REPORT- *Not later than 1 year after the date of the enactment of this Act, the Secretary shall transmit to Congress a report on the results of the study conducted under this section.*

FAA carried out this study on behalf of the Secretary of Transportation.

2.2 Background

New York City has spawned the most extensive utilization of helicopter services of any city in the world. The New York City’s heliports have over 150,000 takeoffs and landings annually. There have also been increasing community noise complaints leading to the formation of anti-helicopter interest groups. In response, the City of New York initiated and prepared a comprehensive assessment of the City’s heliport infrastructure and related helicopter activities to better balance local helicopter industry’s operational needs and the affected communities’ quality of life. Completed in 1999, the City’s master plan outlined a comprehensive framework of developmental planning, review of commerce, economics, and environmental issues and proposed long-term planning guidelines.[3] In addition, New York City has established a policy not to support air tour activities.[4] However, state and local governments do not have the authority to regulate aircraft flight operations. Such authorities lie with the FAA and must be addressed in accordance with all applicable FAA orders and regulations. To minimize their noise liability, state and local governments, acting as airport proprietors, have authority to adopt reasonable nondiscriminatory restrictions on access that do not impose on undue burden on interstate commerce.

[3] Edwards and Kelcey Engineering, Inc.

[4] R. Grotell, Docket Comment #76: The City of New York: Office of the Mayor,” October 20, 2000.

2.3 FAA Study Process

The FAA used three methods to gather data to complete this study. The methods included: (1) solicit comments via Federal Register notice(s) and at public workshop(s), (2) review current noise effects literature, and (3) measure helicopter source noise in a densely populated metropolitan area.

The FAA hosted two public workshops and opened a docket for submission of written comments after soliciting information in the Federal Register. The comment period was extended to provide sufficient time for public responses.

2.4 Report Format

This report presents the urban helicopter noise study information that the FAA was required to prepare pursuant to Section 747 of the Wendell H. Ford Aviation Investment and Reform Act for the 21st Century.

Section 1 is the Executive Summary.

Section 2 presents an introduction including the general background on the circumstances that led to this legislative mandate. It also outlines the approach implemented by the FAA to perform the study; i.e., seek public input, literature review, and urban source noise measurements.

Section 3 presents the current state of scientific research on noise effects on individuals based on past socio-acoustic study findings. Where appropriate, it relates the criteria to aviation noise and more specifically helicopter noise.

Section 4 is a compilation of the helicopter noise reduction comments offered by the public and helicopter industry. The information is summarized and presented as an issues list with a synopsis of responses.

Section 5 presents the ATC procedures and regulations that support safe helicopter operations. Specific helicopter noise issues that relate to ATC operations are discussed. The needs of law enforcement and other emergency services are addressed.

Section 6 takes into consideration the views expressed by the public and industry. It offers the FAA's response to each of the issues identified.

Section 7 presents the FAA sponsored helicopter source noise measurements recorded in a densely populated metropolitan urban area. This noise data consists of a limited sample of *in-situ* noise measurements. In addition, a technical assessment of the noise-altitude sensitivity for a broad range of helicopters is discussed.

Section 8 summarizes the conclusions and recommendations for helicopter noise reduction on individuals in densely populated (urban) areas.

3.0 Noise Effects on Individuals

In this section, current scientific research concerning noise effects on individuals has been compiled and summarized.

3.1 Health Effects - Introduction

In a recent report, the World Health Organization (WHO) offers guidance on the potential health effects due to community noise exposure. The report categorizes the effects as follows:

- Noise-induced hearing impairment;
- Interference with speech communication;
- Effects of noise on performance;
- Sleep disturbance;
- Cardiovascular and physiological effects;
- Mental health effects; and
- Effects of noise on residential behavior and annoyance.[5]

The WHO study considered both environmental and occupational settings. Noise-induced hearing impairment is normally associated with occupational settings. Only when the 24-hour equivalent level exceeds 70 dB does the threat of environmental noise-induced hearing impairment arise.[6] Helicopters rarely produce 24-hour equivalent levels that exceed 70 dB. In fact, such worst case, high noise levels only occur near very busy military airfields operating heavy lift helicopters and frequent flights. Thus, noise-induced hearing impairment due to nonmilitary helicopters operations in urban environments is an unlikely condition.

3.2 Noise Effects on Communications and Performance

The WHO, based upon a study by Lazarus (1998), suggests that "noise interference with speech comprehension results in a large number of personal disabilities, handicaps and behavioral changes." The report goes on to say: "Problems with concentration, fatigue, uncertainty and lack of self-confidence, irritation, misunderstandings, decreased working capacity, problems in human relations, and a number of stress reactions have all been identified. Particularly vulnerable to these types of effects are the hearing impaired, the elderly, children in the process of language and reading acquisition, and individuals who are not familiar with the spoken language."

Nearly all information on this topic relates to the workplace or the classroom setting. The FICAN position on research in effects of aircraft noise on classroom learning states: "Research on the effects of aircraft noise on children's learning suggests that aircraft noise can interfere with learning in the following areas: reading, motivation, language and speech acquisition, and memory." No such data exist in other environmental noise settings. WHO (2000) states: "However, there are no published studies on whether environmental noise at home also impairs cognitive performance in adults."[7] Thus, at the present time, little can be said of environmental noise effects on communications and performance except as it relates to the classroom setting.

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[5] WHO 2000 - "Guidelines for Community Noise," edited by Berglund, B., Lindvall, T., Schwela, D., and Goh, K., World Health Organization/Ministry of the Environment, 2000.
[6] WHO 2000.
[7] WHO 2000.

Since at least the 1970s, research results have shown that environmental noise—primarily aircraft or road traffic—can adversely affect classroom learning.[8,9,10] Recent work near Heathrow airport and near the new and old Munich airports show similar results.[11,12,13,14] These studies treat the entire population of students in a cohort group as one single population. The study results generally show small but statistically significant effects. Masser (1970) showed larger effects by splitting the cohort groups into three sub-groups- the high achievers, the low achievers, and a middle group.[15] His studies showed that it was primarily the low achievers that were adversely affected by environmental noise. There was little effect from noise on the middle or high achiever groups. Thus, the small effects found in other studies maybe the result that mainly the low achievers are adversely affected but less discriminating within the unaffected majority of the population.

While the general effects of noise on learning have been demonstrated, there are also sub-groups of students that may be more affected than others. Students with hearing impairments, students for which English is a second language, music classes, and foreign language classes are all thought to be particularly susceptible to extraneous noise.[16,17]

To avoid the adverse effects of noise in classrooms, WHO (2000) recommends an indoor equivalent level in classrooms of 35 dB.[18] Similarly, a draft American National Standard that is being developed primarily with the noise from heating and ventilating equipment in mind also recommends an indoor classroom equivalent level of 35 dB.[19] With respect to helicopter noise in urban areas, it can be expected that, where flights are frequent, the indoor equivalent level from

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[8] S. Cohen, D.A. Glass, and J.E. Singer, 1973, "Apartment Noise, Auditory Discrimination, and Reading Ability in Children," *J. of Experimental Social Psychology*, 9, 407-422.

[9] A. Bronzaft, and D. McCarthy, 1975, "The effects of elevated train noise on reading ability," *Environment and Behavior*, **7**, 517-527.

[10] K.B. Green, 1980, "The Effects of Community Noise Exposure on the Reading and Hearing Ability of Brooklyn and Queens School Children," Ph. D. Thesis, Program in Environmental Health Sciences, Faculty of the Graduate School, New York University, New York, NY.

[11] S. Hygge, G.W. Evans, and M. Bullinger, 1996, "The Munich Airport noise study: cognitive effects on children from before to after the change over the airports," *Inter-Noise 96 Proceedings*, 2189-2194, Liverpool, England.

[12] S. Hygge, and G.W. Evans, 2000, "The Munich Airport noise study—Effects of chronic aircraft noise on children's perception and cognition," *Inter-Noise 2000 Proceedings*, in publication, Nice, France.

[13] S. Standfeld, M. Haines, J. Head, B. Berry, M. Jiggins, S. Brentnall, and R. Rhiannon, 2000, "Aircraft noise at school and child perform and health: Initial results from the west London schools study," *Inter-Noise 2000 Proceedings*, in publication, Nice, France.

[14] P. Lercher, G. Brauchle, W. Kofler, U. Widmann, and M. Meis, 2000, "The assessment of noise annoyance in schoolchildren and their mothers," *Inter-Noise 2000*, in publication, Nice, France.

[15] A. Masser, circa 1970, Private communications with P. Schomer re Highline School District vrs Sea-Tac Airport, School System Psychologist, Highline School District, Highline, WA.

[16] H. Lazarus, 1998, Noise and Communication: The present state. In N.L. Carter and R.F.S. Job (Eds.) Noise as a Public Health Problem, Vol. 1, pp. 157-162, Noise Effects '98 PTY Ltd., Sidney, Australia.

[17] WHO 2000.

[18] WHO 2000.

[19] ANSI, 2000, American National Standard Quantities and Procedures for Description and Measurement of Environmental Sound—Part 6: Methods for Measurement of Awakenings Associated with Noise Events, ANSI S12.9-1996—Part 6, Draft—to be circulated for 30-day review prior to final adoption, American National Standards Institute (ANSI), New York, NY.

helicopter noise may exceed 35 dB. It is also highly probable that other urban noise sources, such as street traffic and subway trains, would exceed this threshold more frequently than helicopter operations.

3.3 Sleep Disturbance

The effects of noise on sleep disturbance remain the subject of much debate.[20,21] Studies performed in laboratories generally show effects of noise such as awakening at relatively low noise levels. However, the laboratory subject is in unfamiliar surroundings and connected to probes. In contrast, field studies near major airports found that behavioral awakenings occur only when the sound levels of individual events get very loud. Based on over 10,000 subject-nights in field studies, the percent of awakenings, P, is given by American National Standards Institute (ANSI) 2000:

$$P = 0.13 \text{ ASEL} - 6.64 \quad (1)$$

where A-weighted Sound Exposure Level (ASEL) is in decibels.[22] Equation 1 suggests that there is no behavioral awakenings until the indoor sound exposure level exceed 51 dB. At 60 dB indoors, there is the probability that 1 percent will be awakened.

To further point out the difference between laboratory and field results in this area, Figure 3-1 shows separate regression lines fit to laboratory and field data for behavioral awakenings.[23] It is clear that the laboratory data and the *in-situ* data are not measuring the same effects. Most would agree that the field data represent what is actually happening to people in their homes while the laboratory data must be confounded by other variables such as adaptation, the presence of probes connected to the subject, unfamiliarity with the noise, and unfamiliarity with the surroundings. Nevertheless, the WHO (2000) has chosen to concentrate on the laboratory data and largely ignore the field data.

The FAA supports the FICAN* recommendation of a new dose-response curve for predicting awakening, based on field data[24]. The FICAN took the conservative position that, because the adopted curve represents the upper limit of the field data, it should be interpreted as predicting the “maximum percent of the exposed population expected to be behaviorally awakened” or the “maximum % awakened” (see Figure 3-2).

* FICAN - Federal Interagency Committee on Aviation Noise was formed in 1993 to provide forums for debate over future research needs to better understand, predict and control the effects of aviation noise, and to encourage new technical development efforts The Department of Defense (DOD), the Federal Aviation Administration (FAA) and the National Aeronautics and Space Administration (NASA) are the primary agencies responsible for addressing aviation noise impacts through general R&D activities.

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[20] K. Pearsons, D. Barber, B. Tabachnick, and S. Fidell, 1995, Analysis of the predictability of noise-induced sleep disturbance,” *Journal of the Acoustical Society of America*, **97**, 331-338.
[21] S. Fidell, K. Pearsons, R. Howe, L. Silvati, and D. Barber, 1995, “Field study of noise-induced sleep disturbance,” *Journal of the Acoustical Society of America*, **98**, 1025-1033.
[22] ANSI 2000.
[23] ANSI 2000.
[24] “Effects of Aviation Noise on Awakenings from Sleep,” Federal Interagency Committee on Aviation Noise, June 1997.

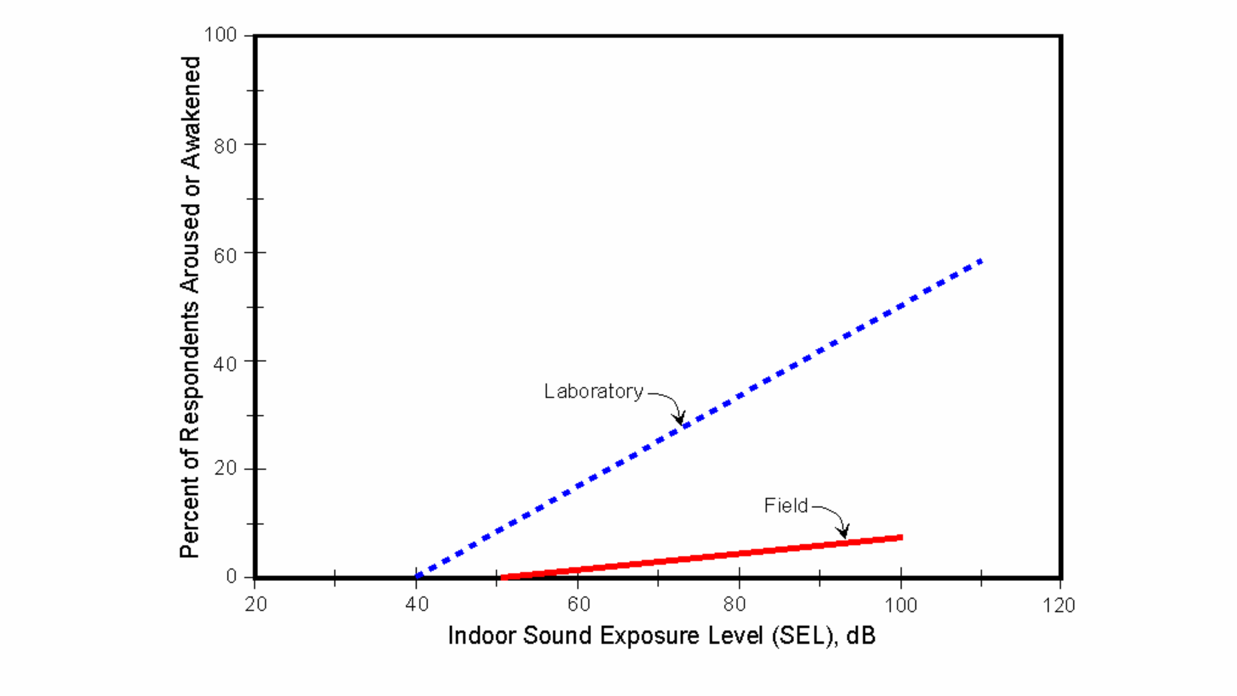

Figure 3-1. Behavioral awakening results: laboratory and field studies (ANSI 2000)

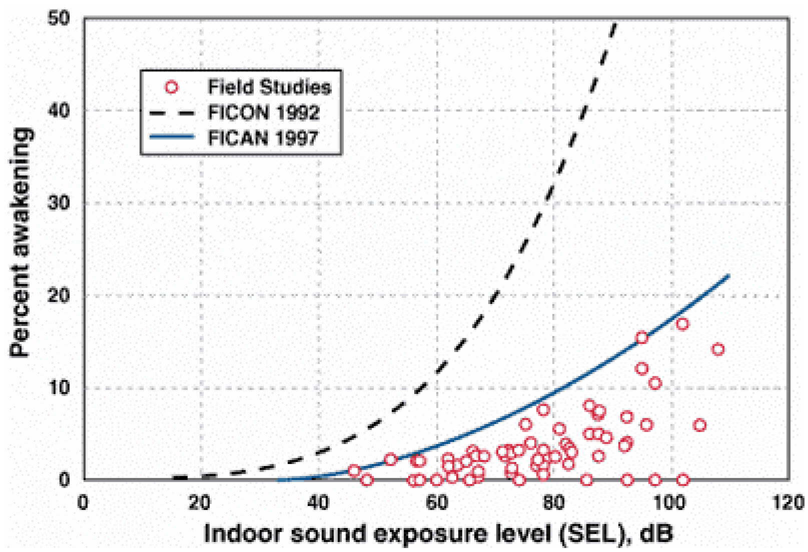

Figure 3-2. FICAN Recommended Sleep Disturbance Dose-Response Relationship

3.4 Cardiovascular and Other Physiological Effects

The WHO states: "The overall conclusion is that cardiovascular effects are associated with long-term exposure to 24-hour equivalent level values in the range of 65-70 dB or more, for both air- and road-traffic noise. However, the associations are weak…"[25] Reporting on results from the Health Council of the Netherlands, Passchier-Vermeer gives a 24-hour equivalent level of 70 dB as the "observation threshold of an effect for which the causal relationship with noise exposure is

[25] WHO 2000.

judged to be sufficient."[26] The term "observation threshold" is not defined but one can assume that it represents a small fraction of the total population. In any case, urban helicopter noise will not normally exceed a 24-hour equivalent level of 65 to 70 dB. These types of levels can be found only near the busiest of military airfields. Thus, one can conclude that urban helicopter noise does not represent a threat with respect to cardiovascular and other physiological effects.

3.5 Annoyance - Introduction

The assessment of helicopter noise has been the subject of much study over the past 30 years. Most NATO countries use the ASEL to assess helicopter noise. An alternative measure is the Effective Perceived Noise Level (EPNL). When using ASEL, the noise events over a period of time are combined into an equivalent level (LEQ). For daytime flights, Fields and Powell (1987) demonstrated a strong relationship between average LEQ and average annoyance over the range of 1 to 32 flights per 9 hours. In the Fields and Powell study, annoyance was flat up to an LEQ of 47 dB and then grew as a linear function of LEQ up to 59 dB.[27] No one has carried out a similar experiment for nighttime noise. Schomer found that the traditional 10 dB nighttime penalty, used in the determination of DNL, is consistent with community attitudinal data.[28]

During the 1970s, there was a widespread belief among environmental noise scientists in the U.S. Department of Defense that a given LEQ from rotary-wing is more annoying than an equal LEQ from fixed-wing aircraft. This belief was reflected in official policy through the imposition of a 7 dB penalty to be added "to meter readings obtained under conditions where Blade-Slap was present until and unless meters are developed which more accurately reflect true conditions."[29] Blade-Slap or BVI noise occurs during the descent condition for landing. It is the result of interaction by a rotor blade with previously shed tip vortices. These interactions generate a complex unsteady pressure field that propagates below the rotor as high impulsive noise.

The need for a Blade-Slap penalty was based primarily on laboratory studies. Leverton (1972) conducted one of the first studies comparing the A-weighted sound level from helicopter operations with and without Blade-Slap. The study, conducted in a simulated living room, found that the presence of Blade-Slap increased the subjects' annoyance to helicopter noise by the equivalent of 4-8 dB.[30] Other researchers who found that there was a need for a Blade-Slap correction included Man-Acoustics (1976), Lawton (1976), Wright and Damongeot (1977), Galanter *et al*., (1977), Galloway (1978), Klump and Schmidt (1978), and Sternfeld and Doyle (1978).[31,32,33,34,35,36,37]

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26 W. Passchier-Vermeer, and W.F. Passchier, 2000, "Noise Exposure and Public Health," *Environmental Health Perspectives*, **108** Supplement 1, 123-131, March 2000

27 J.M. Fields and C.A. Powell, 1987, "Community reactions to helicopter noise: Results from an experimental study," *Journal of the Acoustical Society of America*, **82**, 479-492

28 P.D. Schomer, 1983b, "A Survey of Community Attitudes Toward Noise Near a General Aviation Airport," *Journal of the Acoustical Society of America*, **74**, 1773-1781

29 DOD, 1977, Department of Defense Instruction 4165.57, 8 November 1977, "Air Installations Compatible Use Zones."

30 J.W. Leverton, 1972, "Helicopter Noise – Blade-Slap, Part 2, Experimental Results," NASA Technical Report CR1983, March 1972.

31 Man-Acoustics & Noise, Inc., 1976, "Certification Considerations for Helicopters Based on Laboratory Investigations," Report prepared for U.S. Department of Transportation, FAA-RD-76-116, July 1976.

Other laboratory studies suggested that a simple measure of impulsivity does not capture the unique annoyance of helicopter noise. Berry *et al*. (1975) found subjects to be more responsive to the "roughness" quality of the sound than to the Blade-Slap, per se.[38] Similarly, Galloway (1977) found the annoyance to be related to the rate of impulses.[39] Ohshima and Yamada (1987), using a variable high pass filter, concluded that low-frequency energy below 50 Hz did not contribute to the annoyance, but that low-frequency energy between 50 and 200 Hz did contribute.[40]

Subsequent field studies failed to produce support for a Blade-Slap penalty. In a U.S. Army study, listeners judged the annoyance of overflights by different helicopters and a control fixed-wing aircraft heard outdoors. The study found that their annoyance judgments correlated with A-weighting without the need for further correction.[41] Although the U.S. Army researchers concluded that a 2 dB penalty was consistent with the results, they asserted, "no correction for Blade-Slap was found which improves the prediction of annoyance." In a NASA study, listeners compared the annoyance of helicopter and propeller aircraft flights heard both indoors and outdoors. Annoyance was accurately predicted by SEL.[42] In a subsequent community noise study of Fields and Powell (1987), unsuspecting residents reacted similarly to the flights of two helicopter types that had very dissimilar noise signatures.[43]

There is general agreement among a wide range of experts that adding a penalty to the A-weighted SEL to account for the annoyance of Blade-Slap is not justified.[44,45,46,47,48,49,50] In spite

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[32] B.W. Lawton, 1976, "Subjective Assessment of Simulated Helicopter Blade-Slap Noise," NASA Langley Research Center, NASA TN D-8359, December 1976.
[33] S.E. Wright, and A. Damongeot, 1977, "Psychoacoustic Studies of Impulsive Noise," Paper #55, Third European Rotorcraft Powered Lift Aircraft Forum, Aeronautical and Astronautic Association of France, September 1977.
[34] E. Gallanter, R.D. Popper, and T.B. Perera, 1977, "Annoyance scales for simulated VTOL and CTOL overflights," Paper given at the 94th meeting of the Acoustical Society of America, Miami, Florida, December 1977.
[35] W.J. Galloway, 1978, "Review of the Development of Helicopter Impulsive Assessment Proposals by ISO TC43/SC1/WG2 – Aircraft Noise," Memorandum Report, January 1978.
[36] R.G. Klump and D.R. Schmidt, 1978, "Annoyance of Helicopter Blade-Slap," Naval Ocean Systems Center Technical Report 247, 3 July 1978.
[37] H.M. Jr. Sternfeld, and L.B. Doyle, 1978, "Evaluation of the Annoyance Due to Helicopter Noise," NASA Contractor Report 3001, June 1978.
[38] B.G. Berry, A.J. Renie, and H.C. Fuller, 1975, "Rating Helicopter Noise: The Feasibility of an Impulsive Noise Correction," National Physical Memorandum for ISO/TC43/SC1/WG2, October, 1975.
[39] W.J. Galloway, 1977, "Subjective Response to Simulated and Actual Helicopter Blade-Slap Noise," Bolt, Beranek and Newman Report No. 3573 for NASA, December 1977.
[40] T. Ohshima and I. Yamada, 1987, "The evaluation of normal take-off/landing helicopter noise," *Inter-Noise 87*, 1037-1041.
[41] J.H. Patterson, Jr. B.T. Mozo, P.D. Schomer, and R.T. Camp, 1977, "Subjective Ratings of Annoyance Produced by Rotary-Wing Aircraft Noise," U.S. Army Medical Research and Development Command, USAARL Report, No. 77-12, May 1977.
[42] C.A. Powell, 1978, "A Subjective Field Study of Helicopter Blade-Slap Noise," National Aeronautics and Space Administration, Langley Research Center, NASA Technical Memorandum 78758, July 1978.
[43] J.M. Fields and C.A. Powell, 1987.
[44] ICAO, 1981, Loughborough University of Technology, Studies of Helicopter Noise Perception: Background Information Paper, ICASo Committee on Aircraft Noise, Working Group B, December 1981.

of the objective evidence that helicopter noise, at a given A-weighted decibel level, is no more annoying than fixed-wing aircraft noise, there is survey evidence that the public reacts more negatively to helicopter noise than to fixed-wing aircraft noise. This phenomenon is discussed below.

3.5.1 Heightened reaction to helicopter noise

Typical of heightened reaction to helicopter noise is the experience of the U.S. Navy at Miramar Marine Corps Air Station. Miramar had long been a naval air station famed for its Top Gun School and its F-14 Tomcats. But with Top Gun moving to Fallon, Nevada, and the Tomcats being assigned to other bases, Miramar was turned over to the Marine Corps in 1997, which brought in helicopter and F-18 operations. Almost from the beginning, residents have complained about noise and pollution and expressed concerns over possible helicopter crashes. Yet, the noise contour map is not significantly different from when the F-14 aircraft were operating.[51] In addition, the contribution of helicopter operations to the overall DNL is much less than that of the F-18 operations.

An example of heightened reaction to helicopters at a general aviation airport was published by Schomer (1983b).[52] At an airport where the noise exposure was dominated by fixed-wing aircraft and with less than two helicopter operations per week, 7 percent of the people exposed to a DNL of 66 dB reported themselves to be "highly annoyed" by helicopters. A 1982 study from the United Kingdom also found a heightened reaction to helicopter noise.[53,54,55] In the community of Lower Feltham, the contribution of fixed-and rotary-wing aircraft to the overall noise exposure was about equal. However, the percentages of people who considered helicopters more disturbing than fixed-wing aircraft were 2 to 2.5 times as large as the percentages that considered helicopters less disturbing. In the communities of Esher and Epsom, where the numbers of helicopters and a fixed-wing aircraft were about equal, the disturbance due to helicopter noise was 2.5 times as large as that due to fixed-wing aircraft noise. People were more annoyed by the helicopters even though, on average, the fixed-wing aircraft were 5.0 dB louder.

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[45] J.A. Molino, 1982, "Should Helicopter Noise Be Measured Differently from Other Aircraft Noise?," NASA Contractor Report No. 3069, Wyle Laboratories, Crystal City, VA.
[46] J.B. Ollerhead, 1982, "Laboratory Studies of Scales for Measuring Helicopter Noise," NASA Contractor Report 3610, November 1982.
[47] W. Passchier-Vermeer, 1994, "Rating of Helicopter Noise was Respect to Annoyance," English Version, TNO-Report 94.061, Leiden, The Netherlands.
[48] T. Ohshima, and I. Yamada, 1993, "Psycho-Acoustic Study on the Effect of Duration on the Annoyance of Helicopter Noise Using Time Compressed or Expanded Sounds," *Inter-Noise 93*, 1087-1090.
[49] T. Gjestland, 1994, "Assessment of helicopter noise annoyance: A comparison between noise from helicopters and from jet aircraft," *Journal of Sound and Vibration*, **171**, 453-58.
[50] G. Bisio, U. Magrini, and P Ricciardi, 1999, "On the helicopter noise: A case history," *Inter-Noise 99*, 183-188.
[51] Wyle Research Report WR 94-25, 1995, Aircraft Noise Study for Marine Corps Air Station Miramar, CA, Wyle Laboratories, Arlington, VA, August 1995.
[52] P.D. Schomer, 1983b.
[53] C.L.R. Atkins, 1983, "1982 Helicopter Disturbance Study: Tabulations of the Responses to Social Surveys," London Civil Aviation Authority, DR Communication 8302.
[54] C.L.R. Atkins, P. Brooker, and J.B. Critchley, 1983, "1982 Helicopter Disturbance Study: Main Report," London: Civil Aviation Authority, DR Report 8304.
[55] P. Prescott-Clarke, 1983, "1982 Aircraft Noise Index Study and 1982 Helicopter Disturbance Study: Methodological Report," Social and Community Planning Research, London.

In general, there are a number of possible explanations for heightened community response to helicopter noise. The possible explanations, which are not mutually exclusive, include the following:

- A subsection of the population may be more sensitive to the low-frequency helicopter noise than is the majority of the population;
- A-weighting is possibly not the most appropriate metric with which to assess helicopter noise because A-weighting attenuates the low-frequency noise component;
- Noise-induced building vibration and rattle has been shown to significantly increase noise annoyance and helicopter sound is rich in low-frequency content;
- There is some evidence that suggests helicopter noise is slightly more annoying than fixed-wing aircraft noise at the same sound exposure level;
- Helicopter noise may be more noticeable because of its periodic impulsive characteristic;
- There is the possible phenomena of "virtual noise" in which a set of non-acoustical factors, such as bias (a personal judgment that the helicopter does not need to fly here) and fear (of crashes/injury/death), greatly enhances people's negative attitudes; and
- The way helicopters are operated can influence reactions, i.e., stationary hover and flexible low altitude flight capability.

3.5.2 Low-frequency sensitivity

Over the past 30 years there have been a series of papers describing a subset of the population that is especially sensitive to low-frequency noise. In general, low-frequency noise includes the range from about 16 Hz to about 100 Hz. Apparently, a subset of the population is very sensitive to noises in this frequency range and is quite bothered and disturbed by this noise almost as soon as it crosses the threshold of audibility.[56,57,58,59] The size of this subset is not known. Patterson *et al.* (1977) used 25 subjects to study the subjective ratings of annoyance produced by rotary-wing aircraft noise. In an outdoor setting, the subjects judged the sounds from many types of military helicopters performing level flyovers climbs, descents, and turns. A numerical rating scheme was used and a DC-3 aircraft served as the control sound source. Statistical correlations were performed using A, B, C, and D-weighting and various forms of EPNL. Most of the 25 subjects had subjective ratings that correlated well with A-weighted measures. However, 11 of the subjects had subjective ratings that correlated well with C-weighted measures. For three of

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[56] S. Yamada, 1982**,** "Occurrence and control of low frequency noise emitted from an ice cream storehouse, *Journal of Low Frequency Noise and Vibration*, **1**(1), 19-21.
[57] W. Tempest, 1985**,** "Discussion at end of 3rd International Conference on Low Frequency Noise and Vibration, London, September 1985," *Journal of Low Frequency Noise and Vibration*, **4**(4), 168-180.
[58] S. Yamada, T. Watanabe, T. Kosaka, and N. Oshima, 1987**,** "Construction and analysis of a database of low frequency noise problems," *Journal of Low Frequency Noise and Vibration*, **6**(3), 114-118.
[59] M. Mirowska, 1998**,** "An investigation and assessment of annoyance of low frequency noise in dwellings," *Journal of Low Frequency Noise and Vibration*, **17**(3), 119-126.

these, the correlation with C-weighting was better than the correlation with A-weighting, and for one, the correlation is much better.[60] Thus this study appears to have discovered a subset of individuals who are more sensitive to the low-frequency energies than are the majority.

3.5.3 Is A-weighting the optimum weighting for assessing helicopter sound?

As discussed above, there is some evidence that the A-weighting metric may not fully characterize human reactions to noise events with substantial low-frequency content. With the focus on industrial noise sources, ANSI S12.9 Part 4 provides a supplemental measure to A-weighting for the assessment of sounds with strong low-frequency content. This measure combines the sound energies in the 16, 31, and 63 Hz octave bands.[61] Both Germany and Denmark have special low-frequency sound measures that utilize sound energy in the 16, 31, and 63 Hz octave bands and Denmark adds energies in the 125 Hz band. As a possible alternate to A-weighting (which changes only with frequency), Schomer (2000) suggested the use of the equal-loudness level contours as a weighting function that changes with both amplitude and frequency. He showed that the 2 dB adjustment that possibly should be applied to helicopter sounds compared with fixed-wing aircraft sounds can be derived from the known functions of human hearing.[62]

As noted above, low-frequency noise complaints begin at the threshold of hearing. Further, small increases (decreases) in low-frequency noise levels can yield large increases (decreases) in annoyance. Møller (1987) measured both equal loudness and equal annoyance functions at low-frequencies (4, 8, 16, and 31.5 Hz). At these frequencies, changes of 2, 3, 4, or 5 dB yielded the same change in annoyance as a 10 dB change in sound level at 1000 Hz. That is, a 2 dB change in level at 4 Hz yields the same change in annoyance as a 10 dB change at 1000 Hz.[63]

For throbbing low-frequency noise, the complaint threshold can be below the threshold of audibility. The throbbing noise or distinctive rhythmic low-frequency helicopter sound is an inherent consequence of the main rotor blades periodic motion. Vercammen (1989) suggests a 5 dB adjustment for throbbing noise.[64] The Schomer paper (May 2000) explains this effect. The hearing function reacts to a 2 to 5 dB change in level as if it were a change in loudness of 10 dB. When throbbing occurs at low-frequencies, the actual loudness is greater than that predicted by the equivalent level. Stated another way, even though the equivalent level of a sound may be below the threshold of audibility, the sound is audible. The mistake is using the equivalent level at low-frequencies.[65] Schomer and Bradley (2000) have confirmed this effect using independently gathered data.[66]

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[60] J.H. Patterson, B.T. Jr. Mozo, P.D. Schomer, and R.T. Camp, 1977.

[61] ANSI, 1996, American National Standard Quantities and Procedures for Description and Measurement of Environmental Sound—Part 4: Noise Assessment and Prediction of Long-Term Community Response, ANSI S12.9-1996—Part 4, American National Standards Institute (ANSI), New York, NY.

[62] P.D. Schomer, 2000, "Loudness-Level Weighting for Environmental Noise Assessment," *Acustica—Acta Acustica*, **86**, 49-61, January 2000.

[63] H. Møller, 1987, "Annoyance of audible infrasound," *Journal of Low Frequency Noise and Vibration*, **6**(1), 1-17.

[64] M.L.S. Vercammen, 1989, "Setting limits for low frequency noise," *Journal of Low Frequency Noise and Vibration*, **8**(4), 105-109.

[65] P.D. Schomer, 2000.

[66] P.D. Schomer and J.S. Bradley, 2000, "A test of proposed revisions to room noise criteria curves," *Noise Control Engineering Journal*, **48**(4), 124-129, (July/August 2000).

3.5.4 Noise induced building vibrations and rattles

In a study by Schomer and Neathammer (1985), subjects made judgments of the annoyance of helicopter flights while outdoors, in the living room of a new mobile home, and in an old frame house. During the tests, the supervising technician judged the amount of rattle during each flyover. The annoyance judgments were grouped by whether no rattle had been present, a little rattle had been present, or a lot of rattle was present. Clear differences emerged. When there was a little rattle, annoyance increased by an equivalent 10 dB. When there was a lot of rattle, annoyance increased by an equivalent 20 dB.[67] When the same experiments were repeated using better-built military housing, the annoyance due to rattle was quite reduced.[68]

In a study by Schomer and Averbuch (1989), subjects judged the annoyance of simulated blast sounds created using a giant (3 by 4 meter) woofer. Two groups of subjects responded in the same facility to the same set of test sounds using the same control sounds. The only difference was a small source of rattle on one window in the test house in which the subjects were situated. Although the rattle sounds were virtually unmeasurable at the ears of the test subjects compared with the blast sound itself, the mere presence of these rattle sounds raised the equivalent annoyance by about 6 to 13 dB depending on blast sound level.[69] The evidence seems to support the notion that annoyance increases on the order of 10 dB when there are noticeable rattle sounds over the annoyance predicted based on measures of just the sound itself. If the helicopter sound produces noticeable rattles, then the study results suggest that it is likely that the annoyance will be significantly greater than that predicted on the basis of just the A-weighted measures.

The C-weighting has been used in the United States for almost 30 years to assess blast noise and sonic booms in order to account for the noise-induced rattles generated by these sounds, and currently, several other countries also use the C-weighting for this purpose. It is primarily the sound energies in the 10 to 30 Hz ranges that induce wall vibrations. The C-weighting could be used to identify those helicopter sound energies that will induce wall vibrations.

3.5.5 Helicopter noise is more annoying than fixed-wing aircraft noise

Some studies have shown no increase in annoyance for helicopter noise as compared with fixed-wing aircraft noise. Others have shown a small adjustment. The most realistic studies are those that use subjects outdoors or in real houses with real helicopters to create the stimulus. Unfortunately, most studies are performed in the laboratory using simulated sounds. As discussed above, Patterson *et al.* (1977) used 25 subjects to study the subjective ratings of annoyance produced by real rotary-wing aircraft noise. On a per event basis, he found a +2 dB adjustment for the annoyance of helicopter sounds as compared with fixed-wing aircraft sound producing the same A-weighted sound exposure level.[70] In a similarly constructed experiment using real helicopters and a fixed-wing aircraft as the control, Powell (1981) placed subjects both

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[67] P.D. Schomer, and R.D. Neathammer, 1985.
[68] P.D. Schomer, B.D. Hoover and L.R. Wagner, 1991, "Human Response to Helicopter Noise: A Test of A-Weighting," Technical Report N-91/13, USA Construction Engineering Research Laboratory, November 1991.
[69] P.D. Schomer and A. Averbuch, 1989, "Indoor human response to blast sounds that generate rattles," *Journal of the Acoustical Society of America*, **86**(2), 665-673, August 1989.
[70] J.H. Patterson, B.T. Jr. Mozo, P.D. Schomer, and R.T. Camp, 1977.

outdoors and inside real houses. He found a 3 to 5 dB adjustment of the EPNL for subjects situated indoors and no adjustment for subjects situated outdoors.[71]

3.5.6 Helicopter sounds may be more readily noticeable than other sounds

At the same A-weighted sound exposure, a helicopter may be much more noticeable than a fixed-wing aircraft because of the impulsive blade-slap sound. Schomer and Wagner (1996) performed an *in-situ* study in respondents' homes. Clusters of subjects were chosen and an outdoor sound monitor was used to measure ASEL and to record the times at which they occurred. The three sources studied were helicopters, fixed-wing aircraft, and trains. For the same ASEL, helicopter sounds were not found to generate any greater *annoyance per event* than did the other two sounds. *Rate of response* was used as the main indicator of noticeability. Rate of response is defined as the ratio or relative order of magnitude of percent average noticeability comparing two unique sources of noise. In this case, helicopter noise was compared to fixed-wing airplane and train noise. The *rate of response* function for helicopter sounds grew at three times the *rate of response* functions found for airplanes and trains. This paper showed that sound noticeability may be a significant variable for predicting human response to noise. The character of the sound was a key ingredient to noticeability. Helicopters, with their distinctive sound character, appeared to be more noticeable than other sounds for the same A-weighted sound exposure level.[72]

3.5.7 Attitudes—non-acoustic factor

The community attitudes towards the noise source can be an important influence on the degree of annoyance. The Environmental Protection Agency (EPA) in 1974 suggested that the measured noise level can be adjusted downward by 5 dB when the party that generates the noise maintains very good community relations and convinces the community that everything possible that can be done is being done to reduce the noise.[73] Further study is needed to confirm EPA's result in this regard. The meta-analyses of Fields (1993) confirmed that community attitude is an important modifier of annoyance. This was one of five attitudes confirmed as important by the study. In addition to "noise prevention beliefs," Fields listed "fear of danger from the noise source," "beliefs about the importance of the noise source," "annoyance with non-noise impacts of the noise source," and "general noise sensitivity."[74]

In a more detailed study of attitudes, Staples *et al* (1999) combined elements of Fields' "noise prevention beliefs," "beliefs about the importance of the noise source," and "annoyance with non-noise impacts of the noise source" into a 10-item Environmental Noise Risk Scale. Their 351 subjects were living in the 55 to 60 dB DNL zone of a former military airfield that had been converted for civil use. They found that the environmental noise risk scale accounted for

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[71] C.A.Powell, 1981, "Subjective Field Study of Response to Impulsive Helicopter Noise," NASA Technical Paper 1833, April 1981.
[72] P.D. Schomer and L.R. Wagner, 1996, "On the Contribution of Noticeability of Environmental Sounds to Noise Annoyance," *Noise Control Eng. J.*, **44**(6), 294-305, Nov-Dec 1996.
[73] EPA, 1974, "Information on Levels of Environmental Noise Requisite to Protect Public Health and Welfare with an Adequate Margin of Safety," US Environmental Protection Agency, Office of Noise Abatement and Control (ONAC), Rpt. EPA550/9-74-004, Washington D.C.
[74] J.M. Field, 1993, "Effect of Personal and Situational Variables on Noise Annoyance in Residential Areas," *Journal of the Acoustical Society of America*, **93**, 2753-2763.

36 percent of the variation in individual disturbance from noise. Particularly powerful was a statistical factor that they labeled, "appraisal of one's neighborhood as inadequately protected and vulnerable to future increases in noise."[75]

Several of the attitudinal factors described above appear in the written submissions to the FAA. There is the belief that helicopters used for transportation of corporate executives, sightseeing, or ENG are unimportant. There is also the fear factor associated with helicopter overflights. There is the perception that helicopters could fly higher than they do and over less noise-sensitive areas. People feel that their privacy is being invaded when a helicopter flies low or hovers near their residence. Ollerhead and Jones (1994) noted the importance of privacy, noise prevention beliefs, and fear of crashes in neighborhoods around the Battersea Heliport. Ollerhead and Jones (1994) suggested people feel that a helicopter is "a rich man's toy."[76]

3.5.8 Vertical TakeOff/Landing (VTOL) capability

In contrast to fixed-wing aircraft, helicopters have additional flight capabilities, such as hover and vertical operations. These additional operational degrees of freedom can produce uniquely different noise signatures due to the varying complex source noise mechanisms. Noise generated over an extended period of a hover operation can lead to low-frequency droning that could enhance annoyance. Where fixed-wing aircraft require an airport with sizable runways for landings and takeoffs, helicopters can operate on much smaller landing sites that could be relatively close to residential communities. This creates an immediate local environment of higher noise levels that can be further compounded by the other dynamic helicopter noise effects. Related operational approaches for noise mitigation regarding VTOL capabilities are discussed in detail in Section 6.1.

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[75] S.L. Staples, R.R. Cornelius, and M.S. Gibbs, 1999, "Noise disturbance from a developing airport: Perceived risk or general annoyance," *Environment and Behavior*, **31**(5), 692-710.
[76] J.B. Ollerhead and C.J. Jones, 1994, "Social Survey of Reactions to Helicopter Noise," London: Civil Aviation Authority.

4.0 Public Input on Noise Reduction

In this section, responses to the FAA's request for information are summarized. Suggested noise reduction approaches and concerns expressed by the public are presented. Written comments were solicited by publication of notices in the Federal Register. The FAA held two public workshops in Washington, DC to obtain additional comments. The compiled study information (comments and workshop presentations) are accessible on the FAA's Office of Environment and Energy website:

http://www.aee.faa.gov/
under the link: "Section747-Nonmilitary Helicopter Noise"

As the result of a thorough review, the issues were grouped as either operational or non-operational. These issues were then sub-categorized according to applicable FAA regulations creating the following outline:

A. Operational Issues **–**

[related to 14 CFR part 91 - General Operating and Flight Rule]

1) Minimum altitude for overflight and hover;
2) Operational routes & routing design guidelines;
3) Hover duration time;
4) Retirement of noisiest helicopters;
5) Visible identification markings;

[related to:
14 CFR part 150 regulation – Airport Noise Compatibility Planning and
14 CFR part 161 regulation -Notice and Approval for Airport Noise & Access Restrictions

6) Frequency of helicopter operations (number of flights);
7) Time frame of helicopter operations (hours of operation);
8) Heliports/airports operations (i.e., ground run-up duration);
9) Noise abatement procedures;

[related to with 14 CFR part 36 - Noise Standards: Aircraft Type and Airworthiness Certification]

10) Noise certification limit stringency;
11) Implementation of noise reduction technology (i.e., helicopter "hushkits?");

B. Non-operational Issues **–**

12) Industry's voluntary "Fly Neighborly" program effectiveness;
13) ENG redundant flights;
14) Acceptance of public service helicopter operations; i.e., law enforcement, EMS, and fire fighters;
15) VFR/IFR ATC operations access for helicopters;
16) Empowerment of local municipalities with airspace control;

(Note: military helicopters are not addressed because they are outside of the mandate scope)

Supporting Technology Initiatives-

17) Socio-acoustic (psychoacoustic) study relating medical and health effects;
18) Tracking helicopter traffic growth and noise measures to quantify impact of noise sensitive community sites (parks, hospitals, neighborhoods, etc);
19) Utilize GPS approach/departure for noise abatement operations; and
20) Insensitivity of A-weight measurements to low-frequency noise impact of helicopters.

4.1 Synopsis of Responses

Views from representatives of the helicopter industry and organizations with an interest in reducing nonmilitary helicopter noise were sought, reviewed, and are presented in this section.

The organizations offering input were as follows:

Helicopter Noise Coalition of New York City - New York City, NY
League of the Hard of Hearing - New York City, NY
W400 Block Association - New York City, NY
Fifteenth Street Block Association (represents the West 200 Block) - New York City, NY
Federation of Citywide Block Associations - New York City, NY
Vinegar Hill Neighborhood Association - Brooklyn, NY
Community Board 7 - New York City, NY
The City College of the City University of New York - New York City, NY
Weehawken Environment Committee - Weehawken, NJ
Coalition to Quiet Our Neighborhood - West Orange, NJ
Noise Pollution Clearinghouse - Montpelier, VT
The MARCH Coalition Fund, Inc. - Poway, CA
Homeowners of Encino - Encino, CA
Sherman Oaks Homeowners Association (SOHA) - Sherman Oaks, CA
Lake Balboa Neighborhood Association - Van Nuys, CA
West Hill Property Owners Association (WHPOA) - Encino, CA .
Citizens for a Quiet Environment - Corrales, NM
Federation of University Neighborhoods - Albuquerque, NM
South Broadway Action Team - Albuquerque, NM

Similarly, the helicopter industry was represented by:

American Helicopter Society (AHS) International, VA - technical society
Helicopter Association International, VA - national operators association
Bell Helicopter Textron Inc., TX - manufacturer
Robinson Helicopter Co., CA- manufacturer
Whisper Jet Inc., FL - retrofit manufacturer
Eastern Regional Helicopter Council, PA - operators’ affiliate

Congressional representatives and local governments also contributed their comments and recommendations. Other specialized related aviation industry representatives, such as the helicopter law enforcement, helicopter medical services, and airports, also provided information and comments. The specific affiliation and concerns expressed are summarized in Table 4-1.

4.2 Scoping Questions

The FAA published a notice in Federal Register [Docket No. 30086: Report to Congress on Effects of Nonmilitary Helicopter Noise on Individuals in Densely Populated Areas in the Continental United States (65 FR 39220)] on June 23, 2000, requesting information from people concerned with nonmilitary helicopter noise. The request for information was confined to the context of the effects of nonmilitary helicopter noise on individuals in densely populated areas of the continental United States. The following four questions were posed:

- What are the types of helicopter operations (law enforcement, electronic news gathering, sightseeing tours, etc.) that elicit the negative response by individuals in densely populated areas?
- What air traffic control procedures are applicable in addressing helicopter noise reduction? Why?
- What impacts could restrictive air traffic control procedures have on operation of:
  - Law enforcement helicopters?
  - Electronic news gathering (ENG) helicopters?
  - Sightseeing tour helicopters?
  - Emergency medical services (EMS) helicopters?
  - Corporate executive helicopters?
- What are the recommended solutions for reduction of the effects of nonmilitary helicopter noise?

Although the comments received were not always directly responsive to the four questions, responses were grouped to the extent practical according to the questions. An overall summary of the responses is presented in Table 4-1. The responses are described in detail below.

TABLE 4-1. SUMMARY OF COMMENTS IN RESPONSE TO REQUEST: LISTED IN ORDER OF RECEIPT

	Question #		Current Concerns						Suggested Solutions												
#	Respondent		Low AGL	Hours	Route	Hover	Struct Vib/ Dam.	Operation Type*	Curfew	Min AGL	Max SPL	Spec Route	Visible ID	Limit # Ops	Limit Hover	Pool Ops	Hush Kit	Stage 3	Part 91	Heliport	#
1	Ontario Police Dept.	CA	<500'	X																	1
2	MARCH Coalition	CA						Mil		X		X									2
3	Individual, Springfield	VA	<1000'	X			X	PD, Mil, EMS		X									X		3
4	Individual, Sherman Oaks	CA	X					ENG	X	X		X			X					X	4
5	Individual, Juneau	AK						SS	X												5
6	Individual, Portland	OR	X	X		X		ENG		X	X			X					X		6
7	Hayward Airport	CA	X		X			PD, ENG,PT, EMS		X		X								X	7
8	Robinson Helicopter	CA								X	X										8
9	Seattle Council on Airport Affairs	WA	X	X		X		All	X	1500'		X	X								9
10	Clark Co. Dept Aviation	NV								1000'/500'								X			10
11	Hel. Noise Coalition NY City (O)	NY			X		X	All	X	X		X	X		X	X		X		X	11
12	Assoc. Air Medical Services	VA																			12
13	Representative Carolyn Maloney (O)	NY						All	X	X			X								13
14	AHS International (O)	VA						Indeter		1000-2000'		X									14
15	City of Portland	OR								2000'									X		15
16	Bell Helicopter/Textron	TX	X					Indeter									X				16
17	Helicopter Assoc. International (O)	VA						Indeter		1000-2000'											17
18	Individual, NY City	NY		X					X	1500'		X	X		X	X				X	18
19	Individual, Sherman Oaks	CA		X			X	ENG, PD	X	X						X					19
20	Jones Farm HOA, Hillsboro	OR	X	X	X			PT						X						X	20
21	Whisper Jet, Inc., Sanford (O)	FL								X							X				21
22	Lake Balboa Neigh. Assoc, Van Nuys	CA	X	X	X		X	ENG, SS	X	X		X		X						X	22
22A	Fairway Park Neigh, Assoc., Hayward	CA						None													22A
23	Individual, Sherman Oaks	CA	X	X	X			ENG										X			23
24	Eastern Region Helicopter Council (O)	PA		X	X			Indeter		2000'		X									24
25	Individual, Chester	VA	X		X					1000'+									X		25
26	Individuals, Portland	OR	X					ENG		X				X							26
27	Individuals, Portland	OR	X	X				ENG		X											27
28	Individuals, Portland	OR	X	X			X	ENG,EMS,Taxis		X								X			28
29	Homeowners of Encino (NHNC) (O)	CA	X	X	X			All	X	1500'		X	X	X	X	X		X	X		29
30	Individual, Torrance	CA	X		X					X		X		X				X			30
31	Individual, San Lorenzo (Hayward) (O)	CA	X	X	X	X		ENG,PT,PD		X			X					X		X	31
32	Member Community Board 7, NYC	NY						All	X	1500'		X	X		X	X		X			32
33	Airport Commission, San Francisco	CA	X			X				1000'					X						33
34	Wrong docket																				34
34A	NY State Senator T. Duane	NY						All	X	X		X	X		X	X					34A
34B	President, Borough of Manhattan	NY																			34B
34C	Representative Adam Smith	WA																			34C
34D	Council Member C. Quinn, City of NY	NY																			34D
35	Individuals, Encino (O)	CA	X	X	X		X	ENG, SS	X	X		X		X		X				X	35

TABLE 4-1. (CONT). SUMMARY OF COMMENTS IN RESPONSE TO REQUEST: LISTED IN ORDER OF RECEIPT (CONTINUED)

	Question #		Current Concerns						Suggested Solutions												
#	Respondent		Low AGL	Hours	Route	Hover	Struct Vib/ Dam.	Operation Type*	Curfew	Min AGL	Max SPL	Spec Route	Visible ID	Limit # Ops	Limit Hover	Pool Ops	Hush Kit	Stage 3	Part 91	Heliport	#
36	Individual, City College	NY						All		1500'		X	X	X	X	X					36
36A	Individual, Brooklyn	NY																			36A
37	Individual, Brooklyn	NY	X	X		X	X	ENG, SS, Com												X	37
37A	Individual. NY City	NY		X				All													37A
37B	Air Methods Corp, Englewood	CO								1000-2000'											37B
38	Individuals, NY City	NY		X		X								X							38
39	Individual, NY City	NY	X			X		PD,ENG,SS Film		X		X				X					39
40	W400 Block Assoc.	NY	X			X						X		X	X						40
41	Individual, NY City	NY			X							X									41
42	Individual, Puunene	HI																			42
43	Hel. Noise Coalition NY City (O)	NY																			43
44	League for the Hard of Hearing	NY																			44
45	Individual, Hoboken	NJ		X		X		SS. Com. ENG						X				X			45
46	Individual, Brooklyn	NY		X	X			Corp. Gov	X			X		X							46
47	Federation of University Neighborhoods	NM	X	X		X		ENG. EMS		2000'		X			X						47
48	Individual, Brooklyn	NY		X	X	X		ENG. SS. Corp						X							48
49	Individual, NY City	NY	X			X		SS.ENG.PD.Corp.Film						X						X	49
50	Individual, NY City	NY	X	X			X	Corp. SS		X				X	X	X		X			50
51	Individual, Brooklyn	NY	X	X		X		Corp. ENG		X			X								51
52	Noise Pollution Clearinghouse	VT	X	X	X	X				3000'		X						X		X	52
53	Individual, NY City	NY	X	X	X	X	X	SS.ENG.Corp.Com													53
54	Council Member K.Fisher, City of NY	NY		X	X		X	ENG. Corp		X		X		X		X					54
55	Representative Jerrold Nadler (O)	NY	X	X				SS.ENG.Corp		X		X			X			X			55
55A	Individual, NY City	NY	X	X		X		ENG		X		X			X	X					55A
56	Individual, NY City	NY	X	X	X	X	X	ENG		X				X	X	X					56
56A	WestHillsPropOwnerAssoc/HOEncino(O)	CA	X	X	X			ENG	X	1500'		X	X	X	X	X		X	X	X	56A
57	Individuals, Brooklyn	NY		X		X		ENG		X											57
58	Individual, Pleasant Hill	CA						PT													58
59	Individual, El Segundo (O)	CA				X		ENG		X				X	X			X			59
60	Individual, NY City	NY			X						X										60
61	Individual, NY City	NY	X																		61
61A	NY Assembly Member R Gottfried	NY																			61A
61B	Weehawken Environment Committee	NJ																			61B
62	Individual, NY City	NY			X	X				X			X	X							62
63	Fifteenth Street Block Assoc.	NY										X			X	X					63
64	Individual, Albuquerque	NM		X	X	X		PD. ENG			X										64
65	NY Assembly Member E Connelly	NY			X			ENG													65
66	Representative Jerrold Nadler	NY																			66
67	NY Assembly Member R Gottfried	NY				X		ENG.SS		X		X	X							X	67
68	Individual, NY City	NY																		X	68
69	Weehawken Environment Committee (O)	NJ	X	X	X	X	X	SS.ENG.Corp	X	X		X		X	X	X		X			69
70	Individuals, NY City	NY	X	X		X		ENG		X		X			X						70

TABLE 4-1. (CONT). SUMMARY OF COMMENTS IN RESPONSE TO REQUEST: LISTED IN ORDER OF RECEIPT (CONTINUED)

	Question #		Current Concerns						Suggested Solutions												
#	Respondent		Low AGL	Hours	Route	Hover	Struct Vib/ Dam.	Operation Type*	Curfew	Min AGL	Max SPL	Spec Route	Visible ID	Limit # Ops	Limit Hover	Pool Ops	Hush Kit	Stage 3	Part 91	Heliport	#
71	Individual, Brooklyn	NY	X	X		X		ENG		X		X									71
71A	Mayor, City of El Segundo	CA						ENG. Corp		X									X		71A
72	Individuals, Sherman Oaks	CA	X	X				ENG	X					X		X					72
73	Sherman Oaks Homeowners Assoc. (O)	CA	X	X				All	X	X		X		X	X						73
74	Individual, NY City	NY																			74
75	Vinegar Hill Neighborhood Assoc.	NY	X		X	X	X			X		X		X							75
76	Office of Mayor, NY City	NY	X	X				ENG. SS.													76
76A	Coalition to Quiet Our Heighborhood (O)	NJ	X	X			X		X	1500'		X									76A
77	Individual, NY City	NY						ENG.SS.Corp													77
77A	Regional Commission on Airport Affairs	WA																			77A
77B	Regional Commission on Airport Affairs	WA																			77B
77C	Citizens for a Quiet Environment	NM		X		X		ENG.PD.SS.Corp		2000'	X	X	X					X			77C
77D	Individual, San Lorenzo	CA																			77D
77E	Inidividual, NY City	NY																			77E
77F	Inidividual, NY City	NY																		X	77F
77G	City Councillor, Cambridge	MA	X	X		X		ENG				X									77G
77H	S. Broadway Action Team, Albuquerque	NM		X		X		PD, ENG													77H
78	Air Methods Corp, Englewood	CO																			CO
79	MD Helicopters, Inc	AZ	X	X		X		PD				variable									AZ
80	Individual, NY City	NY		X	X	X	X	COMM,SS													NY
81	Individual, Las Vegas	NV		X	X			SS	X	X		X		X							NV
82	Citizens for a Quiet Environment	NM	X					ENG,PD		2000'	55dBA		X				X				NM
83	Individual, Brooklyn	NY	X		X		X	ENG, SS		2500'		mandatory		X							NY
84	Individual, Lake Balboa	CA	X		X																CA
85	Metro NY Aircraft Noise Mitigation Commi	NY	X			X				X		X			X	X					NY
86	Individual, Brooklyn	NY	X	X			X	PD													NY
87	Individual, NY City	NY		X	X		X							X							NY
88	Individual, NY City	NY												X							NY
89	Individual, NY City	NY			X									X							NY
90	Individuals, NY City	NY	X	X	X	X		MIL, SS, FIL													NY
91	Individual, NY City	NY		X		X															NY
92	Individual, San Francisco	CA		X	X			SS						X							CA
93	Individual, Valley Village	CA	X	X	X			ENG, PD,EMS,COM	X	X		X	X	X	X	X					CA
94	Individual, Philadelphia	PA	X			X		SS,ENG,COM,PD													PA
95	Individual, Hoboken	NJ		X	X	X		SS,ENG,COM,PD	X			X		X		X					NJ
96	Individual, Locust	NJ					X	COM	X	X		X									NJ
97	Metro NY Aircraft Noise Mitigation Commi	NY								X				X	X	X					NY
98	City of NY Community Brd Six Manhattan	NY							X			X	X								NY
99	Individual, Brooklyn	NY	X	X																	NY
100	Individual, NY City	NY						COM													NY
101	NY Assembly Member Scott Stringer	NY																			NY
102	Individual, Brooklyn	NY	X	X					X	X		X									NY
103	Individual, Brooklyn	NY	X	X		X		PD, ENG		X											NY
104	Community Board 7 Manhattan	NY	X	X	X			PD, ENG, COM	X	X		X			X						NY
105	City of NY, Community Board 2 Manhattan	NY	X			X		PD,ENG, FILM,SS	X	X		X		X		X					NY
106	Brooklyn Heights Association, Inc	NY		X		X								X							106
107	Individual, Brooklyn	NY		X				ENG,COM						X							NY
																					0
	Total Count @ #107	122	56	57	36	39	19		26	64	6	46	17	36	24	22	3	16	7	18	
		%	46	47	30	32	16		21	52	5	38	14	30	20	18	2	13	6	15	

* Mil = Military: PD = Police/Fire Dept.: EMS = Emergency Medical Service: ENG = Electronic News Gathering: SS = Sightseeing: Taxis = Helicopter Taxis: PT = Pilot Training: Indeter = Unable to determine: Com = Commuter: Film = Filming: Corp = Corporate/Business: Gov = Non-emergency governmental

(O) denotes was represented also by oral presentation at one of the two hearings at FAA Headquarters.

4.3 Respondents

After adjusting for duplicate submissions, a total of 122 independent responses were recorded. The breakdown of the respondents by group is given in Table 4-2.

TABLE 4-2: BREAKDOWN OF RESPONDENTS BY GROUP

Group	**Number of Respondents**	**Percentage of Total**
Individual Citizens	67	54.9%
Homeowners' Associations	10	8.2%
Citizens' Associations	16	13.1%
Elected Officials	15	12.3%
Helicopter Manufacturers and Technical Associations	5	4.1%
Helicopter Operators' Associations	2	1.6%
Emergency Service Operators and Associations	3	2.5%
Police Departments	1	0.8%
Airport Operators	3	2.5%
Total	122	100%

The distribution of the respondents by state of residence, operation or office location is given in Table 4-3.

In the case of New York and New Jersey, all 67 (54.9 percent) respondents reside in the New York City area. In the case of California, 23 (18.9 percent) respondents reside in the Los Angeles area, and 5 of the 6 (4.9 percent) respondents from Oregon reside in the city of Portland.

Two (1.6 percent) responses came from states (Alaska and Hawaii) that are outside the contiguous United States, but they are included in the analysis for completeness. In addition, one response (from California) is concerned solely with military helicopters. That response is also included for completeness.

Sixteen individuals who submitted written comments also attended and testified at the public workshops. The respondents at the two public workshops consisted of three individuals, three homeowners' associations, three citizens' associations, two elected officials, two helicopter manufacturers and technical associations, two helicopter operators' associations, and one EMS operator.

TABLE 4-3: DISTRIBUTION OF RESPONDENTS BY STATE

State	Number of Respondents	Percentage of Total
Alaska	1	0.8%
Arizona	1	0.8%
California	23	18.9%
Colorado	2	1.6%
Florida	1	0.8%
Hawaii	1	0.8%
Massachusetts	1	0.8%
New Jersey	5	4.1%
New Mexico	5	4.1%
Nevada	2	1.6%
New York	62	50.8%
Oregon	6	4.9%
Pennsylvania	2	1.6%
Texas	1	0.8%
Virginia	5	4.1%
Vermont	1	0.8%
Washington	3	2.5%
Total	122	100%

4.4 Helicopter Operations Eliciting Negative Response

The respondents were asked to identify the types of helicopter operations that elicit negative reaction. Eleven specific types of operation were cited by 63 of the respondents and 9 other respondents stated that all helicopter operations were of concern. The 11 specific types of operation and the number of citations for each type of operation are identified in Table 4-4.

Four respondents were unable to determine the nature of the operations and one respondent stated that there was no noise problem associated with helicopter operations. The remaining 45 respondents did not respond to the question. The specific operations identified by each of the respondents can be found in Table 4-1.

There is strong sentiment among individual citizens, homeowners associations, and citizen associations that ENG operations and sightseeing operations create the most adverse reactions and are the least justifiable.

Several respondents distinguished between police, fire, and medical services. If the operations are truly emergencies, the majority of these respondents indicated that they accept such operations as beneficial to the community. However, routine police patrols and return flights from an emergency are viewed more strictly as non-emergency operations.

TABLE 4-4: TYPES OF HELICOPTER OPERATIONS ELICTING NEGATIVE RESPONSE

Type of Operation	**Number of Citations**
Electronic News Gathering (ENG)	47
Sightseeing (SS)	24
Corporate/business (Corp)	19
Police (PD)	17
Pilot training (PT)	4
Emergency medical services (EMS)	5
Commuter (Com)	10
Filming (Film)	4
Military (Mil)	2
Helicopter taxis (Taxi)	1
Non-emergency governmental (Gov)	1
All Operations	9

4.5 Operations of Concern

Five specific concerns - low flight altitude, hours of operation, flight routes, hovering, and structural vibration and damage - were given as the main reasons for negative reaction to helicopter operations in urban areas. These concerns are listed in Table 4-1 under the column headings "Low AGL," "Hours," "Route," "Hover," and "Struct. Vib/Dam," respectively.

4.5.1 Low Flight Altitude

Low flight altitude was cited by 56 (46 percent) respondents (see Table 4-1), although in only two cases were flight altitudes quoted -- 500 and 1,000 feet Above Ground Level (AGL). Several responses attributed the low flight altitudes, at least in part, to FAA or ATC procedures which either do not specify minimum flight altitudes for helicopters or do not encourage the use of higher flight altitudes for noise abatement. In particular, several respondents referred to FAR Part 91, Section 91.119(d), because it does not specify minimum flight altitudes for helicopters. Section 91.119 exempts helicopters from the altitude restrictions that are imposed on fixed-wing aircraft flights over congested areas. The minimum altitude restriction for fixed-wing aircraft is "1,000 feet above the highest obstacle within a horizontal radius of 2,000 feet of the aircraft." The regulation requires that helicopters be operated without hazard to persons or property on the surface and that the operator should comply with any routes or altitudes specifically presented for helicopters by the FAA Administrator.

4.5.2 Hours of Operation

Helicopter operations early in the morning and late at night were cited by 57 (47 percent) respondents as causing negative response. The concern cited most frequently was the loss of sleep. Several types of operations were cited, including early morning ENG flights and nighttime police surveillance flights. Respondents from both New York City and Los Angeles claim that ENG helicopter operations begin as early as 5 a.m.

4.5.3 Flight Route
Helicopter flight routes are of concern to 36 (30 percent) respondents, but there is a divergence of opinion regarding the nature of the problem. Some respondents stated that concentrating helicopter flight routes along specific corridors, such as along freeways, unfairly exposes certain residents to even higher noise levels than they endure from freeway traffic. In addition, the helicopters tend to fly over residential areas to the left and right of the freeway rather then directly over the freeway. These respondents suggested that the routes be directed towards open space or industrial areas. Other respondents expressed the concern that helicopter flights followed routes of maximum convenience to the operator, such as following the shortest distance between two points, without regard to residents below. They requested more control over the flight routes. Some respondents recognized that changing the helicopter flight routes to reduce noise levels in one community would probably result in an increase in noise in another community.

There is a divergence of opinion in the responses to the effectiveness of voluntary flight route restrictions. Helicopter operators cite examples where voluntary changes to flight routes have reduced noise exposure of residents of New York City. However, citizen associations claim that helicopters do not always follow voluntary rules.

4.5.4 Hovering
Helicopter's hovering for long durations was the cause of concern for 39 (32 percent) respondents. ENG and police operations were cited as the cause of the majority of the hovering occurrences. There was particularly strong negative reaction to the tendency of ENG helicopters to congregate over a particular incident and hover, as a group, for extended periods of time.

4.5.5 Structural Vibration and Damage
Nineteen (16 percent) respondents stated that helicopter operations caused building structures and fixtures to vibrate and rattle. Several of the responses also claimed that there was a potential for damage to the structures and contents due to the low-frequency vibration. One respondent claimed that actual damage to property had occurred due to helicopter noise.

5.0 Helicopter Air Traffic Control Procedures

In this section, general ATC procedures applicable to helicopters are discussed. Also, the consideration of helicopter law enforcement and other public emergency services are addressed regarding needs and public response.

The NAS is confronted by demand of record growth in passenger volume and flight operations.[77] As a result, ATC operations are at times strained and encountering congestion and delays. As changes to meet capacity needs are continual, ATC procedures are complex in nature and influence a multitude of interrelated factors. For example, the airspace in and around New York City is one of the busiest urban metropolitan areas with the most complex ATC environments in the country. Heavy volume of air traffic is managed for multiple international airports (LaGuardia, JFK, and Newark), numerous general aviation airports, multiple heliports, and the several exclusion corridors. Defining, managing, and altering the procedures in this airspace will require a comprehensive FAA review. An ATC aircraft operational change, whether for helicopter or small fixed-wing airplane, is certain to pose an impact to large fixed-wing transport during en route, approach, and/or departure operations. Changes must be carefully considered and demonstrated before implementation to fully assess the impact to the overall NAS safety.

5.1 ATC Discussion

The helicopter industry stated that the FAA ATC limited helicopter altitude operations (see Section 5.2 “VFR and IFR Operations”) could benefit noise abatement operations.[78] FAA believes that current helicopter high altitude boundaries are flexible enough to facilitate noise abatement if desired and requested by pilots. Current helicopter route charts for several major metropolitan areas, such as Boston, Chicago, and New York, were established in collaboration with industry operators to identify "voluntary" operational corridors for safe and minimal noise flights over sensitive areas. The study team reviewed the eight metropolitan helicopter charts and identified more than appropriate upper altitude bounds that would allow for higher altitude noise reduction flight if desired by helicopter operations. For example, within the New York City metropolitan area, the Class B airspaces, surrounding Kennedy/LaGuardia/Newark airports, are controlled from ground surface to 7,000 feet AGL and are available for utilization upon ATC request. Under the lateral boundaries and beneath any available floor of the Class B airspace, VFR operations may be utilized. The opportunity to request higher altitudes for operations, in the interest of noise abatement, is unconstrained by regulation.

Within the metropolitan area of New York City, voluntary noise mitigation operational procedures have been negotiated and established between the FAA and helicopter industry operators. Such procedures endorse general operations along waterway corridors and limitations over specified areas, such as parks. These recommended guidance are published on the Helicopter Route Charts. Eight (8) metropolitan areas have established helicopter route charts. These metropolitan areas are Baltimore-Washington, Boston, Chicago, Dallas-Fort Worth, Houston, Los Angles, New York, and U.S. Gulf Coast.

[77] Aviation Week & Space Technology magazine, “Commercial Aviation on Ropes,” September 18, 2000, pp. 46-51.
[78] Docket Comment #17 by Helicopter Association International, VA, July 24, 2000.

A related ATC comment stated "helicopter IFR operations are limited by the FAA that could otherwise offer noise abatement operations."[79] IFR flight was not established as a noise reducing operational mode but as an operational airspace utilization mode. The principal ATC priority is to uphold safety considerations while minimizing delays in aviation system. This gives greater priority to large fixed-wing transports that move more passengers and require higher operating speed within the airspace. Helicopters are relatively slower and carry few passengers. To avoid conflict with IFR fixed-wing aircraft, helicopters have an alternative flight profile of flying to high altitudes in visual flight rules/uncontrolled condition (VFR/UNC) airspace. This helicopter alternative averts slowing down large transports aircraft and decreases demand on the ATC system.

14 CFR part 91 regulations - General Operating and Flight Rule

FAA regulations addressing helicopter ATC procedures are specified in the Part 91 for "Air Traffic and General Operating Rules." Presently, in Part 91 under Subpart I- "Operating Noise Limits," noise regulations are specified primarily for fixed-wing transport aircraft and do not address helicopters and small airplanes.

5.2 Law Enforcement and Other Public Emergency Services

Law enforcement operations support air patrol for crime prevention of highways and communities, crowd control observation, and immediate response to ground base officers. The needs of law enforcement, like many specialized public services, operate over extended business hours if not around the clock 24 hours a day. For example, one California helicopter police unit responded that it operates daily from 7:30 a.m. to 3:00 a.m., except weekends when it operates from 5:00 p.m. – 3:00 a.m. "Establishment of altitude restrictions beyond safety requirements could **seriously** inhibit the conduct of airborne law enforcement operations," as expressed by a law enforcement respondent.[80]

Several other public emergency services, such as fire fighting and EMS, employ the helicopter's versatility to provide critical life saving and time sensitive operations. One service provider of emergency medical transportation systems and services has served an estimated 200,000 missions among 40 hospitals across the country.[81]

In the Federal Register notice, scoping questions (in Section 4.2) were proposed to assess helicopter noise concerns by functional type of operations. Respondents recognized role of law enforcement helicopters. This sentiment was also expressed for other emergency services, including medical, fire fighting and limited specialized public services. Such services are regarded

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[79] Docket Comment #17.
[80] Docket Comment #1 by Ontario Police Dept., CA, July 5, 2000.
[81] Docket Comment #78 by Air Methods, CO, September 14, 2000.

as vital community needs.[82,83] FAA concurs and recommends that these public services be exempt from any consideration of proposed ATC procedures that would otherwise impose operational limitations.

[82] August 16, 2000 Public Workshop Transcript #1.
[83] October 20, 2000 Public Workshop Transcript #2.

6.0 Consideration of Views (Public/Industry Comments)

In this section, the primary issues of concern are identified and reviewed based upon the public comments received. They are assessed with regard to technical merit (safety and effectiveness) and applicability within statutes, laws and regulations. The issues are broadly categorized either as operational, relating to aircraft/airspace operational issues, or non-operational. Operational issues are further grouped and discussed in context with the appropriate FAA regulation. Each issue is individually discussed to examine the potential for noise mitigation benefits.

6.1 Operational Issues

Five operational issues were identified that relate to "General Operations and Flight Rule" specified under 14 CFR Part 91. These operational issues are: 1) minimum altitudes, 2) noise sensitive route and design guidelines, 3) hover duration time, 4) retirement of noisiest helicopters, and 5) visible identification markings requirements. Preceding the discussion is a brief description of the Part 91 regulation.

Part 91 Regulation

Helicopters have unique VTOL capability that allows them to operate at variable altitudes, low speeds, and hover. The helicopter's versatility is well established in public services such as law enforcement, EMS, fire fighting missions, and heavy lift. In many cases, these operations are highly warranted and only viable by helicopters.

Except during takeoff and landing, Section 91.119 mandates that, when flying over congested areas, aircraft maintain an altitude of at least 1,000 feet above the highest obstacle and a horizontal radius of at least 2,000 feet from another aircraft. In other than congested areas, aircraft are required to maintain an altitude of at least 500 feet above the surface over open water or sparsely populated areas. Over open water or sparsely populated areas, aircraft may operate at less than 500 feet above the surface, provided that they do not fly closer than 500 feet to any person, vessel, vehicle, or structure.

Helicopters may be operated at less than these minimum altitudes provided that they are conducted without hazard to persons or property on the surface.

In comments received, several respondents recommended that Section 91.119 be amended to establish a minimum flight altitude for helicopters similar to that for fixed-wing airplanes. Such a change would require that helicopters in urban areas maintain an altitude of 1,000 feet above the highest obstacle within a horizontal radius of 2,000 feet of the helicopter. One respondent stated that public safety helicopters should be exempted from the minimum altitude restriction.

6.1.1 Minimum Altitude for Overflight and Hover

The noise reduction solution suggested by the majority of the respondents proposed the establishment of a minimum altitude AGL regulation for helicopters. The solution was contained in 64 responses, or 52 percent of the total number of responses received, and was the most prevalent recommendation. Minimum flight altitudes were suggested in 18 responses (see Table 1), with the majority suggesting a minimum altitude above ground level ranging from

1,000 to 2,000 feet. Neither the police department respondent nor the helicopter industry respondents were in favor of this regulatory solution.

A similar noise reduction solution suggested by five respondents proposed the establishment of regulation limiting the allowable maximum sound pressure level (SPL) on the ground. Such an approach can serve to standardize the noise impact threshold on ground observers. One respondent suggested that this approach would be more customary and consistent with existing noise ordinances for other ground-based noise sources like cars, radios, and human disturbances. Three respondents propose this approach principally be implemented for noise sensitive areas, such as hospitals. Two respondents proposed it applicable for all helicopters. Individual helicopter models generate different noise level. As such, the establishment of a noise level on the ground becomes a function of overflight altitude. So noisier helicopters would be required to fly higher to maintain the same noise level emitted to the ground.

Both suggested solutions apply relative altitude or stand off distance as the primary mechanism for attenuating the noise. By establishing a fixed minimum altitude to limit overflight operations spatially over the public, noise levels are likely to fall. Different model helicopters generate different noise levels. Depending on the absolute minimum altitude selected, the noise from different helicopters, although lower in level, may still vary by the ground observer's perception. By prescribing a noise limit on the ground, conceptually the perceived noise reduction becomes a constant allowable noise level with the variability imposed on the helicopters operational altitude. In practice it would place the onus on the aircraft manufacturers to noise test and identify the relative minimum altitude or stand off distance that satisfies the established SPL_{max} criteria on the ground. Both concepts require further research to assess the noise benefits and establish as operational process, procedures, and/or regulation.

Noise reductions are achieved by operating at greater altitude for overflight. This is supported by historical helicopter noise measurements (Newman et al. (1979)) and the present urban *in-situ* noise measurements. Notwithstanding the noise benefits, instances of heavy traffic volume in complex urban airspace regions may trigger an overriding recognition for greater aircraft separation distance for safety. To preserve separation, ATC may accede to alter its priority and limit higher altitude helicopter flight in lieu of the voluntary high altitude low noise flight alternative. Any new procedures or redesign of airspace will require integration of a "keep aircraft high" philosophy. The challenge to optimize airspace utilization continues. Changes can potentially affect other areas of the NAS. Any proposed procedural changes will receive careful consideration and will require testing for feasibility prior to implementation.

6.1.2 "Noise sensitive" Routes & Routing Guidelines

Aviation routes are established to provide for safe and efficient flow of air traffic. The FAA attempts to establish routes over non-noise sensitive areas. It is not practical for aircraft to avoid overflights of some residential communities between their point of departure and destination. This issue is more pronounced for helicopters as most heliports and vertiports are situated within densely populated areas with limited real estate to buffer noise. Forty-six (38 percent) of the respondents recommended changes to the routes flown by helicopters in urban areas. The most frequent recommendation (21 respondents) was that helicopter flight be directed away from residential areas. Some of the respondents suggested that preference be given to helicopter flight routes over commercial and industrial areas. It was also recommended that careful analysis be made of land uses with comments requested from the affected communities prior to the designation of specific flight routes.

The FAA helicopter route charts for several urban areas show helicopter routes along major highways. Respondents disagreed with this approach because of the potential concentration of helicopter noise in residential areas. One respondent specifically called for helicopter routes that were more spread out. Respondents from urban areas along major rivers recommend that actual helicopter operations be flown over the river center rather than along the riverbanks.

One respondent recommends that VFR routes be reexamined, as they have not always been chosen with environmental considerations. The revisions should take into account requirements for high angle-of-bank turns that cause increases in noise level.

The respondents state that routes should be mandated and the rules enforced. They claim that voluntary compliance does not work. It is generally accepted that emergency services be exempted from flight route restrictions.

Identification of optimum helicopter route planning for avoidance of noise sensitive areas should be incorporated and emphasized specifically within the overall planning and development process for an urban airspace design process. Pursuit and implementation of any proposed ATC procedure would require comprehensive evaluation in accordance with all applicable FAA orders and regulations. It would include but not be limited to the environmental and economic review processes.

6.1.3 Limit Hover Duration
Twenty-four respondents or 20 percent presented concepts for limiting hover operations. Twenty proposed limiting the time spent by helicopters in hover for specific sites. Two respondents made the general suggestions for the reductions of hover duration for all operations. Sixteen of the respondents recommended that strict time limits be imposed on the duration of hover. Two examples of such limitations are (a) no more than 5 minutes hover in any hour or (b) no hover period should exceed 2-3 minutes. Two respondents recommended an outright ban on hover operations.

Current flight regulations offer operational flexibility for helicopter operators to exercise voluntary procedures and judgment for hover operations. The FAA strongly encourages that voluntary criteria for minimum hover duration be instituted. FAA encourages operators to increase pilot awareness training for noise mitigation procedures that would include limiting hover duration where possible. Voluntary hover guidelines could state hover duration be kept to a minimum to mitigate noise over populated areas unless the hover operation qualifies as an emergency.

6.1.4 Retire Noisiest Helicopters

Sixteen respondents or 13 percent recommended that quieter helicopters be introduced in urban areas. Ten respondents called for a phased out of service or retirement of helicopters that could not meet a newly defined Helicopter Stage 3 criteria by some specified data; i.e., 2005.

The current civilian helicopter fleet is categorized as either Stage 1 or Stage 2 based upon its compliance to the noise certification limit under Part 36. Helicopters, for which application for issuance of type certificate in primary, normal, transport, or restricted category was made prior to March 6, 1986, are Stage 1. Numerous Stage 1 helicopters continue to offer a productive service that otherwise might be cost prohibitive. The suggested retirement or phase out of any helicopters would require a comprehensive study of environmental benefit and economical impact under rulemaking. Pursuit and implementation of a new Stage 3 standard would require rulemaking under Part 36. FAA would be authorized to phase out Stage 1 and Stage 2 helicopters only if through a rulemaking action it was determined economically reasonable or technically practical under 49 U.S.C. 44715.

Currently, several factors complicate the assessment of a helicopter technology “phase-out” evaluation study. These factors are: 1) the lack of comprehensive operational usage and representative flight profile data for most helicopters, 2) modeling complexity (not simply “point A to point B” flight operations as airplanes) due to helicopters dynamic operational flexibility, and 3) the lack of an up-to-date helicopter noise model database for impact assessment. Until such information and data can be established, a present “phase-out” assessment of noise is unsubstantiated. The FAA is establishing an update of the helicopter noise database with recent technology flight test measurements under the auspices of Society of Automotive Engineers 21 Committee on Aircraft Noise.

6.1.5 Visible Identification

Seventeen respondents or 14 percent suggested that helicopters be prominently marked with visible identification that is readable by ground observers. Concepts proposed consider utilizing the existing N-numbers issued by the FAA, or other identifiers, placed on the belly of the helicopter. Lights were also recommended for identification luminescent at night. The discrimination of police, fire, and other emergency helicopters users was proposed. It called for a flashing blue light installed beneath the helicopter. This is similar to sirens on fire trucks for public acknowledgement, safety, and avoidance. The suggested markings and visual identification proposals sought the identification of helicopters causing negative noise impacts or violating any regulatory flight procedures.

Most helicopters are not appreciably sizable in surface area to display a far-visible, distinctive identification. Some helicopters can be visually recognizable due to unique commercial painted designs used primarily for advertising recognition. Although aircraft are required to display a registration number, the mark display requirements, as specified 14 CFR Section 45.29, ranges from 2 to 12 inches in height. The relatively small sized mark display can result in limited long distance recognition. A more fundamental limitation of this approach includes no guarantee that the helicopter of concern will operate within a reasonable relative distance or line of sight.

Land Use/Access

Three operational issues were identified with relationships to "Airport Land Use Planning Compatibility/Airport Noise and Access Restrictions" specified under Part 150/161. These issues are frequency of operations, time frame of operations, and topics associated with heliports/airports (i.e., ground run-up duration). Also presented is the aim of noise abatement procedures. The background leading to Part 150 and Part 161 regulations is briefly discussed.

Part 150/161 Regulations

Proposing to minimize number of aircraft operations and establish a curfew of operational time frame implies airport/heliport access and usage restrictions. These measures are within the interest of the airport operator. Airport access and use restrictions include such topics as hours of airport operation, types of aircraft allowed to utilize the airport, and limits on number of aircraft operations or passenger enplanements. However, the FAA restricts airport operators from establishing policies which impact safety that are unreasonable, unjustly discriminatory, impose an undue burden on interstate commerce, or interfere with Federal regulations.

Background

The FAA has provided technical and financial support for airport noise compatibility planning since 1976. The 1976 Aviation Noise Abatement Policy encouraged airport proprietors and others to consult with FAA about their plans and proposals and to suggest innovative ways to meet the noise problem in their communities. Airport proprietors were encouraged to consult and review proposals to restrict use with airport users and the FAA before implementation.

In 1979, Congress enacted the Aviation Safety and Noise Abatement (ASNA) Act to encourage airport operators to adopt noise abatement plans on a voluntary basis and to provide Federal grants-in-aid for approved plans. This voluntary program was enacted through FAA's issuance of Federal Aviation Regulation Part 150 "Airport Noise Compatibility Planning." ASNA directed the FAA to establish by regulation a single system for measuring aircraft noise exposure, to identify land uses that are normally compatible with various noise exposure levels, and to receive voluntary submissions of noise exposure maps and noise compatibility programs from airport proprietors. Based on the noise exposure maps, strategies are developed and evaluated to reduce noise exposure and non-compatible land uses around an airport.

In 1990, the Airport Noise and Capacity Act (ANCA) was enacted partly in recognition of growing constraints that local airport noise and access restrictions were imposing on the national aviation system. The ANCA affirmed pre-existing law obligating airport operators to not impose restrictions that would, among other things, place an undue burden on interstate or foreign commerce or the national aviation system. In 1991, the FAA established Federal Aviation Regulation Part 161 "Notice and Approval of Airport Noise and Access Restrictions," to implement the requirements under ANCA relating to airport restrictions. Part 161 established requirements for notice, analysis, and review of local Stage 2 aircraft restriction proposals and notice, analysis, and Federal approval of Stage 3 aircraft restriction proposals. The FAA determined that Part 161 should cover operations by all Stage 2 aircraft, including those weighing less than 75,000 pounds that were not subject to the Stage 2 "phase out" requirement.

Part 161 also applies to proposals to restrict operations by helicopters that are certified as Stage 2. Part 161 applies to federally funded airports and heliports or those that plan to seek Federal funding for development projects.

Noise or access restrictions are defined in Part 161 as restrictions affecting access or noise that affect the operations of Stage 2 or Stage 3 aircraft, such as limits on the noise generated on either a single event or cumulative basis; a limit on the total number of aircraft operations; a noise budget or noise allocation program that includes Stage 2 or Stage 3 aircraft; a restriction imposing limits on hours of operations; a program of airport-use charges that has the direct or indirect effect of controlling airport noise; and any other limit on Stage 2 or Stage 3 aircraft that has the effect of controlling airport noise. The rule does not apply to aircraft operational procedures that must be submitted for adoption by the FAA, such as preferential runway use, noise abatement approach and departure procedures and profiles, and flight tracks. Other noise abatement procedures, such as taxiing and engine run-ups, are not subject to Part 161 unless the procedures imposed limit the total number of aircraft operations, limit the hours of aircraft operations, or affect aircraft safety at the airport or heliport.

For Stage 2 aircraft, Part 161 requires that airports provide a cost-benefit analysis concerning proposals to restrict operations and a public notice and opportunity for comment. The analysis must include costs and benefits of the proposal, a description of alternative measures considered, and comparative cost-benefit analyses of these alternative measures. The notice and analysis required must be completed at least 180 days prior to the effective date of the restriction, with a minimum 45-day comment period.

ANCA provides a regulated means through which airport operators, users, and communities could work together to reach solutions which would reduce incompatibility of airport-generated noise with sensitive land uses while ensuring that the airport’s role in the national aviation system is not jeopardized. The FAA also encourages airport proprietors to seek to enter into voluntary agreements with users. Voluntary agreements are not subject to ANCA and may include agreed-upon enforcement mechanisms that are consistent with Federal law.

6.1.6 Frequency of Operations

The 36 respondents (or 30 percent of the total comments) recommended limiting the frequency or number of helicopter operations. This issue also encompasses the suggestion for pooling helicopter utilization to reduce number of flight operations. These recommended solutions cover a wide range of options, including, in an increasing order of severity:

(a) Limiting the number of ENG and traffic helicopters;
(b) Reducing the number of operations by Sightseeing (SS)/tour and ENG helicopters;
(c) Permitting ENG helicopters only for specific events;
(d) Eliminating SS helicopters;
(e) Eliminating SS helicopters, and reducing the number of ENG helicopters;
(f) Eliminating SS and non-essential flights;
(g) Permitting only emergency operations; and

(h) Banning all helicopter flights over densely populated areas.

Such proposals to limit, ban, or eliminate the frequency or number of helicopter flights require federally funded airport/heliport operators to comply with Part 161 procedures for implementing restrictions. Such restrictions must establish claim that it would not affect aircraft safety, be unjustly discriminatory, impose an undue burden on interstate commerce, or interfere with Federal regulations.

6.1.7 Time Frame of Operations

Twenty-six respondents or 21 percent proposed instituting helicopter operational curfews. In some cases the curfews were proposed in a general sense without specificity of function of operator. In other cases, the proposed curfews were restricted to either SS or ENG operations or to both. Seven respondents recommended specific curfew time frames. The proposed starting time for a curfew ranges from 9:30 p.m. to 11 p.m. and the proposed ending time is either 7 a.m. or 8 a.m. It was suggested that exemptions be permitted for emergency flights or flights with special justification.

The more stringent proposal specified SS flights operations only from 12 noon to 5 p.m. on weekdays with a total ban during weekday nights and during the entire weekend. All other operations are limited to daylight hours with one recommendation that there be no corporate operations after 6 p.m. on weekdays and no operations on weekends.

Similarly, such proposals to limit helicopter time frame of operation requires federally funded airport and heliport operators to comply with Part 161 procedures for implementing restrictions. Such restrictions must establish claim that it would not affect aircraft safety, be unjustly discriminatory, impose an undue burden on interstate commerce, or interfere with Federal regulations.

A prototype system for aircraft tracking and management of low altitude air traffic in an urban area was demonstrated during the 1996 Centennial Olympic Games in Atlanta, Georgia. Under Operation Heli-STAR (Helicopter Short-Haul Transportation and Aviation Research), a Heli-STAR tracking system was tested in the proof-of-concept evaluation of National Aeronautics and Space Administration's (NASA) AGATE Advanced General Aviation Transportation Experiment Program requirements and temporarily utilized to allow cargo hauling operations of time critical goods.[84] The ADS-B (Automatic Dependent Surveillance-Broadcast) tracking system demonstrated a promising technology that could offer a VFR tracking solution to support the concerns of this study. More R&D investment is required to prepare and fully demonstrate the system for commercialization and field implementation.

6.1.8 Airports and Heliports

Eighteen respondents or 15 percent addressed the operation of helicopters in the neighborhood of airports and heliports. The recommendations covered a wide range of options:

(a) Curfews for arrivals and departures;

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[84] Stephen T. Fisher *et al*, "Operation Heli-STAR – Summary and Major Findings," DOT/FAA/ND-97/9 Report, September 1997.

(b) Prescribed arrival and departure routes;
(c) Limits on the number of helicopters based at an airport or heliport;
(d) Limits on the number of helicopter operations at an airport or heliport;
(e) Noise abatement procedures for takeoff and landing at an airport or heliport;
(f) Restrictions on ground operations such as idling and run-up time for helicopters and limitations on pilot training time; and
(g) FAA rules to allow local government to restrict or ban the placement of helicopter landing and takeoff facilities in urban areas.

One respondent addressed the use of IFR and GPS for helicopter operations at heliports in lieu of ground-based precision approach aids. It was further recommended that the FAA develop, and implement, GPS point-in-space approaches to heliports and GPS IFR departure procedures that recognize the full range of helicopter operational capabilities.

Once again, such proposals to limit airport/heliport operations require federally funded airport and heliport operators to comply with Part 161 procedures for implementing restrictions. Such restrictions must establish claim that it would not affect aircraft safety, be unjustly discriminatory, impose an undue burden on interstate commerce, or interfere with Federal regulations. Concerns regarding idling and run-up time for helicopters may not require compliance with Part 161 if it does not affect total number of hours of operations or affect aircraft safety, but are addressed through voluntary operational guidance of noise awareness pilot training.

6.1.9 Noise Abatement Procedures

Noise abatement procedures are designed to lessen the impact of aircraft noise on communities. These procedures depict or describe geographic areas to avoid, approach and departure paths to follow, or limit direction to certain times of day. Noise abatement procedures may also specify rate of climb, altitude restrictions, or power settings. They may provide techniques for ground operations such as use of reverse thrust, reverse thrust back-ups, and maintenance run-ups. The FAA ensures that ATC personnel are cognizant of and do not issue control instructions contrary to noise abatement procedures to the extent they do not impact aircraft safety or air traffic efficiency. Airport sponsors are responsible to ensure pilot compliance with these measures.

Two operational issues were identified with relationships to “Noise Standards: Aircraft Type and Airworthiness Certification” specified under Part 36.

Part 36 Regulations

Under Part 36, Noise Standards: Aircraft Type and Airworthiness Certification, noise certification regulations for helicopters are in subpart H with references to Appendix H, Noise Requirement for Helicopters, and Appendix J, Alternative Noise Certification Procedure for Helicopters. It directly addresses limiting allowable noise levels by setting certification noise limits based on achievable noise reduction and aviation technology and reasonable economic basis. Under the noise certification process, helicopters must demonstrate under strict standards

and test procedures that its worst case maximum noise emission can satisfy established noise limit requirements prior to aircraft production or modification for operations. Helicopters that demonstrated noise levels, at or below the set limits, are in noise compliance and are subject to satisfying applicable airworthiness regulations.

6.1.10 Helicopter Stage 3 limits

Sixteen respondents or 13 percent recommended a requirement that only quieter helicopters may operate in urban areas. In some cases, the recommendation was made in general terms for all operations and unspecific to only urban areas. Ten respondents made specific reference to the categorization of helicopters into Stages 1, 2, and 3 in a manner similar to fixed-wing airplane usage. Two respondents recommended setting new quieter helicopters standards and termed them Stage 4 for helicopters. Internationally, aviation environmental policy is heavily stressing noise stringency (strict limitation on noise) and actively pursuing harmonization of international noise guidelines. The United States is a leading member of ICAO and participates in continued harmonization of noise regulations in the preservation of environmental concerns. Under the Fifth Session of the Committee on Aviation Environmental Protection (CAEP5), a proposal to increase stringency of ICAO Annex 16 noise guidelines for helicopters was adopted within the ICAO steering committee. Proposed stringency would affect the existing regulations by reducing noise limit curves: -4.0 dB for overflight, -3.0 dB for takeoff, and -1.0 dB for approach conditions. Consistent with ICAO council approval, the FAA will promulgate the stringency proposal for U.S. regulatory adoption under 14 CFR Part 36.

6.1.11 Source Noise Reduction (hushkit?)

Three respondents or 2 percent recommended reduction of helicopter noise at source. Some noise reduction is achievable by retrofitting existing helicopters either with a “quiet cruise kit” (response #16) or the installation of a “hushkit” (response #21)[85,86]. In general, respondents identified the need for the development of quieter helicopters and the phasing out of noisier helicopters.

Presently, helicopter “hushkits” do not exist in a generic retrofit process like that of fixed-wing aircraft “hushkits.” Yet, Vertical Aviation Technology, Inc., successfully retrofits a vintage Sikorsky S-55 helicopter primarily for noise reduction. The noise reduction methods applied are uniquely helicopter model dependent and cannot simply be applied to all types of helicopters. The retrofit cost and market demand has not stimulated the larger manufacturers’ technology investment. Major manufacturers find it much more cost effective to build the noise technology into new aircraft rather than retrofit existing aircraft. The $10 million invested by Vertical Aviation Technology Inc. was very specifically aimed at meeting the sightseeing/tour operator needs. This was in anticipation of the impending noise restrictions in national park areas being proposed.

Investments and implementation of noise reduction technology has not completely been a recognized priority by all manufactures. Internationally harmonized requirements for stricter

noise certification regulation will compel implementation of noise reduction technology. More aggressive manufacturers are promoting their development of quieter helicopters in the market

[85] Docket Comment #16: by Bell Helicopter Textron Inc., TX. July 24, 2000.
[86] Docket Comment #21: by Whisper Jet Inc., FL. July 25, 2000.

place. Public recognition for advocating “quiet” helicopters and consumer/operator awareness is gradually changing the buyer/operator “lowest purchase price” paradigm for helicopter to one of community friendly/environmentally compatibility. The U.S. helicopter industry highly recommended the infusion of Government basic research and development funding for “quiet” rotorcraft technology to equally compete with foreign entities.

6.2 Non-operational Issues

In the following, non-operational issues are presented. These are issues not mutually exclusive but are, rather, interrelated. Note that military helicopter operations are not addressed because they are outside of the scope of this mandate.

6.2.1 Voluntary Rules

There is consensus among individual respondents, homeowners’ associations and citizens’ associations that voluntary restrictions on helicopter operations in urban areas do not work. However, respondents from helicopter operators’ associations dispute this conclusion. Eastern Region Helicopter Council of operators has quoted examples where New York City route changes to mitigate noise exposure on residents have resulted in complaint reductions. The helicopter operators also referred to their “Fly Neighborly” as an effective voluntary program to minimize noise levels in urban communities.

For helicopters, special voluntary routes are established making full use of the VTOL operating characteristics that would otherwise constrain flight corridors due to miss matches in speed criteria with fixed-wings. Although use of these routes is not mandatory, it is recommended by FAA for its mutually established benefits, i.e., avoidance of noise sensitive areas and reduction in general flight corridor traffic.

6.2.2 Pooling of Operations

Twenty-two respondents or 18 percent suggested that there be pooling of ENG helicopters so that there is only one helicopter flying to cover a particular event. Television and radio stations would share the signal transmitted from that pool helicopter. The responses ranged from recommendations of voluntary participation to recommendations of mandatory regulations.

With specific application to the reporting of traffic problems, it was recommended that ground-based systems be used instead of ENG helicopters for the reporting of traffic problems; i.e., cameras installed along the freeways by Caltrans in Southern California.

Pooling of operations, specifically of ENG helicopter operations, is a concept targeted at limiting the number of operations which could reduce the frequency (number) of noise events and accumulation (amplification) from multiple helicopters simultaneously operating at the same event and concentrated airspace.

Although outside of the FAA purview, one suggestion is that business incentives for “pooling” ENG helicopter operations among operators be considered. By pooling ENG operations, it reduces the noise that otherwise is generated by multiple operations covering the same incident. Such a proposed program is encouraged for state/city governments and/or local municipalities and businesses desiring to retain ENG operations while also mitigating noise for their area.

6.2.3 Exempt Law Enforcement and Emergency Medical Services

For the noise reduction alternatives suggested, several could inhibit public service helicopter operations. However, the public expressed supported for exemption from noise restriction alternatives for services in performance of emergency operations. Yet, they still recommended adherence when operating in a non-emergency response condition; i.e., returning to base station.

As a specific concern outlined under the mandate, the discussion regarding law enforcement and EMS is given in Section 5.2, Law Enforcement and Other Public Emergency Services.

6.2.4 VFR and IFR Operations

The helicopter industry recommends that the FAA revise current VFR corridors and checkpoints to minimize noise exposure in urban areas. They also seek that ATC be more aggressive in assigning helicopter flight altitudes for minimum noise whether or not requested by the helicopter flight crew. In addition, the FAA and ATC should develop a better understanding of the helicopter noise problem in urban areas and devise better techniques and training with respect to the unique characteristics of helicopters.

The helicopter industry also recommends that the FAA develop easier access for helicopters to the IFR system with approach and departure capability to and from the actual heliport facilities. It was stated that the changes would eliminate the current lower altitude VFR transitions between the current heliports and the IFR access points. The operators project that there would be higher use of the IFR system by operators that currently opt for lower altitude VFR operations rather than face the delays and uncertainties of the current IFR environment.

Further discussions regarding the VFR,UNC, and IFR operations are addressed in more depth in Section 5.0, Helicopter Air Traffic Control Procedures.

6.2.5 Airspace Control

Local legislative and city authorities commented on requesting authority for determinations of noise and airspace control decisions. However, Federal law outlines the FAA as the agency with jurisdiction and responsibility for airspace control with necessary adherence to environmental policy.

One commenter summarized FAA's options to regulate helicopter traffic and stated that, regardless of whether the best solution is to turn control over to state and local governments or to the FAA to impose strict controls, thousands of urban residents are awaiting a comprehensive and well-reasoned environmentally responsible document. In the past, FAA has worked with local communities and helicopter operators in the New York area and other areas of the country to establish memoranda of understanding designating voluntary noise abatement routes and

procedures, such as for helicopter sightseeing in the vicinity of the Statue of Liberty. FAA is willing to continue to facilitate voluntary solutions to address community concerns. While the FAA's exclusive statutory responsibility for noise abatement through regulation of flight operations and aircraft design is broad, the noise abatement responsibilities of state and local governments through exercise of their police powers are circumscribed. Local governments are currently preempted from regulating overflights, in part because of the national need for uniform regulation of the navigable airspace. A patchwork quilt of state and local government airspace regulations would impose an undue burden on interstate commerce. State and local governments play a critical role in protecting their citizens from unwanted noise using their powers of land use control. FAA continues to study the issue in order to abate aircraft noise to protect public health and welfare.

6.2.6 Military Helicopters

Military helicopters were specifically excluded from the current study. However, several respondents observed that the general public could not differentiate between civilian and military helicopters. Military helicopters flying over urban areas are usually performing transit operations that are similar to those performed by civilian helicopters. Thus, respondents recommended that military helicopters be included in the study.

Military helicopters utilize the same airspace system, making it difficult to determine the influence the sector that contributes to the public's disturbance. Many military helicopters are not designed to civil noise standards in order to satisfy stringent mission performance requirements. In the long term, it would be beneficial for both sectors, civil and military, to resolve such issues mutually for any future noise solutions to be more effective (and possibly more economical). One proposal is that the Department of Defense consider assimilation of civil noise standards for military rotorcraft in order to address noise reduction in a unified national strategy that mitigates noise from all types of helicopter operations.

Technology Research Initiatives

Respondents identified several topics for further research to better understand the impact of helicopter noise on residents of urban areas and to foster the development of quieter helicopters.

6.2.7 Socio-Acoustic (Psycho-Acoustic) Survey

Ten respondents or eight percent, inclusive of the helicopter industry's support, recommended that a socio-acoustic survey of the people living and working in urban communities exposed to helicopter noise be conducted. The survey should include determination of the types of operation and the noise characteristics that the public find annoying. "Psycho-acoustic" experts in the field of environmental health should design it. Public comments encouraged that any implemented noise methodology be subject to peer review by members of the scientific and medical communities to ensure that it is unbiased. The results of the survey would be used in the development and implementation of methods to reduce the effects of helicopter noise in urban areas. Socio-noise author Professor Bronzaft recommends that Congress consider allocation of funds to support a multi-year, socio-acoustics study at an approximate cost of $150,000 annually to capable universities.[87]

6.2.8 Flight Tracking and Noise Monitoring System

Workshop respondents raised the concern the FAA does not formally track number of operations, normally considered by takeoffs and landings, for helicopters as well as overflights through a given area. This concern was incited in the acceptance of quantifiable helicopter

[87] Communications with Bronzaft, 2000.

statistics that are currently retained by operators. Communities argued this information was unreliable, without through traffic noise effects and biased, when seeking to gauge noise impact. Hence, recommendations were made for the FAA to track helicopter operations and also perform noise monitoring to quantify the impact, in particular, for specific noise sensitive sites such as parks, hospitals, and neighborhoods.

The FAA does not formally track the number of helicopter operations (takeoffs and landings) nor does the FAA actively monitor noise in metropolitan areas. No process exists for tracking VFR flights below radar controlled airspace. For helicopter operations within the ATC controlled airspace, the radar tracking system records such approved operations. The current VFR procedures are structured for independent operational tracking that helicopters greatly utilize given their vertical short takeoff and landing capabilities. The priority for tracking focuses primarily on IFR controlled airspace and commercial transport operations. The FAA main priority is dedicated to maintaining the IFR system functions. FAA has limited infrastructure tracking resources and budget to expand capabilities to VFR operations.

6.2.9 Global Positioning System approach/departure Noise Abatement Technology

"Spin-off" GPS technology, from an effort to improve radar guided landing and takeoff operations for bad weather, holds the prospect of mitigating noise. By prescribing approach and departure profiles using GPS guidance technology, helicopters can be flown or directed to avoid the high noise generating aircraft states or minimize operations through them.

Under NRTC/RITA activities, preliminary research and testing has indicated the promise of reducing approach noise. However, further development is required to validate a commercially viable system. This new technology offers another alternative for enhancing the capability of operational noise abatement procedures.

6.2.10 Improved Helicopter Noise Metric

Several respondents claim that there is no adequate metric for measuring the response of humans to helicopter noise. Studies indicate the metrics developed for airplane noise are not completely adequate for helicopters. There is a need for further development of appropriate annoyance metric with improved correlation for helicopters.

As discussed in "effects on individuals" (Section 3), there are multiple noise metrics utilized to assess noise (EPNL, ASEL, DNL, etc). However, civil helicopter annoyance assessments utilize the same acoustic methodology adopted for airplanes with no distinction for helicopter's unique noise character. As a result, the annoyance of unaccustomed, impulsive helicopter noise has not been fully substantiated by a well-correlated metric. The FAA favors the chartering a technical effort to focus on low-frequency noise metric to evaluate helicopter annoyance.

6.2.11 Quieter helicopters

Recommendations were made that helicopter manufacturers be encouraged to design quieter helicopters. FAA, NASA, and industry agree it could only be accomplished through stable continued funding of the joint research programs.

Unlike fixed-wing aircraft that benefited from the leap from jet to turbofan technology, helicopter noise reduction technology has not achieved comparative orders of noise reductions. Much of the R&D returns has come from improved understanding and identification of physical mechanisms and phenomenon modeling, such as BVI noise and HSI noise occurring during approach and high speed cruise. Studies have identified “noise reducing” design trades and concepts such as increasing number of blades, reducing tip speed, thin blade tips, high technology airfoils, and a variety of other parameters. Presently, stiff international competition and greater environmental sentiment are making manufacturers more cognizant of their need to invest and implement “quiet” technology into helicopter design.

Noise database

The FAA continues to work with NASA and the aviation industry to identify and create aggressive research programs. There is a strong global awareness for engineering innovations in “quiet” technology for aircraft now and in the future. With the completion of the Advanced Subsonic Technologies Program, many of the concepts await an overall integrated technologies demonstration. NASA has been the Nation’s leader in fostering comprehensive helicopter design methods and the establishment of noise test databases for rotorcraft. Together with the FAA, technical studies to bridge the gap between inaccuracies in helicopter predictions, when compared to measurements, require a serious resolution. Overall, the course of our Nation’s aviation noise reduction technology effort, especially for rotorcraft, must consider revitalization if significant long-term improvements for noise integration technology are to occur.

7.0 Source Noise Modeling and Sensitivity Assessment

In this section, noise measurements made to establish the helicopter source noise effects with an urban environment are presented. This is followed by a helicopter altitude-noise sensitivity evaluation to consider the benefits of operations at higher altitude.

7.1 Helicopter Source Noise Measurements in an Urban Environment

Figure 7-1. AStar Helicopter Flyby in an Urban Environment (Liberty State Park, NY/NJ)

Helicopter source noise measurements in a densely populated area were necessary to quantify the influences of helicopter noise relative to an urban setting (other noise contributions are automobile traffic, harbor ferry, people, etc.) and understand urban setting effects.

In support of the FAA, the Volpe National Transportation Systems Center Acoustics Facility (Volpe Center) conducted field measurements in the greater New York City area during the week of July 17, 2000. Although the Section 747 mandate is national in scope, the New York City area was chosen for the collection of *in-situ* acoustic data because it was representative of an urban environment exposed to helicopter operations and offered many sites suitable for the collection of such data. Measurements were primarily conducted in New Jersey's Liberty State Park (see Figure 7-2). Additionally, data were collected near one of the downtown heliports, adjacent to the Wall Street financial district. The collected data were studied to identify the urban noise effects relative to conventional common ground conditions and assessed for noise reduction/altitude sensitivities. Similar New York City *in-situ* test data and other available aircraft noise measurements were compared. FAA's Helicopter Noise Model/Integrated Noise Model (HNM/INM) was utilized to model altitude-noise attenuation effects.

Figure 7-2. Liberty State Park - Helicopter Noise Measurement Site

Figure 7-3. Digital Video-based Tracking System

During the measurements, acoustic data were collected using at least one microphone, depending on the site. Additionally, detailed aircraft position data were collected using a digital video-based tracking system (Figure 7-3). Reduction of these data renders time-correlated X, Y, Z and velocity data for each aircraft event. As a backup to the video tracking data, redundant slant range data for the aircraft were collected via 35mm camera-based photo scaling methods as well as using laser range-finding devices. Meteorological data were collected periodically throughout the measurements.

Figure 7-4. An Urban High Density Setting

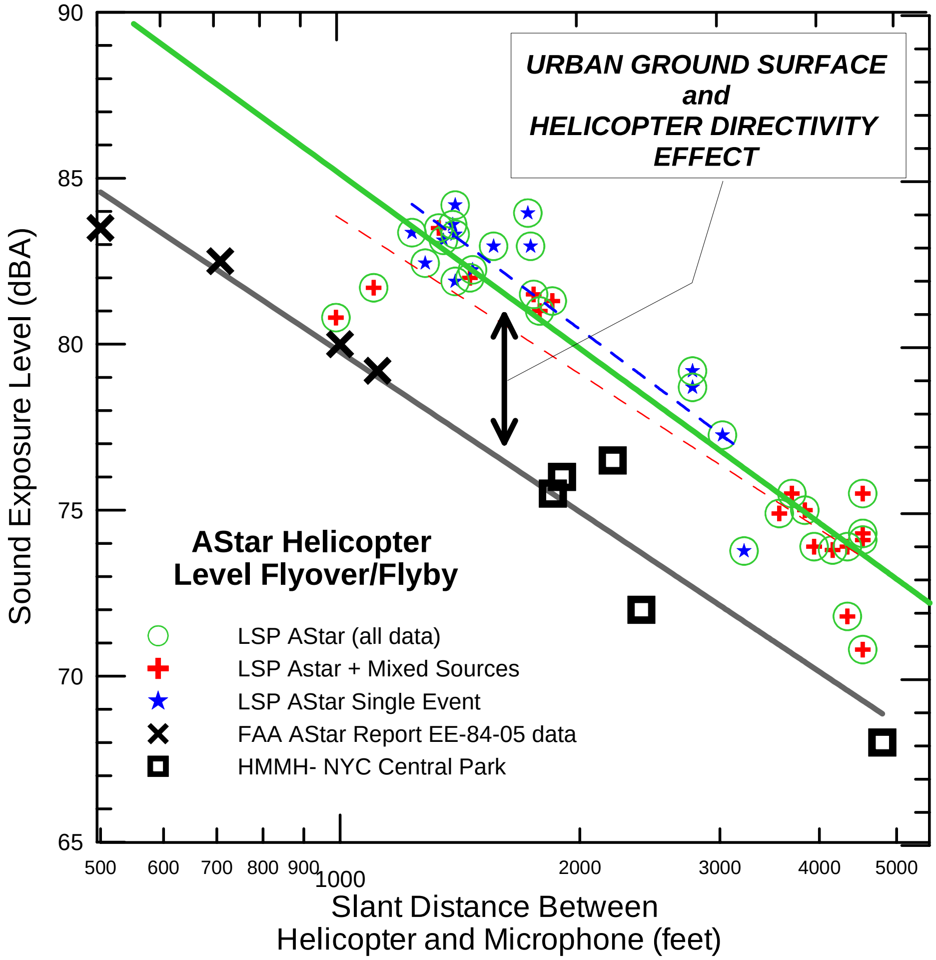
Urban Noise Results

In assessing the acoustical effects of an urban environment, noise data for different ground conditions are investigated. Measured Liberty State Park AStar helicopter noise data are compared with available AStar helicopter noise data from a non-urban setting. In Figure 7-5, SEL and corresponding distance data from Appendix G, Tables (1a) and (1b), are plotted. The single event and mixed helicopter data are depicted as circled star and plus symbols, respectively. It represents helicopter noise over hard ground conditions, characteristic of urbanization, as it was principally measured over calm water. AStar helicopter noise certification data and recent measures from the New York City Master Plan are plotted as "X" and squares, respectively. The latter data were measured over common semi-absorptive ground conditions such as cut grass. Equivalently, the New York City Master Plan noise data are from flights recorded in Central Park.[88]

[88] Edwards and Kelcey Engineering, Inc., *"Heliport and Helicopter Master Plan for the City of New York,"* Final Report, March 1999.

As shown in Figure 7-5, an ASEL difference of approximately +3.5 dB exists between fitted curves for each dataset. Helicopter noise predictions with ground surface noise reflection effects by Leverton and Pike predicted the noise difference being lower than that given by the data. Based on the comprehensive ground reflection analysis, presented in Appendix G, the sound reflections due to hard ground appeared to cause an approximate +2 dB increase in noise levels relative to a semi-absorptive ground conditions. The additional +1.5 dB contribution is possibly due to the helicopter's nonuniformed noise directivity that was a recognizable factor given the *in-situ* measurement situation. In Figure 7-6, the AStar helicopter noise directivity is presented in an azimuthal polar plot. It reveals the higher ASEL at the starboard side as approximately +1.5 dB greater than the port side. The *in-situ* measures distinguish directivity effects that otherwise are averaged lower by multi-microphone measurements. Other factors such as variability in altitude, airspeed, and meteorological effects contribute additional deviations of the data.

Figure 7-5. AStar Noise Measurements Comparing Liberty State Park Noise Effects



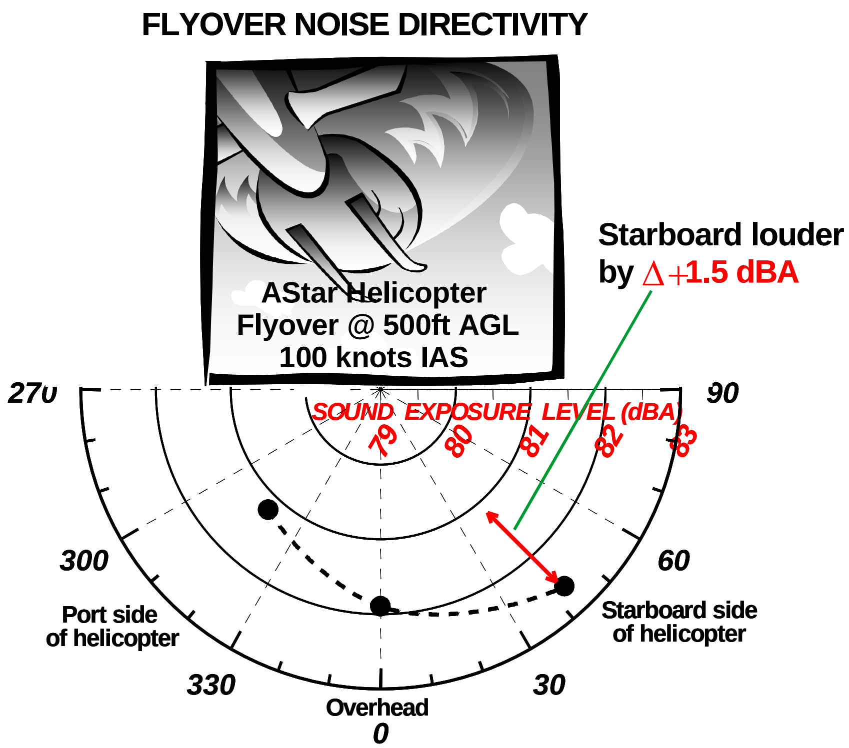


Figure 7-6. Azimuthal Noise Directivity Polar of an AStar Helicopter for 100 knot Flyovers (Ref. FAA-EE-84-05 Report)

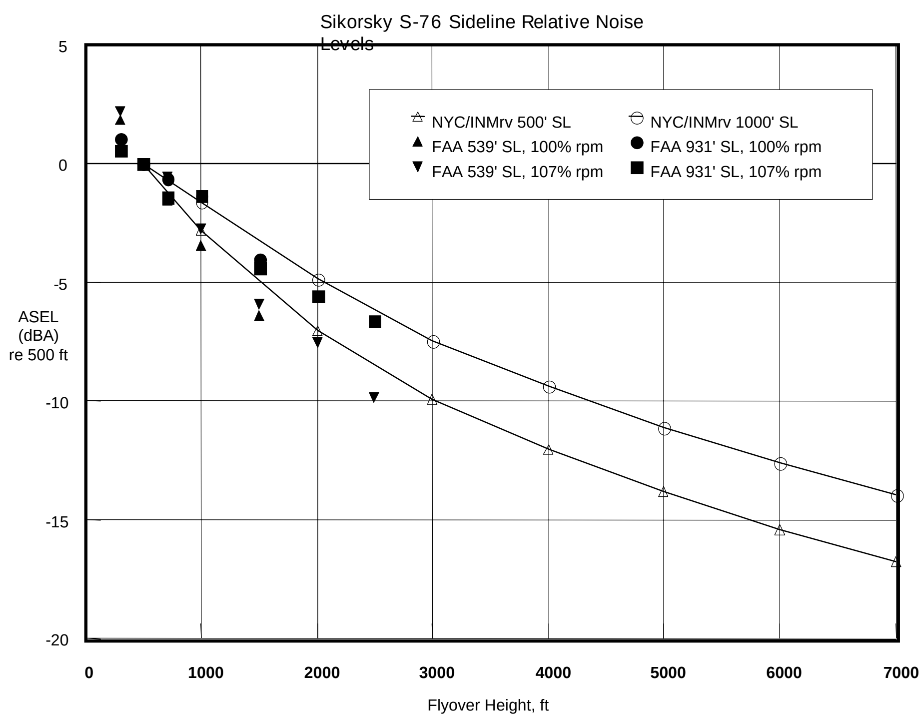


Figure 7-7. S-76 Altitude-Noise Reduction Sensitivity for Liberty State Park

The Research Version of the INM (INMrv) was utilized with Liberty State Park data to model altitude-noise reduction sensitivity effects. The details of the analysis are discussed in Appendix G. Shown in Figure 7-7, the normalized 500-foot Liberty State Park noise results, given by the solid curves, are consistent with past data for lateral sideline noise reduction with increasing altitude. It reveals the possible noise reduction benefit with increased altitude flight for the S-76 given the 500-foot or 1,000-foot lateral observers. The attenuation rates are consistent with previously documented measurements offering high confidence in the data.[89]

In conclusion, an approximate +2.0 dB increase in noise is a result of the noise propagation over a hard ground condition. In this case, it was water. The *in-situ* measurement distinguish directivity effects that otherwise are averaged lower by multi-microphone measurements. Certainly, other factors such as variability in altitude, airspeed, and meteorological effects contribute some deviation to the data. The Liberty State Park data have been checked and revalidated for repeatability. The rates of noise reduction with increasing altitude are consistent whether over common ground or in urban environment. However, the absolute levels should be adjusted to include the +2.0 dB effects of urbanization.

7.2 Altitude-Noise Sensitivity - Introduction

The most highly cited operational issue that was expressed to the FAA requested establishing a minimum altitude for helicopters. The public comprehends the benefit of reducing noise by creating a greater stand off distance and seeks minimum altitude AGL operations. However, there existed some concern that, because of excess ground attenuation effects, sideline noise levels could actually increase as helicopter altitude increased, reaching a maximum for some altitude and then eventually decrease as helicopter altitude is increased further. Several published FAA/industry helicopter noise certification databases have been reviewed in an attempt to address that concern and establish an understanding of altitude-noise sensitivity for observers under the immediate flight path.

Background

It is well known in the certification of transport category and turbojet powered airplanes that values of EPNL measured at takeoff sideline (lateral) locations have a maximum for airplane altitudes of about 1,000 feet although the maximum may not be well-defined in some cases. The explanation is that, during an airplane's takeoff roll and very low altitude lift-off, the effect of excess ground attenuation (EGA) is strongest at shallow incidence angles which contribute a reduction to the sideline noise levels. Shortly after reaching an approximate 1,000 feet altitude, the effect of EGA decreases with incidence angle and the sideline noise levels peak to maximum levels due to spherical spreading dominance. Beyond this point, the sideline noise levels decrease correspondingly with the airplane's increase in relative distance. This sequence of contributing noise effects is identified and depicted in Figure 7-8 for a large transport jet for the three segments of departure.

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[89] J.S. Newman, Rickley, E. J., Bland, T. L., Beattie, K. R., "Noise Measurement Flight Test: Data/Analyses Sikorsky S-76A Helicopter", FAA-EE-84-06, September 1984.

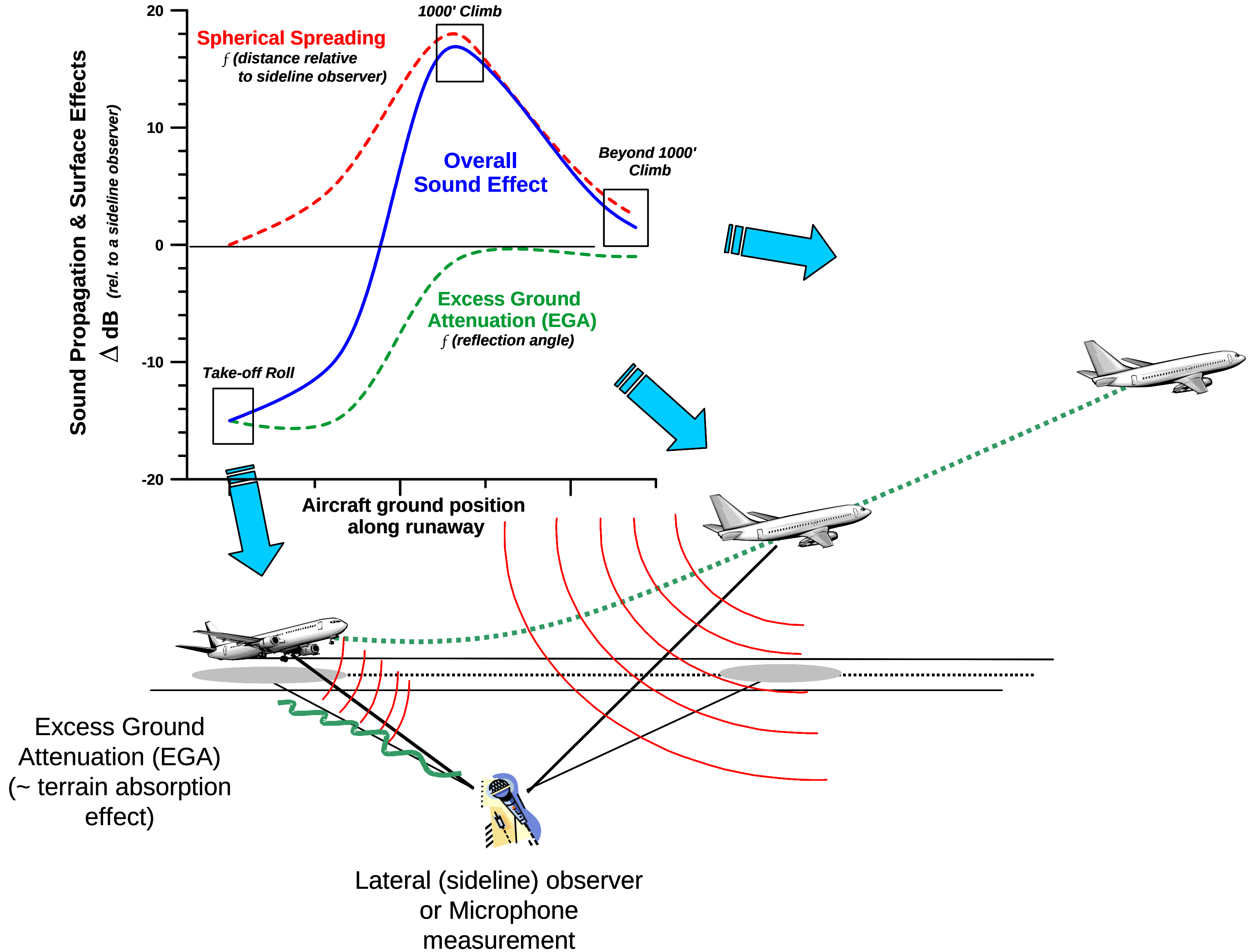

Figure 7-8. Noise Effects For Jet Transport During Departure

Helicopter Noise Database

The FAA has conducted several noise tests on various helicopter types, but most of the tests suffer from the same limitation in that the sideline measuring location is only 492 feet (150 meters) from the flight path.[90,91,92,93,94,95,96,97,98,99,100,101] However, in one case, Newman *et al* made measurements at sideline distances of 539 feet (164 meters) and 931 feet (284 meters). Level flyovers were made at altitudes of 300, 500, 700, 1,000 and 1,500 feet (also 2,000 and 2,500 feet for some helicopters). These combinations of sideline distance and helicopter altitude give elevation angles of 29° to 70° for the 539 feet sideline location and 18° to 58° for the 931 feet sideline location. These elevation angles are greater than those associated with a typical airplane noise certification, but are at least comparable with them in the case of the 931 feet location. Thus, it might be expected that effects of ground attenuation, if any, would be observed in data measured at the 931 feet sideline location.

The measurements reported by Newman *et al* were conducted at the FAA Technical Center (Atlantic City, New Jersey), off the end of the runway. It was reported that there was a cleared circle, approximately 200 feet in diameter, of mowed grass around each microphone location. Low scrub bush and grass bordered each cleared circle. The helicopters tested were Agusta 109, Bell 206L, Sikorsky S-76, and Sikorsky UH-60A Blackhawk. In the case of the Sikorsky S-76, tests were conducted at two engine power settings.[102]

Variation of Noise Level

Data from Newman *et al* are plotted in Figures 7-9 through -13 in terms of the noise level relative to the level measured for a flyover altitude of 300 feet. In some cases, sound levels measured beneath the flight path are included with the sideline data for comparison. The relative

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[90] J.S. Newman,and Rickley, E. J., "Noise Levels and Flight Profiles of Eight Helicopters using Proposed International Certification Procedures", FAA-EE-79-03, March 1979.

[91] J.S. Newman, Rickley, E. J., and Ford, D. W., "Helicopter Noise Definition Report: UH-60A, S-76, A-109, 206L", FAA-EE-81-16, December 1981.

[92] J.S. Newman, Rickley, E. J., and Bland, T. J., "Helicopter Noise Exposure Curves for use in Environmental Impact Assessment", FAA-EE-82-16, November 1982.

[93] J.S. Newman, Rickley, E. J., Bland, T. L., and Daboin, S. A., "Noise Measurement Flight Test: Data/Analyses Bell 222 Twin Jet Helicopter", FAA-EE-84-01, February 1984.

[94] J.S. Newman, Rickley, E. J., Daboin, S. A., and Beattie, K. R., "Noise Measurement Flight Test: Data/Analyses Aerospatiale SA 365N Dauphin 2 Helicopter", FAA-EE-84-02, April 1984.

[95] J.S. Newman, Rickley, E. J., Daboin, S. A., Beattie, K. R., "Noise Measurement Flight Test: Data/Analyses Hughes 500D/E Helicopter", FAA-EE-84-03, June 1984.

[96] J.S. Newman, Rickley, E. J., Beattie, K. R., Daboin, S. A., "Noise Measurement Flight Test: Data/Analyses Aerospatiale AS 355F TwinStar Helicopter", FAA-EE-84-04, June 1984.

[97] J.S. Newman, Rickley, E. J., Bland, T. L., Beattie, K. R., "Noise Measurement Flight Test: Data/Analyses Aerospatiale AS 350D AStar Helicopter", FAA-EE-84-05, September 1984.

[98] J.S. Newman, Rickley, E. J., Bland, T. L., Beattie, K. R., "Noise Measurement Flight Test: Data/Analyses Sikorsky S-76A Helicopter", FAA-EE-84-06, September 1984.

[99] J.S. Newman, Rickley, E. J., Bland, T. L., Beattie, K. R., "Noise Measurement Flight Test: Data/Analyses Boeing Vertol 234/CH 47-D Helicopter", FAA-EE-84-07, September 1984.

[100] J.S. Newman, Rickley, E. J., Locke, M., "International Civil Aviation Organization Helicopter Measurement Repeatability Program: U.S. Test Report, Bell 206L-1, Noise Flight Test", FAA-EE-85-6, September 1985.

[101] J.S. Newman, Rickley, E. J., Levanduski, D. A., Woolridge, S. B., "Analysis of Helicopter Noise Data using International Helicopter Noise Certification Procedures", FAA-EE-86-01, March 1986.

[102] J.S. Newman, Rickley, E. J., and Ford, D. W.

noise levels are presented in terms of four parameters: EPNL, SEL, Maximum A-weighted Sound Level (Lmax), and Maximum Perceived Noise Level Tone corrected (PNLTM).

Each set of test data for Lmax or PNLTM has an associated (broken) curve showing the sound level decay according to spherical spreading (inverse square law). For the integrated measures (EPNL and SEL) the estimated level decay is based on the relationship $12.5\log(R_2/R_1)$, where the factor of 12.5 is the net result of adding a factor of 20 for the inverse square law and a factor of –7.5 for the duration correction as applied in Part 36.

The following observations can be made regarding the data in Figures 7-9 through -13. In no case does the noise level increase as helicopter altitude increases. Thus, if EGA is present, it is not very marked for the distances and angles involved with the tests. In most cases, the measured values of PNLTM and Lmax decrease more rapidly than is predicted by spherical spreading as helicopter altitude increases. This implies that excess ground attenuation is negligible.

Integrated measures (EPNL and SEL) show trends similar to those of the instantaneous measures (PNLTM and Lmax), but the rate of decrease of noise level as helicopter altitude increases is slower because of the duration effect.

Whether or not there is any contribution from EGA, the results show that there is only a small reduction in sideline noise level as helicopter altitude increases, until an altitude of about 1,000 feet is reached. For a sideline distance of 931 feet, the integrated noise levels are typically reduced by about 2 dB when the helicopter altitude increases from 300 feet to 1,000 feet, and the PNLTM and Lmax are reduced by about 3 dB.

Discussion

The test data indicate that helicopter sideline noise levels decrease as helicopter altitude increases, at least for sideline distances up to 1,000 feet and elevation angles greater than 18°. The data do not allow conclusions to be drawn for greater sideline distances where the elevation angle of the helicopter would be less than 18°. EGA influences fixed-wing airplane sideline noise levels under Part 36 certification conditions, where the elevation angle is between 11° and 34° (airplane altitudes of 300 to 1,000 feet). However, excess ground attenuation is applied by Newman *et al* only when the helicopter is in hover in the ground effect and the elevation angle is 0° or when the helicopter is in hover out of the ground effect and the elevation angle is near 0° (although “near” is not defined in the reference).[103] Thus, the conditions under which excess ground attenuation would have the greatest influence on helicopter noise propagation are not well defined.

While the role of EGA on helicopter noise propagation over vegetation is not completely defined by the FAA helicopter test data, the results may be indicative of conditions for flight over water. Not defined at all by these data is the effect of helicopter altitude on sideline noise levels in an urban environment with numerous buildings. Thus, the *in-situ* measurements were made as

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[103] J.S. Newman *et al*, FAA-EE-82-16, November 1982.

discussed in Section 7.1, Source Noise Modeling and Sensitivity Assessment, and in Appendix G, *In-situ* Urban Helicopter Noise Measurements (New York City).

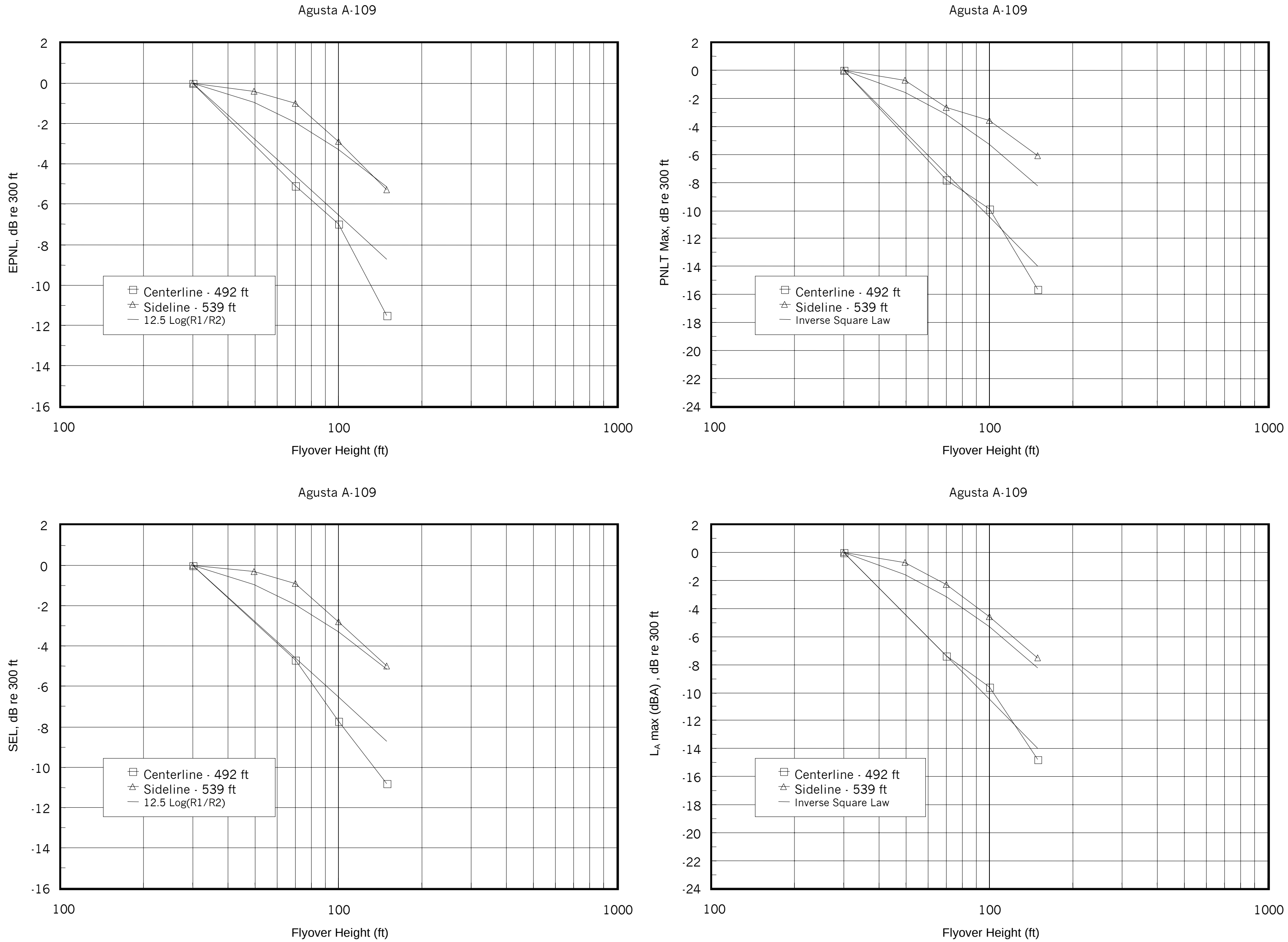

FIGURE 7-9. RELATIVE NOISE LEVELS OF AGUSTA A-109 HELICOPTER AS A FUNCTION OF HELICOPTER ALTITUDE

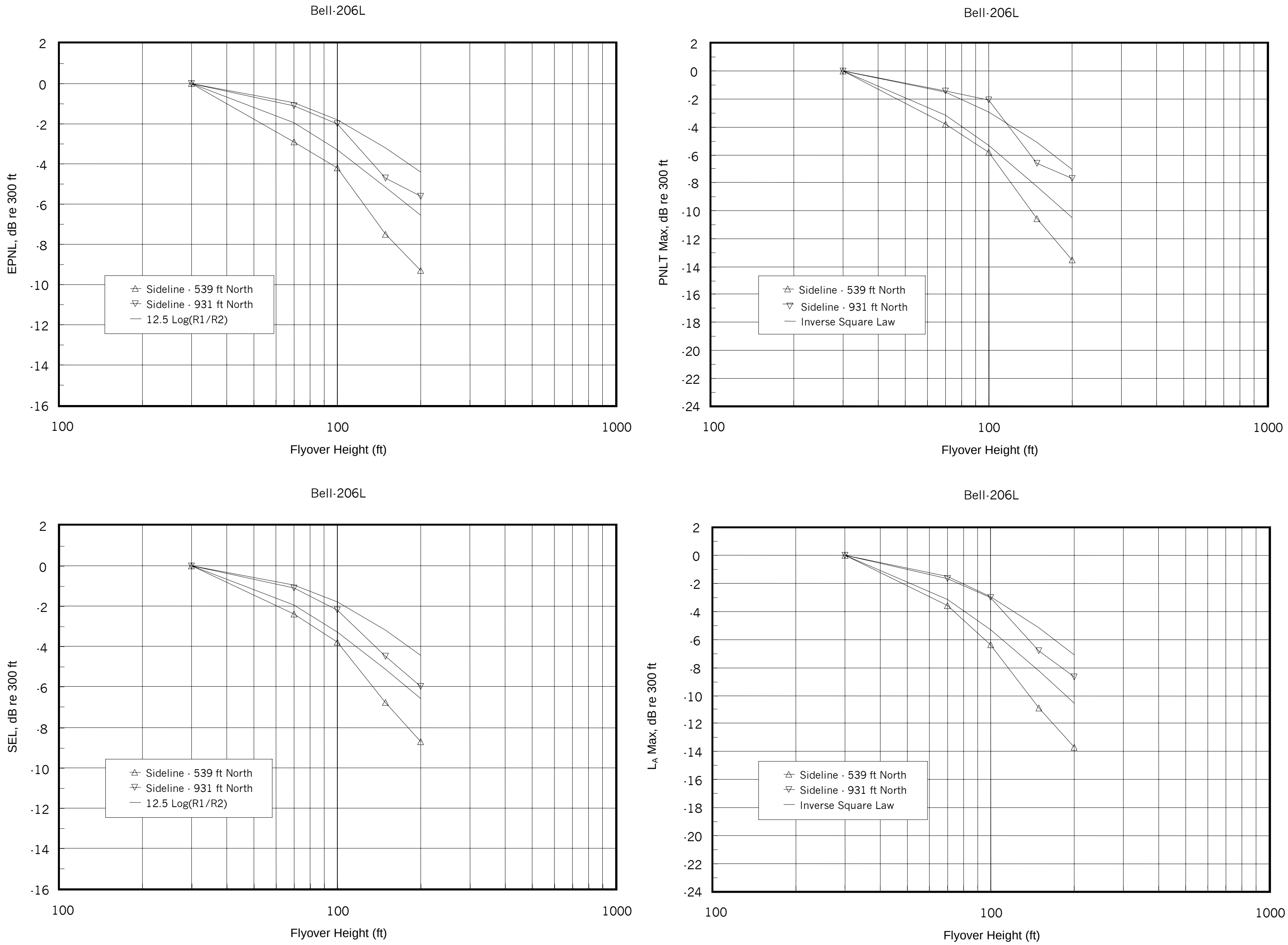

FIGURE 7-10. RELATIVE NOISE LEVELS OF BELL 206L HELICOPTER AS A FUNCTION OF HELICOPTER ALTITUDE

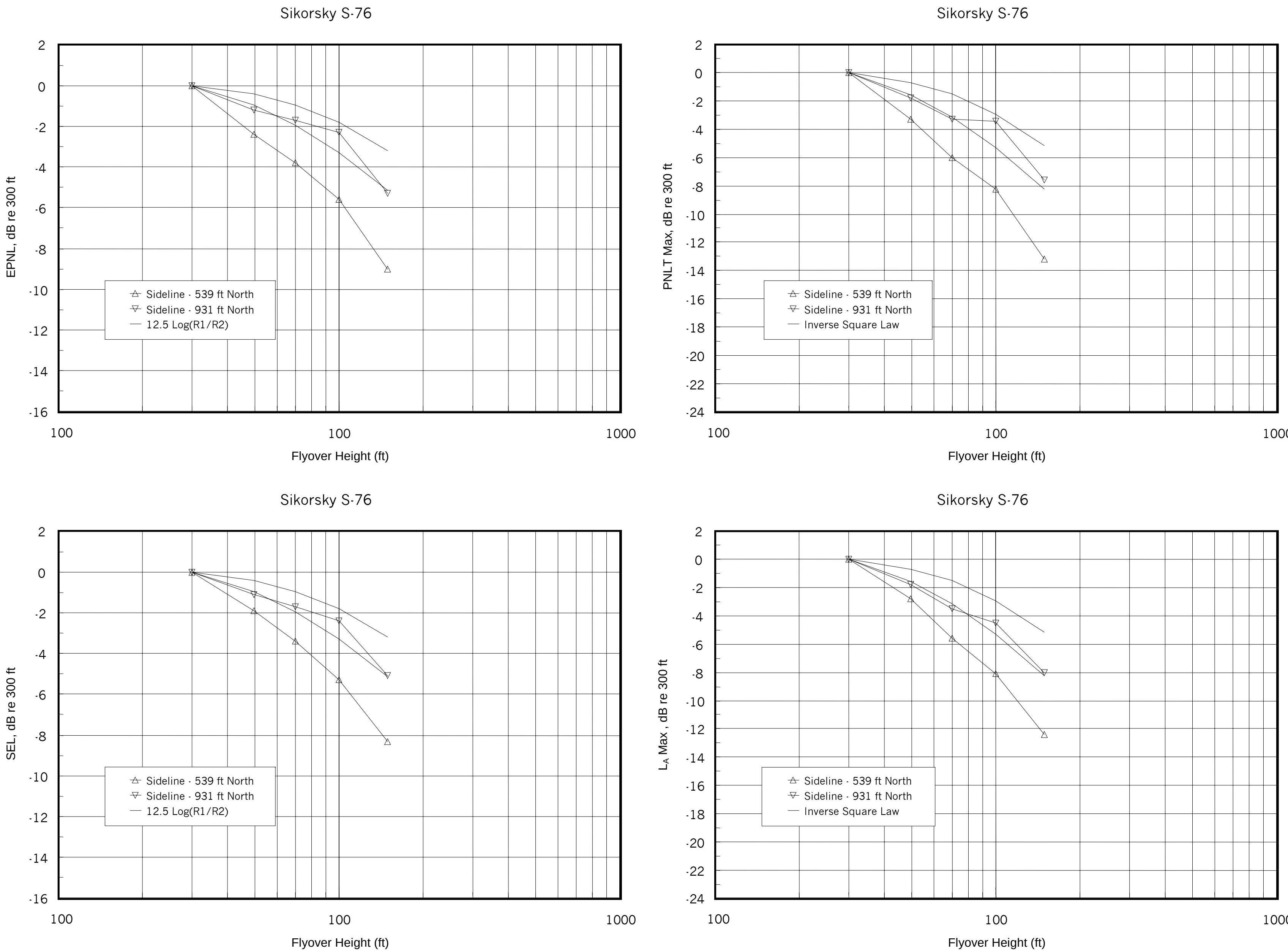

FIGURE 7-11. RELATIVE NOISE LEVELS OF SIKORSKY S-76 HELICOPTER AS A FUNCTION OF HELICOPTER ALTITUDE

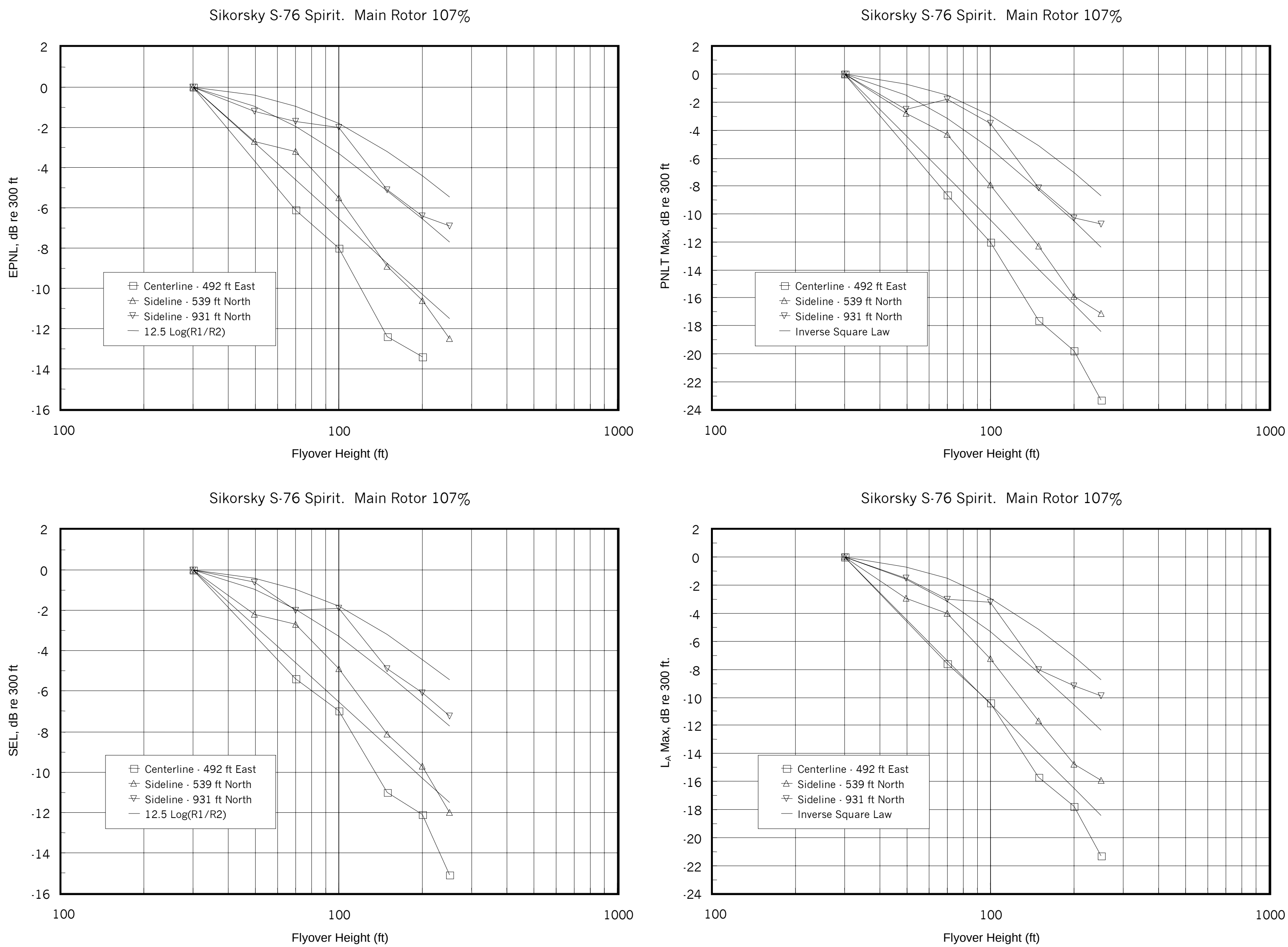

FIGURE 7-12. RELATIVE NOISE LEVELS OF SIKORSKY S-76 (107% RPM) HELICOPTER AS A FUNCTION OF HELICOPTER ALTITUDE

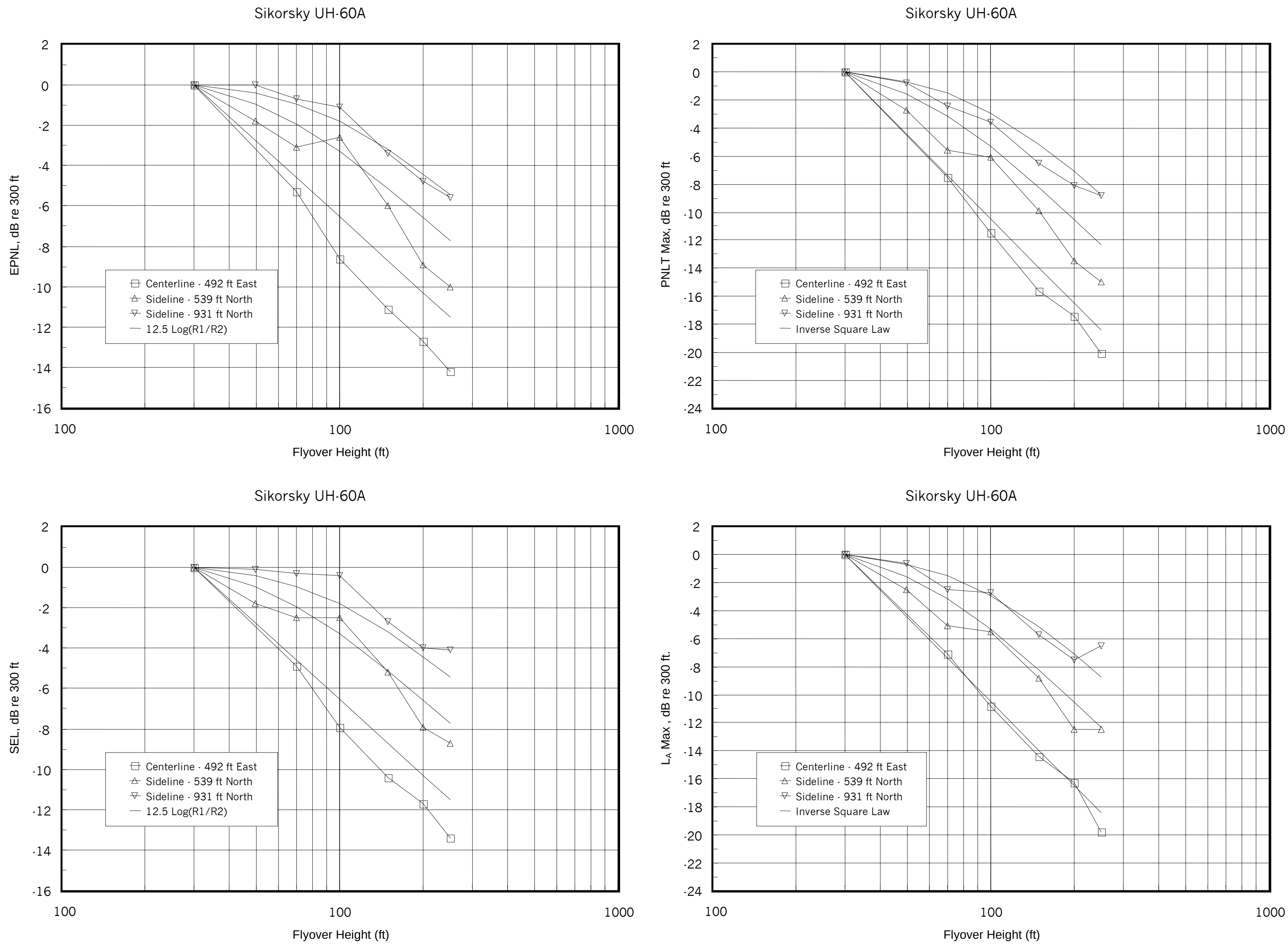

FIGURE 7-13. RELATIVE NOISE LEVELS OF SIKORSKY UH-60A HELICOPTER AS A FUNCTION OF HELICOPTER ALTITUDE

Based upon the FAA's preliminary *in-situ* noise measurements (see Figure 7-14), increasing operational altitude or height AGL does reduce noise from helicopters (for details see Appendix G). Also, the *in-situ* data corroborates operational noise measurements reported in the New York City Master Plan Report. In general, trends support the industry's voluntary operational guidance to "fly higher" altitudes.

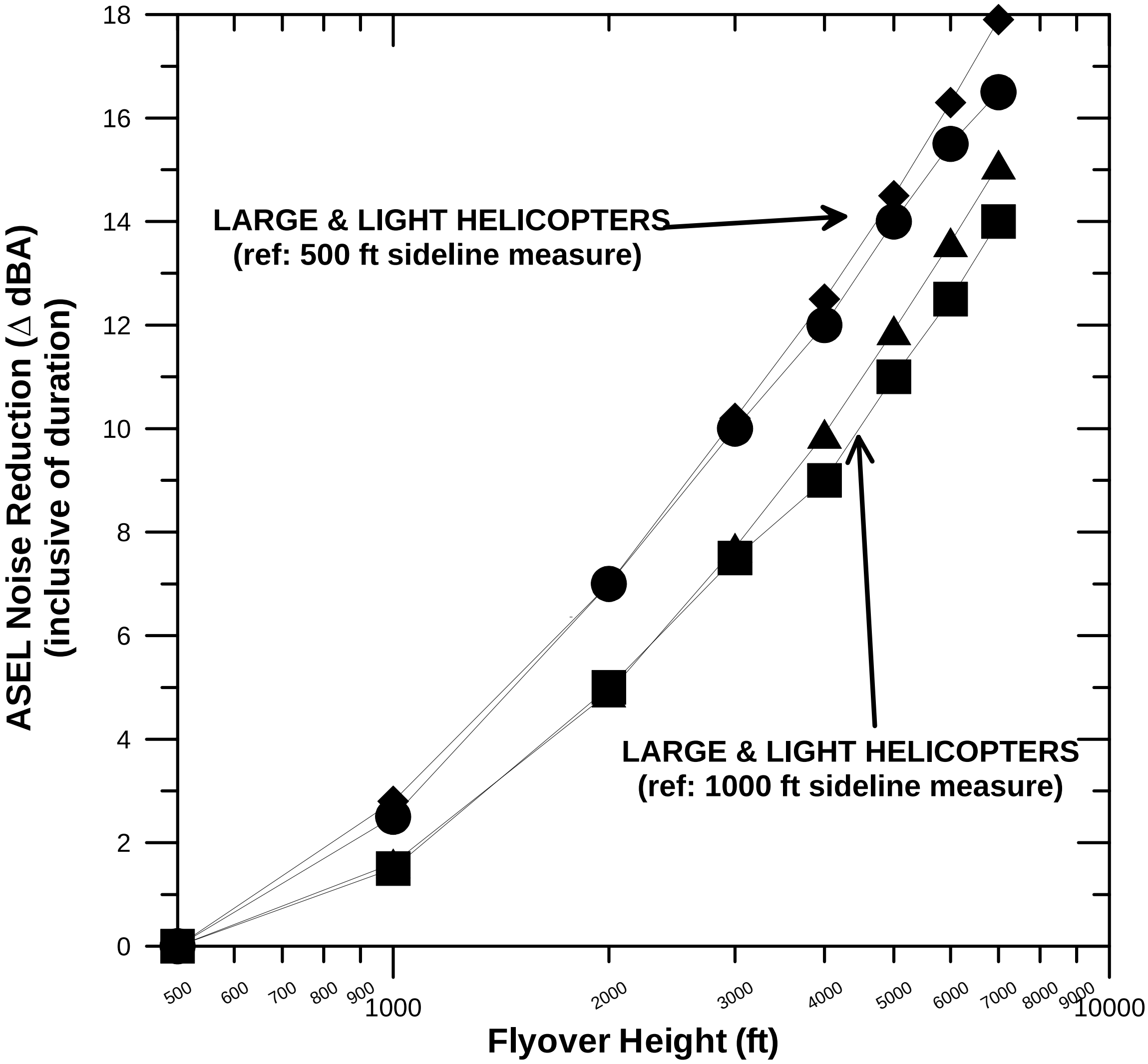

Figure 7-14. Altitude-Noise Reduction Sensitivity for Liberty State Park data

8.0 Summary and Recommendations

8.1 Summary of Noise "Effects on Individuals"

For this study, the background findings on the potential health "effects on individuals" due to community noise exposure, which were discussed in Section 3, are summarized as follows:

- Noise-induced hearing impairment. This is improbable by civil helicopters as they rarely produce 24-hour equivalent levels that exceed 70 dB.

- Noise effects on communications and performance. There is a lack of conclusive effects evidence for an average population. Adverse communication and performance effects has only been identified for under achievers in a classroom environment. But, general alleviation of possible effects is achievable by means of sound proof building construction and HVAC noise reduction sufficient to 35 dB indoor. For urban helicopter noise it can be expected that, where flights are frequent, the indoor equivalent level from helicopter noise may exceed 35 dB. It is also highly probable that other urban noise sources like street traffic and subway trains would similarly exceed this threshold.

- Awakening and sleep disturbance. This is nominally low for steady state sounds of familiarity as indicated by Equation 1 for field data. Yet, it can be likely for close random urban helicopter operations of long duration hover that occur at minimal background noise levels conditions such as early morning and late evening.

- Cardiovascular and physiological effects. When associated with long-term exposure, it does not represent a health threat due to helicopter noise when applying a 24-hour equivalent level that range from 65-70 dB or more criteria.

- Mental health effects. These are not believed to be a direct cause from noise. The notion of noise-induced mental health disorders has been rejected.

- Heighten annoyance factors. Several factors have been identified that relate to heightened community annoyance:
  - **Low- frequency noise susceptible population**.
  - **Non-acoustical effects:** 1) vibration and rattle and 2) *"virtual noise."*
  - **Perception:** 1) helicopter noise characteristics and 2) rate of response.

8.2 Summary of Noise Reduction Conclusions and Recommendations

The FAA offers the following conclusions and recommendations based upon the study:

Additional development of socio-acoustic methodology to deal with helicopter noise should be pursued. Civil helicopter annoyance assessments utilize the same acoustic methodology adopted for fixed-wing airplanes with no distinction for a helicopter's unique noise character. As a result, the annoyance of unaccustomed "impulsive" (spontaneous changing) helicopter noise has not been fully substantiated by a well-correlated metric. Comments from both the helicopter industry and the public strongly recommended that further socio-acoustic investigations be pursued. Additional civil helicopter annoyance studies may help refine current noise measurement analysis methodology that would lead to improved noise mitigation effectiveness. FICAN could charter a technical study to focus on low-frequency noise metric to evaluate helicopter annoyance, including performance of multi-year socio-acoustic (noise) studies to correlate helicopter annoyance and health effects of urban helicopter operations. In the meantime, the FAA will continue to rely upon the widely accepted DNL as its primary noise descriptor for airport and heliport land use planning. The FAA will also continue the use of supplemental noise descriptors for evaluation of helicopter noise issues.

To date, this recommendation has been incorporated into the Rotorcraft Research and Development Initiative for Vision 100 – Century of Aviation Reauthorization Act (Public Law 108-176) under Sec. 711. For Sec. 711, NASA, FAA, and the rotorcraft industry defined a 10-year rotorcraft research and development (R&D) plan that included the study of Psychoacoustics. The research proposes to determine human annoyance levels due to helicopter noise, both in its native condition and synthetically modified. Studies would be conducted to uncover neglected characteristics of noise and develop a refined metric more representative of the true human response.

- <u>Further operational alternatives that mitigate noise should be explored</u>. A number of operational alternatives, proposed by the public and industry, have the potential to mitigate urban nonmilitary helicopter noise and preserve the safe and efficient flow of air traffic. In particular, the FAA found:

  - Noise reduction benefits can be achieved with higher altitude flight. With more conclusive demonstrations addressing safety, such noise mitigation approaches could be integrated within the ATC design planning in specific urban airspaces;

  - Optimal helicopter route planning to avoid noise sensitive areas will require comprehensive evaluation for each specific region of concern;

  - The promotion of noise abatement procedures should be pursued on two fronts--helicopter pilots and air traffic control personnel. The FAA will continue training ATC personnel to increase awareness of noise abatement procedures that best mitigate noise over communities; and

  - The use of advanced technologies, such as GPS, in helicopter approach and departure procedures does show to be beneficial for noise abatement operations. Preliminary GPS/noise research sponsored by the NRTC/RITA has indicated promising noise reductions using more precise procedures.

  The implementation of any of these alternatives would require comprehensive evaluation, and demonstration where appropriate on a case-by-case basis, in accordance with all applicable FAA orders and regulations. Also, careful consideration would have to be taken of any ATC changes to an urban segment of the NAS that could impact the heavily utilized and highly burdened large commercial transport sector. Finally, funding levels required to develop and explore the technology and procedures listed above will be significant.

Similarly under the 2004 Vision 100 Rotorcraft R&D plan, operational noise reduction studies were defined to aid in the noise mitigation of legacy helicopters, such as the Sikorsky S-76 and Bell helicopter products. The expansion of noise abatement flight techniques would be tested for consistency with safety and passenger comfort for several classes of rotorcraft: light, medium and advanced configurations. At the R&D program conclusion, the compilation of noise mitigation technology and abatement operational procedures is to be integrated and demonstrated in a selected single flight vehicle for noise and system validation.

Also, under the Vision 100 plan, there is the "Zero ceiling/Zero visibility" operational goal that addresses advances in navigational system such as wide area augmentation system (WAAS) and local area augmentation system (LAAS) and moving to a comprehensive differential global position system (dGPS) precision navigation capability. Such research applications have proven beneficial to noise mitigation and are expected to enhance the noise abatement operational procedures development.

- <u>Emergency helicopter service should be exempt from restrictions</u>. A key outcome of the FAA-hosted workshops was the mutual agreement among public and industry participants that emergency helicopter service (air medical, law enforcement, fire-fighting, public services, etc.) should be exempted from any proposed limitations or restrictions considered by Congress following this study. These services are time-critical and provide a "noise-excusable" public service.

- <u>Helicopter operators and communities should develop voluntary agreements to mitigate helicopter noise</u>. Federal, state and local governments should encourage voluntary mutual cooperation by operators, the community, and local authorities to establish a "noise response" process; e.g., New York City Heliport Oversight Committee (informal). Also, Federal, state and local governments establish business incentives that encourage the "pooling" of helicopter operations, especially for redundant Electronic News Gathering (ENG) operations.