

AVIATION NOISE IMPACTS RESEARCH ROADMAP 2011



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Aviation Noise Impacts Research Roadmap

Organization Plan and Project Reference

**Federal Aviation Administration
Office of Environment and Energy
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Executive Summary

The Aviation Noise Impacts Research Roadmap (ANIRR) documents the aircraft noise impacts research process being pursued jointly by the U.S. federal agencies interested or affected by aviation noise. This process aims to coordinate, organize, and maximize the efficiency of aviation noise impacts research.

This ANIRR document includes a national aviation noise impacts mission statement, identifies research gaps, documents currently funded projects, and lists recently published research. It is a product of the public Interagency Aviation Noise Impacts Roadmap meeting held on April 19-20, 2011, in Washington, DC. Several U.S. federal agencies, international organizations, industry, academia, and the public met to update and advance our collective scientific knowledge of the impact of aircraft noise on society in order to improve our ability to address various aspects of noise impacts and develop optimal mitigation solutions.

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1 Introduction

The public interagency meeting on the Aviation Noise Impacts Research Roadmap was held on April 19-20, 2011, in Washington, DC. The meeting objectives were to:

- coordinate research activities and findings among stakeholders;
- update and advance our collective scientific knowledge of the impact of aircraft noise on society;
- continue to pursue collaborative research; and
- prepare for policy implications of research.

The following U.S. Federal agencies participated at the April meeting and in the preparation of this document:

- Department of Transportation:
 - Office of the Secretary of Transportation (OST)
 - Volpe Center
 - Federal Aviation Administration (FAA)
- Department of Housing and Urban Development (HUD)
- National Aeronautics and Space Administration (NASA)
- Department of Defense (DOD)
- National Park Service (NPS)
- Centers for Disease Control and Prevention (CDC)
- National Oceanic and Atmospheric Administration (NOAA)
 - National Marine Fisheries Service
- National Institutes of Health (NIH).

The meeting was attended by representatives from European research organizations who made valuable contributions by presenting their research findings at the meeting. The following organizations were represented:

- European Network on Noise and Health (ENNAH), European Union
- Community Oriented Solutions to Minimize aircraft noise Annoyance (COSMA), European Union
- German Aerospace Center (DLR)
- *IfADo* Leibniz-Institut für Arbeitsforschung an der TU Dortmund, Germany
- Manchester Metropolitan University, UK

- Queen Mary University of London, UK

All presentations are available at Federal Interagency Committee on Aviation Noise (FICAN) website: www.fican.org

The first ANIRR draft was prepared by agencies and distributed at the Aviation Noise Impacts Roadmap Annual Meeting in Washington, D.C., to solicit additional information from attendees and their organizations.

The additional two questionnaires were also distributed to solicit input and feedback from meeting participants:

- April 2011 meeting feedback questionnaire (Appendix C) and
- Research needs questionnaire (Appendix D).

This final ANIRR -2011 was prepared based on material provided by Federal agencies listed above, April meeting presentation materials, Q&A and discussion sessions of the April meeting, and questionnaires' input.

One of the major comments received after the April meeting is that the face-to-face meeting open to all interested parties is very important for more efficient work and needs to be continued on an annual basis.

The digital copy of this document is posted on the FICAN website. It will be updated annually as research efforts progress.

2 Mission Statement

The Aviation Noise Impacts Research Roadmap (ANIRR) documents aviation noise research activities and findings of the U.S. Federal agencies, and other national and international organizations with an interest in aviation noise impacts.

The intent of the Roadmap is to define systematic, focused, non- duplicative and complementary research activities, so that limited resources can be more effectively pooled to advance the knowledge on how best to address the impacts of aviation noise on society.

ANIRR first identifies noise related problems (knowledge gaps) faced by these organizations as they review or establish policies aimed at describing, eliminating, or minimizing the impacts of aircraft noise on the public. In identifying the problems, the ANIRR recognizes that Federal agencies may face noise problems other than those associated with aircraft, and that resolution of both aircraft and some of these related non-aircraft noise problems may benefit from joint consideration. Methods, knowledge, and research used to solve some aircraft noise problems may also apply to non-aircraft noise problems.

Once the problems are identified and clearly stated, the roadmap establishes a plan for examining existing knowledge and research results and then defines future research needs, as appropriate, to provide sufficient knowledge for resolving the problems and eliminating the knowledge gaps.

3 Scope

The roadmap document will, to the extent possible, incorporate noise impacts research and issues of multiple Federal agencies on the following four research areas (topics):

Area A - Noise effects on health and welfare

Area B - Noise in National Parks and wilderness

Area C - Aircraft noise modeling

Area D - Costs of aircraft noise on society

The research conducted in this area aims to determine whether the basis for establishing significant noise needs updating to better reflect the current state of community response to today's aircraft noise exposure (R. Girvin "Advancing Aircraft Noise Impacts Research: A White Paper", FAA Office of Environment and Energy.).

		Area A	Area B	Area C	Area D
	Organization	Health	Modeling	Parks	Costs
#					
1	FAA				
2	NASA				
3	DOD				
4	NPS				
5	OST				
6	Volpe				
7	HUD				
8	NOAA				
9	CDC				
10	NIH				



Figure 1: Research Scope

4 Description of Current Noise-Related Research

The following sections summarize recent relevant research (completed in 2009 or more recently) as reported by or available from the organizations identified.

A. Noise Effects on Health and Welfare

A.1 FAA

A.1.1 PARTNER

Low Frequency Noise Study

Prepared by: Kathleen Hodgdon, kkh2@psu.edu

Anthony A. Atchley

Robert J. Bernhard

From PARTNER: Project 1

This report documents a study to investigate human response to the low-frequency content of aviation noise, or low-frequency noise (LFN). A-weighted Sound Pressure Level (L_{Amax}) and C-weighted Sound Pressure Level (L_{Cmax}) metrics correlate well with laboratory based subjective response to indoor aircraft noise when LFN levels are low to moderate. The same holds for rattle annoyance (again for low to moderate level LFN). Also, multiple low level LFN events may cause rattle (i.e. simultaneous multiple runway operations). When high levels of LFN are present, Tokita & Nakamura thresholds with C-Weighted Sound Exposure Level (L_{CE}) metric should be used as an indicator of potential for LFN annoyance.

Full Article at: <http://web.mit.edu/aeroastro/partner/reports/proj1/lfnreport-2007-001.pdf>
Report completed 4/07

Outreach

Lead Investigator: Kathleen Hodgdon, kkh2@psu.edu
 Project Manager: Laurette Fisher, laurette.fisher@faa.gov
From PARTNER: Project 10

The goal of the Outreach team is to provide educational information on aviation noise and to facilitate Outreach efforts by airports and community groups. The Outreach team has developed and released [NoiseQuest](#), a Web site about aviation noise and its impact on communities. NoiseQuest provides an outreach forum for airports too small to have an established community program as well as information that supports existing outreach efforts.

Full Article at: <http://web.mit.edu/aeroastro/partner/projects/project10.html>
Status: Active

A Review of the Literature Related to Potential Health Effects of Aircraft Noises

Prepared by: Hales Swift
From PARTNER: Project 19

This literature survey looks at two potential pathways, sleep disruption and noise induced stress, which had both been proposed as pathways leading from noise exposure to eventual cardiovascular outcomes. It recognizes that there are several potential problems that arise in health studies, e.g., unaccounted for confounding factors; removal of the impacts of certain factors which are known to be risk factors for cardiovascular disease but might also be outcomes of the noise exposure; inaccurate prediction of exposure to noise sources of interest; difficulties disambiguating impacts of total noise exposure versus exposure to a particular noise source of interest.

Full Article at: <http://web.mit.edu/aeroastro/partner/reports/proj19/proj19-healtheffectnoise.pdf>
Report completed 7/10

Annoyance

Lead Investigators: Professor Patricia Davies, daviesp@ecn.purdue.edu
 Professor Victor W. Sparrow, vws1@psu.edu
 Project Manager: Dr. Mehmet Marsan, mehmet.marsan@faa.gov
From PARTNER: Project 24

The goal of PARTNER Project 24 is to develop a deeper understanding of how noise affects annoyance in communities in proximity to airports. The ultimate aim is to construct models that can be coupled with sound prediction models to predict annoyance that would result from future airport developments or changes in air traffic patterns. Part of the research is focused on assessing how different attributes

(loudness, spectral balance, roughness, tonality, and fluctuation strength) of aircraft noise can impact annoyance. Another aspect of the research is focused on understanding the impact of low frequency noise on annoyance. In another part of Project 24, researchers are investigating whether knowledge of the noise source (e.g., air, road, rail) influences annoyance, and, if so, how to quantify that source dependence in the annoyance model. Another part of the research has been focused on gathering old survey data to determine if it is feasible to use it in validation of proposed annoyance models that take into account sound attributes other than average level.

Full Article at: <http://web.mit.edu/aeroastro/partner/projects/project24.html>

Status: Active

Noise Exposure Response: Sleep Disturbance (SD)

Lead Investigator: Professor Patricia Davies, daviesp@ecn.purdue.edu

Project Manager: Laurette Fisher, laurette.fisher@faa.gov

From PARTNER: Project 25

Project 25's goal is to understand the impact of aircraft noise on sleep, and to develop models that predict sleep disruption for a given aircraft noise profile. The amount of time spent in different sleep stages is important in terms of physical and psychological wellbeing. What is not fully understood is how much aircraft noise impacts sleep in communities around airports, and how impacts due to aircraft noise compare with those due to other things (other noise sources, weight, age, stress, etc.) that are known to affect sleep. The model will be tuned to produce results that replicate those observed in field studies (usually conscious awakenings) and in laboratory studies (both awakenings and sleep structure).

Full Article at: <http://web.mit.edu/aeroastro/partner/projects/project25.html>

Status: Active

Open Rotor Noise Impact on Airport Communities

Lead Investigator: Dr. Jimmy Tai, jimmy.tai@aerospace.gatech.edu

Project Manager: Dr. Hua He, hua.he@faa.gov

From PARTNER: Project 35

Spectra from propeller designs are typically dominated by tones at harmonics of the blade passage frequency, whereas turbofans generate much smoother spectra. Disagreement already exists regarding the need for tone corrections for turbofans, with certification noise levels including a tone correction and community noise contours not including one through the use of Day-Night Average Sound Level (DNL). A tone-corrected DNL (DNLT) is presented and compared to alternative metrics, including those with and without tone and duration corrections, for turbofan, turbo-prop, and open rotor engines. The compatibility of DNLT with existing DNL contours will be demonstrated, as well as the predictive capability of the certification points with respect to various contour metrics. The results will show the variance between the contours from the different metrics as well as the need for regulatory bodies to consider the potential for increased annoyance above that predicted by DNL. In addition, the applicability of the identified metrics within the FAA's Aviation Environmental Design Tool will be addressed.

Full Article at: <http://web.mit.edu/aeroastro/partner/projects/project35.html>

Status: Active

A.1.2 ACRP

Assessing Aircraft Noise Conditions Affecting Student Learning

Principal Investigator: Dr. Ben Sharp

Staff Responsibility: Lawrence D. Goldstein

From ACRP 02-26

Concerns over the effects of noise on student learning present potential barriers to airport operations and expansion and can contribute to delays in both facility and capacity improvements. In FY07, the FAA awarded \$56.5 million in grants to insulate public buildings—mostly schools—often based on a criterion of achieving a maximum Day-Night Average Sound Level (DNL) of 65 dB. Despite this history, there has been little research to date as to whether this criterion is appropriate for determining when noise levels impact schools and learning. The Environmental Working Group (EWG) Science and Metrics Standing Committee of the Joint Planning and Development Office (JPDO) has proposed metrics to the EWG Policy Standing Committee for consideration in their preparation of the EWG environmental targets. What is evident from available studies is that there is no clear understanding of the conditions as to when aircraft noise affects student learning and when to implement mitigation measures. Research is needed to enhance that understanding. The objectives of this study are (1) to identify and evaluate conditions under which aircraft noise affects student learning, and (2) to identify and evaluate one or more alternative noise metrics that best define those conditions.

Full Article at: <http://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=2797>

Report start date 6/10

Expected Completion 2/12

Current Status: Work is underway. Project completion is expected in early 2012.

Aircraft Noise: A Toolkit for Managing Community Expectations

Principal Investigator: Jon M. Woodward

From the ACRP: Report 15 Project 02-05

The objectives of this project were to (1) develop an informative guidebook about local aircraft noise to inform readers with a direct interest, involvement, or investment in airports; (2) develop a toolkit that airport decision makers can use to manage expectations related to aircraft noise within the community; (3) investigate alternative metrics to communicate noise issues to the community; and (4) suggest other improvements that go beyond current practice to ease aircraft-noise issues. This study emphasizes the importance of public engagement, as opposed to one-way communication techniques, and the time to develop a relationship with the public is much, much earlier than in the middle of a crisis. It then provides a list of six best practices that characterize an effective communications program, basic information about noise and its abatement to assist in responding to public inquiries, and a discussion on which metrics to use to communicate the characteristics of noise. This document is intended for all airport managers who seek to better their relationships with surrounding communities.

Full Article at: http://onlinepubs.trb.org/onlinepubs/acrp/acrp_rpt_015.pdf

Enhancing Airport Land Use Compatibility

Principal Investigator: Stephanie Ward

ACRP Manager: Michael R. Salamone

From the ACRP: Report 27

This report provides guidance to help protect airports from incompatible land uses that impair current and future airport and aircraft operations and safety. Key tasks in this research included collecting published

material related to land uses that are incompatible with federal and/or state land use safety standards for airports; collecting and evaluating state compatible land use legislation, rules and directives to identify commonality; collecting data on aircraft accident locations in the vicinity of airports to establish potential high risk areas; identifying airports where major expansion projects have been delayed or abandoned due to opposition from surrounding communities that arose from a failure to have taken appropriate measures to ensure compatible land uses around those airports; and developing land use compatibility zoning examples incorporating land use and third party risk that state and local governments can use as a basis for their ordinances. It provides guidance for incorporating aircraft noise in a local land use ordinance.

Full Article at: http://onlinepubs.trb.org/onlinepubs/acrp/acrp_rpt_027v1.pdf
Report completed 2010.

Case Studies on Community Challenges to Airport Development

Principal Investigator: James B. McDaniel

Prepared by: Jaye Pershing Johnson, J.D.

From the ACRP Legal Digest 9 Project 11-01

This digest summarizes judicial decisions and explains the bases of the challenges, the defense to the challenges, and the outcome of the case. This collection is intended to convey the strategies the FAA and airport operators rely upon to address community challenges and identify which strategies have succeeded, which have failed, and the reasons for both. In addition to the results of a comprehensive review of court cases involving such challenges, and equally important, this digest includes a summary of responses from airport proprietors to a survey regarding litigation strategies. It appears that a major component of such strategies is directed toward litigation avoidance. A questionnaire was circulated among airport proprietors in connection with the preparation of this digest, which was intended to elicit specific feedback about litigation strategies used in the face of community challenges to airport development.

Full Article at: http://onlinepubs.trb.org/onlinepubs/acrp/acrp_lrd_009.pdf
Report completed 6/10.

A.1.3 Sponsored by Volpe

Dose-response relationship between aircraft noise exposure in terms of DNL and annoyance

Lead Investigators: Dr. Sanford Fidell, Fidell Associates, Vincent Mestre, Mestre Greve Associates
 Division of Landrum & Brown, Dr. Paul Schomer, Schomer and Associates

Objectives: An Information Paper to the Volpe Center will address the following two questions:

- 1) Is the Federal Interagency Committee on Noise's (FICON) 1992 original dosage-effect relationship still appropriate for evaluating current aviation noise impacts?
- 2) Can an improved relationship between DNL and annoyance better reflect contemporary community response to aircraft noise exposure?

This work supports FAA AEE's interests in facilitating the efforts of Working Group 45 of the International Standards Organization's (ISO) Technical Committee on Environmental Noise Assessment to standardize best current practice for analyzing noise impacts due to aircraft noise exposure. The nature of community exposure to aircraft noise has changed notably since Schultz's original (1978) derivation a dose-response relationship between Day-Night Average Sound Level (DNL) and the prevalence of high annoyance. These changes include reductions in sound exposure levels created by the most common

aircraft in the civil fleet, increases in total numbers of operations, and changes in the time of occurrence of airport operations. Tasks include identifying data to use for an update of the relationship between DNL and annoyance; formatting data for statistical analysis; analyze formatted data to compare effects of infrequent high noise levels and frequent moderate noise levels at same values of DNL, to identify outlying annoyance data and seek to characterize common aspects; to determine effects of demographic parameters; derive an updated model between DNL and annoyance.

Completion: December 31, 2010

Technical Support for Day/Night Average Sound (DNL) Replacement Metric Research

Investigators:

Wyle Laboratories, Inc.

Fidell Associates, Inc.

Objectives: Prepare a report to the Volpe Center will address the following objectives:

1. Identify supplementary or replacement metrics to DNL that could help to better capture the relationship between community annoyance and noise exposure due to aircraft.
2. Identify metrics that could be used to address effects other than community annoyance, such as metrics which could be used to predict sleep disturbance and speech interference.
3. Identify existing data that can be used to compute some or all of these metrics.
4. Identify any data that does not yet exist which would be needed to compute some or all of these metrics.

Tasks include:

- 1) **Investigate existing US data** - Development of a detailed plan for identification of data needed for US analysis, additional factors that may be analyzed and additional metrics prevalent in the US which may correlate to these additional factors. This analysis shall focus on a US perspective, but the analysis shall provide commentary on how the US perspective relates to the European perspective. It shall include investigation of the utility of existing US data and determination of whether additional data are required. The investigation should consider various measures of speech and sleep disturbance, psychoacoustic metrics, and non-acoustic measures such as number of events. The investigation should examine how these various metrics should be used to better capture the US relationship between community annoyance and exposure to aircraft and the effects of aircraft noise on sleep disturbance and speech interference.
- 2) **Investigate existing European data** – Develop a detailed plan for identification of European analysis data. Conduct analyses similar to those conducted with the US data.

Completion: February 28, 2011

Address Noise Issues beyond the 65 DNL Contour

Investigators: Wyle Laboratories, Inc.

Objective: Prepare a report that investigates and evaluates a broad set of options for addressing noise issues beyond the 65 DNL contour requirements. Options should include, but not be limited to, consideration of land use planning, especially developing guidance for the establishment of noise buffers beyond the 65 DNL contour. Additional considerations may include improved methods of modeling impact, methods of evaluating cost, or other approaches to mitigating the effects of aircraft noise outside the 65 DNL contour. An evaluation of the options in terms of costs and benefits as well as implementation issues associated with the options will also be developed.

Beginning Date: March 2011

Period of Performance: One year

A.2 NASA

A.2.1 Sonic Boom Research

The research is aimed at modeling and understanding the impact of sonic booms is divided into three areas: 1) Human response and modeling; 2) Structural response and modeling; and 3) Atmospheric propagation modeling.

A.2.2 Human Response

Principal Investigator: Dr. Alexandra Loubeau

Studies of human response to sonic booms heard indoors and outdoors have identified several factors that may contribute to an increased annoyance indoors, including rattle noise. Human response testing in the indoor sonic boom simulator will be conducted to further the understanding of human reaction to booms heard indoors. A pilot community response survey of human reaction to booms is planned for 2011, in preparation for future community surveys with an experimental low-boom aircraft.

On-going

A.2.3 Human Response to Low-Intensity Sonic Booms Heard Indoors and Outdoors

B. M. Sullivan, J. Klos, R. D. Buehrle, D. A. McCurdy, E. A. Haering

Test subjects seated inside and outside a house were exposed to low intensity N-wave sonic booms during a 3 -week test period in June 2006. The house was instrumented to measure the booms both inside and out. F-18 aircraft were flown to achieve a variety of boom overpressures from approximately .1 to .6 psf. During four test days, seventy-seven test subjects heard the booms while seated inside and outside the house. Using the Magnitude Estimation methodology and artificial reference sounds, the subjects rated the annoyance of the booms. Since the same subjects heard similar booms both inside and outside the house, comparative ratings of indoor and outdoor annoyance were obtained. For a given metric level, indoor subjects gave higher annoyance scores than outdoor subjects. For a given boom, annoyance scores inside were on average the same as those outside. In a post-test questionnaire, the majority of subjects rated the indoor booms as more annoying than the outdoor ones. These results are discussed in this paper.

NASA TM 2010-216685, 2010

Full report Available at: http://www.fican.org/pdf/Sullivan_TM_EAFB_Boom.pdf

A.3 DOD

A.3.1 Strategic Environmental Research and Development Program (SERDP)

An Investigation of Community Attitudes towards Military Blast Noise

Principal Investigator: Edward Nykaza, U.S. Army ERDC/CERL

Current blast noise impact assessment procedures do not fully meet the military's noise management needs. Blast noise is emitted by projectiles, explosives, and artillery and armor muzzle blast. These noise events are of short duration, typically a fraction of a second, with most of the acoustical energy concentrated at low frequencies (between 1 and 100 Hz). Blast noise impact has been assessed using

procedures that follow standards developed to assess transportation noises that are based on annual averaged exposures. This method has proven to be unsatisfactory for the extremely variable blast military noise. Individual blast noise events can be loud enough to elicit noise complaints, yet when all of the events are averaged over a year's time, the average noise level meets established acceptability criteria. The objectives of this project are to enhance the understanding of community attitudes toward military blast noise through interviews and surveys with residents including acquiring near real-time responses to blasts, and to develop a methodology for accurately predicting human response to military testing and training activities that produce blast noise.

On-going, anticipated completion – 2013; see following for partial results

An Investigation of Community Attitudes toward Blast Noise

Kathleen Hodgdon, Trent Gauglerb, The Pennsylvania State University
Edward T. Nykaza, Engineering Research and Development Center, CERL
Peg Krecker, PA Consulting Group
George Luz, Luz Social and Environmental Associates

The objectives of Strategic Environmental Research and Development Program (SERDP) Project SI-1546, "An Investigation of Community Attitudes toward Blast Noise," are to enhance the understanding of human response to blast noise and to develop a better methodology for predicting human response to impulsive military noise. The focus of this report is the Personal Interview (PI) Protocol, which is the initial component of a series of studies being conducted as part of SERDP Project SI-1546. The PI was executed in the vicinity of three military installations between October 2008 and February 2009. The objective of the PI was to identify the language/terminology that residents living near military installations use to describe their community, environment, and blast noise. These descriptors were then compared to the descriptors that will be used in other forthcoming SERDP SI-1546 survey instruments. It was found that the language PI participants used to define noise and their environment was similar to the language that will be used in the upcoming survey instruments. The qualitative PI findings indicate that residents living near military installations are aware of the installation and the noise generated by the installation. Participants reported that they adapt to the basic noise environment over time and often do not notice smaller noise events, but do notice unusually large noise events or noise in conjunction with house vibrations. A number of participants reported that their current neighborhood is less noisy than other areas in which they have lived and is a better place to live. Several of the participants stated that they would not leave the area because of the noise, and almost all participants expressed that they are content with their neighborhood. The PI results will also be important for interpreting the findings from future SERDP SI-1546 protocols.

Full Report at: <http://www.serdp.org/content/download/6566/86579/file/SI-1546-IR.pdf>

Modeling of Near-Ground Propagation of Impulsive Noise

Dr. Michelle Swearingen, Engineering Research and Development Center, CERL
Dr. Michael White, Engineering Research and Development Center, CERL
Dr. Daniel Valente, Engineering Research and Development Center, CERL

This is on-going research examining the effects of meteorology on near-ground propagation of impulsive noise. The focus is on defining "propagation classes" based on the meteorology, and determining the expected variability within each class.

Assessing Community Reactions to Blast Noise, CERL

Edward T. Nykaza, Engineering Research and Development Center, CERL
Dr. Daniel Valente, Engineering Research and Development Center, CERL

Kathleen Hodgdon, The Pennsylvania State University

This on-going research examines individual and community response to blast noise produced by military training operations. The work consists of an in-situ study (individuals) and community assessments (community surveys).

Minimizing sleep disturbance from blast noise producing training activities for residents living near a military installation

Edward T. Nykaza, Larry L. Pater, and Robert H. Melton, U.S. Army Engineer Research and Development Center, Construction Engineering Research Laboratory, 2902 Newmark Drive, Champaign, Illinois 61822-1078

George A. Luz, Luz Social and Environmental Associates, 4910 Crowson Avenue, Baltimore, Maryland 21212

Field research was conducted during 2004 in the vicinity of a United States military installation to determine if awakening of residents due to blast noise from large military weapons might vary during the night. Analysis of the data indicates that awakening from blast noise is significantly less likely during the time period between midnight and 0200 h compared to time periods before midnight and approaching dawn. These findings suggest that postponing noisy evening training until after midnight could effectively reduce the negative impact of nighttime training on local residents and thus help to preserve nighttime training capabilities.

J. Acoust. Soc. Am. Volume 125, Issue 1, pp. 175-184 (January 2009)

Article Available at: <http://dx.doi.org/10.1121/1.3026325>

A.11 Other Organizations

A.11.1 United States

Aviation and the Environment: Systematically Addressing Environmental Impacts and Community Concerns Can Help Airports Reduce Project Delays

Principal Investigator: Gerald Dillingham, dillinghamg@gao.gov

From GAO

This report addresses (1) airports' actions to reduce their environmental impacts, (2) the extent airports believe environmental issues delay development or operational changes, and (3) the strategies airports can adopt to address environmental issues. GAO reviewed pertinent federal laws and regulations; interviewed airport officials, state and local regulatory agencies, metropolitan planning organizations, and community groups for 10 selected airports, as well as federal officials and national industry and advocacy groups; and surveyed the 150 busiest airports as measured by the number of operations. This report does not contain recommendations.

Full Article at: <http://www.gao.gov/new.items/d1050.pdf>

Report completed 9/10

Acoustical model and theory for predicting effects of environmental noise on people

Karl D. Kryter, School of Speech, Language, and Hearing Sciences, College of Health and Human Services, San Diego State University, San Diego, California 92182

The Schultz [(1978). J. Acoust. Soc. Am. 64, 377–405]; Fidell et al. [(1991). J. Acoust. Soc. Am. 89, 221–233] and Finegold et al. [(1994). Noise Control Eng. 42, 25–30] curves present misleading research information regarding DNL/DENL levels of environmental noises from transportation vehicles and the impact of annoyance and associated adverse effects on people living in residential areas. The reasons are shown to be jointly due to (a) interpretations of early research data, (b) plotting of annoyance data for noise exposure from different types of transportation vehicles on a single set of coordinates, and (c) the assumption that the effective, as heard, levels of noise from different sources are proportional to day, night level (DNL)/day, evening night level (DENL) levels measured at a common-point outdoors. The subtraction of on-site attenuations from the measured outdoor levels of environmental noises used in the calculation of DNL/DENL provides new metrics, labeled EDNL/EDENL, for the calculation of the effective exposure levels of noises perceived as equaling annoying. Predictions of judged annoyance in residential areas from the noises of transportation vehicles are made with predicted errors of <1 dB EDNL/EDENL, compared to errors ranging from ~6 to ~14 dB by DNL/DENL. A joint neurological, physiological, and psychological theory and an effective acoustical model for the prediction of public annoyance and related effects from exposures to environment noise are presented.

J. Acoust. Soc. Am. Volume 125, Issue 6, pp. 3707-3721 (June 2009)
 Article Available at: <http://dx.doi.org/10.1121/1.3125320>

Development of a noise metric for assessment of exposure risk to complex noises

Xiangdong Zhu, Jay H. Kim, and Won Joon Song, Department of Mechanical Engineering, University of Cincinnati, Cincinnati, Ohio 45221-0072

William J. Murphy, Research and Technology, Engineering and Physical Hazards Branch, Hearing Loss Prevention Team, 4676 Columbia Parkway, MS C-27, Cincinnati, Ohio 45226-1998

Seongho Song, Department of Mathematical Sciences, University of Cincinnati, Cincinnati, Ohio 45221-0025.

Many noise guidelines currently use A-weighted equivalent sound pressure level LAeq as the noise metric and the equal energy hypothesis to assess the risk of occupational noises. Because of the time-averaging effect involved with the procedure, the current guidelines may significantly underestimate the risk associated with complex noises. This study develops and evaluates several new noise metrics for more accurate assessment of exposure risks to complex and impulsive noises. The analytic wavelet transform was used to obtain time-frequency characteristics of the noise. 6 basic, unique metric forms that reflect the time-frequency characteristics were developed, from which 14 noise metrics were derived. The noise metrics were evaluated utilizing existing animal test data that were obtained by exposing 23 groups of chinchillas to, respectively, different types of noise. Correlations of the metrics with the hearing losses observed in chinchillas were compared and the most promising noise metric was identified.

J. Acoust. Soc. Am. Volume 126, Issue 2, pp. 703-712 (August 2009)
 Article Available at: <http://dx.doi.org/10.1121/1.3159587>

A.11.2 International

Approach Noise at Heathrow: Concentrating the Problem

AEF Director: Tim Johnson

Email for AEF: info@aef.org.uk

Email for HACAN: info@hacan.org.uk

From the AEF Report for HACAN

This report examines how recent changes to the way in which flights at Heathrow are directed on the approach to the airport have begun to generate a new set of concerns for local people. Most notably, while changes in the joining point to optimize Continuous Descent Approaches have resulted in a reduced number of people affected by airplane noise, it has increased the concentration of flight paths over particular communities. But this report outlines a number of schemes which are being trialed, or at least being assessed, at airports around the world including steeper approaches (UN's IACO) and curving of CDA approaches to more evenly distribute airplane traffic. Finally, this report claims that the Government's noise objective, which focuses on only the number of people affected, is simplistic and out-of-date, and it urges the government to revise its noise policy as well as put pressure on manufacturers to develop new designs that allow for steeper approaches.

Full Article at: <http://www.hacan.org.uk/resources/reports/flight.paths.report.pdf>
 Report completed 3/10

New style, old story: A review of UK Airport Noise Action Plans

Email for AEF: info@aef.org.uk
 From the AEF

Our analysis suggests that while the Scottish airports have taken steps towards meeting the objectives of END, the English and Northern Ireland airports have collectively failed to accept the spirit of the Directive, and have in fact subverted its aims and objectives. Even the Scottish airports rely on the use of a 57 dBLAeq contour rather than the 55 Lden and 50 Lnight contours specified by the Directive. We consider that the noise action plans produced by English airports do not meet the requirements of the Environmental Noise Regulations (England) regulation 15.1(a). We recommend that the Secretary of State should exercise his duty under regulation 24 to reject these action plans.

Full Article at: http://www.aef.org.uk/uploads/AEF_NAP_critique_final_1st_Feb.pdf
 Report completed 2/10

Present and Future Aircraft Noise and Emissions Trends

From the ICAO

As requested by Assembly Resolution A36-22, Appendix A, the Council's Committee on Aviation Environmental Protection (CAEP) has assessed "the present and future impact of aircraft noise and aircraft engine emissions" and has approved tools for this purpose that permit the consideration of interrelationships between aircraft noise, emissions that affect local air quality (LAQ), and emissions that affect the global climate. In absolute terms, the total global population exposed to aircraft noise, total global aircraft emissions that affect LAQ, and total global aircraft emissions that affect the global climate are expected to grow. Aviation's noise and emissions footprint is, however, predicted to grow at a rate slower than the demand for air travel and on a per-flight basis; efficiency is expected to improve throughout the period.

Full Article at: http://www.icao.int/icao/en/assembly/a37/wp/wp026_en.pdf
 Report completed 7/10

Response to a change in transport noise exposure: Competing explanations of change effects

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Irene van Kamp, Centre of Environmental Health Research, National Institute for Public Health and the Environment, P.O. Box 1, 3720 BA Bilthoven, The Netherlands

Annoyance response to a change in noise exposure appears to demonstrate an excess response relative to those predicted from exposure-response curves obtained under steady-state conditions. This change effect also appears to persist well after the change. Numerous explanations have been postulated for this phenomenon. This paper catalogs the different explanations and reviews the evidence for each. The evidence is of limited and variable quality but, while inadequate to endorse any one explanation, is sufficient to reject some notions and to identify a residual set of plausible explanations. These include two explanations based on modifiers of exposure-response relationships that potentially change between before and after conditions, an explanation based on differential response criteria of respondents chronically exposed to different steady-state levels of noise, and an explanation based on retention of coping strategies. All have ramifications for the assessment of human response (annoyance) where noise exposure changes, and some have wider implications for the interpretation of generalized exposure-response curves obtained in the steady state.

J. Acoust. Soc. Am. Volume 125, Issue 2, pp. 905-914 (February 2009)

Article Available at: <http://dx.doi.org/10.1121/1.3058636>

Annoyance responses to stable and changing aircraft noise exposure

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This article reports the two extensive aircraft noise annoyance surveys subsequently carried out among residents in the vicinity of Zurich Airport in 2001 and 2003 in order to update and validate existing exposure-effect relationships for aircraft noise and annoyance in Switzerland. Logistic and polynomial approximations of the exposure-annoyance relationships for both the years 2001 and 2003 are presented for the L_{dn} , L_{den} , and $L_{A,eq24}$ noise metrics. The results confirm other recently published international research and provide further evidence that community annoyance due to aircraft noise has increased over the past decades. Between the two survey years, a considerable amount of early morning and late evening flight operations have been relocated to use another runway than before; thus both the effects of a recent step decrease and recent step increase on the exposure-annoyance relationship could be investigated. Residents that experienced a step increase elicited a quite pronounced over-reaction of annoyance which correlated with the magnitude of the change. Two logistic regression models are provided to forecast the effects of changes in exposure during shoulder hours in the early morning and the late evening.

J. Acoust. Soc. Am. 124 (5), November 2008, Pages: 2930–2941

Available at:

<http://scitation.aip.org/getpdf/servlet/GetPDFServlet?filetype=pdf&id=JASMAN000124000005002930000001&idtype=cvips&prog=normal>

Annoyance from environmental noise across the lifespan

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Curvilinear effects of age on self-reported annoyance from environmental noise were investigated in a pooled international and a Dutch sample of in total 62,983 individuals aged between 15 and 102 years. All respondents were frequently exposed to varying levels of transportation noise (i.e., aircraft, road traffic, and railway noise). Results reveal an inverted U-shaped pattern, where the largest number of highly annoyed individuals was found in the middle-aged segment of the sample (peaking around 45 years) while the lowest number was found in the youngest and oldest age segments. This pattern was independent of noise exposure level and self-reported noise sensitivity. The inverted U-shape explains the absence of linear age effects in previous studies. The results are discussed in light of theories predicting an age-related vulnerability to noise.

J. Acoust. Soc. Am. Volume 126, Issue 1, pp. 187-194 (July 2009)
Article Available at: <http://dx.doi.org/10.1121/1.3147510>

The role of annoyance in the relation between transportation noise and children's health and cognition

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On the basis of this study it cannot be ruled out that the appraisal of the noise affects the association between air and road traffic noise exposure and children's health and cognition. However, the conclusion is limited due to the relatively small group of annoyed children, which may have influenced our group comparisons. Furthermore, the observed relation between annoyance and perceived health is possibly biased due to the fact that both were measured within the same questionnaire. These are the main conclusions of a cross-sectional multi-center study carried out among 2,844 schoolchildren (age 9–11 years) attending 89 primary schools around three European airports. The aim was to investigate how annoyance affects the relation between air and road traffic noise exposure and children's health and cognition. Different, sometimes competing, working mechanisms of how noise affects children's health are suggested. Some effects are supposed to be precipitated through (chronic) stress, while others may arise directly. There is still no theory that can adequately account for the circumstances in which noise will affect cognitive performance.

J. Acoust. Soc. Am. Volume 128, Issue 5, pp. 2817-2828 (November 2010)
Article Available at: <http://dx.doi.org/10.1121/1.3483737>

Attitudes to Noise from Aviation Sources in England (ANASE)

Paul Le Masurier, John Bates, Jenny Taylor, MVA Consultancy, London W1S 1HU, United Kingdom
Ian Flindell, ISVR, Highfield, Southampton S017 1BJ

This was a multi-part major survey in 2005-2006 of attitudes in the UK as an update of a previous 1982 survey (ANISE). The objectives were to re-assess attitudes of aircraft noise in England, to re-assess their correlation with the Leq noise index, and to examine (hypothetical) willingness to pay in respect of nuisance from such noise, in relation to other elements, on the basis of stated preference survey evidence. Interviews were undertaken at 2,733 households in 76 different sites. A sound level measuring and modeling exercise was carried out in parallel with the social survey data collection, to derive aircraft sound level estimates for each respondent. One of the results was that for all except one of the areas with LAeq greater than 57, more than 60% of respondents were at least very annoyed. These results suggest

an increase in annoyance since the 1982 survey, independent of noise level. A modeled mean annoyance of 50 is at 63dB in ANIS and at 55dB in ANASE, a different of 8dB. Analyses of both data sets suggest that inclusion of number of operations, in addition to noise exposure, equalizes the response data from the two surveys as a function of noise exposure.

Available at:

[http://webarchive.nationalarchives.gov.uk/+/http://www.dft.gov.uk/pgr/aviation/environmentalissues/Ana se/](http://webarchive.nationalarchives.gov.uk/+/http://www.dft.gov.uk/pgr/aviation/environmentalissues/Ana%20se/)

Noise Annoyance Mitigation at Airports by Non-Acoustic Measures

Ruud Vader, Communication researcher, Vader Management, Netherlands

This report then contains the results of a review of Non Acoustic Noise Annoyance Mitigation Measures (NANAMM's). It describes how and why non acoustic factors play an important role in determining the level of annoyance that people can experience from aircraft noise. And it lists 50 NANAMM's that we have grouped in eight main types, e.g. Community Programs, Consultation, Compensation, Financial, Information, Insulation, Land Use and Property. Theory and experiments teach us that the same noise can produce different levels of annoyance with different people. Some may be more sensitive to noise than others, or some others may not mind so much about noise because they work at an airport. In all we have identified 31 of such so called Non Acoustic Factors. They are the basis upon which LVNL (ATC Netherlands) added another question to the initial question 'How do we reduce noise pressure levels?' They now also ask: 'How do we reduce noise annoyance levels?' Based on anecdotal reports, LVNL suspected the existence of operational measures at airports around the world that are making use of non-acoustic factors, and commissioned this study to find examples of such measures.

Research report 07 026 version 1 0 (2).doc, 10/1/2007, available at:
<http://www.wyle.com/PDFs/archive/ResearchReportNonAcoustic.pdf>

Community Oriented Solutions to Minimise aircraft noise Annoyance (COSMA)

Michael Bauer, European Aeronautic Defense and Space Company, EADS, Project Coordinator
Uwe Müller, DLR-German Aerospace Center, Cologne, Work Package (WP) 2 leader

COSMA aims to develop engineering criteria for aircraft design and operations in order to reduce the annoyance within airport communities due to aircraft exterior noise. The results from WP2 field studies and psychometric testing will be used for setting up optimised aircraft noise shapes. Special techniques for a realistic synthesis of aircraft noise around airports will be developed for the simulation and validation of optimised aircraft noise shapes. Social surveys and laboratory testing are being conducted to help determine what aspects of aircraft noise produce annoyance and how this information can be used to model the impact of aircraft noise and to develop engineering guidelines and operating practices aimed to minimise the noise annoyance, supported by a set of validated tools

B Aircraft Noise Modeling

B.1 FAA

B.1.1 PARTNER

Source Emission and Propagation

Lead Investigator: Professor Victor W. Sparrow, vws1@psu.edu

Project Manager: Dr. Hua He, hua.he@faa.gov

From PARTNER: Project 2

Project 2 is primarily concerned with the radiation (emission) of sound from aviation noise sources and how that sound is transmitted (propagated) from noise source to receiver. One task has been to assess thrust reverser noise for aircraft landing operations. Another task has been to try to understand the effects of terrain on the sounds of supersonic aircraft sonic booms heard near buildings and other natural ground topography. Recently, PARTNER Project 2 began work related to high altitude enroute aircraft noise, and noise of proposed open rotor aircraft. Since the integrated noise model has primarily been concerned with aviation noise around airports, our ability to predict this type of enroute noise is quite limited at present. Compared to traditional turbofan engines, open rotors can have substantially decreased emissions due to a reduced fuel burn. However, the cost of this reduced emissions impact could be an increase in radiated noise. Current research is focusing on developing a roadmap to address the gaps and research needs for predicting the noise from open rotor aircraft.

Full Article at: <http://web.mit.edu/aeroastro/partner/projects/project2.html>

Status: Active

Sonic Boom Mitigation

Lead Investigator: Professor Patricia Davies, daviesp@ecn.purdue.edu

Project Manager: Laurette Fisher, laurette.fisher@faa.gov

From PARTNER: Project 8

The aim of the proposed work is to determine if sufficient new data exists to warrant a reevaluation of the FAA's regulation prohibiting supersonic flight over land. Recent research on shaped sonic booms has indicated low boom designs are possible and result in significantly less objectionable signatures than classic booms of the 1960s – 1980s. Due to this technological progress and resulting potential commercial and military application for the United States, supersonic aircraft operation and sonic boom signatures should be investigated for low boom designs, and this is the overarching goal of Project 8. This research is expected to lead to the re-evaluation of existing regulations and, possibly, to the development of new regulations to permit operation of commercial supersonic aircraft over both land and water in the United States and worldwide, for the specific case of shaped boom aircraft designs.

Full Article at: <http://web.mit.edu/aeroastro/partner/projects/project8.html>

Status: Active

Sonic Boom and Subsonic Aircraft Noise Outdoor Simulation Design Study

Lead Investigators: Professor Steven L. Garrett,

Professor Victor W. Sparrow, vws1@psu.edu

Project Manager: Mehmet Marsan, mehmet.marsan@faa.gov

From PARTNER: Project 24

The objective of this project was to determine if it is possible to construct a simulation device that can generate sonic boom noise and subsonic aircraft noise for an individual house, or a part of a house. Such a device would be very useful for the subjective testing of individuals to determine their annoyance thresholds to sonic boom and aviation noise. It was shown that such a simulator likely can be constructed to meet every design goal, but it will not be inexpensive. It was shown that one particular technology for low frequency sound generation, the rotary subwoofer, will not meet several requirements needed for such a simulator. It is recommended that a low-cost, small scale simulator be constructed using electrodynamic loudspeaker components, specially constructed for the purpose. This small scale simulator could be used to assess whether the system components can meet the strict volume velocity and impulse response requirements, and thus provide an experimental basis for the construction of a more expensive, full scale simulator.

Full Article at: <http://web.mit.edu/aeroastro/partner/reports/proj24/proj24-2010-002.pdf>

Report completed 5/10

Sound Transmission Indoors – Integrated Windows

Lead Investigator: Professor Kai Ming Li, mmkml@purdue.edu

Project Manager: Dr. Bill He, hua.he@faa.gov

From PARTNER: Project 26

The major outcome of Project 26 will be the development of simple models for estimating the transmission of low frequency noise (LFN) through single-pane and double-pane windows. The study will highlight and quantify the need for appropriate elastic mounting methods that optimize window noise-blocking performance. This will help window manufacturers and the building industry to establish criteria for classifying window acoustic performance.

Full Article at: <http://web.mit.edu/aeroastro/partner/projects/project26.html>

Status: Active

Sound Transmission Indoors – Study of Whole Houses

Lead Investigators: Dr. Erica E. Ryherd, Erica.ryherd@me.gatech.edu

Kathleen Hodgdon, kkh2@psu.edu

Project Manager: Hua He, hua.he@faa.gov

From PARTNER: Project 38

This study will leverage existing technologies in sound transmission to model the combined sound isolation of dwelling envelopes. The model will be whole-housed focused; that is, the research will focus on composite dwelling envelopes (walls + windows + roof, etc). Initial focus will be on continuous noise signatures using the 50 Hz to 10,000 Hz range. Additionally, typical construction types around major U.S. airports will be identified and used to develop model predictions of indoor noise levels. Finally, a pilot effort will explore the application of the finite element method for continuous noise signatures including spectral content below 50 Hz, thus potentially extending the whole house model into the low frequency region.

Full Article at: <http://web.mit.edu/aeroastro/partner/projects/project38.html>

Status: Active

B.1.2 ACRP

Enhanced Modeling of Aircraft Taxiway Noise—Scoping

Prime Contractor: Wyle Laboratories, Inc., in Arlington, Virginia

From ACRP: Document 9, Project 11-02 Task 8

The objective of this scoping project was to determine the best way to model airport noise from aircraft taxi operations and, based on that assessment, to create a plan for implementing a taxi noise prediction capability into INM in the short term and AEDT in the longer term. One study outcome revealed that the primary weakness for taxi noise modeling is related to a definition of engine source noise characteristics, including level, spectra, and directivity. In fact, there is no direct noise database for taxiing operations. Within the current INM/AEDT models, source noise is obtained through an approximate extrapolation of NPD data. For long-term requirements, the study suggested that additional measurements be made for taxi operations to obtain synchronized noise and engine operating parameters which can then be used to determine noise sensitivity at low thrust settings and allow a realistic evaluation of break-away thrust impact.

Full Article at: http://onlinepubs.trb.org/onlinepubs/acrp/acrp_webdoc_009.pdf

Report completed 6/09

A Comprehensive Development Plan for a Multimodal Noise and Emissions Model

Principal Author: Thomas L. Connor

From ACRP: Document 11 Project 2-09

The purpose of this study is to create a framework for developing a tool that would allow for the assessment of the noise and air quality impacts on the population from each transportation source, assess the total costs and impacts, and assist in the design and implementation of mitigation strategies. This model would enable more efficient use of federal, state, and local funds. In addition to public sector entities, this capability would be made available to airports, airport consultants, and others as a framework for conducting environmental assessments for regulatory, business, and community purposes. The goal of ACRP Project 02-09 is to produce a comprehensive Model Development Plan (MDP) that will guide future development (by others) of a model to facilitate integrated quantification of multimodal noise and emissions, as well as economic analysis of alternative scenarios.

Full Article at: http://onlinepubs.trb.org/onlinepubs/acrp/acrp_webdoc_011.pdf

Report completed 8/10

Environmental Optimization of Aircraft Departures: Fuel Burn, Emissions, and Noise

Principal Investigator: Fabio Grandi

Staff Responsibility: Lawrence D. Goldstein

From ACRP Project 02-12

The objective of this research is to develop a departure optimization methodology to (1) quantify potential reductions in fuel burn and source emissions, (2) estimate possible increases in air traffic capacity that can be achieved by optimizing departure procedures while continuing to address noise exposure for communities around airports, and (3) account for existing and future fleet mixes and improvements envisioned under NextGen. In the context of current noise abatement departure procedures, this methodology should estimate environmental and capacity-related benefits associated with the following localized contributors: (a) source noise reduction in future engine/airframe technologies, and (b) realistic alterations to present noise abatement departure procedures to help regulators and airport management make environmentally optimal decisions. Although novel approaches to compare the impacts of climate change, degraded air quality, and community noise are welcome, the output of this research should, at a minimum, provide directly quantifiable metrics.

Full Article at: <http://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=2575>

Report start date 4/09

Expected Completion 11/15/2011

Current Status: Interim report has been reviewed and work on Phase II is now underway.

Aircraft Taxi Noise Database for Airport Noise Modeling

Principal Investigator: Juliet Page, Wyle

From ACRP Project 02-07

The objective of this research is to develop a noise-power-distance (NPD) and spectral class database for nominal taxi, break-away, and idle thrust levels for use in FAA's Integrated Noise Model (INM) as it transitions into the Aviation Environment Design Tool (AEDT). The database will be presented in a spreadsheet format and will encompass the fixed-wing fleet mix provided in INM/AEDT. The preferred method involves taking data from an existing study, such as "Aircrafts' Taxi Noise: Sound Power Level and Directivity Frequency Band Results," and developing a fully populated taxi noise database by extrapolating the

calculated noise levels. Should this method prove unsuccessful, then a modest measurement program should be undertaken to record a sufficient number of taxi operations to develop statistically valid source characteristics for aircraft commonly in use. The resulting database would remove the gap in the current INM noise database and allow for much improved taxi noise estimates.

Full Article at: <http://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=2798>

Report start date 6/10

Expected Completion 10/11

Current Status: Work is underway including the development of initial analytical databases.

Integrated Noise Model Accuracy for General Aviation Aircraft

Principal Investigator: Nicholas P. Miller, Harris Miller Miller & Hanson Inc.

Staff Responsibility: Joseph D. Navarrete

From ACRP Project 02-37

Although the FAA has developed and continuously improved its Integrated Noise Model (INM) since the 1970s, the focus of these improvements has been on the sound level database for large commercial jets. Information from some general aviation (GA) airports suggests INM has over predicted GA noise impacts resulting in an inaccurate representation of noise contours. These disparities can lead to noise contours that do not reflect actual sound levels, which, in turn, may compromise compatible land use planning and result in unnecessary funding of noise mitigation. The objectives of this research are to (1) assess the predictive accuracy of the INM for GA aircraft, (2) identify causes for deviations between actual and predicted values, (3) identify potential solutions to improve the model's accuracy, and (4) describe the steps needed for their implementation.

Full Article at: <http://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=3038>

Status: Contractor Selected.

Contract Time: 20 Months

B.2 NASA

Fundamental Aeronautics Program (FAP) – Acoustics Research

(Multiple NASA personnel)

The FAP research in acoustics and noise encompasses a broad range of research activities in three projects, emphasizing the analyses of different modes of noise sources, generation, propagation and the attendant environmental impact. The goal is to develop technologies that will mitigate and/or significantly reduce sound levels and adverse environmental and health effects.

Subsonic Fixed Wing Project: The overall goal is to reduce aircraft noise to accommodate the anticipated growth in global air traffic. The goal is to enable aircraft designers to determine trade-offs of noise against other performance factors using validated aircraft noise prediction tools while using noise reduction technologies that have minimal impact on the aircraft operation. This goal will be accomplished through the continued development of the ANOPP2 aircraft noise prediction system.

Subsonic Rotary Wing Project: The acoustics research focuses on advancing the fundamental understanding of rotorcraft source noise generation (both internal and external) and propagation phenomena to develop and validate physics-based and first-principles-based analysis tools. Experimental test data (model and flight) will be obtained for developing, validating and improving the accuracy of the analysis methods. Research topics include modeling and prediction, reduction and diagnostics of cabin noise, structural/acoustic modeling or interior noise, and human response to rotorcraft noise. Rotorcraft aeroacoustics also includes source noise physics, flight, and rotorcraft noise mitigation science.

Supersonics Project: Aircraft noise has been one of the dominant reasons why no commercial supersonic aircraft exists today. The noise standard for public acceptance around airports (that is, certification for flight) is based on the noise level produced by conventional subsonic aircraft. To make a viable supersonic aircraft that meets certification noise levels, variable cycle engines are required, and even the NASA N+2 and N+3 system (advanced technology aircraft) studies show that a modest 3-5dB of jet noise suppression will still be required. The goal therefore is to provide propulsion noise reduction concepts which can be applied to variable cycle engines, in addition to engineering design tools for implementation on an aircraft system.

Sonic Boom Research – Atmospheric Propagation

Principal Investigator: Edward Haering

Models of sonic boom propagation from the aircraft to the ground will be evaluated for realistic atmospheric conditions and for important flight conditions. Measurements will be performed to validate these models for several cases, such as at Mach cutoff, when the boom does not hit the ground, focused booms that occur during transonic acceleration and maneuvers, and over-the-top booms.

On-going

Advanced Sonic Boom Prediction Using Augmented Burger's Equation

Sriram K. Rallabhandi

Presented at 49th Aerospace Sciences Meeting, Orlando, FL, 4-7 January 2011

Sonic Boom Research – Structural Response

Principal Investigator: Jacob Klos

In order to fully understand human reaction to sonic booms, it is necessary to be able to predict the transmission of booms into buildings. Both interior noise levels and structural vibration are of interest since both are important characteristics of the indoor environment. Over the next few years, a full-frequency model of sonic boom transmission into buildings will be developed and validated. Data from field tests of sonic booms and structures will be analyzed and documented.

On-going

Vibro-Acoustic Response of Buildings Due to Sonic Boom Exposure: June 2006 Field Test

Klos, Jacob; Buehrle, Ralph; Sullivan, Brenda; Gavin, Joseph; Salamone, Joseph; Haering, Edward A., Jr.; Miller, Denise M.

Two experiments have been performed to measure the vibroacoustic response of houses exposed to sonic booms. In 2006, an old home in the base housing area of Edwards Air Force Base, built around 1960 and demolished in 2007, was instrumented with 288 transducers. During a 2007 follow-on test, a newer home in the base housing area, built in 1997, was instrumented with 112 transducers. For each experiment, accelerometers were placed on walls, windows and ceilings in bedrooms of the house to measure the vibration response of the structure. Microphones were placed outside and inside the house to measure the excitation field and resulting interior sound field. The vibroacoustic response of each house was measured for sonic boom amplitudes spanning from 2.4 to 96 Pa (0.05 to 2 lbf/sq ft). The boom amplitudes were systematically varied using a unique dive maneuver of an F/A-18 airplane. In total, the database for both houses contains vibroacoustic response data for 154 sonic booms. In addition, several tests were performed with mechanical shaker excitation of the structure to characterize the forced response of the houses. The purpose of this paper is to summarize all the data from these experiments that are available to

the research community, and to compare and contrast the vibroacoustic behavior of these two dissimilar houses.

NASA TM 2007-214900

Report Available at:

<http://ntrs.nasa.gov/search.jsp?R=458124&id=2&as=false&or=false&q=Ns%3DArchiveName%257c0%26N%3D4294699831>

Transmission of Sonic Booms into a Rectangular Room with a Plaster-Wood Wall Using a Modal-Interaction Model

Marcel C. Remillieux, Ricardo A. Burdisso, Georg Reichard, Mechanical Engineering Department, Virginia Polytechnic Institute and State University, Blacksburg, VA 24061, USA

As a first step in the development of a model for predicting the noise transmission of sonic booms inside buildings, a numerical solution for the transmission of a shock wave with an arbitrary time history into a rectangular room with a plaster-wood wall is investigated. The dynamics of this fluid-structure system, including their interaction, is computed in the time domain using a modal-interaction method. The formulation of the problem, illustrative numerical results, and a parametric study are presented. The experimental effort dedicated to validating the numerical formulation is also presented. A speaker generating sonic booms with various durations is used to structurally load a plaster-wood wall mounted in the opening of a cinderblock room. The measured wall vibration and pressures at several locations inside the room are compared to the numerical predictions, showing a fairly good agreement overall. Results from this study can potentially be used by aircraft designers to minimize the noise impact in residential houses.

Journal of Sound and Vibration, Volume 327, Issues 3-5, 13 November 2009, Pages 529-556

Article Available at: http://www.sciencedirect.com/science?_ob=ArticleURL&_udi=B6WM3-4WY5BJR-

[1&_user=10&_coverDate=11%2F13%2F2009&_rdoc=1&_fmt=high&_orig=search&_origin=search&_ort=d&_docanchor=&_view=c&_searchStrId=1653594067&_rerunOrigin=google&_acct=C000050221&_version=1&_urlVersion=0&_userid=10&md5=c42405b4fb9c9de0523a8db0e8e67f6a&searchtype=a](http://www.sciencedirect.com/science?_ob=ArticleURL&_udi=B6WM3-4WY5BJR-1&_user=10&_coverDate=11%2F13%2F2009&_rdoc=1&_fmt=high&_orig=search&_origin=search&_ort=d&_docanchor=&_view=c&_searchStrId=1653594067&_rerunOrigin=google&_acct=C000050221&_version=1&_urlVersion=0&_userid=10&md5=c42405b4fb9c9de0523a8db0e8e67f6a&searchtype=a)

Aircraft noise modeling: ANOPP2, New Aircraft Type

Principal Investigator: Casey L. Burley

Development of next generation aircraft system noise prediction capability ANOPP2. Current ANOPP is for conventional aircraft (namely with turbofan engines) configurations, ANOPP2 will provide acoustic prediction for conventional and unconventional (ex. Hybrid wing) configurations with different propulsion systems (including open rotor).

On-going

Aircraft noise modeling: ANOPP2, Propagation

Principal Investigator: Dr. X. Di,

The development of an atmospheric propagation method for use within ANOPP2 based on Gauss Beam theory.

On-going

Aircraft noise modeling: ANOPP2, Open rotor aeroacoustics

Principal Investigator: Dr. Douglas Nark

Develop capabilities for single- and contra- rotation propellers (i.e. open rotor) to predict near and far-field noise. Develop a capability applicable for system noise assessments within ANOPP2 or stand-alone.

On-going

Open Rotor Noise Prediction at NASA Langley - Capabilities, Research and Development

Dr. F. Farassat, NASA Langley Research Center

The high fuel prices of recent years have caused the operating cost of the airlines to soar. In an effort to bring down the fuel consumption, the major aircraft engine manufacturers are now taking a fresh look at open rotors for the propulsion of future airliners. Open rotors, also known as propfans or unducted fans, can offer up to 30 per cent improvement in efficiency compared to high bypass engines of 1980 vintage currently in use in most civilian aircraft. NASA Langley researchers have contributed significantly to the development of aeroacoustic technology of open rotors. This report discusses the current noise prediction technology at Langley and reviews the input data requirements, strengths and limitations of each method as well as the associated problems in need of attention by the researchers. We present a brief history of research on the aeroacoustics of rotating blade machinery at Langley Research Center. We then discuss the available noise prediction codes for open rotors developed at NASA Langley and their capabilities. In particular, we present the two useful formulations used for the computation of noise from subsonic and supersonic surfaces. Here we discuss the open rotor noise prediction codes ASSPIN and one based on Ffowcs Williams-Hawkings equation with penetrable data surface (FW - Hpds). The scattering of sound from surfaces near the rotor are calculated using the fast scattering code (FSC) which is also discussed in this report. Plans for further improvements of these codes are given.

NASA/TM-2010-216178; L-19770,LF99-9570 Jan 2010 30p

Report Available at:

http://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20100003364_2010003030.pdf

B.3 DOD

B.3.1 SERDP

The Advanced Acoustic Model and Three-Dimensional Noise Sources (AAM)

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D.K. McLaughlin, V.W. Sparrow, S.A. McNerny, Pennsylvania State University

The Advanced Acoustical Model (AAM) is a three-dimensional noise simulation model, developed as Strategic Environmental Research and Development Program (SERDP) Project WP-1304. It computes full spectral time histories of noise at specific receiver points or on a grid covering an area. When run in grid mode, the output can be rendered into two- or three-dimensional animations of the aircraft's flight path and noise. With full time histories available, virtually any noise metric can be computed, including ones that are beyond the realm of integrated models.

As a point-by-point simulation, AAM can implement propagation models without the approximations associated with integrated models. It currently includes a basic straight ray ground impedance model, a layered atmospheric refraction model with ground impedance, and a geometric theory of diffraction model that accounts for propagation over irregular terrain and shielding by hills or barriers. It also includes nonlinear propagation, which can occur for some high-thrust military aircraft.

AAM requires three-dimensional noise sources, generally measured with a combination of ground and elevated microphones. Such measurements have been performed for a number of military aircraft (both fixed and rotary wing) and one modern airliner. Sources can be developed from ground-only microphones, using jet noise directivity models developed by Penn State University as part of the SERDP project. Techniques have also been developed to prepare 3-D sources from integrated data in the INM database or Noisemap's Noisefile database. Those techniques yield results superior to short segment integrated models, which embed directivities associated with noise fraction approximations rather than the physics based directivities developed under this project.

Continued development of AAM would include further population of the 3-D source database and integration of higher order propagation models.

Wyle Report WR 10-17, September 2010

C. Noise in National Parks and Wilderness

C.4 National Parks Service (NPS)

C.4.1 General Environmental and Habitat Effects

Letter to the Editor: Airplane noise: a pervasive disturbance in Pennsylvania Parks, USA

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Before creating legislation and restrictions on aircraft noise and overflights in state and national parks, it is important to quantify and document aircraft use over these areas. The objective of this study was to record the number of aircraft overflights and the audible duration of aircraft noise in state parks in Central Pennsylvania, USA. In addition, the hypothesis that the audible duration of aircraft noise in state parks is related to the density of the number of surrounding skyways and airports was tested.

Journal of Sound and Vibration 274 (2004) 411–420

Environmental Effects of Off-Highway Vehicles on Bureau of Land Management Lands: A Literature Synthesis, Annotated Bibliographies, Extensive Bibliographies, and Internet Resources

Douglas S. Ouren, et al, U.S. Geological Survey

This report and its associated appendixes compile and synthesize the results of a comprehensive literature and Internet search conducted in May 2006. The literature search was undertaken to uncover information regarding the effects of off-highway vehicle (OHV) use on land health, or “natural resource attributes,” and included databases archiving information from before OHVs came into existence to May 2006. Information pertaining to socioeconomic implications of OHV activities is included as well. The literature and Internet searches yielded approximately 700 peer-reviewed papers, magazine articles, agency and non-governmental reports, and internet websites regarding effects of OHV use as they relate to the Bureau of Land Management's (BLM) standards of land health. Discussions regarding OHV effects are followed by brief syntheses of potential indicators of OHV effects, as well as OHV-effects mitigation, site-restoration techniques, and research needs.

U.S. Geological Survey, Open-File Report 2007-1353

Report Available at: http://www.fort.usgs.gov/products/publications/pub_abstract.asp?PubID=22021

C.4.2 Soundscape and Visitor Effects

Reducing visitor noise levels at Muir Woods National Monument using experimental management

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Noise impacts resources and visitor experience in many protected natural areas, and visitors can be the dominant source of noise. This experimental study tested the efficacy and acceptability of signs asking visitors to be quiet at Muir Woods National Monument, California. Signs declaring a “quiet zone” (at the park’s Cathedral Grove) or a “quiet day” (throughout the park) were posted on a randomized schedule that included control days (no signs). Visitor surveys were conducted to measure the cognitive and behavioral responses of visitors to the signs and test the acceptability of these management practices to visitors. Visitors were highly supportive of these management practices and reported that they consciously limited the amount of noise they produced. Sound level measurements showed substantial decreases on days when signs were posted.

J. Acoust. Soc. Am. Volume 129, (6), pp. 1375-1380 (March 2011)

Article Available at: http://asadl.org/jasa/resource/1/jasman/v129/i3/p1375_s1?isAuthorized=no

C.4.3 Wildlife

The effects of aircraft on cetaceans: implications for aerial whalewatching

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E.C.M. Parsons, University Marine Biological Station Millport (University of London)

The effects of anthropogenic noise on marine mammals are a rich subject for study and have attracted considerable attention in the past two decades. Aircraft noise may not only affect the biology of cetaceans but may also skew aerial survey data. Since 1995 few studies have been published, but these have documented behavioral responses of cetaceans to aircraft in much greater detail. This paper reviews and discusses progress in the study of aircraft noise effects on marine mammals since the landmark review of Richardson et al. (1995). In each of the studies reviewed here, cetaceans responded to aircraft to some extent, in most cases by diving. Several major gaps in knowledge on the effects of noise on marine mammals also apply to aircraft noise, e.g. quantification of received sound level, the role of vision, knowledge of baseline behavior, the effect on vocalizations. The possible implications for whalewatching by aircraft are discussed.

International Whaling Commission, Scientific Committee, 2009

Report Available at: http://iwcoffice.org/documents/sci_com/sc61docs/SC-61-WW2.pdf

D. Costs of Aircraft Noise on Society

D.11 Other

Effect of Suburban Transit Oriented Developments on Residential Property Values

Dr. S. Mathur and Dr. C. Ferrell, Mineta Transportation Inst., San Jose, CA. Coll. of Business

The development of successful TODs often encounters several barriers. These barriers include: a lack of inter-jurisdictional cooperation, auto-oriented design that favors park and ride lot over ridership generating uses, and community opposition. The community opposition may be more vocal in suburban areas where residents of predominately single-family neighborhoods may feel that the proposed high-density, mixed-use TOD will bring noise, air pollution, increased congestion and crime into their area. Community opposition has been instrumental in stopping many TOD projects in the San Francisco Bay Area. While community opposition to TODs has been pronounced, *very* little empirical research exists that indicates whether this opposition is well-founded. Economic theory suggests that if a TOD has a negative effect on the surrounding residential neighborhoods, then that effect should lower land prices and in turn, the housing prices in these neighborhoods. Similarly, an increase in the housing prices would mean a positive effect of TODs on the surrounding neighborhoods. This study empirically estimates the impact of four San Francisco Bay Area suburban TODs on single family home sale prices. The study finds that the case study suburban TODs either had no impact or had a positive impact on the surrounding single-family home sale prices.

CA-MTI-09-2609 Jun 2009 102p, MTI Report 08-07

Report Available at: <http://transweb.sjsu.edu/mtiportal/research/publications/summary/mti0807.html>

Meta-Analysis of Airport Noise and Hedonic Property Values: Problems and Prospects

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Meta-analysis is applied to the negative relationship between airport noise exposure and residential property values. The effect size in the analysis is the percent depreciation per decibel increase in airport noise, or the noise discount. Twenty hedonic property value studies are analyzed, covering 33 estimates of the noise discount for 23 airports in Canada and the United States. About one-third of the estimates have not been previously reported in the literature or were not included in previous meta-analyses. The weighted-mean noise discount is 0.58% per decibel. A meta-regression analysis examines the variability in the noise discounts that might be due to country, year, sample size, model specification, mean property value, data aggregation, or accessibility to airport employment and travel opportunities. The analysis indicates that country and model specification have some effect on the measured noise discount, but the other variables have little systematic effect. The cumulative noise discount in the U.S. is about 0.5% to 0.6% per decibel at noise exposure levels of 75 dB or less, while in Canada the discount is 0.8% to 0.9% per decibel.

Journal of Transport Economics and Policy, January 2004.

Noise versus Access: The Impact of an Airport in an Urban Property Market

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The effects of a major airport are unlikely to exhibit a uniform spatial distribution. The benefits to industries and individual households may extend well beyond the local economy, whereas many of the costs are spatially concentrated in the immediate environment. In particular, the problems of noise and traffic generation can be expected to fall principally upon adjacent populations. This paper addresses the general question of whether the costs to local economies of airport proximity, which are in the nature of externalities, outweigh the benefits of access, employment and improved infrastructure. Based on data relating to Manchester airport and its surrounding areas, the specific approach adopted in the paper involves an investigation of the extent to which such proximity effects are capitalised into residential property prices. Our results provide some evidence to suggest that circumstances may exist where positive attributes, such as improved access and employment opportunities, may be more highly valued by local residents than the negative externality effects of airport proximity.

Urban Studies, Vol. 35, No. 2, 243± 258, 1998

Airport noise and residential housing valuation in southern California: A hedonic pricing approach

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A large and detailed data set is used to examine the influence of airports and airport light paths on housing prices. The results indicate that individuals consider airport proximity and airport flight patterns in their housing purchases. This shows that there exist two distinct measurable price gradients that distinguish large airports from small airports. In addition, homes located under the flight path of a large airport have a price gradient that is significantly larger than homes located under the flight path of a small airport.

International Journal of Environmental Science & Technology Vol. 1, No. 1, pp. 17- 25, Spring 2004

5 Future Research

A. Noise Effects on Health and Welfare

Key Research Projects Identified by FAA Aircraft Noise Impacts Workshops, 2009-2010

The FAA held three public workshops in 2009 and 2010 that focused entirely on two issues of immediate interest: Annoyance and Sleep Disturbance (SD). The workshops identified five research projects related to annoyance and eight related to sleep disturbance.

With these recommendations in mind, the FAA has launched several research projects through the FAA-sponsored program managed by the National Academies Airport Cooperative Research Program (ACRP), the FAA Center of Excellence, Partnership for Air Transportation Noise & Emission Reduction (PARTNER) sponsored by the FAA, NASA, Transport Canada, DoD and the Environmental Protection Agency, and the John A. Volpe National Transportation Systems Center. Below are brief descriptions of several projects.

Annoyance

1. **Project A1 – Review Available Studies/Data:** There are some 628 surveys cataloged.¹ These should be reviewed with respect to the key issues:
 - i. Has annoyance increased over time?
 - ii. Is it different for different aircraft?
 - iii. Is it different in locations dominated by low frequency noise or in different areas of an airport?
 - iv. Is it affected by airport/community interactions?
 - v. Is it due to a step change?
 - vi. Are there differences in exposure-response relationships between transportation modes?
 - vii. Would a model based on noise metrics other than DNL or a model based on DNL's separate components be better than the current DNL model?

Are secondary analyses possible for some of the studies, singly or in combination? International Standard Organization (ISO) is currently reviewing existing survey data for a possible update of the %HA relationship (Schultz curve).

2. **Project A2 – Conduct New Surveys in U.S.:** This is intended to be a comprehensive set of telephone interviews around multiple airports. Data to update noise contours, to document non-acoustic measures taken by airports and noise abatement procedures implemented would be collected in addition. The intent of this study would be to document changes, if any, between the multiple sources of transportation noise used by T. Schultz to develop the annoyance curve in his 1978 paper, while during the same evaluation, to assess whether there has been a substantive shift in the degree of high annoyance in communities exposed to aircraft noise since the phaseout of Stage 1 (and Stage 2) aircraft in the early to mid-80s and in 1999. The study would also shed light on research topics such as difference in responses due to step change versus gradual change in noise exposure, type/number of aircraft operations, alternative noise metrics, and non-acoustic factors.

This study is presently being funded as ACRP FY11 Project 02-35:
<http://www.trb.org/ACRP/Public/ACRP.aspx>.

3. **Project A3 – Retrospective Study of Community Reactions:** The objective of this research is to develop analysis methods to help identify communities that may react negatively and strongly to the noise environment resulting from airport/airspace projects. Such knowledge could:
 - i. Improve the effectiveness of public outreach during the National Environmental Policy Act (NEPA) process;
 - ii. Ensure that study assumptions and analyses address critical community concerns;
 - iii. Provide an opportunity during the NEPA process to explore reasonable alternatives that would lower the likelihood of adverse community action;
 - iv. Yield information that may be useful to help manage public expectations;
 - v. Help airports and communities investigate abatement alternatives that are raised in such forums as roundtables or during general community outreach processes.

¹ Bassarab, R., *et al*, "An Updated Catalog of 628 Social Surveys of Residents' Reaction to Environmental Noise (1943 – 2008)" WR 09-18, November 2009,
http://www.faa.gov/about/office_org/headquarters_offices/apl/research/science_integrated_mode ling/media/An%20Updated%20Catalog%20of%20628%20Social%20Surveys.pdf

The results of this research are not intended to alter the basic NEPA requirements and procedures only to assist the proponent to better understand the likely effects on surrounding communities and plan for them, either by modifying the project alternatives, providing supplemental metrics, or by identifying and reporting additional analysis deemed important to surrounding communities.

4. **Project A4 – Develop Standardized Noise Complaint Handling System:** In the U.S. and other developed nations, many thousands of formal complaints are generated every year about noise due to transportation systems, particularly aircraft noise, but there is no standardized methodology available to capture and evaluate this freely provided data stream in order to understand what issues are generalizable across airports versus those that are truly airport-specific, and what common approaches may be used to reduce and/or address complaints. This proposed research project sets out to answer two main questions:
- i. What can complaints usefully tell us and how could we use them to improve airport operations?
 - ii. What is the best way of handling complaints in a standardized format utilizing modern technology to improve communication and transparency across the aviation industry and with the residents in communities near airports?

The project would include interviewing airport staff, residents, airlines, and aviation agencies to understand current complaint management and value of a standardized complaint handling system. Current complaint handling would be investigated. Complaints from selected airports would be analyzed.

5. **Project A5 – Test Methods for Communicating about Aircraft Noise with the Public:** The approach would be to work with panels to test various ways of talking about what changes in noise exposure would occur and where, using such measures as changes in numbers of operations and distributions of aircraft sound levels by location. There has been at least one pilot test in the U.K. to explore how best to communicate these technical issues with the public.² The study used a group of citizens, both living near airports and distant from airports, to test different methods of presenting information. The study identified some useful findings that should be further explored in the U.S. One of the clearest findings was:

“Universal acknowledgement that bar charts, for specific locations illustrating the numbers of events within ranges of maximum sound levels for given periods of the day, were the most informative and easiest to interpret of all the metrics viewed.”

Sleep Disturbance (SD)

6. **Project S1 – Meta study of reports of SD:** This initial project is needed to determine what previous studies, data, and results might be useful to address the key issues:
- i. Are there factors that might cause different populations to respond differently to nighttime noise?
 - ii. Is there a noise metric that correlates with SD?
 - iii. How important for SD is the time of night?
 - iv. What is the relationship between noise-induced SD and next-day effects?
 - v. How does a given population react to different levels of nighttime operations?

² Hooper, P. et al, “OMEGA Community Noise Study, Indices to enhance understanding & management of community responses to aircraft noise exposure,” Manchester Metropolitan University / University of Southampton January 2009

- vi. Does L_{night} correlate with noise-induced SD?
- vii. What non-noise studies of SD might inform our understanding of noise induced SD?

A first step would be to clearly identify the important variables associated with each of the key issues. The previous studies would be reviewed to identify those issues that have been included or addressed. Needed information that is not available will represent a gap in knowledge that will be used to formulate follow-on studies.

7. **Project S2 – Compare SD Studies of U.S. Populations with Results of Studies of Other Populations:** The most recent U.S. SD studies are those of S. Fidell. These studies used behavioral awakenings (the subject was instructed to press a button when awakened) and hence need to be compared with other studies that used the same technique, of which there is at least one. A statistical comparison should reveal similarity or differences of the populations studied. Reasonable similarity could be used to justify application of other European or other country study results to the U.S. Cultural differences should be documented if possible. Additional differences include different house construction techniques and window-opening practices. Weakness of the correlations would suggest need for additional U.S. studies – probably modeled on an accepted EU approach.
8. **Project S3 – Compare SD Models and Prediction Results for Realistic Scenarios of an Entire Night of Operations:** One standardized method is available,³ but other approaches should be developed and compared for a given set of realistic nighttime aircraft noise events and incorporate the populations affected. Time of night should be included.
9. **Project S4 – Review and Examine Available Studies of Next-Day Effects for Sufficiency and Determine whether Additional Studies are Warranted:** Next day self-reports are generally regarded as unreliable. Studies, both of noise-induced SD and other SD studies should be reviewed for objective measures of next-day effects such as reaction times. If non-noise studies indicate thresholds of disturbance that produce next-day effects, then the task is to determine, possibly from Project S3, under what conditions such disturbance thresholds would be reached due to noise.
10. **Project S5 – Review and Examine Available Studies to Identify Populations that Experienced Variable Nighttime Exposures and Attempt Separating Effects by Exposure:** At some airports, runway use or operations can vary from night to night. If such an airport has been a site for a SD study, it may be possible to separately examine subject nights, segregated by noise exposure. Such a study could provide insight into how changing nighttime noise affects a single population. Application of results would permit evaluation of the benefits of altering nighttime operations, such as changed flight operations or runway use, or by providing additional sound insulation.
11. **Project S6 – Use Available SD Models and Compare Nightly Awakenings with Corresponding Values of L_{night} :** Most SD studies include for each subject, for each night, the levels of the individual aircraft noise events as heard in the sleeping room. If these levels are, or can be converted to, Sound Exposure Levels (SEL), then it is a simple matter to compute L_{night} , inside for each subject night. Models that predict SD can also be applied to each night of operations to determine the associated probability of disturbance/awakening. Plotting of

³ American National Standard, ANSI S12.9-2008, Part 6: “Methods for Estimation of Awakenings Associated with Outdoor Noise Events Heard in Homes,” July 3, 2008.

probability of disturbance versus Lnight, inside will show whether there is any correlation between the two variables.

12. **Project S7 – Review and Examine Available Non-Noise SD Studies of Health Effects for Applicability to Disturbances Produced by Noise:** Assistance from SD researchers will be required to identify applicable studies and to properly interpret study results for application to noise-induced disturbance.
13. **Project S8 – Work with the National Institutes of Health to Determine whether Previous or Pending Research has or could Include Noise and Sleep.**

The final report from the “Impacts Workshop” contained recommendations that identified gaps related to aviation noise effects on health and welfare.⁴

Gaps –

- Assessing aircraft noise impacts should go beyond number of people exposed to significant noise and focus more on health effects
- Effects of noise on sleep structure insufficiently known
- Effects on coronary heart disease insufficiently known
- Trade-offs of number and sound level of individual aircraft on effects uncertain
- Existing exposure-response relationships and thresholds may not generalize across countries and could be answered by coordinated international noise research

B. Aircraft Noise Modeling

The future for aviation noise modeling will include the consideration of potential noise impacts within the context of other, interdependent environmental consequences. There will likely be improvements to noise model algorithms in the future that will not only improve the accuracy of models, but also have implications on the use of the tools.

Lateral attenuation algorithms have been updated in the last decade – continued review of these equations will result in the ability for models to directly account for varying ground impedance values for propagation. This will require the user to specify ground characteristics, such as acoustically “hard”, “soft” or otherwise, as a part of other model inputs. This will enable modelers to account for characteristics such as large bodies of water and concrete, or other materials of known acoustic impedance, which may affect modeled sound levels in some areas.

Based on the body of international research over the last two decades, atmospheric absorption algorithms will be updated in the near future. While not requiring additional input by users, these improvements will result in more accurate predictions, especially for larger propagation distances, when using off-reference meteorological conditions.

⁴ Maurice L. Q., Lee D. S. (eds) 2009. “Assessing Current Scientific Knowledge, Uncertainties and Gaps in Quantifying Climate Change, Noise and Air Quality Aviation Impacts,” Maurice, L. Q., Lee, D. S., Wuebbles, D. W., Isaksen, I., Finegold, L., Vallet, M., Pilling, M. and Spengler, J. Final Report of the International Civil Aviation Organization (ICAO) Committee on Aviation and Environmental Protection (CAEP) Workshop, US Federal Aviation Administration and Manchester Metropolitan University, Washington DC and Manchester. ICAO / CAEP is considering approaches for a way forward to benefit from the recommendations, recognizing the scarcity of resources, see CAEP/8-WP/8, 11/1/10.

The behind start of takeoff roll noise directivity adjustment will be updated in the near future. This update is based on empirical data representing the current aircraft fleet, and will result in jet- and turboprop aircraft-specific directivity adjustments. These updates will not require any additional input by the user and will result in more accurate noise predictions behind departing aircraft.

The effects of including helicopter spectral data below 50 Hz in noise computations have recently been evaluated. Specifically, the inclusion of helicopter noise data between 12.5 Hz and 10 kHz (as opposed to the standard AEDT/INM frequency range of 50 Hz to 10 kHz) has been found to have a small but noticeable effect on atmospheric absorption, and line of sight blockage adjustments, as well as the computation of C-weighted metrics in general. Noise computations based on these extended range frequency data are more accurate and do not require any additional input from the users.

Another area of noise modeling research is the de-rated thrust take-offs. Currently, many noise models model aircraft using full thrust take-offs. It is understood that a certain amount of aircraft no longer perform full thrust take-offs and instead use de-rated thrust take-offs. More modeling research needs to be completed to determine the correct methodology for modeling the de-rated thrust, including whether there should be an allowance for multiple rates of thrust or a single de-rated thrust.

While aviation noise modeling has traditionally been focused on aircraft takeoff and approach operations, it becomes increasingly important to enhance or extend the modeling capability to other phases of operations. This allows for the ability to predict aircraft noise runway-to-runway. To successfully do that, three phases of flight where additional research is needed for better modeling methodology are: thrust reverser noise, taxiway noise and en route noise.

The thrust reverser noise is currently supported in noise models, but the thrust levels and the corresponding procedures are generic, rather than aircraft type specific. Near-term research will be to develop aircraft type specific reversal thrust levels and reverser deployment procedures. The research should enable better modeling of not only noise, but also emissions and fuel burns when thrust reversers are used in landing.

Taxiway noise operation is minimally supported in current noise models. Research projects are underway to develop a predictive methodology and a new set of NPD (Noise-Power-Distance) data to represent various modes of taxi operations ranging from break-way/acceleration to constant speed taxiing. The research is mature and should be implemented within the FAA tool in the short term. The research is expected to impact AEDT 2b release.

En route noise refers to flight operations away from terminal areas, such as top of climb, cruise and top of decent. Research is currently underway to characterize noise sources of jets flying at high altitudes. Existing jet engine noise models will be used to quantify jet engine noise as function of atmospheric conditions and engine state parameters. The jet aircraft performance modeling will leverage the new capability being developed in AEDT. In parallel to the noise source characterization, noise propagation modeling research is also underway. The work will focus on long range sound propagation through atmosphere, which not only attenuates noise energy through absorption, but also bend sound ray upward or downward depending on temperature and wind speed profiles. The noise source modeling and noise propagation, when combined and supplemented with supporting databases, will allow for noise impact analysis of high altitude flights in noise sensitive areas such as the national parks. The work would also pave the way for noise impact analysis of future aircraft powered by advance propulsion systems such as open rotors.

If supersonic aircraft are re-introduced for commercial service, they will need to be modeled for noise impact to airports and regions into which they fly. As with other common aircraft types, regulatory model system databases will likely be updated to include these aircraft. Users, however, will be required

to model them as appropriate in specific scenarios, including accounting for any preferential flight corridors they may be assigned and/or separation considerations.

In addition, for improvements in audibility and time above metrics, enhancements in modeling simultaneous events are a potential area for modeling research. The FAA is currently funding research for time compression algorithms to improve the calculation of audibility. In the future, as these improvements are implemented, it will need to be seen how these methodologies can be exploited for time above metrics.

As aircraft technology continues to advance, it is imperative that noise modeling tools continue to evolve to be able to handle the new technologies. Hence, exploring methodologies to model non-conventional aircraft is a growing area in noise modeling research. Research has already begun in this area as explorations in the effects of open rotor aircraft has begun. In the coming years, this research can be expanded to determine if noise and performance methodologies within noise modeling tools need to be altered to account for blended wing aircraft, N+2, N+3 and beyond aircraft.

As for the direction for the models themselves, modeling across various transportation modes (multi-modal) must be considered for the long term. Regional planners have long understood the implications policy decisions in one mode (say aviation) have on others that service the same geographic area. This has implications on motor vehicle, heavy and light rail environmental modeling, but similar to the modeling of environmental interdependencies, should ultimately allow for better-informed policymaking.

Further still in the future, simulation tools may enable regulatory and policy planners to better account for the time-specific considerations of environmental planning for which integrated tools currently do not fully account.

The future of noise modeling research is vast. From improving methodologies to better meet the needs of the users of the tools to longer term planning of moving to multi-modal or simulation-based tools, it's an exciting time that will continue into the future.

C. Noise in National Parks and Wilderness

Key Wildlife Research Problems Identified during Workshop in Cambridge, September 2010

A three day workshop on the effects of aviation noise on wildlife in national parks was held at the Volpe Transportation Systems Center in Cambridge, MA in September 2010. This workshop identified key issues, summarized here as gaps, and a research plan described below.

Topic: Effects of aviation noise on wildlife in the national parks; responses;

Objective : Dose-response information

Gaps –

- No definition of “harassment” which NPS must prevent
- Need a hierarchy of impacts in NPS scale of:
 - Negligible – affects “discountable number” of individuals
 - Minor
 - Moderate – mitigation desirable
 - Major or high – must provide mitigation
 - Impairment or unacceptable impact
- What constitutes significant impact?

Research Plan Proposal

The research plan has three tracks and ten experiments.

- Track 1: Broad Geographic/Multispecies Information (Field)
- Track 2: Laboratory Experiments on Responses (Lab)
- Track 3: Behavior, Movement, and Physiological Responses (Field)

Track 1 – Priority #1 – Broad Geographic/Multispecies Information

1) Spatial screening – distributions of a variety of species – highest level screening experiment

- Include birds breeding pop/breeding success. Utilize regional and national noise maps in concert with bird census or survey data to determine whether there is any correlation of density or breeding success with noise exposure.
- Mammalian study may include fecal collection and some additional physiological data as sub-part of data collection (pop structure, etc.), possibly augmented with stress assays of fecal collections.
- Utilize acoustical monitoring to determine whether vocal activity changes in relation to noise (after accounting for changed detection probabilities and changed densities due to noise).
- Behavioral observations (compensatory behaviors, etc.).
- Potential to look at a park with new modification and look at before and after. Major changes in local noise levels (airport projects) or en route noise levels (route structure, relocations of major airports, like Las Vegas) should receive high priority as unique opportunities for before-after controlled exposure experiments (BACE).
- Duration would depend on species – potential for year to year experiments due to territoriality, etc. (needs to be teased apart from air tour effects on distribution)

Key information gained:

- For those species where saw reduction in use, would see what cost is in habitat availability or species abundance
- Could indicate some information about minor/moderate/major effects if can get transects that cover a gradient of exposure and see range of effects

2) Measures of reproductive success linked to spatial distribution

- Reproductive effects have been observed from road noise – do we see it with aircraft noise (intermittent source)?
- Similar set up to #1 (broad community) –
 - alter flight routes and have exposed areas versus controls
 - Possible variant: actual flights versus playback at ground level?)
- Look at reproductive metrics (clutch size, fledgling #, provisioning) in natural contexts
- Look at compensatory behaviors
- Multi-year study with control sites and overflight sites.
- Find nests and find ways to monitor technologically or with observers

Key information gained:

- Reproductive effects (potential level of impact),
- Relative effects of various factors (both natural and anthropogenic),
- Potential for source/sink dynamics (provides supporting/complementary info for counts/presence).

Track 2: Lab/Response Track

1) Audiograms for animals

Key information gained:

- Can estimate at what distance noise source would be detectable by various species
- Can hypothesize whether masking effects from aircraft would be important for a given species

2) Masking thresholds

Key information gained:

- Masking source and specific signals for individual species

3) Use results from Track 2 Experiments 1 and 2 to predict behavioral responses and test in field and correlate with different metrics of sound level.

Key information gained:

- Applicability of laboratory experiments to field settings
- Improved understanding and selection of acoustic dose metrics

4) Controlled experiments adjusting sound quality

- What aspects of noise cause annoyance/behavioral change (allow animal to turn off sound or other behavioral observations)

Key information gained:

- Parameters that could be changed in order to adjust sound quality (distance, technology) to reduce impacts,
- Consistency of response among species
- High quality information for estimating exposure

5) Captive and field predator behavior

- Frequency masking in field,
- Expansion to multiple species (owls, bats, harriers)
- Bats have advantage that can use acoustic signals to find bats, record behavior (hunting, success)
- Harriers, great grey owls – daytime predator with acoustic localization

Key information gained:

- Whether air tours are changing habitat by altering hunting behavior/use of habitat

Track 3: Behavior, Movement, and Physiological Responses

1) Controlled experiment varying signal (aircraft noise) periodicity and intensity to look at change in response

- Identify taxa
- For long-term information, preferably would have extensive radio-tagging already in place to reduce set-up and costs.
- Short-term distribution changes could be done with track plates⁵, etc. – smaller up-front cost and could be started from scratch
- Expose to regularized or unpredictable air tours.

Key information gained:

- How does timing / predictability of events structure response?
- Is there a way to regularize schedule or run overflights at certain times of day (increase predictability) to mitigate response.

⁵ A hard sheet of material with a soft coating that can be imprinted with animal footprints, sometimes in great detail.

- 2) Measure reproductive effects of short-term isolated noise exposure versus intermittent exposure over course of season
- Fecal glucocorticoids
 - Total reproduction

Key information gained:

- Correlation of short-term responses with long-term reproductive effects
- Separation of effects of isolated events versus intermittent, repeated events

- 3) Measure effects of air tours on sleep/hibernation disruption in wildlife
- Place noise monitor in bear den
 - Track behavioral response to noise/hibernation disruption.

Key information gained:

- First sleep disruption information on wildlife,
- Both noise reception information and behavioral differences,
- Changes in energy budget,
- Can identify other sounds that might have same or more influence
- Potential effects on maternal care.

NOAA/National Marine Fisheries Service

Topic: Effects of aircraft noise on marine mammals (pinnipeds & cetaceans); specifically behavioral responses;

Gap – General lack of knowledge

Topic: Levels marine mammals receive based on aircraft type, altitude, speed, etc. (what factors affect response);

Gap – General lack of knowledge

Topic: Chronicle affects for haul-out marine mammals, as well as population-level impacts of disruptions;

Gap – This topic is not limited to airborne noise sources (i.e., an issue with all noise sources): How do chronic effects of short-term behavioral disruptions affect individuals, as well as populations?

Application – Better understanding of chronic (long-term) impacts of noise on individuals and populations.

D. Costs of Aircraft Noise on Society

ICAO / CAEP

The final report from the “Impacts Workshop” contained recommendations that identified gaps related to aviation noise Cost Benefit Analyses, CBA.⁶

Gaps –

- Noise panelists uncertain that state-of-the-practice analyses using noise depreciation index, NDI (based on property values) or willingness-to-pay, WTP, capture the full extent of noise effects, such as the value of cardiovascular effects and the effects of SD on worker productivity and worker accidents.

⁶ Op. Cit. Maurice (2009), footnote 4

- Other methods, DALY (disability-adjusted life years) and QALY (quality-adjusted life years) used for air quality impacts can be applied to noise and used to compare noise and air quality impacts.

Appendix A Aviation Noise Impacts Roadmap Annual Meeting Agenda

Agenda: Aviation Noise Impacts Roadmap Annual Meeting, April 19-20, 2011, HUD HQ, Conference room C, 451 7th Street, SW, Washington, DC

19-Apr-11				
Start	Duration	End	Title	Presenter
8:00	0:30	8:30	Registration	
8:30	0:05	8:35	Welcome	HUD: James Potter
8:35	0:20	8:55	Aviation Noise Impacts Roadmap	FAA: Lourdes Maurice
8:55	0:15	9:10	Introductions and meeting overview	FAA: Natalia Sizov
9:10	0:20	9:30	An overview of NASA's Fundamental Aeronautics Program research activities on noise	NASA: Endwell Daso
9:30	0:15	9:45	Aircraft noise research in DLR - An overview with special focus on noise modeling in airport vicinity	DLR: Bridgitte Brunner
9:45	0:20	10:05	DoD Noise Working Group (DNWG) current actions and future needs	DoD: Lynn Engelman
10:05	0:15	10:20	BREAK	
10:20	0:05	10:25	1: NOISE EFFECTS ON HEALTH AND WELFARE	UPenn: Mathias Basner
10:25	0:20	10:45	Summary and results of three earlier FAA Aviation Noise Impacts Research workshops	FAA: Fisher/Marsan
10:45	0:20	11:05	The European Network on Noise and Health (ENNAH): new directions in noise and health research	UL: Charlotte Clark
11:05	0:30	11:35	New directions in noise and sleep research	IfADo: Barbara Griefahn
11:35	0:20	11:55	The ongoing EU-project COSMA (Community Oriented Solutions to Minimize aircraft noise Annoyance) - an overview	DRL: Uwe Muller
11:55	1:00	12:55	LUNCH	On your own
12:55	0:20	13:15	Airport noise and self-reported sleep insufficiency: results from CDC's Behavioral Risk Factor Surveillance System	CDC: James Holt
13:15	0:20	13:35	Biomedical research: informing the discussion of sleep health	NIH: Michael Twery
13:35	0:20	13:55	Investigation of community attitudes towards military blast noise	Army: Edward Nykaza
13:55	0:20	14:15	Progress and plans regarding sonic boom impact	NASA LaRC: Kevin Shepherd
14:15	0:15	14:30	Exposure-effect relationships between aircraft and road traffic noise exposure at school and children's cognition and health: a cross-national study	UL: Charlotte Clark
14:30	0:20	14:50	How can complaints be used as an index of community disturbance?	MMU: Ken Hume

14:50	0:15	15:05	Some ideas for future directions in annoyance research	Purdue: Patricia Davies
15:05	0:25	15:30	Open discussion on topic Noise effects on Health and Welfare: Key problems, gaps, research needs	UPenn: Mathias Basner
15:30	0:15	15:45	BREAK	
15:45	0:05	15:50	2: IMPACT/COST OF NOISE ON SOCIETY	FAA: Maryalice Locke
15:50	0:30	16:20	Valuation of aircraft noise damages	PennState: Jon Nelson
16:20	0:25	16:45	Aviation environmental Portfolio Management Tool (APMT): Impacts noise model	MIT: Christoph Wollersheim
16:45	0:20	17:05	Sound insulation related research - COE/PARTNER and ACRP projects	FAA: Bill He
17:05	0:25	17:30	Open discussion on topic Costs of aircraft noise on society: Key problems, gaps, research needs	FAA: Maryalice Locke

20-Apr-11

Start	Duration	End	Title	Presenter
8:30	0:05	8:35	Welcome	HUD: James Potter
8:35	0:05	8:40	3: AIRCRAFT NOISE MODELING	Volpe: Christopher Roof
8:40	0:20	9:00	Aircraft System Noise Prediction- the status of ANOPP2	NASA LaRC: Casey Burley
9:00	0:20	9:20	The Advanced Acoustic Model and Three-Dimensional Noise Sources	Wyle: Kenneth Plotkin
9:20	0:20	9:40	Do nonlinear effects in jet noise alter perception of loudness?	Blue Ridge: Micah Downing
9:40	0:20	10:00	Recent COE/PARTNER work in aviation noise modeling	PennState: Vic Sparrow
10:00	0:20	10:20	BREAK	
10:20	0:20	10:40	Aviation Environmental Design Tool (AEDT)	FAA: Rebecca Cointin
10:40	0:30	11:10	FAA noise modeling tool enhancement	Volpe: Christopher Roof
11:10	0:20	11:30	Supporting park management through noise modeling	Volpe: Cynthia Lee
11:30	0:20	11:50	En route noise modeling - a recent initiative	FAA: Bill He
11:50	0:25	12:15	Open discussion on topic Aircraft Noise Modeling: Key problems, gaps, research needs	FAA/Volpe: Cointin, He/Roof
12:15	1:00	13:15	LUNCH	on you own
13:15	0:05	13:20	4: NOISE IN NATIONAL PARKS AND WILDERNESS	Volpe: Cynthia Lee
13:20	0:20	13:40	Visitor surveys of sound sources: acceptability, appropriateness	CSU: P. Newman/D. Taff
13:40	0:20	14:00	Analysis of visitor survey responses in relation to aviation noise exposure	Volpe: Aaron Hastings

ANIRR

14:00	0:20	14:20	Summary of wildlife noise issues	BSU: Jesse Barber
14:20	0:20	14:40	National Marine Fisheries Service: Airborne noise issues from the perspective of the Marine Mammal Protection Act	NOAA: Amy Scholik-Schlomer
14:40	0:20	15:00	Psychological evaluations of park sound environments	CSU: Jake Benfield
15:00	0:20	15:20	Ambient noise data collection and analysis	Volpe: Cynthia Lee
15:20	0:20	15:40	Survey of aircraft noise exposures in parks	NPS: Kurt Fristrup
15:40	0:25	16:05	Open discussion on topic Noise in National Parks and Wilderness: Key problems, gaps, research needs	Volpe: Cynthia Lee
16:05	0:20	16:25	BREAK	
16:25	1:00	17:25	Open discussion: Future of Roadmap and annual meetings	FAA/HMMH: Sizov/Miller

Appendix B List of Acronyms:

AAM	Advanced Acoustic Model
ACRP	Airport Cooperative Research Program
AEF	Aviation Environment Federation
ANIRR	Aviation Noise Impacts Research Roadmap
AEDT	Aviation Environmental Design Tool
ANASE	Attitudes to Noise from Aviation Sources in England
ANOPP	Aircraft Noise Prediction Program
BACE	Before-After Controlled Exposure
BLM	Bureau of Land Management
CAEP	Committee on Aviation and Environmental Protection
CBA	Cost-Benefit Analysis
CDA	Continuous Descent Approach
CDC	Centers for Disease Control and Prevention
CERL	Construction Engineering Research Laboratory
COSMA	Community Oriented Solutions to Minimize aircraft noise Annoyance
DALY	Disability-Adjusted Life Years
DENL	Day-Evening Night Level
DLR	German Aerospace Center
DNL	Day-Night Average Sound Level
DOD	Department of Defense
ENNAH	European Network on Noise and Health
ERDC	Engineer Research and Development Center
EWG/JPDO	Environmental Working Group/Joint Planning Development Office
FAA	Federal Aviation Administration
FAP	Fundamental Aeronautics Program
FICAN	Federal Interagency Committee on Aviation Noise
FICON	Federal Interagency Committee on Noise
GAO	Government Accountability Office
HACAN	Heathrow Association for the Control of Aircraft Noise
HUD	Department of Housing and Urban Development
ICAO	International Civil Aviation Organization
IfADO	Leibniz-Institut für Arbeitsforschung an der TU Dortmund, Germany
INM	Integrated Noise Model
ISO	International Standards Organization
LAQ	Local Air Quality
LFN	Low-Frequency Noise
NANAMM	Non Acoustic Noise Annoyance Mitigation Measures
NASA	National Aeronautics and Space Administration
NEPA	National Environmental Policy Act
NIH	National Institutes of Health
NOAA	National Oceanic and Atmospheric Administration
NPD	Noise-Power-Distance
NPS	National Park Service
OHV	Off-Highway Vehicle
OST	Office of the Secretary of Transportation
PARTNER	Partnership for AiR Transportation Noise & Emissions Reduction
QALY	Quality-Adjusted Life Years

SD	Sleep Disturbance
SEL	Sound Exposure Level
SERDP	Strategic Environmental Research and Development Program
TOD	Transit Oriented Developments
WTP	Willingness-to-Pay