

**SUMMARY REPORT  
OF THE  
INTERNATIONAL FORUM ON  
AIRCRAFT NOISE IMPACTS RESEARCH**

**OTTAWA, CANADA - AUGUST 27, 2009**

**Federal Aviation Administration  
Office of Environment and Energy  
November 19, 2009**

## **Acknowledgements**

We would like to acknowledge Nick Miller of HMMH for his expertise in facilitating the International Forum on Aircraft Noise Impacts Research and preparing this Summary Report in collaboration with the Planning Panel Members for Sleep Disturbance and Annoyance and the FAA Office of Environment and Energy. We would also like to acknowledge Laura Taylor of HMMH for her excellent note-taking during the forum.

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**SUMMARY REPORT OF THE  
INTERNATIONAL FORUM ON AIRCRAFT NOISE IMPACTS RESEARCH  
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**INTRODUCTION**

The Federal Aviation Administration (FAA) organized and sponsored a one-day forum in Ottawa, Canada, following InterNoise 2009 on August 27, 2009. The purpose of the forum was to convene as many international experts as could be available to discuss specific research questions addressing the effects of aircraft noise on people. The questions were developed over several weeks preceding the forum by FAA with two small planning panels and addressed specific issues associated with sleep disturbance and annoyance caused by aircraft noise. The planning panel members are provided in Table 1. The forum consisted of two facilitated discussions, a morning session addressing sleep disturbance and an afternoon session addressing annoyance. A total of 15 research questions were discussed (8 for sleep disturbance, 7 for annoyance); each question was allotted approximately 30 minutes for discussion. After completion of each discussion session, attendees rated the importance of the questions from the perspective of value for future research.

Potential attendees were notified of the forum through a widely distributed “Save the Date” email. Those in the email distribution list were then sent a pre-forum package which included: the forum agenda, the research questions to be discussed, an FAA white paper “Advancing Aircraft Noise Impacts Research: A White Paper,” and forms to provide additional comments to FAA. This package is included in **Appendix A**. The list of attendees is in **Appendix B**, as well as pie charts showing general demographics of the attendees.

This report summarizes, first for sleep disturbance, then for annoyance, the main concepts discussed during the forum<sup>1</sup>. It is intended to document the discussions and to provide background for the first FAA Noise Research Roadmap Workshop to be held December 10 and 11, 2009, at the National Academy of Sciences Keck Center in Washington, DC. The report presents the discussions first by showing graphically the participant ratings of the importance of the questions, then listing as bullet items the main concepts discussed. For each question or series of questions, FAA’s Office of Environment and Energy (AEE) provides an initial assessment of the discussion. **Appendix C** provides written comments submitted by some of the invited experts.

<b><u>Panelists for Sleep Disturbance:</u></b>	
Mathias Basner	German Aerospace Center DLR
Patricia Davies	Purdue University
Jim Fields	Independent Consultant
Barbara Griefahn	Leibniz Research Center, TU Dortmund
Sarah McGuire	Purdue University
Nick Miller	HMMH
<b><u>Panelists for Annoyance:</u></b>	
Kenneth Hume	Manchester Metropolitan University
Sandy Lancaster	Dallas-Ft Worth International Airport
Mayor Arlene Mulder	O'Hare Noise Compatibility Commission
Paul Schomer	Schomer and Associates, Inc.
Catherine Stewart	U.S. Department of Army
Kevin Shepherd	NASA

**Table 1: Planning Panel Members**

<sup>1</sup> Detailed notes and an audio recording of the discussions served to aid the writing of this report.

## DISCUSSION

### SLEEP DISTURBANCE

#### Questions:

1. **Is it possible to design a new research project that will provide significant information in the short-term to markedly strengthen FAA's review and reformulation of policy regarding night-time flights?**

**Barbara Griefahn gave an introductory presentation on sleep disturbance research. The main points of the presentation were:**

- Know that noise can cause sleep disturbance
- Sleep disturbance can have many effects:
  - Sleep structure
  - Next day performance
  - Health related issues
- Contribution of noise to long-term health effects not quantified, and will be difficult to determine
- Major gaps in knowledge of sleep disturbance effects on individual vulnerabilities

#### Group Discussion:

- Though people rated use of existing study data in the near-term more important than conduct of new studies, there was recognized difficulty, at least in a rigorous "meta-study" sense of making comparisons or synthesizing all study results - different methods, different / unknown window conditions, different climates and house constructions – though there is some opinion that people are the same everywhere in their likely reactions to aircraft noise awakenings. There was some support that it would be useful to study U.S. versus Europe and / or to study different house types to show repeatability of responses.
2. **If there should be a new study for short-term research, how should it be designed? Specifically, is there a preferred measure of sleep disturbance - behavioral awakenings, motility, etc. What are the strengths and weaknesses of these various measures and do some address the differences between "spontaneous" and "aircraft noise induced" awakenings better than others?**

**Mathias Basner gave a brief introduction to the measures of sleep disturbance. Within the presentation, he:**

- Summarized basics of sleep disturbance.
- Highlighted difficulty in identifying cause for sleep disturbance.
  - A very sensitive measure gives too many reactions to associate one with aircraft noise and may be expensive to administer.
  - Too insensitive a measure may miss important changes in sleep.
  - Leans toward using ECG as a predictor for EEG awakenings as compromise; picks up awakenings that would likely be missed by button-push type method, which likely requires awakening to last for more than about 1 minute.

**Group Discussion:**

- Those who spoke (about four people) seemed to support the use of the EEG as a means to measure awakenings.
- At this point, the concept of using two types of contours was first raised – one for annoyance (like DNL) the other for some measure of awakenings – Norway uses such a two-criteria system, choosing whichever gives the largest area for decision making.
- Ratings suggest either ambiguity on the importance of this question, or that it is less important as a research question. However, at this point in developing the research agenda, all research issues are being retained for consideration.

**Preliminary AEE Assessment for Questions 1 and 2:** Although discussions didn't lead to answers to the questions or clear directions on how to handle the research questions, the discussions do suggest that more in-depth discussion is needed on what types of studies should/could be conducted.

**3. Should a new study incorporate vulnerable groups (children, diseased, elderly, shift workers) and if so, how?****Group Discussion:**

- Different definitions of “vulnerability” are possible. For the military, Post Traumatic Stress Disorder clearly identifies a vulnerable group. Children are sometimes thought of as vulnerable, though no one knew of any conclusive work regarding sleep disturbance. Some people identify themselves as “noise sensitive,” and there is some uncertainty whether these people experience different reactions, possibly cardio-vascular effects, from those who do not identify themselves as noise sensitive. On the other hand, some people may be identified as physiologically noise sensitive, and little is known about their reactions to noise.
- This question is rated as high importance by a small plurality (18 rated as high, 14 rated as medium).

**Preliminary AEE Assessment:** Discussion needs to center on implication of not studying vulnerable groups.

**4. Should there be an epidemiologic study on the effects of (nocturnal) aircraft noise?****Group Discussion:**

- Though Mathias made the point that epidemiologic studies do not have to be long, there was little enthusiasm for pursuing this type of study in the near term, as is also reflected in the ratings of importance.

**Preliminary AEE Assessment:** Plan to invite broader sleep and health research community to address this question.

**5. For data collection and analysis, what is the most appropriate descriptor of an aircraft noise event – is either SEL or Lmax sufficient, or should additional variables such as event time history or frequency content be investigated?**

**Group Discussion:**

- People clearly rated this as a research question of high importance. Judging from the discussion, this rating is based on the widely expressed importance of communicating clearly with the public, but also on concerns about setting impact thresholds (repeated in discussion of question 7, below). The participants were not in complete agreement that any descriptor should be used to identify a threshold of impact or of acceptability / unacceptability. Discussions ranged from developing indices that permit trading permits for air traffic noise (the MIME project, [www.mimeproject.com/portal/Actions.do](http://www.mimeproject.com/portal/Actions.do)<sup>2</sup>), a clearly regulatory approach, to providing only information such as numbers and levels of operations, to describing, in some way, the number of awakenings produced.
  - Facilitator made the point that the thresholds originally developed for and by the U.S. EPA were based on first examining the relationship of effects – annoyance, speech interference, complaints (nothing known then about sleep disturbance) – then identifying a level that would minimize these, and that, if set lower would result in little additional important benefits.
- 6. How should sleep disturbance results be extended to an entire night; to populations, to sub-populations?**

**Nick Miller discussed translation from single event to entire night of aircraft operations:**

- Results of all sleep disturbance research is for probability of disturbance from a single event
  - But during the night there may be many operations of different levels at different times of night
- 7. What metric(s) are most suited to regulation? (L<sub>night</sub>, % “impacted”) and why?**  
(Note that, due to time constraints, and flow of the discussion, participant discussion flowed right into question 7, with little time spent specifically on question 6. Ratings for these two questions are significantly different, with question 6 generally not thought of as high in importance, while question 7 is rated by more people as high in importance.)

**Group Discussion:**

- Some participants expressed concern that limited research data couldn't be extended to the entire country, taking into account city background noise versus rural background noise, though others pointed out that the “Schultz curve” has been applied universally to explain reactions to aircraft noise and this approach could be used for sleep awakenings as well. Also, considerable analysis (by J. Fields) showed that background sound has little if any effect on annoyance. It was noted, however, that the nature of background noise in a sleep situation is likely to be a phenomenon quite different and separate from the effects (if any) of background levels on annoyance. There is also an ANSI standard available for determining awakenings. Sleep disturbance contours could be useful information for potential home buyers.

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<sup>2</sup> The MIME concept is to buy and sell the right to produce annoyance, similar to emissions trading.

**Preliminary AEE Assessment for Questions 5, 6, and 7:** These are questions that need to be further explored in determining what studies should be conducted.

**8. Exposure-response relationships are usually “s-shaped” continuous functions, and not “all-or-nothing” relationships. In this situation, what is the best way to select scientifically based limit values or goals for mitigation measures?**

**Mathias Basner discussed issue of selecting “thresholds” or criteria:**

- Not only is there no clear division between effect and no effect, but it is likely that there are a number of s-curves applicable to different sensitivities to awakening.

**Group Discussion:**

- Two primary points were made. First, sleep disturbance data are not nearly as extensive as the annoyance data. Second, policy goals can not be set on effects alone, but should include costs and feasibility, but there was no clear expression of how costs relate to preventing sleep disturbance, though Norway provides a recommended level indoors and a required level – cost being the determinant of how much below the required level is achievable. Are there cost savings to be had through limiting sleep disturbance? People rated this question lower in importance than any other question.
- Field and lab studies differ (Basner); also sleep test subjects are not randomly selected while annoyance survey subjects are.
- Complexities of sleep disturbance were also discussed including habituation for sleep (generally little evidence, at least not complete habituation or wouldn't be awakenings to measure), self-selection for living near airports (no evidence of self-selection).

**Preliminary AEE Assessment:** We have no control over the shape of exposure-response relationships. What may be helpful to establish significance is placing aircraft-induced awakenings within the context of other awakenings. For this, again, broader sleep & health research community help may be needed.

**Rating Importance of the Sleep Questions by Forum Attendees:** The following figures show how participants rated the importance of each sleep disturbance question. Some ambiguity as to how people decided the rating for each is inevitable since questions were designed to elicit discussion rather than a clear judgment of importance. Nevertheless, these ratings provide additional information when judged in relation to the discussions summarized below. Figure 1 provides the simple counts of how people voted for low, medium and high importance. Figure 2 shows a weighted summation where the number of ratings for each question is normalized for the total votes, and then summed with a weighting of 1 for low votes, 2 for medium votes and 3 for high votes.<sup>3</sup>

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<sup>3</sup> FAA did not participate in the voting for either the sleep or annoyance questions.

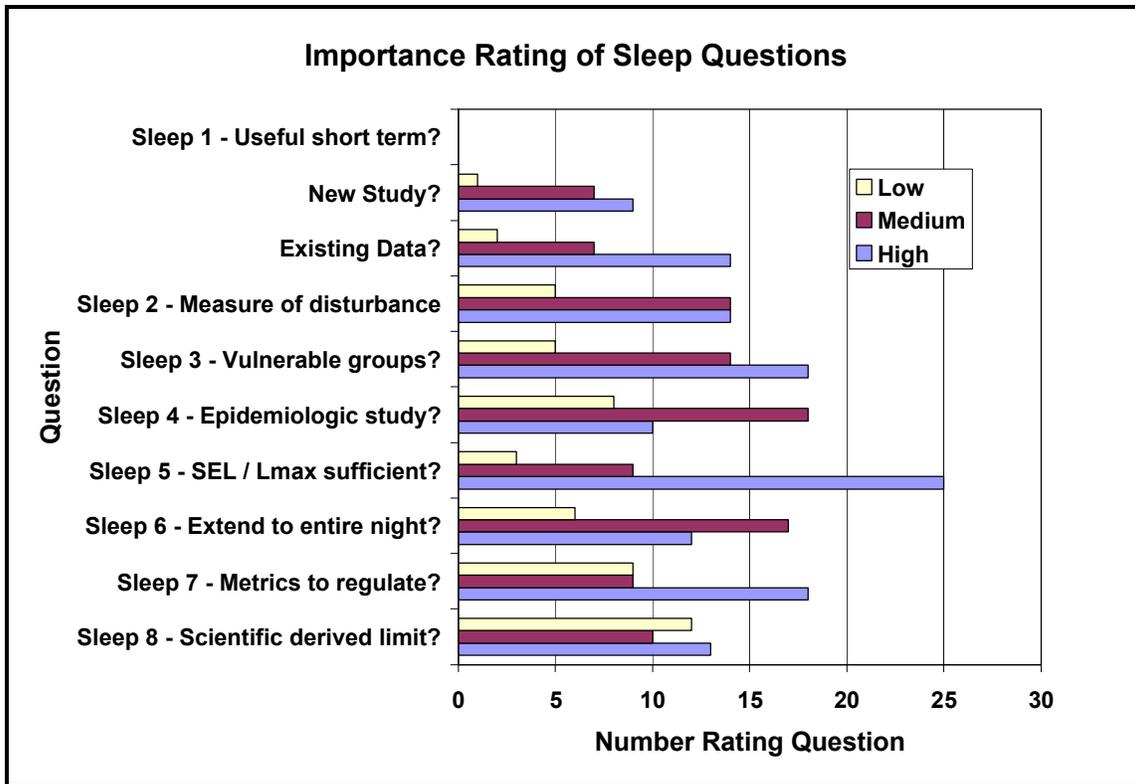


Figure 1: Participants' Ratings of Sleep Questions

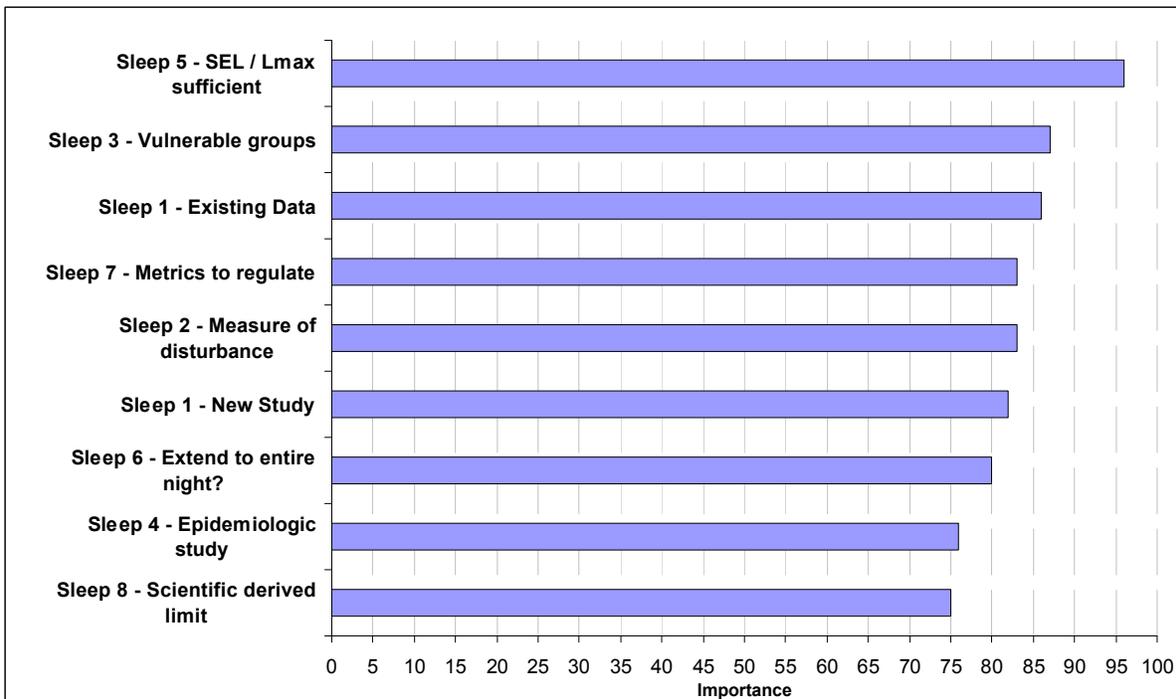


Figure 2: Participants' Weighted Rating of Sleep Questions

## ANNOYANCE

### Questions:

#### 1. Assuming %HA vs. DNL is an important measure of noise impact, what types of research would:

- Reduce the scatter of annoyance versus DNL?
- Update the relationship of annoyance to DNL - e.g., to account for changing conditions such as increased sensitivity to noise or increasing numbers of quieter operations (does “equal energy” apply), to focus solely on aircraft noise?
- Identify alternative or additional metrics to DNL that correlate with %HA?

### Group Discussion:

- A strong consensus was clear that the relationship of %HA to exposure needs to be updated. The updated relationship should be for aircraft only, and the exposure should be maintained as an Leq (10Log Number of events) type of metric. Current ISO (1996) and ANSI (S12.9) standards need to be considered, but an update should also look at the more recent survey results.
- Factors mentioned that could reduce the scatter include (not in any particular order): 1) including number of aircraft operations in the independent variable, 2) exploring reasons for variations in community (not individual) response (the variations would not be socio-economic or demographic, but history of interaction with airport, political activity), 3) alternative metrics, especially those that are functions both of sound amplitude and frequency (e.g., EPNL, LLSSEL, “integrated” loudness) since these may better correlate with human hearing as the sound is heard *indoors*– (requires new data), 4) differences between communities such as the sound isolation provided by homes typical to a community. Concept of equal energy [energy average] appeared to remain acceptable; Leq has held to be a good metric throughout many experiments but should evaluate others. Survey data have been collected over many years and may make examination of changes in reaction over time possible.
- Several attendees discussed the need to quantify noise exposure in a manner that more closely reflects actual experience –e.g., time indoors / outdoors, effects of house construction on indoor levels, etc.
- Socioeconomic effects were discussed, but research (according to attendees Schomer and Fields) rejects the hypothesis that annoyance reactions are influenced by socioeconomic status.
- Scatter can occur not only in the independent variable of level, but in the determination of %Highly Annoyed – over the years there have been different scales, different questions, applied to different communities.
- Supplemental metrics were discussed as well and judged as very useful for communication with the public, but probably difficult to apply to land use planning (policy).

**Preliminary AEE Assessment:** Consensus in elements of this discussion is leading FAA to pursue near-term research using existing data.

**2. Assuming impact should be based on more than annoyance, what further research is required, if any, to develop defensible relationships between aircraft noise and such effects as:**

- Sleep disturbance (discussed this morning)
- Daytime annoyance (or other times of day)
- Induced house vibrations and audible rattle
- Interference with learning
- Speech interference indoors and outdoors

**Group Discussion:**

- There was discussion of the effects on learning and on low frequency effects on houses. The ratings showed no strong support for researching this area further. However there are standards for sleep (ANSI 12.9 part 6) and for schools (ANSI S12.60-2002) that should be considered.

**Preliminary AEE Assessment:** Given that these are known noise effects, FAA will continue to keep these in mind as potential research areas, albeit at different priority levels. FAA is already involved in upcoming/ongoing research efforts in some cases, such as in children's learning and sleep disturbance.

**3. Assuming impact should be based on more than annoyance, what studies can be done to combine, relate or prioritize multiple effects in a way to inform a policy that needs to be implemented across the wide variety of airports in the country?**

**Group Discussion:**

- Though there was some disagreement on having multiple effect metrics, this question was rated as of high importance by a strong majority of the participants. The consensus was that multiple effects should not be combined, but determined separately and presented as information, not necessarily with any standards set. International standards and guidance should be consulted.
- Discussion on need for up-to-date synopses of state of knowledge of many effects of noise. One potential source is ICBEN.

**Preliminary AEE Assessment:** As noted in Question 2, FAA acknowledges that there may be multiple effects. For now, it may be simpler to address the effects separately as suggested by the discussion.

**4. What research can identify whether impact from steady-state or gradual change in exposure can be assessed in the same manner as impact caused by a step change; if not how should it be done?**

**Group Discussion:**

- A fairly strong difference of opinion was evident here, though judging by the ratings there is, if not strong differences, possibly some uncertainty of the importance of this question. The fundamental issues were: 1) current response data are based on steady-state, 2) from attempts to research this issue it appears abrupt changes are very rare, 3) abrupt changes and resulting

reactions are what must commonly be addressed by airports and politicians after changes in airport / aircraft operations occur, 4) current analysis approaches provide information only about steady-state reactions and hence underestimate the reactions. The policy question is therefore, should information about abrupt change effects/reactions be provided as part of the study process, and if so, how should such abrupt change effects information be developed?

- The data available for quantifying reactions to abrupt changes is weak and can't be generalized, but it suggests there is "excess" change in reaction that may be equivalent to an additional 10 to 15 dB increase on top of the reaction expected from the steady-state reaction. This excess change appears to reduce toward the steady-state reaction only over a period of years.
- A five year study at Schiphol (cited by attendee van Kamp) showed clear incidence of "excess change" in response do to a change in exposure.

**Preliminary AEE assessment:** Look for opportunities to study projects with known anticipated step changes.

## **5. What research can inform the process of setting thresholds of impact?**

### **Group Discussion:**

- Participants had very little to say about setting thresholds, and the ratings showed a near majority thought it to be a question of low importance. The discussion turned to alternative / supplemental metrics – good for communication but probably not land use planning.

**Preliminary AEE Assessment:** Given limited discussion, could reopen discussion at workshop.

## **6. What research can identify the types of information that should be provided, the forums / presentation formats, and the extent and timing of outreach that are most effective?**

### **Group Discussion:**

- General support was shown for using the focus group approach to test different methods of information presentation and to find the most effective approaches. Ratings also recognized this question as of high importance. The approach might start with using psychologists and students to inexpensively narrow down to most effective methods. Could also use neighbors from around airport(s) to test ways to communicate clearly. Ken Hume has done some focus group work and will provide Raquel with a website address. It might be useful to study airports that provide public access through the internet to flight tracks as a means that helps a community accept / understand airport operation.
- EU has published (2002) a set of rules on how to communicate with public.

**Preliminary AEE Assessment:** ACRP projects are investigating best practices and developing guidebook; discussion suggests more scientific approach could be used to study improving communication.

**7. What research will identify which acoustic and non-acoustic factors are correlated with negative community reactions such as complaints, legal action, and involvement of politicians that can occur after noise changes from airport actions or airspace redesign?**

**Group Discussion:**

- General support for examining historical information on how communities reacted to new runways. The approach should be to study new runway situations over past 10 years, gathering systematic data – history, publicity, local newspapers – not social survey or socio-economic factors, but political and organizational variables. Ratings show high level of support for this question as well.

**Preliminary AEE Assessment:** It is likely that such a study can be conducted in the US in the near term; would be interested in similar studies outside US.

**Rating Importance of the Annoyance Questions by Forum Attendees:** The following figures show how participants rated the importance of each annoyance question. Some ambiguity as to how people decided the rating for each is inevitable since questions were designed to elicit discussion rather than a clear judgment of importance. Nevertheless, these ratings provide additional information when judged in relation to the discussions summarized above. Figure 3 provides the simple counts of how people voted for low, medium and high importance. Figure 4 shows a weighted summation where the number of ratings for each question is normalized for the total votes, and then summed with a weighting of 1 for low votes, 2 for medium votes and 3 for high votes.<sup>4</sup>

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<sup>4</sup> FAA did not participate in the voting for either the sleep or annoyance questions.

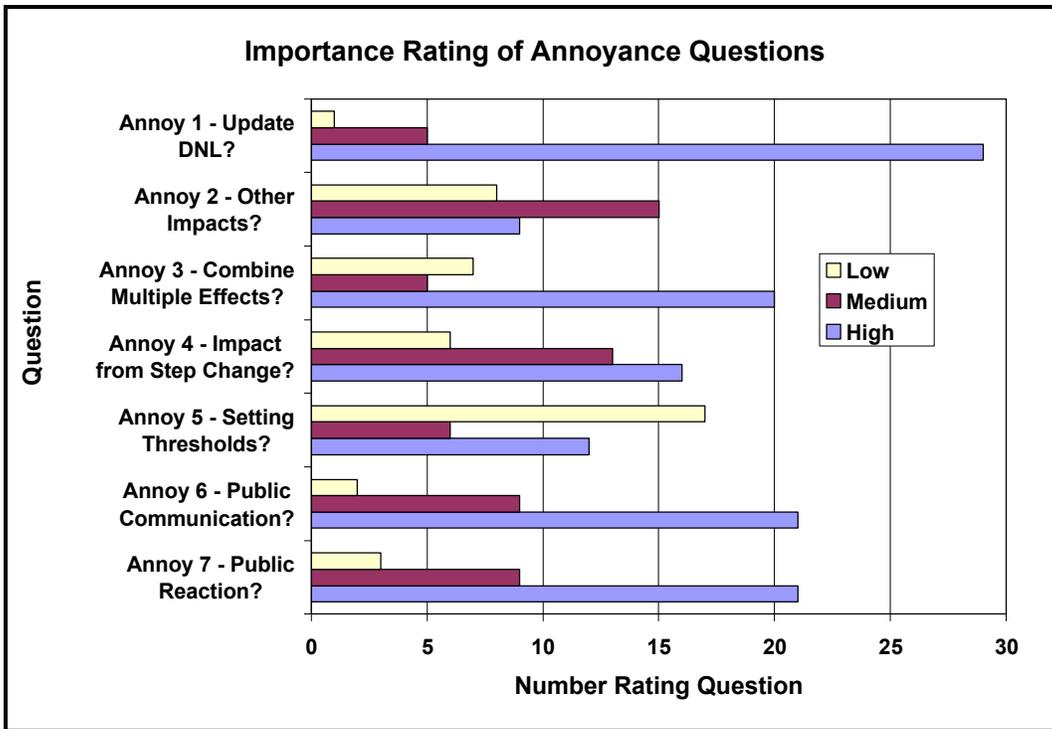


Figure 3 Participants' Ratings of Annoyance Questions

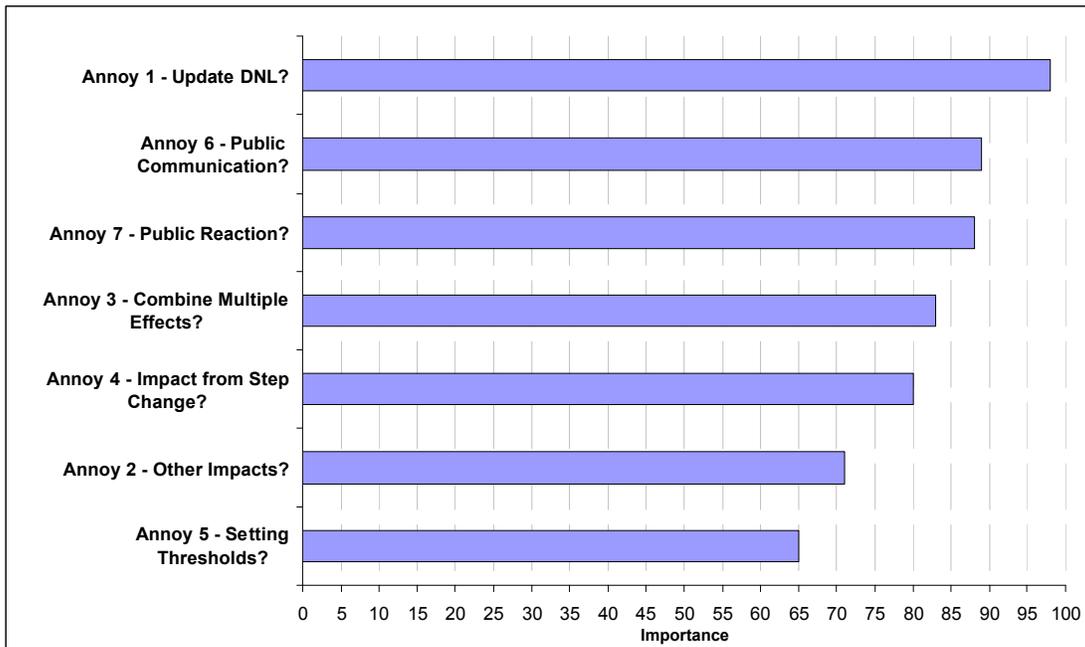


Figure 4 Participants' Weighted Rating of Annoyance Questions

## **Appendix A – Pre-Forum Package**

## **Appendix A Pre-Forum Package**

### **CONTENTS**

#### **Agenda for the International Forum on Noise Impacts**

#### **Attachment 1 - Advancing Aircraft Noise Impacts Research: A White Paper**

#### **Attachment 2 - Sleep Research Discussion**

#### **Attachment 3 – Sleep Research Comments**

#### **Attachment 4 – Annoyance Research Discussion**

#### **Attachment 5 – Annoyance Research Comments**

The goal of this forum is to solicit expert opinions about key questions related to each of two methods for judging the impacts of aircraft noise – effects on sleep and annoyance response. Sleep questions will be addressed in the morning, annoyance in the afternoon. All recipients of this package, whether or not they attend the forum, are encouraged to provide their comments. Attachments 3 (sleep research comments) and 5 (annoyance research comments) are part of this package and are in MSWord format as well. The opinions about these questions will provide guidance to FAA as it begins development of a research roadmap that when implemented will provide defensible science based information for use in formulating policy with respect to aircraft noise impacts.

**Appendix A**  
**Pre-Forum Package**

**Agenda – International Forum on Noise Impacts**  
**August 27, 2009**

**8:00 FAA Background, Objective and Timeline**

FAA plans to map out 5-year research program that will provide scientific basis to characterize impact of aircraft noise on sleep. (See Attachment 1- FAA white paper.)

**8:30 Key Sleep Research Questions**

Discussion will focus on what the key research questions are that need to be answered in order to meet FAA's objective. Participants are asked to consider the attached set of key research questions:

- Do they capture the most important issues? If not, what and how to phrase the research questions?
- How would you answer them?

**10:30 Break**

**10:45 Prioritization of Key Sleep Research Questions**

Answering which research questions would yield the greatest payoff?

In which areas are we most likely to make substantive progress in the next 5 years?

**11:15 Ongoing or Near-Term Planned Sleep Research; Opportunities to Collaborate**

What related research is already ongoing or planned in the near term?

Are there opportunities to collaborate – in terms of study design, sharing data, testing analytical approaches, etc?

Whom should we contact for further discussion?

**11:45 Wrap-up and Next Steps**

**12:00 Lunch**

**12:45 FAA Background, Objective and Timeline**

FAA seeks to map out 5-year research program that will determine if current basis for establishing impact (percent population highly annoyed vs. DNL) needs updating. (See Attachment 1- FAA white paper.)

**1:15 Key Annoyance Related Research Questions**

Discussion will focus on key questions that will help meet FAA's objective.

Participants are asked to consider the attached set of key research questions:

- Do they capture the most important issues? If not, what other questions need to be posed?
- How would you answer them?

**3:15 Break**

**3:30 Prioritization of Key Annoyance Related Research Questions**

Which research would yield the greatest payoff?

In which areas are we most likely to make substantive progress: in the near term (within 2 years) and in the next 5 years?

**4:00 Ongoing or Near-Term Planned Research; Opportunities to Collaborate**

What related research is already ongoing or planned in the near term?

Are there opportunities to collaborate – in terms of study design, sharing data, testing analytical approaches, etc?

Whom should we contact for further discussion?

**4:30 Wrap-up and Next Steps**

# Appendix A Pre-Forum Package

## Attachment 1

8/7/2009

### **Advancing Aircraft Noise Impacts Research: A White Paper**

Raquel Girvin\*

FAA Office of Environment & Energy, Noise Division

This paper highlights critical research needs identified by the Federal Aviation Administration's (FAA) Office of Environment and Energy to advance analysis of the impacts of aviation noise and to develop optimal mitigation solutions.

The FAA continues to work towards providing the safest, most efficient aviation system in the world that operates in an environmentally sound manner. Contours of annual average noise exposure for long-established U.S. airport communities have decreased because of continuing reductions in the amount of noise emitted by individual aircraft and other noise mitigation measures, despite an over 50 percent increase in passenger enplanements since 1990. Nevertheless, airport communities remain concerned about aircraft noise, as illustrated by the public's response to aircraft operations from the newly opened runways at Chicago O'Hare and Seattle-Tacoma airports.<sup>1</sup> Improving efficiency through airspace redesign, airport capacity expansion, and other initiatives of the FAA Next Generation Air Transportation System (NextGen), may be hampered without an aggressive program to address the environmental consequences of aviation noise.

The FAA Office of Environment and Energy seeks to develop a comprehensive research roadmap addressing critical noise impacts research needs, in collaboration with and participation of researchers across numerous disciplines and around the world, as well as with the broad community of aviation stakeholders including the public. Such a roadmap will enable FAA and interested parties to define systematic, focused, and complementary research programs, in which limited resources could be pooled to advance the scientific knowledge on how best to address the impacts of aviation noise on society. We envision a periodic review to track research progress against the roadmap as well as adjust FAA policy as warranted by new knowledge gained from the research.

#### *FAA State-of-the-Practice in Noise Impact Analysis, Mitigation, and Land-Use Compatibility*

For aviation noise impact analysis, the FAA has determined that the cumulative noise energy exposure of individuals to noise resulting from aviation activities must be established in terms of yearly day/night average sound level (DNL) as FAA's primary metric (as stated in FAA Order 1050.1E, "Environmental Impacts: Policies and Procedures").<sup>2</sup> The criterion establishing significant noise impact from a proposed action

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<sup>1</sup> "New Runway Causing New Noise Problems", *THE JOURNAL & TOPICS NEWSPAPERS* | THURSDAY, NOVEMBER 27, 2008, <http://www.journal-topics.com/eg/08/eg081127.3.html>; "New O'Hare runway seeing tons of traffic, and nearby residents not keeping quiet"; *Chicago Tribune*, Friday, December 05, 2008, [http://archives.chicagotribune.com/2008/dec/05/local/chi-ohare-noise\\_05dec05](http://archives.chicagotribune.com/2008/dec/05/local/chi-ohare-noise_05dec05); "Sea-Tac neighbors feel duped over 3rd-runway noise", *The Seattle Times*, December 11, 2008, [http://seattletimes.nwsourc.com/html/localnews/2008493979\\_runway11m.html](http://seattletimes.nwsourc.com/html/localnews/2008493979_runway11m.html)

<sup>2</sup> The FAA recognizes CNEL (community noise equivalent level) as an alternative metric for California.

8/7/2009

## **Appendix A Pre-Forum Package**

is: “A significant noise impact would occur if analysis shows that the proposed action will cause noise sensitive areas to experience an increase in noise of DNL 1.5 dB or more at or above DNL 65 dB noise exposure when compared to the no action alternative for the same timeframe.” This significance threshold is based on the exposure-response relationship between DNL and the percentage of the exposed population “Highly Annoyed” (%HA), originally derived from studies of urban and suburban community responses to transportation noise by Schultz (1978) and re-affirmed by the Federal Interagency Committee on Noise, FICON (1992). However, FAA recognizes that different criteria as yet undefined are needed for noise-sensitive areas within national parks, national wildlife refuges and historic sites, including traditional cultural properties, where other noise is very low and a quiet setting is a generally recognized purpose and attribute.

FAA supports the assessment of aircraft noise impacts by developing and maintaining noise-evaluation models and methods. Airport community noise from aircraft takeoffs and landings is computed using the Integrated Noise Model (INM); for larger-scale analyses involving multiple airports in a region or changes in air traffic operations, noise exposure throughout a region is computed using the Noise Integrated Routing System (NIRS). Current modeling capabilities are primarily for conventional subsonic aircraft operating at a maximum of 18,000 ft above ground level (AGL).<sup>3</sup>

FAA uses supplemental analyses and a variety of single-event and cumulative noise metrics on a case-by-case basis either to characterize specific noise effects tailored to local concerns or to describe noise exposure to the public in other ways in addition to DNL. Individual supplemental metrics have limitations and do not provide a complete analysis of the magnitude, duration, or frequency of the noise events under study. FAA guidance cautions that a supplemental noise analysis is not, by itself, a measure of adverse aircraft noise or significant aircraft noise impact.

FAA land use guidelines generally consider land uses compatible with airport operations in areas where the annual average aircraft noise exposure is below 65 dBA DNL. Airport noise-compatibility programs are usually based on establishing or maintaining compatible land uses in areas at or above 65 dBA DNL. There are exceptions. Deference is given to local authorities to determine acceptable and permissible land use in specific noise contours according to “local needs or values” (Code of Federal Regulations Title 14 Part 150). The guidelines are insufficient to determine the noise compatibility of areas within a national park or national wildlife refuge where other noise is very low and a quiet setting is a generally recognized purpose and attribute, and the guidelines do not address noise effects on wildlife.

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<sup>3</sup> In addition to INM and NIRS updates, FAA is currently developing an integrated aviation noise and emissions model called the Aviation Environmental Design Tool (AEDT) so interdependencies between noise and emissions impacts can be assessed.

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### *Critical Research Needs to Advance Noise Impact Analysis, Mitigation, and Land Use Compatibility*

Despite a large body of research, how best to quantitatively characterize the relationship between aircraft noise exposure and its impacts remains a fertile area to be further investigated, in part because of significant research methodological differences. Much of recent research has been conducted outside the United States. The challenge for FAA lies in determining the extent to which sleep quality, children's learning, and other aspects of public health and welfare are affected by aircraft noise, in areas currently considered non-compatible with aircraft noise exposure as well as areas considered aircraft noise-compatible. Critical research is needed in multiple areas identified below.

#### Noise effects on health and welfare

- **Determine whether the basis for establishing significant noise impact needs updating to better reflect the current state of community response to today's aircraft noise exposure.**
- **Quantify potential noise impact on health and welfare in areas considered noise compatible (i.e., beyond 65 dBA DNL) by establishing correlations between noise exposure metrics and impacts.**

The relationship between noise exposure and community response first derived by Schultz (1978), expressed in terms of percent of Population Highly Annoyed as a function of the cumulative noise metric DNL relies on the equivalent-energy principle, which suggests that annoyance from the cumulative effect of a few loud events equates to annoyance from a greater number but quieter events. DNL carries a penalty for nighttime noise events to reflect the potential for added annoyance at night due to sleep disturbance, speech interference, and other effects. Schultz derived a single, undifferentiated exposure-response relationship without evaluating possible differences for different transportation noise sources (road, rail, and aircraft).

Since Schultz' derivation of the annoyance exposure-response relationship, all components that contribute to the DNL metric: frequency of daytime events (especially for passenger airlines), frequency of nighttime events (especially for cargo airlines), and loudness per event, have dramatically changed with the surge in commercial air traffic accompanied by significant decreases in aircraft noise levels. While the current economic downturn has reduced air traffic, the general trend of aviation system growth, albeit with quieter aircraft, is expected to continue. Some research (e.g., UK Department for Transport's ANASE study (2007)) suggests that whether due to changing attitudes towards aircraft noise or whether due to the significant increase in air traffic, or a combination of both, there may be a need to reassess whether the exposure-response relationship derived from older data would hold true for an order of magnitude increase in air traffic with quieter aircraft. And with air traffic demand pressure for round-the-clock operations, it may also be necessary to re-evaluate the nighttime weighting factor in DNL. Meanwhile, an ongoing debate among researchers continues regarding which

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exposure-response relationship curve best represents annoyance to aircraft noise. The ISO Standard (1996-1; 2003) is consistent with FICON (1992), but ANSI 12.9 Part 4 (2005) is a variation of ISO (1996), while the European Union has adopted the curve derived by Miedema and Oudshoorn (2001). Researchers such as Miedema and Vos (1998) and Fidell (2003) have also suggested re-examining the current state of practice of using the Schultz curve or variations of it as the basis for assessing the impact of aircraft noise.

A complicating feature of analyzing the impacts of aircraft noise is the subjectivity of human response to sounds, where non-acoustic factors together with other acoustic factors not captured by the DNL metric, may also affect community annoyance levels. Questions that persist include whether using other metrics in combination with or in lieu of DNL would correlate better with community annoyance, as well as what significance threshold(s) should be used.

Furthermore, FAA-funded research has shown that people are aggregating immediately outside DNL 65 contours, 50% of lands within 5 miles of airports are undeveloped and vulnerable to encroachment, and intensification of development is occurring around airports. Research has also shown a proliferation of noise complaints from areas beyond DNL 65. All the above suggests the timeliness of systematically reviewing the basis of FAA practice.

### Noise in National Parks and Wilderness

- **Quantify impacts to national parks and wilderness areas exposed to aircraft noise by establishing correlations between noise exposure metrics and impacts.**
- **Model noise propagation from aircraft operations above 18,000 feet AGL.**

FAA recognizes that the 65 dBA DNL significant noise threshold inadequately addresses the effects of noise in naturally quiet areas such as national parks and wilderness. The significance of impacts at noise exposure levels below 65 dBA DNL remains to be determined both for visitors and wildlife. Commercial air tour noise, lower flying general aviation aircraft, and airport arrival and departure paths over national parks have generated the greatest attention, but there is also concern by resource agencies and environmental/conservation groups about increases in lower level noise as high altitude air traffic increases in quantity over these areas.

### NextGen Noise Modeling Enhancements: Other Operational Regimes and Unconventional Aircraft

- **Model noise propagation from all phases of aircraft operations.**
- **Model noise propagation for future unconventional aircraft and engine configurations.**

- **Investigate acceptability standard and noise impact criteria (metrics and correlations) for supersonic overflights; a similar effort may be needed for other future unconventional aircraft.**

FAA has a well-established program to update analytical tools to model noise from subsonic aircraft operations at or near airports. However, for NextGen airspace and operational initiatives, the capability to model noise from aircraft at cruise altitudes may be needed, and noise modeling for on-ground operations may need enhancement. In addition, FAA must prepare to develop the ability to model noise for future aircraft with substantially different (and some potentially significant) noise characteristics from conventional subsonic aircraft, such as aircraft with open rotors or hybrid wing body aircraft, aircraft flying supersonically over land with publicly acceptable low sonic boom levels, and heavier as well as faster rotorcraft.

Current research by aircraft manufacturers and research establishments worldwide continues to demonstrate progress on reducing sonic boom intensity for business jet-size aircraft. The aircraft manufacturing industry is seeking an international standard for setting the maximum sonic boom level permissible for supersonic flight over land. The United States (more specifically, NASA and FAA) is leading a collaborative effort within the International Civil Aviation Organization (ICAO) to develop a roadmap that identifies research needed to demonstrate that sufficient data exist to consider developing new sonic boom standards.

#### Overall Costs of Aircraft Noise on Society

- **Quantify the societal cost of noise relative to other environmental impacts.**

FAA is developing a cost-benefit analysis model to inform the environmental decisionmaking process, given that environmental mitigation actions are interdependent. For example, reducing or mitigating noise may result in more energy consumption and greenhouse gas emissions and/or poorer air quality. Therefore, in order to assess all environmental impacts relative to each other, it is necessary to use a common currency, whether by monetization or other means, to compute their costs and benefits. Computing the overall costs of aircraft noise on society, including its public health and welfare costs, will require knowledge gained from the other critical research areas above.

#### *Concluding remark*

The FAA Office of Environment and Energy looks forward to a productive period of research and constructive discourse addressing the critical noise research needs outlined in this paper, as we work to realize the operational and environmental aspirations of NextGen.

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#### *Acknowledgments*

The author thanks her colleagues at the FAA (AEE, AGC, APP-400, ATO) and FICAN for their helpful comments but takes responsibility for any errors in the paper.

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### REFERENCES

1. American National Standard, Quantities and Procedures for Description and Measurement of Environmental Sound – Part 4: Noise Assessment and Prediction of Long-term Community Response, ANSI S12.9-2005/Part 4.
2. American National Standard, Quantities and Procedures for Description and Measurement of Environmental Sound – Part 6: Methods for Estimation of Awakenings Associated with Outdoor Noise Events Heard in Homes, ANSI/ASA S12.9-2008/Part 6.
3. Federal Interagency Committee on Noise (FICON), Federal Agency Review of Selected Airport Noise Analysis, August 1992, <http://www.fican.org/pdf/nai-8-92.pdf>.
4. Fidell, S., “The Schultz Curve 25 Years Later: A Research Perspective”, *The Journal of the Acoustical Society of America*, Vol. 114 no.6, December 2003, pp. 3007-3015.
5. International Organization for Standardization, Acoustics -- Description, measurement and assessment of environmental noise -- Part 1: Basic quantities and assessment procedures, ISO 1996-1:2003.
6. LeDoux, T., “Airports and Their Cities: The Effectiveness of Mitigating Noise Exposure through Land Use Planning, 1990-2000”, Wyle Research Report WR 07-23, October 2007.
7. Li, K. M., et al., “Land Use Management and Airport Controls: Trends and indicators of incompatible land use”, Report No. PARTNER-COE-2008-001, December 2007, <http://web.mit.edu/aeroastro/partner/reports/landmgt-proj6-2008-01.pdf>.
8. Li, K. M and G. Eiff, “Land Use Management and Airport Controls: A further study of trends and indicators of incompatible land use”, Report No. PARTNER-COE-2008-006, September 2008, <http://web.mit.edu/aeroastro/partner/reports/proj6/proj6-landmgtaptcontrol.pdf>.
9. Miedema, H.M. and H. Oudshoorn, “Annoyance from Transportation Noise: Relationships with Exposure Metrics DNL and DENL and Their Confidence Intervals”, *Environmental Health Perspectives*, Vol. 109 no. 4, April 2001, pp. 409-416.
10. Miedema, H.M. and H. Vos, “Exposure-Response Relationships for Transportation Noise”, *The Journal of the Acoustical Society of America*, Vol. 104 no.6, December 1998, pp. 3432-3445.
11. Schultz, T. J., “Synthesis of Social Surveys on Noise Annoyance”, *The Journal of the Acoustical Society of America*, Vol. 64, pp. 377-405.
12. United Kingdom Department for Transport “Attitudes to Noise from Aviation Sources in England” (ANASE) Final Report by MVA Consultancy, October 2007.

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13. United States Department of Transportation Federal Aviation Administration National Policy Order 1050.1E Change 1 Effective date March 20, 2006,

[http://www.faa.gov/documentLibrary/media/order/energy\\_orders/1050-1E.pdf](http://www.faa.gov/documentLibrary/media/order/energy_orders/1050-1E.pdf)

14. United States Code of Federal Regulations Title 14 Aeronautics and Space Part 150 Airport Noise Compatibility Planning, current as of July 10, 2009,

[http://ecfr.gpoaccess.gov/cgi/t/text/textidx?](http://ecfr.gpoaccess.gov/cgi/t/text/textidx?c=ecfr&sid=a5158aa639032dbf09d149fc955658f2&rgn=div5&view=text&node=14:3.0.1.3.18&idno=14)

[c=ecfr&sid=a5158aa639032dbf09d149fc955658f2&rgn=div5&view=text&node=14:3.0.1.3.18&idno=14](http://ecfr.gpoaccess.gov/cgi/t/text/textidx?c=ecfr&sid=a5158aa639032dbf09d149fc955658f2&rgn=div5&view=text&node=14:3.0.1.3.18&idno=14)

**Appendix A  
Pre-Forum Package**

**Attachment 2  
Sleep Research Discussion**

**8:00            Sleep: FAA Background, Objective and Timeline**

**Background**

The goal of this forum is to solicit expert opinions about key questions related to each of two methods for judging the impacts of aircraft noise – effects on sleep and annoyance response. The opinions about these questions will provide guidance to FAA as it begins development of a research roadmap that when implemented will provide defensible science based information for use in formulating policy with respect to aircraft noise impacts.

Experts are requested to provide opinions about these key questions; if they are not key, what other key questions would they identify or how would they modify these questions? At the end of discussions, attendees will be asked to provide judgments of the relative importance of these questions. For both attendees and those who cannot attend, Attachment 3 (also available in MSWord format) provides a form for written comments.

**FAA Objectives – First Topic: Effects on Sleep:**

- Short-term – Initial research and results should produce findings that are sufficiently strong to support policy analysis and revisions within 2 to 3 years.
- Longer-term - Research design should consider future linking to adverse health effects even though more than 3 years might be required.
- For policy purposes, results must:
  - Be able to address a variety of conditions that would affect sleep at airport communities (e.g., change in nighttime or “shoulder hour” operation, sound insulation in housing, etc.)
  - Be easy to explain to and be understood by the lay public; considerations should include explanations in terms often cited by citizens – difficulties returning to sleep, intermittent and premature awakening.

**FAA timeline / funding – 5 year research plan:**

International forum August 09  
First research roadmapping workshop Dec 09 (modest funding for FY10 and FY11, next opportunity to seek targeted research funds is for FY12)  
Follow-on roadmapping workshop Spring 10  
Annual meetings to track research progress (successive springs; stand-alone or in coordination with other annual noise research meetings?)  
Target end of FY15 to meet research goal supported by strong technical evidence

**Appendix A  
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**Key Questions for Designing Research Roadmap**

**8:30**

**SLEEP DISTURBANCE QUESTIONS**

***TYPES OF FUTURE STUDIES***

- 1. Is it possible to design a new research project that will provide significant information in the short-term to markedly strengthen FAA's review and reformulation of policy regarding night-time flights?**

*(Barbara Griefahn will provide a brief introduction to current knowledge and gaps.)*

A large number of studies have already been conducted and the question needs to be asked as to whether or not any new study (probably only one) completed in the next 2 to 3 years can provide enough valuable information and insight to better inform FAA's policy review that it is worth the expenditure of resources? One perspective is that it would be beneficial to have a new study conducted in the U.S. to counter arguments that most recent results were derived from studies in other countries.

- 2. If there should be a new study for short-term research, how should it be designed. Specifically, is there a preferred measure of sleep disturbance - behavioral awakenings, motility, etc. - what are the strengths and weaknesses of these various measures and do some address the differences between "spontaneous" and "aircraft noise induced" awakenings better than others?**

*(Mathias Basner will provide a brief introduction to the measures of sleep disturbance.)*

The different measures (EEG arousals, EEG awakenings, vegetative arousals, motility, behavioral awakenings, questionnaires) differ not only in their sensitivity and specificity, but also in their methodological expense. The perfect method would be sensitive, specific, and cost effective.

- 3. Should a new study incorporate vulnerable groups (children, diseased, elderly, shift workers) and if so, how?**

Most of the studies on the effects of aircraft noise on sleep have been conducted in healthy populations of (young) adults. How can vulnerable subgroups be investigated, and does the expected small size of these subgroups make meaningful research in any reasonable time frame infeasible? Do we expect large variations in sensitivity for these groups *versus* healthy adult populations?

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**4. Should there be an epidemiologic study on the effects of (nocturnal) aircraft noise?**

Although epidemiologic studies specifically investigating the influence of (aircraft) noise exposure on health outcomes are scarce, a few recent works suggest that nocturnal noise exposure may be more important than daytime exposure. Would, e.g., a case-control study conducted over the next three to four years be able to relevantly improve FAA's knowledge on the long-term health effects of nocturnal aircraft noise exposure?

***TYPES OF METRICS***

**5. For data collection and analysis, what is the most appropriate descriptor of an aircraft noise event – is either SEL or Lmax sufficient, or should additional variables such as event time history or frequency content be investigated?**

This question concerns both the scientific requirements – which descriptor or descriptors correlate best with measures of sleep disturbance – and the requirement for public acceptance, – what descriptors are easiest to understand and explain?

**6. How should sleep disturbance results be extended to an entire night, to populations, to sub-populations?**

*(Nick Miller will provide a brief description of the issue.)*

**7. What metric(s) are most suited to regulation? (Lnight, % “impacted”) and why?**

***SETTING CRITERIA***

**8. Exposure-response relationships are usually “s-shaped” continuous functions, and not “all-or-nothing” relationships. In this situation, what is the best way to select scientifically based limit values or goals for mitigation measures?**

**9. ?? (Forum attendees suggest additional important questions.)**

**10. ??**

**11. ??**

**Appendix A  
Pre-Forum Package**

**Attachment 3  
Sleep Research Comments**

**Please submit to us your comments and/or responses in writing (ahead of or at the end of the meeting).**

**FAA Background, Objective and Timeline**

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**Key Sleep Research Questions**

- Do they capture the most important issues? If not, what other questions need to be posed?

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- How would you answer them?

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**Appendix A**  
**Pre-Forum Package**

**Study Costs and Duration**

How much would it cost and how long would it take to conduct the high priority research items?

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**Appendix A  
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**Attachment 4  
Annoyance Research Discussion**

**12:45 Annoyance: FAA Background, Objective and Timeline**

**Background**

The goal of this forum is to solicit expert opinions about key questions related to each of two methods for judging the impacts of aircraft noise – effects on sleep and annoyance response. The opinions about these questions will provide guidance to FAA as it begins development of a research roadmap that when implemented will provide defensible science based information for use in formulating policy with respect to aircraft noise impacts.

Experts are requested to provide opinions about these key questions; if they are not key, what other key questions would they identify or how would they modify these questions? At the end of discussions, attendees will be asked to provide judgments of the relative importance of these questions. For both attendees and those who cannot attend, Attachment 5 (also available in MSWord format) provides a form for written comments.

**FAA Objective – Second Topic: Annoyance**

Map out research needed to determine whether the current basis for establishing significant impact (population highly annoyed) needs updating to better reflect the current state of community response to today's aircraft noise exposure. (Include brief summary of current FAA practice)

**FAA timeline / funding – 5 year research plan:**

- International forum August 09
- First research roadmapping workshop Dec 09 (modest funding for FY10 and FY11, next opportunity to seek targeted research funds is for FY12)
- Follow-on roadmapping workshop Spring 10
- Annual meetings to track research progress (successive springs; stand-alone or in coordination with other annual noise research meetings?)
- Target end of FY15 to meet research goal supported by strong technical evidence



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3. **Assuming impact should be based on more than annoyance, what studies can be done to combine, relate or prioritize multiple effects in a way to inform a policy that needs to be implemented across the wide variety of airports in the country?**
4. **What research can identify whether impact from steady-state or gradual change in exposure can be assessed in the same manner as impact caused by a step change; if not how should it be done?**

Communities and politicians react to the effects that are perceived immediately or soon after changes in aircraft noise occur. But decisions (e.g., about mitigation measures, sound insulation, land use) should perhaps be made on only long-term impacts. Can research assist policy to balance these two time frames and types of impact?

5. **What research can inform the process of setting thresholds of impact?**

### ***PUBLIC COMMUNICATION RESEARCH***

This category relates primarily to proposed projects that will result in changes in aircraft noise and should be considered unrelated to the above policy issues. Communities / individuals can react very negatively after changes in aircraft noise occur. There is a general perception and considerable experience that providing better, clearer information to the public and to aviation stakeholders in general about aircraft noise and the expected changes can reduce the negative reactions and / or increase acceptance of the changes.

6. **What research can identify the types of information that should be provided, the forums / presentation formats, and the extent and timing of outreach that are most effective?**

### ***PUBLIC REACTION RESEARCH***

From the perspectives of an airport that wishes to be a good neighbor and still respond to the needs of increased operations, of the FAA that needs to increase national airspace system efficiency and ensure the ability of the air transport system to grow to respond to increasing demand, and of the elected official whose limited resources can be consumed trying to mediate between irate citizens and an airport or the FAA, it would be valuable to know before changes in aircraft noise occur, where strong community reactions are likely to occur and if so, whether and how they can be minimized or avoided.

7. **What research will identify which acoustic and non-acoustic factors are correlated with negative community reactions such as complaints, legal action, and involvement of politicians that can occur after noise changes from airport actions or airspace redesign?**

Factors to consider in developing research approaches to community reaction are not only noise level / noise exposure related, but may include such variables as attitudes, prior experience, expectations, information available prior to the change and prior relationship of the airport and the communities.

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**Attachment 5  
Annoyance Research Comments**

**Please submit to us your comments and/or responses in writing (ahead of or at the end of the meeting).**

**FAA Background, Objective and Timeline**

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**Key Annoyance Research Questions**

- Do they capture the most important issues? If not, what other questions need to be posed?

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- How would you answer them?

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## **Appendix B**

### **Attendees**

## Appendix B Attendees

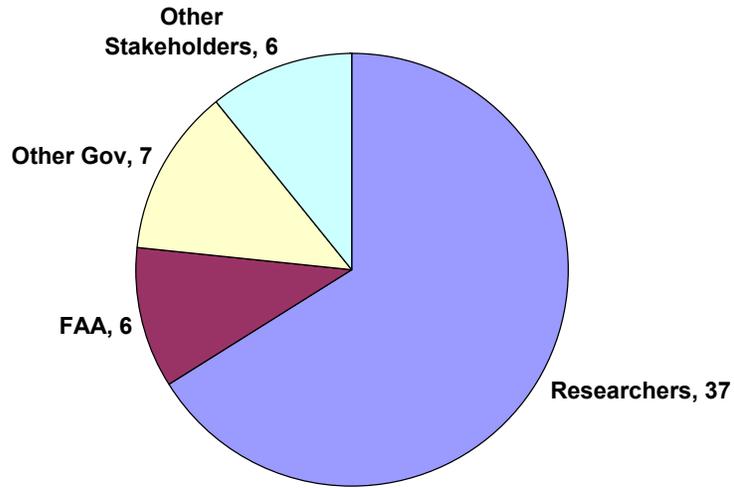
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## Appendix B Attendees

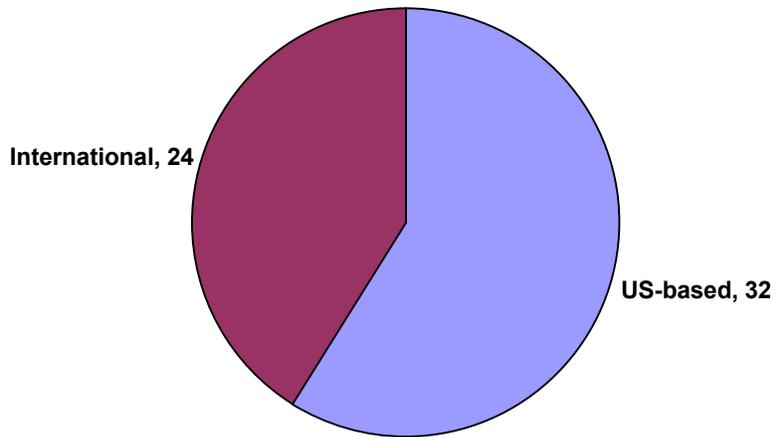
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**Appendix B  
Attendees**

**International Forum Attendance  
By Discipline**



**International Forum Attendance  
By Origin**



**Appendix C**  
**Additional Comments**

## Appendix C Additional Comments

### Sleep Comments - Jim Fields

#### COMMENTS ON OUTLINE AND QUESTIONS FROM THE WORKSHOP {NOTE: The workshop questions are in bold font.}

#### **1. Is it possible to design a new research project that will provide significant information in the short-term to markedly strengthen FAA's review and reformulation of policy regarding night-time flights?**

Yes: I think it should start with an examination of previous work before planning a new study. I would suggest that the focus should be on issues such as:

- Determining what single-event and nighttime noise metrics are best able to predict each measure of sleep disturbance.
- Determining the best predictions for total amount of sleep disturbances as measured by:
  - Morning-after surveys (recalled periods of not being able to get to sleep, not getting back to sleep, and being awakened)
  - Actimetry
  - Signaled awakening
  - Arousals of the autonomous nervous system (vegetative arousals such as ECG and heart rate changes)
  - EEG changes including EEG awakenings
- Summarizing the best available knowledge about the relationship between polysomnographic EEG awakenings and each of the above. Such an evaluation may be needed before deciding what combination of methods should be used in any new study.
- Determining the extent to which sleep disturbance occurs within and outside of night-time periods (for example 22 to 07) of different lengths with different beginning and ending times.
- Whether or not different single event metrics or disturbance models have important regulatory implications when they must predict average reactions over a long time period for the range of yearly nighttime environments that are currently found around airports

#### **2. If there should be a new study for short-term research, how should it be designed. Specifically, is there a preferred measure of sleep disturbance - behavioral awakenings, motility, etc. - what are the strengths and weaknesses of these various measures and do some address the differences between "spontaneous" and "aircraft noise induced" awakenings better than others?**

It seems to me that all four of the above methods are flawed, but all are useful. There appears to be a hierarchy of cost and difficulty which is inversely related to study sample size and also the representativeness of the sample.

By comparing aircraft noise nights and other nights, wouldn't it be possible to adjust for spontaneous awakenings for any method except the "morning after" surveys.

## Appendix C Additional Comments

### **3. Should a new study incorporate vulnerable groups (children, diseased, elderly, shift workers) and if so, how?**

*How can vulnerable subgroups be investigated, and does the expected small size of these subgroups make meaningful research in any reasonable time frame infeasible?*

I am less concerned with deriving separate estimates for these groups, than with being certain that we have not biased our estimates of effects by excluding such groups and, possibly most of the population, from past studies. It might be possible to assess these types of biases using general population surveys that included groups that would not normally be recruited for EEG or other invasive surveys.

### **4. Should there be an epidemiologic study on the effects of (nocturnal) aircraft noise?**

It seems to me that the FAA cannot justify devoting resources to the design of health effect surveys. The basic sleep science knowledge is not sufficient to determine the health effects of lack of sleep, let alone the small contribution that noise is likely to make to diminished sleep. With the exceedingly weak relationships between noise and health that have been discussed thus far, it seems to be unrealistic to expect that any such research will provide evidence of sufficient specificity to guide FAA decisions. About all that would seem to be justified would be to offer to provide small amounts of money and technical consultative support to other sleep studies if they would include aircraft noise as a source of disturbance.

#### ***TYPES OF METRICS***

### **5. For data collection and analysis, what is the most appropriate descriptor of an aircraft noise event – is either SEL or Lmax sufficient, or should additional variables such as event time history or frequency content be investigated?**

It seems to me that this question has not been answered and that the primary task for the FAA is to determine the relative value of different descriptors to explain the alternative measures of sleep disturbance. The effects of rise-time and other characteristics of the events should be studied as well as the effects that are associated with the location of an event within the sleep period and the effects that may derive from interdependencies between different awakenings. On the other hand, sensitivity analyses should also determine whether these types of distinctions will actually have a major impact on regulatory actions when applied to complex, long-term averaged environments.

As for suitability for public understanding, this should be considered only after the relative value of different metrics is known. Efforts should be made to develop, test, and refine methods for explaining the best metric rather than immediately assuming that we can pre-judge whether or not the public can understand a metric.

### **6. How should sleep disturbance results be extended to an entire night, to populations, to sub-populations?**

## **Appendix C Additional Comments**

Perhaps I am naïve, but it seems to me that sleep disturbance results would be extended to a whole night by studying the total number of aircraft noise-induced awakenings within the context of the whole night's awakenings. It seems like most analyses have only analyzed noise sleep disturbance as a function of the immediately preceding noise and the time of night. It might be useful to conduct more analyses that explore more complex dependencies, such as the effect of previous awakenings (noise or non-noise) on the probability of another noise-induced awakening.

As noted above, my concern is less with sensitive subpopulations, than with being confident that we can produce good estimates for the population as a whole and not for only some smaller group that is typically recruited for standard sleep studies. One approach to this is to examine data from surveys that have weaker sleep disturbance measures (for example, motility) but have studied representative population groups.

### **7. What metric(s) are most suited to regulation? (L<sub>night</sub>, % “impacted”) and why?**

As noted above, I think we should first determine the extent to which different metrics provide accurate predictors of sleep disturbance and then be concerned about regulation. However, it seems to me that one important side issue that should be explored is the implications of different criteria for aircraft noise management. A sensitivity analysis could determine whether different metrics would lead to different operational changes around airports, while recognizing the non-noise constraints on airport operations.

## **SETTING CRITERIA**

### **8. Exposure-response relationships are usually “s-shaped” continuous functions, and not “all-or-nothing” relationships. In this situation, what is the best way to select scientifically based limit values or goals for mitigation measures?**

While this causes great *angst* among regulators, I don't see that there is much prospect that scientific research will be able to help on this. Unless there was an enormous sound insulation program and the population rigorously kept their windows closed, I would suspect that there will be a rather gradual continuous relationship between outdoors aircraft noise (the only level that can be modified in the absence of insulation) and awakenings. Even if there were a sharp threshold for one indicator, the ambiguities about the various sleep disturbance definitions and health implications would seem to me to mean that keep regulators would still not have a definite scientifically-defined threshold.

## **MY TENTATIVE CONCLUSIONS**

A few main problems that the FAA might be able to resolve are:

- Are there any noise metrics that are relatively successful in predicting sleep disturbance across different types sleep disturbance indicators?
- What proportion of the population experiences sleep disturbance according to each of the sleep disturbance indicators at specified values of the best noise metrics?

## **Appendix C**

### **Additional Comments**

- Are the best indicators of sleep disturbance unbiased by:
  - Biased selections of the parts of the population that are studied
  - The impact of the study method on the quality of the subject's sleep

Problems that the FAA cannot expect to resolve with research in the foreseeable future may include:

- What are the health effects associated with FAA decisions about alternative airport operation scenarios?
- What are the noise levels at which regulations should be set? (This seems like a cost-benefit analysis.)

## Appendix C Additional Comments

### Annoyance Comments - Jim Fields

#### Suggestions for New Research and Comments on “Key Questions for Designing Research Roadmap”: Annoyance Workshop

### INTRODUCTION

These comments are divided into two sections. The first section reproduces the “Key Questions for Designing Research Roadmap” (in bold font, highlighted in yellow) and provides comments on each of the questions. The second section outlines nine types of research projects that might be considered.

### KEY QUESTIONS FOR DESIGNING RESEARCH ROADMAP

#### **1:15 ANNOYANCE QUESTIONS ANNOYANCE**

##### ***POLICY RELATED RESEARCH***

**If the current basis for establishing impact (percent population highly annoyed or %HA vs. DNL) needs updating, what issues need to be researched?**

**Currently, 65 dB DNL sets the significant impact and land use compatibility threshold, which has been assumed to limit the number of people highly annoyed.**

Even though the percentage of people annoyed outside DNL 65 is lower, so many more people live outside DNL 65 that the most significant impact is outside DNL 65. As a result, limiting the number people annoyed, even for a high level of annoyance, means that steps must be taken outside DNL 65.

**1. Assuming %HA vs DNL is an important measure of noise impact, what types of research would:**

**Reduce the scatter of annoyance versus DNL?**

The issue of scatter might best be divided into two types of scatter: scatter in individual reactions within communities and scatter in the average reactions between communities. The individual scatter is largely irrelevant because we know and expect that individuals give different answers to questions that have qualitative judgments at different times and that different people, even within the same family, react differently to the same noise exposure. The key question is whether there are differences between communities or other situations which could be legitimately used as a basis for FAA regulations. Research should be directed at any variables that the FAA could incorporate into regulations, if the issue has not been thoroughly studied before. I give my suggestions for future research in the second section of this document.

## Appendix C Additional Comments

### **□ Update the relationship of annoyance to DNL - e.g., to account for changing conditions such as increased sensitivity to noise**

“Updating the relationship” and thus obtaining a good measure of the current DNL/response relationship cannot be achieved by conducting a single survey around a small number of airports. The reason is that past surveys conducted at about the same time period have provided different relationships. The Schultz curve is just the average of some of those previous disparate surveys. Since the previous surveys had such different annoyance and acoustical measures, we do not know whether the differences in reactions were due to differences in methods or to genuine differences in reactions. If the FAA only conducts one limited survey now, we have no way of knowing whether this single new survey would measure a change in reactions or a change in methods or survey conditions. If a new survey were conducted around only a small number of airports and study areas, the “update” might be a function of the particular airports chosen.

Due to the methodological difficulties considerable care would be needed to decide how to determine whether there has been a genuine change in sensitivity to noise or whether any differences are an artifact of the noise or social survey measurement techniques or of having studied different populations at different times. For example, almost all older surveys used interviewer-administered questionnaires, but recent surveys have been more likely to use self-administered questionnaires without random selection of households or respondents within households. Some research in the Netherlands has indicated that these self-administered, questionnaires yield higher estimates of annoyance than do interviewer-administered questionnaires. To determine whether the population is becoming generally more sensitive, a secondary analysis could be conducted of surveys that were conducted around the same airport at different times with the same methodology.

Possible strategies for determining whether updates are needed include:

- 1) Making carefully controlled comparisons between the DNL/response relationships at two or more points of time around the same airport following the same methodologies. (Some data sets are available that would permit such analyses with existing data around some airports.)
- 2) Determining whether the factors that have changed (for example increased numbers of aircraft) are sufficiently large to not be accurately predicted by DNL. For example, the numbers of aircraft at airports has generally increased, however, previous studies examined neighborhoods with numbers of flyovers that were much higher than the average at the time of those studies and may in fact be as high or almost as high as the numbers experienced in the most heavily impacted neighborhoods around current airports.

## Appendix C Additional Comments

### **or increasing numbers of quieter operations (does “equal energy” apply),**

Although there may be increasing total numbers of operations at airports, it is the number of operations for individual residents that is important. At least two steps should be taken before assuming that this requires major new research:

- Determine the numbers of operations that are currently experienced in individual neighborhoods and then examine past studies to determine whether high number areas in those studies included most current conditions.
- Compare the ratio of current to previous numbers for those studies and, in light of the equal energy principle consider whether the ratios are so high that it is reasonable to expect differences in reactions based solely on numbers. My own expectation is that if the equal energy principle is incorrect, it is probably for very small numbers of operations not for very large numbers of operations.

### **to focus solely on aircraft noise?**

If the “focus solely on aircraft noise” phrase means that reactions to different noise sources are different, then a large amount of data are already available and have been analyzed, at least for Western countries. There are more than 20 years of research that show that reactions to aircraft noise are more severe than those to road traffic or railways. However, some care is needed in using this information in light of the fact that Japanese surveys do not find the same pattern for railways in Japan. This suggests that the differences in reactions may be at least partly cultural rather than acoustical in character.

### **Identify alternative or additional metrics to DNL that correlate with %HA?**

Because debate about the value of equivalent energy indices continues, it would be useful to reanalyze existing data to determine whether there is evidence that rejects the equal energy principle. It must be noted, however, that such reanalyses would only be useful if they included large numbers of studies that include variations in the variables of interest and values of those variables that are not highly correlated. Conducting a new study of alternative metrics would be of almost no value unless sufficient numbers of study areas can be studied so that findings about differences between metrics would not be confounded with random differences between study areas.

It seems to me that it is very unlikely that new studies will provide an improved metric unless the purpose is to study strikingly different types of aircraft noise (for example, low altitude helicopters in comparison to distant jet aircraft). Within very broad groups of aircraft types, it is likely that new metrics will have no important effect on our ability to predict annoyance within communities.

### **The scatter we now have means that the response curve is an average with little or no predictive ability.**

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My points on “scatter” above may help to provide a more useful way to think about the scatter in reactions. Annoyance is a subjective feeling and, like all attitudes that are studied in social science, differs greatly for individuals who are exposed to nominally identical circumstances. The assertion of “little or no predictive ability” is fundamentally incorrect when applied to estimates of overall impact using variables that can be used in public policy. All community noise studies find that, on the average, a reduction in noise level leads to a reduction in reactions and that negative reactions are quite low as noise levels become very low.

**Reducing the scatter could help us better understand the concept of “impact.”**

I am not clear about what the above statement means.

**Also, there are some indications that populations have become more sensitive to (more annoyed with) aircraft noise at a given level (in terms of equivalent level), and one hypothesis is that this increase results from having more operations despite having quieter aircraft.**

This was discussed in some detail above. Another hypothesis for continued annoyance and community action in the face of reduced noise levels is that, as explained above, the very large population at lower noise levels with small percentages of people being impacted still translate into very large numbers of impacted individuals. The assumption that DNL65 was an adequate limit for defining impact was based on the percentage of people impacted not the number of people impacted.

**2. Assuming impact should be based on more than annoyance, what further research is required, if any, to develop defensible relationships between aircraft noise and such effects as:**

- Sleep disturbance (was discussed this morning)**
- Daytime annoyance (or other times of day)**

It is not obvious that the impact on annoyance should be different at different times of day. Residents are likely to be especially annoyed if they are kept awake at night, but they are unconscious most of the night and are more likely to be in a shielded indoors environment and thus may be less likely to hear nighttime than daytime events. Residents are more likely to be at home in the evening, but are more likely to be indoors. It seems very unlikely that a survey can accurately estimate time-of-day weightings because the levels at different times of day are highly correlated. There may be some value in repeating earlier attempts to estimate time-of-day weightings from an analysis of community survey data. Since this was last performed in the 1980’s new analysis techniques have become widely used,

## Appendix C Additional Comments

### Induced house vibrations and audible rattle

Feelings about vibration and rattle are related to annoyance. Assuming that home construction and the placement of furnishings cannot be controlled in existing residences, it would seem that the main implication would be that a new metric would need to give greater emphasis to frequencies and characteristics of sounds that would be more likely to induce vibration. Since such change in a metric might not correlate as well with other reactions, it would seem that any testing should be directed at testing alternative metrics in surveys or in settings that would as fully as possible reflect the range of activities encountered in normal living conditions. I am not clear about just how this would be done. It would seem that this topic would only be of great importance to the FAA if an index is needed that accurately represents aircraft noise environments that differ greatly in the characteristics that induce vibration or cause rattles.

### Interference with learning

### Speech interference indoors and outdoors

### Etc.

Studies of aircraft noise annoyance have wrestled with this problem since the very first aircraft noise reaction surveys in the 1950's. The early surveys asked for separate reactions to different types of activity interference such as sleep, concentration, and various types of speech interference (television, telephone, speaking indoors/outdoors, etc). They also asked separate questions about vibration. The response indices formed using these items did not provide a generally more precise DNL/reaction relationship than the simple, overall annoyance indices. In addition, the respondents' self reports of such interference levels are averaged over such a complex mix of conditions that they are probably no more objective than are their reports of annoyance.

### **3. Assuming impact should be based on more than annoyance, what studies can be done to combine, relate or prioritize multiple effects in a way to inform a policy that needs to be implemented across the wide variety of airports in the country?**

It is important to distinguish between impacts in residential areas and impacts in more specialized, goal-directed settings such as schools. In goal-directed settings, it is possible to allow information about the goals in the contexts to identify the effects that are of importance.

It is not clear that measures other than annoyance can make an important contribution in residential environments in which the goal is diffuse (to live in a pleasant setting) and the method for combining different effects is determined by multiple, complex different objective conditions and subjective, personalized values, life styles and conditions. For example, speech interference can be objectively described under specified conditions such as distance, level of speaker's voice, attentiveness of listener, and familiarity with the message. However, in the course of a year, a resident experiences an enormous

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variety of such communication conditions. In addition, evidence is not available about the relative importance of different situations (for example: speech interference out-doors at twenty feet and clearly hearing the television from an adjacent room indoors) and how the relative importance would vary between individuals. The uncertainties of weighting these complex, varied exposure conditions and residents' varying values largely explain why researchers use the residents' own summary judgments of annoyance to assess noise impact in residential areas.

### **4. What research can identify whether impact from steady-state or gradual change in exposure can be assessed in the same manner as impact caused by a step change; if not how should it be done?**

Research could provide answers if step-change situations could be identified in advance and if reactions could be tracked from before the change until several years after the change. I prepared a NASA report on the requirements for this type of survey that still appears to be relevant. Lex Brown reports that an answer has been found on the topic, at least for road traffic. It would be useful to evaluate that report to see if the findings are sufficiently strong to provide a basis for policy. In the past, it is been very difficult to locate aircraft noise areas with substantial, long-term step changes in noise exposure.

### **5. What research can inform the process of setting thresholds of impact?**

Any research on dose/response relationships is useful by detailing the impacts at different noise levels. However, the research shows that over moderate or high levels of exposure there are no sharp thresholds of reactions upon which regulations could be based.

## ***PUBLIC COMMUNICATION RESEARCH***

**This category relates primarily to proposed projects that will result in changes in aircraft noise and should be considered unrelated to the above policy issues. Communities /individuals can react very negatively after changes in aircraft noise occur. There is a general perception and considerable experience that providing better, clearer information to the public and to aviation stakeholders in general about aircraft noise and the expected changes can reduce the negative reactions and / or increase acceptance of the changes.**

It would be useful if we clearly distinguish between two concepts that are often confused because they both come under the label of "community response". These two concepts are:

- 1) Personal impact (annoyance, speech interference, other interruptions, etc.)
- 2) Public action (individual complaints, legal action, community organization, political action, etc).

If the steering committee could decided on a single term for each and no longer use the term "community response" there might be more useful, clearer discussions about future research and aircraft noise impacts.

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### **6. What research can identify the types of information that should be provided, the forums/presentation formats, and the extent and timing of outreach that are most effective?**

This seems to me to be a very promising area of research. It would be very useful to consider all the issues that are involved and then determine how each issue might be addressed. For at least some issues, for example explaining the equal energy principle, the best approach may not be field research, but rather basic laboratory research with communication experts who develop and test alternative methods for presenting the basic principles.

### ***PUBLIC REACTION RESEARCH***

**From the perspectives of an airport that wishes to be a good neighbor and still respond to the needs of increased operations, of the FAA that needs to increase national airspace system efficiency and ensure the ability of the air transport system to grow to respond to increasing demand, and of the elected official whose limited resources can be consumed trying to mediate between irate citizens and an airport or the FAA, it would be valuable to know before changes in aircraft noise occur, where strong community reactions are likely to occur and if so, whether and how they can be minimized or avoided.**

A major question is whether a program like this will direct government and community action away from dealing with a legitimate problem that impacts many residents while instead manipulating communities so that the individual residents' problems are ignored. On the other hand, research that would examine the relationship between personal impact and public action, could lead to a better understanding of when public actions from an area are indicators for serious impacts on a population or, alternatively, only indicate that the particular community has been more effective in obtaining government attention than other similarly impacted communities.

### **7. What research will identify which acoustic and non-acoustic factors are correlated with negative community reactions such as complaints, legal action, and involvement of politicians that can occur after noise changes from airport actions or airspace redesign?**

Research could uniformly collect information about all of these variables for all large airports in the United States and for a stratified random sample of smaller airports. This research would obtain community-level information from officials, knowledgeable informants, and documents.

The statement refers to public actions after changes. The greatest amount of public action may be during the planning period, not after a change.

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### Possible Future Research

Nine types of projects are suggested below.

#### PERSONAL IMPACT RESEARCH (Annoyance, etc.)

I think that substantial progress can be made on a number of issues in the immediate future by secondary analyses of previous, individual-level data sets. However, the steering group and workshop participants need to decide whether these reanalyses will provide sufficiently strong evidence to guide policy before the analyses are conducted. In some cases new surveys might be conducted to follow the reanalyses.

It is assumed that annoyance and other types of personal impact are important issues for only residential environments. Other projects would be recommended if it is important to examine the effects in workplace or outdoor recreation settings.

1. **Increased sensitivity to noise.** As described above, the issue is whether dose/response planning curves need to be adjusted because the population has become more sensitive.
  - 1) **Project A:** As suggested above, a reanalysis could make carefully controlled comparisons between the DNL/response relationships at two or more points of time around the same airport using the same method. Data sets are available that would permit such analyses with existing data around at least a few major airports. The possibility of drawing on road traffic studies that have been conducted at different times in the same country should also be considered.
  - 2) **Project B:** Any new survey that is conducted around a previously studied airport should include a methodology that permits close comparisons with the previous survey.
  
2. **Equal energy principle in noise indices.** Discussion continues about whether or not Leq adequately represents the relative importance of noise levels of individual noise events and the numbers of those events. Several types of projects might help to resolve this issue.
  - a. **Project A:** Previously collected social surveys that measure both the numbers of aircraft and the levels (average levels) of the events could be reanalyzed. I performed such analyses in the 1980's but additional surveys have become available since then and new analysis techniques have emerged that are widely accepted. A part of such a project would be to develop a statistical tool that could determine whether a new survey could resolve this or other equal-energy index issues.
  - b. **Project B:** New surveys could be conducted at multiple airports to provide better tests of the equal energy principle. This might be especially important if there are other types of aircraft noise environments that were not represented in previous studies. If a large number of suitable environments were located, more complex acoustical indices might be examined. Of course

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these and other surveys should not be conducted unless the statistical planning tool indicates that accurate estimates can be obtained from community surveys.

3. **Ambient noise impact.** My 1996 review of ambient noise studies found little or no effect of ambient noise on reactions to other noises. Since that time additional studies have been conducted. Only a small amount of evidence was available at that time about reactions in rural areas.
  - a. **Project A:** An updated analysis of ambient noise studies could be conducted which would include an attempt to locate information about reactions in rural areas.
  - b. **Project B:** A new survey would be very likely to provide strong evidence on the effect of road traffic on reactions to aircraft noise. A survey might also be able to compare reactions to distant aircraft noise in remote suburban and urban environments.
  
4. **Reactions to changes in noise exposure:** Strong evidence is not available about the impact of changes in aircraft noise on residents. My report from 2000 provides a guideline for how to design a new survey, if suitable change situations can be identified far enough in advance of the change.
  - a. **Project A:** Plans for changes at airports could be monitored and new surveys could be conducted as opportunities arise. These studies should monitor both changes in annoyance and changes in public actions over the course of a change. If there will in fact be very few abrupt changes, it may be that studies should be conducted even if the changes are gradual and extend over several years.
  - b. **Project B:** Reanalyses could be conducted of previous surveys of reactions to changes in aircraft and road traffic noise. This may not yield very much improvement in estimates of change effects for aircraft noise, but could provide additional information about the extent to which existing or future road traffic noise studies could provide evidence that is relevant for aircraft noise change studies.
  
5. **Aircraft-specific dose/response curve:** Reanalyses of existing survey data have consistently shown differences between reactions to different noise sources. Most comparisons show that aircraft are most annoying and railways least annoying, but Japanese studies display a different pattern. If it is concluded that new surveys in the United States are needed to update the aircraft relationship several projects would be useful.
  - a. **Project A:** Reanalyzing the data from previous surveys could provide direct estimates of aircraft impacts and statistical parameters that would guide the design of new surveys
  - b. **Project B:** New surveys around airports in the United States could provide convincing evidence for updating a dose/response relationship if the study was conducted in a large number of neighborhoods around many airports and the study examined characteristics of local areas that could affect reactions.

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6. **Time-of-day weighting:** DNL has a nighttime penalty. If sleep disturbance were protected with another metric, it is not clear that a nighttime weighting can be justified on the basis of survey data. However, such weightings are so widely used in noise indices that the FAA may not want to consider alternatives, especially when the evidence is not likely to be definitive.
  - a. **Project:** At least two reanalyses of social survey data nighttime weightings have been conducted that came to different conclusions. However, additional data have become available since those analyses. A new analysis might better evaluate the evidence for a time-of-day weighting and more clearly determine whether a new field survey would be useful.

### CLEAR COMMUNICATION

7. **Communicating acoustical information:** This seems to me to be a good area for new original work. It is sometimes assumed that the public cannot understand the equal energy principle and that the public will always be confused by DNL and other acoustical concepts. I do not have a specific research program in mind. I would suggest, however, that communication experts who are not acousticians should direct or be heavily involved in such a project. Additional research perspectives might discover that new, more effective approaches might be used such as some type of interactive, computer-based exercise.
  - a. **Project A:** If studies have not been performed before, it seems to me that it would be useful to carefully examine public meetings and other public discourse on acoustical regulations to try and understand the major communication problems and possible solutions. It would also be useful to compare different acousticians' approaches to these problems.
  - b. **Project B:** With the knowledge gained in Project A, new laboratory or small group research could be conducted to determine what types of presentations or other exercises are most effective at helping people understand acoustical concepts...

### PUBLIC ACTION

8. **Comparison of annoyance (individual impact) and complaints (public action).** Some early surveys provided some evidence about the differences and similarities between personal impact and public action. New work could provide clearer and more definitive information.
  - a. **Project A:** A reanalysis of some existing data sets could determine to what extent complaints may represent or misrepresent the underlying impact of noise on a community. This analysis would compare the characteristics of the larger annoyed population with that smaller proportion of the population that takes public action. This information would help to determine what the strengths and weaknesses of complaint information may be.
  - b. **Project B:** To further understand the relationship between complaints and underlying annoyance, the FAA might identify ongoing annoyance surveys

## **Appendix C**

### **Additional Comments**

and then obtain records of complaint data for neighborhoods in the survey areas. This would provide another source of information about the conditions under which complaint actions are more or less accurate representations of the underlying annoyance experienced in a community.

**9. Community and acoustical factors that explain public actions.**

To my knowledge the causes of public actions against noise have not been systematically and scientifically studied. A frequently cited graph of community response by adjusted noise level from a 1950's Wyle study is not based on sound scientific methods.

- a. **Project:** As suggested above, new research could uniformly collect information about a wide range of community variables for all large airports in the United States and for a stratified random sample of smaller airports. This research would obtain community-level information from officials, knowledgeable informants, and documents. Acoustical data could also be examined, but it seems unlikely that this project would provide very much information about the effects of noise exposure itself because noise exposure varies greatly between subareas around airports while the actions themselves are not tied to a particular subarea. Research of this type requires very little acoustical knowledge, but should draw on areas of social science expertise that examine community conflicts and organization.

**10. Community /airport interactions.** I do not know of research that has systematically examined the methods for mediating community/airport conflicts.

- a. **Project A:** Conducting case studies of airport community relations could identify hypotheses about procedures that would most efficiently manage airport/community conflicts.
- b. **Project B:** Follow-on studies or real time monitoring of such conflicts might provide guidelines for managers' and communities' actions around airports. As with the previous topic, the primary expertise required for this expertise comes from the social sciences not from acoustics.

## Appendix C Additional Comments

### **Annoyance Comments - Vic Sparrow**

**Please submit to us your comments and/or responses in writing (ahead of or at the end of the meeting).**

### **FAA Background, Objective and Timeline**

*All very reasonable; Raquel Girvin has done a good job with this.*

### **Key Annoyance Research Questions**

- Do they capture the most important issues? If not, what other questions need to be posed?

*Yes, most of the important points. However, as I mentioned at the forum, I suspect that a good bit of the uncertainty in our current knowledge of annoyance to subsonic aircraft noise is related to our limited understanding of low frequency noise and how it affects people. There is tremendous variability in home construction, and we have very little data taken for indoor to outdoor transmission below 50 Hz, where people seem to react strongly*

- How would you answer them?

*Regarding low frequency noise, I think it would be helpful to do a few things. 1. There should be an in-home study conducted to see how people react to low-frequency noise specifically. This could be conducted in parallel with laboratory type studies of low frequency noise annoyance, at NASA Langley or elsewhere. In addition there needs to be continued study on the artificial generation of low frequency noise, and study on how low frequency noise transmits from outdoors to indoors. PARTNER is looking at this artificial generation of low frequency noise and its transmission, and that should continue. However, nothing has been started regarding the in-home or lab studies of low frequency noise and its resulting annoyance.*

### **Prioritization of Key Research Questions – Annoyance**

Which research would yield the greatest payoff?

In which areas are we most likely to make substantive progress: in the near term (within 2 years) and in the next 5 years?

*I suggest at least one study should be conducted addressing low-frequency noise annoyance in homes. This would be a 2 year effort, with at least a 2 year lead time to set it up. Another idea would be to make a good set of measurements of low frequency transmission from outdoors to indoors for different types of home construction. Such a study requires specialized low frequency microphones and instrumentation, and this hasn't already been done, surprisingly.*

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### **Ongoing or Near-Term Planned Related Research; Opportunities to Collaborate**

What related research is already ongoing or planned in the near term? (Please provide project title, principal investigator, sponsor, and any descriptive information or links.)

Are there opportunities to collaborate – in terms of study design, sharing data, testing analytical approaches, etc?

Whom should we contact for further discussion?

*PARTNER work related to low frequency noise transmission should be continued. One idea for collaboration would be to use the data the sleep disturbance people have taken over the years to assess outdoor to indoor transmission. This is usually approximated by the noise annoyance community and not measured. The sleep disturbance researchers have measured this, and those datasets could be helpful for annoyance prediction. It is doubtful, however that the sleep disturbance folks measured the sound down to the low frequencies that would REALLY be helpful.*

### **Study Costs and Duration**

How much would it cost and how long would it take to conduct the high priority research items?

*Good question. Since this low frequency noise annoyance study would involve interviews and working with people in their homes, this is not an inexpensive new project.*

*I would be happy to comment more or answer questions about this idea.*

*Thanks, Vic Sparrow, [vws1@psu.edu](mailto:vws1@psu.edu)*

## **Appendix C**

### **Additional Comments**

#### **Annoyance Comments - Ken Hume**

Following reflection on the Ottawa meeting/forum the one issue that I am not sure was made strongly enough is that I think that the research work road-map should include some aim to investigate the links/relationship between annoyance and complaints. This may need to involve a systematic adoption of a prescribed method by which complaints are collected, coded, analyzed and reported - this may involve development of complaint metrics, in order to improve the validity, transferability and usefulness of the data.

## Appendix C Additional Comments

### Comments - Pieter Stallen

FAA-INTERNATIONAL FORUM ON NOISE IMPACTS, OTTAWA, CANADA,  
AUG. 27<sup>TH</sup>, 2009

CONTRIBUTION BY PIETER JAN STALLEN (AUG 25<sup>TH</sup>)

The introduction by Raquel Girvin identifies several areas in need of applied noise research over the next 2 to 5 year period. I would like to suggest two extra areas A and B (below), based upon my experience with decision makers finding it generally difficult to communicate why and how to change from primarily acoustical policy to policy based upon acoustical and non acoustical measures in one. 1-3 provides the underlying logic as I see it 'dictated' by empirical evidence.

- I. Typically, the efficiency of environmental noise reduction policies is low: less than 30%. Whereas, if non-acoustical factors are addressed simultaneously, efficiencies go up to twice this value.
  1. In short, the most important health (WHO definition) impact from noise exposure is *environmental noise annoyance*. Environmental noise annoyance also is a significant moderator of the relationship between exposure and (psycho)somatic health effects, such as night time hypertension.
  2. Environmental noise annoyance does never result from physical exposure ('decibel') alone. Environmental noise annoyance, essentially being a manifestation of psychological stress, is always determined by physical and (social) psychological factors together: *you expose me*, etc.
  3. The belief that social factors deserve address but only after physical factors have been fully utilized, is counterproductive. Perhaps except for highest dose levels (>70 dB Ldn), both factors must be addressed explicitly simultaneously.
- II. For significant increases in efficiency of environmental noise reduction policies to be realized in 2-5 years time, major R&D efforts are required in two areas: A and B.
  - A. **The development of training packages (e.g., gaming/simulation) that provide to relevant decision makers within companies (airport, ATC, etc.), public groups and regulatory agencies case-wise experiences about how acoustical and non-acoustical factors interact in practice; that sensitize decision makers to the transactional nature of all noise (stress) reduction measures; that facilitate the shared understanding between decision makers of the optimal (acoustical and non-acoustical) conditions for effective noise reduction.**
  - B. **The development of tools that aid decision makers of various sides in understanding how (in)equitable exposure determines the (in)acceptability of noise; of tools that enable communication about alternative means to (re)distribute noise loads over communities (nearby and far-out residents, tranquil and urban areas, etc.).** After all, 'unwanted sound' will always be dependent upon perceived fairness of noise exposure as no-noise societies do not exist.

## **Appendix C**

### **Additional Comments**

III. At the University of Leiden (Chair ‘Community Noise Annoyance’), together with the Delft University of Technology and To70, R&D is conducted in areas A and B. For this research to produce more robust and more widely applicable results within 2-5 years, collaboration with US and Asian R&D-partners is sought. Please, contact: [stallen@fsw.leidenuniv.nl](mailto:stallen@fsw.leidenuniv.nl)

Dr Pieter Jan Stallen, Professor Community Noise Annoyance  
Leiden University, Netherlands

In addition, Pieter wanted to provide the following comments that he submitted recently on a somewhat similar effort, “Environmental Noise and Health in the UK – Draft Report.”

## Appendix C Additional Comments

### 'ENVIRONMENTAL NOISE AND HEALTH IN THE UK' - DRAFT REPORT 1

#### Comments by Pieter Jan M. Stallen 2

Professor Community Noise Annoyance  
Leiden University, The Netherlands

It is a generally clear review of scientific findings. My comments concern inaccuracies and incompleteness on two subjects: causation and effect of noise annoyance. Results from scientific studies presented in journals and conference proceedings that have been consulted by the authors of the draft report justify a more advanced and different description of causes and effects than presented in the draft report, however much I agree that much is still unknown or unresolved. Particularly as it concerns the assessment of *social* scientific progress I believe that the report might benefit from a more explicitly differential assessment of theory-based and exploratory studies.

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ON CAUSES.

In the Executive Summary it is stated as Observation 7 that the typical scatter in the measurement of noise annoyance, labeled as “probably the most widespread adverse effect of noise”, is due to “variations in individual sensitivity to noise and/or susceptibility to annoyance. These variations are not well understood (...)” (p. 1-2).

Comment 1.

A. The concept ‘susceptibility to annoyance’ is not common in the literature on non-acoustical determinants of environmental noise annoyance. I have seen it referred to only by Van Kamp *et al.* (2004) as “susceptibility to annoyance, not necessarily by noise” and, therefore, as “general sensitivity” (p. 3472), with no further attention paid to it in their study. I also do not know of any significant number of later environmental noise studies where the trait has been measured or reported to be an important cause of noise annoyance. Indirectly, the draft report itself testifies to this theoretical and empirical scarcity by nowhere explaining the term ‘susceptibility’, and by using it only one second time and in a different context.<sup>3</sup>

B. Social scientific findings on non-acoustical factors other than noise sensitivity have been reviewed by various authors several times, with the first extensive review by Fields (1993).<sup>4</sup> They have been referred to succinctly as “attitudes towards the noise source” by Van Kamp *et al.* (2004, p.3472). To my knowledge, the most recent overview of non-acoustic determinants of environmental (aircraft) noise annoyance was presented by Maris *et al.* (2007ab).

**I suggest to stay clearer and closer to the (sets of) variables that have been identified in the social scientific literature on environmental noise annoyance, such as sensitivity [which you did identify] and attitudes towards exposure.** Repeatedly mentioned examples of negative affect associated with exposure (generally leading to increased noise annoyance) are: fear, distrust.

<sup>1</sup> Draft as available 07/22/09 at [http://www.hpa.org.uk/web/HPAwebFile/HPAweb\\_C/1246433634856](http://www.hpa.org.uk/web/HPAwebFile/HPAweb_C/1246433634856)

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<sup>3</sup> At the end of the report it is recommended to do “further research on the susceptibility of population groups to health effects of environmental noise” (p.84). By the way, should this ‘groups’ be taken seriously, that is, does it mean something different from some aggregate of ‘individuals’? If so, it would help the reader to know which particular groups the authors are assigning priority here.

<sup>4</sup> In 1999 a special issue ‘non acoustical factors of environmental noise’ of the scientific journal *Noise & Health* was edited by Flindell and Stallen.

## Appendix C Additional Comments

### Comment 2.

Evidently, each of the above identified non acoustical variables has its own history. For example, distrust, in turn, may (in part) have originated from being (purposefully or not) misled by inappropriate information. When discussing possible causes and effects it is generally helpful to distinguish between first and second order explanatory variables. If this distinction would be adopted in clarifying the various causal paths of noise annoyance, then I think that the message which observation 7 intends to convey is

- there have been identified first-order variables other than dose-variables which help to explain the scatter in the relationship ‘annoyance  $\propto$  dose’;
- this scatter can be reduced more and/or more effectively to the extent that first-order acoustical and first-order non-acoustical factors are addressed at the same time.

I do not think that it is the intention of observation 7 to emphasize that we must know better how second-order variables lead to differences in the major first-order non acoustical determinants of noise annoyance: sensitivity and attitudes towards exposure. Also the conclusion 8.8. (p.81) suggests that the better understanding of first-order determinants is the primary interest of the report. Indeed, detailed knowledge about second-order processes are not a prerequisite for effective action regarding first-order relationships.<sup>s</sup> I also do not think that it is the intention of observation 7 to state that we do not know much about what are the major factors causing the scatter in the dose-response (=annoyance) displays. This would be in contradiction with the last but one sentence where the very message was that there already exists “important” knowledge about the scatter: it is “*due to* variations in individual sensitivity (...) [emphasis mine]”.

**In order to convey a consistent and scientifically clear message, I suggest to drop the final sentence of observation 7 entirely.**

### Comment 3.

Environmental injustice and perceived unfairness have become known as major obstacles to the efficient abatement of pollution in general. It is unfortunate that the 2007-studies by Maris *et al.* (see footnote 1) have been overlooked as these are the first to have showed, by controlled experiments, that the *social* factor of ‘unfair treatment’ is also a major determinant of environmental noise annoyance. This result is particularly relevant to policy makers who, when facing situations of *collective* exposure, would like to take action by addressing causal factors at the supra-individual level first. Fairness, almost by definition, is such a supra-individual factor. Given the recognition by the authors that, particularly in the area of noise, “more subjective factors” (p. 4) need to be addressed to enable policy makers to take financially healthy decisions, the facts found by Maris *et al.* deserve wider attention.

**I suggest to expand items 1.5 and 1.6 of Chapter 1 with information on the psychological and political significance of social factors, and to adjust the relevant observations of the Executive Summary accordingly.**

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<sup>s</sup>A good example is noise sensitivity itself. In general, individual persons themselves know best whether they are (highly) noise-sensitive and whether they wish to be eligible for noise-reduction support. Then, noise(policy) need to do no more than designing the opportunities (with degrees of freedom appropriate to the level of sensitivity) that allow the individual person to make his personal choices. E.g., establishing a system of partial reimbursement of costs of moving to quieter place. For such measures to take effect it is not necessary to know *who* in particular is noise sensitive, nor *how* it has come about.

## Appendix C Additional Comments

### ON EFFECTS.

In the Executive Summary it is stated that recent research shows that long term exposure to transport noise is “related to likelihood” (p. 2) of developing elevated blood pressure (Observation 10), and that “there is increasing evidence that environmental noise, from both aircraft and road traffic noise is associated with raised blood pressure” (Observation 15).

### Comment 4.

When human health is addressed by (psycho)somatic measures like changed blood pressure it is important to be as clear as possible about paths of causation as well as about their effect-sizes. In this respect, the observations 10 and 15 do not reflect significant information about the important mediating status of noise annoyance as reported in sources consulted by the authors at the time of drafting the report. In particular, it concerns three large scale investigations:

- The study by Kroesen *et al.* (2008) regarding ‘self reported health status’ and ‘health complaints’ as predictor/proxy of ‘health’.  
The analysis by these authors of data from more than 10.000 residents in the Amsterdam Airport area showed that “inclusion of the mediating paths between aircraft noise exposure and perceived health renders the direct effect between these two variables insignificant.” (p.6).
- The epidemiological study by Niemann *et al.* (2006). This Large Analysis and Review of European housing and health Status (LARES; about 8500 residents of 8 European cities) revealed that there is “increased health risk from chronic noise annoyance” (p.78). This finding was explained by “the negative emotionality” of annoyance” which “ can be converted into reactions that show up in the neural, hormonal and immune systems as well as in the basic structure of the extracellular matrix (connective tissue).”(p.77) .
- The study by Babisch *et al.* (2007)<sup>6</sup>, also Babisch *et al.* (2008), regarding ‘hypertension’ as predictor/proxy of ‘health’.  
The analyses by these authors of data from nearly 5000 residents who had lived for at least 5 years near any of six major European airports showed that noise annoyance is positively associated with blood pressure (Babisch *et al.* 2007)<sup>7</sup>; that aircraft noise during the day was not significantly associated with hypertension; that aircraft noise during the night was significantly associated with hypertension only for residents highly annoyed by aircraft noise during the day, but not for residents less annoyed (Babisch *et al.* , 2008).

Thus, there is clear evidences<sup>8</sup> provided by the above studies that there is, within the ranges of sound-exposure levels assessed, no direct effect of environmental noise exposure on health as measured by raised blood pressure when controlled for by noise annoyance. With Kroesen *et al.* I concur that in situations of no noise there will be no noise annoyance. But in most real life situations zero noise is highly unlikely to become any near-term goal. Then, it will stay important to know the (cost-)effectiveness of alternative measures reducing detrimental health effects from noise exposure. Consequently, information about the role of potential mediators will be of utmost importance.

In line with the emphasis of Observation 15 of the Executive Summary on ‘well being’, and of Observation 7 on noise annoyance as a major risk to this well being **I suggest to rewrite Observation 10 and 15 so as to better reflect the empirical evidence of the pivotal role of noise annoyance (and, thus, of measures to reduce noise annoyance) in preventing or reducing detrimental health effects like hypertension.**

<sup>6</sup> Although this study is referenced in the draft report (p. 66), nowhere in the report I have found the findings of the report discussed.

<sup>7</sup> See also the

<sup>8</sup> On the basis of the strengths of effects reported from these large scale studies, I would call the evidence *fairly strong* for aviation noise exposure. For road traffic noise exposure a different evaluation may be required.

## Appendix C

### Additional Comments

#### REFERENCES:

- Babisch, W., D. Houthuijs, G. Pershagen, K. Katsouyanni, M. Velonakis, E. Cadum, M.L. Dudley, G. Bluhm, O. Breugelmans, A. Charalambidis, K. Dimakopoulou, P. Savigny, I. Seifferta, J. Selander, P. Sourtzi, W. Swartz, F. Vigna-Taglianti, L. Järup (2007) *Association between noise annoyance and high blood pressure*, Proceedings of the INTERNOISE-2007 Congress, Istanbul
- Babisch, W., D. Houthuijs, G. Pershagen, K. Katsouyanni, M. Velonakis, E. Cadum and L. Järup (2008) *Hypertension and exposure to noise near airports-Results of the HYENA study*, Proceedings of the 9<sup>th</sup> International Congress on Noise as a Public Health Problem, (ICBEN), Foxwood CT.
- Kroesen, M., P.J.M. Stallen, E.J.E. Molin, H.M.E. Miedema, H. Vos, S.A. Janssen, B. van Wee (2008) *Assessing the role of mediators in the noise-health relationship via Structural Equation Analysis*, Proceedings of the 9<sup>th</sup> International Congress on Noise as a Public Health Problem (ICBEN), Foxwoods CT.
- Maris, E., P. J. M. Stallen, R. Vermunt and H. Steensma, (2007a), Noise within the social context: Annoyance reduction through fair procedures, *The Journal of the Acoustical Society of America* **121**, pp.2000-2010.
- Maris, E., P. J. M. Stallen, R. Vermunt and H. Steensma, (2007b) Evaluating noise in social context: The effect of procedural unfairness on noise annoyance judgments, *The Journal of the Acoustical Society of America* **122**, p.3483–3494, (2007).
- Niemann, H., X. Bonnefoy, M. Braunbach, K. Hecht, C. Maschke, C. Rodrigues and N. Röbbel (2006) Noise-induced annoyance and morbidity results from the pan-European LARES study, *Noise & Health* **8** (31), p.63-79
- Van Kamp, I., R.F.S. Job, J. Hatfield, M. Haines, R.K. Stellato, S.A. Stansfeld (2004) The role of noise sensitivity in the noise-response relation: a comparison of three international airport studies, *Journal of the Acoustical Society of America*, **116** (6) p. 3471-3478