RESPONSE TO FICAN COMMENTS ON LOW FREQUENCY NOISE EXPERT PANEL REPORT

June 18, 2003

INTRODUCTION

The Low Frequency Noise Expert Panel of the Richfield-MAC Noise Mitigation Agreement of 17 December 1998 (the "Expert Panel") produced a 227 page, three volume report of its findings in April 2000. The report documents the findings of extensive laboratory and field measurements of low frequency noise and its effects, including a comprehensive review of the technical literature on low frequency noise effects, with well over 100 illustrations and 150 references. Two of the three members of the Expert Panel attended a meeting with FICAN in Washington on 27 June 2001 to describe the findings. More than a year after this meeting, FICAN posted seven pages of commentary on the Expert Panel report on its website.

The Expert Panel prepared this response to raise important issues about these FICAN comments. It particular, panel members want to assure that these responses are publicly available, so that FICAN's dismissive and frequently incorrect analysis of the Expert Panel's work does not prevent full knowledge of the Panel's work as further efforts are undertaken to understand and mitigate community annoyance caused by low-frequency aircraft noise.

This response reflects the consensus views of all three members of the Expert Panel, but not necessarily those of the sponsors of the original work, the Metropolitan Airports Commission and the City of Richfield.

Area of apparent agreement

The Expert Panel is pleased that FICAN concurs with its basic finding that the low frequency noise in question "*will not pose a public health risk, risk of structural damage or an increase in speech interference*". The Panel also acknowledges and appreciates FICAN's agreement that "*noise-induced vibration may heighten reaction to the event*". Given this basis for common understanding, the Panel is disappointed that FICAN's comments have diverged widely from this common ground.

FICAN acknowledges the "wealth of information" that the Expert Panel report contains, but is generally dismissive of its findings. FICAN takes particular exception to

- the noise metric that the Expert Panel developed to predict annoyance due to rattling noises;
- the decision of the Expert Panel not to make vibration measurements;
- drawing inferences from the combined information of social surveys conducted at

different airports; and

- the utility of the Expert Panel's findings for purposes of land use planning.

The Expert Panel takes issue with FICAN's divergence below. For the reader's convenience, the Expert Panel's reply is organized in the same sequence of topics as FICAN's comments. Superscripts identify supporting endnotes. The Expert Panel believes that FICAN's objections (reproduced in *italics*) misconstrue important aspects of its report, and are not supportable on technical grounds.

ANALYSIS OF FICAN COMMENTS

I) EFFECTS OF LOW FREQUENCY AIRCRAFT NOISE

Relationship between perceptible vibration and annoyance

> " *World Health Organization (WHO) in its new guidelines [WHO, 1999]. The FICAN also notes studies of other transportation sources, such as trains, that found a similar relationship [Öhrström, 1997]. However, it is not a foregone conclusion that the presence of vibration increases annoyance."*

FICAN attributes to the Expert Panel a conclusion that it does not make. The Expert Panel did not limit its attention to the annoyance of vibration *per se*, nor did it rely for its conclusions on an assumption that vibration increases noise-induced annoyance. The primary focus of the Expert Panel's work was on the annoyance of rattling noises associated with low frequency aircraft noise, not on the annoyance of whole body or perceptible vibration. The original research conducted by the Expert Panel concentrated on analyses of the annoyance of secondary emissions (audible rattling noises created by light architectural elements and household paraphernalia) in homes.[1]

FICAN's suggestion that vibration may not always increase annoyance is not directly relevant to the Expert Panel's documentation of the association between the annoyance of rattling noise and low frequency aircraft noise levels. Because the Expert Panel's primary interest was in quantifying community reaction to rattle produced by low frequency airborne acoustic energy, rather than in measuring structureborne vibration, the issue of perceptible whole body vibration is tangential to the Panel's conclusions.

Relevance of Laboratory vs. In-home findings

> *"The FICAN's own experience with studies of sleep disturbance demonstrated that discoveries made in laboratories frequently are not replicated in subsequent field studies [FICAN, 1997]. With respect to noise induced vibration and annoyance, a NASA study of helicopter noise did not find any increase in annoyance in which the events, based on measured noise levels, should have produced appreciable rattle [Powell and Shepherd, 1989]."*

FICAN's observations indicate 1) that findings of laboratory studies of noise-induced sleep disturbance may not be relevant to field experience (as documented by Pearsons *et al.* in 1995), and 2) that one technical report of a study of the annoyance of helicopter noise did not reveal an association between a mean annoyance rating and the A-weighted equivalent level of helicopter overflights that "were either between 500 ft and 1000 ft or greater than 1500 ft from the single family dwellings" (Powell and Shepherd, 1989).[2] Given the insensitivity of the A-weighting network to low frequency energy, one would not expect the A-weighted measurements reported by Powell and Shepherd to reliably reflect differences in low frequency sound levels that would correlate with the degree of building vibration or rattle. Thus, these data are of little value for evaluating annoyance due to rattle.

Powell and Shepherd (1989) account for the absence in their laboratory study of increased annoyance to noise accompanied by sounds of rattling glassware by suggesting that "because the glassware did not belong to the test subjects, they were not annoyed by the possibility of damage." FICAN's comment also does not take account of the findings of two later and larger scale social surveys of the annoyance of aircraft noise-induced rattle that were more closely related to the Expert Panel's work (Fidell, Silvati, Pearsons, Lind, and Howe, 1999, and Fidell, Pearsons, Silvati, and Sneddon, 2002). These peer-reviewed publications of studies conducted in residential areas near two airports demonstrate the utility of LFSL as a predictor of the prevalence of a consequential degree of annoyance associated with aircraft noise-induced rattle.

Given that the comment acknowledges the limited generalizability of the findings of laboratory studies to residential settings, one might expect that the results of community studies of the annoyance of rattle-induced annoyance would be more persuasive than less direct linkages between measurements of vibration and laboratory judgments of annoyance.

Objections to non-technical aspects of Expert Panel's analyses

> *"It is also important to note that the FAA had used criteria that included both window rattling and wall vibration in the approval of low-frequency noise mitigation for BWI...."*

The Expert Panel was chartered to focus on technical issues, not on the administrative practices of regulatory agencies. Objections to the Expert Panel's findings on non-technical grounds overlook the statement in Section 2.2 of the Expert Panel report that "clear distinctions must be maintained

- between a noise descriptor and criteria relating the descriptor to a predicted effect;
- between such criteria and an environmental policy based on a particular value of a noise descriptor; and
- between technical and other reasons for preferring certain noise descriptors."

FICAN's comment may reflect the limited information available about community response to low frequency aircraft noise prior to completion of the Expert Panel's work. FAA-funded engineering studies on which the agency's administrative rationale for approving low frequency noise mitigation at BWI were conducted prior to publication of the Expert Panel's studies. Given what has since been learned about the relationship between the annoyance of rattling noises and outdoor levels of low frequency aircraft noise, no technical rationale supports the necessity for basing predictions of annoyance due to rattle exclusively on house-specific vibration levels.

Applicability of BWI Study

> *"The FAA offered technical advice to the Policy Committee during the development of the MSP study plan that drew on the experience of the BWI Study. Among the advice was to use the 'Hubbard criteria' cited in the BWI study [Hubbard, 1982]...The Expert Panel findings do not address why this FAA precedent was ignored."*

The terms of the Richfield-MAC Noise Mitigation Agreement of 17 December 1998 established two distinct bodies: one for policy considerations, and one for technical considerations. The comment implies that FICAN expected the Expert Panel — a separate body with a charter different from that of the Policy Committee — to adopt an FAA-favored *vibration* criterion for its analyses of reactions to rattling *noises*. The comment further suggests 1) that in FICAN's view, the technical findings of the Expert Panel investigation should have been consistent with FAA's policy preferences, and 2) that the Expert Panel ignored FAA's interpretation of Hubbard's findings. Neither of these beliefs is applicable to the work of the Expert Panel.

Consideration accorded to Hubbard's work

The Expert Panel was well aware of both Hubbard's work and of FAA's policy preferences prior to FAA's advice to the Policy Committee. Hubbard's work is cited in more than 20 places in the Expert Panel report. Appendix B (specifically, Sections B.4, B.5, and Figures 94 and 100) of the Expert Panel report contains extensive analysis and discussion of the technical nature and relevance of the work of Hubbard and of many other researchers to the Expert Panel's concerns.

Annoyance due to rattle and the noticeability of whole body vibration are distinct matters. Primary structural elements of residences such as walls and floors need not noticeably shake for people to be highly annoyed by the noise of secondary emissions of light architectural elements and bric-a-brac. Hubbard's vibration measurements do not in themselves address or support useful prediction of the annoyance of rattling noises.

Hubbard measured vibrations produced by several noise sources (*e.g.*, aircraft, helicopters, wind turbines and sonic booms) with various spectral characteristics and levels. However, Hubbard's study was not designed to be dispositive of low frequency aircraft noise problems in airport neighborhoods, nor of the annoyance of rattle produced by low frequency aircraft noise. More to the point, Hubbard's criterion was not based on an evaluation of the frequency response characteristics of buildings, but on (1) an experimentally-derived, frequency-independent relationship between peak sound level and peak building acceleration, and (2) one ISO standard for the frequency-dependent human perception to vibration in terms of acceleration. These data are shown in Fig. 94 (page III-39) and Fig. 100 (page III-48), respectively, of the Expert Panel Report. The resulting Hubbard criteria define estimates of sound levels required to produce perceptible vibration, not rattle.

In contrast, the Expert Panel report develops an experimentally validated, frequency-dependent, vibro-acoustic structural response model and more thoroughly validated frequency-dependent human perception vibration criteria, presented in detail in Sections B.4 and B.5 (pp III-37 to III-51). These were used to define a more accurate, frequency-dependent model for predicting sound levels required to produce perceptible vibration of building components. The net result was a demonstration that the Hubbard criterion, while a reasonable approximation, was generally too conservative in the low frequency range of interest (see. Fig. 102, page III-49 of the Expert Panel Report).

Even more pertinently, Section B.6 of the Expert Panel Report develops a frequency-dependent model for the probable occurrence of rattle. The predicted values for the probability of rattle onset in various building components vs. the Low Frequency Sound Level (LFSL) descriptor were consistent with observed trends in annoyance from rattle (see Fig. 67, page II-91 of the Expert Panel Report).

In short, the Expert Panel developed a far more precise evaluation of acoustically-induced building vibration than was available from Hubbard's work. This evaluation produced estimates of the onset of rattle consistent with the subjective response data on annoyance from low frequency aircraft noise. This consistency provided further validation of the dose-response relationship developed in the Expert Panel's report for general land-use planning purposes.

Logical necessity for vibration measurements

> *"Finally, the MSP study failed to demonstrate that the phenomena would occur in the selected communities due to the absence of direct measurements of vibration."*

This comment implies that indoor measurements of vibration are somehow necessary to legitimize findings about the annoyance of rattling noises. A requirement for indoor measurements is not consistent with FICAN-approved practice for all other forms of aircraft noise measurement. FICAN does not argue, for example, that the indoor cumulative noise exposure of residents of airport neighborhoods must be documented before findings about the prevalence in a community of annoyance due to aircraft noise merit consideration.

The purpose of the measurements made by the Low Frequency **Noise** Expert Panel was to predict community response to low frequency aircraft noise, not to vibration. Measurements of structureborne vibration levels have neither a direct nor a consistently linear relationship to levels of secondary acoustic emissions inside residences. The Expert Panel's work did in fact demonstrate annoyance due to rattling noises, and closely linked the prevalence of such annoyance to the level of an outdoor measurement of outdoor aircraft noise levels. It is both doubtful and largely irrelevant whether costly and strongly location-dependent measurements of vibration levels could have accounted for any more of the variance in the annoyance reports than the broader, area-wide outdoor low frequency noise measurements actually did.

The dependency of vibration levels on sensor position would lead to considerable variation among houses, among structural assemblies within the same house (*e.g*, on walls oriented toward or away from a runway), and among specific locations within the same structural assemblies. For the same value of LFSL, structural vibration levels would vary markedly — probably by an order of magnitude or more

— for any practical protocol for positioning vibration sensors. A lower correlation between annoyance response and structural vibration response would thus have been unavoidable, vitiating any potential advantage of representing dosage by means of vibration measurements.

For reasons noted above, the claim that "*the absence of direct measurement of vibration*" somehow compromises the credibility of the findings of the Expert Panel is also inconsistent with FICAN's approving citation of the study of Powell and Shepherd (1989). (Recall that Powell and Shepherd reported only A-weighted measurements of helicopter noise, and made no measurements of helicopter-induced vibration levels in any home.) In fact, the comment does not challenge the evidence that the Expert Panel produced that annoyance due to rattling noises, both in neighborhoods near LAX and near MSP, increases in orderly relation to increasing levels of airborne low frequency *noise* produced by aircraft operations. Given the well-defined general vibro-acoustic response characteristics of residential structures, such an orderly relationship would be expected.

II) DESCRIPTORS OF LOW FREQUENCY AIRCRAFT NOISE

Supposed "artificiality" of LSFL

> *"The FICAN is not comfortable with the proposed measure on several grounds. First, LFSL is an artificially constructed single event noise metric that is the arithmetic average of the maximum sound levels in the one third octave bands from 25 to 80 Hz during a given event. In other words, the metric will often be made up of one-third octave-band frequency data measured at different times during a particular event. No other noise metric used in airport noise analysis is artificially constructed in such a manner. The FICAN finds little scientific justification for this artificial construction."*

Characterization of LFSL as "*artificially constructed*" suggests that other metrics used to predict community response to transportation noise are somehow more "natural".[3] Although this claim merits more detailed examination than is appropriate for this reply, discomfort with the "*artificial*" nature of LFSL is inconsistent with the standard federal practice of basing predictions of community response to transportation noise on indices constructed primarily for convenience of characterization of noise exposure.

FICAN's recommendation of indoor vibration measurements is ironic, given that LFSL and every other descriptor of aircraft noise acceptable to FAA is measured outdoors. Structural vibration, like indoor rattle, is idiosyncratic to individual structures. As noted above, this is a major reason that the Expert Panel preferred a broader measure of outdoor low frequency noise in the community rather than a highly sensor location-dependent measure of indoor vibration as a predictor of annoyance due to rattle. When every other aircraft noise metric acceptable to FICAN is measured outdoors, it is unreasonable to characterize LFSL as uniquely inconsistent and "artificial".

The objection that "*The FICAN finds little scientific justification for this artificial construction*" is thus misleading, since it implies that FICAN finds sufficient scientific justification for more "naturally" constructed noise metrics. In fact, noise metrics on which FICAN relies to predict community response to aircraft noise are <u>all</u> engineering expedients with scant theoretical linkages to community response.

The relationship between FICAN's preferred predictor of community noise exposure (DNL) and community response accounts for less than half of the variance in the prevalence of a consequential degree of noise-induced annoyance in a very large body of social survey data. DNL is also highly insensitive to low frequency aircraft noise (see Section 2.3 of Expert Panel report), completely insensitive to well-documented non-acoustic determinants of annoyance, and can produce highly inaccurate and demonstrably biased predictions of community response to aircraft noise. None of the inconveniences, limitations, and manifest artificialities of DNL prevent FICAN from endorsing the noise metric as a preferred and universal predictor of community response to transportation noise exposure.

In short, there is no technical basis for FICAN's rejection of LFSL as artificial and unscientific that does not apply in equal or greater measure to other noise metrics that FICAN endorses to describe aircraft noise.

Objection to rejection of ANSI standard

> *"Another concern is that the ANSI standard for evaluating low-frequency noise was rejected by the Expert Panel because it depends upon obtaining sound pressure levels in the 16 Hz one-third octave band, which are not typically available through aircraft noise certification. This does not seem to be a sufficient reason to reject its use when field measurements would be required in any future study of low-frequency noise impact around airports."*

FICAN cites <u>one</u> of the reasons that the Expert Panel provides in Section 2.5.3 of its report for recommending against the L_{LF} metric of ANSI S12.9, Part 4 for predicting the annoyance of rattling noises due to low frequency aircraft noise. FICAN's comment does not mention two additional reasons stated in the same section of the report for rejecting the metric: 1) the lack of experience (to this day) in application of the metric to aircraft noise analyses; and 2) the awkward and indirect translation of L_{LF} measurements into an equivalent A-weighted noise level rather than directly into a prediction of the prevalence of rattle-induced annoyance. FICAN's comment also ignores the Expert Panel's interest in a metric that the INM could eventually model. The availability of noise data for modeling is a critical condition for use of the INM. The aircraft certification data underlying the INM data base do not include 16 Hz data.

At the time of the Expert Panel's evaluation of alternative metrics, only one noise descriptor (LFSL) had been successfully applied to prediction of the annoyance of rattling noises induced by aircraft noise. The Expert Panel was also aware that the spectral range of alternate metrics (including both L_{LF} and the G-weighting curve) extended below the frequency range in which the jet engines that power large transport aircraft emit much energy, and into a frequency range in which helicopter rotor systems and large industrial fans emit considerable acoustic energy.

FICAN's comment does not acknowledge the Expert Panel's practical concern for the use of standard instrumentation-grade microphones, pre-amplifiers, and recorders for making field measurements. FICAN's objection might nonetheless be based on a concern that LFSL does not measure the small amount of noise emitted by jet transport aircraft at frequencies at the lower end of the 16 Hz octave bandpass. If so, FICAN did not attend to the information presented in section 2.6.1 of the Expert

Panel report, which indicates (in pertinent part) that

> "For purposes of predicting rattle produced by the noise emissions of aircraft ground operations, a low-frequency noise metric need not encompass *all* of the low-frequency energy produced by jet engines. (When used as a predictor of rattle, the critical issue is not the scaling factor of the predictor, but the correlation of the descriptor with the prevalence of rattle-induced annoyance.)"

In other words, any reasonable measure of low frequency spectral content, as provided by the LFSL descriptor, will accurately indicate the presence of potentially rattle-inducing building vibration and hence serve as a reliable measure of the "dose" for correlation with annoyance responses. The use of an alternate bandwidth for the descriptor would not have changed the general pattern of the empirical LFSL vs. annoyance relationship.

"An ANSI Standard undergoes intense technical scrutiny before adoption..."

One of the members of the Expert Panel who was a member of the ANSI working group that drew up ANSI S12.9 attests that: (1) there was no database whatsoever to support the descriptor LLF; and (2) no ballot response to the adopted standard from any of the ANSI S12 members was received concerning this descriptor. The L_{LF} descriptor was selected empirically, as a reasonable measure of low frequency spectral content that could be safely expected to provide a predictor for building vibration. Since the standard was intended to apply to all sources of low frequency energy, including such narrow-band spectral sources as power plant system noise, it was considered prudent to include the 16 Hz band, which corresponds closely to the typical resonance frequency of residential building walls. No such spectral provision was needed in the LFSL descriptor, given the much broader aircraft-generated low frequency spectrum (as noted above).

Objection to ambiguous threshold for "valuation" of LSFL

> *"The proposed threshold (LFSL = 60 dB) is very nebulous as judged by the lack of clarity in its valuation and its origin in residential surveys...."*

FICAN makes one explicit and one implicit claim in this objection: 1) that the "valuation" of LFSL is not clearly defined, and 2) that a noise metric intended for use as a predictor of the annoyance of rattling noises should not reflect information provided by people asked about the annoyance of rattling noises in residential surveys. Neither claim withstands close examination.

"...lack of clarity in...valuation [of LFSL]"

There is nothing nebulous about the definition of the LFSL noise metric provided in Section 2.6 of the Expert Panel report:

> "LFSL is a single-event noise metric that sums the maximum one-third octave band sound levels from 25 to 80 Hz, inclusive, that occur during the course of an individual aircraft passby."

FICAN's concern is evidently with dosage rather than its metric, since the comment about the "valuation" of LFSL seems to refer to a footnote to a bullet on page II-34 of the Expert Panel report:

"• The estimated low-frequency noise levels were adjusted to reflect the measurements made at six sites within the interviewing area. (Original footnote 5, immediately below)"

"5. This final step took into account not only the absolute values of the measured LFSL values of aircraft noise events, but also their distribution function. The value sought was not the single maximum noise event level, but the arithmetic mean of the maxima of LFSL values of aircraft noise events in excess of 75 dB. Since the bulk of the aircraft noise event maxima exceeded 75 dB, the average LFSL value of the maxima in excess of 75 dB was little different from the average of aircraft noise events with LFSL values in excess of 60 dB. The average of the maxima of noise events in excess of 75 dB corresponds approximately to the 70th centile of the distribution of maximum LFSL values."

The bullet and the footnote describe one aspect of the care taken to assign appropriate LFSL values to the individually geo-coded street addresses of residents of a runway sideline neighborhood near MSP. Two different types of information — field measurements and C-weighted maximum noise level contour information — were reconciled to minimize errors of estimate of low frequency aircraft noise dosage, although in principle, a separate value could have been directly measured at each residence.[4] Cumulative distribution functions of LFSL values were calculated from direct acoustic measurements made at six locations within the interviewing area. C-weighted contour information was produced by the then-current Version 6.0 of FAA's Integrated Noise Model Software. Figure 24 of the Expert Panel report shows the relationship between the two sources of information at each of the six sites.

Footnote 5 of the Expert Panel report explains that LFSL values used to predict the prevalence of a consequential degree of rattle-induced annoyance in the community corresponded to the 70th centile (L_{30}, in Schultz's terminology) of the distribution of maximum LFSL values actually measured in the field.

FICAN's comment about *"The proposed threshold (LFSL = 60 dB)..."* thus applies not to the LFSL noise metric, but to one step in the reconciliation of measured LFSL values with C-weighted maximum noise contours. Both sources of information were used to estimate low frequency aircraft noise exposure at the homes of individual survey respondents.

"...origin [of LFSL] in residential surveys..."

The notion that a noise metric or dose measurement intended for use as a predictor of the annoyance of rattling noises should not reflect information provided by people asked about the annoyance of rattling noises is a peculiar one. It implies, for example, that metrics and definitions of dosage for assessing community response to noise that do not reflect people's reactions to noise should be preferred to those that do.

FICAN's objection to identification of a value of LFSL to represent a noise dose that occurs "*a few times a day is so meaningless as to make the* ***metric*** *almost meaningless* ***[emphasis added]***" is mis-aimed. FICAN's comment does not address the unit of measurement, but the definition of dose. If FICAN prefers not to define low frequency aircraft noise dosage as residents of airport neighborhoods do, it should provide the technical evidence that supports selection of a different centile level of a distribution of LFSL values as a better predictor of the annoyance of rattling noises inside residences. Since correlation is insensitive to constants, however, defining dose as a different value of LFSL (say, dosage as defined at MSP and LAX, ± 5 dB) will not affect the predictability of response from dose.[5] The net practical effect of changing the definition of dose in the same units is nil.

> *"How can an authority prioritize mitigation actions when all there is to judge the situation is "a few more" or "a few less" times a day?"*

FICAN's question is rhetoric, not analysis. A dose of low frequency aircraft noise expressed in LFSL units is a definite, well-specified quantity of acoustic energy, expressed in units of decibels. It is neither more nor less interpretable than any other acoustic quantity expressed in decibel units. The fact that a particular value of LFSL selected to represent dosage corresponds to a particular centile value in a distribution of low frequency noise events (say, the 70th centile, as at MSP) is immaterial. Picking a different centile (say, the median, or 50th centile) as a definition of dose changes only a constant, not the interpretability of the dose.

> "*The factors of amplitudes of the events, times of day, and number of occurrences are all equally important to fairly assess noise impact as demonstrated in the current Federal criteria based upon DNL. However, these factors, especially numbers of occurrences, are not part of the proposed metric.*"

The rationale for cumulating A-weighted aircraft noise and normalizing the resultant measure to 9 and 15 hour sub-periods for purposes of predicting community response is that all noise produced by aircraft overflights over the course of a day is annoying in some degree. The Expert Panel has documented that the annoyance of rattle produced by low frequency aircraft noise is episodic ("a few times a day") rather than continuous in nature: not every airplane produces annoying rattling noises. FICAN nonetheless asserts a preference for a DNL-like cumulative measure of low frequency aircraft noise.

FICAN's comment does not distinguish between the definition of dosage with its units of measurement, especially in the complaint that numbers of occurrences are not explicitly taken into consideration (*v.s.*). The definition of dose selected by the Expert Panel does in fact express "the numbers of occurrences" and "the amplitudes of the events" (as maximum 1/3 octave band levels during the course of an aircraft noise event). If FICAN believes that an arbitrary penalty should be added to LFSL to account for rattling noises during customary sleeping hours, it must be prepared to show that doing so will further improve the predictive utility of the dose measure.

FICAN's assertion ignores empirical evidence that the measure of dose identified by the Expert Panel supports a linear regression that accounts for 88% of the variance in reports of the notice of rattle at two airports (*cf.* Figure 29 of the Expert Panel report) and essentially all of the variance in reports of high annoyance with rattle; and that the prevalence of high annoyance linked to aircraft noise is greater than predicted by DNL (*cf.* Figure 32 of the Expert Panel report) among residents living in both acoustically treated and untreated homes in neighborhoods exposed to low frequency aircraft noise.

Given that dosage as measured in units of LFSL accounts for nearly all of the variance in the notice and annoyance of aircraft-induced rattling noises in homes, it is unlikely that a different predictor variable could account for yet more — especially since DNL, FICAN' favored predictor of annoyance, accounts for only about half of the variance in the annoyance of aircraft noise, and very little of the variance in the annoyance of aircraft noise-induced rattle.

LFSL as a surrogate for vibration measurement

FICAN asserts that

"...it is important to remember that LFSL is a surrogate for assessing the effect of perceptible vibration, as it is not a direct, physical measurement of the vibration phenomena."

This comment reflects, incorrectly, FICAN's assertion that the Expert Panel focused on noise-induced vibration. The issue on which the Low Frequency **Noise** Expert Panel focused was the annoyance of rattle, not the annoyance of perceptible vibration. Physical measurement of vibration is no more of a necessity for prediction of the annoyance of rattling noises than it is for prediction of any other form of noise-induced annoyance. Any physical measure of low frequency acoustic energy emitted by aircraft that correlates highly enough with the prevalence of a consequential degree of annoyance with rattling noises in residential settings can productively serve as a predictor of the annoyance of rattle.[6]

FICAN's comment implies that unless the walls and floors of a dwelling vibrate strongly enough to produce perceptible whole body vibration, no physical basis can exist for adverse community reaction to low frequency airborne noise. It is not the case, however, that walls and floors must vibrate strongly enough to produce perceptible whole body vibration before windows, teacups, windows, ductwork, picture frames and other household paraphernalia can rattle. LFSL, an outdoor noise measurement, is a demonstrably useful predictor of the ability of individual low frequency aircraft noise events to generate audible secondary emissions inside dwellings.

III) Relationship between Low Frequency Noise and Annoyance

Structure of Questionnaire

"...the FICAN has strong misgivings about the questionnaire used in this study....the survey did not seem to afford the residents the opportunity to indicate whether other sources, such as wind or road traffic, could also cause vibration or rattling in the home."

FICAN's strong misgivings are misplaced. As indicated in Section 4.2.1 of the Expert Panel report, "For the sake of comparability of findings with those documented in communities near other airports, the detailed methods of the current study closely resemble those of similar social surveys conducted elsewhere (*cf*. Fidell, Barber and Schultz, 1991; Fields, 1998). These surveys include many of those relied upon by FICON (1992) in developing its dosage-response relationship for community response to aircraft noise exposure."

The questionnaire was introduced as a study of neighborhood living conditions. Respondents were asked first about the most and least favored aspects of neighborhood life; then whether they viewed their neighborhoods as quiet or noisy; then whether they were annoyed by street traffic noise; and then whether they were annoyed by aircraft noise. FICAN does not indicate where else questions about notice of "vibrations or rattling sounds" should logically have been posed if not after these initial questions.

If FICAN believes that sources of low frequency noise other than aircraft could have accounted for the findings of the Expert Panel, it must indicate why wind speed and traffic noise are highly correlated with runway sideline distance. In fact, wind and traffic acted uniformly on all neighborhood residences in the interviewing area, and thus could not have correlated highly with a measure of low frequency noise created by aircraft operations (*cf.* Figure 21 of Expert Panel report).

FICAN's suggestion that wind or traffic noise could "*also cause vibration or rattling in the home*" must be strongly questioned. Estimates of the fluctuating component of wind pressures for` average wind speeds of about 11 MPH for the Minneapolis area indicate a possible vibration of typical residential building walls (see Table 28, p. III-45 in the Expert Panel Report) of the order of 0.0025 g, about 25% of the estimated rattle threshold value given on page III-52 of the Report. While it might be argued that higher wind gusts could still be a cause of building vibration, such atypical wind gusts would occur irregularly during weather cycles with periods of the order of days instead of the low frequency noise from the more regular daily pattern of aircraft operations. Furthermore, ambient low frequency noise levels (LFSL), in neighborhoods near MSP, presumably dominated by traffic noise, are about 65 ±3 dB (see Table 17, p II-73 of the Report). This is near the bottom of the 62 to 92 dB range of the aircraft-generated values of LFSL values observed at LAX and MSP.

> *"Coupled with the absence of any physical measurement of vibration in the home, it raises concern that some response bias may be present in the MSP study to elicit evidence of perceptible vibration when none exists."*

The Expert Panel questionnaire was reviewed and approved by the Low Frequency Noise Policy Committee, a body with great sensitivity to political nuance. FICAN nevertheless invokes the specter of questionnaire bias as a potential source of the Expert Panel's findings, arguing that the questionnaire might "*elicit evidence of perceptible vibration when none exists*". FICAN's comments go on to speculate about "*The problem of 'false positive' results*", citing sleep disturbance data as an example.[7]

This comment once again overlooks the primary focus of the Expert Panel on the annoyance of rattle rather than the sensation of vibration. The comment also implicitly calls into question the veracity of self-report by survey respondents, and insinuates that response bias may render annoyance an unreliable indication of aircraft noise impacts. Such misgivings are inconsistent with FICAN's endorsement of the prevalence of a consequential degree of annoyance as the primary indication of community response to transportation noise, and suggest a basic misapprehension about the nature and determinants of annoyance.

Annoyance is an attitude that cannot be directly and objectively measured by microphones, accelerometers, or by inserting electrodes into people's heads. Attitudes are covert mental processes that are subjective by definition, just as the problem of aircraft noise is an inherently "subjective" or "political" problem. If aircraft noise did not disturb people, there would be little reason to measure it. Self-report is the only way to measure attitudes. For FICAN to raise doubts about measurement of adverse attitudes toward aircraft noise effects is to cast doubt on its own reliance on DNL as a predictor of community response to noise exposure.

Commingling of survey results

> *"The FICAN also questions whether it is appropriate to commingle survey results made near LAX with those of MSP. The FAA had many times expressed concern to the Policy Committee that no rms acceleration measurements were obtained in either of the field tests near MSP or LAX as part of the study....To assume that these findings are applicable, one must assume that the residential structures in El Segundo, CA near LAX have similar responses to aircraft noise excitations as those homes in Richfield, MN. As the climates of these two communities are drastically different, structural qualities, such as stiffness and tightness, should be substantially different."*

An objection to "commingling" of survey results from two communities is inconsistent with FICON's reliance on its own dosage-response relationship for predicting the prevalence of annoyance due to aircraft noise. This relationship was constructed not merely from the results of surveys conducted in communities world wide (many of which undoubtedly differed from others in residential construction characteristics), but also from "commingled" data about the annoyance of noise sources as diverse as rail, street, and air traffic. In fact, it is the ability of LFSL to account for most of the variance in the commingled data from two different communities that demonstrates beyond cavil the utility of the noise measure as a predictor of annoyance due to rattle.

This comment reiterates earlier misplaced concerns about the necessity for vibration measurement. Because structural vibration levels have limited value as reliable predictors of levels of rattling noises, interior vibration measurements have little relevance to the Expert Panel's findings about the annoyance of rattling noises.

According to the summary of aircraft noise induced building vibration of Powell and Shepherd (1989) cited by FICAN, the degree of similarity of residential structures in California and Minnesota is a red herring. In discussing several NASA studies of the vibration response of houses, Powell and Shepherd note that "The house constructions investigated covered a fairly wide range typical of the frame and brick veneer houses of the 40's, 50's and 60's....Because of the similarities in spacing, size, and length of the structural members and panels, the different houses had similar vibration characteristics." This topic is also discussed at length in Appendix B of the Expert Panel report.

Likewise, outdoor-indoor noise reduction data for 143 rooms in warm climates and/or 59 rooms in cold climates reviewed in Sutherland (1978) showed no systematic difference in the low frequency noise reduction values — a measure of the relative low frequency structural vibration characteristics of the buildings for acoustic excitation.

IV) ACCEPTABILITY CRITERIA

"More research is necessary..."

> *"It is premature to consider adopting LFSL and the impact criteria without further*

research...."

FICAN's comment ignores the necessity and common practice of making regulatory and policy decisions on the basis of less-than-complete and less-than-certain information.

"...further research is necessary to address the complex interaction between (1) building construction, (2) the contribution of loudness to annoyance, and (3) the contribution of rattle to annoyance."

Microscopic analyses of "complex interactions" are unlikely to facilitate administrative decisions. For the record however, the Expert Panel report identifies and explains the complex interactions between building construction, rattle, and annoyance that FICAN believes only further research can fully clarify. The report also shows summary relationships developed over three decades by (among others) Carden, Findley and Mayes (1969), Hubbard (1982), Sutherland, Chan and Andriulli (1968), Eldred (1985), and Sutherland, Brown and Goerner (1990); addresses vibroacoustic response parameters for windows, brick, concrete block, wood frame construction with and without plaster; and presents careful field measurements of low frequency noise reduction of actual homes, as well as meticulous acoustic intensity measurements in the laboratory of very low frequency transmission loss of purpose-built, full scale wood frame, brick, and stucco residential construction.

The report also notes the likelihood that recent installation of high quality windows may reduce annoyance due to rattle, and quantifies both the probability of occurrence of noise-induced rattle in residential building components, and the actual prevalence of annoyance due to aircraft noise-induced rattle in two different communities. It identifies rattling windows and other light architectural elements as the most likely source of annoying rattle, and demonstrates through direct measurement that conventional aircraft noise mitigation treatments yield no meaningful low frequency noise reduction benefits.

> *"Ideally, the research would be conducted in real houses located within the critical distances from runways...."*

FICAN's suggestion for "further research" is a controlled exposure study in which panels of paid test subjects would make annoyance judgments of aircraft noise events in a few houses. Had the Expert Panel conducted such research, FICAN would undoubtedly have characterized the study as limited in scope, not generalizable to realistic community settings, and susceptible to "false positives". The issue is moot in any event, because FICAN's comments make no commitment to the conduct of any such research. Indeed, given the current national concern with aviation security and other budgetary priorities, it is unlikely that FAA, NASA, or any other federal agency will have the resources or priorities to sponsor additional research in this area in the foreseeable future.

SUMMARY AND RECOMMENDATIONS

FICAN'S comments on the Expert Panel report hold its findings about the utility of LFSL as a predictor of annoyance to standards of rigor and completeness that FICAN's preferred noise descriptors and practices do not meet. Although FICAN claims that its comments "*...take into account the wealth of information presented in the Expert Panel reports along with other pertinent standards, technical reports, and journal articles*", FICAN's objections to specifics of the Expert Panel report do not withstand technical scrutiny.

FICAN's comments are thus of greater interest for what they do not say than for what they do say. FICAN's comments:

- do not deny the existence of annoyance caused by aircraft noise-induced rattle in residences near airports;
- do not claim that A- or C-weighted noise descriptors can usefully predict the annoyance of aircraft noise-induced rattle;
- do not claim that conventional (A-weighted) noise reduction criteria yield any meaningful mitigation of annoyance due to rattle;
- do not identify any alternate technical means (other than costly, impractical, and predictively unhelpful indoor vibration measurements that are inconsistent with other FICAN-endorsed measurement practices) for characterizing the annoyance of low frequency aircraft noise exposure; and
- do not commit to any timetable for addressing the problem of low frequency aircraft noise, apart from a suggestion that small-scale, controlled exposure research, sponsored by unidentified parties, should continue for an indefinite period of time.

The understandings documented in the report of the Low Frequency Noise Expert Panel are adequate to support at least interim criteria for assessments of low frequency aircraft noise impacts. Although "further research" can obviously document additional findings of the same sort as those of the Expert Panel report, it is unlikely that further studies will yield a marked improvement in the technical basis for regulatory policy concerning effects of low frequency aircraft noise in residential areas near airports.

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ENDNOTES

1. Nonetheless, Appendix B of the Expert Panel report deals extensively (in 16 pages and 12 figures) with building response to noise-induced vibration, the production of rattle, and perception of noise-induced vibration of structures. Careful vibration measurements were also made on laboratory test articles.

2. FICAN's comments fail to note substantial differences between the source levels, directivity, and sensitive dependence on flight regime of airborne helicopter impulsive noise versus the noise emissions of jet transports during takeoff and landing. They also fail to take note of an empirical counterexample of a reliable effect of **at least** a 3 dB increase in the judged annoyance of aircraft noise (*not* vibration) unequivocally attributable to faint rattling sounds, as documented in a fully controlled laboratory study (*cf.* Section 3.3.4 of the Expert Panel report).

3. Consider, for example, the concept of "annual average day" aircraft noise exposure. For purposes of constructing airport noise exposure contours in a manner acceptable in FAR Part 150 studies, airport noise exposure is routinely predicted for a hypothetical single day on which all of the factors that affect aircraft noise emissions *simultaneously* assume their mean annual values. On no "natural" day of the year is it plausible that the wind blows all day long from its annual average direction at its annual average speed while the annual average number of each aircraft type in the airport's annual average fleet fly the annual average number of operations at the annual average times of day along annual average flight paths.

For that matter, any noise metric with a time constant grossly discrepant from that of the human ear (about a quarter of a second) is self-evidently artificial. DNL, a noise descriptor with two separate 9 and 15 hour time constants, can hardly be considered a wholly "natural" noise metric. The arbitrary time-weighting of DNL is a greater artifice than the calculation of an average of the maximum levels of six adjacent one-third octave bands — any of which has the potential for exciting audible secondary emissions in household bric-a-brac — during a single aircraft noise event. Given the relatively short duration of low frequency noise events produced by aircraft activity in homes near runways, people are far more able to appreciate the experience of a noise dose measured in units of LFSL than in units of DNL.

Furthermore, no reliable "scientific" evidence exists that 10 dB is the optimal weighting factor to apply to nighttime noise exposure, nor that 10:00 PM to 7:00 AM are the most natural hours during which the factor should apply. Adoption of nighttime weightings a few dB lesser or greater than 10 dB, and time periods an hour or two longer or shorter, are no more nor less supportable on the basis of technical information than those actually used in the definition of DNL. Adoption of an artificially precise 10 dB weighting factor rather than an 8 or 12 dB factor is neither a natural nor a scientific imperative, but rather a matter of artifice, convenience and a preference for round numbers.

FICAN's claim that "No other noise metric used in airport noise analysis is artificially constructed in such a manner" is also incorrect. In recent litigation, FAA has endorsed a noise descriptor that it calls "cumulative certificated noise value". This is a single valued, explicitly "artificially constructed" metric calculated by adding together noise levels measured at points miles apart, at different times, of aircraft in different flight regimes.

Furthermore, as specified in FAR Part 36, calculations of tone-corrected Perceived Noise Levels require averaging of the levels of five half-second samples around the time of occurrence of the maximum tone corrected half-second sample, and substitution of the average value for the value that actually occurs at the time of the maximum value if the maximum level of the tone occurs at a time other than the maximum PNL. Part 36 also permits combining of four adjacent time samples with 1 and 2 second time constants and averaging times, and estimation (rather than direct measurement) of one-third octave band levels by extrapolation as may be required (*i.e.*, at high frequencies and low signal to noise ratios when ambient levels exceed aircraft noise levels).

FAA has in the past also endorsed composite rather than instantaneous spectra for purposes of calculating Composite Noise Rating values.

4. It is no more practical or cost-effective to directly measure LFSL values at the home of every survey respondent than it is to measure DNL values for each survey respondent.

5. It may help to clarify the effect of constants on assessments of community response to noise by considering the effect of adding an arbitrary 5 dB to measured or modeled DNL doses. The resulting noise metric, "L_{dn+5}", will not predict any more or less of the variance in community response to noise in dosage-response analyses than DNL predicts, but will merely shift the exposure value considered "compatible" with aircraft noise from L_{dn} = 65 dB to L_{dn+5} = 70 dB.

6. By analogy, consider the use of DNL as a predictor of the annoyance of transportation noise. The measure was created in the early 1970s as a convenient means of summarizing cumulative noise emissions of transportation noise sources, years before it was discovered that it can fortuitously account for about half of the variance in annoyance prevalence data. DNL intentionally confounds all of the physical characteristics of noise events (level, duration, and frequency of occurrence) that could plausibly give rise to noise-induced annoyance into a single index, yet nonetheless retains FICAN's endorsement as the primary acoustic predictor of community response to aircraft noise.

7. Defining awakenings caused by factors other than aircraft noise as "false positive results" misconstrues the design and intent of the cited studies. It is well documented that people awaken about twice a night for reasons unrelated to noise exposure. If test subjects are instructed to push a button whenever they awaken, irrespective of the cause of awakening, then awakenings unaccompanied by aircraft noise intrusions are not "false positive" responses.