Advancing Aircraft Noise Impacts Research: A White Paper

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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.[1] 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").[2] The criterion establishing significant noise impact from a proposed action

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[1] "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; "Sea-Tac neighbors feel duped over 3rd-runway noise", *The Seattle Times*, December 11, 2008, http://seattletimes.nwsource.com/html/localnews/2008493979_runway11m.html

[2] The FAA recognizes CNEL (community noise equivalent level) as an alternative metric for California.

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).[3]

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.

[3] 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.

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

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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