Annoyance and Sleep Disturbance Roadmaps – New Ideas after 10 Dec 09 workshop discussion: a very crude and informal synthesis

Compiled by R. Girvin
11 Dec 09

Federal Aviation Administration

New material highlighted in yellow

- **Post-1st day inputs from Vince Mestre, David Michaud, Ambrose Clay, Ken Plotkin, Russell Young, Jon Woodward, Arnie Konheim, Nick Miller, Vic Sparrow, Pieter Jan Stallen – THANK YOU**

- **Also tried to include, but likely incomplete inputs from 1st day discussions**

- **Notes:**
  - Initials of contributors for reference
  - Reflects some rewording/editing
  - Interspersed with charts used for 1st day discussion

Considerations

- There may be justification for changing current practice. However, this could not happen quickly. *L*dn was adopted after extensive scrutiny that included testimony before Congress in which the leading acousticians endorsed this metric. EPA pushed all agencies to adopt *L*dn; however, FAA resisted. Congress enacted legislation requiring FAA to review its metric (then NEF), which resulted in FAA adopting *L*dn. In reviewing any change in policy, DoT OST would be concerned on, among others, its effect on other Government agencies, ANSI and ISO. We would need a coordinated effort among all of these organizations. (AK)

Other steps

- **Follow-on intra-agency and/or intra-government only workshop(s)**
- **Papers that synthesize conclusive results (definitive findings) regarding certain issues that continue to be raised – so we have a reference and rationale for discarding them in future studies**

Annoyance

New questions

- What do the experts say happens to people at DNL 65 or greater? (DM)
  - **How much annoyance and to how many people? Once you have consensus on what happens at 65, then your experts can tell you if this means the DNL 65 is adequately protective or not.**
- What (if any) health effects have been attributed to long term annoyance? (DM)
- What about research on innovative mitigation approaches currently not used, e.g., if research showed that white noise at a certain level relative to aircraft noise could substantially reduce or eliminate sleep disturbance in relatively low DNL areas without causing other problems? Low cost solution could be fans for bedrooms instead of soundproofing houses. (RY)

Comprehensive model for annoyance

In ideal world, with unlimited resources, research would develop comprehensive model for annoyance.

- Trust
- Fear
- Culture
- Visual
- Socio-economic status
- Age
- Health

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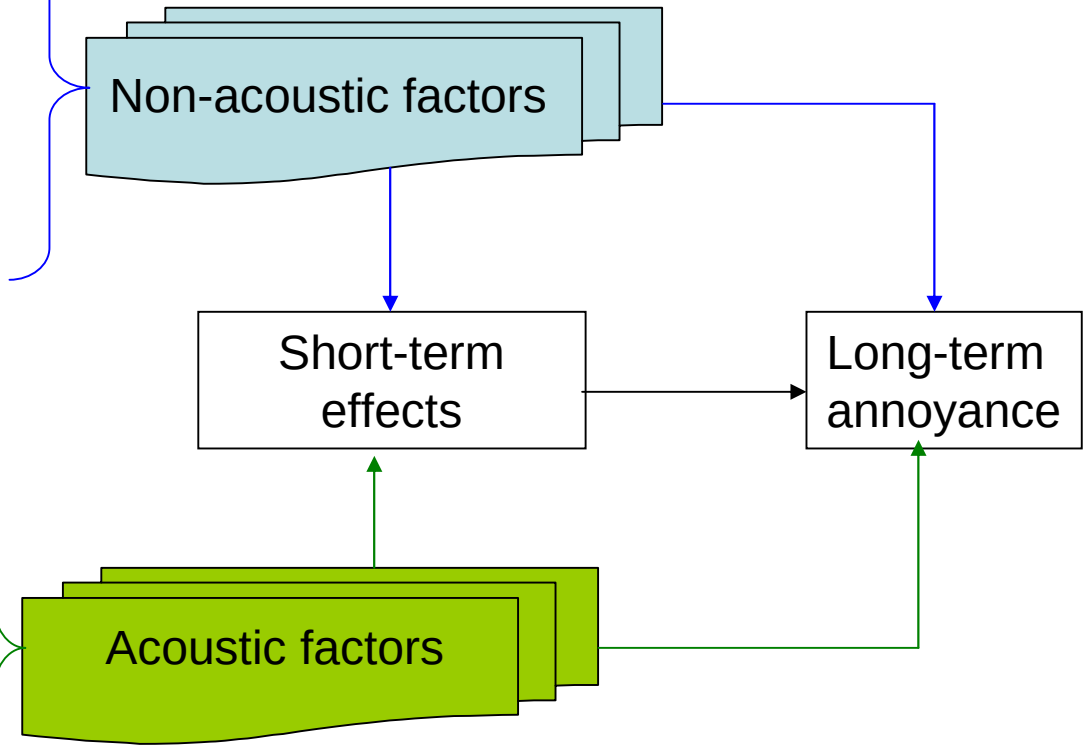


- Max sound level
- No. events
- Time of day
- Vibration/rattle
- Time-varying sound
- Frequency spectrum
- Roughness
- Duration of events
- Tonality
- Ambient sound levels
- Gradual vs. step change

…

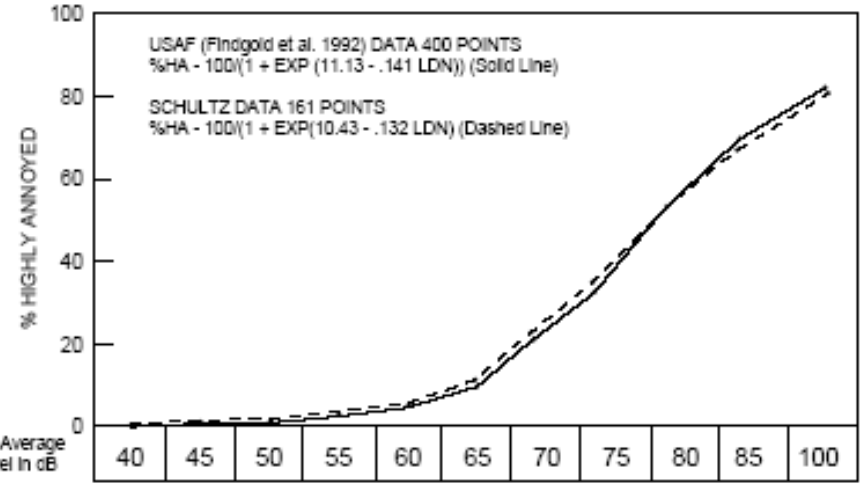
Simple model for annoyance

- Equivalent energy principle with time of day weighting
  - ❑No. events
  - ❑Time of day
  - ❑A-weighted sound level

DNL → Long-term annoyance

Assumptions and/or have sufficient evidence

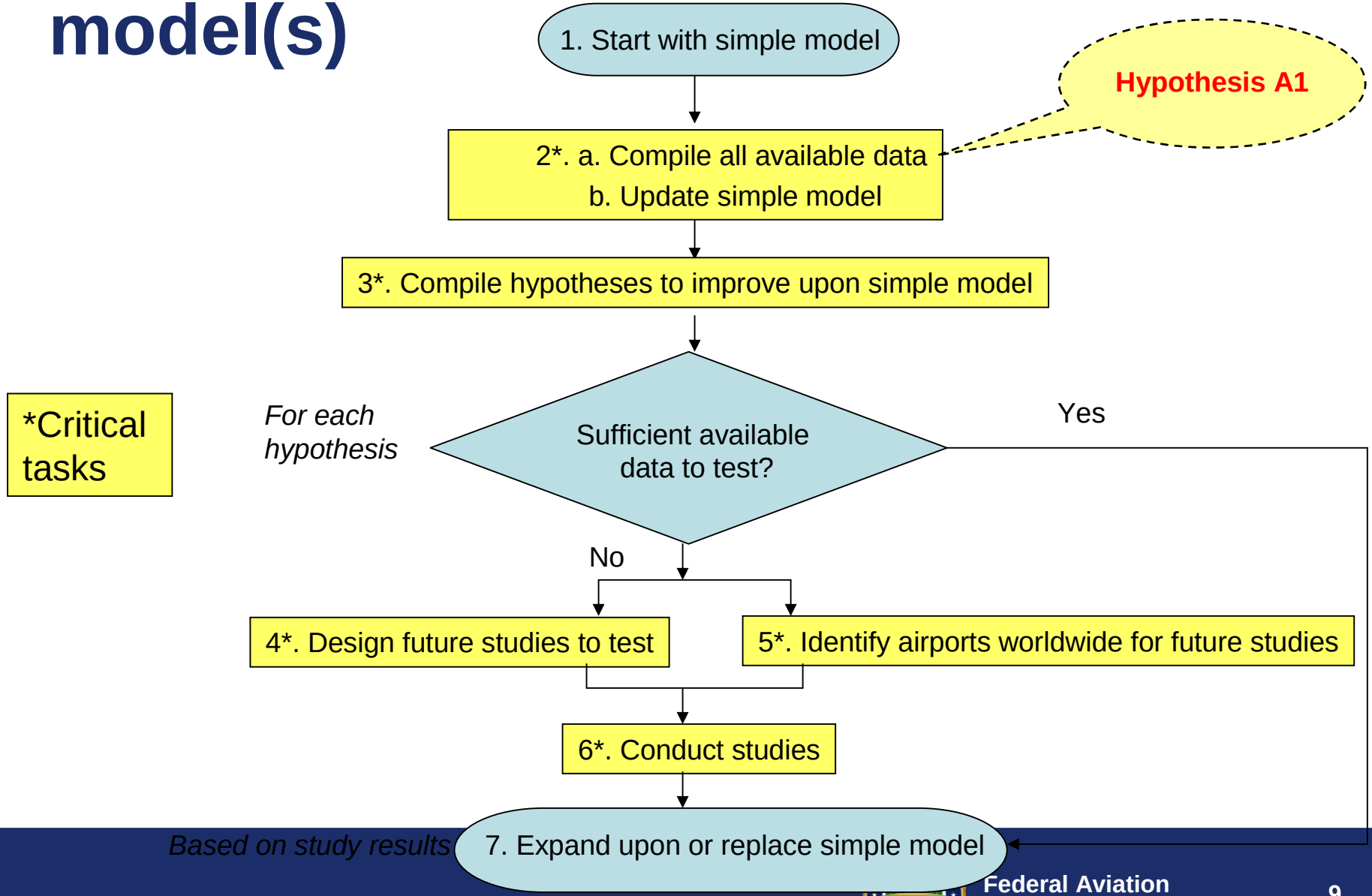
- Relationship bet. DNL & %HA works as a **first-order approximation** of annoyance from long-term aircraft noise exposure



Day - Night Average Sound Level in dB	40	45	50	55	60	65	70	75	80	85	100
Calculated %HA Points: USAF	0.41	0.831	1.66	3.31	6.48	12.29	22.1	36.47	53.74	70.16	82.64
Calculated %HA Points: SCHULTZ	0.576	1.11	2.12	4.03	7.52	13.59	23.32	37.05	53.25	68.78	81

[FICON 1992, Federal Agency Review of Selected Airport Noise Analysis Issues]

Roadmap to improved annoyance model(s)



Hypothesis A1

Data and results from available surveys of community annoyance and aircraft noise exposure can be organized and summarized in a way that permits exploration of a variety of hypotheses to improve upon the simple model of %People Highly Annoyed (%HA) to DNL

- **Parse Schultz data into common groups to better understand data. (VM)**
  - Examples are North America vs non North America data, data pre stage 2 phase out and after phase out, and aircraft vs road vs rail. While policy may be based on composite data, understanding the differences may be helpful.
- **Examine some of the outlier data points in Schultz data. Are there explanations? Should we re-survey some of these communities and see if response has changed and why the high sensitivity in one community and low in another. (VM)**

Simple model for annoyance

- Equivalent energy principle with time of day weighting
  - ❑No. events
  - ❑Time of day
  - ❑A-weighted sound level

DNL → Long-term annoyance

Discussion – Hypotheses A2:

All other things being equal, single %HA vs DNL curve may not be generalizable because of

- *Effect of time: Relationship between DNL & %HA has shifted upward over time*
- *Effect of step change: Relationship between DNL & %HA is shifted upward for communities that experience step change in noise exposure relative to those exposed to gradual change*
- *Effect of type/number of aircraft operations: Relationship between DNL & %HA is different for communities exposed to primarily commercial operations relative to communities exposed to primarily general aviation or military operations.*

Hypothesis A2

A single %HA vs DNL curve may not be generalizable because, despite all other things being equal, of the effects of

Time: Relationship between DNL & %HA has shifted upward over time.

Step changes: Relationship between DNL & %HA is shifted upward for communities that experience step change in noise exposure relative to those exposed to gradual change

Type and number of aircraft operations: Relationship between DNL & %HA is different for communities exposed to primarily commercial operations relative to communities exposed to primarily general aviation or military operations

Alternative models of increasing complexity (1)

- Trust
- Fear
- Culture
- Visual
- Socio-economic status
- Age
- Health

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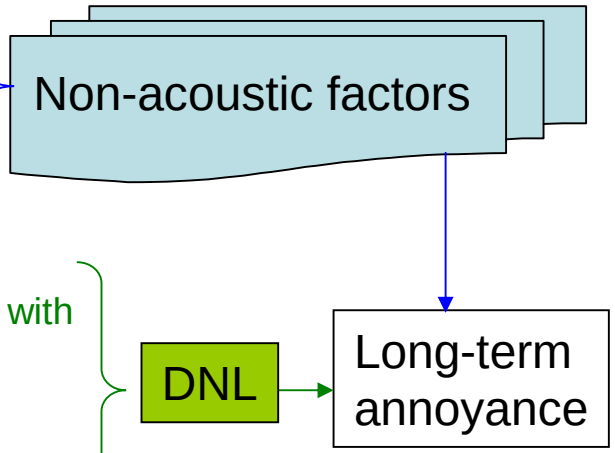
- Equivalent energy principle with time of day weighting
  - ❑No. events
  - ❑Time of day
  - ❑A-weighted sound level



Assumptions and/or have sufficient evidence

Hypothesis #A3

- Non-acoustic factors contribute to ***community annoyance*** and their contribution is quantifiable.

Discussion:

- **What are the most Important non-acoustic factors to study?**
- **Which non-acoustic factors can be dismissed?**

Hypothesis A3.
Non-acoustic factors contribute to community annoyance and their contribution is quantifiable. (Adjusting for non-acoustic factors (attitude toward airport, fear of crashes, opinion about airlines / pilots / flying public, etc.) improves correlation between %HA and DNL.)

- Is the fear component of the non-acoustic factors a function of distance from flight track, ie, under tracks vs sideline. (VM)

Alternative models of increasing complexity (2)

Assumptions and/or have sufficient evidence

Hypothesis # A4

•DNL may not sufficiently capture elements of noise exposure that cause long-term annoyance.

•Self-reported annoyance may be complemented by other ways to measure annoyance

•Equivalent energy principle with time of day weighting
- ❑No. events
- ❑Time of day
- ❑A-weighted sound level

DNL → Long-term annoyance

Other noise exposure metrics → Long-term annoyance

Discussion – corollary candidate hypotheses

- *Numbers of operations influence extent of annoyance, independent of exposure (DNL)*
- *Sound levels of loudest aircraft influence extent of annoyance, independent of numbers of quieter aircraft*
- *Aircraft noise levels as heard indoors correlate better with the extent of annoyance than do outdoor aircraft noise levels*
- *24-hour exposure metrics become less correlated with extent of annoyance if aircraft operations are concentrated either in the daytime or the nighttime*
- *Duration of "quiet periods" correlates with extent of annoyance*
- *Vibration and/or rattle from low frequencies influence extent of annoyance periods" correlates with extent of annoyance*
- *Acoustic metrics that correlate with other noise effects (such as speech interference, sleep disturbance, induced house vibrations) correlate better with extent of annoyance than does DNL*

Hypothesis A4
DNL may not sufficiently capture elements of noise exposure that cause long-term annoyance

- **Consider number of events as an independent variable similar to Noise and Number Index. Can the number of flights be determined for the older studies by knowing the year of the study and the airport? (VM)**
- **Do we know if existing social surveys have data for other metrics? If not, a** new social survey aimed at really looking at metrics would be nice, but expensive. (KP)
- The current batch of supplemental metrics are part of a continuum that includes DNL. NA is one extreme, keeping the number part with level being on/off. Multipliers other than 10 log N are not a computational problem for modelers today. Patricia Davies has gotten a start on the number multiplier; useful basic research on those metrics can be done in a hybrid lab setting. (KP)

Hypothesis A4
DNL may not sufficiently capture elements of noise exposure that cause long-term annoyance

- **Consider low frequency noise effects on annoyance (AC)**
- Determination of annoyance thresholds due to low frequency noise and low frequency induced building vibration effects due to large subsonic aircraft takeoff (VS).
  - **Phase I: subjective tests in NASA Langley's new sonic boom /low frequency noise chamber (available as soon as Winter of 2010-2011).**
  - **Phase II: subjective tests in residences near major airport.**
-
- Determine frequency of occurrence of low frequency noise and low frequency induced building vibration effects. Experimental study of LFN with no human response component. Would focus on frequency of occurrence of LFN as a function of propagation variability due to the atmosphere with proper low-frequency capable instrumentation (VS).
-
- Development of and subjective testing with new hybrid metrics including combinations of both traditional equal-energy metrics with new measures of low-frequency noise and low frequency induced building vibration. **(VS)**

Related discussion

- **Different metrics serve different problems, and only if such problems are identified there can be reason for different metrics. There undoubtedly is great value in aggregate metrics, like DNL, as these typically serve first order regulatory needs: to look at *total* exposure (day *and* night) and to look at *all* individuals equally (*percentages* of highly annoyed).**
- **The issue of alternative/supplementary metrics does fascinate scientists of different disciplines but it will not *per se* drive FAA to go beyond 65 DNL, that is, beyond the "single system" that it was asked to establish according to the 1980 Noise and Safety Act.**
- **FAA will only go beyond the 65 DNL (or will expand the present "single system") if by doing so it would resolve a *significant* societal problem.**
- **This question needs to be answered first: what is the *significant* problem? Where then are the unbearable costs (whether costs already now or in the foreseeable future)? Where is pain felt?**
- **The observation that many complaints come from beyond the 65 DNL *by itself* is <u>not</u> a sign of a significant societal problem. Complaints have various meanings, many are taken serious (perhaps by far not many enough). Sleep research findings also learn that public and civil servants alike are likely to make uncritical inferences. E.g., aircraft induced changes of sleep may not be as worrisome as stated given 'base rate changes'. Rather, sleep complaints may signal the presence of some other (noise related) stressors.**
- **A significant problem it will be if airport development (read: development of air-side and related land-side infrastructure) comes to a full or partial stop. If air spaces and/or land spaces cannot be allocated/redesigned timely leading to high infrastructural (and commercial) inefficiencies.**
- **Is there evidence of such a full or partial stop? I think: full = no (typically court cases are won by airports), partial = yes. There are huge costs caused by litigation and inaction as a consequence, and these costs result from local community action from (inside and) beyond the 65 DNL. There may also be costs of inefficient land-use and real-estate/housing development.**
- **The above (7) is stated negatively. It can be stated positively: Is there evidence that good community relations regarding the subject of aircraft noise exposure lead to less costs? I think: <u>yes</u>. Certainly enough evidence to justify that FAA calls forth a more proactive approach by local parties, with airport-parties to take the lead (after all, they impose the load on the local community).**
- **Costs may be such that even with a 10% probability that my above yes is true it would be more than wise to invest in a study identifying these costs and the opportunities for cost reduction/savings. This identification first by order of magnitudes.**
- **'Good community relations' should be given operational value: what do we mean by it in the area of aircraft noise exposure? I attach a powerpoint which identifies a variety of acts of mutual accommodation by aviation parties to community parties and the other way around. In general, the more mutuality installed, the less conflict on noise. FAA could develop such frames of transaction any further, and it could set some money aside for those local aviation and community parties who want to experiment with mutual accommodation. (PJS)**

Related discussion

- If we can get / build reasonably decent models for sleep disturbance, speech interference, induced vibrations, why not use these three models for determining impact? Annoyance is so variable and unpredictable, dump it for effects that we can predict. (NM)

- Maybe we have to acknowledge that we don't know what the health effects are and select thresholds based on limiting effects to reasonable numbers. Maybe we can use surveys to get ideas of what people find acceptable amounts of activity interference. (NM)

Alternative models of increasing complexity (3): combining (1) and (2)

- Trust
- Fear
- Culture
- Visual
- Socio-economic status
- Age
- Health

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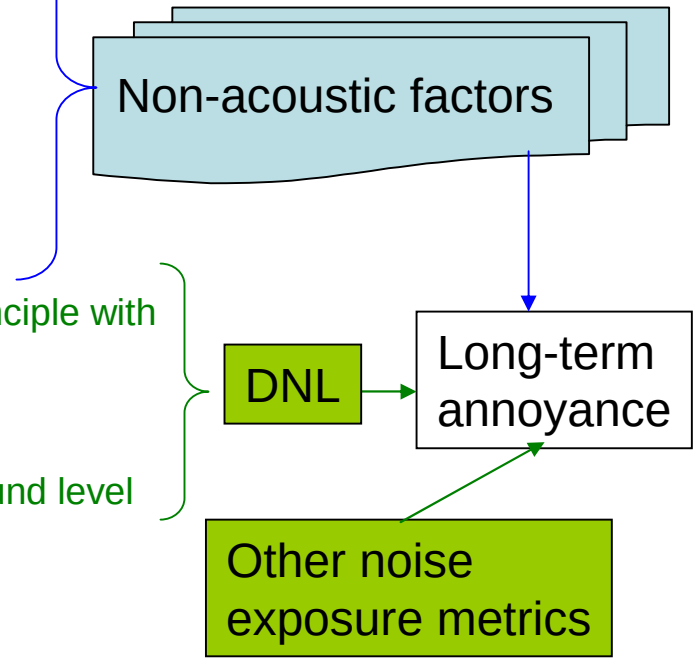

- Equivalent energy principle with time of day weighting
  - No. events
  - Time of day
  - A-weighted sound level

Alternative models of increasing complexity (4)

- Max sound level
- No. events
- Time of day
- Vibration/rattle
- Time-varying sound
- Frequency spectrum
- Roughness
- Duration of events
- Tonality
- Ambient sound levels
- Gradual vs. sudden change

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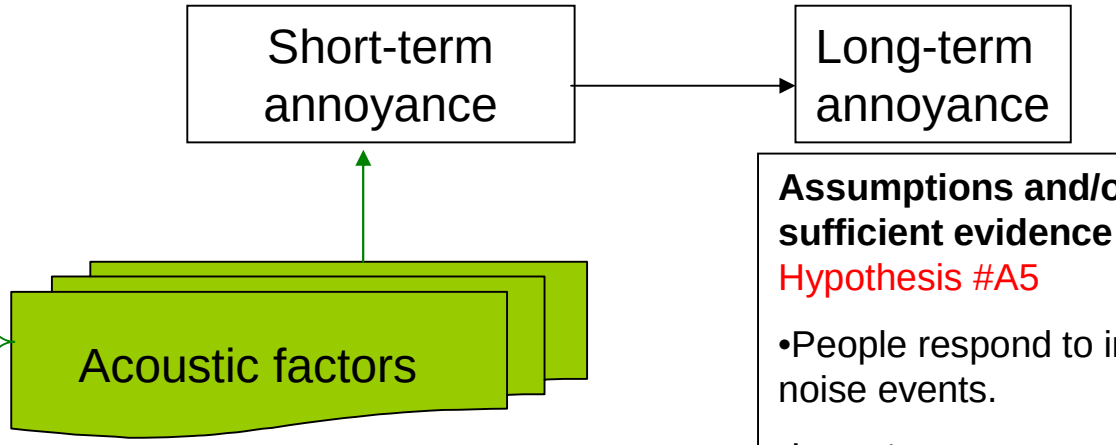


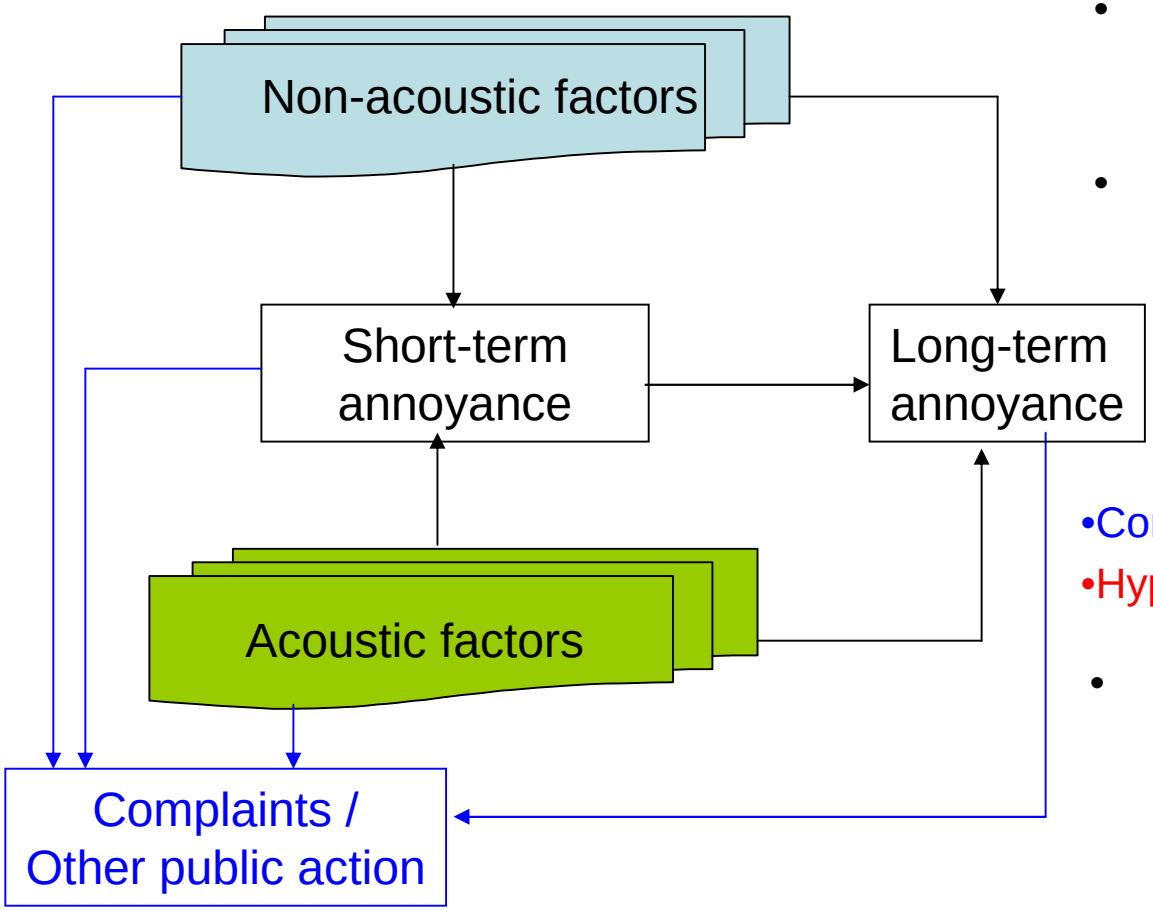
Assumptions and/or have sufficient evidence
Hypothesis #A5

- People respond to individual noise events.
- Long-term annoyance can be correlated with short-term annoyance from single events.
- Percent of population that is noise sensitive (self-reported or physiological) influences extent of annoyance

Discussion:

- **What are the most Important single-event acoustic factors to study?**
- **Which acoustic factors can be dismissed?**

Companion research to annoyance model(s)



- Model for public action
- Hypothesis A6
  - *An extensive database of complaints will be useful in understanding possible causes of complaints*
  - *Analysis of more than a decade of experiences around the world with new or extended runways or altered airspace use will provide greatly improved understanding of public action*
- Communicating noise exposure
- Hypothesis A7
  - *There are effective methods for communicating with the public about aircraft noise, its effects and what changes in noise will mean to the individual.*

Hypothesis A6

An extensive database of complaints will be useful in understanding possible causes of complaints

- **look at complaint data as part of a geo-referenced database (VM)**

Hypothesis A7

There are effective methods for communicating with the public about aircraft noise, its effects and what changes in noise will mean to the individual.

- a comparative study of airports that work to be good neighbors and those that don't might be illuminating (KP)
- If the FAA determines that DNL and 65 decibels should remain the metric and level of significance for environmental decisions, then the Agency should prepare a **SIMPLE** statement of why that is the policy. For years we have had to tell the public that it's FAA policy without a scientifically based justification of the decision. I believe explaining the rationale behind the policy in non-technical terms for the public will go miles toward a greater acceptance of it and reduce challenges for a revised metric or a different threshold of significance. (JW)

Additional task

- ***Investigate applicability of EPA risk assessment methodology***
  - *FAA may need to establish new land use compatibility guidelines based on the above proposed research*
  - *EPA has long-term experience in judging risk and costs for setting thresholds of exposure*
  - *FAA may be able to benefit from the EPA experience*

Considerations for future studies

- **Collaborative approach**
  - Build on state-of-art research to develop survey questionnaire
  - Identify state-of-art technologies to acquire noise data and conduct surveys
  - Plan similar studies for airports worldwide

- **Propose comprehensive survey of persons residing around American airports to determine unbiased level of annoyance with aircraft noise (JW)**
  - include areas around airports that have experienced controversial development, as well as areas that have had stable environments and little controversy over the past decade
  - include airports of several sizes and missions
  - Noise level (Leq?) and number of aircraft operations should be treated as independent variables in evaluating dose – response relationships. Compare to Schultz and subsequent studies (but would need to go back to DNL?)

Sleep disturbance

New questions/considerations

- What do the experts say happens to people at DNL 65 or greater? (DM)
  - **How much sleep disturbance and to how many people? Once you have consensus on what happens at 65, then your experts can tell you if this means the DNL 65 is adequately protective or not.**
- **How does aircraft noise induced sleep disturbance rank against other known sources of sleep disturbance? (DM)**
- **Knowledge gap: we have no idea if sleep disturbance that would be expected to result from aircraft noise causes any health effects (DM)**
- **Consider a nighttime noise exposure metric for nighttime effects (MB)**
- **Regarding hypothesis S6, if we are to compare the aircraft-exposed and non-aircraft-exposed populations, some limits must be imposed on the selection of non-aircraft-exposed populations. One example: since commercial aircraft operations are not perceived as a threat, the non-aircraft operations should *not* include populations that are exposed to sounds that are perceived as threatening, e.g. those in a high-crime area. (AK)**

Potential studies

- **Consider low frequency noise effects on sleep disturbance (AC)**
- Determination of sleep disturbance due to low frequency noise and low frequency induced building vibration effects due to large subsonic aircraft takeoff (VS)
  - **Phase I: subjective tests in NASA Langley's new sonic boom /low frequency noise chamber (available as soon as Winter of 2010-2011).**
  - **Phase II: subjective tests in residences near major airport.**

Other steps

- **The U.S. is spending a lot of money around health – NIH- see what they are doing. Is noise measured or asked about? Anything in any of those databases? Piggyback a study? (DD)**
- **Look at effects ratios to see how large study(ies) are needed (DD)**

Potential studies

- **If can come up with similar cohorts in studies already conducted in Europe, do similar study in US and compare (DD)**