Recommended Metrics to Better Quantify the Effects of Aircraft Noise on Populations Around Airports

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Quantification of Noise Effects

- Non-Auditory Health Effects — Larry Finegold
- Annoyance — Nick Miller
- Sleep Disturbance — Nick Miller
- Effects on Learning — Ken Plotkin

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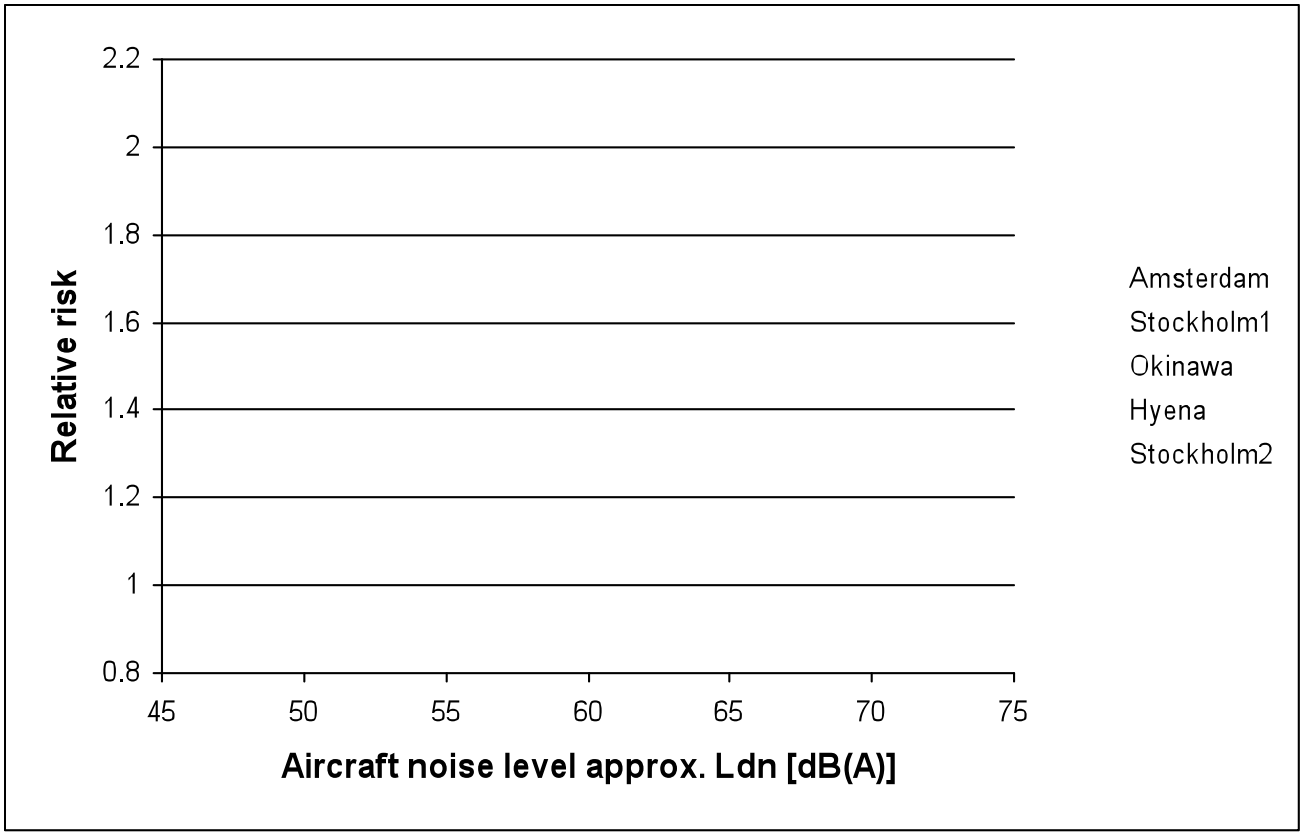
Identified Effect on Populations	Quantification of Effect
Non-Auditory Health Effects	Number of people with elevated risk of medically defined “clinical hypertension”
Annoyance	Number of people highly annoyed
Sleep Disturbance	Number of people awakened at least once during the night by aircraft noise events
Effects on Learning	Number of children in schools with aircraft noise exposure exceeding ANSI guidelines

Quantification - Non-Auditory Health Effects

- **Many studies of health effects – primarily cardiovascular**
- **Best approach would be meta-analysis**
- **Many difficulties comparing / combining studies**
  - Different measures of blood pressure
  - Different means of determining noise exposure
- **However, strong suggestions of correlation of aircraft noise w/ higher blood pressure**

Quantification - Non-Auditory Health Effects

- **Results of recent meta-analysis**



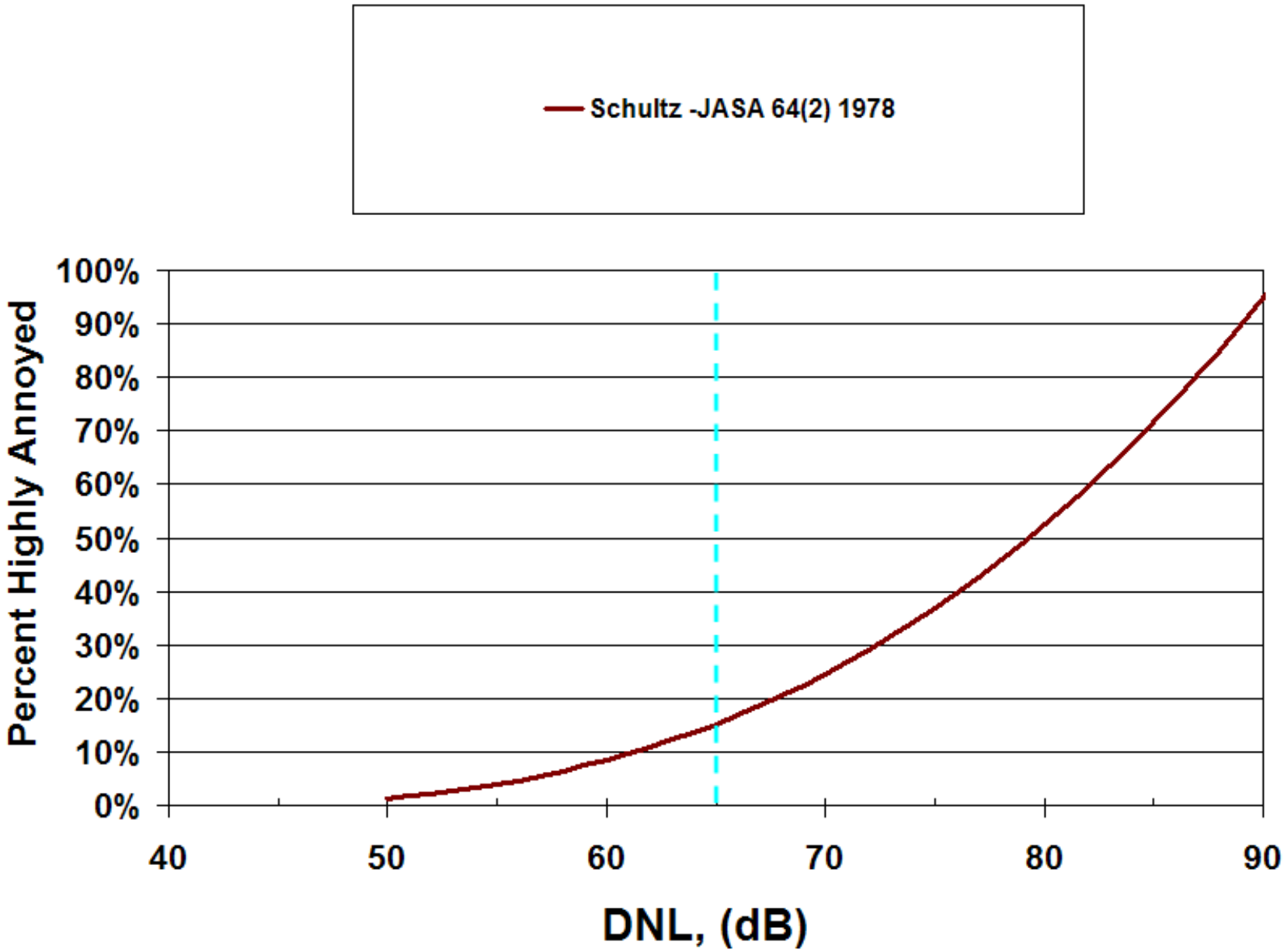
from Babisch, W and van Kamp, I., Draft WHO Workshop Report: "AIRCRAFT NOISE AND HEALTH; Cardiovascular effects of aircraft noise," 2nd draft, December 2007. (Unpublished report)

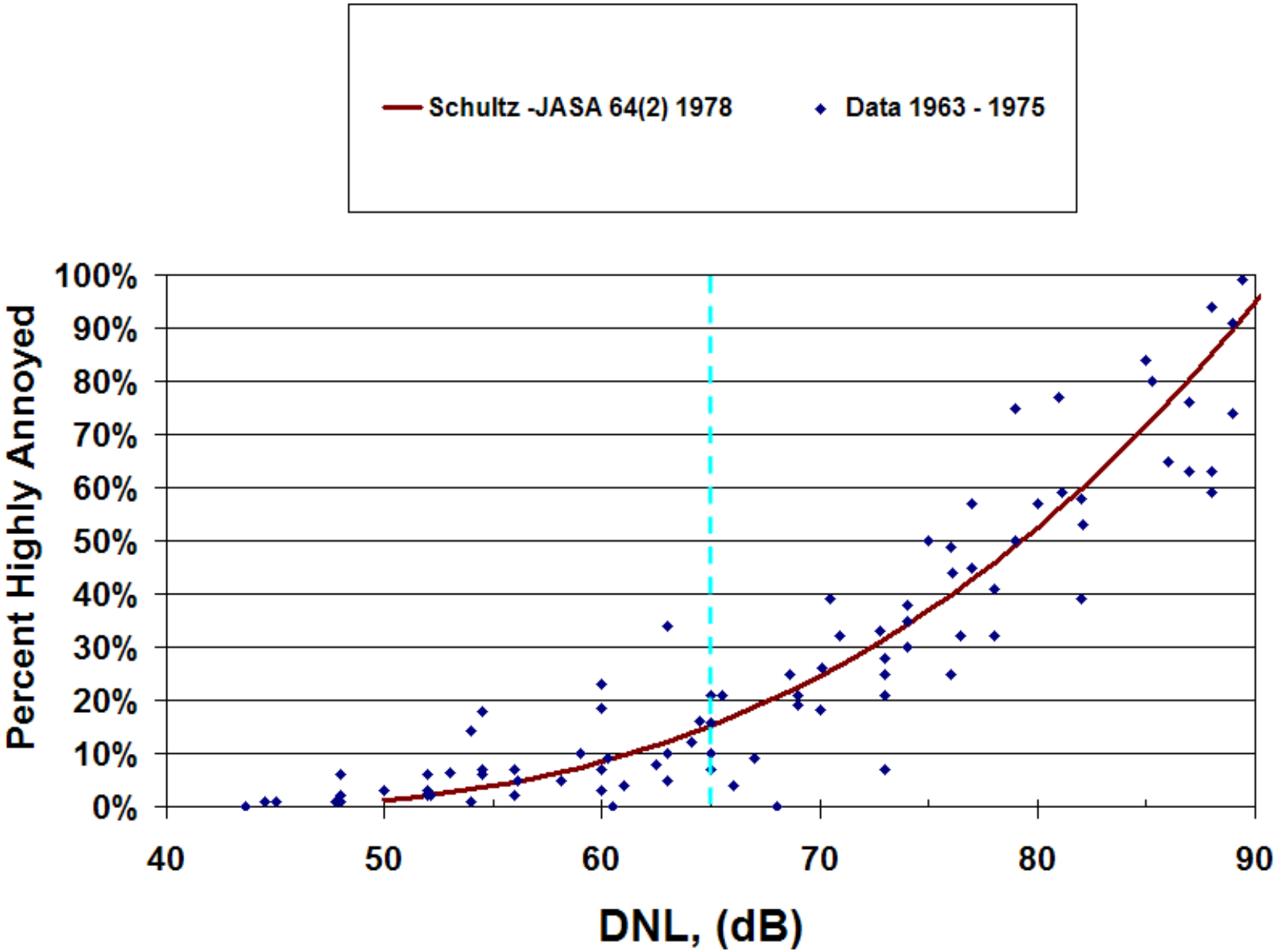
Quantification - Non-Auditory Health Effects

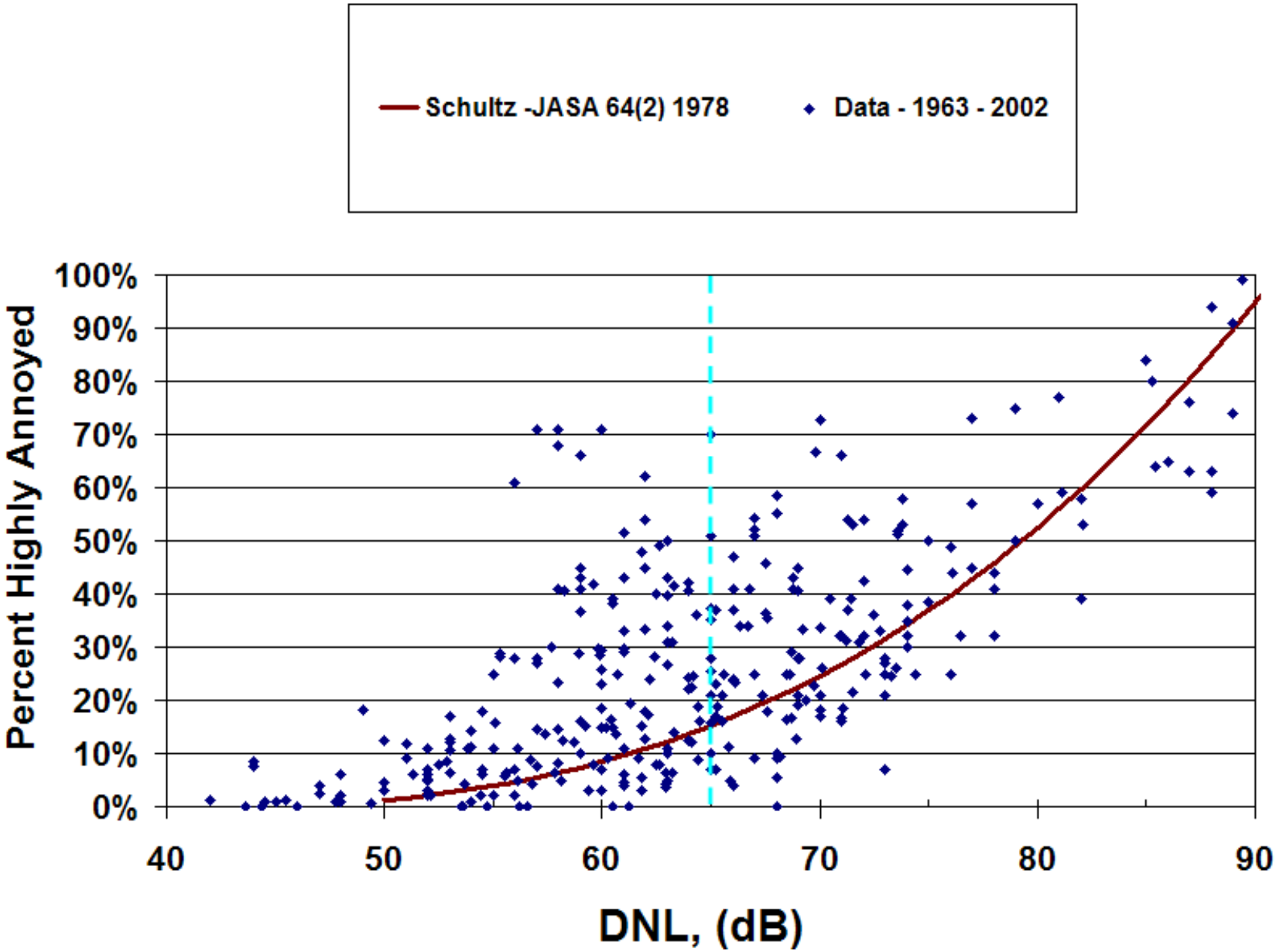
- **Recommendation**
  - Indication of association of hyper-tension with aircraft noise
  - Insufficient consistency of results to make any recommendation for quantification at this time

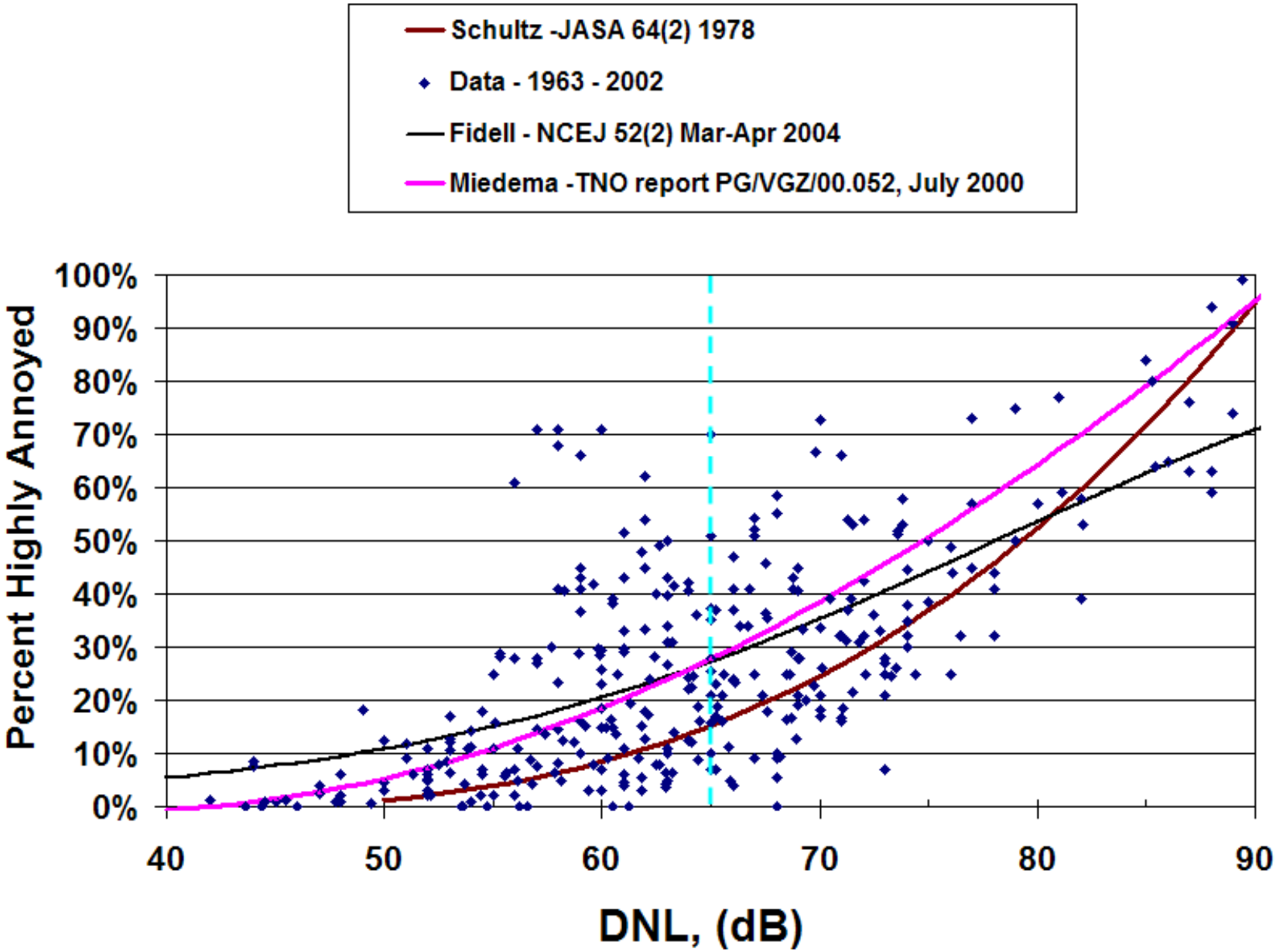
Quantification - Annoyance

- The “Schultz Curve” is traditional (1978)
- Included all transportation sources
- We want annoyance from aircraft
- Many more annoyance surveys now available


Schultz -JASA 64(2) 1978
Percent Highly Annoyed
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
40
50
60
70
80
90
DNL, (dB)


Schultz -JASA 64(2) 1978
Data 1963 - 1975
Percent Highly Annoyed
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
40
50
60
70
80
90
DNL, (dB)


Schultz -JASA 64(2) 1978
Data - 1963 - 2002
Percent Highly Annoyed
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
40
50
60
70
80
90
DNL, (dB)


Schultz -JASA 64(2) 1978
Data - 1963 - 2002
Fidell - NCEJ 52(2) Mar-Apr 2004
Miedema -TNO report PG/VGZ/00.052, July 2000
Percent Highly Annoyed
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
40
50
60
70
80
90
DNL, (dB)

Quantification - Annoyance

- **Recommended using Miedema:**

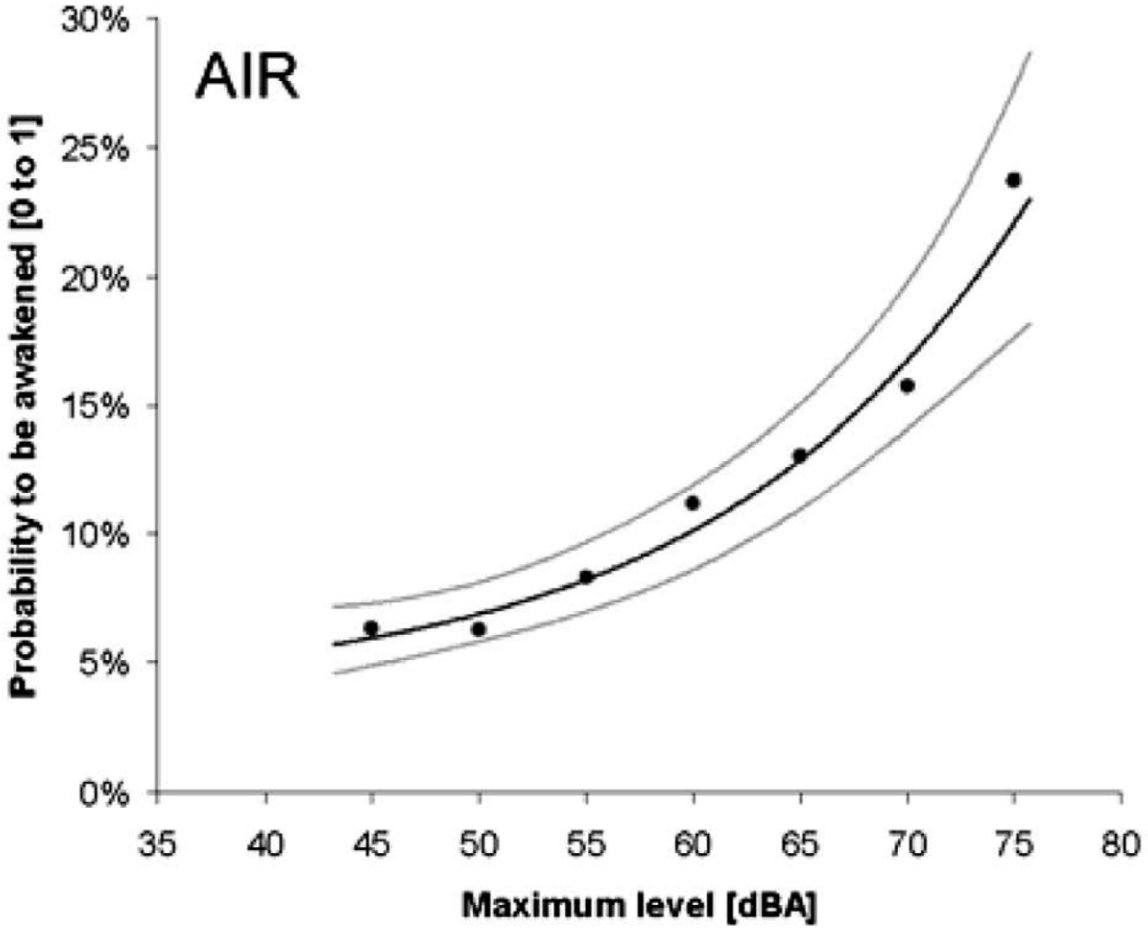
$$\%HA = -1.395 \times 10^{-4} (Ldn - 42)^3 + 4.081 \times 10^{-2} (Ldn - 42)^2 + 0.342 (Ldn - 42)$$

$$\%HA = -9.199 \times 10^{-5} (Lden - 42)^3 + 3.932 \times 10^{-2} (Lden - 42)^2 + 0.2939 (Lden - 42)$$

Quantification - Sleep

- **Awakening research available**:
  - Behavioral Awakenings
  - Motility
  - Change of sleep structure
- **Recommended Behavioral Awakenings (supported by FICAN)**
  - Easiest to communicate to public
  - No ambiguity about determining awakening

Quantification - Sleep

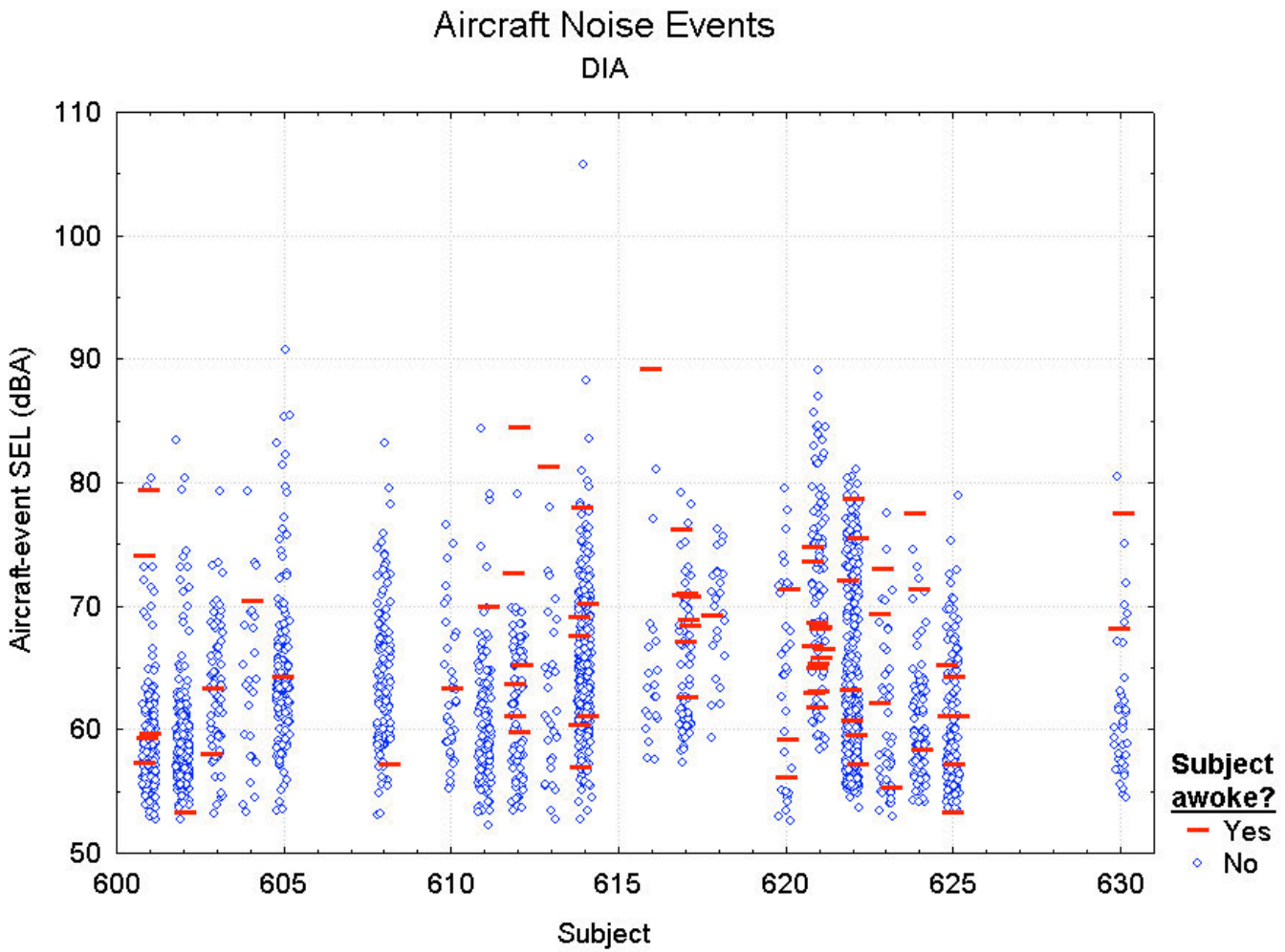


From: Marks A, Griefahn B, Basner M (2008). Event-related awakenings caused by nocturnal transportation noise. Noise Control Eng. J. 56 (1), Jan-Feb

Quantification - Sleep

- **Chance of Awakening from Many Aircraft:**
  - One aircraft (Indoor) SEL ~ 90 dB:
    - 10% (or 0.10) chance of awakening
    - 90% (or 0.90) chance of not awakening
  - Two aircraft, both SEL ~ 90 dB:
    - Not awakening or "Sleeping through" means:
      - not awakening from the first, AND
      - not awakening from the second
    - Chance of sleeping through:
      - » = (0.9)(0.9) = 0.81 = 81%
    - Therefore chance of not sleeping through:
      - » = 1 – 0.81 = 0.19 = 19%
- **Not sleeping though means you awoke at least once.**

Quantification - Sleep



Quantification - Sleep

- Resulting probabilities of awakening:

$$p_{awake,single} = \frac{1}{1 + e^{-Z}}$$

Quantification - Sleep

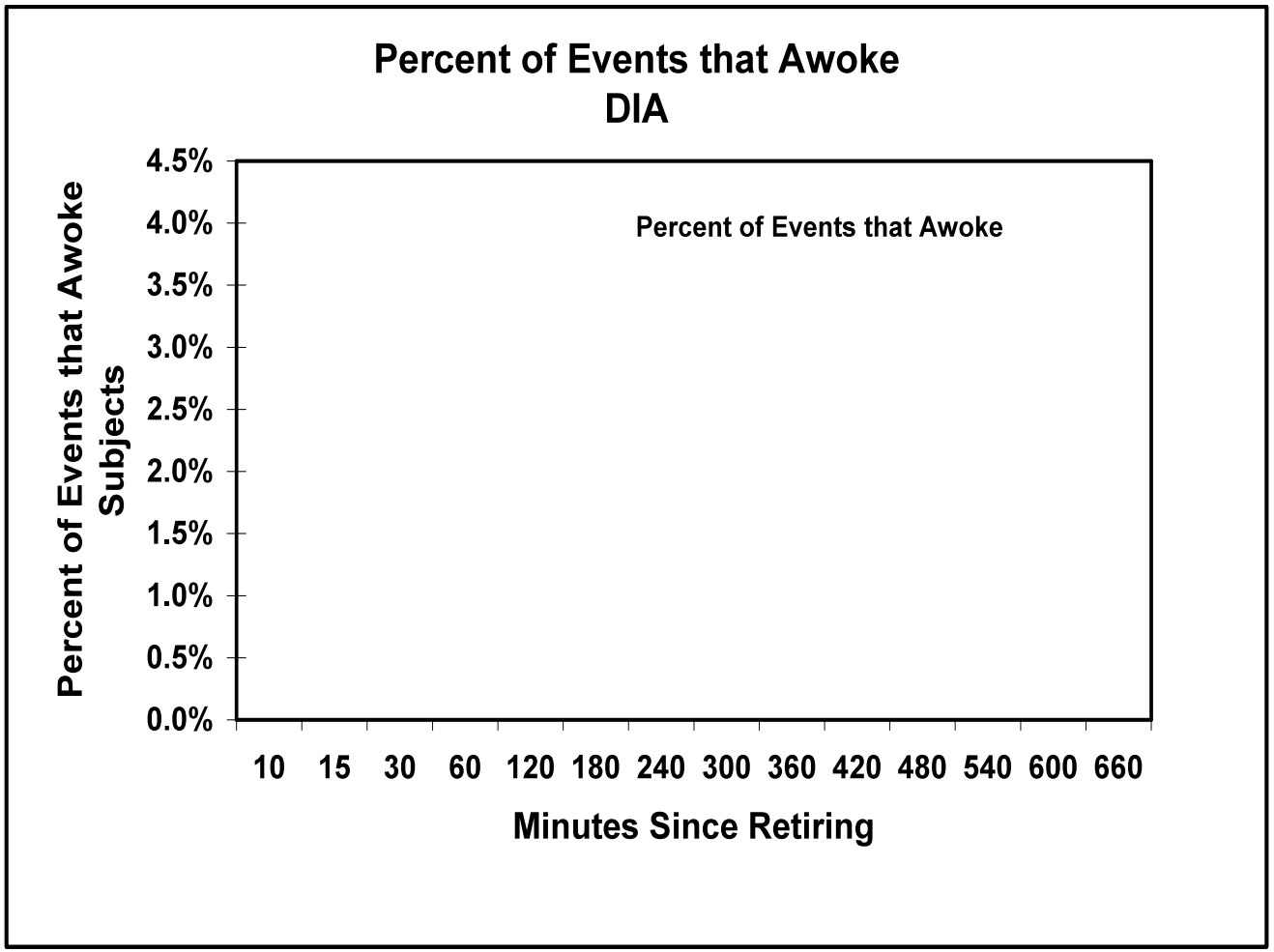
- **Where:**

$$Z = \beta_0 + \beta_L L_{AE} + \beta_T T_{retire} + \sum_{s=1}^{s=n-1} \beta_S s$$

Awakening Dose-Relationship	β_0	β_L	β_T	β_S
ANSI (1)	-6.8884	0.04444	0	0
ANSI (2)	-7.594	0.04444	0.00336	0
W/SENS	-10.723	0.08617	0.00402	Multiple

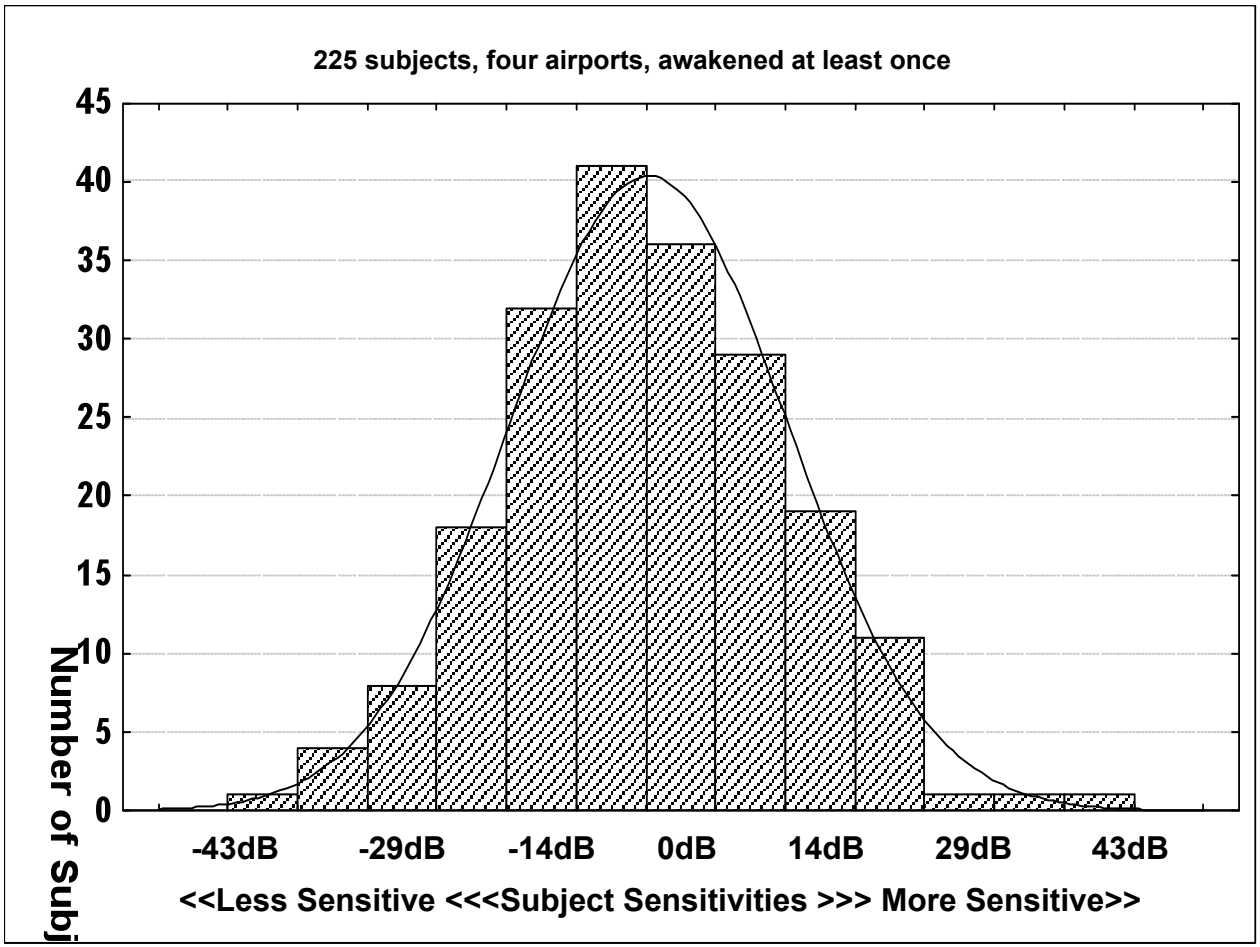
Quantification - Sleep

- But people awaken more easily as the night passes

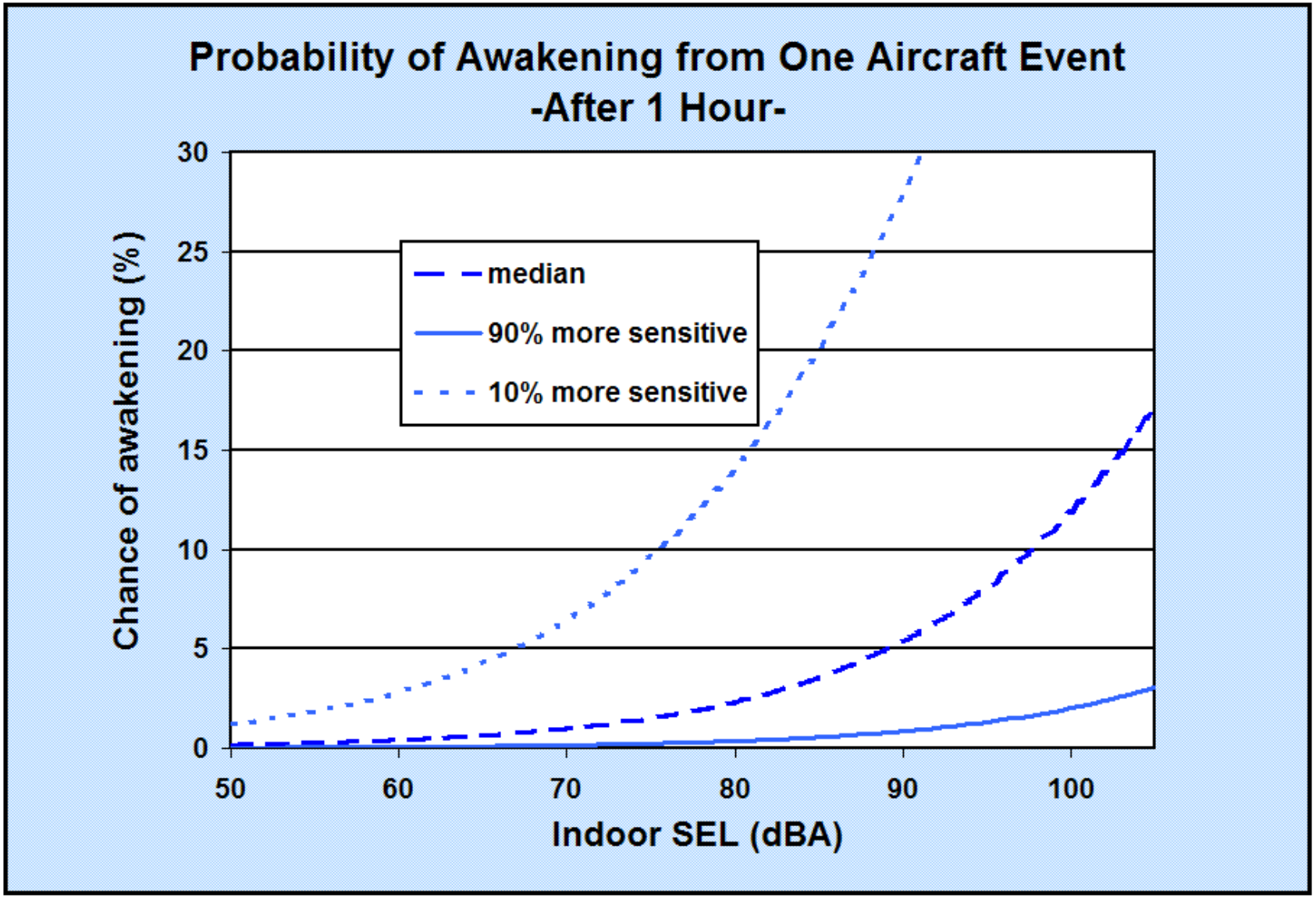


Quantification - Sleep

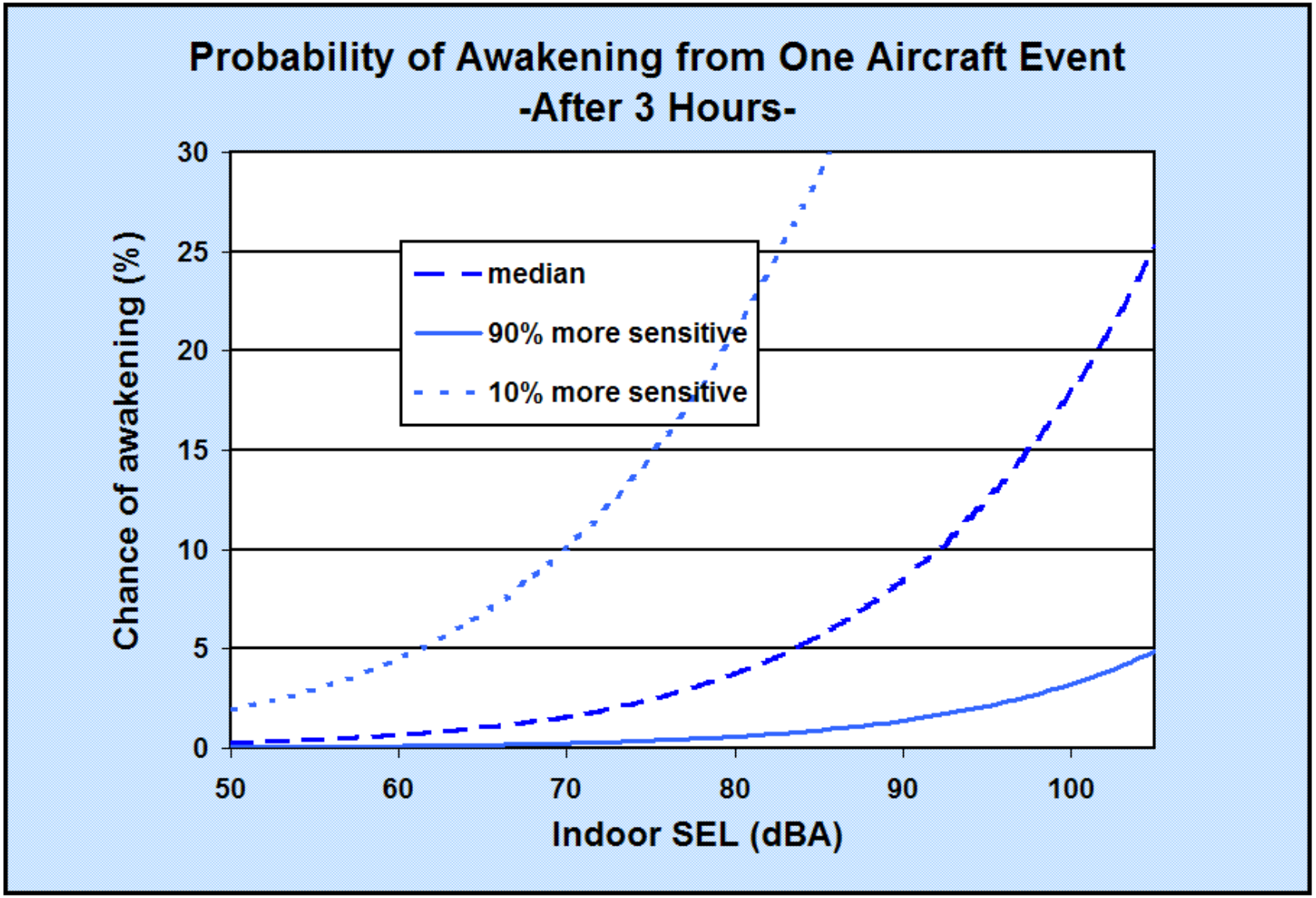
- And people vary in their sensitivity to awakening



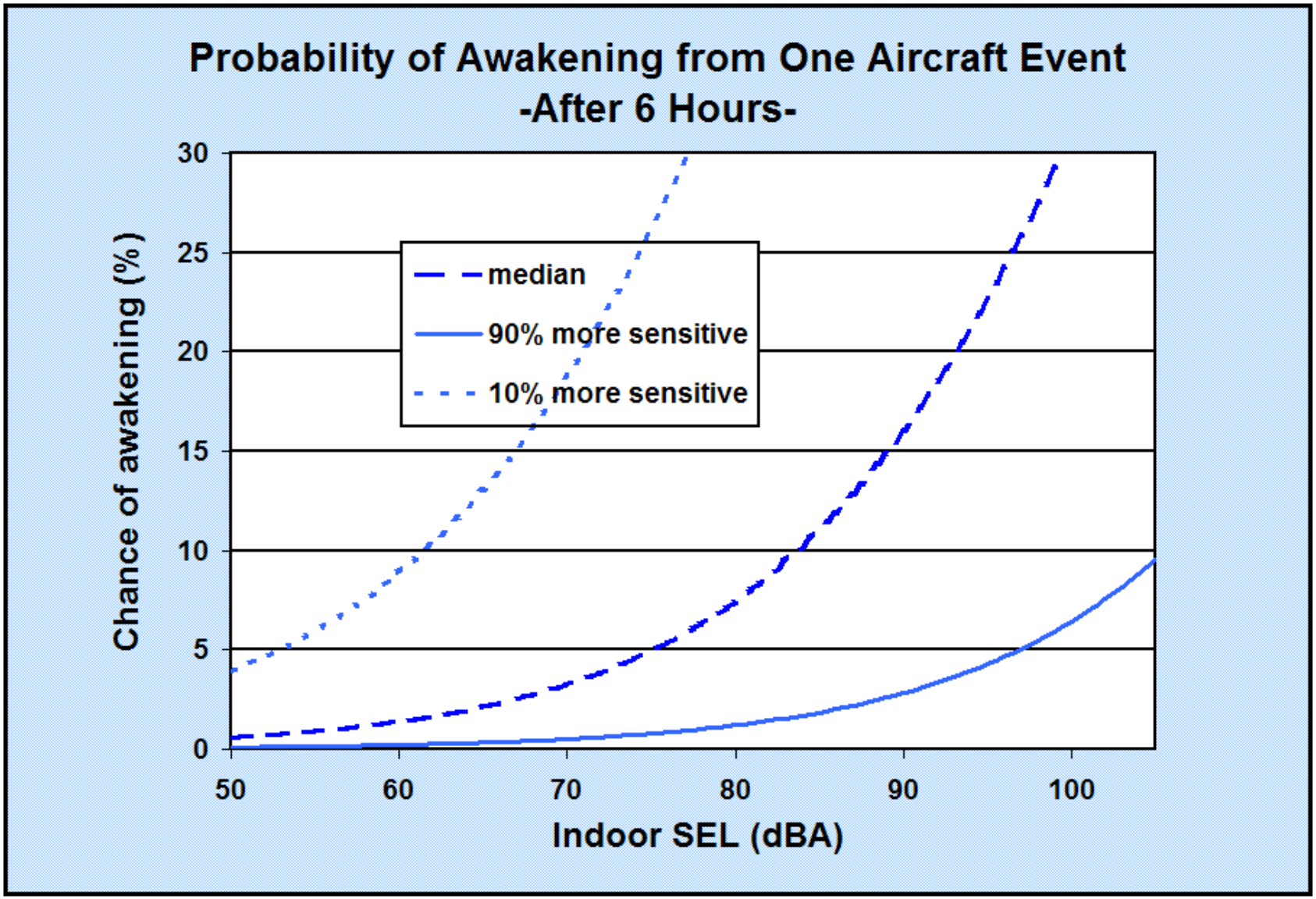
Quantification - Sleep



Quantification - Sleep

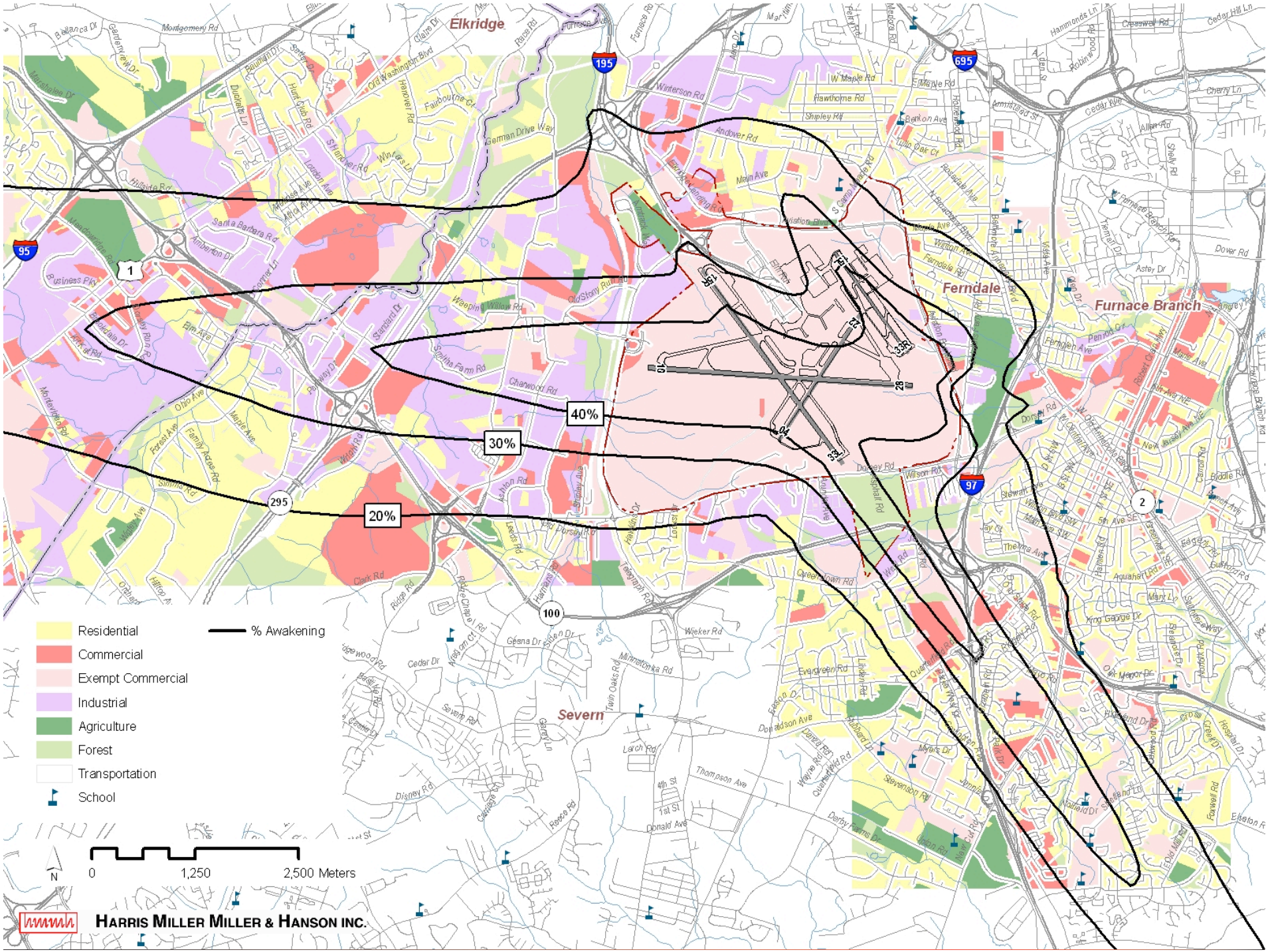


Quantification - Sleep



Quantification - Sleep

- **Application is point – by – point**
  - Block of population / neighborhood
  - Same sound levels across the block
  - Known number of people
- **Use INM to compute (detailed grid):**
  - All SEL values by time of night (3 periods ok)
  - Number of aircraft for each SEL value
- **The rest is multiplication – for each sensitivity level**
  - Chance of sleeping through all SELs
  - Then 1-chance of sleeping though = chance of awakening
  - Multiply chance of awakening times population
- **Add all sensitivities for number of people awakened at least once**


Elkridge
Ferndale
Furnace Branch
Severn
40%
30%
20%
Residential
Commercial
Exempt Commercial
Industrial
Agriculture
Forest
Transportation
School
% Awakening
N
0
1,250
2,500 Meters
HARRIS MILLER MILLER & HANSON INC.

Quantification - Learning

- **One of the effects of aircraft noise is speech interference**
  - Produces annoyance – addressed with DNL
  - Can affect learning
- **Acoustical Society of America and the Institute of Noise Control engineers addressed learning**
- **Lead to American National Standards Institute Standard:**
  - ANSI S12.60-2002, "Acoustical Performance Criteria, Design Requirements, and Guidelines for Schools," June 2002

Quantification - Learning

- **ANSI S12.60-2002 for core spaces < 20,000 cubic feet**
  - Steady noise: Leq not to exceed 35 dB
  - Transportation noise: L_{eq} and L_{10} not to exceed 40 dB
  - > 20,000 cubic feet, 5 dB higher
  - Based on signal to noise ratio of at least 15 dB
- **Recommendation**
  - Assume outdoor-to-indoor reduction is 25 dB to 30 dB
  - Use outdoor school day hourly L_{eq} > 65 dB to indicate impact on learning (accounts for situations where $L_{10} > L_{eq}$)
  - Use actual outdoor-to-indoor reduction if known
  - Compute number of students in schools with impact