A Pragmatic Re-analysis of Sleep Disturbance Due to Aircraft Noise

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Session 349: Environmental Metrics for Policy Makers

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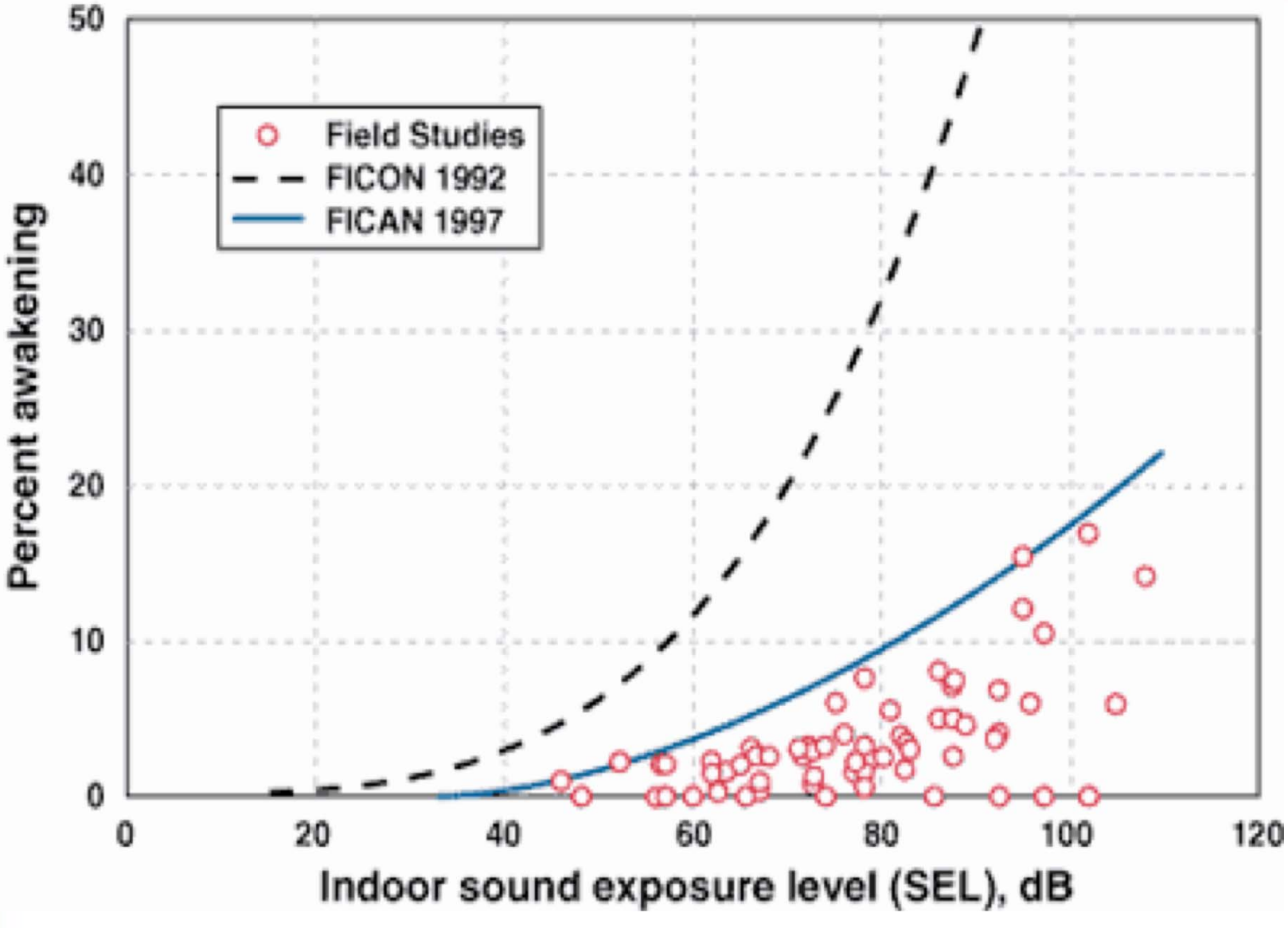
Questions Policy Makers Need to Answer

- How do we evaluate the effect of an entire night's operation on an individual? A community?
- How do we compare one alternative to another?
- What is 'significant'?

Current Method:
1997 FICAN Sleep Disturbance Curve



Use of the FICAN Curve is Problematic

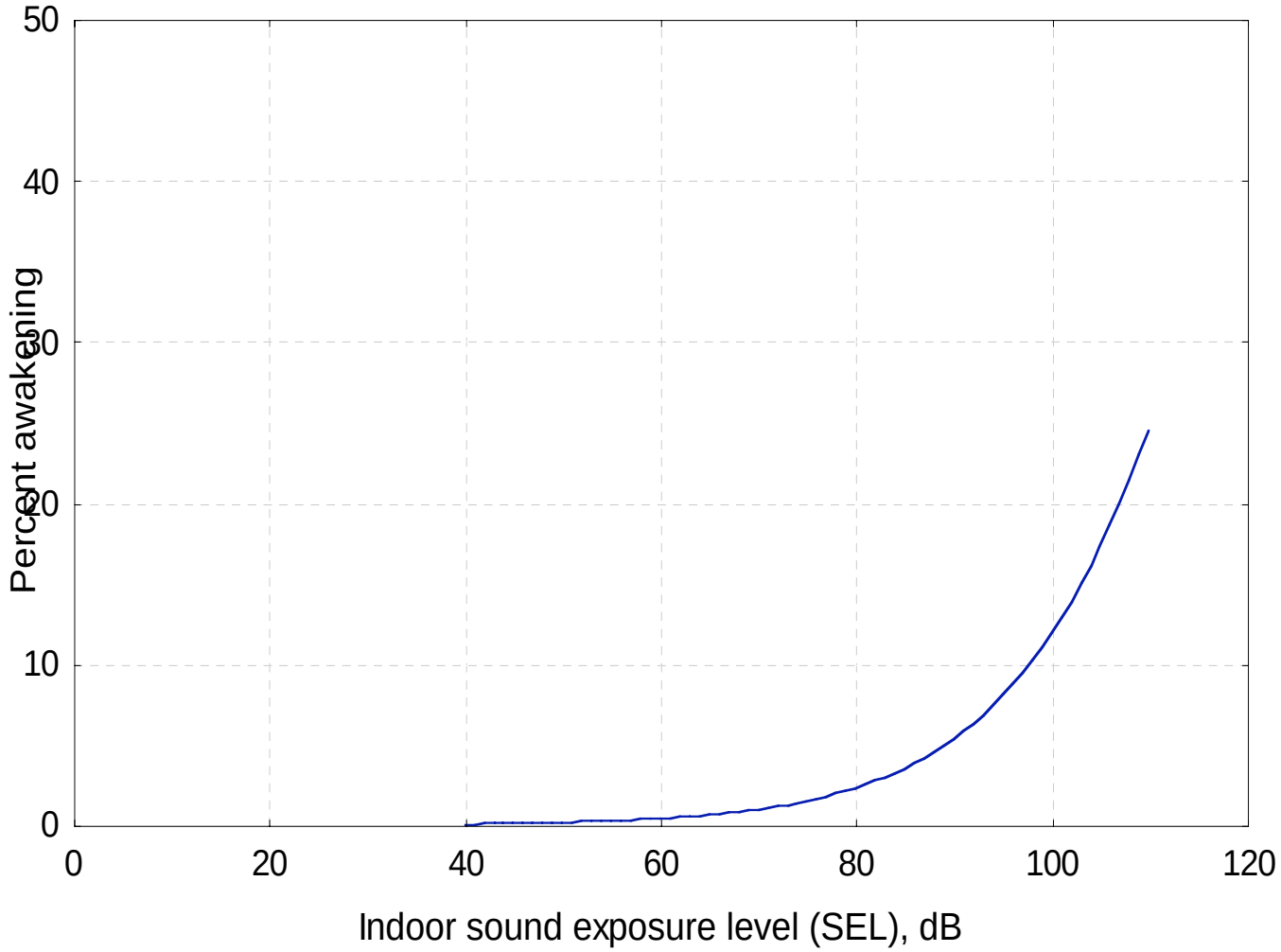
Past analyses have

- Selected a low “percent awakening” (5-10%)
- Used the upper bound of the curve to identify an indoor SEL that would produce the same percentage awakening
- Converted the indoor SEL to an outdoor SEL
- Used outdoor SEL contours to tabulate the number of awakenings due to a single event

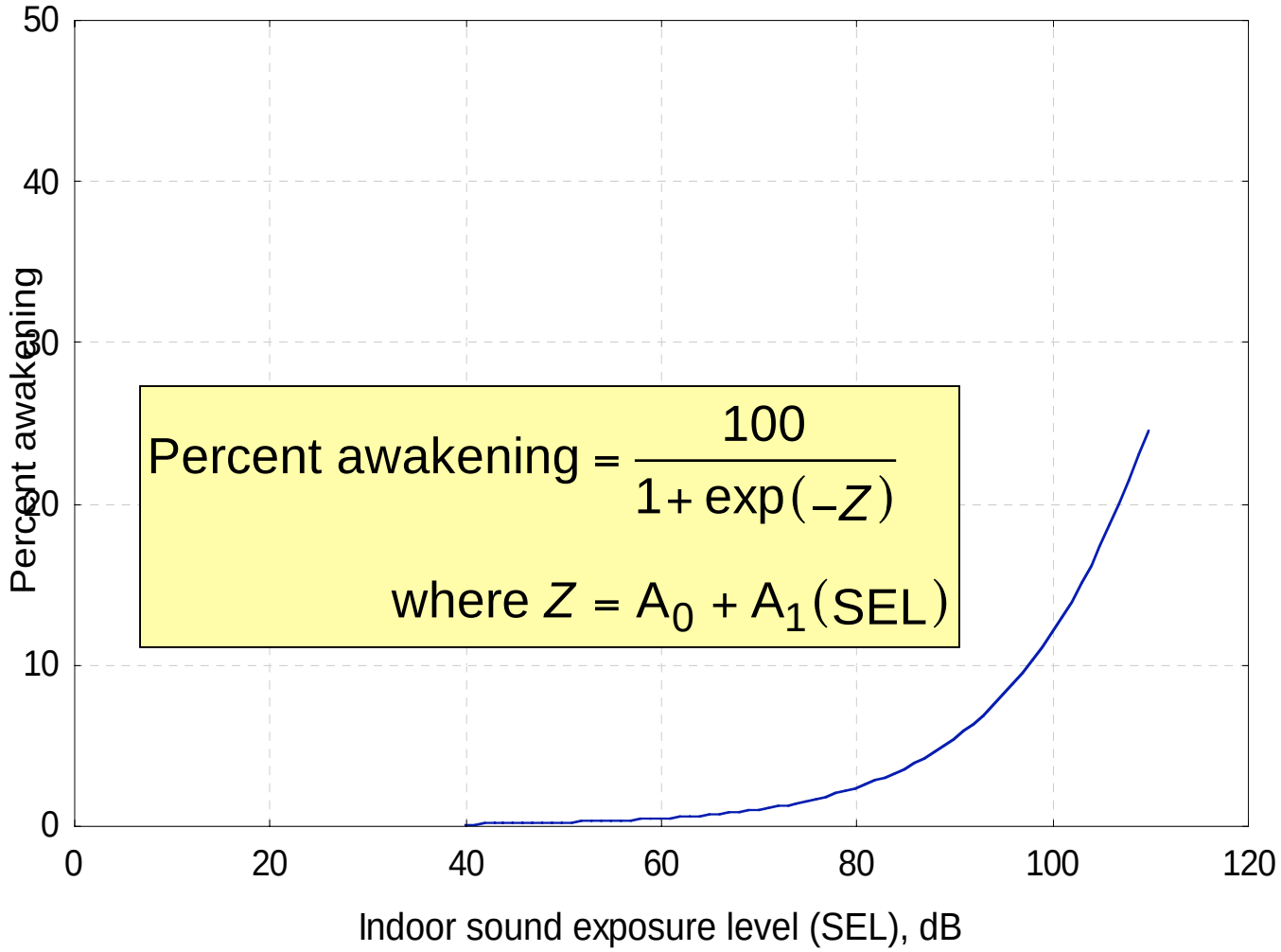
Proposed Approach: simple but practical

- **Use existing dose-response relationships**
  - Dose = Aircraft indoor SEL
  - Response = Probability of awakening
- **Adjust for:**
  - Activity level (many aircraft each night)
  - Person-to-person differences in awakening response

Dose response: Original regression curve
USAF Study at LAX and Castle AFB (Fidell, 1994)



Dose response: Actual regression curve



Many aircraft each night

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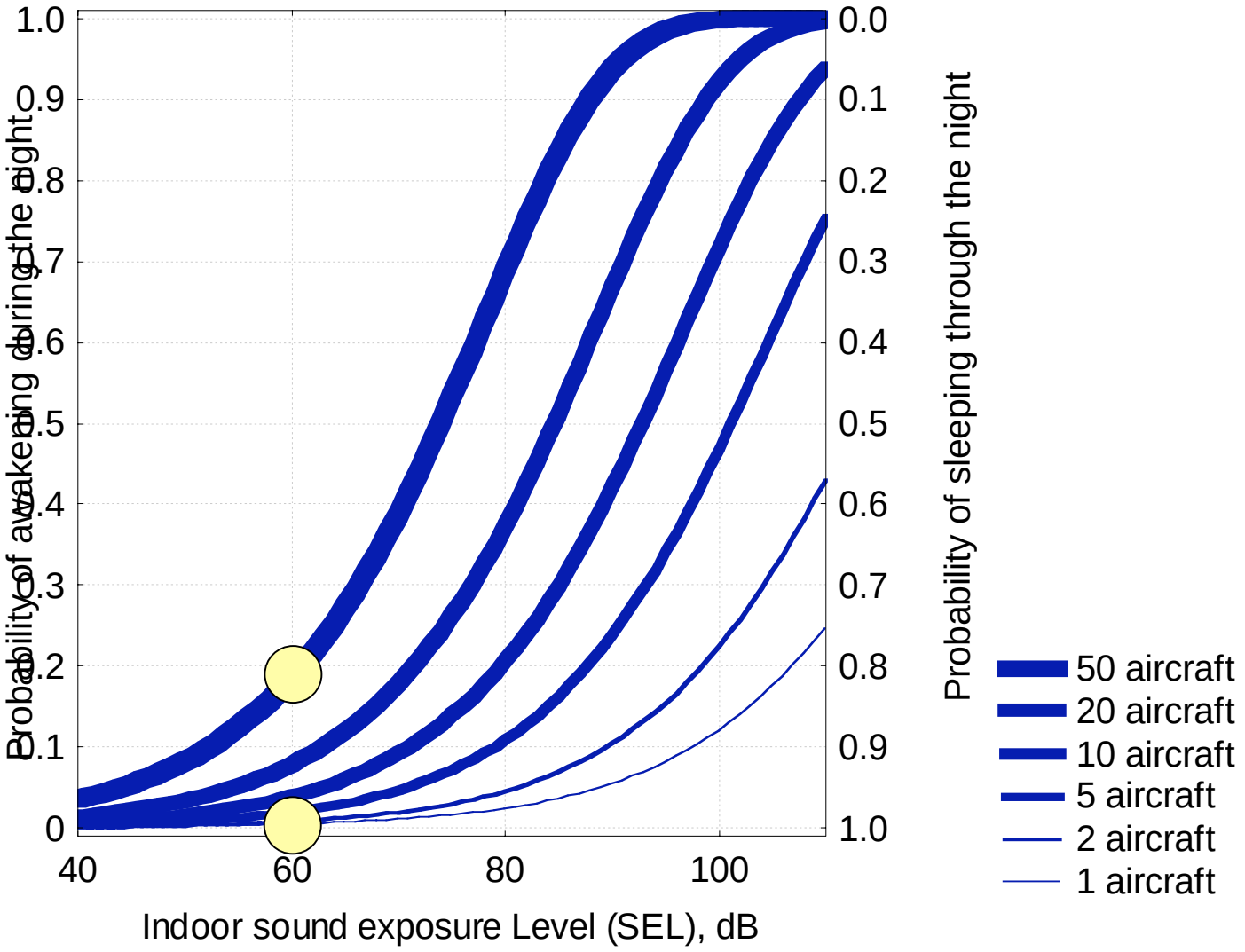
- **One aircraft:**
  - 0.1 probability of awakening
  - 0.9 probability of not awakening
- **Two aircraft:**
  - "Sleeping through" means:
    - not awakening from the first, **AND**
    - not awakening from the second
  - Probability sleeping through = (0.9)(0.9) = 0.81
  - Probability awakening at least once
    = 1 – 0.81 = 0.19

Many aircraft each night

$$\left(\begin{array}{c}\text{Probability}\\ \text{awakening}\\ \text{during the night}\end{array}\right) = 1 - \left(\begin{array}{c}\text{Probability}\\ \text{sleeping through}\\ \text{all N aircraft}\end{array}\right)$$

$$= 1 - \left(\begin{array}{c}\text{Probability}\\ \text{sleeping through}\\ \text{one aircraft}\end{array}\right)^{N}$$

Many aircraft each night



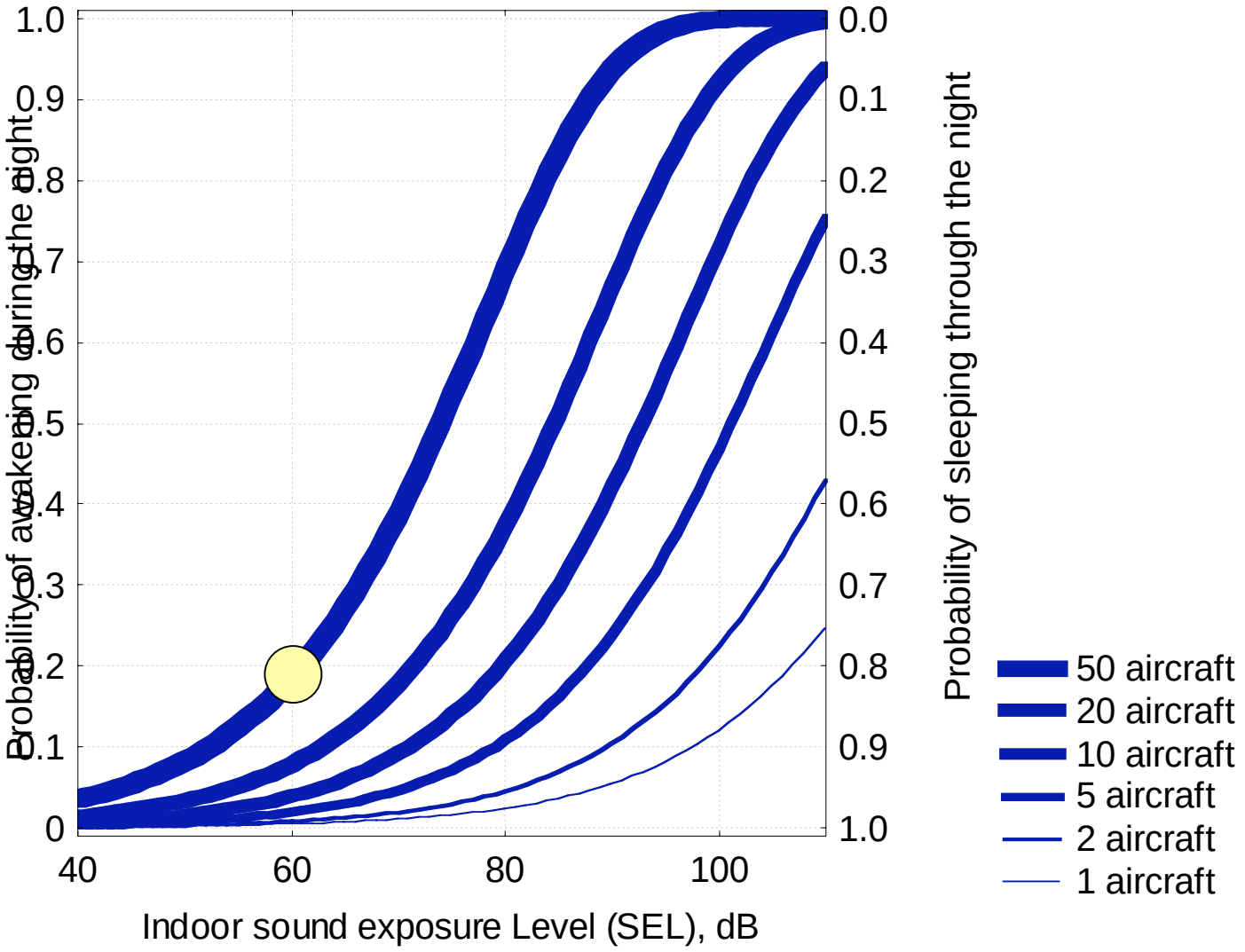
Person-to-person differences

- **50 aircraft at 60 dB**
  - Dose response: 0.2 probability awaken during night
  - If everyone slept equally well:
    - 20% of “everyone” would awaken

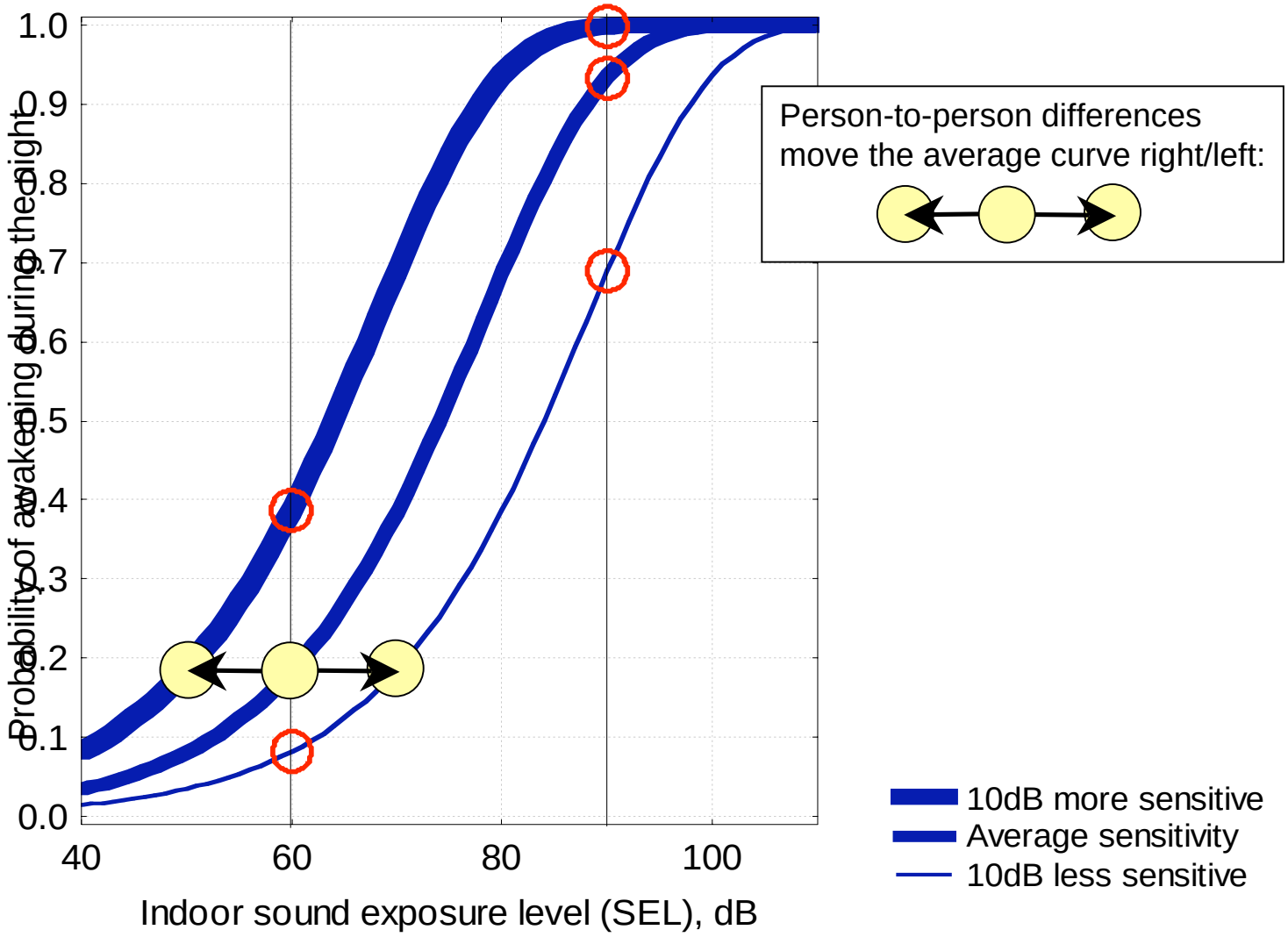
Person-to-person differences

- **50 aircraft at 60 dB**
  - Dose response: 0.2 probability awaken during night
  - If everyone slept equally well:
    - 20% of “everyone” would awaken
  - BUT different people sleep differently
    - So they have different, individual dose-response curves

Person-to-person differences



Person-to-person differences



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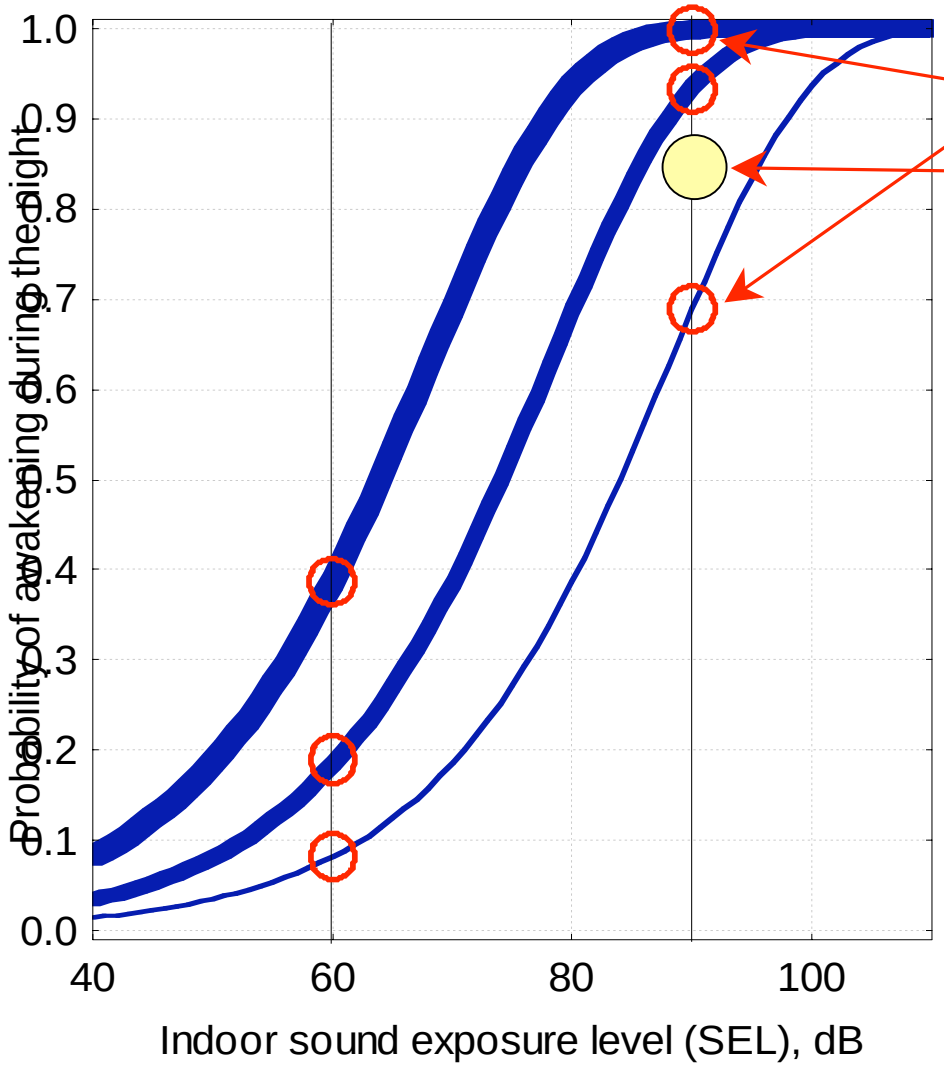
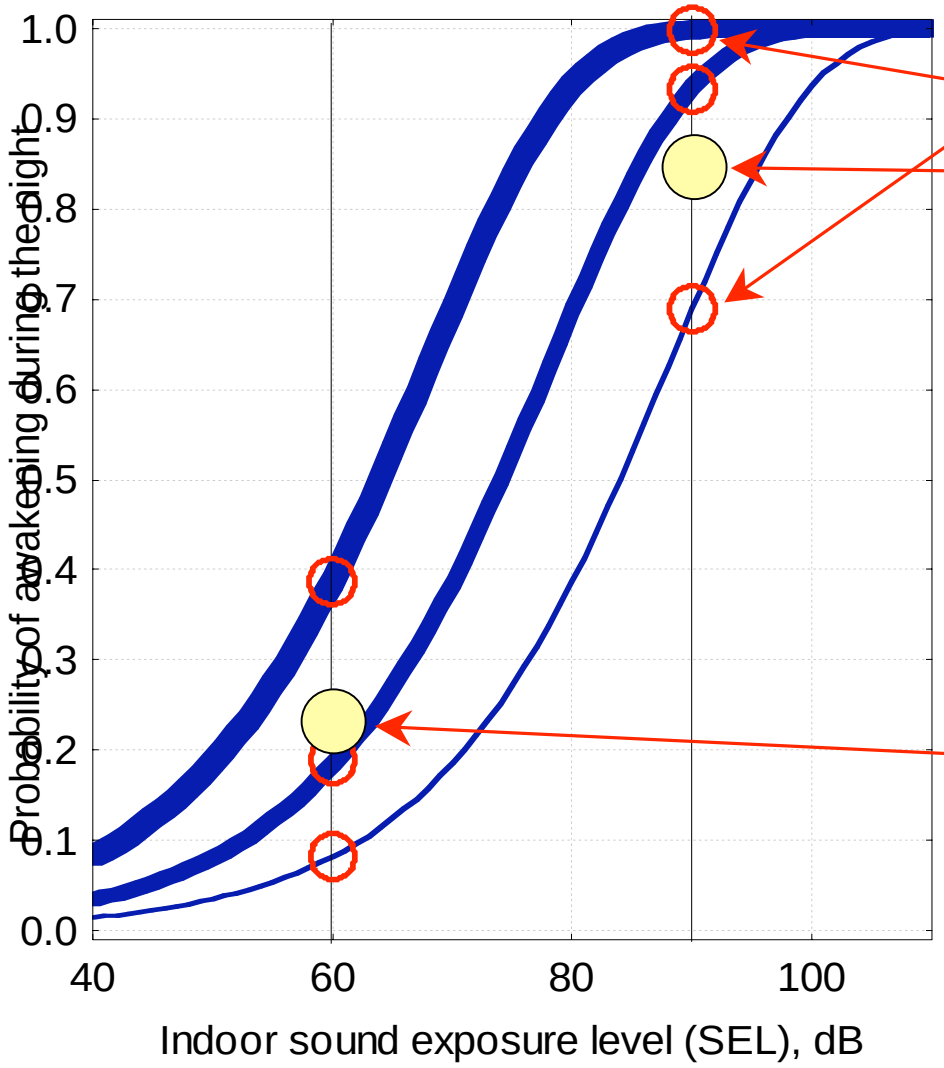


- Half the people: top curve
- Other half: bottom curve
- Result, which is less awakening than the middle (average) curve

10dB more sensitive
Average sensitivity
10dB less sensitive

Person-to-person differences



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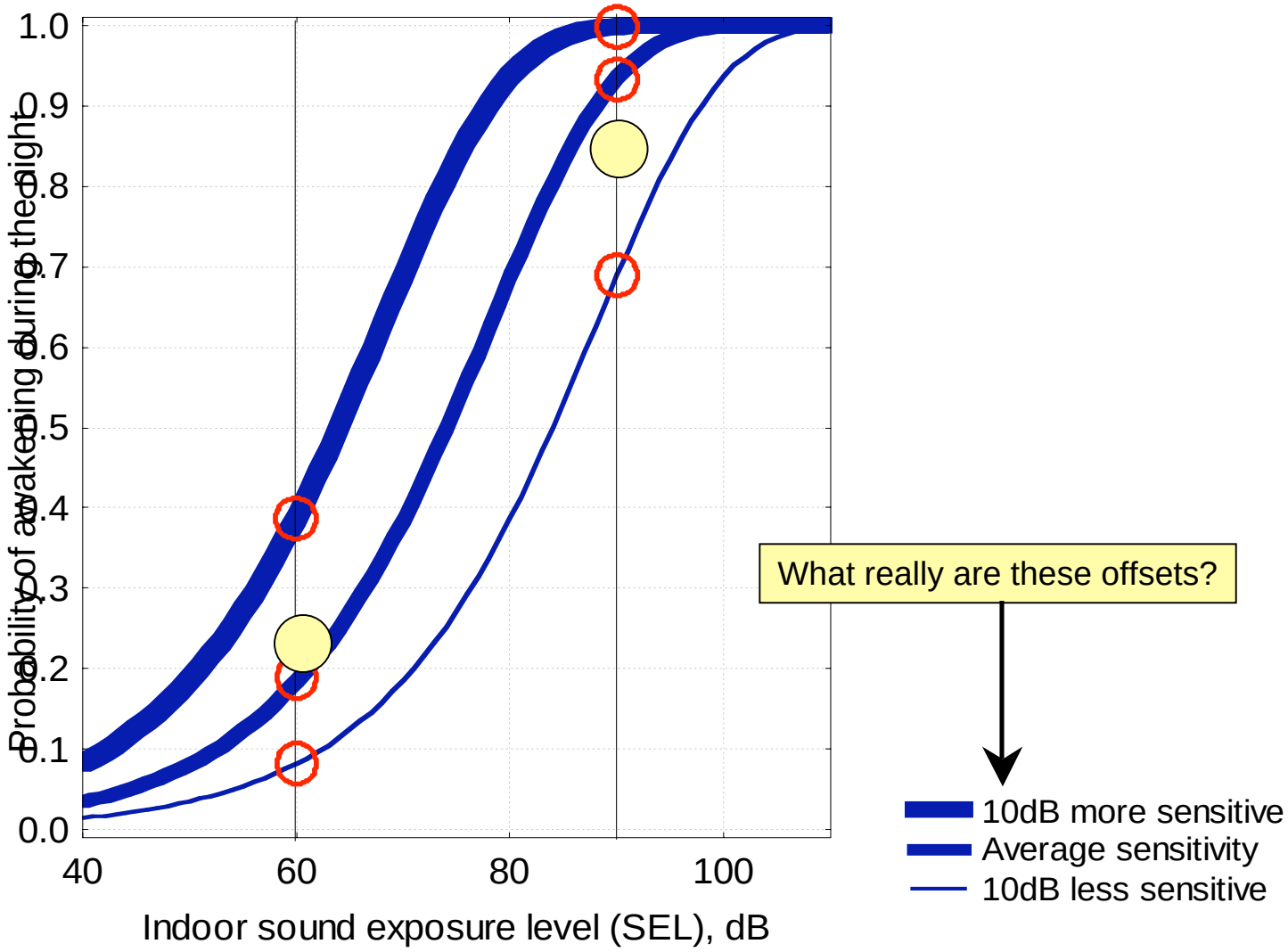
- Result, which is less awakening than the middle (average) curve

Just the opposite down here: more awakening

10dB more sensitive
Average sensitivity
10dB less sensitive

Person-to-person differences



Person-to-person differences

$$\text{Probability awakening} = \frac{1}{1+\exp(-Z)}$$

$$\text{where } Z = A_0 + A_1(\text{SEL}) + \sum_{p=2}^{P} B_p d_p$$

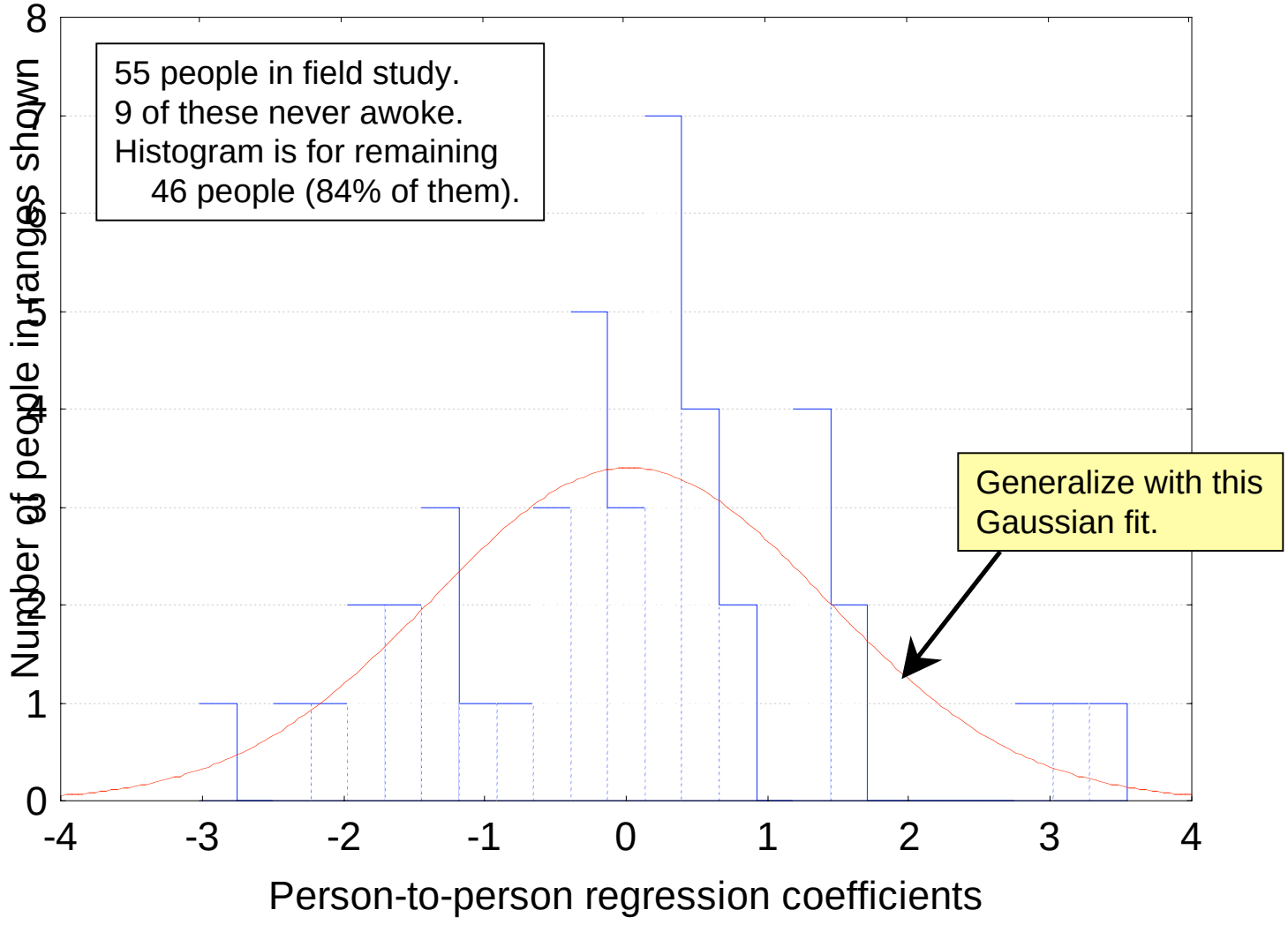
$$Z = -10.7383 + 0.0874(\text{SEL}) + \sum_{p=2}^{P} B_p d_p$$

Person 1: $Z = -10.7383 + 0.0874(\text{SEL}) + 0$

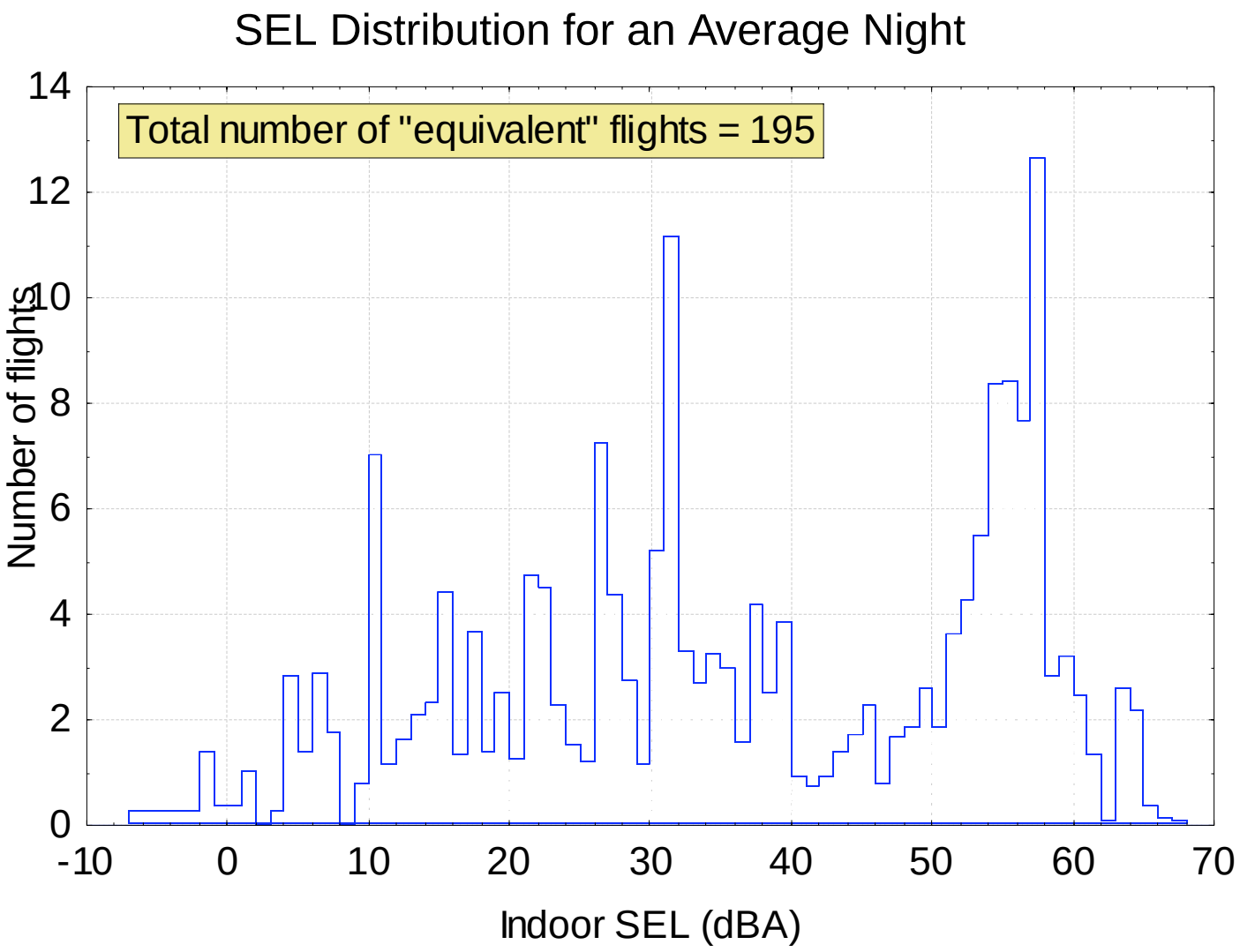
Person 2: $Z = -10.7383 + 0.0874(\text{SEL}) + B_2$

Person 3: $Z = -10.7383 + 0.0874(\text{SEL}) + B_3$

Person-to-person differences

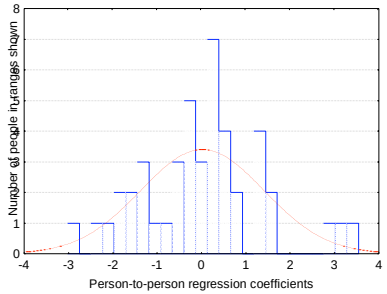


One grid point in detail

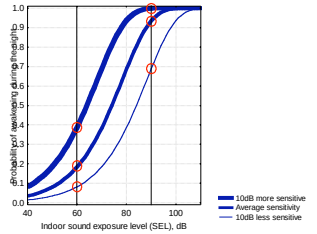


Percent awakened at each grid point

- **Start with 84% of the number of people, N, at that grid point**
- **Split into 32 "sensitivity groups"**



- **Each sensitivity group:**
  - Each SEL at that grid point:
    - Find probability of sleeping through "n" of these SEL's, from that group's dose-response curve

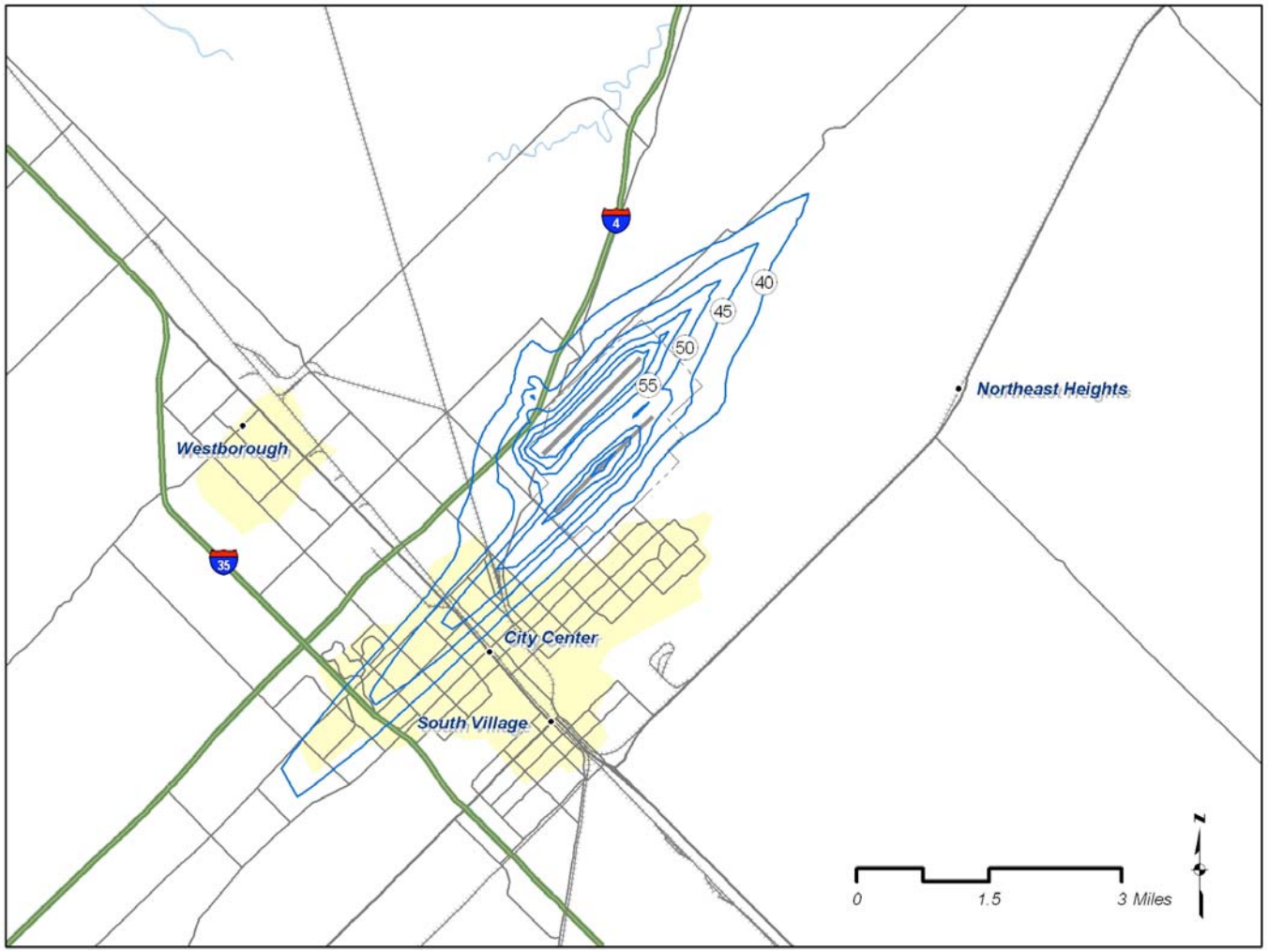


  - Next SEL
  - Multiply these probabilities together and convert to probability awakened

$$\begin{pmatrix}\text{Probability}\\ \text{awakening}\\ \text{during the night}\end{pmatrix} = 1 - \begin{pmatrix}\text{Probability}\\ \text{sleeping through}\\ \text{all SEL}_1\text{ aircraft}\end{pmatrix}^{n_1} \begin{pmatrix}\text{Probability}\\ \text{sleeping through}\\ \text{all SEL}_2\text{ aircraft}\end{pmatrix}^{n_2} \ldots$$

  - Convert to number awakened by this SEL
- **Next group**
- **Add up total number awakened over all groups**
- **Divide by total population at grid point**
- **Percent Awakened = 100 x (number awakened/total population)**

Application



Summary

- **Improved analysis of sleep disturbance**
  - Uses all available data – not averages
  - Uses standard INM output
  - Provides sleep disturbance contours
- **Examine sleep disturbance effects of alternatives**
  - New flight schedules
  - Altered runway use
  - Different fleet mixes
  - Changes in number of night time operations