Uncertainty and Variability in Historical Time Weighted Average Exposure Data

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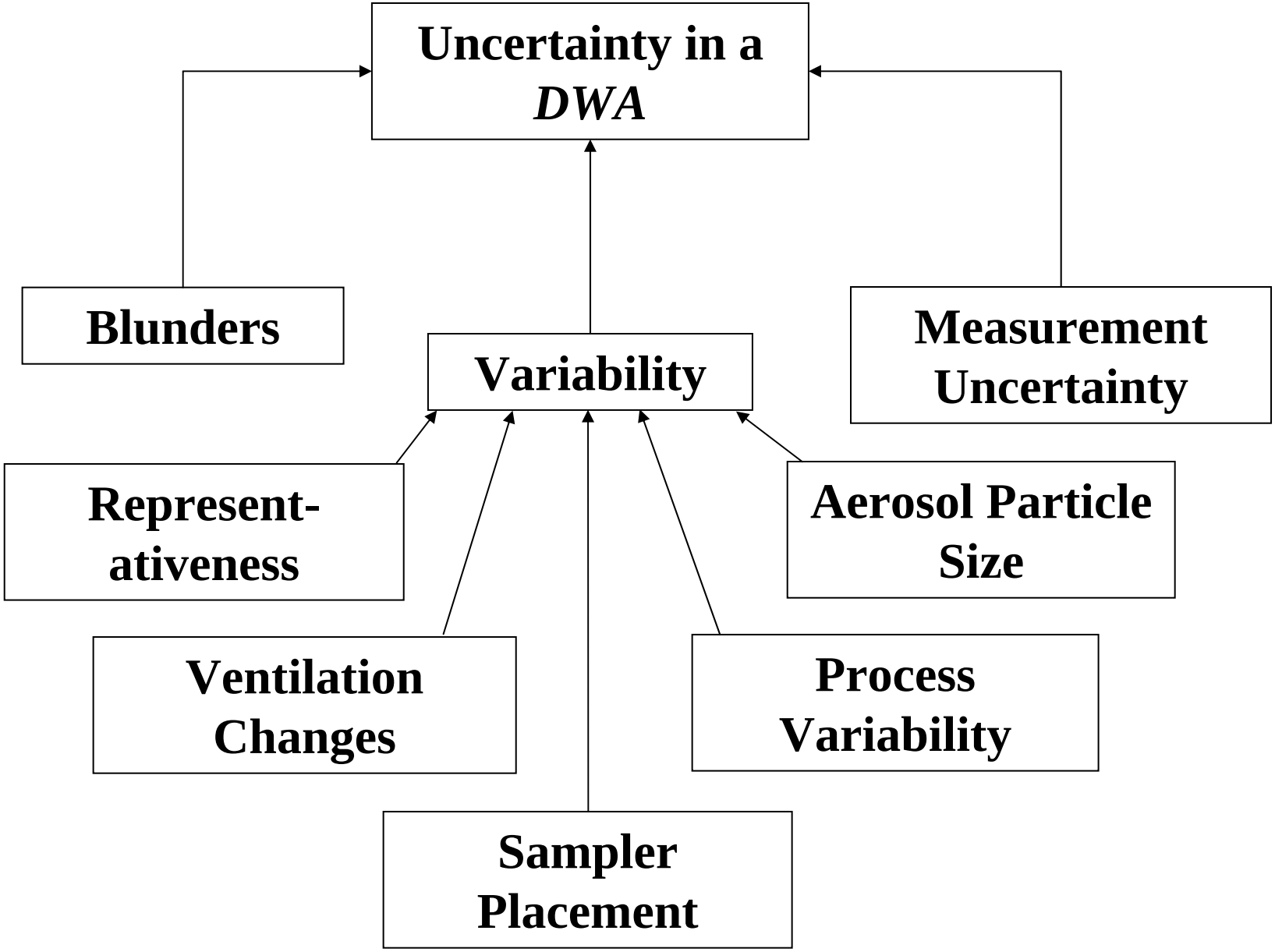
Questions and Goals (1)

- How does one quantitatively express the uncertainty associated with air sample data?
- What is the major contributor to uncertainty in the air-sample data?
- Does analysis of a distribution of all air samples from a plant produce a daily weighted average (*DWA*) or geometric standard deviation (*GSD*) that is representative of an individual worker?

Questions and Goals (2)

- Is there a better representation of the exposure received by workers than a point estimate of a *DWA*?
- Which is more favorable to the claimant when used as input into the Integrated Radio-Epidemiological Program (IREP)?
  - the 95th percentile value of all air samples at a site used as a constant
  - the DWA_D value as simulated

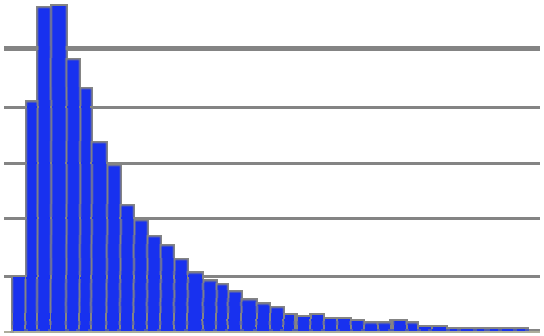

Uncertainty in a *DWA*
Blunders
Measurement Uncertainty
Variability
Represent-ativeness
Aerosol Particle Size
Ventilation Changes
Process Variability
Sampler Placement

Summary of Data

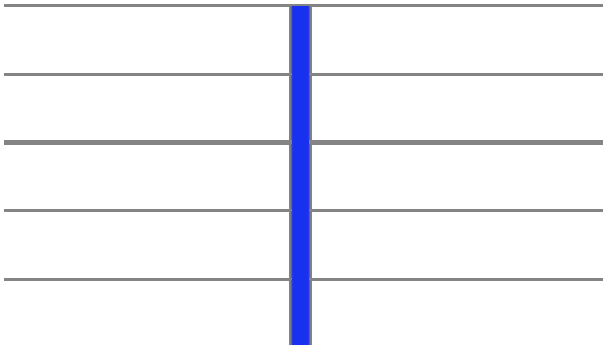
- 6 Health and Safety Laboratory (HASL) reports covering 5 sites between 1948 and 1955
- Radiological hazards from use of U, U ore, Th, or ^{226}Ra-^{222}Rn
  - 63 job titles for which *DWA* air concentrations were reported
  - Each job title held by 1 to 12 employees (165 total)
  - 1 to 13 operations per job title
  - 1 to 27 air samples per operation (428 total)
- No information on uncertainty was reported

Calculating Uncertainties

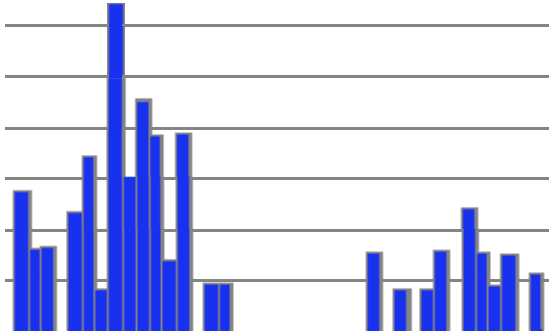
- Monte Carlo simulations are run in Crystal Ball to calculate uncertainties in the DWA_H
- *DWA* distributions based on sampling
  - Discrete concentration measurements
  - Lognormal fits to concentration measurements



$\boldsymbol{DWA_{\mathrm{L}}}$



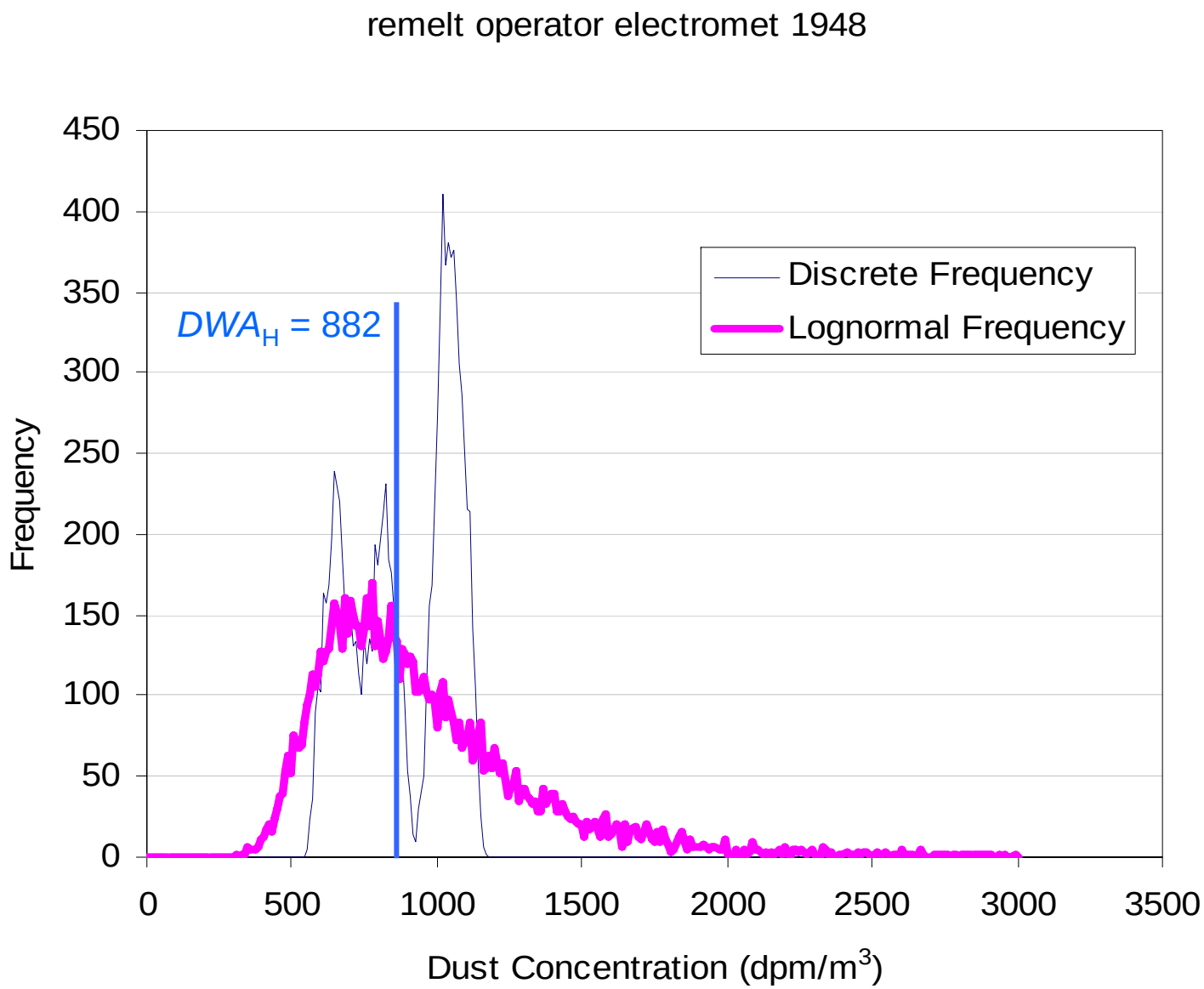
$\boldsymbol{DWA_{\mathrm{H}}}$



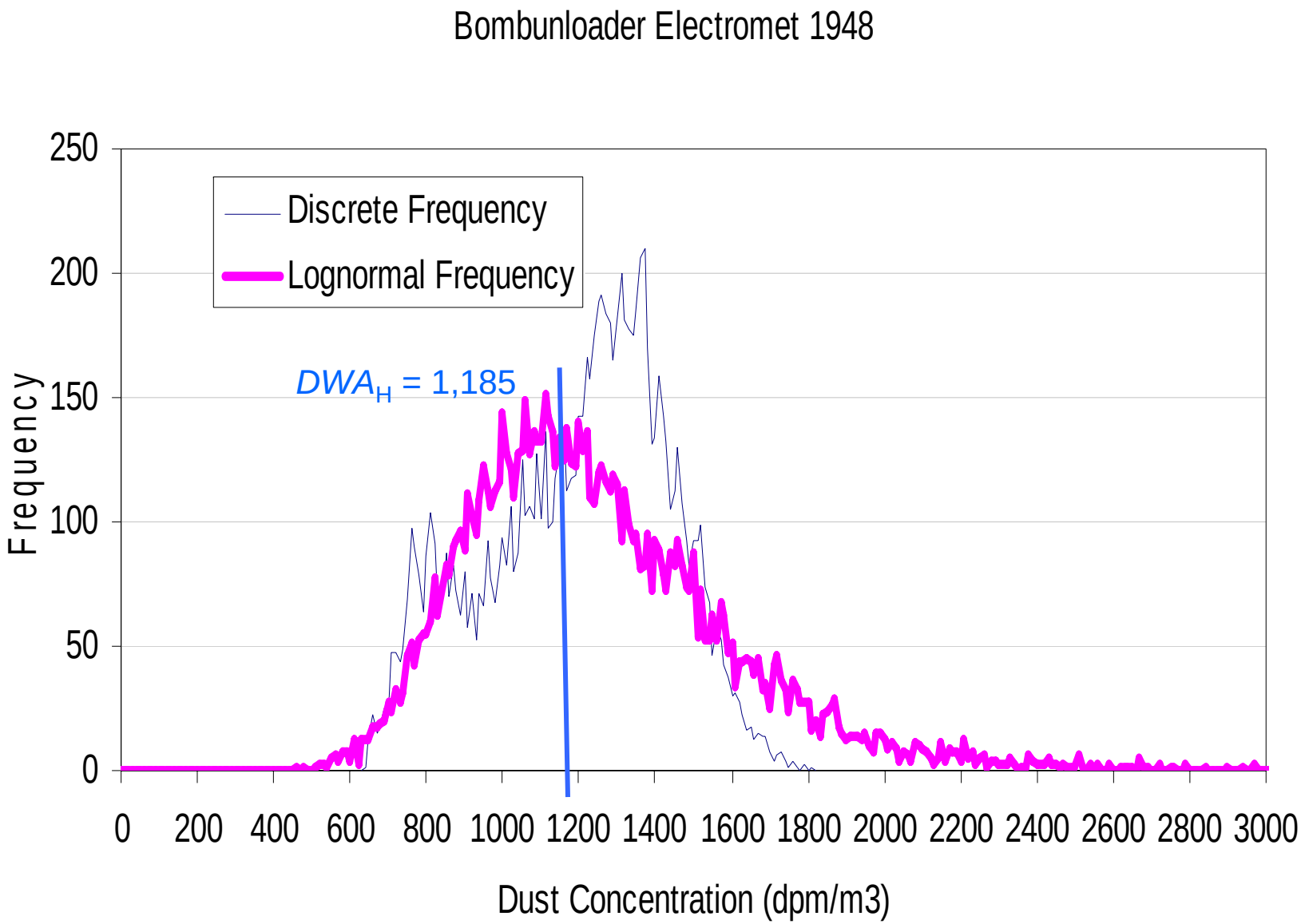
$\boldsymbol{DWA_{\mathrm{D}}}$

$$DWA_j = \frac{\sum_{i=1}^{N_j} T_{\mathrm{S},i} \times C_{\mathrm{OA},i}}{\sum_{i=1}^{N_j} T_{\mathrm{S},i}}$$

Differing Distributions of DWA_D and DWA_L

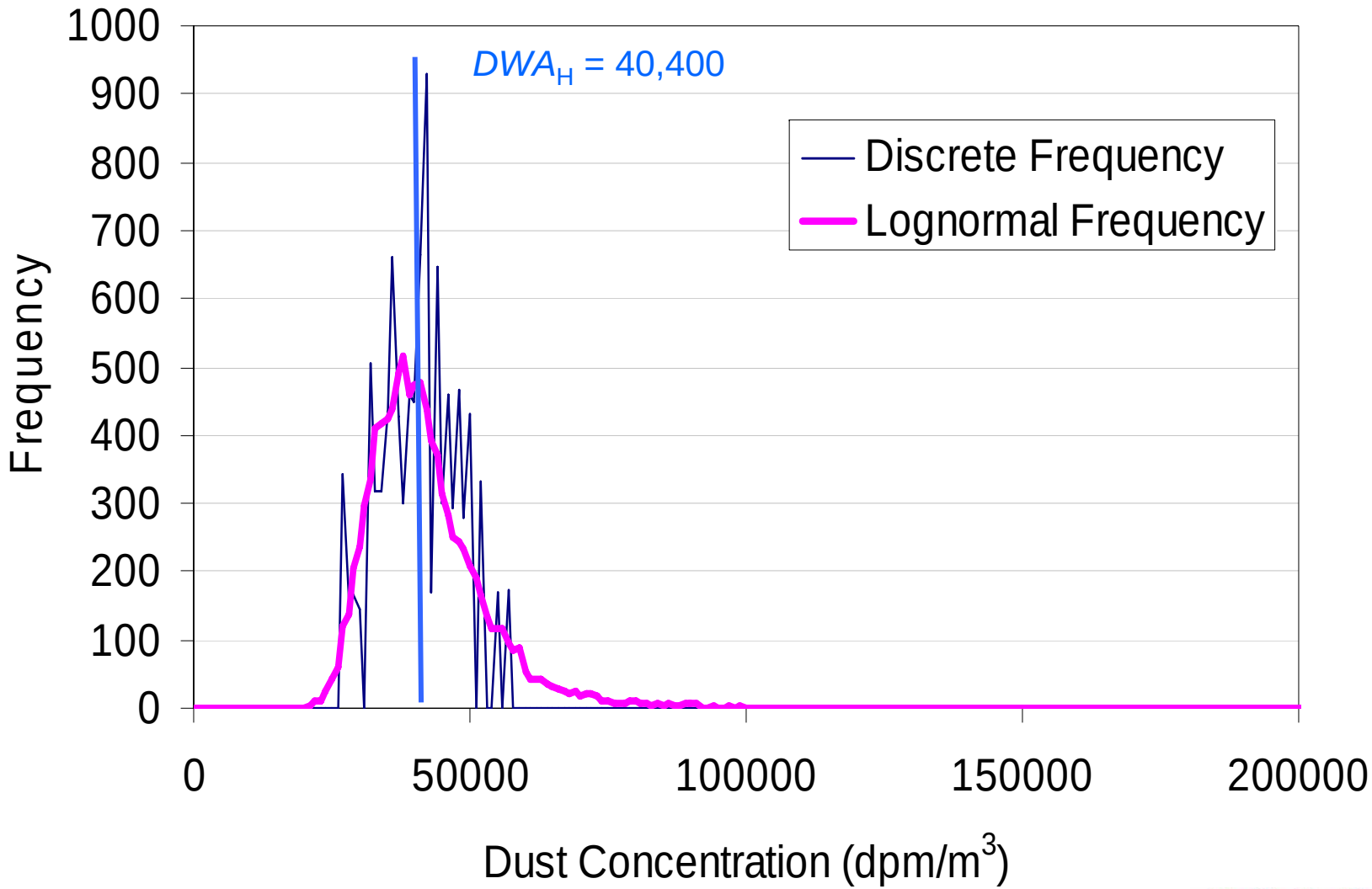


Similar Distributions of DWA_D and DWA_L

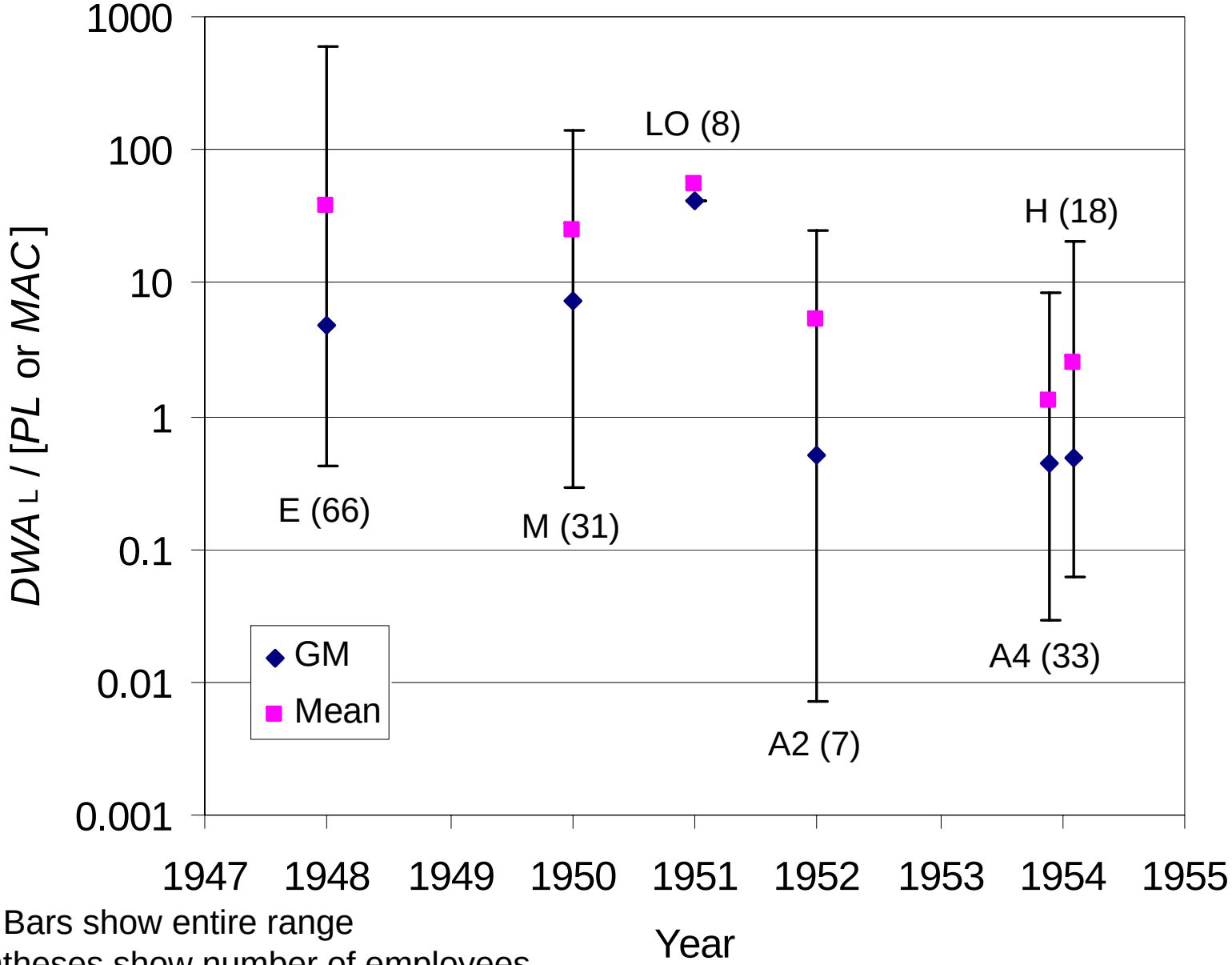


Similar Distributions of DWA_D and DWA_L

Greenroom Operator Electromet 1948

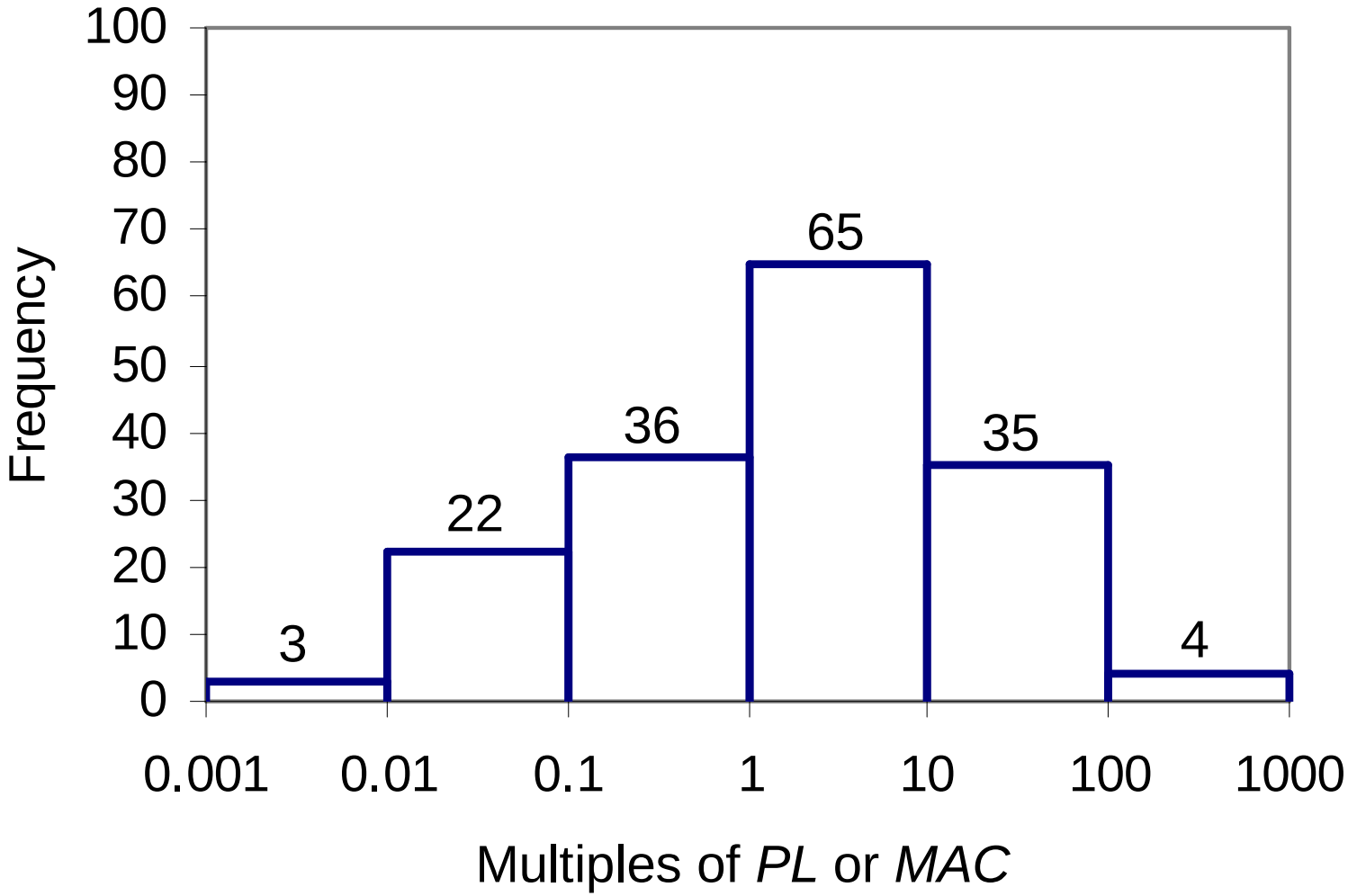


Normalized *DWA*s Across Sites



Note: Bars show entire range
Parentheses show number of employees

DWA_Ls of Employees



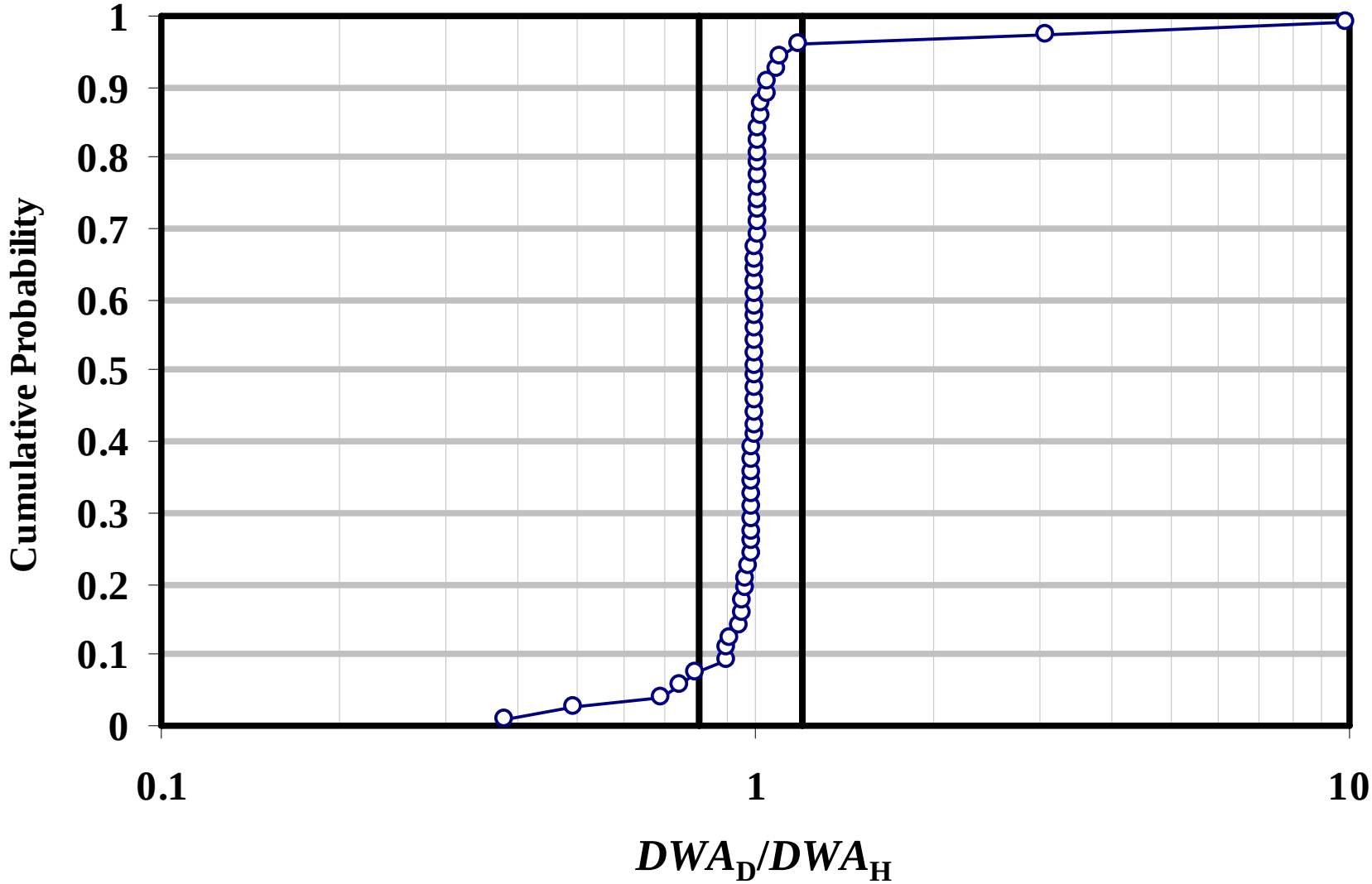
Comparison of All Air Samples to DWA_D

- Means of site-wide average concentrations obtained using all air samples exceeded DWA_D for all workers in 60 of 63 cases
  - In 3 cases DWA_js were 4.7, 2.0, and 1.9 times higher than site-wide average
- Upper 95th percentile from all air samples at a site exceeded the DWA_D for all workers in 62 of 63 cases
  - 1 case the DWA > 95th percentile by 7%
  - site with the smallest GSD (7.88)

Blunders

- "Blunders in recording or analyzing data can introduce a significant unknown error in the result of a measurement. Measures of uncertainty are not intended to account for such mistakes" (ISO 1995)
- Not anticipated in the early stages of the study
  - Transcription error
  - Calculation error
  - Rounding of data
  - Self contradictions
  - Data imputation needed

Magnitude of Blunders



Conclusions (1)

- Monte Carlo methods can produce uncertainty distributions for *DWA* concentrations of airborne radioactivity from historical records
- Variability dominates the *DWA* uncertainty
- Using all air sample data from a plant without regard to time-weighting or job title produces distributions
  - with huge *GSD*s and CVs
  - that are not representative of any *DWAs* or uncertainty
  - whose upper 95th percentile exceeds almost all *DWA*s
- Using the upper 95th percentile of site-wide air concentration data will almost always be favorable to the claimant, if unrealistically high for almost everyone

Conclusions (2)

- DWA_H not always representative
  - In the absence of blunders, the DWA_D should be similar to the DWA_H, but DWA_D differed from DWA_H by more than 20% for 7 of 60 job titles
  - $0.38 \leq DWA_D/DWA_H \leq 9.9$
  - Blunders add unpredictably to uncertainty
- *GSD*s and *CV*s of simulated *DWA*s were generally less than *GSD*s and *CV*s of air concentrations for single operations
  - except when a single operation dominated a workday