# A Unified Approach to Uncertainty in Dosimetry for JCCRER: A Proposal

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# Outline

- Customers of Dose Assessments
- Goals
- Criteria
- Paradigm shift
- Multiple Dose Realizations
- Next Steps

## Who Are the "Customers" for Dose Reconstruction?

- Biostatisticians (not epidemiologists) will use our numbers
- Other researchers
  - the tissue repository
  - EPR
  - FISH
- The Scientific Review Group will review our methods and results
- Editorial Boards of scientific journals will scrutinize our work
- Our funding agencies
- [Lawyers, workers, relatives of workers…]

## What Do the "Customers" Need?

- Biostatisticians need
  - Best point estimates of doses for exploratory analyses
    - For each individual
    - For each year (annual, not cumulative, doses)
    - To each tissue or organ
    - For each kind of radiation
  - Many replications of dose for uncertainty analysis with correct handling of
    - shared and unshared uncertainty
    - Berkson (grouping) and classical (measurement) uncertainty
- Tissue repository needs individual tissue doses until death with quantitative expression of uncertainty
- EPR needs dose to individual's teeth until time of extraction
- FISH needs dose to individual's bone marrow until time of sample

# Goals for Next Few Years

- Create a unified format for *quantitative* expression of uncertainty for all JCCRER (not just Project 2.4) tissue and organ doses from *rad types*
  1. occupational external: gamma
  2. occupational external: beta
  3. occupational external: neutron low-LET component
  4. occupational external: neutron high-LET component
  5. occupational internal: Pu + associated contamination
  6. medical: partial body, non-uniform, high dose-rate x-ray
  7. [Project 1.1: environmental external: gamma]
- Develop approaches for the near future and farther along

## Criteria

- A unified approach to uncertainty in dosimetry is
  - desirable
  - possible
- The form of uncertainty expression must
  - meet needs of epidemiologists & biostatisticians
  - disaggregate grouping (Berkson) & measurement (classical) components
  - properly account for shared & unshared uncertainty
    - shared among whom?
    - shared over what period of time?
  - account for intra-individual covariance over time of annual organ doses

## The Old Paradigm

- The physicist's uncertainty paradigm:
  - a numerical dose value
  - a numerical uncertainty value associated with the dose value
- The physicist's paradigm does not meet the needs of JCCRER epidemiologists
- A new paradigm is needed
  - Parts of "Errors and Uncertainties in Dose Reconstruction for Radiation Effects Research" (PNNL-17465, April 2007) are obsolete
- The Hanford Environmental Dose Reconstruction (HEDR)-Techa River Dosimetry System (TRDS) paradigm can be adapted for occupational and medical doses

## New Uncertainty Paradigm: First Steps

- Write the equations or models for each type of dose emphasizing uncertainty
- Do the best possible job to get the doses right
- Establish "dosimetry error structure" by characterizing the uncertainty of each term in the models by
  - Grouping (Berkson) or Measurement (Classical)
  - Unshared or Shared (among whom? for how long?)
  - Intra-individual time covariance
  - Some terms have several uncertainty components
  - Form of distribution of each component
  - Implement structure for calculations

## New Uncertainty Paradigm: A Dose Realization

- Create a "dosimetry environment" analogous to HEDR/TRDS "radiation environment" containing all shared uncertainty terms
- Create an algorithm for a single dose realization
  - each individual in Mayak cohort brings his/her unique individual *(unshared)* parameter values to each dosimetry environment
  - *shared* uncertainty values
    - sampled just once for a single realization
    - each individual has same value of each shared uncertainty parameter for a realization
- Result of a dose realization is a set of dose "vectors" for each individual *m* for realization *j*

$$\vec{D}_{m,j}(\,year, organ, rad\ type, source, data\ provenance\,)$$

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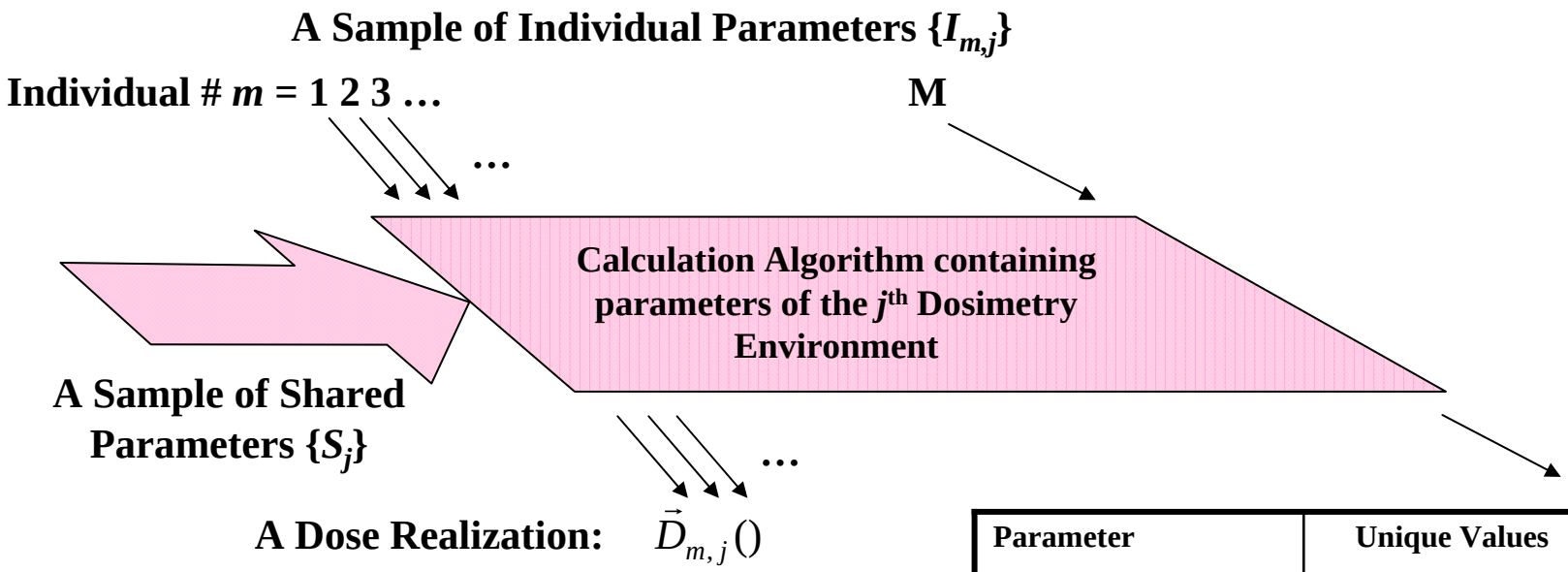
# A Dose Realization




$$\vec{D}_{m,j}(\,year, organ, rad\ type, source, data\ provenance\,)$$

| Parameter | Unique Values |
|---|---|
| *M* | 26,000 |
| *year* | ~60 |
| *organ* | ~25 |
| *rad type* | 6 |
| *source* | ~10 |
| *data provenance* | <10 |
| Total | $24 \times 10^9$ |

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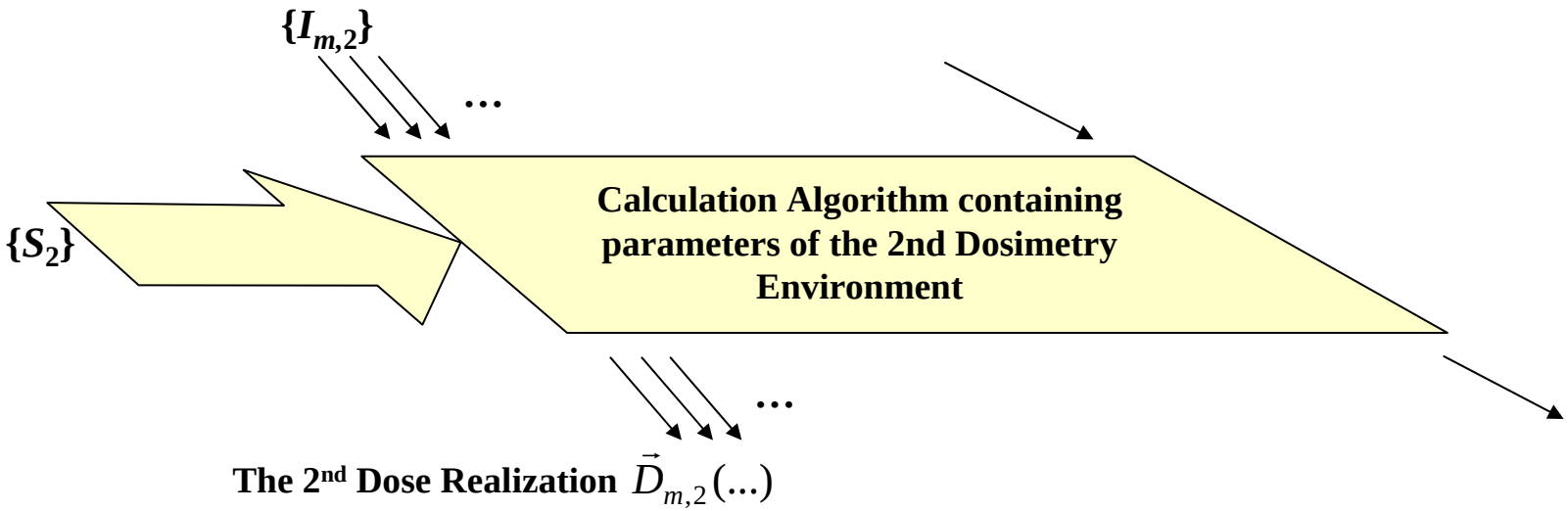
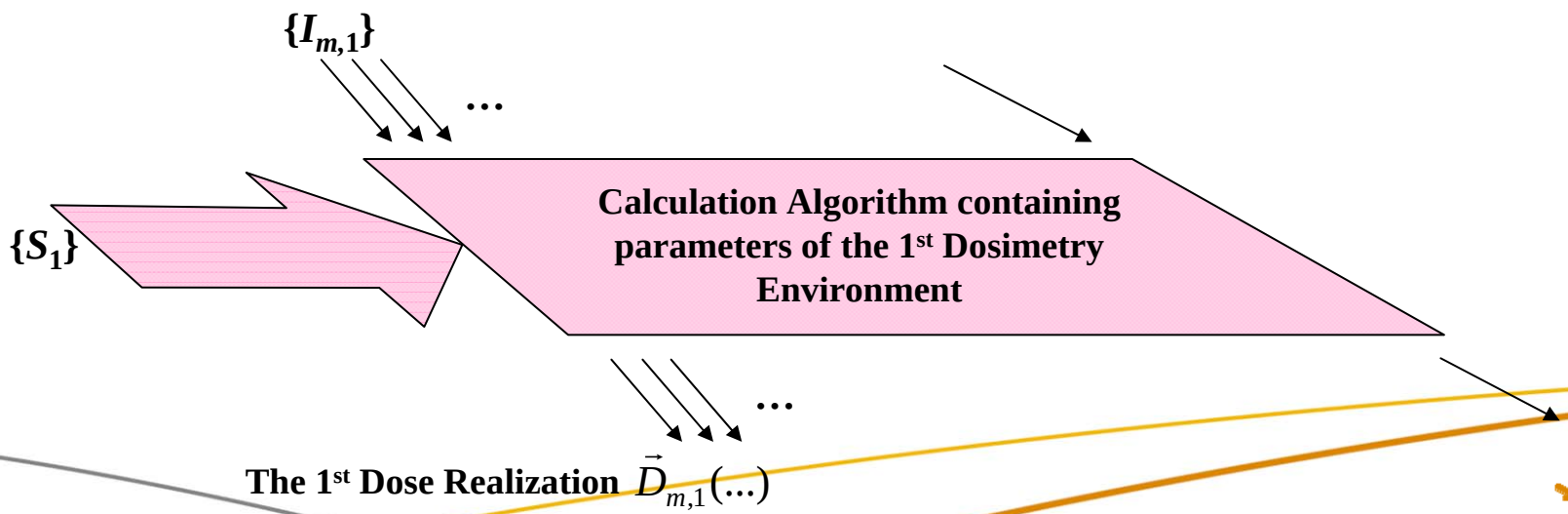
## New Uncertainty Paradigm: Multiple Dose Realizations

- Perform multiple ($J$ = 100, 1,000, or more) dose realizations
  - each realization has new sample from shared uncertainties
- Multiple realizations are the correct *and* currently most feasible method for shared uncertainties

# 2 Dose Realizations

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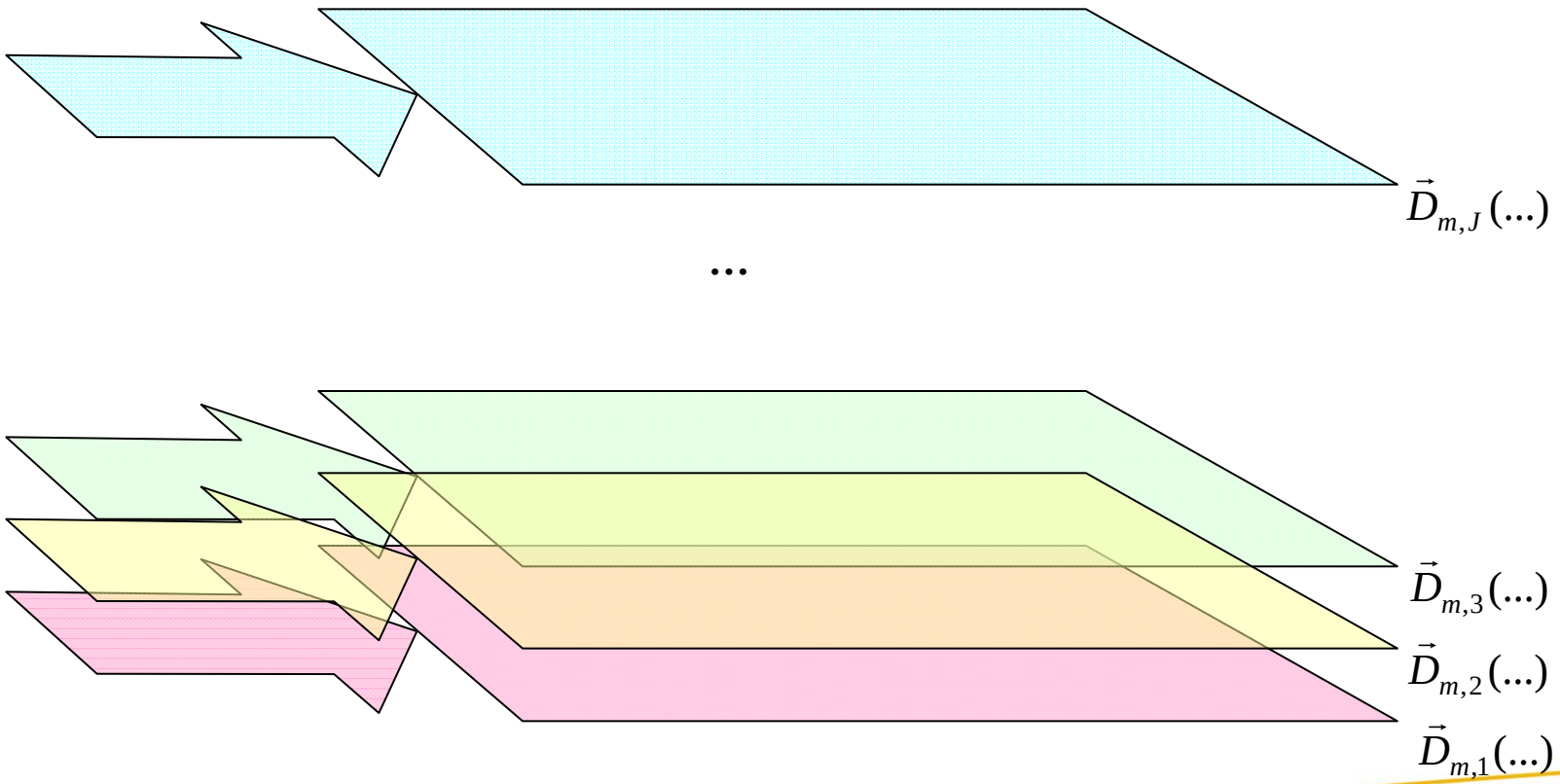
# A Series of *J* Dose Realizations



## New Uncertainty Paradigm: Using Multiple Dose Realizations for Different Customers

- Some "customers" need a dosimetry product that gives a single number for a tissue or organ
  - the tissue repository (dose until death to each specific tissue)
  - comparison with FISH dose to bone marrow up to date of blood draw
  - comparison with EPR on teeth up to date of tooth extraction
- For each individual,
  - Calculate the arithmetic mean dose by averaging over *J* realizations up through the desired ending year
  - Calculate the variance and standard deviation of *J* realizations
  - Form of the uncertainty is implicit in the *J* realizations

## Next Steps

- Engage in a pilot project for all *rad types*
- Write the equations or document the models
  - much of this has been done
  - disaggregate into Berkson & classical
- Establish the dosimetry error structure and calculation algorithms
  - Consensus process with Russian researchers
- Construct Dosimetry Environments for each *rad type* with expectation value estimates of all parameters
- Create a single Dose Realization for each *rad type*
- Begin to vary shared and individual parameters
- Evaluate distributions for individuals

## Challenges and Unresolved Questions

- Can the biostatisticians and epidemiologists agree on this approach?
- Will this method handle classical uncertainties correctly?
  - Hofer's suggestion that "observed" or "assessed" doses have too much variability
  - Is this really a problem for 26,000 workers?
- Is it valid to go part way with Bayesian uncertainties and the rest of the way with a more traditional Monte Carlo approach?
  - May depend on the Bayesian prior probability distribution that is used
  - There are examples of using individual Bayesian results in a classical calculation that results in bias

## Challenges and Unresolved Questions - 2

- Will adequate resources be made available for multiple dose realizations?
  - Computational
  - Human
- How can FISH, EPR and perhaps other results be used to develop confidence in
  - external dosimetry results?
  - medical dose reconstructions?
  - internal dose assessments based on bioassay or autopsy data?

# Current Status of US Participants in JCCRER Project 2.4, Mayak Worker Dosimetry

- Request for proposals issued 10 June 2008
  - http://www07.grants.gov/search/search.do;jsessionid=LPzMZlRSShpGdLZGrnzyPx6TvdDlLfrRZpTlbGnsdqDp9qhgQ6ln!-2076543519?oppId=17857&flag2006=true&mode=VIEW
- Proposals due 21 July 2008
  - Incumbent (University of Utah and PNNL) submitted
  - Others submitted
- Decision expected by October 2008
- Successful bidder will work on Doses 2011 for 3 years
  - 1 Nov 2008 – 31 October 2011