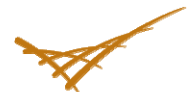


RADIATION DOSE RECONSTRUCTION: PRINCIPLES AND PRACTICES

An NCRP Report

Bruce Napier

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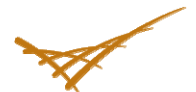
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Just a partial discussion today...

- ▶ Purposes of Dose Reconstruction
- ▶ Basic Elements / Foundation Issues
- ▶ Methodologic Issues
- ▶ Handling of Uncertainty for Epidemiological Inputs

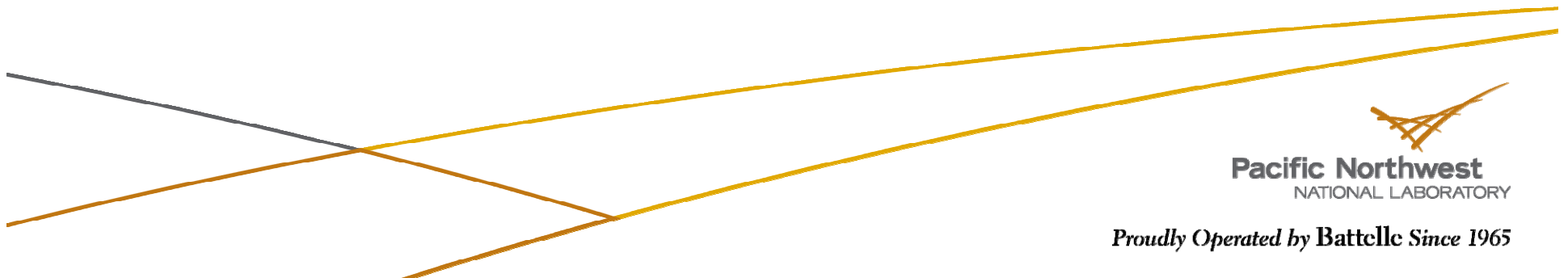


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Dose Reconstruction Defined

- ▶ Retrospective assessment of dose to *identified* or *representative* individuals or populations *by any means*

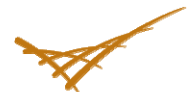


Dose Reconstruction Purpose

- ▶ Dose reconstruction can be done for a variety of purposes
 - Compensation for occupational disease (NIOSH / EEOICPA)
 - Management of radiation emergencies (1976 Hanford americium accident)
 - Information for the public (NCI Fallout Study)
 - Epidemiological use (LSS, NTS, HTDS, Mayak)

Basic Elements/Foundation Issues

- ▶ Definition of exposure scenarios/exposed groups
- ▶ Identification of exposure pathways
- ▶ Development and implementation of dose reconstruction methods
- ▶ Evaluation of uncertainties
- ▶ Presentation/interpretation of results
- ▶ * Data and information
- ▶ * QA/QC

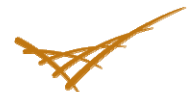


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Basic Elements – Exposure Scenarios

- ▶ Assumptions about conditions of exposure
 - Conceptual representation of a situation of concern
 - Description of individuals/populations
 - Characteristics
 - Activities
 - Time spent
- ▶ Descriptions of the sources of radiation exposure

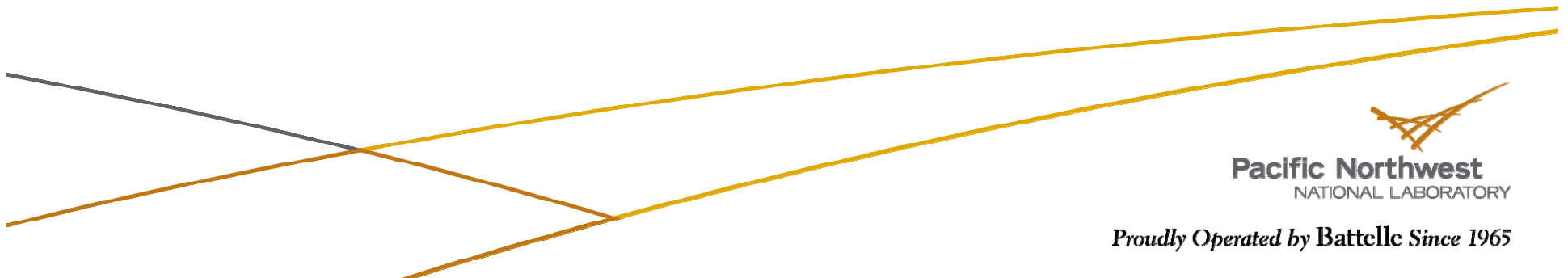


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Basic Elements – Exposure Pathways

- ▶ Pathways of internal and external exposure
 - Simple – medical x-rays
 - Complex – environmental release, transport, deposition, transfer, uptake



Basic Elements – Dose Estimation Methods (1)

- ▶ Dosimetric quantity to be evaluated
 - Generally, absorbed dose to specific organs and tissues
 - Radiation protection quantities are often NOT appropriate!
 - Frequently, time dependent
 - Separation of low and high LET – no “quality factor” or “radiation weighting factor”
 - Separation of internal and external dose

Basic Elements – Dose Estimation Methods (2)

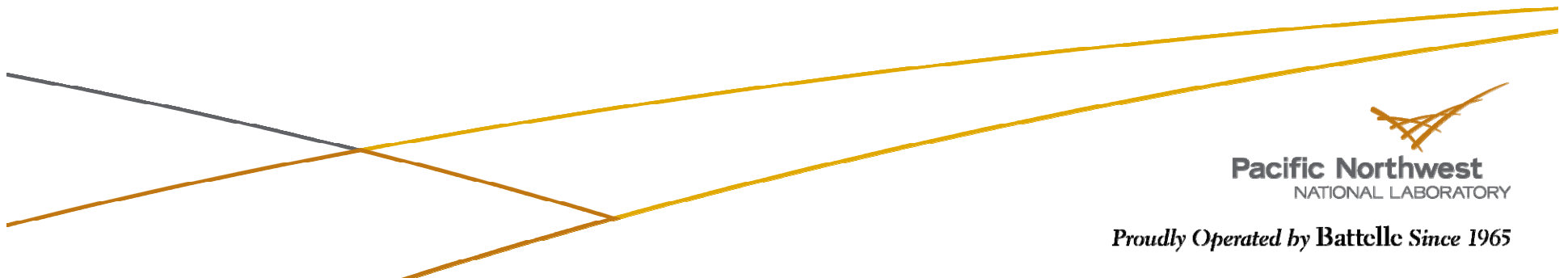
- ▶ Model Use
 - Dosimeter reading conversions
 - Calculation of energy spectra
 - Physical mock-ups
 - Medical symptoms
- ▶ Complexity of modeling should be commensurate with purpose and type, quality, and availability of data
- ▶ Validation is useful

Methodological Issues

- ▶ All computations use “models”
 - Some are relatively simple – converting a meter reading in $\mu\text{R/hr}$ to an organ dose in Gy
 - Some are complex – converting an atmospheric release into an air concentration, deposition, and uptake by a cow into a concentration in milk consumed by a person

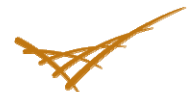
Dose Reconstruction Techniques

- ▶ Direct radiation measurements
 - Film badges, TLD
- ▶ Indirect radiation measurements or estimates
 - Environmental concentrations
 - Biodosimetry
 - Opportunistic dosimeters



Dose Reconstruction Techniques - Biodosimetry

- ▶ Cytogenetic analyses (chromosome aberrations)
 - FISH and others
- ▶ Genetic/molecular markers (Somatic mutations)
 - Glycophorin A
 - T-Cell antigen receptor (HPRT gene inactivation)
 - Micronucleus assay
- ▶ Electron Paramagnetic Resonance
 - Irradiation of hydroxyapatite (tooth enamel) produces stable paramagnetic radicals; linear dose/response 0.1 to 200 Gy



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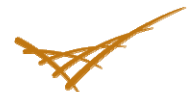
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Dose Reconstruction Techniques – Opportunistic Dosimeters

- ▶ Luminescence – natural TLD, OSL
 - Quartz crystals in bricks
 - Ceramics like glass (electrical insulators), pottery, false teeth
- ▶ Neutron activation
 - Radioactive
 - Accelerator mass spectroscopy – isotopic ratios
 - Cl-36, Ni-63, Eu-152
- ▶ Track Etch
 - Glass, ceramic, plastic

Basic Elements – Estimation of Uncertainty

- ▶ ALL dose estimates are uncertain
 - Lack of complete knowledge of exposure scenario
 - Variability in relevant measurements
 - Lack of knowledge of relevant processes
- ▶ Uncertainty can be *random* or *systematic*
 - Statistical fluctuations
 - Bias (e.g., calibration, desire for “conservatism”)
- ▶ Essential purpose is to provide a credible range within which there is a high degree of confidence the “true” dose lies (We’ll come back to this!)



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Handling of Uncertainties

- ▶ All estimates should address uncertainty
 - If worst-case assumptions indicate small doses, detailed uncertainty analyses may be unnecessary
 - In compensation programs, if reasonable upper-bound assumptions result in doses above a threshold, detailed uncertainty analyses may be unnecessary
 - But in epidemiological applications, best estimates are needed, thus a realistic description of uncertainty is required

Use of Dose Uncertainty in Epidemiology is Rapidly Changing

- ▶ In the mid-1990s, dose/effect estimates did not use dose uncertainties
- ▶ Today, the use of dose distributions is the state of the art, via maximum-likelihood estimation
- ▶ The biostatisticians know about Berkson errors, and have asked that they be identified – but don't yet know what to do with them

Basic Elements – Presenting Results

▶ During the work:

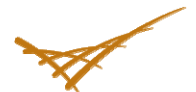
- Peer reviews (SRG for JCCRER)
- Interested parties
 - At Mayak, the combined JCCRER projects have over 200 peer-reviewed open-literature publications

▶ Describing conclusions

- Interpret by discussing in the context of the objectives
- Usually, journal articles are NOT the endpoint; epidemiology, legal uses, etc.

Basic Elements - Data

- ▶ Describe characteristics, locations, activities of people
- ▶ Describe sources of radiation
- ▶ Identify pathways of exposure
- ▶ Can be a major challenge if dealing with tens of thousands of people
- ▶ Human subjects – privacy is important
- ▶ Can be especially important in time-sensitive dose reconstructions – accidents
- ▶ Data validity is often not obvious



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Basic Elements – QA/QC

- ▶ Approaches may vary for research, legal, or accident situations
- ▶ Documentation of sources, assumptions
- ▶ Computer code verification
- ▶ Standard operating procedures

Summary

- ▶ Basic Elements of Dose Reconstruction
 - Definition of exposure scenarios/exposed groups
 - Identification of exposure pathways
 - Development and implementation of dose reconstruction methods
 - Evaluation of uncertainties
 - Presentation/interpretation of results
 - * Data and information
 - * QA/QC

Summary

- ▶ No two dose reconstructions are alike
 - But they have many common features
- ▶ Use all of the data you have available
- ▶ Estimate uncertainties

