Back to Basics - Uncertainty

Presented by:
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Overview

- From NIST TN 1297 (1994)
  - 2.1 In general, the result of a measurement is only an approximation or estimate of the value of the specific quantity subject to measurement, that is, the measurand, and *thus the result is complete only when accompanied by a quantitative statement of its uncertainty*. [emphasis added]
- From ICRP Pub 60 (1990)
  - (271) In Practice, it is usually possible without great difficulty to achieve an accuracy of about 10% at the 95% confidence level for measurements of radiation fields in good laboratory conditions. In the workplace, where the energy and orientation of the radiation field are rarely known, **uncertainties by a factor of 1.5 will not be unusual** in the estimation of annual doses… [emphasis added]

Overview – ctd.

Uncertainty analysis is required by the NVLAP in Handbook 150

From the foreword of NIST Handbook 150 (2001):

> The 2001 edition of NIST Handbook 150 incorporates revisions to the procedures and general requirements of the National Voluntary Laboratory Accreditation Program (NVLAP), set forth in Part 285 of Title 15 of the U.S. Code of Federal Regulations. These revisions were published in the *Federal Register* on May 30, 2001, and became effective on June 29, 2001. The NVLAP procedures were revised to ensure continued consistency with international standards and guidelines, specifically those currently found in ISO/IEC 17025:1999, *General requirements for the competence of testing and calibration laboratories*, and ISO/IEC Guide 58:1993, *Calibration and testing laboratory accreditation systems–General requirements for operation and recognition*.

NIST Handbook 150

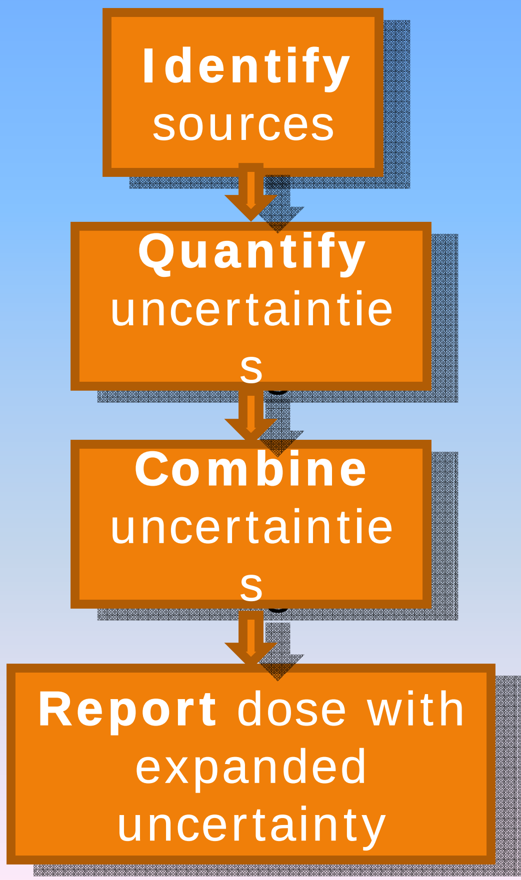
5.4.6 Estimation of uncertainty of measurement

5.4.6.1 A calibration laboratory, or a testing laboratory performing its own calibrations, shall have and shall apply a procedure to estimate the uncertainty of measurement for all calibrations and types of calibrations.

5.4.6.2 Testing laboratories shall have and shall apply procedures for estimating uncertainty of measurement. In certain cases the nature of the test method may preclude rigorous, metrologically and statistically valid, calculation of uncertainty of measurement. In these cases the laboratory shall at least attempt to identify all the components of uncertainty and make a reasonable estimation, and shall ensure that the form of reporting of the result does not give a wrong impression of the uncertainty. Reasonable estimation shall be based on knowledge of the performance of the method and on the measurement scope and shall make use of, for example, previous experience and validation data.

NVLAP Note: ANSI/NCSL Z540-2-1997 and NIST Technical Note 1297, 1994 edition, are considered to be equivalent to the Guide to the Expression of Uncertainty in Measurement (GUM).

Overview –NIST TN 1297



- Identify the sources of uncertainty
- Quantify the sources
  - Type A
  - Type B
- Combine the uncertainties
  - Law of propagation of uncertainties
- Calcuate the expanded uncertainty for given element responses

Identify Sources of Uncertainty

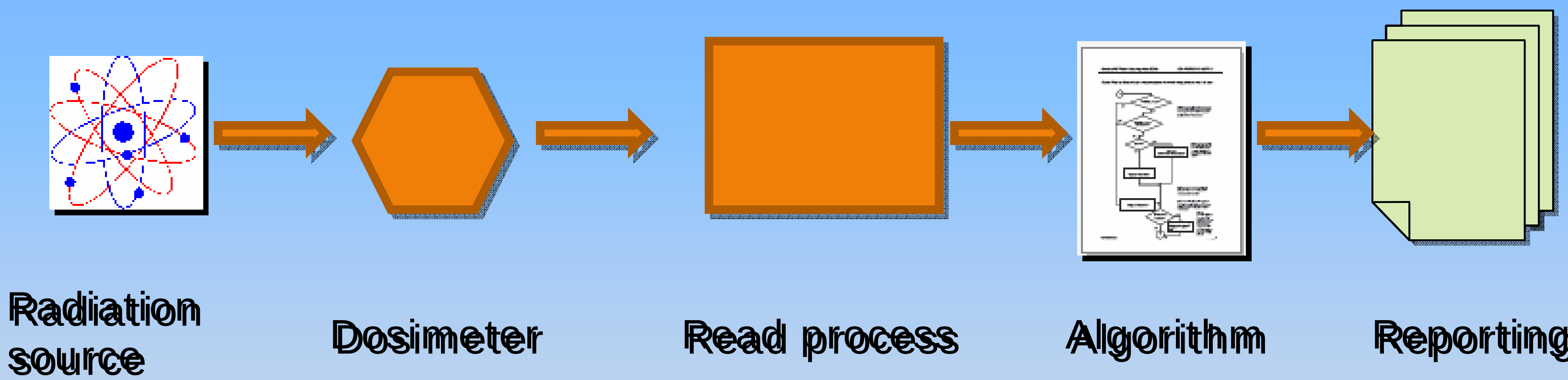
- **Type A -** Any uncertainty evaluated using statistical methods
- **Type B** – Uncertainty evaluated using any other method

For external dosimetry, typically there are <u>no Type A uncertainties</u>. Exceptions include situation using a mean value of several measurements.

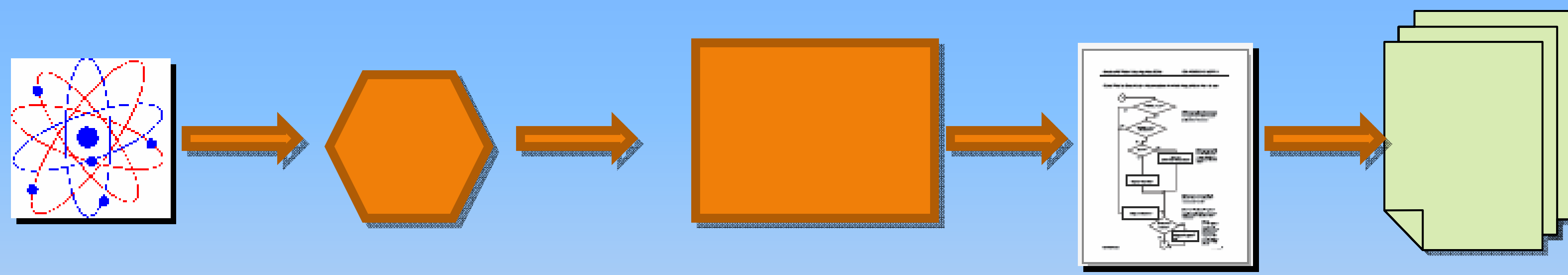
Type B Evaluations

- From NIST 1297 (direct quote)-
  - previous measurement data,
  - experience with, or general knowledge of, the behavior and property of relevant materials and instruments,
  - manufacturer's specifications, data provided in calibration and other reports, and
  - uncertainties assigned to reference data taken from handbooks.

Sources of Uncertainty

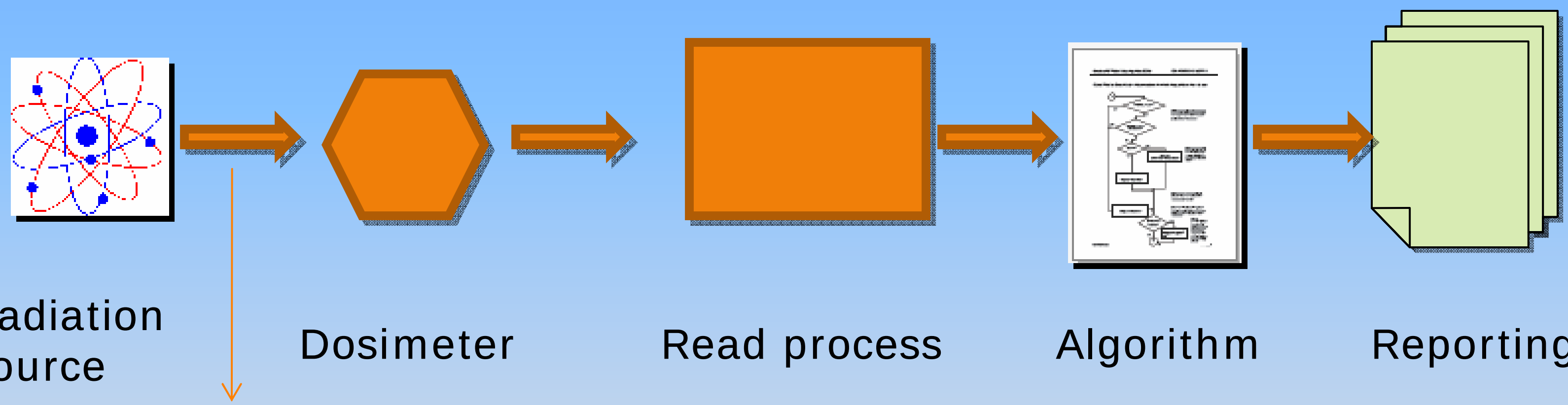


Sources of Uncertainty



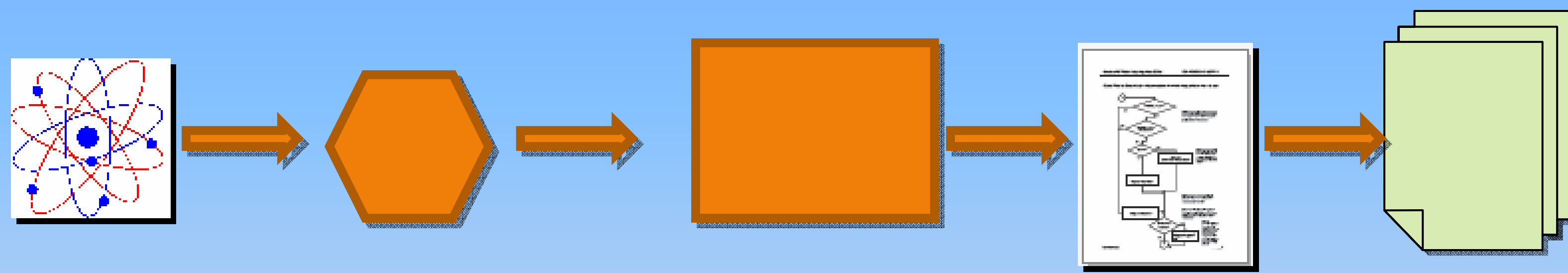
- Energy(ies)
- Radiation type(s)

Sources of Uncertainty



- Orientation
- Time conditions

Sources of Uncertainty

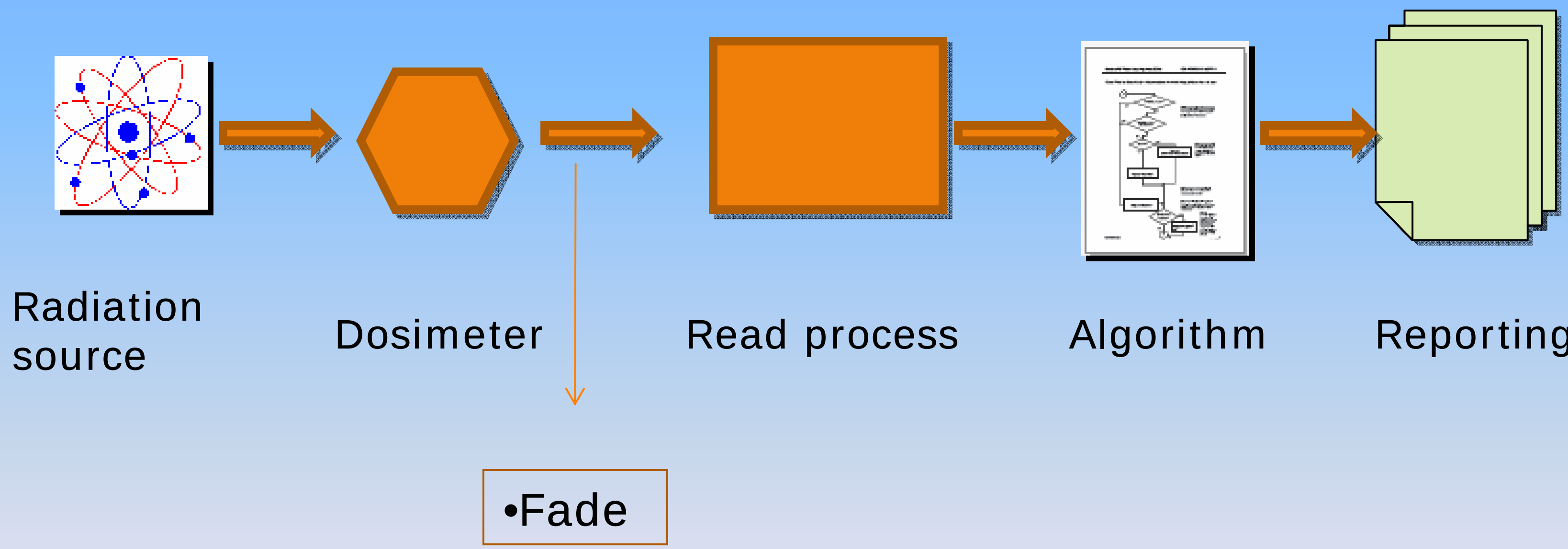


Radiation source → Dosimeter → Read process → Algorithm → Reporting

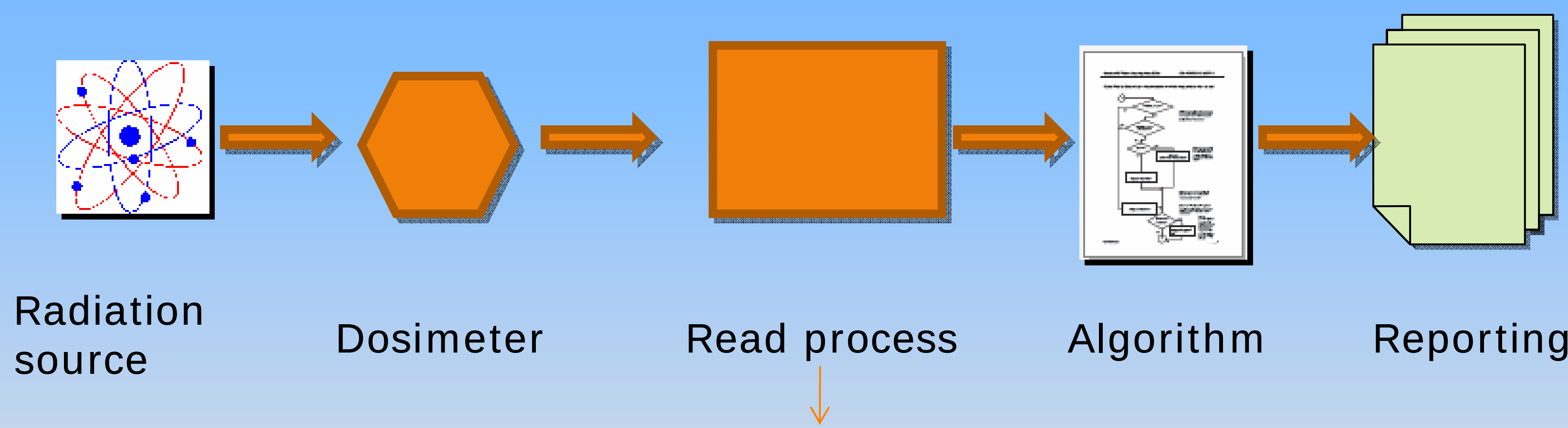
Dosimeter:

- Sensitivity
- Calibration
- Pre-fade
- Linearity
- Background

Sources of Uncertainty

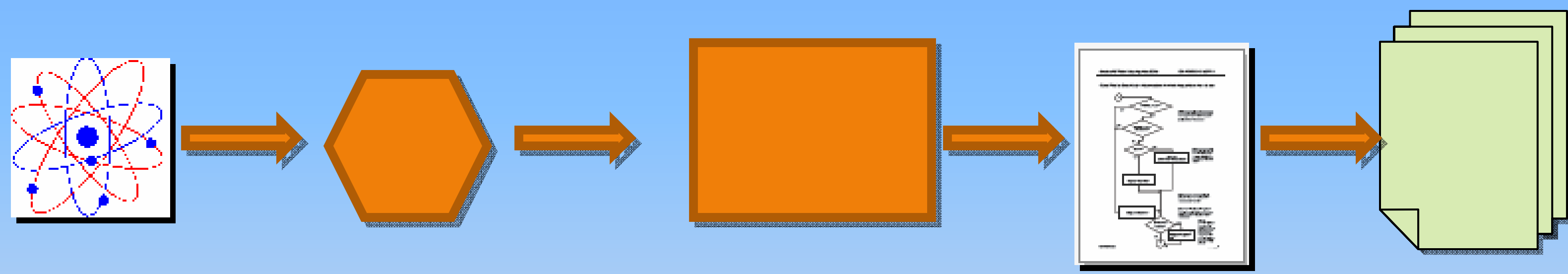


Sources of Uncertainty



- Calibration
- Linearity
- Background/noise
- RCF?

Sources of Uncertainty



Radiation source → Dosimeter → Read process → Algorithm → Reporting

Algorithm ↓

- Test irradiations
- Propagated uncertainty

Not as easy as it looks…

- Very different from uncertainty evaluations for "normal" technologies
  - Many variables with lots of interplay
  - Requires significant number of assumptions – specify them!
- How do you evaluate the algorithm's contribution?
- May not be realistic to arrive at an overall uncertainty estimate for all situations

Alternate Approach- GUM Supp.

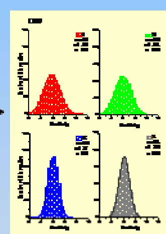
- GUM Supplement
  - Use frequency distributions of all identified sources (angles, energies, types of radiation)
  - Use Monte Carlo methods to generate sample of expected responses
  - Process through algorithm and analyze results
  - Good for overall estimated uncertainty for all doses.
  - Not for individual situations
  - Requires (as all methods) big assumptions

Alternate Approach - Hybrid

Identify sources of uncertainty in element readings

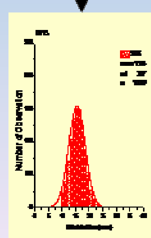
Calculate total combined uncertainty in element readings

Generate file of input responses (GUM Suppl. 1)



Process using PC algorithm

PC algorithm



Analyze output distribution of doses

Presented at last years meeting

1. Calculate combined uncertainties for each element for each situation to be assessed
2. Generate sample of responses based on calculated distribution using Monte Carlo sampling
3. Process sample through algorithm and analyze results

Key Points

- **Identify** as many key sources as possible
- **Evaluate** all identified sources
  - NIST says "A detailed description of how each component of standard uncertainty was evaluated."
  - Use "professional judgment" or experience if no better data exists
- **Combine** sources of uncertainty
  - Explain the methodology used to combine

Key Points (ctd)

- **Propagate** through algorithm
  - Propagate combined uncertainties
  - or at least make some estimate
- **Report** expanded uncertainty, *U*
  - With coverage factor k
  - (typically k=2)
- **Check** for different conditions
  - Dose levels, radiation types, background levels, mixed fields
- **Reality check**
  - Do the numbers look right?

Uncertainty References

- **BIPM/IEC/IFCC/ISO/IUPAC/IUPAP/OIML:1993**, Guide to the Expression of Uncertainty in Measurement (GUM)
- **ISO/PRF Guide 99998**; Guide to the expression of uncertainty in measurement (GUM) -- Supplement 1: Numerical methods for the propagation of distributions, 2004
- "**Evaluating the Uncertainty in Measurement of Occupational Exposure with Personal Dosemeters**"; J.W.E. van Dijk, NRG Radiation & Environment, presented at IM2005, Vienna Austria.
- **ISO/IEC 17025:1999**, General requirements for the competence of testing and calibration laboratories
- **NIST Technical Note 1297**; Guidelines for Evaluating and Expressing the Uncertainty of NIST Measurement Results, 1994.
- **NCRP Report No. 58**, A Handbook of Radioactivity Measurements Procedures, 1985.
- Hirning, C. R. and Yuen P. S., "**Accuracy in External Dosimetry of Ionizing Radiation**," Health Physics 75(2) pp 136-146, 1998.

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