L8 Metrological Traceability

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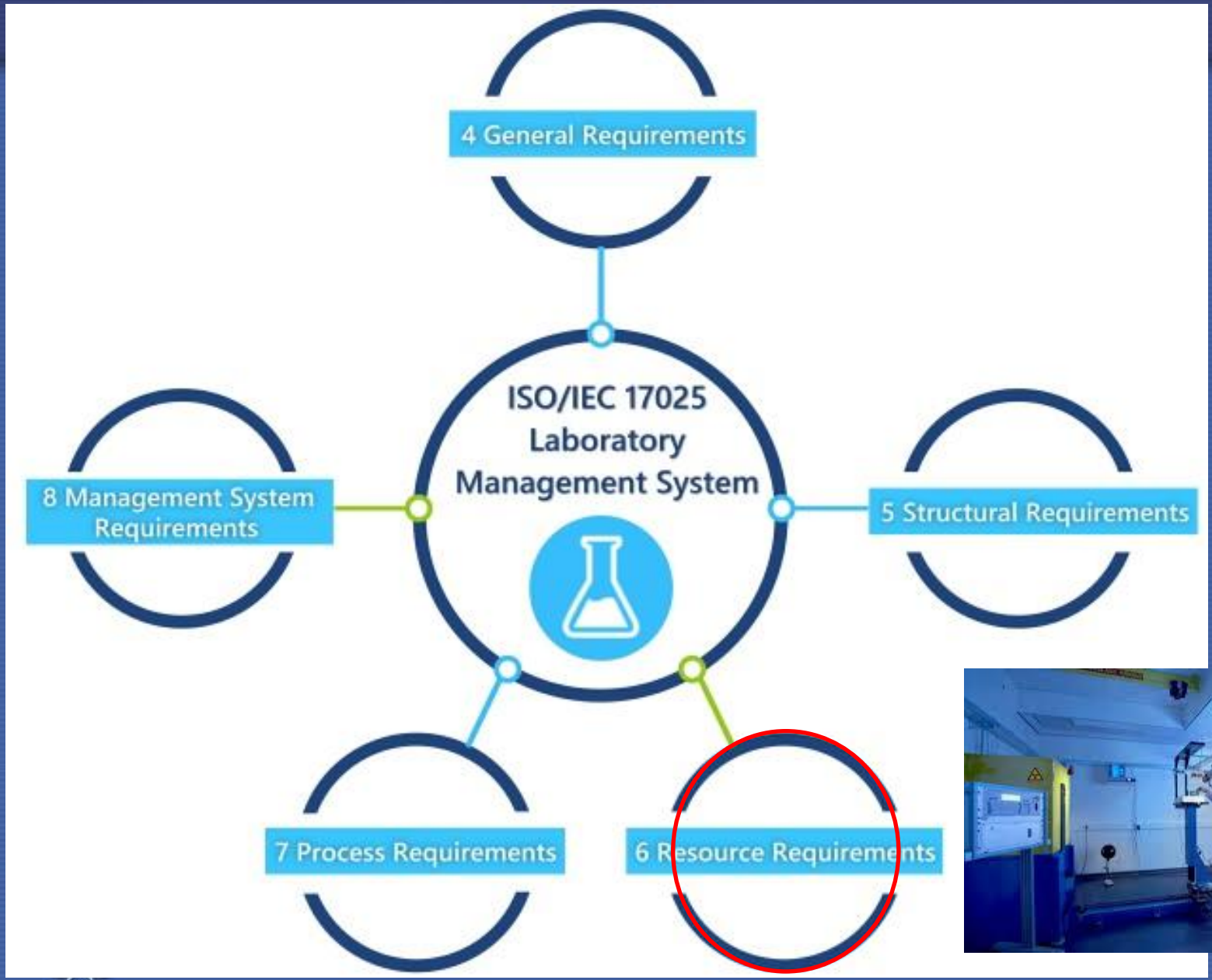
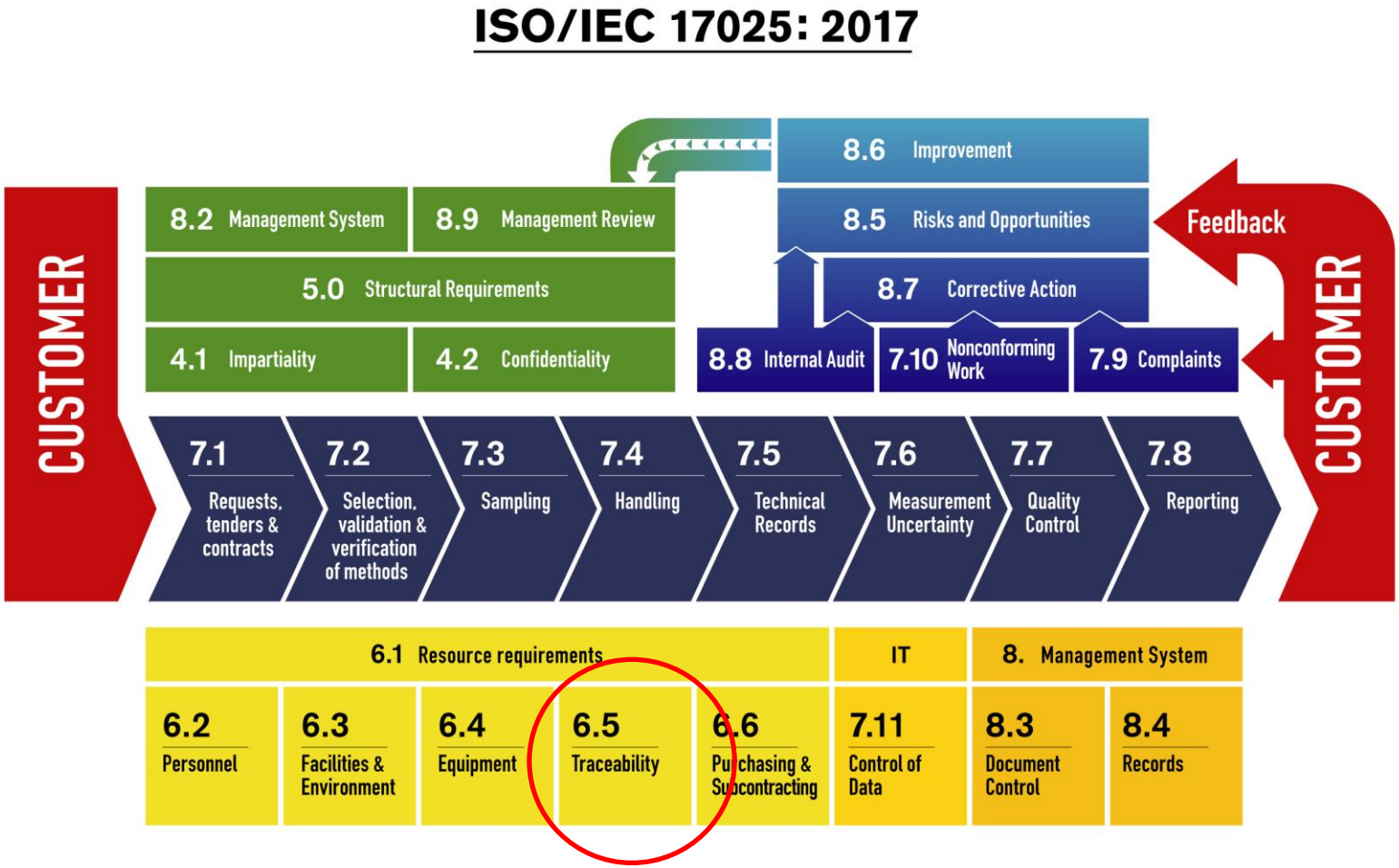
International Atomic Energy Agency


4 General Requirements
ISO/IEC 17025
Laboratory
Management System
8 Management System Requirements
5 Structural Requirements
7 Process Requirements
6 Resource Requirements

Structure


ISO/IEC 17025: 2017
8.6 Improvement
8.2 Management System
8.9 Management Review
8.5 Risks and Opportunities
Feedback
5.0 Structural Requirements
8.7 Corrective Action
CUSTOMER
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CUSTOMER
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IT
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6.5 Traceability
6.6 Purchasing & Subcontracting
7.11 Control of Data
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Objectives

In this lecture we will:

- Define traceability of measurements
- Identify unbroken chains of traceability to primary standards
- Apply traceability concepts to measurement examples from dosimetry applications and
- Establish traceability through sample calibration procedures

6.5 Metrological traceability

6.5.1 Establish and maintain metrological traceability of measurement results by means of a documented unbroken chain of calibrations

6.5.2 To ensure calibration and measurement made by the laboratory are traceable to the international system of units (SI) through:

a. calibration provided by a competent (ISO/IEC 17025 accredited) laboratory

b. certified values of certified reference materials provided by a competent producer (ISO 17034) to the SI

c. direct realization of the SI units ensured by comparison, directly or indirectly, with national or international standards

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6.5 Metrological traceability

6.5.3 Establish traceability to appropriate measurement standard (where calibration or metrological traceability is not as per SI units) as follows;

- The use of certified reference materials
- The use of results of reference measurement procedures, specified methods or consensus standards that are clearly described and accepted as providing measurement results fit for the intended use

VIM definition – Calibration

- **Calibration**: operation that, under specified conditions, in a first step, establishes a relation between the quantity values with measurement uncertainties provided by measurement standards and corresponding indications with associated measurement uncertainties and, in a second step, uses this information to establish a relation for obtaining a measurement result from an indication
  - NOTE 1 A calibration may be expressed by a statement, calibration function, calibration diagram, calibration curve, or calibration table. In some cases, it may consist of an additive or multiplicative correction of the indication with associated measurement uncertainty.
  - NOTE 2 Calibration should not be confused with adjustment of a measuring system, often mistakenly called “self-calibration”, nor with verification of calibration
  - NOTE 3 Often, the first step alone in the above definition is perceived as being calibration.

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VIM definition – Calibration hierarchy

- **Calibration hierarchy**: sequence of calibrations from a reference to the final measuring system, where the outcome of each calibration depends on the outcome of the previous calibration
  - NOTE 1 Measurement uncertainty necessarily increases along the sequence of calibrations.
  - NOTE 2 The elements of a calibration hierarchy are one or more measurement standards and measuring systems operated according to measurement procedures.
  - NOTE 3 For this definition, the 'reference' can be a definition of a measurement unit through its practical realization, or a measurement procedure, or a measurement standard.
  - NOTE 4 A comparison between two measurement standards may be viewed as a calibration if the comparison is used to check and, if necessary, correct the quantity value and measurement uncertainty attributed to one of the measurement standards.

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VIM definition – Metrological traceability

- **Metrological traceability**: property of a measurement result whereby the result can be related to a reference through a documented unbroken chain of calibrations, each contributing to the measurement uncertainty
  - NOTE 1 For this definition, a 'reference' can be a definition of a measurement unit through its practical realization, or a measurement procedure including the measurement unit for a non-ordinal quantity, or a measurement standard.
  - NOTE 2 Metrological traceability requires an established calibration hierarchy.
  - NOTE 3 Specification of the reference must include the time at which this reference was used in establishing the calibration hierarchy, along with any other relevant metrological information about the reference, such as when the first calibration in the calibration hierarchy was performed.
  - NOTE 4 For measurements with more than one input quantity in the measurement model, each of the input quantity values should itself be metrologically traceable and the calibration hierarchy involved may form a branched structure or a network. The effort involved in establishing metrological traceability for each input quantity value should be commensurate with its relative contribution to the measurement result.

VIM definition – Metrological traceability chain

- **Metrological traceability chain**: traceability chain sequence of measurement standards and calibrations that is used to relate a measurement result to a reference
  - NOTE 1 A metrological traceability chain is defined through a calibration hierarchy.
  - NOTE 2 A metrological traceability chain is used to establish metrological traceability of a measurement result.
  - NOTE 3 A comparison between two measurement standards may be viewed as a calibration if the comparison is used to check and, if necessary, correct the quantity value and measurement uncertainty attributed to one of the measurement standards.

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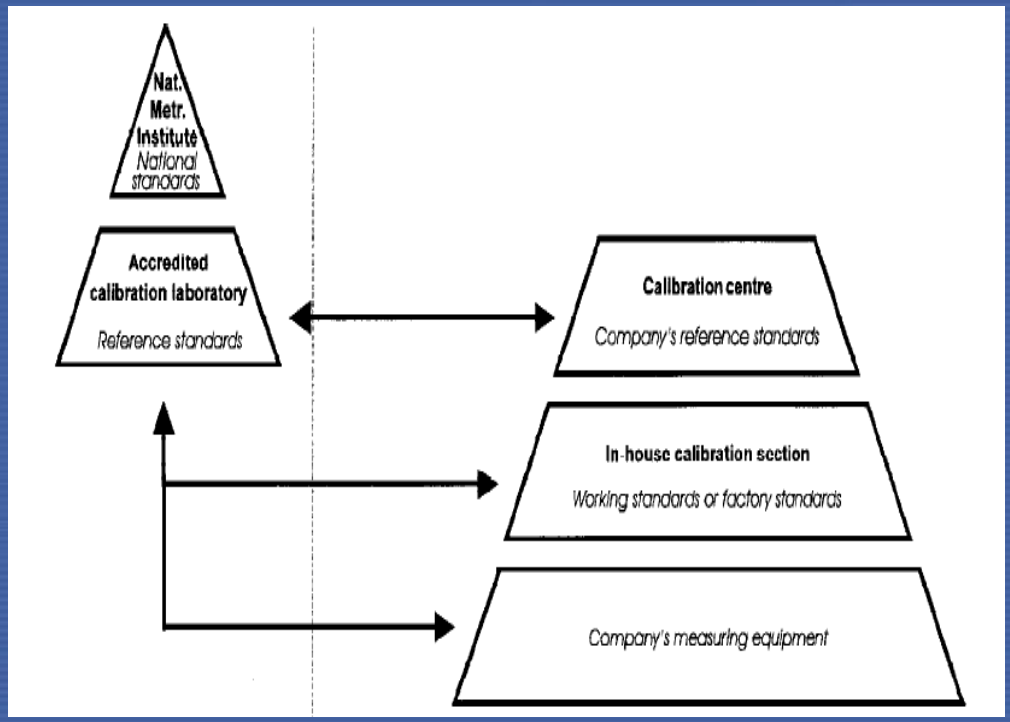
Unbroken chain of calibration

A prerequisite to metrological traceability is a previously established calibration hierarchy:

- Primary standards laboratory
- (Secondary standards laboratories)
- Calibration services
- Measurement laboratory



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Unbroken Chain

- An unbroken chain for traceability to a primary standard exists if any measurement devices and instruments by any laboratory other than the primary standards laboratory are calibrated by reference material directly linked or compared to primary standards laboratory measurements and by this to the International System of Units (SI).

SI unit

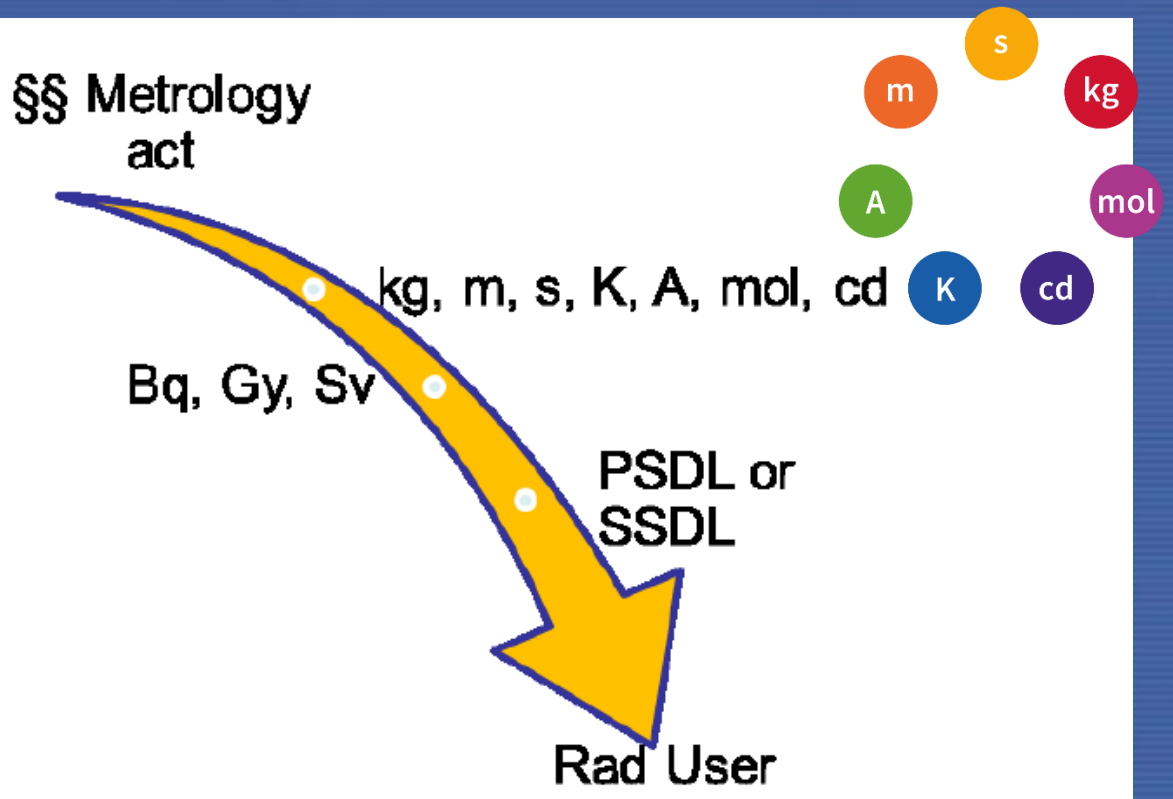


Figure 1 Metrology act regulates the seven SI units, the three IR units, and their dissemination.

Ionising Radiation Metrology

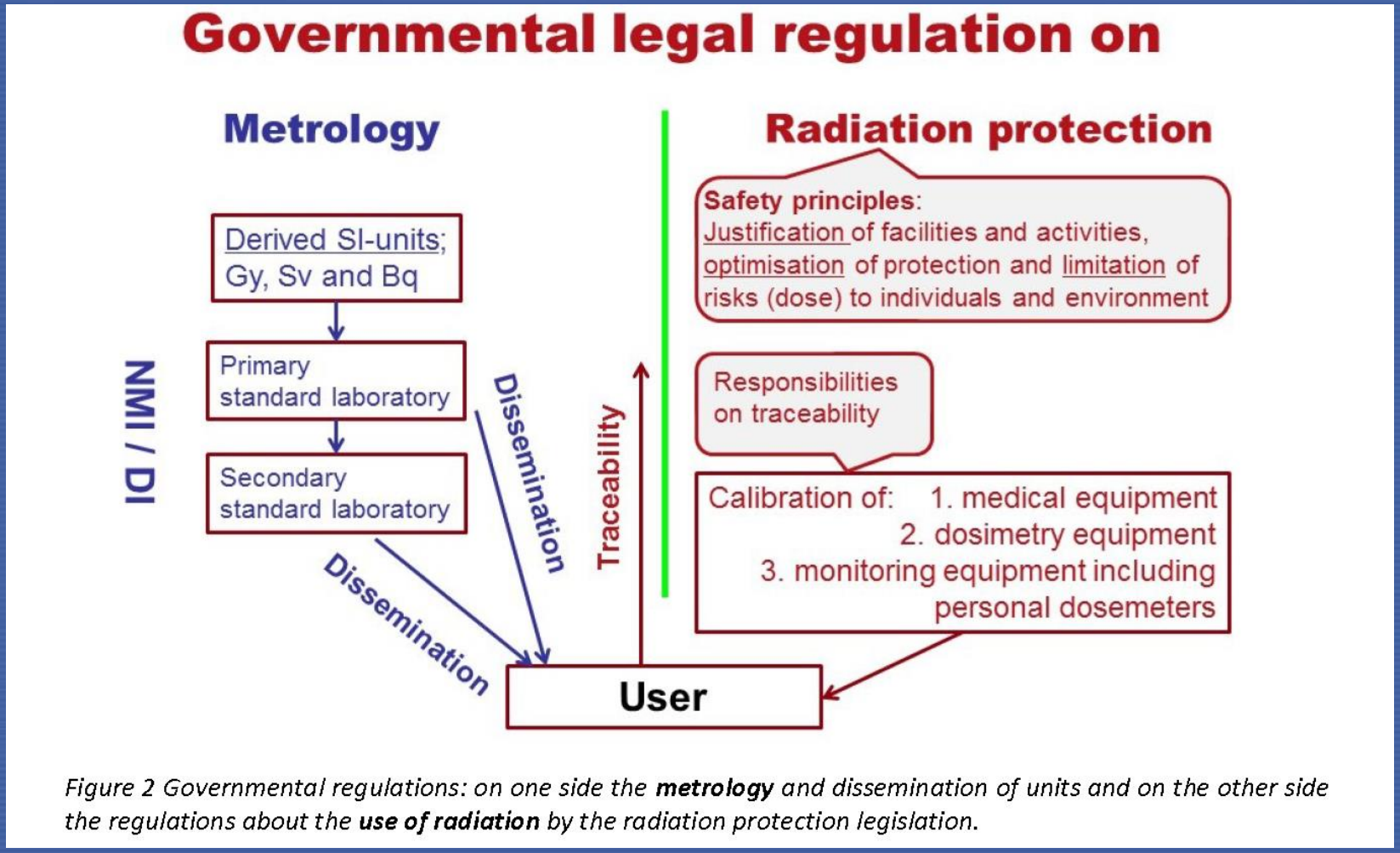
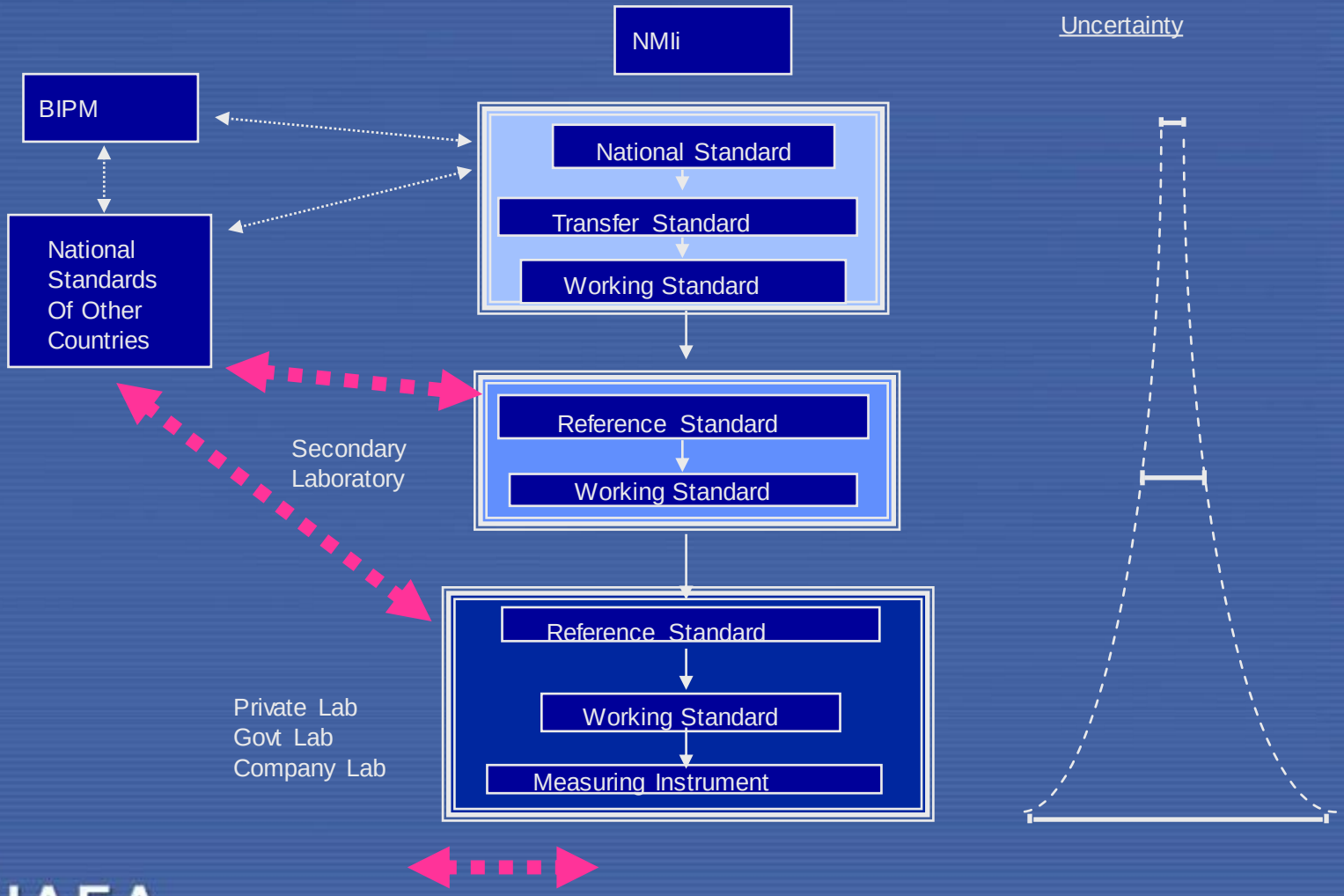


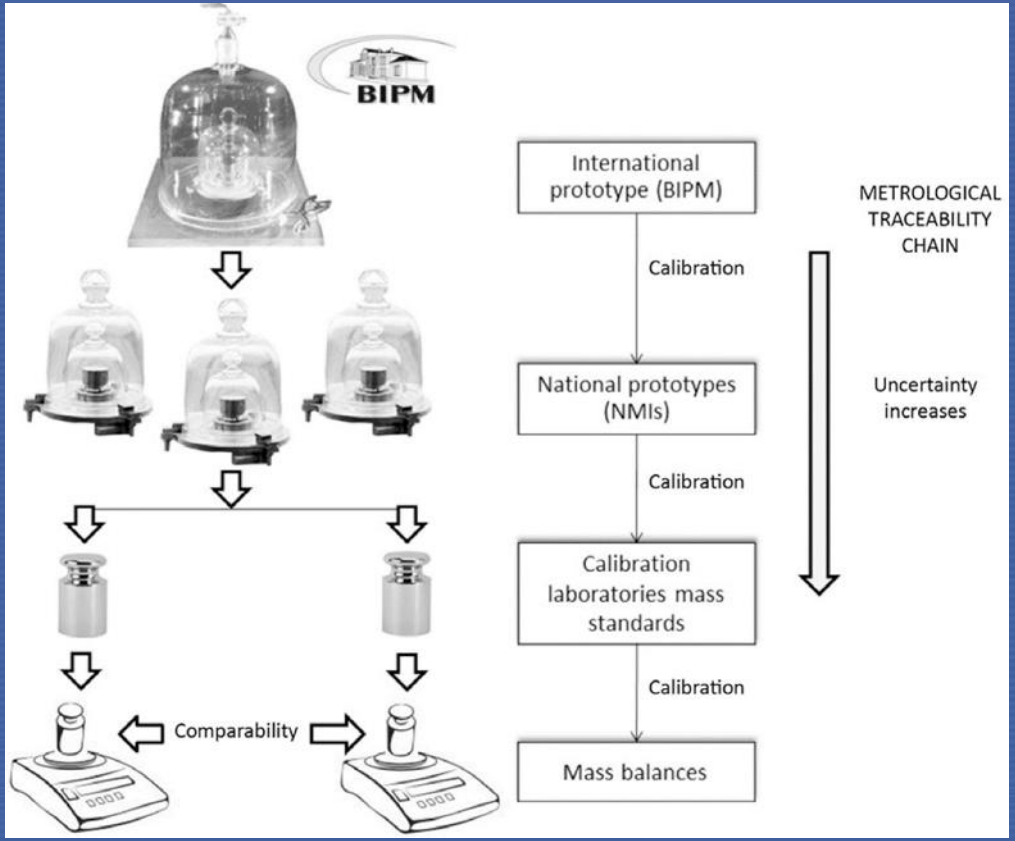
*Figure 2 Governmental regulations: on one side the **metrology** and dissemination of units and on the other side the regulations about the **use of radiation** by the radiation protection legislation.*

Traceability Chain



Recognized traceability to national standards of other countries

E.g Weighing


BIPM
Comparability
International prototype (BIPM)
Calibration
National prototypes (NMIs)
Calibration
Calibration laboratories mass standards
Calibration
Mass balances
METROLOGICAL TRACEABILITY CHAIN
Uncertainty increases

Unbroken Chain (Example)

- Primary standard laboratory produces reference material for use by calibration services
- Calibration services calibrate their measurement devices by reference material by primary standard laboratory

Unbroken Chain (Example) (II)

- Calibration service produces reference material, certifies it by measurements on calibrated devices
- Measurement service uses reference material by calibration service to calibrate measurement devices
- Measurement service provides measurement results to customers

Reference Material

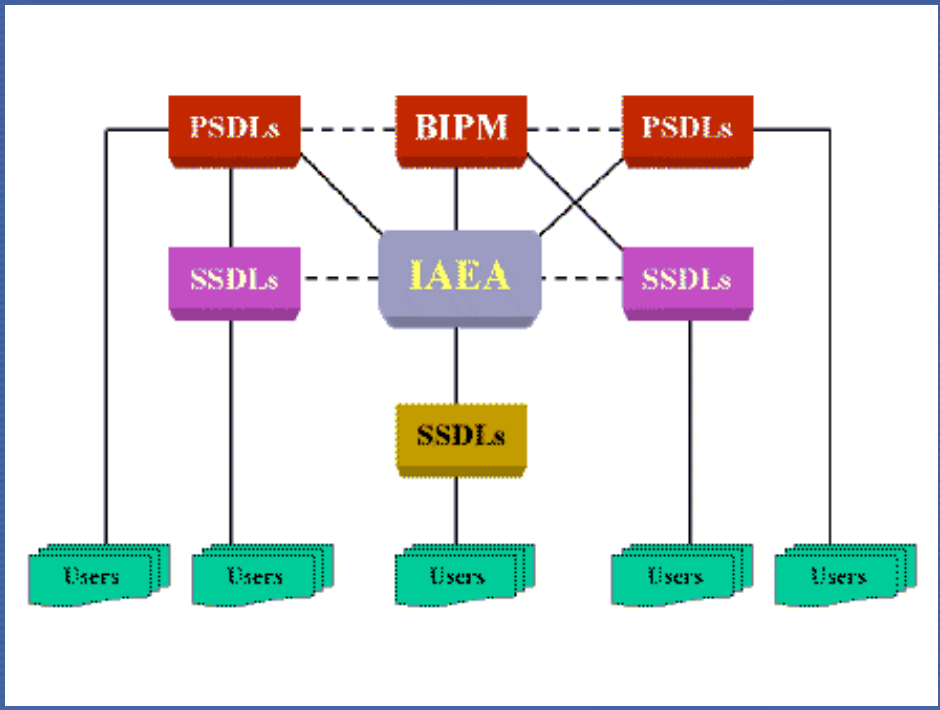
Information on reference materials necessary for calibration and measurement services:

- Standard reference date
- Reference data including reference value and associated uncertainties
- Certificate of traceability of reference material to primary standard through direct calibration or comparison

Traceability Recommendations

- Archiving and organisation of all calibrations standard data
- Archiving of all calibration procedures, calibration outcomes and calibration certificates
- Scheduling of periodic calibrations
- Retention of calibrated spare parts for important devices (reduces down-time in case of malfunction)

Metrological Traceability



6.5 Metrological traceability

CERTIFICATE OF CALIBRATION

S.E. INTERNATIONAL, INC.
436 Farm Road P.O. Box 39 Summertown, TN. 38483
Ph: 931.964.3561 Fax: 931.964.3564
www.seintl.com | radiationinfo@seintl.com

Certificate Number: 17-2181
CAL DATE: 10/26/2017
CAL DUE DATE:10/26/2018

Customer Information:

Mineralab
Tim Flanegin
2860 W. Live Oak Dr.
Prescott, AZ 86305 USA

Inspector EXP SN# 23654-03622

Instrument Information:

Instrument: Radiation Alert
Type: GM Survey Meter
Model: Inspector EXP
Serial: 23654-03622
Make: LND
Tube Model: 7317
Detector: External
Input Sens: 2.4VDC
Inst Voltage set: 508VDC

Contamination Check: ☑
Alarm Check: ☑
Audio Check: ☑
Received: Out of Spec: ☐
Mechanical Check: ☑
Battery Check: ☑ **9.28VDC**
Tolerance: ☑ **± 10%** ☐ ± 20% ☐ Out of Spec

Calibration Data:

S.E. International, Inc. Certifies the above described instrument was calibrated in a known radiation field using a Cs 137 (662keV) beam calibrator. Transfer instrument MDH Industries, Model 2025 X-Ray Monitor, S.N. 4351, with 180cc Probe, S.N. 7773. Calibration is traceable to NIST DG8640/87. GM detectors are positioned perpendicular to source. This calibration conforms to ANSI/NCSL Z540-1, ANSI N323-1978, ISO 17025. The results are tabulated below. Measurement of uncertainty is ± 5%. This certificate may not be reproduced, unless in full, without written approval from S.E. International, Inc. **TENNESSEE LICENSE# R-51002-C27**

Precision/Constancy Check performed with Cs^{137} Source s/n 010818 | Precision: ☑ ± 10% ☐ ± 20%
Constancy Check: 1 uCi of Cs^{137} indicates 34.11 mR/hr when placed against the center of the GM tube opposite the end window. This reading done at the Cal factor in which the unit was recieved.

Reading 1: 34.29 mR/hr
Reading 2: 34.10 mR/hr
Reading 3: 33.93 mR/hr
Mean: 34.11 mR/hr

Temperature: 19.6 °C
Relative Humidity: 52.1%
mmHg: 728.0

Notes:
Cal Factor is set at Cal 100. For more on the Cal Factor...see owners manual. Geiger tube bad....replaced.

Decade Range	Reference Point	Instrument Meter Reading after Calibration *	Correction Factors for > +/- 10%
10 mR/hr - 100 mR/hr	50mR/hr	51.03mR/hr	None
1 mR/hr - 10 mR/hr	5mR/hr	5.107mR/hr	None
0.1 mR/hr - 1 mR/hr	0.5mR/hr	0.496mR/hr	None
0 mR/hr - 0.1 mR/hr**	0.05mR/hr	0.050mR/hr	None

** = Range calibrated to electronic standard for inspector models | * indicates 1 minute average

Cs137 Gamma 6810 Capsule S/N A-855 and Model 28-5A Calibrator S/N 10291 calibrated monthly for decay

Multimeter S/N 86820561 Cal Date:15 Nov. 2016 Cal Due:15 Nov. 2017

Arb Gen. S/N US34004570 Cal Date: 1-16-2017 Cal Due:1-16-2018

Calibrated by: Robert Russell

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Metrological Traceability

- The dosimetry system should be designed and operated so that calibration and measurements are **traceable** to the quantities required such as the relevant operational quantities for individual monitoring of external radiation: dose equivalent Hp(10), Hp(0.07) and Hp(3).

- Traceable calibrations/irradiations, together with reliable estimated uncertainties are provided by **NMI or accredited SSDL's**. Typically, the calibration procedures and data used in these standard dosimetry laboratories follow the ISO standards for calibration of radiation protection instruments [ISO 4037, …]. So, it is very unlikely that you can produce your own metrological traceable calibration

- Traceable calibration, that is those carried out by a standards laboratory, should be performed at regular intervals as part of the quality system. recommendation: **at least every two years**.

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Thermoluminescent Dosimeter

- Primary standards laboratory:
  - Establishes instrumentation to measure physical quantities (air kerma) by use of reference radiation fields (well characterised source activity – units in Bq).
  - Uses established conversion factors to relate physical quantities to operational radiation protection quantities (dose).

Thermoluminescent Dosimeter

- Measurement Laboratory:
- Sends sample dosimeters to reference laboratory for irradiation under standard conditions (reference dose rate and dose, reference field parameters, ICRU slab phantom).
- Uses irradiated dosimeters for direct comparison with measurements.

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Calibration and Verification

- Reproducibility of the calibration should be controlled e.g. monthly by **verification** (quality control QC) of the calibration. The verification can be done under simplified conditions. For example, the verification is done using dosemeters irradiated free-in-air, instead of on a phantom, with a ^{137}Cs source. This can be done using your own irradiator that does **not** have to be accredited.

- The metrological traceability of calibration cannot be achieved through this verification, but it can be used for QC purposes to verify the reproducibility of calibration or the reader. The verification of calibration can follow for example a QA-procedure, where the action limits for the stability/reproducibility of the calibration factors are stated, based on expertise, statistical data and experience of the laboratory

- See separate lecture

Gamma Spectrometry

- Primary standard laboratory:
  - Calibration of reference material /sources with well defined activity of certain nuclides (units in Bq or Bq/mL).
  - For whole body counters:
    Calibration of a “physical phantom”, simulating the human body, with well defined activity.

Gamma Spectrometry

- Measurement laboratory:
  - Calibration of gamma spectrometers by calibration reference material
  - Gamma spectrometric measurements
  - Possibly: removal of bias contributions by correction factors (e.g., cascade summing corrections, …)

Liquid Scintillation Counting

- Primary standard laboratory:

Calibration by reference beta standard with well defined activity of certain nuclides (units in Bq or Bq/mL)

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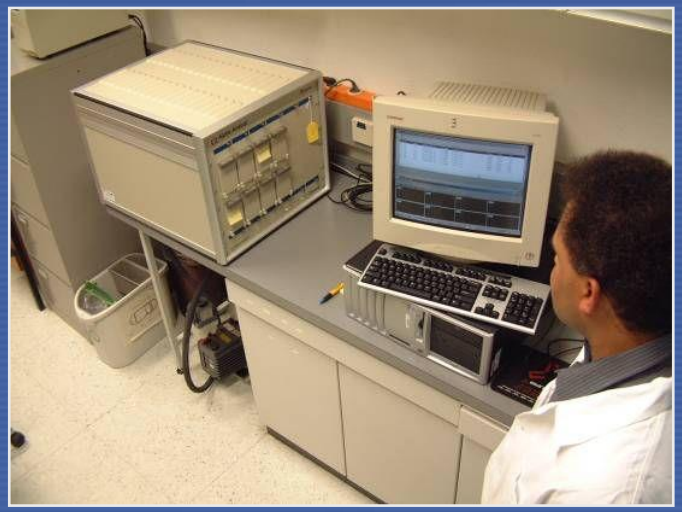
Alpha Spectrometry

- Primary standard laboratory:
  - Calibration of reference material with well defined activity of certain nuclides (units in Bq or Bq/mL).
- Measurement laboratory:
  - Calibration of alpha spectrometers by reference material or tracer