An Overview of the **Radioactivity** Standard Reference Materials Program at NIST

Presentation 21 June 2006
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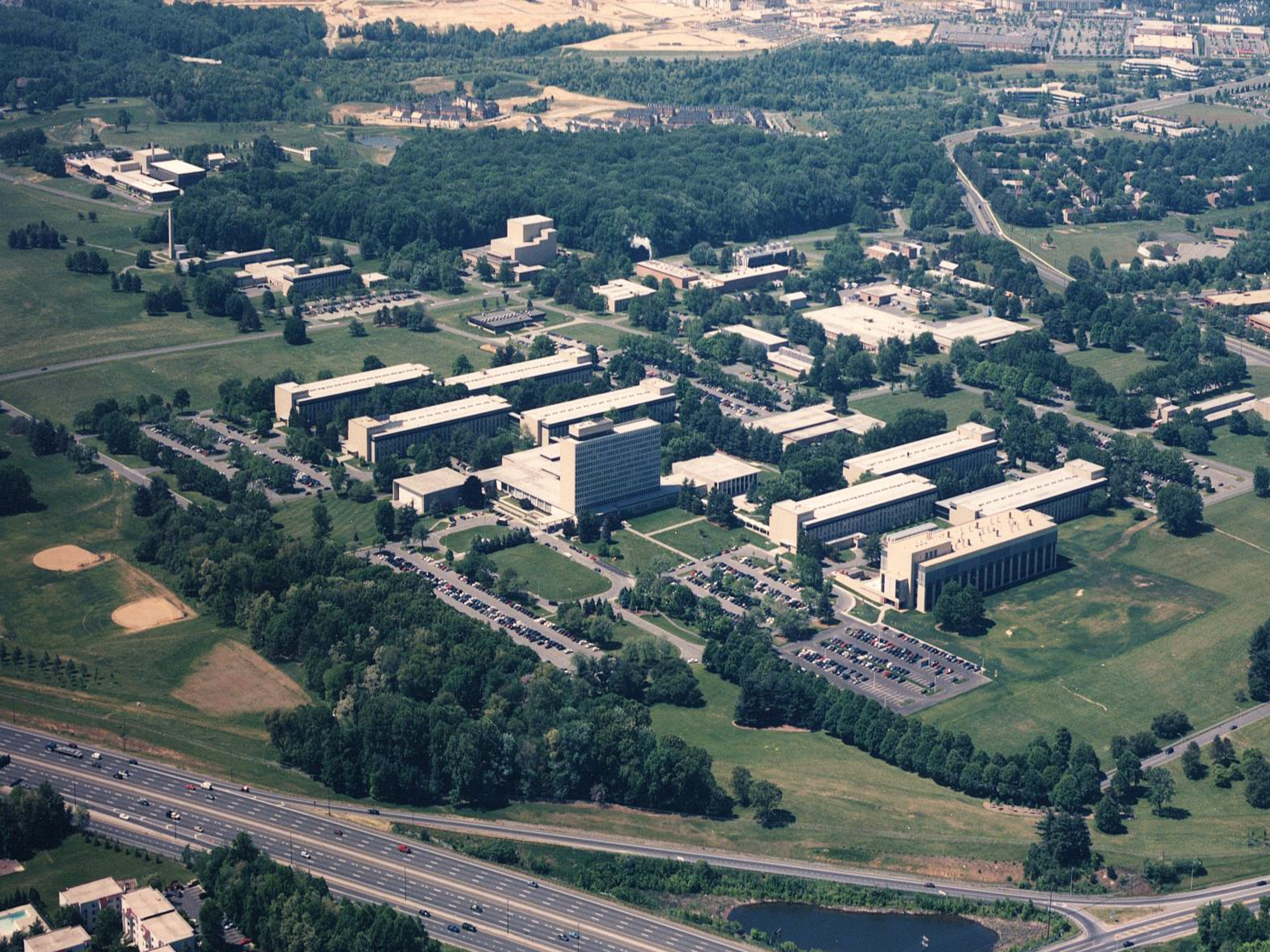
Physics Laboratory
National Institute of Standards and Technology
Gaithersburg, MD 20899 USA

NIST

Who are we ?

And what do we do ?



NIST

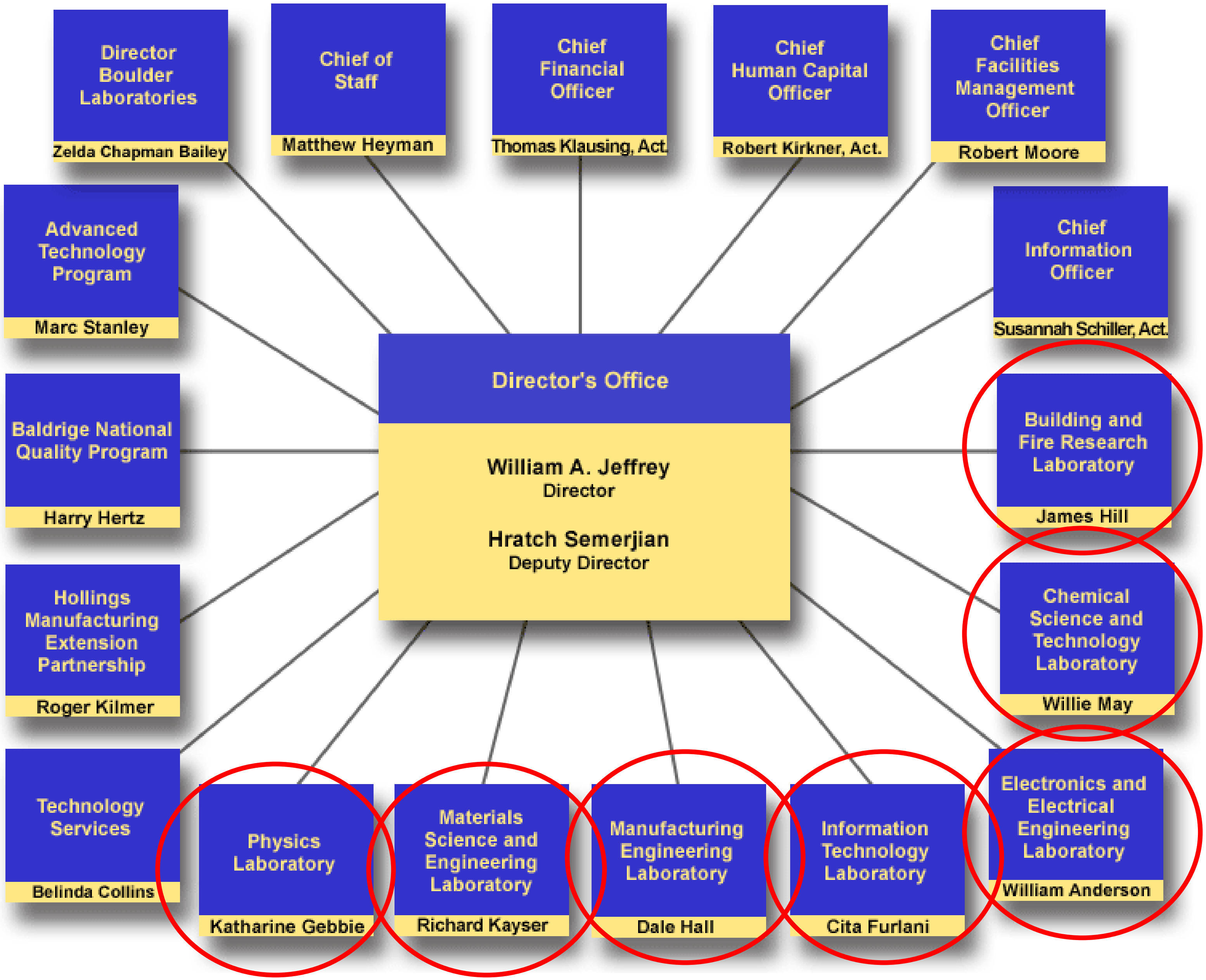
- 1901
- About $ 800 M USD all sources (550 M is real!)
- 234 hectare campus

  (+ 84 Boulder, CO)
- 26^+ buildings

  80 000 m^2 (lab)

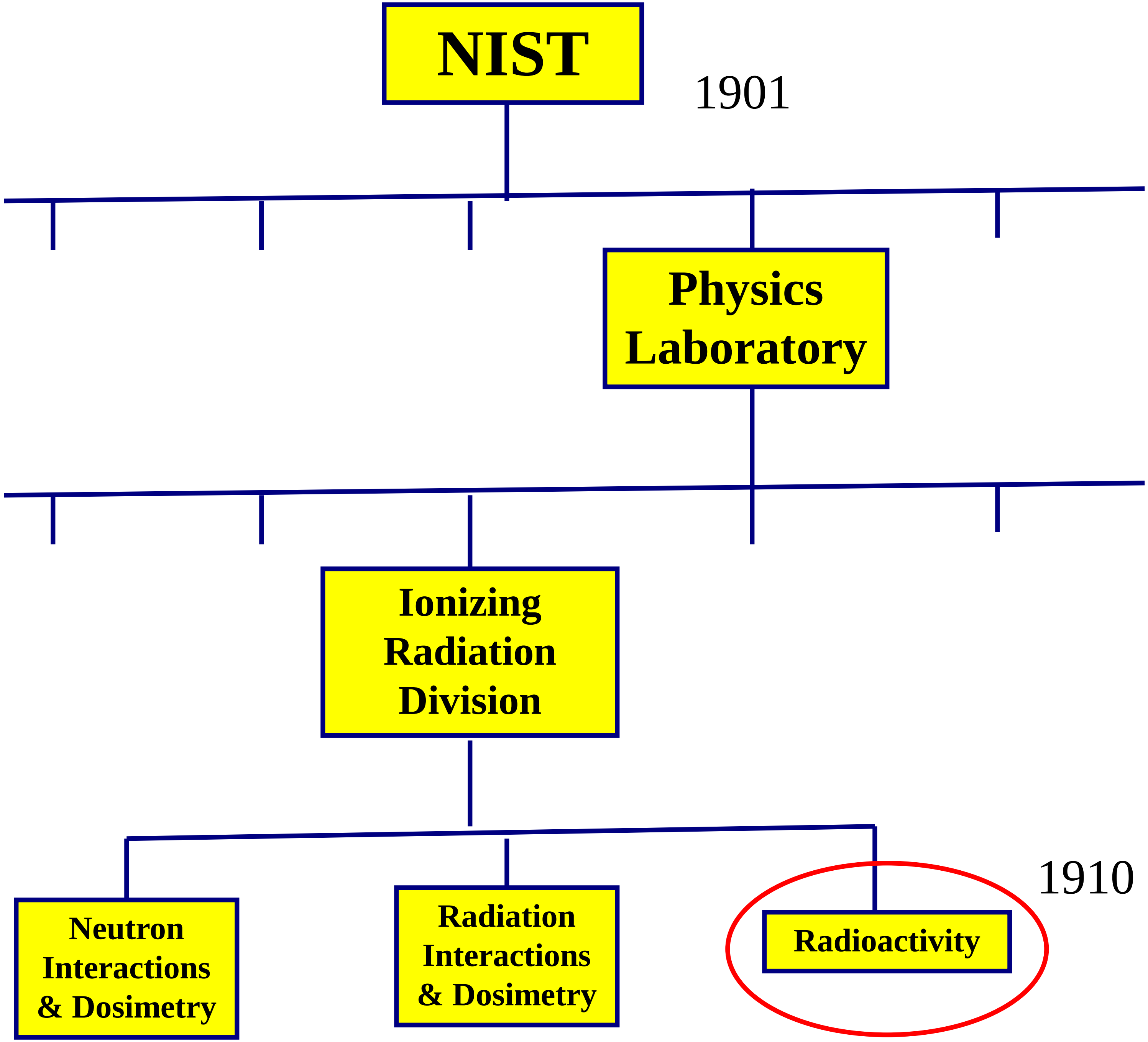
  60 000 m^2 (office)
- 3000 staff

  (+ 1800 guest workers & 1500 external associates)


Director Boulder Laboratories
Zelda Chapman Bailey
Chief of Staff
Matthew Heyman
Chief Financial Officer
Thomas Klausing, Act.
Chief Human Capital Officer
Robert Kirkner, Act.
Chief Facilities Management Officer
Robert Moore
Advanced Technology Program
Marc Stanley
Chief Information Officer
Susannah Schiller, Act.
Director's Office
William A. Jeffrey
Director
Hratch Semerjian
Deputy Director
Baldrige National Quality Program
Harry Hertz
Building and Fire Research Laboratory
James Hill
Hollings Manufacturing Extension Partnership
Roger Kilmer
Chemical Science and Technology Laboratory
Willie May
Technology Services
Belinda Collins
Physics Laboratory
Katharine Gebbie
Materials Science and Engineering Laboratory
Richard Kayser
Manufacturing Engineering Laboratory
Dale Hall
Information Technology Laboratory
Cita Furlani
Electronics and Electrical Engineering Laboratory
William Anderson

NIST Physics Laboratory

- Electron & Optical Physics Division
- Atomic Physics Division
- Optical Technology Division
- **Ionizing Radiation Division**
    - Radiation Interactions & Dosimetry
    - Neutron interactions & Dosimetry
    - **Radioactivity**
- Time & Frequency Division
- Quantum Physics Division


NIST
1901
Physics Laboratory
Ionizing Radiation Division
Neutron Interactions & Dosimetry
Radiation Interactions & Dosimetry
Radioactivity
1910

Radioactivity Group

$ 3.5 M (all sources)

Staff:

10 senior scientists (4 principals)

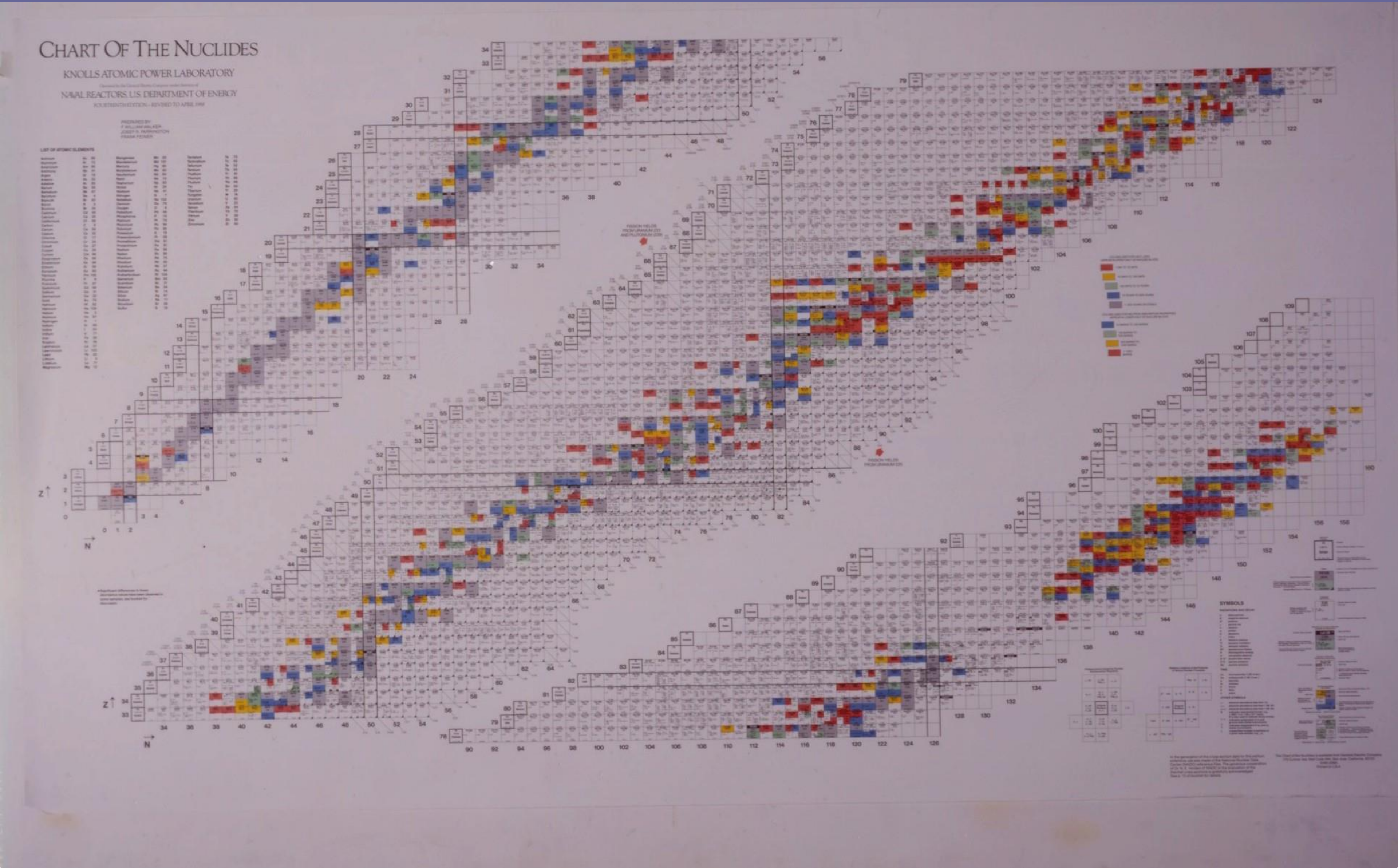
9 junior, technical, and support

8 long-term guest workers (6 FT, 2 PT)

5+ short-term & students

What are our interests？

this is our world of interest … We try to provide standards, calibrations, and metrological research on **any** radionuclides of interest to industry and commercial pursuits; governmental regulatory bodies; academia; the medical, nuclear power, environmental, and homeland security measurement communities, etc..



OUR ROLES

primary objectives

- develop and maintain national standards through primary calibrations
- develop secondary standards and transfer standards;
- disseminate standards;

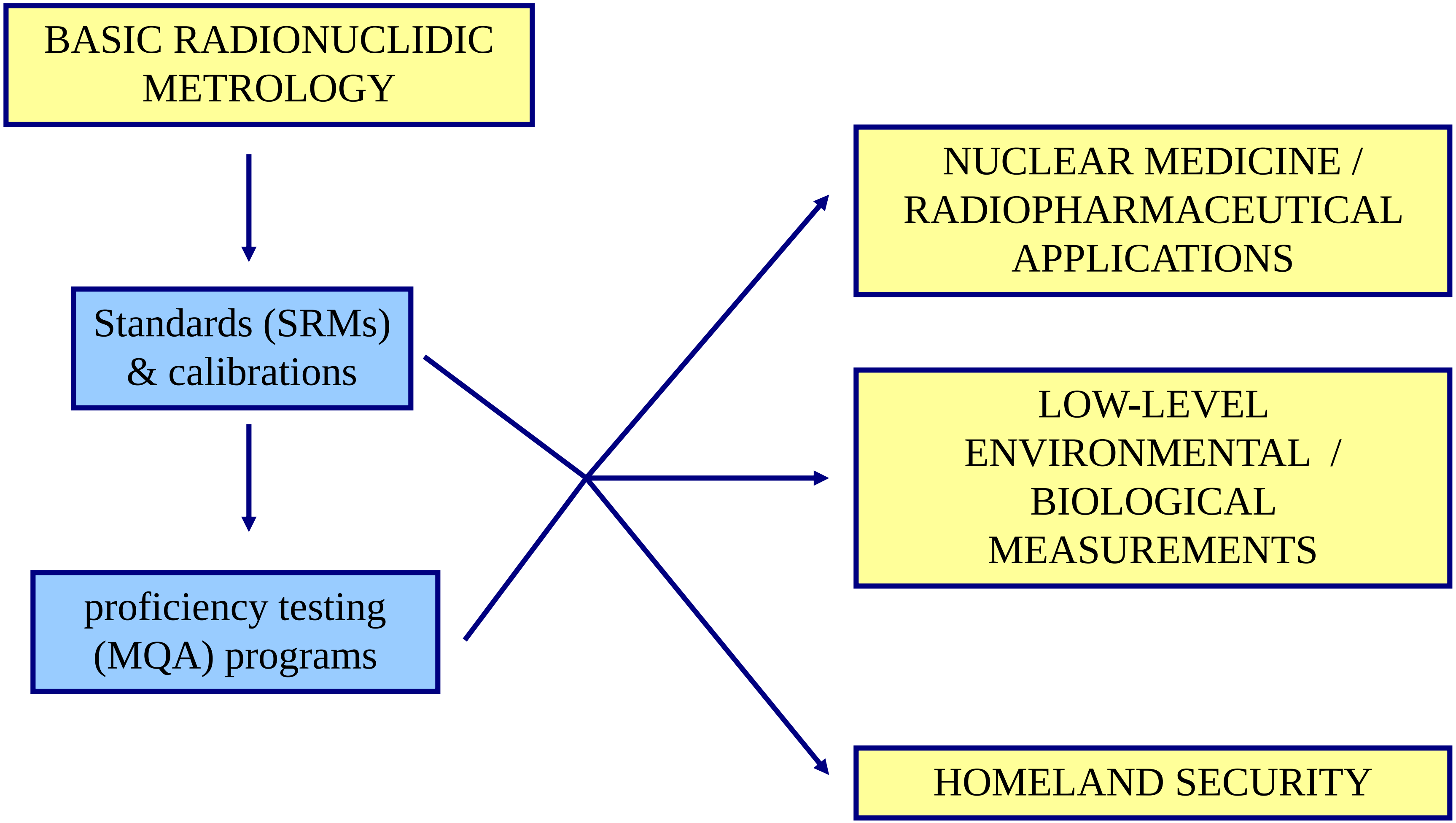
  and ***provide mechanisms*** for insuring the quality of measurements

principal elements of what we do

- basic & applied research

  includes technology & method development
- standards (SRMs) and calibrations
- proficiency testing (MQA)
- international intercomparisons & collaborations

Our Major Program Elements



Some of our ongoing activities

Radionuclide Metrology

- Microcalorimetry
- Coincidence & anticoincidence counting methods
- Liquid-scintillation methods:CIEMAT/NIST & TDCR
- LS cocktail composition effects
- Mass spectrometric methods: RIMS & TIMS

Nuclear Medicine/Radiopharmaceutical Standards

- Diagnostic radionuclides (^{18}F, ^{76}Br, ^{68}Ge/^{68}Ga)
- Therapeutic radionuclides(^{211}At, ^{223}Ra, ^{177}Lu, ^{90}Y)
- Brachytherapy sources (calibrations)
- SRM production & distribution
- MQA programs (NEI)

Environmental Radioactivity

- Chemical speciation
- Traceability programs DOE, EPA, NRIP
- Natural matrix SRM production & certification
- Mass spectrometric methods

Homeland Security

- Cargo container inspection station
- Portal monitors
- Protocols for hand-held detector calibrations
- Radionuclidic forensic methods

Metology

- 130^{+} nuclides
- Many geometries
- > 30 systems

Standards

- 60^{+} nuclides
- 9 natural matrix (multi-nuclide)
- 500 – 1000 units per year
- by over 200 users
- $ 300K - $ 600K USD in sales per year (depends on availability)
- 20 user buy 10 or more SRMs per year

Calibrations

- 100 – 200 routine per year
- 20 – 30 nuclides; many geometries
- $ 100K – 200K USD per year
- few special $ 30 - $ 100K USD **EACH**

MQA programs

- 17 unique
- from monthly to 2x per year

Our measurement methods and instruments include:

- Basic (primary) standardizations
- Secondary standardization methods
- Routine measurements
  (e.g., for monitoring, QC, etc.)
- Ancillary measurements
  (e.g., for impurity analyses, research, etc.)

high-pressure re-entrant ion chamber

our SRM work horse -- calibration factors for 40^{+} nuclides for 30+ years

LS counters (Beckam, Wallac, Packard) – our other SRM work horses!

3-phototube TDCR system (under development)

isothermal microcalorimeter (a low-temp 8K calorimeter is inactive)

high-resolution γ spectrometry with HPGe & Si (4 systems)

defined-geometry $0.8\pi\alpha$ counter

NaI(Tl) x-ray counting system

$4\pi\beta$(LS)-γ(NaI) anticoincidence counting system

$4\pi\beta$-coincidence counting system (inactive)

sum-peak -- 2 NaI(Tl) -- counting system

NaI(Tl) pin-well detector

coupled large (8”) NaI(Tl) detectors in 4π geometry for total efficiency counting and γ-γ coincidence counting

length-compensated proportional counters for gas counting

RIMS + TIMS

primary radon measurement system (pulse ionization chambers + gas handling)

Secondary NaI(Tl)-based radon counting system

α-table with PIPS detector

large-area proportional counter & the α “pancake” counter

Various $2\pi\alpha$ surface-barrier detectors, gas-flow β proportional counters; and γ NaI(Tl) well counters

Fuji phosphor-imaging system

commercial “dose calibrator” ion chambers (6+)

Some photos follow

0.8π α counter

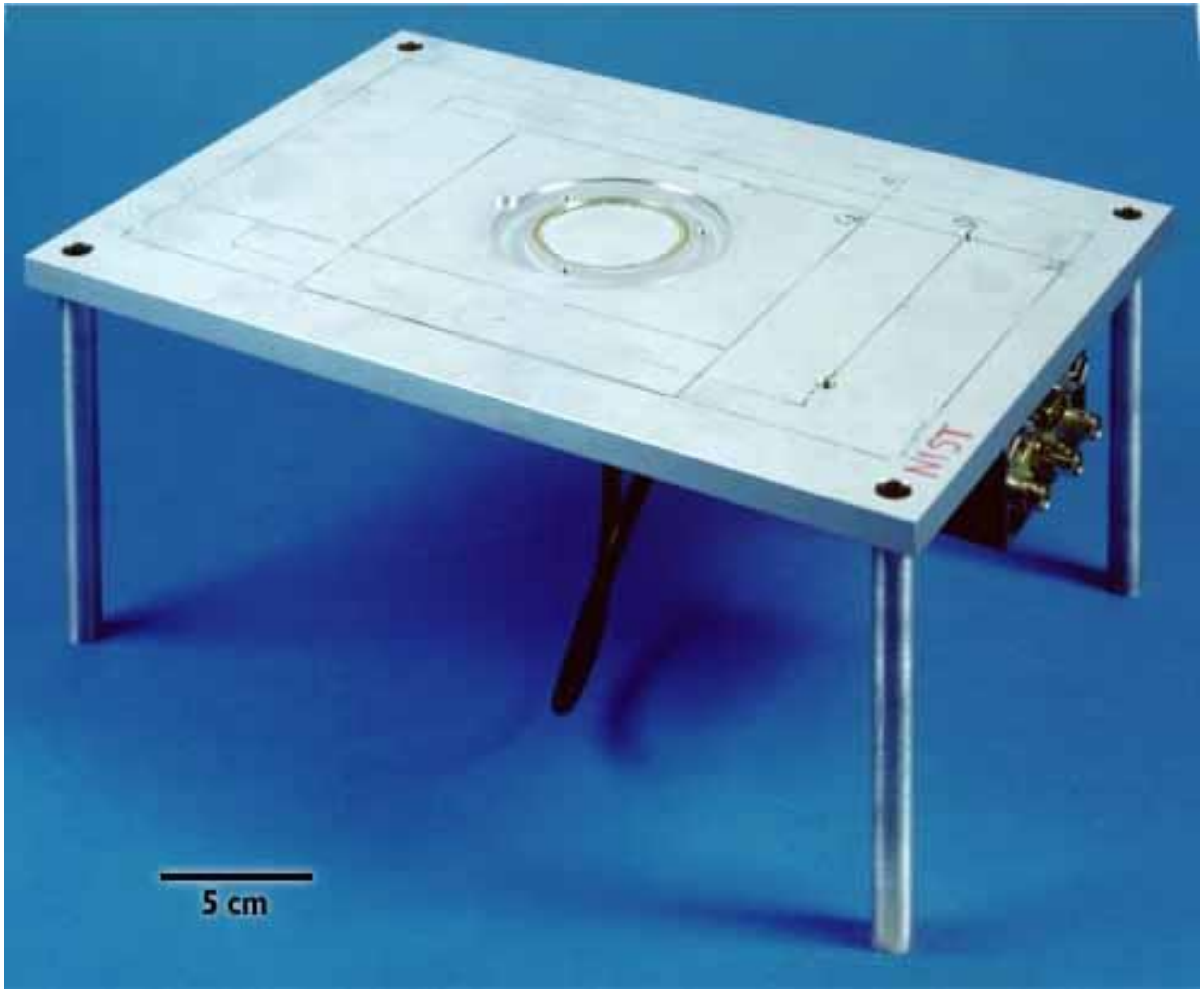
Large surface area 2π proportional counter

HPGe detectors

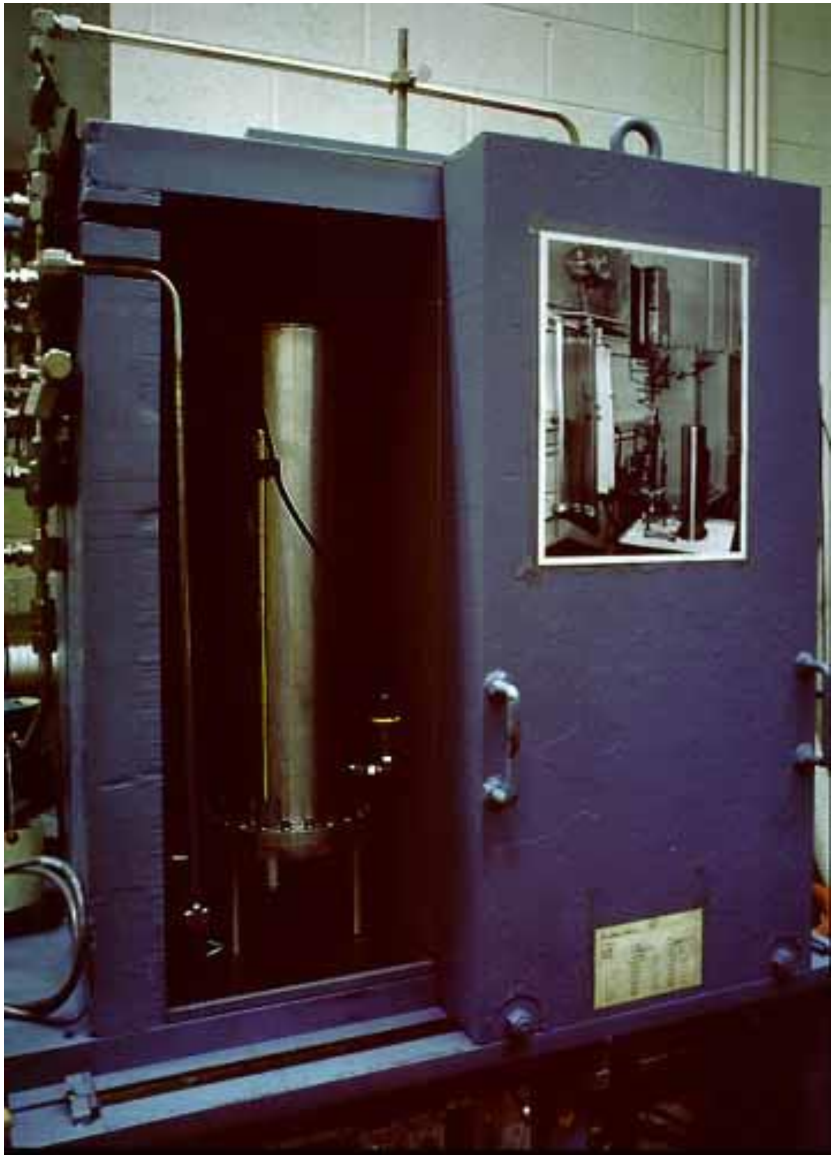

4 pi e⁻-- Gamma Anti-Coincidence
Counting System

$4\pi\beta(LS)$ - $\gamma(NaI)$ anticoincidence counting system

$2\pi\alpha$ detector



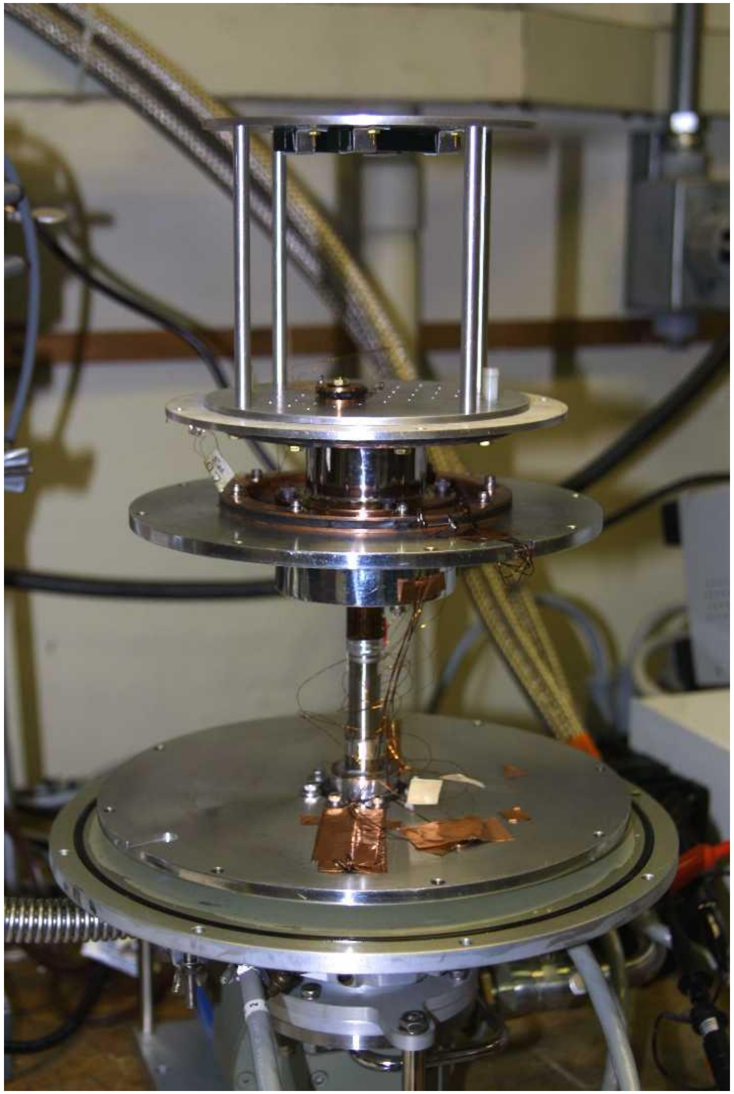
α table with PIPS detector



Gas counters

(for ^{3}H, Kr, Xe, etc.)

CSC “Isothermal Microcalorimeter (IMC)”



8 K cryogenic microcalorimeter

Large (8”) NaI(Tl) detectors in iron cave

Primary ^{222}Rn (^{226}Ra) system

RIMS

3 LS counters

Fuji phosphoimaging

We have some other special facilities & tools too ..

Radiochemistry
(SRM preparation)
labs

fume hoods

glove boxes

vee-cone blenders

etc …

Clean-room radiochemistry lab for very low level measurements

High-level lab facilities

Remote handling

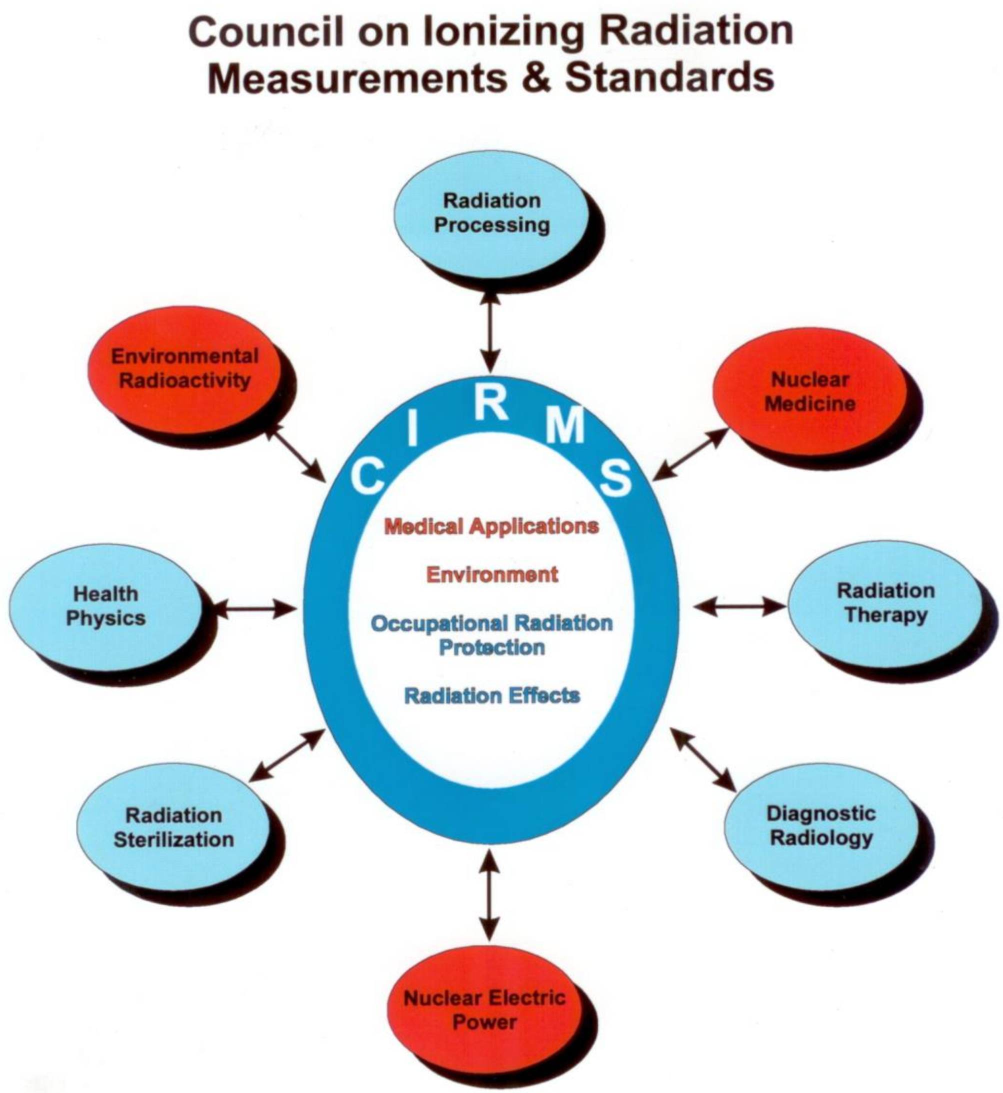
Special source handling and preparation techniques developed over past 30 years

Radionuclides standardized at NIST

H-3	Fe-55	Sr-90	Sb-124	Ce-141	Hg-197	Th-229
Be-10	Co-56	Nb-93	I-124	Ce-144	Au-198	Th-230
C-14	Mn-56	Nb-94	I-125	Pm-147	Tl-201	Th-232
F-18	Co-57	Nb-95	Sb-125	Gd-148	Hg-203	U-232
Na-22	Co-58	Zr-95	Te-125m	Eu-152	Pb-203	U-234
Na-24	Fe-59	Mo-99	I-126	Gd-153	Tl-204	U-235
Al-26	Co-60	Tc-99	Xe-127	Sm-153	Bi-207	Np-237
P-32	Cu-62	Tc-99m	I-129	Eu-154	Po-208	U-238
P-33	Ni-63	Pd-103	I-130	Eu-155	Po-209	Pu-238
S-35	Zn-65	Ru-106	I-131	Eu-156	Bi-210	Pu-239
Cl-36	Ga-67	Ag-108m	Ba-131	Ho-166	Po-210	Pu-240
Ar-37	Se-75	Cd-109	Xe-131m	Ho-166m	Pb-210	Pu-241
Ar-39	Kr-79	Ag-110m	Ba-133	Yb-169	At-211	Am-241
K-40	Sr-82	In-111	Xe-133	Lu-177	Bi-214	Pu-242
K-42	Kr-85	In-113m	Xe-133m	Re-184	Pb-214	Am-243
Ca-45	Sr-85	Sn-113	Cs-134	Re-186	Rn-222	Cm-243
Sc-46	Rb-86	Sn-117m	Cs-137	Re-188	Ra-223	Cm-244
V-49	Y-88	Sn-121m	Ce-139	W-188	Ra-226	
Cr-51	Sr-89	I-123	Ba-140	Ir-192	Ra-228	
Mn-54	Y-90	Te-123m	La-140	Au-195	Th-228	

Who are our users ?

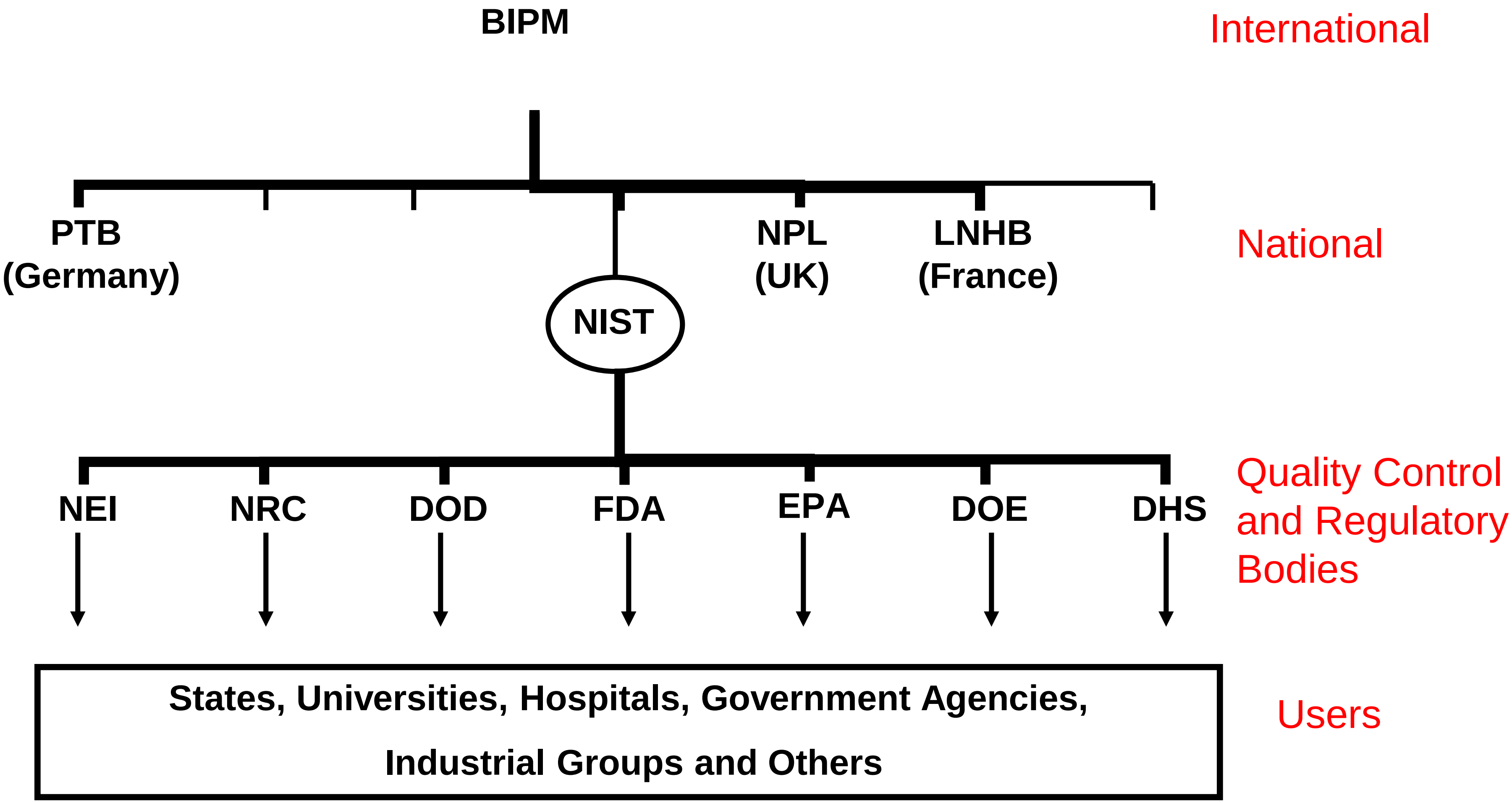
And how do we know their needs?



Community includes:

- National laboratories
- Monitoring laboratories
- Secondary calibration laboratories
- Radioactive source suppliers
- Radiopharmaceutical manufacturers
- Instrument manufacturers
- University research
- Nuclear power industry
- Environmental monitoring
- Governmental regulators
- Health Physics
- Military
- Homeland Security

International and National Radioactivity Measurements "Traceability Tree"

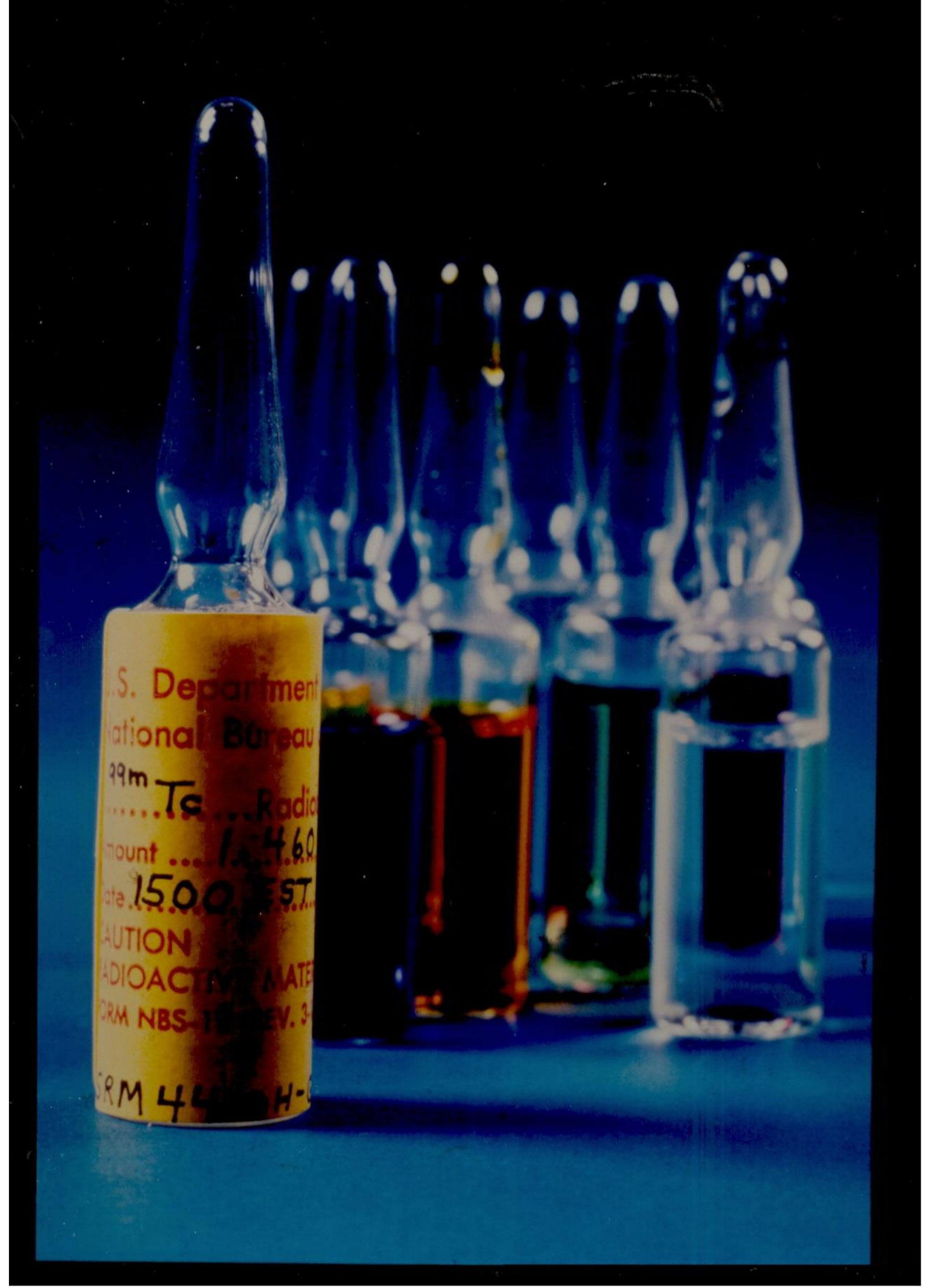


Traceability of Radioactivity Measurements in the U.S

- NIST
  - NRC
    - Regional Labs (5)
    - Other (4)
  - EPA
    - Environmental Monitoring Labs (>100)
    - NRSB → Radon Measurements Laboratories (>100)
  - DOE
    - Radon (~10)
  - NEI
    - Radiopharmaceutical Suppliers (~8)
    - Commercial Labs → End Users (>100)
    - Nuclear Power Plants (10-15)
  - FDA
  - DHS
    - EML
  - DOD
    - USAF → Secondary Labs (5) → Tertiary Labs (100)
    - US ARMY → Secondary Labs (7) → Tertiary Labs (75)
    - US NAVY → QA Labs (~30) → End Users (>100)

Our principal product...

solution standards of radionuclides



2006 Schedule for NEI Program

January	I-131	4401, lot 32	0.8 GBq	30 MBq
February	Mo-99	4412, lot 31	3.0 GBq	75 MBq
March	*open*			
April	Ga-67	4416, lot 27	0.4 GBq	20 MBq
May	Tc-99m	4410, lot 32	7.4 GBq	
June	Tl-201	4404, lot 29	0.4 GBq	33 MBq
July	*open*			
August	In-111	4417, lot 26	0.4 GBq	19 MBq
September	Xe-133	4415, lot 30	7.4 GBq	740 MBq
October	Y-90	4427, lot 10	0.2 GBq	19 MBq
November	*open*			
December	I-125	4407, lot 31	0.8 GBq	6 MBq

NIST Standard Reference Materials (SRMs) for Radionuclides Used in Nuclear Medicine and Biology

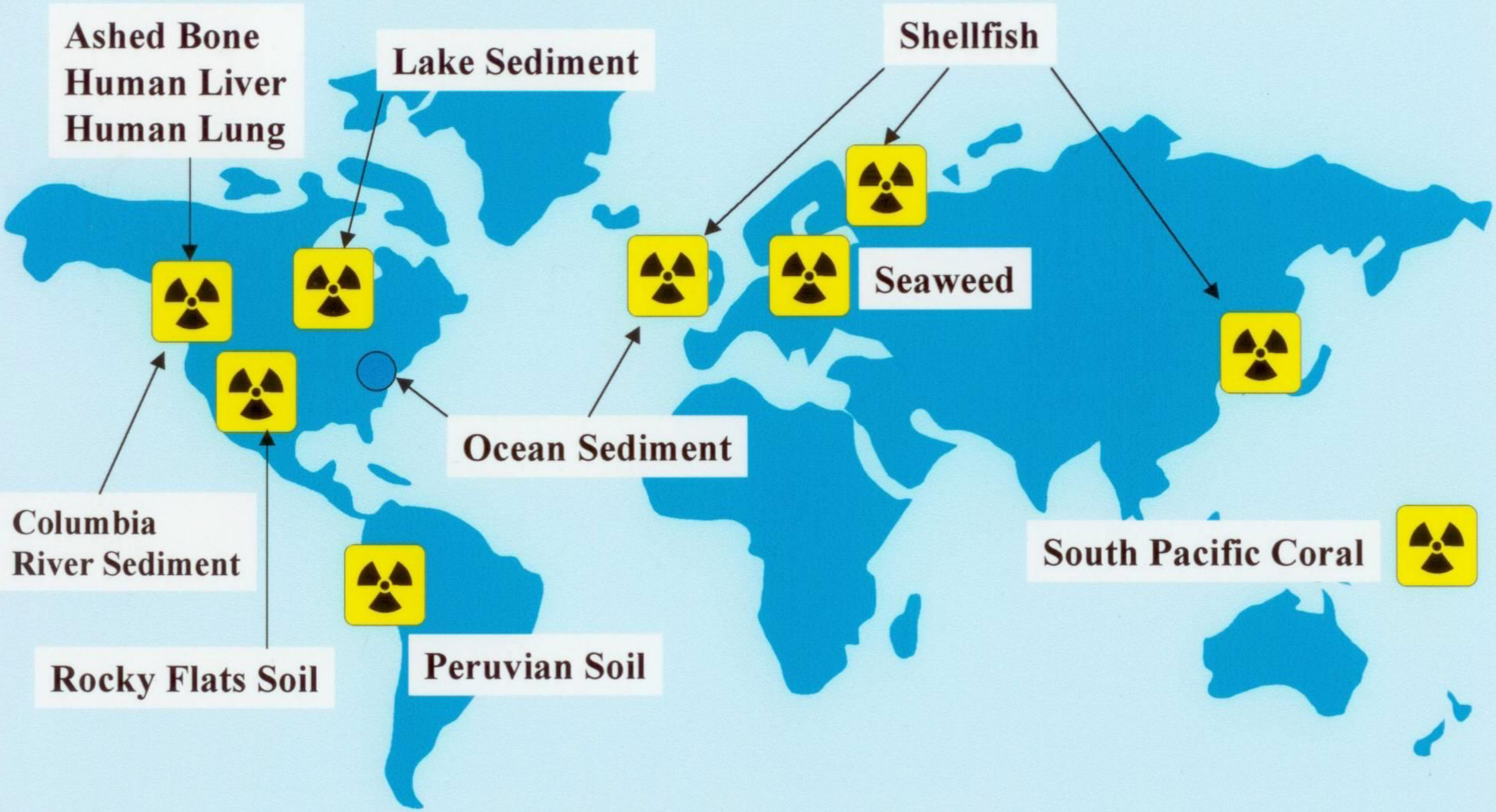
Radionuclide	SRM ID	Last Issued	Radionuclide	SRM ID	Last Issued
Chromium-51	4400N	July 1992	**Xenon-133**	4415, lot 29	September 2005
Iodine-131	4401, lot 32	January 2006	**Gallium-67**	4416, lot 27	April 2006
Tin-113-indium-113m	4402C	October 1980	**Indium-111**	4417, lot 25	August 2005
Strontium-85	4403B	April 1977	**Mercury-203**	4418A	November 1976
Thallium-201	4404, lot 28	June 2005	**Ytterbium-169**	4419C	October 1986
Gold-198	4405B	August 1978	**Lead-203**	4420B	November 1984
Phosphorus-32	4406O	October 1997	**Gold-195**	4421A	December 1979
Iodine-125	4407, lot 31	December 2005	**Chlorine-36**	4422A	April 1980
Cobalt-57	4408F	July 1995	**Strontium-90**	4423A	November 1985
Selenium-75	4409D	August 1981	**Sulfur-35**	4424A	October 1988
Technetium-99m	4410, lot 32	May 2006	**Samarium-153**	4425D	July 2002
Iron-59	4411B	January 1979	**Strontium-89**	4426A	April 1995
Molybdenum-99	4412, lot 31	February 2006	**Yttrium-90**	4427, lot 9	October 2005
Mercury-197	4413A	May 1976	**Gadolinium-153**	4428A	October 1998
Iodine-123	4414C	June 1980			

Natural Matrix SRMs

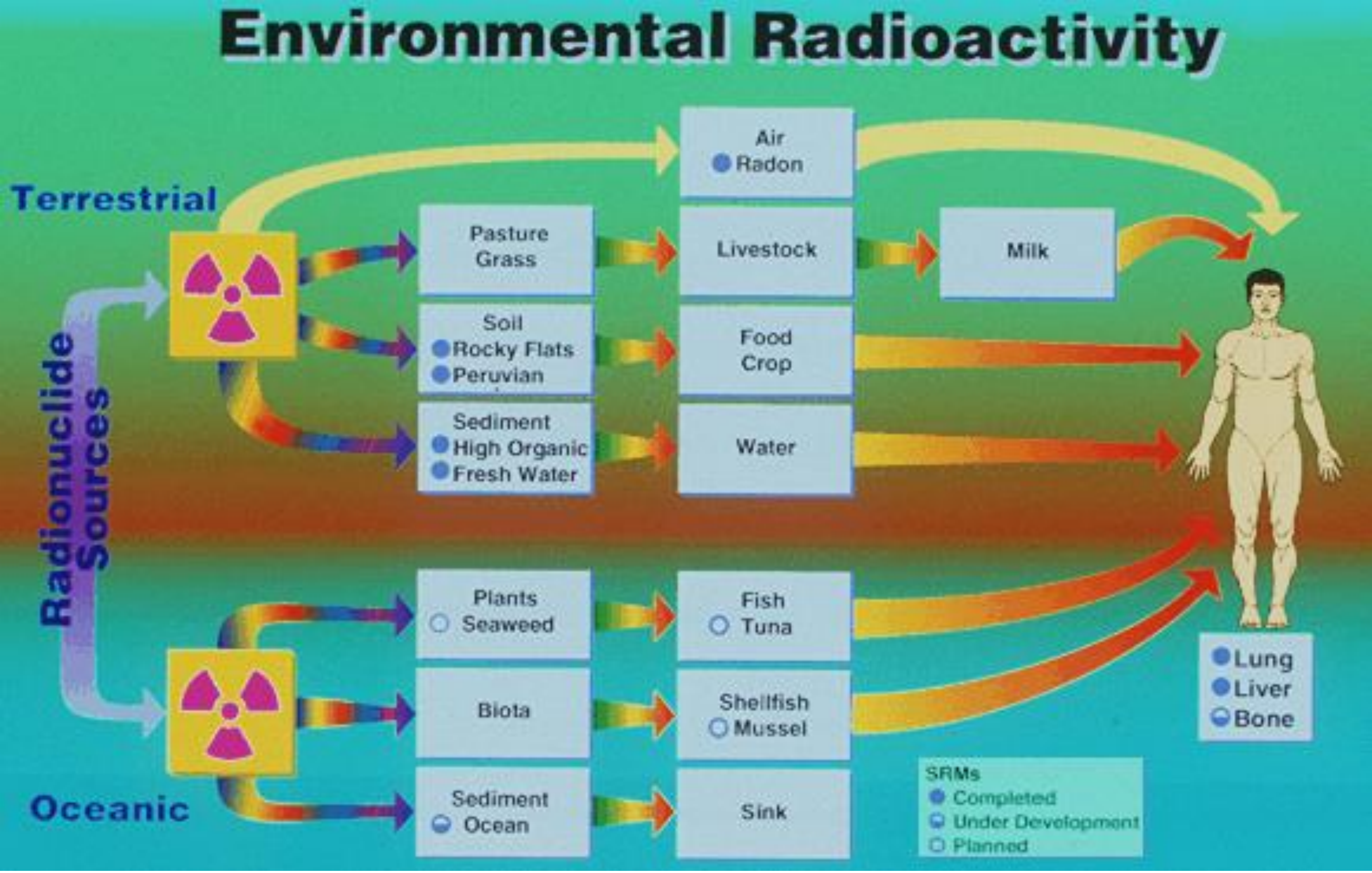
for Environmental Radioactivity Measurement

- Rocky Flat Soil I
- River Sediment
- Peruvian Soil
- Human Lung
- Human Liver
- Lake Sediment
- Ocean Sediment
- Bone Ash
- Shell Fish

Environmental Radionuclide SRM's



^{137}Cs, $^{239/240}$Pu, ^{90}Sr, U, Th, Ra


Environmental Radioactivity
Terrestrial
Radionuclide Sources
Oceanic
Air
Radon
Pasture Grass
Livestock
Milk
Soil
Rocky Flats
Peruvian
Food Crop
Sediment
High Organic
Fresh Water
Water
Plants
Seaweed
Fish
Tuna
Biota
Shellfish
Mussel
Sediment
Ocean
Sink
Lung
Liver
Bone
SRMs
Completed
Under Development
Planned

Natural Matrix Standard Needs

Matrix	Radionuclides	10-Yr Requirements
Soil: High Ca, Low Ca	^{90}Sr, ^{137}Cs, ^{210}Pb, Alpha Emitters	5,000 Aliquants (1 kg Samples)
Sediments: High Ca, Low Ca, Mill Tailings	Alpha- & Beta-Particle, and Photon Emitters	1,600 Aliquants (100 g Samples)
Water:	^{3}H, ^{60}Co, ^{90}Sr, ^{106}Ru, ^{134}Cs, ^{137}Cs, Natural Radionuclides, Alpha-Particle Emitters	Thousands of Aliquants (50-100 mL Samples)
Biological: Lung, Liver, Bone, Milk, Sea Clam, Sea Hare, Seaweed	^{3}H, ^{14}C, Fission & Activation Products, Alpha-Particle Emitters	Several Hundred Aliquants
Air: Filters	Natural Radionuclides	

Many other geometries for standards & calibrations

- Spiked sources (soils, synthetic urine, water)
- Filter sources
- Point Sources
- Marinelli beakers
- Radioactive gas ampoules
- Polyethlene encapsulated radon emanation sources
- Large area sources
- Dose vials
- Brachytherapy sources

Alpha-Particle Emitters Including Mixed Alpha
Beta-Particle Emitters
X- and γ-ray Emitters

Customers include: Department of Defense, Department of Energy, Environmental Protection Agency, Nuclear Regulatory Agency, National Aeronautics and Space Agency, Department of Homeland Security, Nuclear power industry, Source & instrument manufacturers, Radiopharmacies, etc..

Radioactivity Measurement Assurance Programs (MQAs)

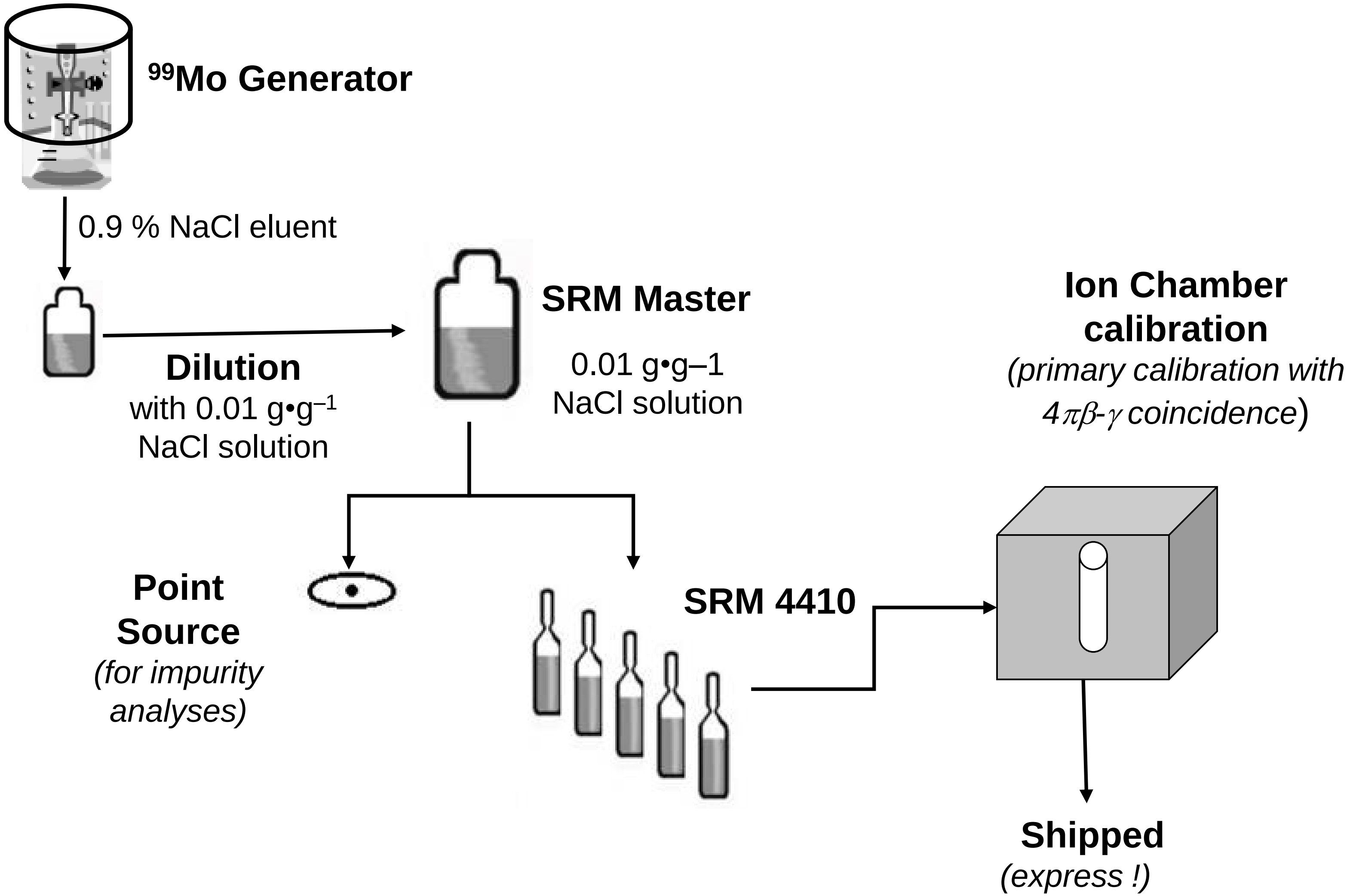
Nuclear Energy Institute – Radiopharmaceuticals
(31 years)

Nuclear Energy Institute – Power Station Radiochemistry
(17 years)

NIST Radiochemistry Intercomparison Program (NRIP)
(8 years)

Some examples

Tc-99m (IC calibration)



NBS
STANDARD REFERENCE MATERIAL
4355
PERUVIAN SOIL
NBS
STANDARD REFERENCE MATERIAL
4354
FRESH WATER
LAKE SEDIMENT
U.S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS
WASHINGTON, DC 20234
NIST
STANDARD REFERENCE MATERIAL
4350b
River Sediment
(For radioactivity measurements)
U.S. DEPARTMENT OF COMMERCE
NATIONAL INSTITUTE OF STANDARDS
AND TECHNOLOGY
4351
HUMAN LUNG
NBS
STANDARD REFERENCE MATERIAL
4352
HUMAN LIVER
NIST
STANDARD REFERENCE MATERIAL
4356
BONE ASH
#781
OCEAN SEDIMENT

Process of Developing a NIST Natural-Matrix Radionuclide SRM

- Matrix Selection
- Matrix Collection
- Matrix Preparation
  - Size
  - Drying
  - Milling/Pulverization
  - Blending
  - Final Drying
  - Sterilization
- Interlaboratory Comparison
  - Traceability
- Data and Statistical Analysis
- Discrepancy Resolution
- Write Certificate

The digestion and detection methods used for the radionuclides of interest in the NIST bone ash SRM

Radio-nuclides	Digestion/Detection Method	Participant
^{40}K	1A	JCAC, PTB
^{90}Sr	(3 + 5)B + 3D	IRMM, JCAC, MAFF, NRPB
^{210}Pb	1A + 3B + 3C	IRMM, JCAC, JSI, MAFF, PTB
^{210}Po	4C	NRPB
^{226}Ra	1A + 5D + 3E	IRMM, JCAC, JSI, MAFF, PTB
^{228}Ra	1A	JSI
^{228}Ac	1A	JCAC, PTB
^{228}Th	1A + (2 + 3 + 6)C	IRMM, JCAC, JSI, MAFF, NIST, PTB
^{230}Th	(2 + 3 + 6)C	IRMM, JCAC, MAFF, NIST
^{232}Th	(2 + 3 + 6)C	IRMM, JCAC, MAFF, NIST
^{234}U	(2 + 3 + 6)C	IRMM, JCAC, LDMC, LDML, MAFF, NIST, PTB
^{235}U	(2 + 3 + 6)C	JCAC, LDMC, MAFF, NIST, PTB
^{238}U	(2 + 3 + 6)C	IRMM, JCAC, LDMC, LDML, MAFF, NIST, PTB
^{238}Pu	(2 + 3 + 6 + 7)C	IRMM, JCAC, LDMC, LDML, MAFF, NIST, NRPB, PTB
$^{(239+240)}Pu$	(2 + 3 + 6 + 7)C	IRMM, JCAC, LDMC, LDML, MAFF, NIST, NRPB, PTB
^{241}Am	1A + (2 + 3 + 6 + 7)C	IRMM, JCAC, JSI, LDMC, LDML, MAFF, NIST, NRPB, PTB
$^{(243+244)}Cm$	(3 + 6)C	JCAC, LDMC, LDML, MAFF

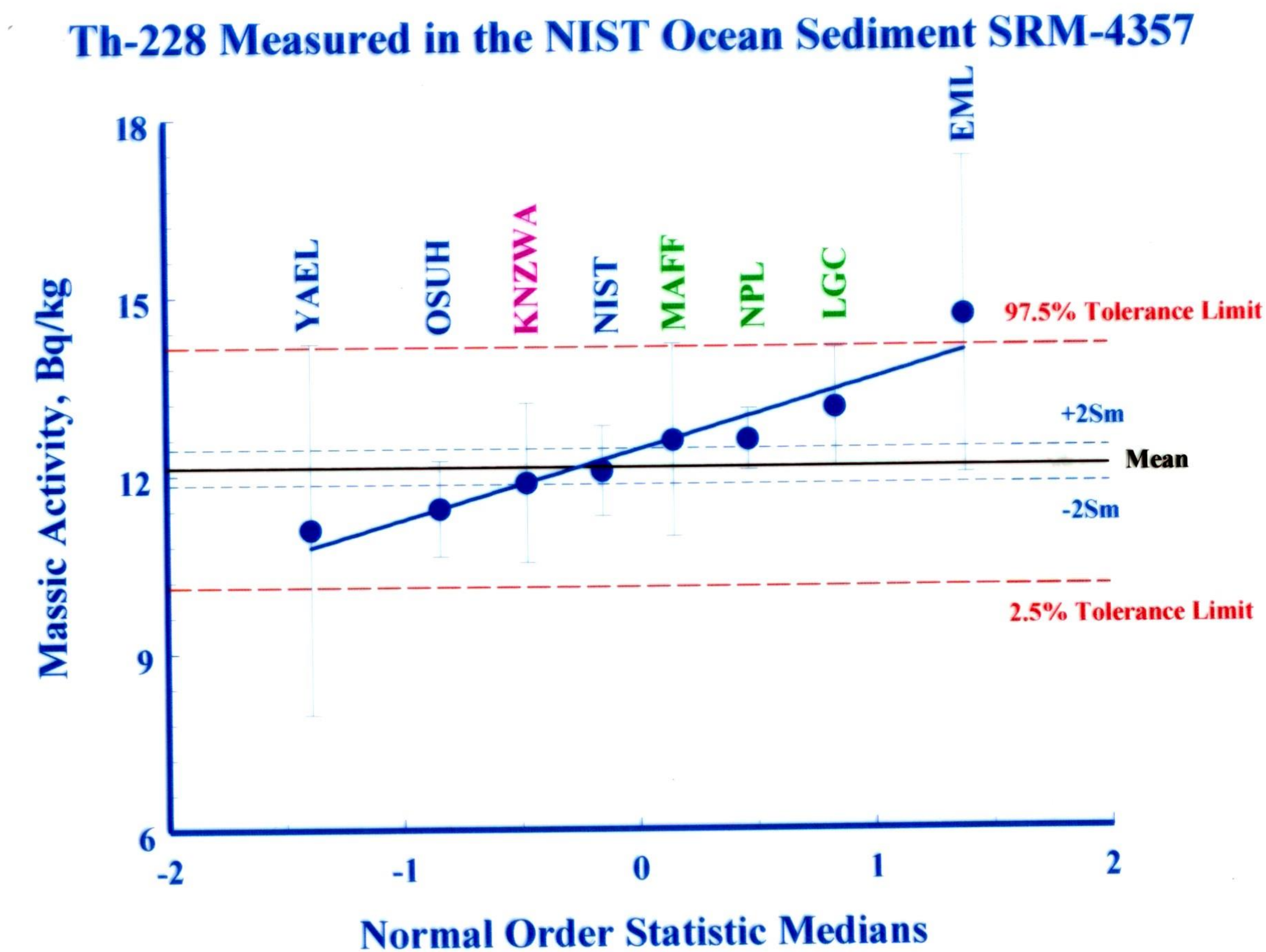
Sample Digestion Methods:

1. Non-destructive
2. $HNO_3 + H_2O_2 + HF + HClO_4$
3. HNO_3
4. $HNO_3 + HCl$
5. $HNO_3 + HF$
6. $HNO_3 + H_2O_2$
7. Calcination at 500°C followed by addition of 8M HNO_3

Detection Methods:

A. (Ge) gamma-ray spectromter
B. Beta-particle Geiger counter
C. Alpha-particle spectrometer

D. Liquid scintillation counting
E. Lucas Emanation Cell

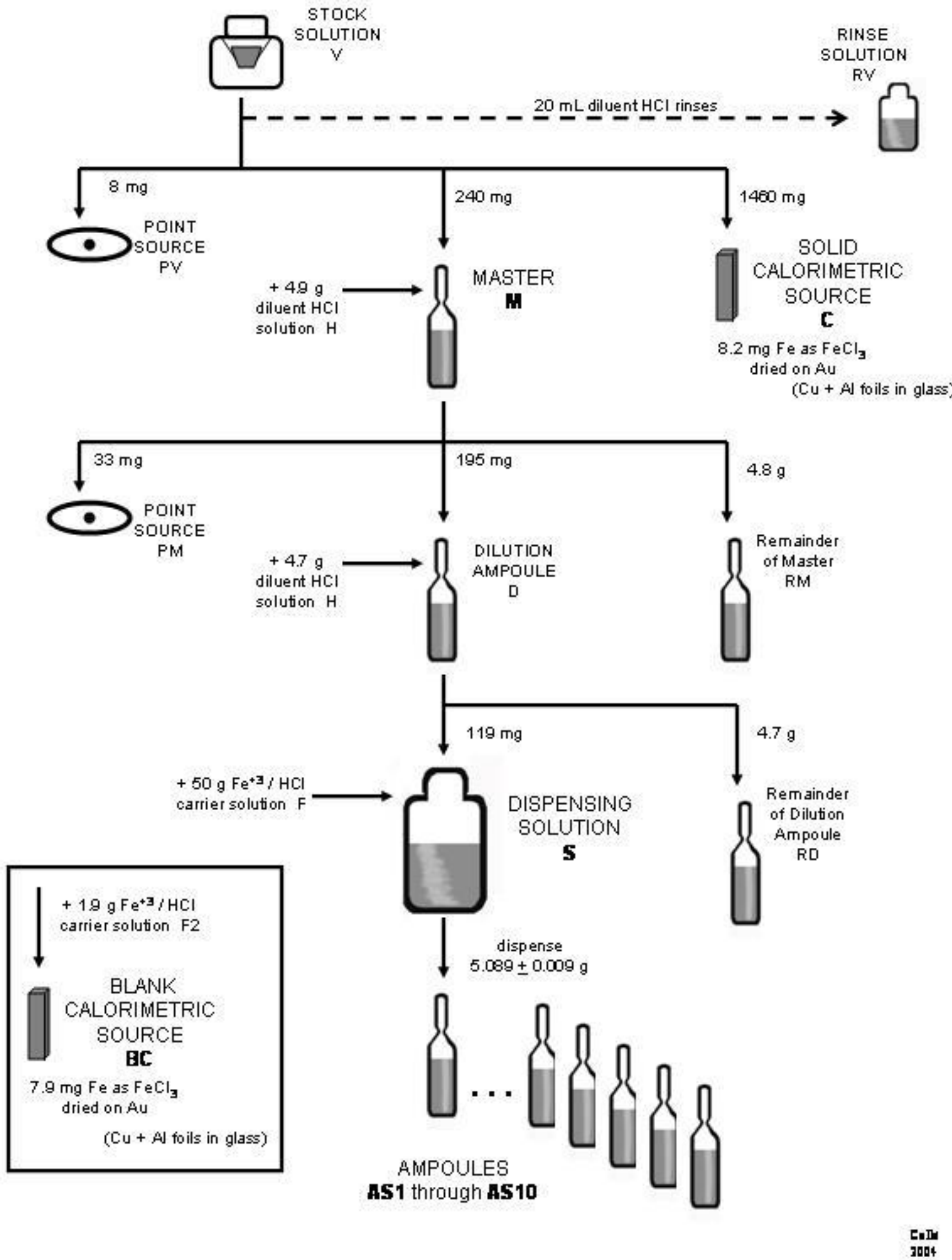

Th-228 Measured in the NIST Ocean Sediment SRM-4357
Massic Activity, Bq/kg
Normal Order Statistic Medians
YAEL
OSUH
KNZWA
NIST
MAFF
NPL
LGC
EML
97.5% Tolerance Limit
+2Sm
Mean
-2Sm
2.5% Tolerance Limit
18
15
12
9
6
-2
-1
0
1
2

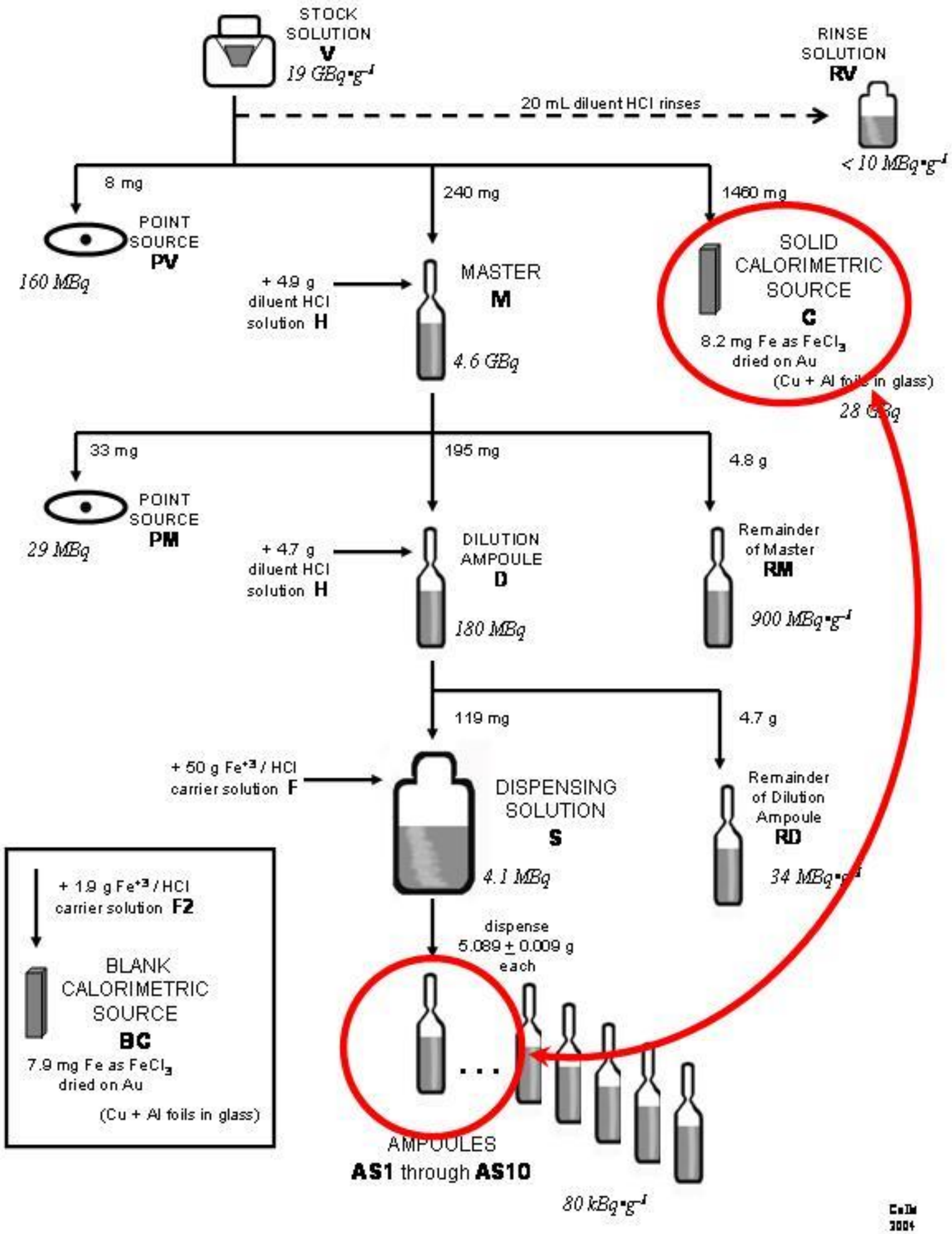
^{55}Fe

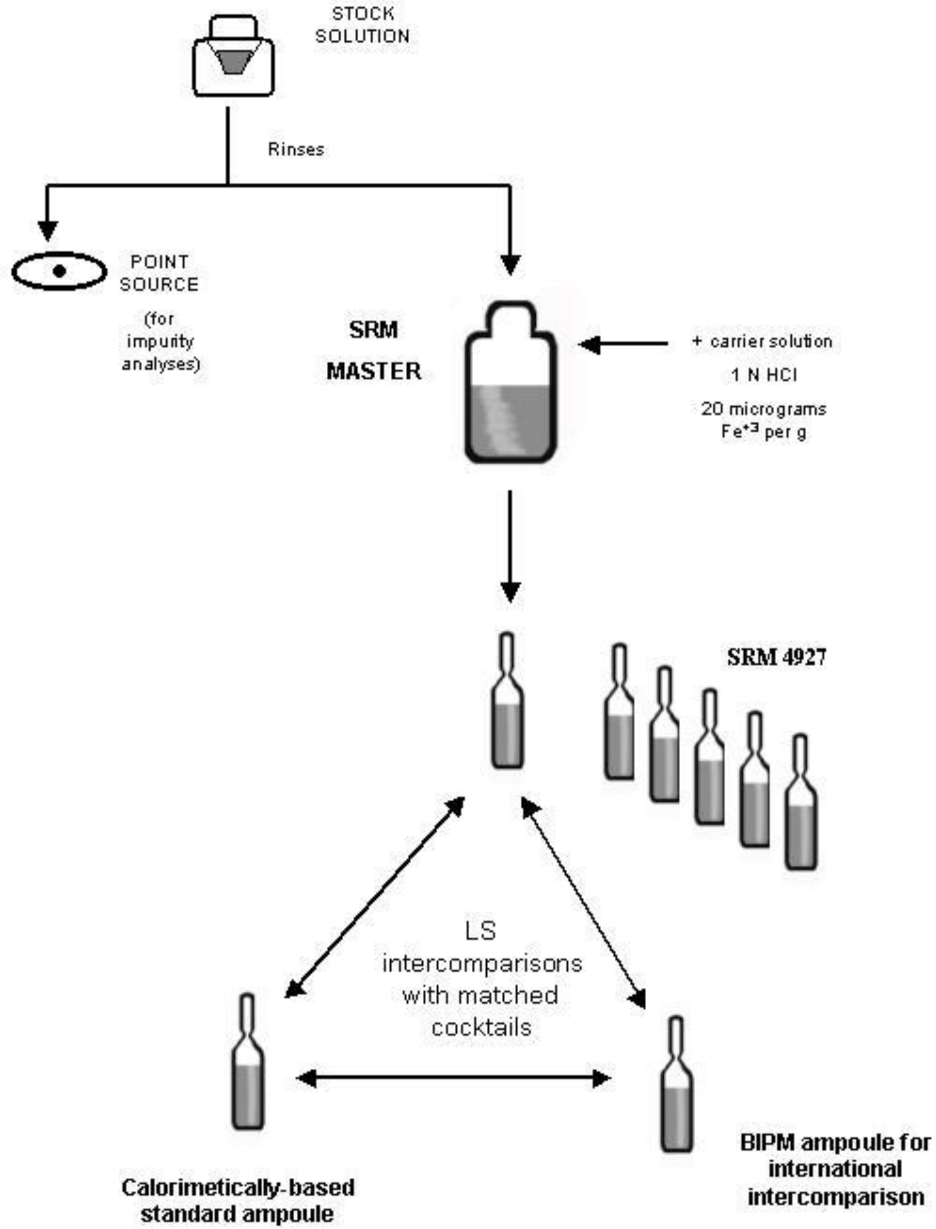
primary standardization by microcalorimetry

linked to SRM

international intercomparison


STOCK SOLUTION V
RINSE SOLUTION RV
20 mL diluent HCl rinses
8 mg
240 mg
1460 mg
POINT SOURCE PV
MASTER M
+ 4.9 g diluent HCl solution H
SOLID CALORIMETRIC SOURCE C
8.2 mg Fe as $FeCl_3$ dried on Au
(Cu + Al foils in glass)
33 mg
195 mg
4.8 g
POINT SOURCE PM
+ 4.7 g diluent HCl solution H
DILUTION AMPOULE D
Remainder of Master RM
119 mg
4.7 g
+ 50 g Fe^{+3} / HCl carrier solution F
DISPENSING SOLUTION S
Remainder of Dilution Ampoule RD
+ 1.9 g Fe^{+3} / HCl carrier solution F2
BLANK CALORIMETRIC SOURCE BC
7.9 mg Fe as $FeCl_3$ dried on Au
(Cu + Al foils in glass)
dispense
5.089 ± 0.009 g
. . .
AMPOULES
AS1 through AS10


STOCK SOLUTION
V
19 GBq•g-1
20 mL diluent HCl rinses
RINSE SOLUTION
RV
< 10 MBq•g-1
8 mg
240 mg
1460 mg
POINT SOURCE
PV
160 MBq
+ 4.9 g diluent HCl solution H
MASTER
M
4.6 GBq
SOLID CALORIMETRIC SOURCE
C
8.2 mg Fe as FeCl3 dried on Au
(Cu + Al foils in glass)
28 GBq
33 mg
195 mg
4.8 g
POINT SOURCE
PM
29 MBq
+ 4.7 g diluent HCl solution H
DILUTION AMPOULE
D
180 MBq
Remainder of Master
RM
900 MBq•g-1
119 mg
4.7 g
+ 50 g Fe+3 / HCl carrier solution F
DISPENSING SOLUTION
S
4.1 MBq
Remainder of Dilution Ampoule
RD
34 MBq•g-1
+ 1.9 g Fe+3 / HCl carrier solution F2
BLANK CALORIMETRIC SOURCE
BC
7.9 mg Fe as FeCl3 dried on Au
(Cu + Al foils in glass)
dispense 5.089 ± 0.009 g each
AMPOULES
AS1 through AS10
80 kBq•g-1
2004



Calorimetry

13 independent determinations

LS intercomparisons

776 activity ratios; variables include:

- 3 counters
- 3 scintillators
- 44 matched cocktails
- 4 distinct aq. fraction (+Fe) compositions
- 2 NIST solution dilutions
- 97 days of aging

NIST Uncertainty Analysis for ^{55}Fe Microcalorimetric Standardization of NIST Solution Standards

Item	Uncertainty component	Assessment Type	Relative standard uncertainty contribution on massic activity of ^{55}Fe (%)
1	Measurement precision for 13 independent calorimetric determinations of the power of solid source C; includes precision in the calibrations & baseline measurements for each determination; std. dev mean for ν=12 degrees freedom (passes Normal test)	A	0.25
2	Gravimetric (mass) linkage of source C to NIST standard solutions	B	0.07
3	Activity loss in source C preparation	B	0.15
4	Power calibration of calorimeter, includes any systemic heat losses	B	0.05
5	Possible heat defect / excess effects	B	0.1
6	^{55}Fe decay corrections during calorimetric measurements	B	0.02
7	^{55}Fe decay corrections from calorimetric reference time to BIPM reference time.	B	0.08
8	Average energy per decay for ^{55}Fe (to convert calorimetric power to activity)	B	0.17
	COMBINED STANDARD UNCERTAINTY		0.39

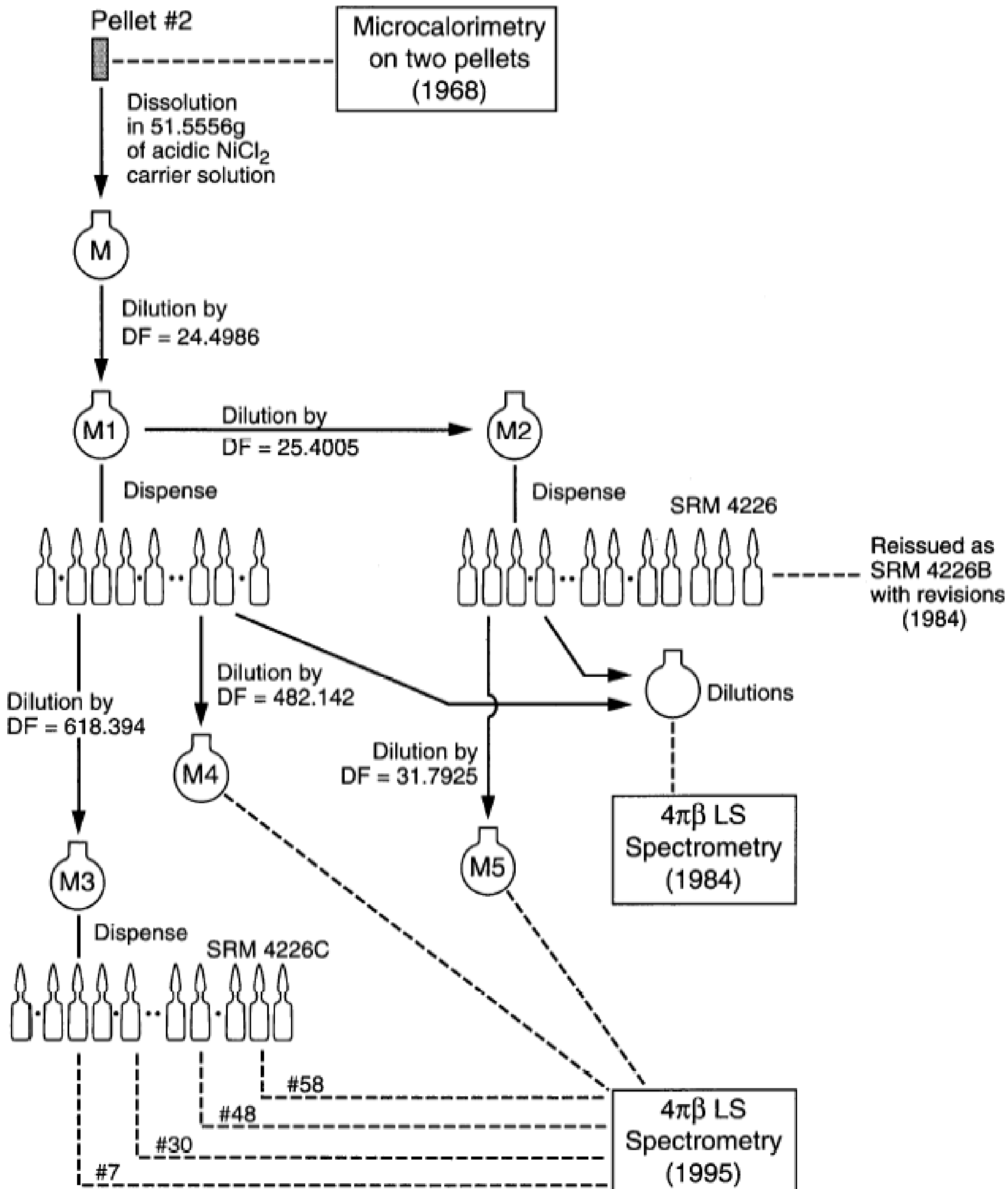
Item	Uncertainty component	Assessment Type	Relative standard uncertainty contribution on massic activity of ^{55}Fe (%)
1	LS measurement precision; reproducibility in activity ratio w/ 44^{+} sets of cocktails of matched composition; std. dev mean for ν =765 degrees freedom (passes Normal test)	A	0.26
2	LS cocktail stability and composition mismatch effects ; std dev mean for ν_{eff} =11 effective degrees freedom (3 scintillants; 4 aqueous fractions; 2 dilutions); passes Normal test	A	0.47
3	Background LS measurement variability; wholly embodied in items 1 & 2	A	---
4	LS counter (energy threshold) dependencies	A	0.06
5	Scintillator dependencies; wholly embodied in items 1 & 2	A	---
6	Gravimetric (mass) measurements for LS sources	B	0.05
7	Gravimetric (mass) measurements for dilutions	B	0.07
8	Livetime determinations for LS counting time intervals; includes uncorrected deadtime effects	B	0.06
9	Decay corrections for ^{55}Fe (assumed half-life unc.)	B	0.012
10	Limit for photon-emitting impurities	B	0.11
11	Calorimetric primary standardization of NIST 55Fe solutiuons (see ATTACHMENT # 6)	B	0.39
	COMBINED STANDARD UNCERTAINTY		**0.68**

NIST Uncertainty Analysis for ^{55}Fe Massic Activity for the BIPM International Intercomarison

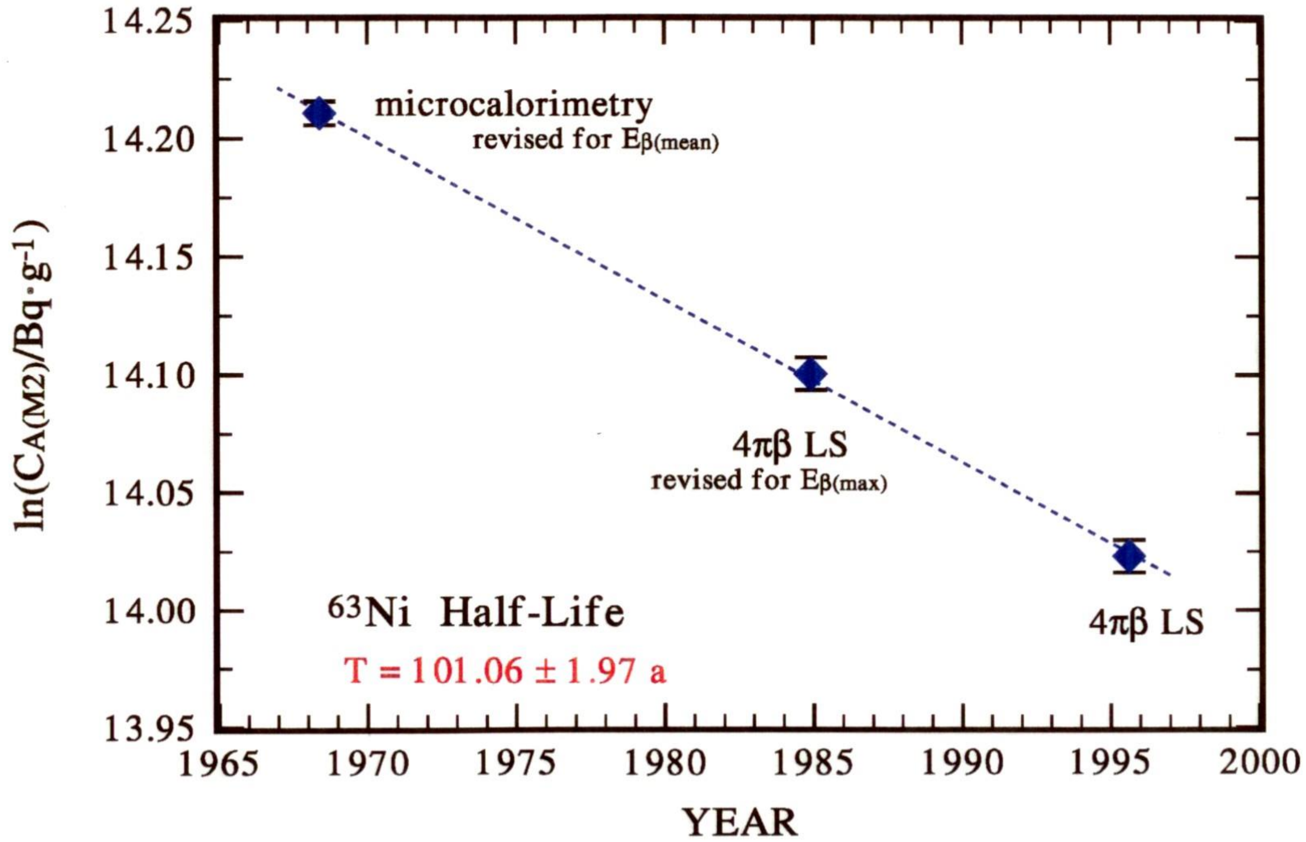
Uncertainty for the ^{55}Fe SRM is comparable;

U (k=2) = 1.7 %

^{63}Ni



Pellet #2
Microcalorimetry on two pellets (1968)
Dissolution in 51.5556g of acidic $NiCl_2$ carrier solution
M
Dilution by DF = 24.4986
M1
Dilution by DF = 25.4005
M2
Dispense
Dispense
SRM 4226
Reissued as SRM 4226B with revisions (1984)
Dilutions
Dilution by DF = 618.394
Dilution by DF = 482.142
M4
Dilution by DF = 31.7925
4πβ LS Spectrometry (1984)
M3
M5
Dispense
SRM 4226C
#58
#48
#30
#7
4πβ LS Spectrometry (1995)



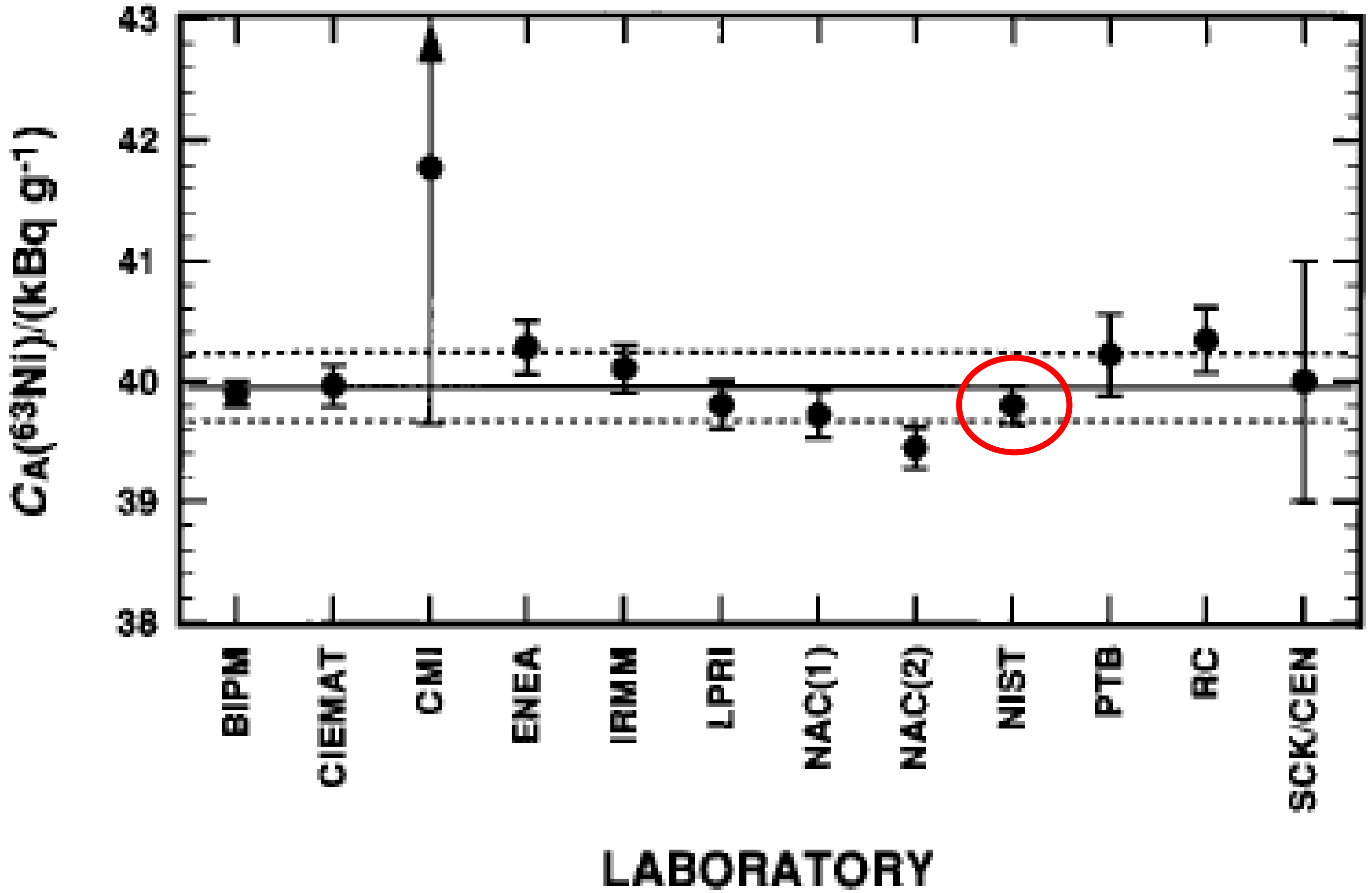
Ongoing LS + TDCR

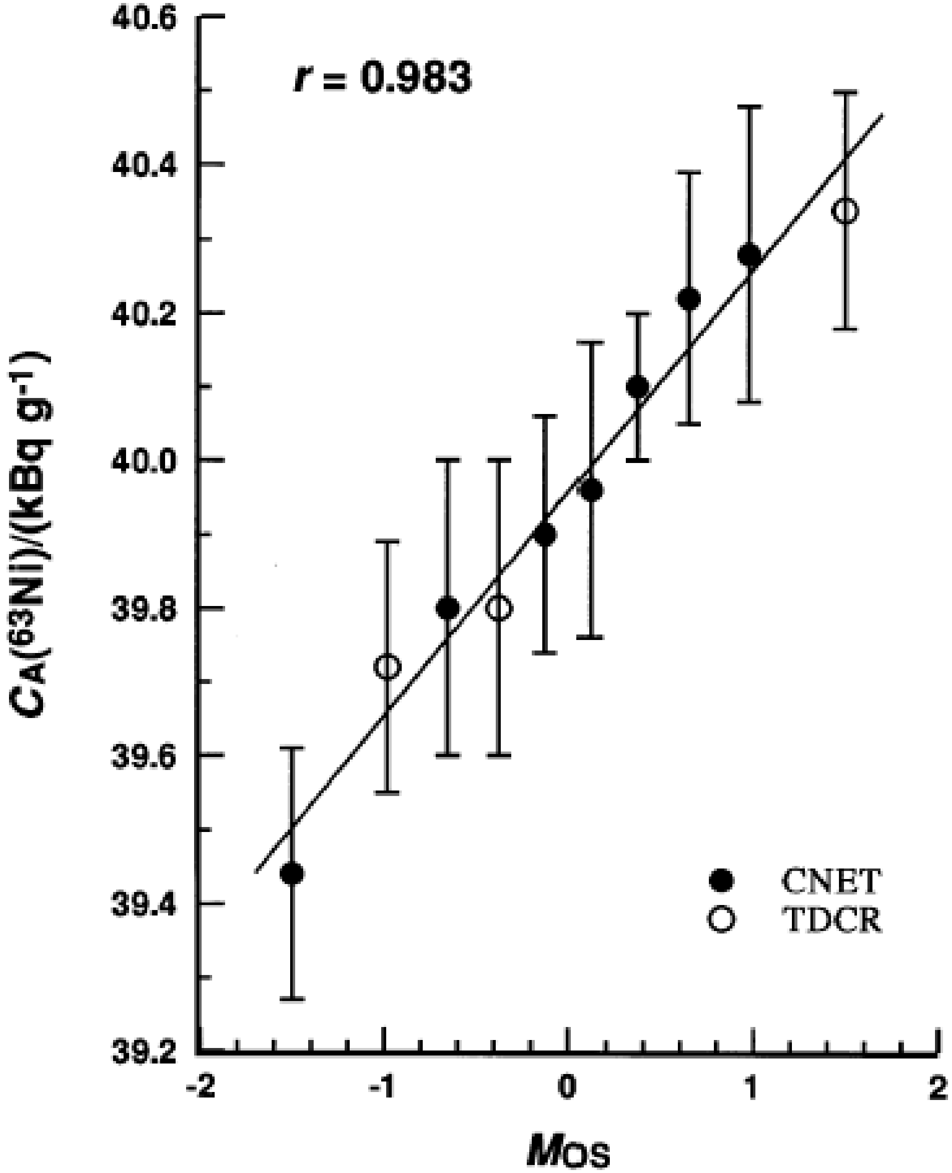
?

2006

+

^{63}Ni international intercomparison



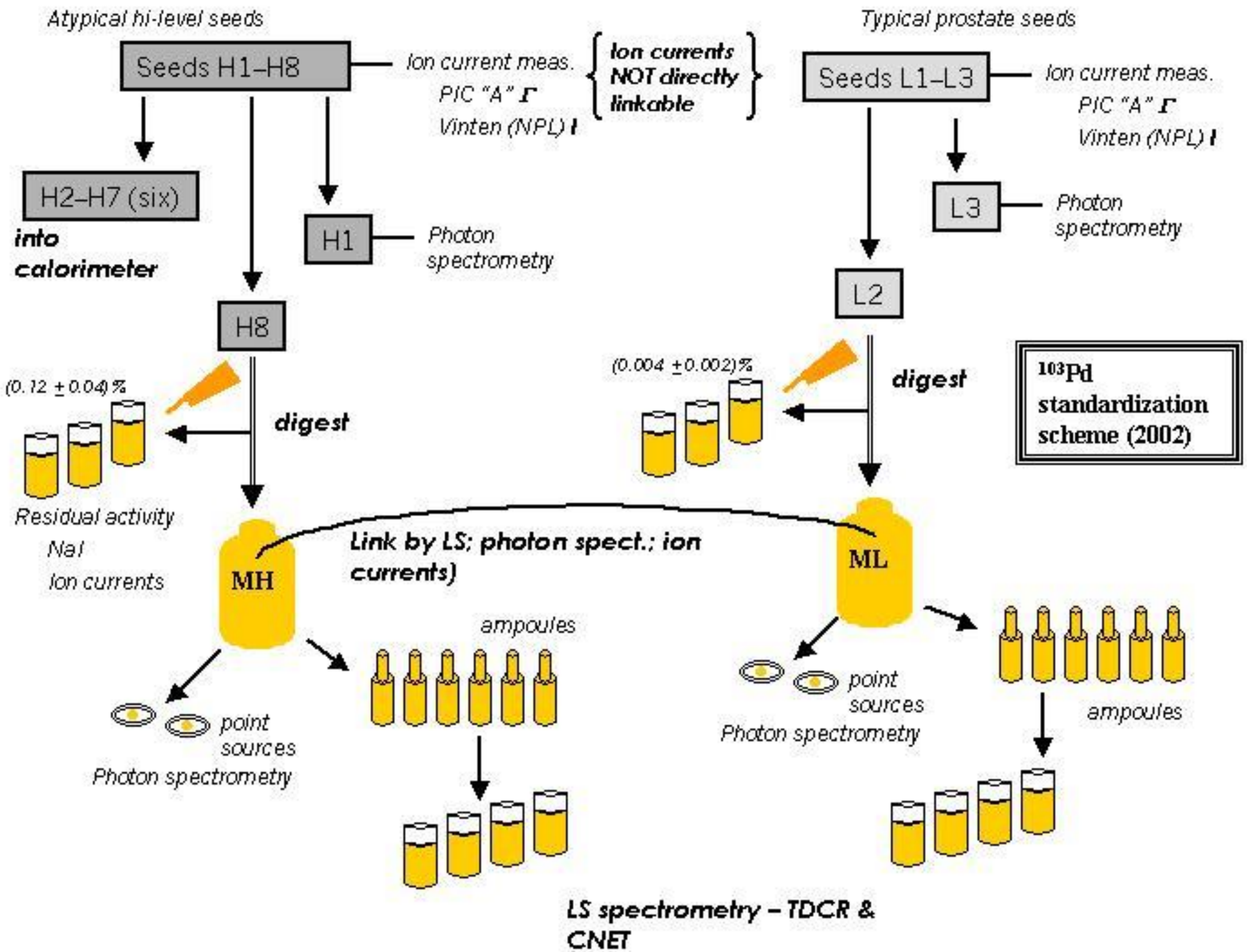


r = 0.983
40.6
40.4
40.2
40.0
39.8
39.6
39.4
39.2
-2
-1
0
1
2
CNET
TDCR
$C_A(^{63}Ni)/(kBq\ g^{-1})$
M_{OS}

Table 16. NIST uncertainty analysis for the EUROMET intercomparison of ^{63}Ni. The analysis makes no estimate for any uncertainty due to the possible presence of radionuclidic impurities, nor for any uncertainty associated with the assumed model assumptions in the CIEMAT/NIST method

Item	Uncertainty component (and Type)	Relative uncertainty contribution to massic activity of ^{63}Ni (%)
1	LS measurement variability; reproducibility with 7 cocktails of comparable composition; $\upsilon = 6$ degrees of freedom (A)	0.034
2	LS sample variability (quench dependence); reproducibility between sample compositions; $\upsilon = 6$ (A)	0.085
3	LS cocktail stability and composition effects; $\upsilon = 3$ (A)	0.06
4	Gravimetric (mass) determinations for LS samples (B)	0.05
5	Experimental ^{3}H efficiency from NIST ^{3}H standard (B)	0.29
6	Background measurement variability; wholly embodied in item 1 above (A)	—
7	Spectrometer and scintillant dependencies; wholly embodied in items 1, 2, and 3 above (A)	—
8	Livetime determinations for LS counting time intervals; includes uncorrected deadtime effects (B)	0.07
9	Decay corrections for ^{63}Ni and ^{3}H (B)	0.001
10	Variability in determination of QIPs for ^{3}H and ^{63}Ni (A)	0.13
11	Precision of ^{3}H efficiency versus figure of merit (M) calculations (step sizes) (B)	0.008
12	Fit of relation between ^{3}H QIP and calculated M (B)	0.02
13	Precision of ^{63}Ni efficiency versus figure of merit (M) calculations (step sizes) (B)	0.002
14	Fit of relation between calculated M and ^{63}Ni efficiency (A)	0.002
15	Effect of ionization quenching assumptions on efficiency calculations (B)	0.1
16	Effect of asymmetry in phototube responses on efficiency calculations (B)	0.14
17	Effect of ^{3}H $E_{\beta(\max)}$ on efficiency calculations (B)	0.09
18	Effect of ^{63}Ni $E_{\beta(\max)}$ on efficiency calculations (B)	0.0024
Relative combined standard uncertainty		**0.40**

END



Atypical hi-level seeds
Seeds H1–H8
Ion current meas.
PIC "A" Γ
Vinten (NPL) I
Ion currents NOT directly linkable
Typical prostate seeds
Seeds L1–L3
Ion current meas.
PIC "A" Γ
Vinten (NPL) I
H2–H7 (six)
into calorimeter
H1
Photon spectrometry
L3
Photon spectrometry
L2
H8
(0.12 ± 0.04)%
digest
(0.004 ± 0.002)%
digest
^{103}Pd standardization scheme (2002)
Residual activity
NaI
Ion currents
MH
Link by LS; photon spect.; ion currents)
ML
ampoules
point sources
Photon spectrometry
point sources
Photon spectrometry
ampoules
LS spectrometry – TDCR & CNET