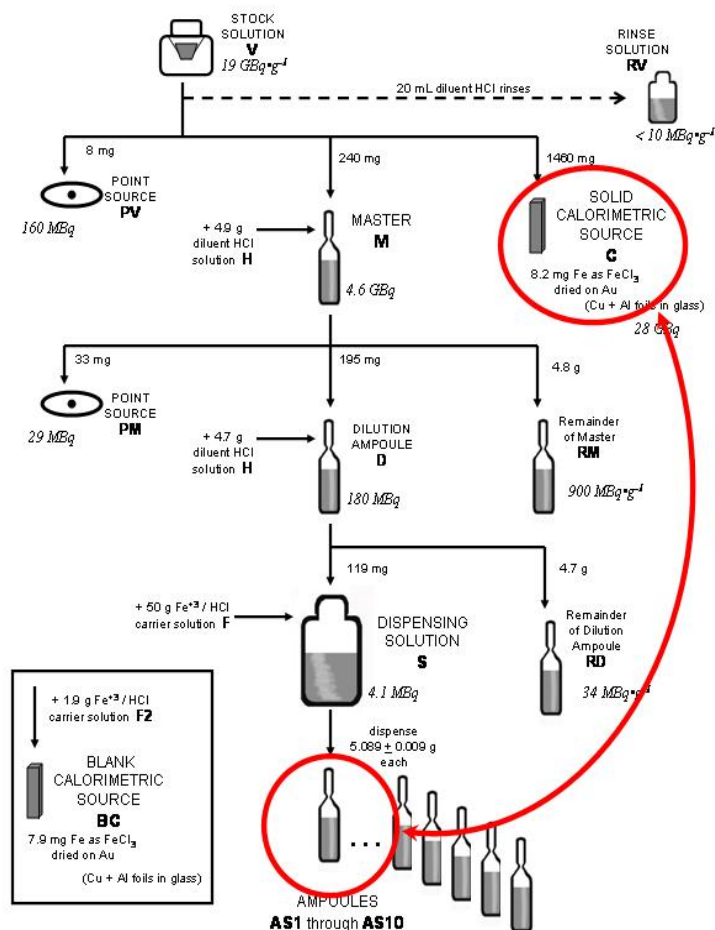


# IONIZING RADIATION DIVISION

## Radioactivity Group

### Technical Activities

## 2006



**Primary standardization of Fe-55 for a New SRM and International Measurement Comparisons**  
 Schema showing the gravimetric linkages between the solid  $^{55}\text{Fe}$  calorimetry source and the NIST standardized solutions that were used to calibrate the SRM and to assay a comparison solution from the BIPM. Determinations of the activity for nuclides that decay by pure, low-Z (atomic number) electron capture (EC) to the ground state of their daughters are amongst the most difficult within the realm of radionuclidic standardization, and the present work on this difficult-to-measure EC nuclide is a return by NIST to the use of calorimetry for primary radionuclidic standardizations.

# Ionizing Radiation Division

## INTRODUCTION

The Ionizing Radiation Division is one of six divisions within the Physics Laboratory at the National Institute of Standards and Technology (NIST). The mission of the Division is to develop, maintain and disseminate the national standards for ionizing radiation and radioactivity, which it does through activities in three technical groups: Radiation Interactions and Dosimetry (Stephen M. Seltzer, Group Leader), Neutron Interactions and Dosimetry (Muhammad Arif, Group Leader), and Radioactivity (Michael P. Unterweger, Acting Group Leader). The Division promotes the accurate and meaningful measurements of dosimetric quantities pertaining to ionizing radiation: X rays, gamma rays, electrons, and energetic, positively charged particles, and maintains the national measurement standards for the Système International (SI) unit for radiation dosimetry, the *gray*, and activity, the *becquerel*. It also provides measurement services, standards, and fundamental research in support of NIST's mission as it relates to neutron technology and neutron physics for industrial research and development, national defense, homeland security, electric and alternative power production, and radiation protection, and maintains and disseminates measurement standards for neutron dosimeters, neutron survey instruments, and neutron sources. Finally, the Division is responsible for developing metrological techniques to standardize new radionuclides for research, and for exploring radiation and nuclear applications in health care, worker protection, environmental protection, and national defense.

The Division continues its focused efforts in providing critical measurements and standards for all aspects of ionizing radiation in industry, health care, environment, homeland security and defense, working closely with the user communities in all of these arenas to define and prioritize our research and programs in metrology. Direct interactions with our international colleagues in metrology (by active participation in implementation of the Mutual Recognition Arrangement through intercomparisons, submission of Calibration and Measurement Capabilities for evaluation, and international meetings) as well as with community members (such as through the Council on Ionizing Radiation Measurements and Standards, CIRMS) serve to provide a strong basis for near term planning and our current programs. In 2006, the Division expanded its quality system to include its production of Radioactivity Standard Reference Materials (SRMs<sup>®</sup>) and for high-dose (industrial) radiation and neutron dosimetry measurements; this completed the initial and thorough assessment of our Quality System, and the subsequent declaration of conformance (dated 21 August 2006) represented the Division's compliance to the updated NIST quality systems that incorporates the relevant requirements of ISO/IEC 17025 and ISO Guide 34. In late October 2006, NIST hosted the 15<sup>th</sup> Annual Meeting of CIRMS; more than 170 participants provided perspectives on developments and needs in ionizing radiation research, measurements and standards in health care, homeland security, environmental and personnel protection, and industrial applications. This year's meeting focus, "Implications of Uncertainty in Radiation Measurements and Standards," was particularly relevant for a wide audience, and garnered participation not only from homeland security and industry, but also from the health care and worker protection communities.

Efforts in the development of standards, methodologies, and technical infrastructural support for homeland security applications, particularly in cooperation with the Department of Homeland Security's Science and Technology Directorate (S&T) and with the Domestic Nuclear Detection Office (DNDO) for radiation and nuclear detection and x-ray screening technologies, continue. In addition to developing new, and validating existing, equipment standards for radiation detection for first responders, efforts for homeland security in 2006 have expanded to address needs in test-bed development, such as the development of the cargo container test bed to be used for validation of and testing to ANSI N42.41, Minimum Performance Criteria for Active Interrogation Systems used for Homeland Security. Development of standards for performance assessment of x-ray screening technologies, including test objects and protocols, for the four classes of x-ray security

screening systems (checkpoint cabinet, computed tomography, cargo and vehicle, and human subject) are progressing, with the active participation of the user and manufacturer communities. Several other standards for rad/nuc detection are at various stages of development and publication; most recently, the standard for spectroscopic portal monitors (N42.38) was published by IEEE/ANSI.

To address needs arising from increasing requests by industry and other customers for accurate transfer dosimetry using alanine/EPR (Electron Paramagnetic Resonance) dosimetry, the server software system has been completed for our program in developing the first Internet-based *e*-certification service for radiation-processing (high-dose) dosimetry, with only some technical choices left to be tested to assure minimum uncertainty in transmitted calibration results. In preparation for the possibility of a radiological dispersal incident (whether accidental or intentional), the Division has leveraged its expertise in low-level and environmental-level radiochemistry to develop a Radioanalytical Emergency Procedures Manual Database which can be used to assist organizations preparing for emergency response. We also continue to apply neutron-imaging methods for industrial research on water transport in fuel cells and on hydrogen distribution in hydrogen storage devices, providing critical services to major automotive and fuel cell companies in our high-demand and high-profile, nationally-recognized program.

In fundamental research and metrology, the Division maintains active programs for precision measurements of and for neutrons (such as in the investigation of the neutron lifetime and improved cold neutron counting techniques), improved metrological techniques for radionuclide standardization (most recently, for  $^{55}\text{Fe}$  and  $^{63}\text{Ni}$ ), and dosimetric calibrations (such as in water calorimetry to realize absorbed dose). In 2006, new neutron interferometry experiments were undertaken to determine the charge distribution of the neutron, and additional efforts were focused on developing and promoting applications of efficient neutron spin filters based on laser-polarized  $^3\text{He}$ . Developments in measurement approaches for radioactivity, such as the new automated multi-sample ionization chamber and resonance ionization mass spectrometry, are presenting opportunities to minimize dose to staff and improve trace analysis. Our accelerator facilities continue to support research efforts in industrial and medical dosimetry, homeland security, and radiation-hardness and materials-effects studies with recent progress in the development of our High-Energy Computed Tomography (HECT) facility and quality-assurance testing continues on the Clinac 2100C medical accelerator.

The Division maintains a strong focus on addressing the needs in standards and measurements to support health care, particularly in radiation and nuclear therapies. In addition to our efforts on developments in calibrations and standards for nuclear medicine (such as  $^{211}\text{At}$  and  $^{223}\text{Ra}$ , which are being investigated for use in targeted radiotherapy), calibrations for brachytherapy sources (e.g., for the photon-emitting  $^{125}\text{I}$ ,  $^{103}\text{Pd}$ , and  $^{141}\text{Cs}$  radioactive seeds used to treat prostate cancer) and reference dosimetry calibrations for x rays used in mammography and beam therapy. Looking to expand our efforts, we are pursuing a new initiative focused on supporting technologies for quantitative medical imaging which will address specific needs in Positron Emission Tomography/X-ray Computed Tomography (PET/CT) and Single-Photon Emission Computed Tomography (SPECT) imaging.

This booklet describes some of the significant activities and accomplishments of the Division in 2006. Contact information for the primary lead on each of these projects is provided and you are invited to contact the NIST staff for more details. In addition, please visit our website (<http://physics.nist.gov/ird>) for more information on these and other activities in the Division. Thanks are due to all the Division staff who contributed to this year's booklet, and especially to Wanda Lease for helping to put it all together. With this issue, we will now be going to a biennial publication of our technical activities report; the next issue will be distributed in late 2008.

Lisa R. Karam  
Gaithersburg, MD  
January 2007

## TABLE OF CONTENTS

<i>INTRODUCTION</i> .....	<b>II</b>
<i>STANDARDS IN RADIOACTIVITY: BACKGROUND AND INTENDED OUTCOMES</i> .....	<b>5</b>
RADIONUCLIDE METROLOGY AND STANDARDS .....	6
HOMELAND SECURITY .....	10
NUCLEAR MEDICINE .....	13
RADIOCHEMISTRY AND ENVIRONMENTAL METROLOGY .....	14
<i>DIVISION PUBLICATIONS 2006</i> .....	<b>19</b>
<i>DIVISION INVITED TALKS 2006</i> .....	<b>27</b>
<i>STAFF CURRICULA VITAE</i> .....	<b>33</b>
<i>DIVISION ASSOCIATES 2006</i> .....	<b>39</b>
<b>Division Office</b> .....	39
<b>Radiation Interactions and Dosimetry Group</b> .....	39
<b>Neutron Interactions and Dosimetry Group</b> .....	40
<b>Radioactivity Group</b> .....	41
<i>IONIZING RADIATION DIVISION (846) STAFF</i> .....	<b>42</b>

*Certain commercial equipment, instruments or materials are identified in this report in order to specify the experimental procedure adequately. Such identification is not intended to imply recommendation or endorsement by the National Institute of Standards and Technology, nor is it intended to imply that the materials or equipment identified are necessarily the best available for the purpose.*

## *Standards in Radioactivity: Background and Intended Outcomes*

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*Strategic element: Develop and provide standards for radioactivity based on the SI unit, the becquerel, for homeland security, environmental, medical, and radiation protection applications.*

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The Radioactivity Group develops and improves the metrological techniques used for the standardization of radionuclides, and carries out a wide range of programs in low-level standards for environmental measurements and monitoring, standards for nuclear medicine, standards and testing criteria for radiological instrumentation used for security, and radionuclide metrology. Its mission is to develop, maintain, and disseminate radioactivity standards, develop and apply radioactivity measurement techniques, and engage in research to meet the requirements for new standards. Recently, new standards of  $^{55}\text{Fe}$  have been developed and the calibration of  $^{63}\text{Ni}$  verified.

We continue to lead the national effort, in collaboration with the Department of Homeland Security (DHS), to develop standards and protocols for radiation instrumentation for early and emergency responders. We are also spearheading the development of ANSI standards and testing protocols for spectroscopic portal monitors, neutron detectors, x-ray and high energy gamma-ray interrogation methods, x-ray imaging, data formats for instrumentation data output, and training standards for responders. The Group has been heavily involved in the testing and data analysis of advanced spectroscopic portal monitors (with DHS/DNDO) at the Nevada Test Site, and is involved with the testing of large-area NaI crystals to be used in these spectroscopic portal monitors.

The Group continues to lead an internationally-recognized program for standards in nuclear medicine, providing the national standards for radionuclides used in 13 million diagnostic procedures and 200,000 therapeutic nuclear medicine procedures annually in the US. Work is currently being carried out on the standardization of two alpha-emitting radionuclides,  $^{211}\text{At}$  and  $^{223}\text{Ra}$ , that are being investigated for use in targeted radiotherapy against two different forms of cancer. A new initiative, aimed at establishing standards and measurement support to improve accuracy and consistency in quantitative Positron Emission Tomography/X-ray Computed Tomography (PET/CT) and Single-Photon Emission Computed Tomography (SPECT) imaging, has also been started.

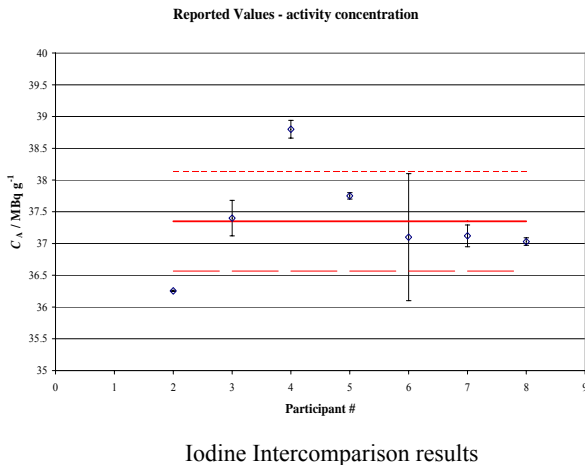
The Group's environmental program leads the community in low-level and natural matrix material measurements and standardization, and continues to be heavily involved in the world-wide measurement of environmental-level radionuclide dispersal and contamination through a large number of international intercomparisons and traceability programs and SRMs. A Radioanalytical Emergency Procedures Manual Database has been developed to assist organizations preparing for emergency response.

With the Nuclear Energy Institute, which issues NIST test samples for the nuclear power and radiopharmaceutical communities, we maintain 11 traceability and quality assurance programs between the Group and major quality control laboratories to allow the transference of NIST calibration factors to over 700 tertiary laboratories. Our participation in international comparison exercises has kept us abreast of efforts of other laboratories and helped us to maintain our own capabilities, and we have had the good fortune to develop close collaborations with many commercial and university groups with common scientific interests.

## Radionuclide Metrology and Standards

**International Comparison of Iodine-131** As part of a program aimed at expanding the existing IAEA/World Health Organization (WHO) Secondary Standard Dosimetry Standard Laboratory (SSDL) Network to include proficiency testing and calibrations for radioactivity, the IAEA, in collaboration with

NIST and other institutions, recently organized a comparison of  $^{131}\text{I}$ . The participating laboratories were metrology institutes and other organizations interested in becoming members of the expanded network and represented Brazil, Cuba, the Czech Republic, India, Iran, the Republic of Korea, Romania, and Turkey. Using solutions prepared and calibrated by a commercial company (QSA Global, Braunschweig, Germany), the participants measured the activity concentration of the solutions with either primary methods or radionuclide activity calibrators in a pre-calibrated geometry. Preliminary results demonstrate equivalence between the laboratories to within 5%. This activity has been registered as a CCRI(II) Supplemental Comparison and a publication describing the comparison and its results is in preparation.



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**Standardization of  $^{223}\text{Ra}$**  Work has started on the development of a standard for the alpha-emitter  $^{223}\text{Ra}$ , which is being investigated as a potential radiotherapeutic agent against metastatic bone cancer. To date, three separate experiments have been performed to attempt to standardize the  $^{223}\text{Ra}$  solutions by liquid scintillation counting (LSC) using both the CIEMAT/NIST and Triple-to-Double Coincidence Ratio (TDCR) methods. Confirmation measurements have been made using high-resolution gamma-ray spectrometry, alpha spectrometry with both a proportional counter and a surface-barrier Si (Li) detector, as well as numerous ionization chambers. Inconsistencies in the results of LSC and gamma spectrometry measurements suggest problems with either the published photon emission rates or the chemistry of the LSC cocktails. Further studies are planned using microcalorimetry that will help determine whether or not the published decay data are correct. Additional studies aimed at investigating LSC cocktail composition effects on the measurement are also planned.

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**Liquid Scintillation with the Triple-to-Double Coincidence Ratio Method** The NIST Triple-to-Double Coincidence Ratio (TDCR) spectrometer has been rebuilt following a catastrophic over-voltage in 2003.



*NIST TDCR system, open view showing the photomultiplier tubes (PMT's) Robotic sample changer-system for ionization chamber*

The present version of the spectrometer is nearly identical to the previous one, with the exception that there is no longer a power supply connected to the first dynode and a Constant Fraction Discriminator is now employed between the fast amplifier and the MAC3 coincidence unit. As part of the testing phase, standard solutions of  $^3\text{H}$  were measured to assess the performance of the spectrometer. An agreement of 0.3 % between the TDCR and certified massic activities was obtained

without any attempt to optimize the value of the ionization quench factor, kB. As a second test, the TDCR was used in the experiments leading to the standardization of  $^{63}\text{Ni}$ . Part of this study involved a direct comparison with LNHB using the same solution. The NIST TDCR result for the massic activity was in excellent (0.3 %) agreement with the value reported by LNHB, which used three different TDCR spectrometers to obtain their result. A short study involving measurements of the electron capture nuclide  $^{55}\text{Fe}$  was somewhat less satisfying, with the NIST TDCR and CIEMAT/NIST results agreeing only to within 4 %, although no effort was made during these experiments to optimize the ionization quench factor, kB. Experiments are currently underway to standardize  $^{90}\text{Sr}/^{90}\text{Y}$  using the TDCR spectrometer and initial results indicate excellent agreement between the TDCR and CIEMAT/NIST.

In order to analyze the data from the NIST TDCR, a series of programs has been developed using *Mathematica*. To date, two programs for beta decay have been written and tested. The first is for pure beta decay of a single radionuclide and the second is for beta decay with multiple branching, parent-daughter decay, or beta decay accompanied by gamma emission. In addition to the usual nuclear decay, the programs use as input calculated beta and Compton electron spectra that can be obtained from programs such as SPEBETA and PENELOPE. These programs have been tested against the LNHB/POLATOM code, TDCRB-02.

A program for analyzing data for  $^{55}\text{Fe}$  was also developed in *Mathematica* using the same approach as those described above for beta emitters. Despite the lack of agreement in the experimental results for  $^{55}\text{Fe}$ , a comparison of calculated efficiencies as a function of TDCR between the NIST program and a program written at LNHB agreed to within 0.01 %. Due to the complexity of the efficiency calculation arising from the need to account for atomic rearrangements and competition between x-ray and Auger electron emission, a separate program needs to be developed for each electron emitter being studied. Programs are also under development to analyze data from the decay of the  $^{223}\text{Ra}$  decay chain,  $^{68}\text{Ge}/^{68}\text{Ga}$  (mixed electron capture, positron annihilation), and the  $^{210}\text{Pb}$  decay chain (beta, conversion electron, alpha).

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**Development of an Automated Multi-Sample Ionization Chamber for Radioactivity Standards** A new ionization chamber system, featuring a robotic sample changer, has been designed and assembled. Presently, NIST radioactivity standards are kept as calibration factors for a single, manually-loaded ionization chamber. The addition of the second chamber will not only provide a badly needed backup system to our current standards program, but also serve to minimize the radioactivity dose to NIST researchers involved in standards development. Currently, each sample to be compared to the standard must

be loaded and unloaded, by hand, into the existing chamber many times over. This usually requires a NIST scientist to spend days or weeks handling radioactive samples. Implementation of the new robotic sample changer will therefore save time, money and radiation exposure by automating sample counting for up to 100 samples with multiple iterations of each. Furthermore, the ease and low-cost of measurements will mean that more samples per batch can be characterized, enhancing the quality control of our SRM and the NEI programs. This will result in a better product.

The detector, robotic sample changer and data acquisition software have all been installed and tested. A new, more precise and rugged sample-holder has been designed for use in the automated system and is presently being manufactured by NIST. The new sample holders will complete the system, which will then undergo final characterization and deployment.

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**Resonance Ionization Mass Spectrometry** The resonance ionization mass spectroscopy (RIMS) facility at NIST is used for trace analysis applications. It is optimized for precisely measuring isotopic ratios, while eliminating isobaric interferences that may be hinder other methods. This year, the quadrupole mass spectrometer (QMS) addition was completed. The new system is operational and is being verified against the original magnetic-sector mass spectrometer system for RIMS measurements on cesium. Furthermore, preparations continue to measure the isotope shifts for the  $6s^2S_{1/2}(F=4) \rightarrow 8s^2S_{1/2}(F=4)$  transition in cesium using Doppler-free two-photon excitation. To assist our efforts, collaboration has been established with a theoretical physicist to perform independent calculations of the isotope shifts. The theoretical and experimental results will be used together to extract important physical information about the cesium nucleus, and inform constraints on parity non-conservation.

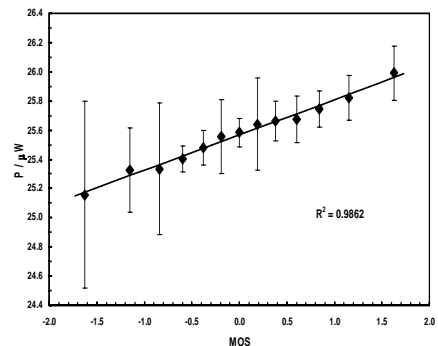
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**<sup>55</sup>Fe: Primary standardization for a New SRM and International Measurement Comparisons** A primary standardization of <sup>55</sup>Fe by isothermal microcalorimetry, initiated in 2004, was completed in 2006. Determinations of the activity for nuclides that decay by pure, low-Z (atomic number) electron capture (EC) to the ground state of their daughters are amongst the most difficult within the realm of radionuclidic standardization. The present work on this difficult-to-measure nuclide is a return by NIST to the use of calorimetry for primary radionuclidic standardizations. While calorimetry was a classical radionuclidic measurement method used by the NIST Radioactivity Group from the early 1950s through 1975 for primary standardizations, it was not used for the past 30 years or so. In the past 5 years, calorimetry was used by NIST to perform calibrations of brachytherapy sources of <sup>32</sup>P, <sup>90</sup>Sr, and <sup>103</sup>Pd.



Normal probability plot for the measured calorimetric power  $P$  in units of  $\mu W$  for the solid Fe source as obtained from 13 independent determinations with the isothermal microcalorimeter. The abscissa is the order statistic medians  $MOS$  from a normal  $N(0, 1)$  distribution. The test statistic  $r$  is the normal probability plot correlation coefficient.



A solid 30 GBq of  $^{55}\text{Fe}$  was prepared and gravimetrically linked to a  $^{55}\text{Fe}$  master solution. The source was used to obtain an accurately-determined power measurement using the NIST dual-cell isothermal calorimeter. The power measurements required many replicate trials of coupled baseline and inserted source determinations to obtain a precise average power value for the source. Thirteen independent trials (having a standard deviation of the mean of 0.25 %) were performed between August 2004 and May 2005. Joule-heating power calibrations of the calorimeter were performed for each trial. The power measurement was converted into a  $^{55}\text{Fe}$  activity through the use of an average energy per decay that was derived by M.M. Bé. This activity was in turn be linked to the master solution, which had an assigned ( $k=1$ ) uncertainty of 0.39 %.

This standardization was used as the basis for calibrating a new  $^{55}\text{Fe}$  solution standard (SRM 4929F) as well as for measurements of a BIPM-distributed  $^{55}\text{Fe}$  solution that was part of international measurement comparison. Liquid scintillation measurements were used to link the SRM and BIPM-intercomparison solutions to the primary standardization. The solutions were compared through 776 LS-based activity ratios, with variables that included: 3 different LS counters, 3 different scintillators, 44 cocktails, 4 distinct aqueous (+Fe) fractions; 2 NIST solution dilutions; 97 days of aging. The assigned ( $k=1$ ) uncertainty on the massic activity for the BIPM solution was 0.68 % (at  $k = 1$ ); whereas the uncertainty ( $k = 2$ ) on the recently issued SRM is 1.7 %. Prior to this standardization, recent calibrations of  $^{55}\text{Fe}$  performed by NIST had uncertainties ( $k=2$ ) in excess of 4 %. Although the results on the international intercomparison are not as yet compiled and released by BIPM, it is known that the NIST results are in very good agreement with several other national metrology laboratories.

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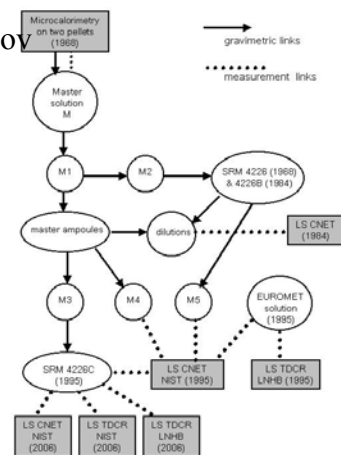
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**$^{63}\text{Ni}$ , its half-life and standardization: revisited**

Recent liquid scintillation (LS) measurements at NIST and at the Laboratoire National Henri Becquerel (LNHB) on a standardized  $^{63}\text{Ni}$  solution that has been tracked for nearly 40 years have resulted in several important findings: (1) The  $^{63}\text{Ni}$  half-life is consistent with a previously derived value of  $(101.1 \pm 1.4)$  a, and appears to be inconsistent with a recently evaluated half-life of 98.7 a. (2) All solution standards of  $^{63}\text{Ni}$  as disseminated by NIST for the past 38 years are internally consistent with past and recent standardizations. (3) Primary LS standardizations of  $^{63}\text{Ni}$  by the triple-to-double-coincidence ratio (TDCR) method and by CIEMAT/NIST  $^3\text{H}$ -standard efficiency tracing (CNET) appear to be comparable, although the latter methodology is believed to be fundamentally inferior. (4) There is excellent measurement agreement between NIST and LNHB for  $^{63}\text{Ni}$  primary standardizations.



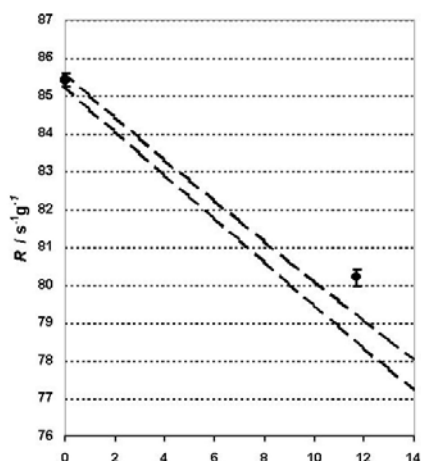
*Schema of the  $^{63}\text{Ni}$  gravimetrically-linked sources and measurements made by NIST and the LNHB laboratories over the past 38*

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The massic alpha particle emission rate  $R$  (in units of alphas per second per gram) for the standardized  $^{209}\text{Po}$  solution standard as a function of time  $t$  (in years). The two data points are from the primary standardizations conducted 11.7 years apart and exhibit an apparent half-life of about 128 years. The error bars show the combined standard uncertainty intervals on the two measurements. The broken curves correspond to the upper and lower uncertainty bounds (for the combined standard uncertainty) on the decay of the 1994 value of  $R$  using a half-life of  $(102 \pm 5)$  a. Refer to the text for additional detail.

**$^{209}\text{Po}$  half-life** Standards of  $^{210}\text{Po}$  are used throughout the worldwide environmental radiation community as the principal radiochemical tracer for the measurement of polonium isotopes, and a reasonably accurate value of its half-life is critically important. Recent measurements at NIST have uncovered a serious discrepancy. The widely adopted value  $(102 \pm 5)$  for the  $^{209}\text{Po}$  half-life, which is based on a single determination reported in 1956, appears to be in error by a large factor. Decay data from two separate primary standardizations of a  $^{209}\text{Po}$  solution standard, conducted approximately 12 years apart at NIST in 1994 and in 2006, are inconsistent with the adopted value and its assigned uncertainty. An estimated half-life, larger than the adopted value by about 25 %, is more consistent with the standardization data. A longer half-life is also supported by measurements on a recently standardized  $^{210}\text{Pb}$  solution standard. It is apparent that a new precise half-life determination is urgently needed. To this end, collaboration between NIST and two Polish Academy of Sciences laboratories, the Institute of Nuclear Physics in Krakow and the Institute of Geological Sciences in Warsaw, was established to perform a new specific activity half-life determination based on coupled alpha spectrometry activity measurements and mass spectrometry. This work is underway. More recently, plans have been initiated to make a similar determination in collaboration with two Commissariat à l'Énergie Atomique (CEA) laboratories at Saclay, France.

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**Homeland Security**

**Development of Radiation Detection Standards for Homeland Security** National standards for, and validation of, radiation and nuclear detection instrumentation performance, as used for homeland security applications, provide users with the confidence that deployed technologies will perform reliably and as intended. In order to be effective, development of standards needs to be done in a collaborative environment among users (with needs and requirements), manufacturers (providing insight on current and state-of-the-art capabilities of equipment), researchers (suggesting potential technical improvements and evolution), and Federal agencies (funding and regulatory issues).

**ANSI N42.42**

**Training Course Syllabus**

Introduction

- What is going to be covered
- What is not going to be covered
- What we hope you will gain from this course
- The goals of the ANSI N42.42 standard
- The non-goals of the ANSI N42.42 standard

XML basics

- A brief history of XML
- XML format: elements and attributes
- XML Schema
- XML Data types
- XML validation and its limitations
- Intro to XML programming

This long-term project has led to the development of minimum performance standards for radiation-measurement equipment available to emergency and early responders, as well as the training and data requirements to provide these responders with the decision-making tools to prevent and respond to a

radiological or nuclear incident. It has evolved from the NIST-led development of four ANSI performance standards for a variety of systems.

The most recent efforts in standards development for radiation and nuclear detection systems has included several new standards, including for advanced spectroscopic portal (ASP) monitors (**N42.38**; anticipated publication by ANSI in January 2007). Revisions of original 4 standards (**N42.32** – pagers; **N42.33** – portable instruments; **N42.34** – radionuclide identifiers; and **N42.35** – portal monitors) were published by IEEE (December 2006). The standard on training requirements for homeland security responders (**N42.37**) was completed and sent for publication (December 2006), as was **ANSI N42.42** (data format; June 2006); NIST held a training course on XML usage (September 2006) in the context of this standard. A new draft of ANSI **N42.39** (neutron detection) has been developed in response to submitted comments, and drafts of standards for active interrogation (**N42.41**) and transportable and mobile systems (**N42.43**) were distributed for comments (currently being addressed). The development and validation of a new standard for personal electronic dose meter performance (**N42.49**) was begun, and the voting result for “alarming PRDs” were submitted through the IEC to improve the chances for international harmonization of evaluating the performance of these critical instruments for radiation screeners across borders.

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**Testing and Measurement Infrastructure for Standards Validation** For equipment manufacturers, testing laboratories, and other users of standards, an approach by which the standards themselves can be validated and shown to be viable for currently available instrumentation is critical. In this way, the standards themselves become a tool that can be used by the whole community as benchmarks for performance and guidance for procurement.

This long-term effort provides testing protocols and well-calibrated radioactive sources (gamma and neutron emitting) that are used for instrument testing at several of the national labs for validation of performance standards and which can be expanded to the testing of instruments for manufacturers, analysis of and reports on results from equipment testing, and additional technical support for radioactive source manufacturers and testing laboratories.

A second round of testing for instruments for first responders was completed, and results posted on the Responder Knowledge Database (RKB). New test protocols for instruments testing to ANSI N42.38, incorporating results from the standard’s validation testing, were developed. Data continues to be obtained from the portal monitor installed at the shipment entrance gate of NIST, which provides a constant source of results for further protocol development as well as an opportunity for a test bed for additional instrument evaluation (a second set of spectroscopic portal monitors are planned to be installed in FY 07 to expand detection capabilities). A laboratory accreditation program, including the T&E protocols, for evaluation of radiation

2.2 Summary of the Radiological Tests

Test	Instrument 1	Instrument 2	Instrument 3	Instrument 4	Instrument 5
Radiation detection response {6.2}	P	C	P	P	P
Gamma exposure rate indication {6.3}	P	P	F	P	P
Alarm {6.4}	G, P	G, P	G, F	G, C	G, P
Radionuclide identification {6.5}	F	C	F	C	P
Single radionuclide identification {6.6}	F	C	F	C	C
Simultaneous radionuclide identification {6.7}	F	F	F	F	C
Interfering ionizing radiation (Gamma) {6.8}	F	C	F	NT	P
Interfering ionizing radiation (Beta) {6.9}	F	P	C	NT	P
False identification {6.10}	F	P	F	P	P
Interference from surrounding material {6.11}	F	P	P	C	P
Variation of identification based on angle of incidence {6.12}	F	P	F	P	P
Neutron response {6.13}	NA	NA	NA	NA	NA
Overload characteristics for identification {6.14}	F	C	NT	P	P
Full width half maximum {6.15}	F	F	F	P	C
Efficiency {6.16}	F	C	F	F	C
Over-range characteristics for dose rate identification {6.17}	F	C	C	P	F
Neutron indication in the presence of photons {6.18}	C	P	F	NA	C

NOTE - The neutron response test is not applicable for all instruments due to the fact that these instruments do not provide a neutron dose equivalent (measured in rem), they provide only a neutron response in counts per second.

detection equipment is being finalized. In addition, anticipating possible modes of deployment for small-scale radiation detectors (such as supported by N42.33), we participated in an exercise using radiation detectors piggy-backed on urban search and rescue (USAR) robots (August 2006) to initiate experimentation with onboard payloads for radiation and nuclear detection. This exercise presented an opportunity to begin experimentation with on-board detectors for radiological sensing. Robot and radiation detector manufacturers were invited to take part in this exercise, which highlighted operationally-relevant USAR scenarios (such as radioactive sources hidden in tankers, storage drums, and train cars), presenting the ideal opportunity to investigate not only the validity of USAR robot test methods, but also the problems and opportunities involved in communication interoperability among robot, controller, and radiation detector and the efficiency of using robots rather than humans to scan a site for radioactive materials. Robot and detector manufacturers were able to assess specific needs from “the other camp,” and were able to network extensively for future collaboration and development. Instruments that were mounted on the robots included pagers (with and without radionuclide identification capabilities), survey meters, and radionuclide identifiers.

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**Large NaI(Tl) Detector Testing for the DHS SIMP Program** Large NaI(Tl) detectors that are developed in the frame of Sodium Iodide Manufacturing Program (SIMP) by Saint-Gobain Crystals will be installed at the Advanced Spectroscopic Portals (ASP) at the points of entrance to the US under ASP DHS program. The detector specification includes tests for crystal uniformity across the large (4” x 16”) entrance window. These tests were performed (in collaboration with L. Cumberland and J.Yen) with new flat <sup>137</sup>Cs sources developed by NIST and using a new method of determination of energy resolution uncertainty. This method, based on non-parametric spline approximation and statistical bootstrap, was reported at 15th CIRMS conference at NIST in October 2006. The paper is under preparation.

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**Homeland Security Standards for Emergency Responders** There has been an initiative to develop standards and guidelines for emergency responders in the event of a radiological or nuclear terrorist incident. Participation in the NFPA writing committee has resulted in NFPA 472 Standard for Professional Competence of Responders to Hazardous Materials Incidents being completed and it is to be released as a nationally recognized standard in 2007. As a member of the IAB, the Radiological Equipment List for the Inter-Agency Board (IAB) publication of the 2005 Annual Report and the 2006 Selected Equipment List (SEL) and the upcoming 2006 Annual Report with the 2007 SEL utilized by all 50 states in obtaining grant funds to purchase radiological equipment for state and local responder organizations have been revised..

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### Radioanalytical Measurements in the NRIP'06 Emergency Preparedness Exercise

Radiological emergency response measurement capability has focused on gross alpha and beta screening and gamma-ray measurements. However, as the  $^{210}\text{Po}$  poisoning incident in the U.K. has pointed out, having the capabilities to conduct radioanalytical measurements for specific alpha- (and beta-) particle emitting radionuclides are also very important. Radioanalytical measurement results were reported in eight hours of sample receipt in the NRIP'06 emergency preparedness exercise for  $^{90}\text{Sr}$ ,  $^{230}\text{Th}$ ,  $^{234}\text{U}$ ,  $^{238}\text{U}$ ,  $^{238}\text{Pu}$ ,  $^{239}\text{Pu}$ ,  $^{241}\text{Am}$  in urine, soil and water. The agreement of the reported radiochemical results with the NIST certified values ranged from 1.4 to 180 percent.

While the results varied from laboratory to laboratory and between radionuclides, the information obtained by the participating laboratories will be helpful for method improvement and improved preparedness for radiological emergency incidences.

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### Nuclear Medicine

**Guidelines for Quality Assurance in Nuclear Medicine** Nuclear medicine continues to grow around the world, with practitioners in nearly every country performing at least one type of diagnostic or therapeutic procedure. Unfortunately, quality assurance (QA) practices for ensuring accurate and consistent radioactivity measurement in the clinic are inconsistent or, as in the case with most countries, not applied at all. One reason for this is the lack of necessary guidance. In response to this problem, the International Atomic Energy Agency (IAEA) gathered a group of experts from the fields of radionuclide metrology, radiopharmacy, and medical physics to develop a comprehensive guidance document that can be used by any laboratory responsible for making radioactivity measurement in nuclear medicine to establish a sound quality management system (QMS). Based on the principles of ISO 17025, the resulting document, IAEA Technical Report Series 454 – “Quality Assurance for Radioactivity Measurement in Nuclear Medicine”, provides guidance for the establishment of such a QMS. In addition to specifying the administrative and documentation requirements for the QMS, it also gives detailed technical guidance for making accurate and consistent radioactivity measurements at both the Secondary Standard and end-user levels and for documenting their results. Personnel from NIST played a vital role in the writing and review of the document, which is available free for download at the IAEA's website: [http://www-pub.iaea.org/MTCD/publications/PDF/TRS454\\_web.pdf](http://www-pub.iaea.org/MTCD/publications/PDF/TRS454_web.pdf). NIST personnel are also involved in the development of the first-ever guidance document for the establishment of QA procedures for PET/CT. Also sponsored by the IAEA, this document will satisfy the need for a set of standardized protocols and tests for acceptance testing and routine QA of PET/CT scanners around the world. It is expected to be published by the end of 2007.

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**NIST/ORNL Nuclear Medicine Calibration Laboratory** The National Institute of Standards and Technology (NIST) established a satellite facility at Oak Ridge National Laboratory (ORNL) in Oak Ridge, Tenn., to promote measurement accuracy for nuclear medicine imaging. NIST Director William Jeffrey and ORNL Director Jeff Wadsworth dedicated the new laboratory 30 March 2007. NIST scientists will use the NIST/ORNL Nuclear Medicine Calibration Laboratory to prepare and measure radioactivity standards used for Positron Emission Tomography (PET). PET is a non-invasive technique that helps doctors diagnose diseases (such as cancer), plan medical treatment and measure the efficacy of therapies. An estimated 650,000 PET procedures were performed in 2003; the number is expected to reach as many as 2 million annually by 2010.

The NIST program needs to be carried out regionally because the short half-lives of most PET radiopharmaceuticals prevent shipment of standard test samples over long distances. Radioactive fluorine-18, for example, decays to half its originally produced total radioactivity in about 2 hours. Therefore, NIST is locating its satellite laboratories at key sites near manufacturers' distribution networks. The sites are selected based on location, capability, and reputation. ORNL has extensive expertise in radiation measurements; already operates a measurement traceability and testing program with NIST; and is licensed and capable of accepting, handling, and shipping radioactive materials.

Initial calibrations were performed in May 2006. The measurement geometry chosen was 1 mL of <sup>18</sup>F-FDG in a 3-mL plastic syringe. A solution provided by PETNET Solutions was calibrated by liquid scintillation counting. From this master solution two syringe samples were prepared. One syringe was used to determine a calibration factor for a Capintec CRC-15 dose calibrator. The other syringe was returned to PETNET to calibrate their in-house dose calibrators. An intercomparison exercise among PETNET customers is planned for early 2007.

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**Standardization of <sup>211</sup>At** There is much interest in the use of alpha-emitting radionuclides for radioimmunotherapy. Astatine-211 is a cyclotron produced isotope, with a half life of 7.214 hours, currently being investigated for such use by the National Institutes of Health (NIH) in Bethesda, Maryland, U.S.A. Proper measurement of the activity of the radionuclide requires the Radioactivity Group at NIST to perform a primary standardization before determining a secondary measurement method. The primary method chosen is liquid-scintillation (LS) counting due to the high efficiency for alpha emitters. Secondary measurement methods and clinical measurement geometries are also being investigated.

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**Radiochemistry and Environmental Metrology**

**Radionuclides Speciation in soils and sediments** Traditionally, measurements of environmental contamination have focused on the determination of total radionuclide concentrations. It is clear; however

that total concentration does not adequately describe the environmental behavior or potential bioavailability of radiological contaminants. Rather, the time dependent spread and uptake of contaminating radionuclides is a function of their geochemical "partitioning" or "speciation" within the sediment matrix. Therefore, for long-term risk assessment, regulatory bodies need information that includes an evaluation of the mobility and bioavailability of radionuclides. This project addresses the identification of radionuclide partitioning in soils and sediments. The approach involves the development of the NIST Standard Extraction Protocol for identifying the distribution of radioactive elements in soils and sediments. The procedure is designed to partition a soil or sediment sample into five operationally defined fractions (1) Exchangeable, 2) Bound to carbonates, 3) Bound to Mn and Fe oxides, 4) Bound to organic matter, and 5) Persistently bound). A full-factorial experimental design methodology is used to establish the optimum conditions for these five extractions. Reaction time, reagent concentration and reaction temperature were chosen as experimental variables. Experiments are carried out on the NIST lake sediment SRM4354. Optimum conditions are chosen based on radiochemical analysis for Pu and U performed by NIST and on stable elemental analysis performed by Environmental Protection Agency (EPA). Work has been carried out for the first two fractions: I exchangeable and II bound to carbonates.

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**Radioanalytical Emergency Procedures Manual Database**

The Radioactivity Group of the Ionizing Radiation Division of the National Institute of Standards and Technology has considerable experience in carrying out performance testing exercises (e.g., NRIP, RPT) for many laboratories engaged in radionuclide bioassay and environmental measurements. A survey of the national radionuclide metrology community indicates a serious need to also include a related program of emergency preparedness performance testing. This innovative approach assesses the capability of participating laboratories to respond quickly to an unexpected release of radioactivity into the environment. As a further step in this direction, the Radioactivity Group is undertaking the development of a Radioanalytical Emergency Procedures Manual Database (REPMDB) to assist organizations preparing for emergency response. REPMDB will collect existing procedures from reliable sources into a guide that can be accessed and searched by laboratories seeking to find appropriate methods, including sampling, screening, surveying and rapid radioanalytical measurements of food, biological and environmental samples and urban materials.

Beyond this immediate need for emergency response, a database of radioanalytical procedures could help elevate the accessibility of these methods to 21<sup>st</sup> century standards for adoption, training, gap analysis, and capability improvement/expansion. Text based search on chemical procedures is highly inefficient and inherently error prone, opening the door to an approach based on indexing these methods/procedures in a commonly understood way, similar to that used in the NEMI database for chemical procedures. (<http://www.nemi.gov/>). Such a database would include an interactive system for method validation, feedback and for web based publications. The database's ability to provide the sought information would therefore also include real life experience of recognized experts in this field. Probably the most famous example for such a publication system is Wikipedia (<http://www.wikipedia.org/>), involving millions of voluntary participants.

A first stage prototype, demonstrating the ability to handle PDF documents describing radioanalytical methods, and simplifying the method collection process, has already been delivered.

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**Certification of a new Rocky Flats Soil (RFS-2) Standard Reference Material (SRM) 4353A** A new Standard Reference Material (SRM) of Rocky Flats Soil has been developed in cooperation with member laboratories of the International Committee for Radionuclide Metrology and a number of experienced metrology laboratories. The SRM consists of approximately 90 grams of air-dried, pulverized soil in a polyethylene bottle. The SRM is intended: for use in tests of measurements of radioactivity contained in matrices similar to the sample; for evaluating analytical methods; and as a generally available calibrated “real” sample matrix for laboratory intercomparison.

This SRM is from the Rocky Flats Plant in north-central Colorado. The material was provided by Rockwell International’s Rocky Flats Plant (RFP), the National Institute of Standards and Technology (NIST) of the U.S. Department of Commerce, and the Environmental Measurements Laboratory (EML) of the U.S. Department of Energy.

The certified massic activity or activity ratio value for  $^{90}\text{Sr}$ ,  $^{137}\text{Cs}$ ,  $^{210}\text{Pb}$ ,  $^{228}\text{Ra}$ ,  $^{238}\text{Pu}$ ,  $^{239,240}\text{Pu}$ ,  $^{234}\text{U}$ ,  $^{235}\text{U}$ ,  $^{238}\text{U}$ ,  $^{234}\text{U} / ^{238}\text{U}$ ,  $^{228}\text{Th} / ^{232}\text{Th}$ ,  $^{230}\text{Th} / ^{232}\text{Th}$ ,  $^{238}\text{Pu} / (^{239}\text{Pu} + ^{240}\text{Pu})$  was determined from the evaluated average of the individual laboratory means. This approach was selected because of the well-behaved normal distribution of the laboratories’ data. The combined standard uncertainties (uc) for each of the certified values were expanded with the Students’ t-statistics. The expanded uncertainty (U) is taken to be the 95 percent confidence interval. The 95/95 tolerance limits means that NIST is 95% confident that 95% of the population of SRM measurements fall within the specified limits. The tolerance limits are used when the number of replicates is small ( $n < 5$ ), e.g. when the material is used as a periodic QC sample. The values for radionuclides activities and isotopic ratios ( $^{40}\text{K}$ ,  $^{208}\text{Tl}$ ,  $^{212}\text{Pb}$ ,  $^{212}\text{Bi}$ ,  $^{214}\text{Bi}$ ,  $^{214}\text{Pb}$ ,  $^{226}\text{Ra}$ ,  $^{228}\text{Th}$ ,  $^{230}\text{Th}$ ,  $^{232}\text{Th}$ ,  $^{234}\text{Th}$ ,  $^{241}\text{Pu}$ ,  $^{241}\text{Am}$ ,  $^{240}\text{Pu}/^{239}\text{Pu}$ ,  $^{241}\text{Pu}/^{239}\text{Pu}$ ,  $^{241}\text{Pu}/^{240}\text{Pu}$ ) for which insufficient numbers of data sets or for which unresolved discrepant data sets were obtained are reported as a mean value of all reported data and the range of reported results. No uncertainties for those values are provided because no meaningful estimates could be made. The massic activities and mass ratios are not certified at this time, but may be certified at some future time if additional data become available. Users are invited to submit measurement data to contribute to the certification process.

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**Russian Roulette with a Hot-Headed Phantom: Sensitivity analysis and optimization of Monte Carlo efficiency estimates**

This work is a continuation of a long term project presented at last year’s conference in which we seek to find a reliable way to estimate the efficiency of gamma ray systems using Monte Carlo computation. This computed efficiency is validated by making real measurements of our standard geometry, a Bottle Manikin Absorption (BOMAB) phantom head spiked with Ga-67. The radioactive BOMAB head is measured at a number of distances from an HPGe detector and the experimental efficiency for our gamma ray spectrometry system is determined. The same set of experiments is then modeled using the Monte Carlo N-Particle

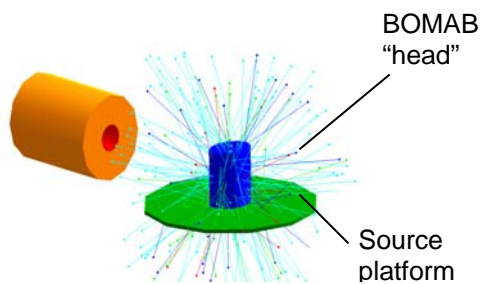


Figure: Time animations produced by a program called Moritz (White Rock Science) depict particle movement throughout the modeled space.



Transport Code (MCNP). As previously reported, analysis of the results showed that the computationally determined and experimentally measured efficiencies are in majority of cases consistent to better than 3 percent. In an effort to achieve better agreement between the theoretical and experimental results at all gamma ray energies, a sensitivity analysis was performed to explore the effects of 13 parameters (Gamma Ray Energy (GRE), Detector Distance (DD), Vertical Distance (VD), Horizontal Distance (HD), Plastic Density (PD), Air Density in Laboratory (ADL), Air Density in BOMAB (ADB), Solution Density (SD), Solution Height (SH), Platform with/without (PL), MCNP version LINUX/Windows (MLW), Presence of Air inside BOMAB (AB), Source Biasing Card (SBC) which are involved in defining the BOMAB head source for the MCNP input file. This 13-dimensional parameter space was explored using an orthogonal fractional factorial experimental design. The result was a quantification of the main effects and parameter interactions. In addition, we studied the importance of modeling various parts of the source-detector geometry by viewing time animations of particle movement through the modeled space.

A second sensitivity analysis which will examine the critical parameters in defining the simulated detector is planned for the near future. This will then be followed by a systematic optimization of our MCNP detector description by varying the parameters to achieve the best agreement possible between our computational and experimental data. The final scope of the project is to create a NIST standard human body phantom, to validate its theoretical efficiency based on a comparison of the Monte Carlo computation with its experimentally measured efficiency, and to calibrate existing phantoms.

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**Evaluation of the stability of NIST natural-matrix radionuclide SRM** Humans are exposed to radiation in various ways. Most radiation exposure from sources in the environment results in small doses which are not particularly harmful. For pathway assessment, samples are gathered from various locations but are not always immediately analyzed. Some samples may take several years before the full analysis is complete. But how can you be sure that the stability of the sample has not affected the accuracy of the measured activity? Similarly, when environmental radionuclide quality control test samples are made up but stored for a number of years, could the stability of the sample over time affect the results of the test? This poses a concern to whether natural-matrix radionuclide samples are stable under stored conditions. In this work, NIST Radiochemistry Intercomparison Program water and synthetic urine samples that have been stored for a number of years were analyzed radiochemically for alpha, beta and gamma-ray emitting nuclides such as Mn-54, Co-57, Sr-90, U-234, Pu-238, and other isotopes as well. Older samples along with more recent ones were examined to determine any change in activity level. One might expect that when the results are compared with previously confirmed massic activities (Bq/g), the radionuclides will show various degrees of stability in their respective matrices. Early results show a reasonable recovery percentage when analyzing for alpha-emitting nuclides. However when analyzing for gamma-ray emitting nuclides, it appears that older samples showed a lower activity. The issue of instability may apply to Standard Reference Materials (SRM); some radionuclides may indeed not be stable over extended periods of time. The results of this work provide important new information that would be very useful to: a) prioritize the analysis of future environmental samples, and b) determine the useful storage time of archived environmental samples, quality control test samples and reference materials.

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**Blueprint for Radioanalytical Metrology CRMs, Intercomparisons, and PT** In 1977, the ICRM LLWG workshop on natural-matrix reference materials developed a long-term blueprint. Over the ensuing decades national and social issues have shifted emphasis and a review of the original blueprint for radioanalytical metrology CRMs, intercomparisons and proficiency testing is needed. A workshop was held in February 2006 at NIST to evaluate the needs for new directions for certified reference materials, interlaboratory comparisons and performance testing programs. The workshop identified new radioanalytical metrology thrust areas needed for radiobioassay (occupational monitoring and emergency preparedness), environment (water treatment, ultra-low actinide monitoring, geochemistry, waste acceptance), emergency consequence management (population monitoring and urban restoration), and nuclear forensics (environmental monitoring, radiochronology, and low-level isotopic ratio measurements). New certified reference materials for each of these new thrust areas were identified, and most of the efforts to develop new intercomparisons and performance testing programs were identified as important but left for future development.

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**The Hot Needle in the Environmental Haystack (Identifying and Isolating Hot Particles from Soils and Sediments)** Anthropogenic and natural hot particles in environmental samples could have a dramatic effect on radioanalytical results, and their subsequent interpretation. The problem affects environmental monitoring and remediation, geochemical studies, as well as certification of the radionuclides in natural-matrix Standard Reference Materials. A number of classical methods were used to identify the presence followed by the isolation of hot particles in the Rocky Flats - I and II soils and Irish Sea sediment with varying degrees of success. As potential hot particles were being isolated, x-ray fluorescence chemical depth profiling was used to characterize the suspect particle that yielded unanticipated information. While this project is a work in progress, it is anticipated that as we learn more about hot particles, the result will be better approaches for radioanalytical methodologies.

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Arif, M., "Neutron Imaging for Fuel Cell Research", Imaging and Neutrons Workshop, Oak Ridge, Tennessee, October 2006

Arif, M., "Imaging with Neutrons", Ohio University, Athens, Ohio, November 2006

Brannon, C., "New NVLAP Program Workshop," Mid-Year Health Physics Society Conference January 2006

Brannon, C., "New NVLAP Program Handbook and Highlights," 25th Annual International Dosimetry Symposium and National Dosimetry Records Conference June 2006

Carlson, A.D., "The Neutron Cross Section Standards," Triangle Universities Nuclear Laboratory Seminar Series, Durham, NC, December 2006.

Carlson, A.D., "Final Report on the ENDF/B-VII Evaluation of the Neutron Cross Section Standards," Brookhaven National Laboratory, Upton, NY, November 2006

Carlson, A.D., "Nuclear Data Standards," Working Party on International Evaluation Cooperation, Nuclear Energy Agency, Paris, France, May 2006

Cessna, J.T., "NRQMP0305 Results and NIST Nuclear Medicine Program Future Directions," National Association of Nuclear Pharmacies Product and Regulatory Update Meeting, San Francisco, CA, March 2006

Cessna, J.T., Schultz, M.K., "A Performance Evaluation Of  $^{90}\text{Y}$  Dose Calibrator Measurements In Nuclear Pharmacies And Nuclear Medicine Clinics In The United States," Society of Nuclear Medicine Annual Meeting, San Diego, CA, June 2006

Collé, R., "An Overview of the Radioactivity Standard Reference Materials Program at NIST," Henryk Niewodniczanski Institute of Nuclear Physics, Polish Academy of Sciences, Krakow, Poland, June 2006

Collé, R., "Standardization Of  $^{55}\text{Fe}$  By Isothermal Microcalorimetry And Its Use For A NIST SRM Calibration And In The BIPM Intercomparison," Laboratoire National Henri Becquerel, Saclay, France, June 2006

Collé, R., "Mixed Number Fractions, Surds, And Other Anglophonic Math Anomalies: Emerging International Mathematics," Colloque sur la baccalauréat internationale. Université Pierre-et-Marie-Curie, University of Paris VI, June 2006

Collé, R., "Measurement Uncertainty Assessment and Reports: Practical Considerations," CIRMS 15th Annual Meeting, NIST, October 2006

Cooper, S.L., "A Method for Establishing e-Traceability to NIST High-Dose Measurement Standards," Alanine Dosimetry for Clinical Applications, Physikalisch-Technische Bundesanstalt, Braunschweig, Germany, May 2006.

Desrosiers, M.F., "Next-Generation Services for e-Traceability to Ionizing Radiation National Standards," Alanine Dosimetry for Clinical Applications, Physikalisch-Technische Bundesanstalt, Braunschweig, Germany, May 2006.

Dewey, M. S., "Neutron Binding Energy Measurements for a Direct Test of  $E=Mc^2$ ", Institut Laue-Langevin, France, October 2006.

Dewey, M. S., "Neutron Binding Energy Measurements for a Direct Test of  $E=mc^2$ ", Tulane University, November 2006.

Gentile, T.R., "Polarized  $^3\text{He}$  Spin Filter Development in the U.S.," Polarized Inelastic Neutron Scattering conference, Brookhaven National Laboratory, April 2006

Gentile, T.R., "Observation Of The Radiative Decay Mode of The Free Neutron", American Physical Society Division of Nuclear Physics Meeting, Nashville, Tennessee, October 2006.

Gilliam, D.M., "Calibration of a Manganese Bath Relative to Cf-252 Nu-bar", China Institute for Atomic Energy, Beijing, China, October 2006

Gilliam, D.M., "Calibration of a Manganese Bath Relative to Cf-252 Nu-bar", China Institute for Atomic Energy, China, October 2006

Gilliam, D.M. "The Use of Polyimide Films to Prevent Self-Sputtering of Cf-252 in High Accuracy Fission Counting," 23rd World Conference of the International Nuclear Target Development Society, Tsukuba, Japan, October, 2006.

Hammond, M. M., "Standardization of  $^{211}\text{At}$  for Nuclear Medicine Applications," Southern University A&M College, Distinguished Alumni Lecture Series, Baton Rouge, Louisiana, August 2006

Hussey, D.S., "In Situ Fuel Cell Tomography at The New NIST Neutron," 2006 American Conference on Neutron Scattering, St. Charles, IL, June 2006

Hussey, D.S., "Tomographic Imaging of an Operating Proton Exchange Membrane Fuel Cell," 8<sup>th</sup> World Conference on Neutron Radiography, NIST, Gaithersburg, MD, October 2006

Inn, K.G.W., "Future Industrial Uses Of Radionuclides and Lasers," Health Physics Society Mid-year Meeting, Scottsdale, AZ, January 2006

Inn, K.G.W. (co-authors: Kurosaki, H., Radford, R., Filliben, J), "An Orthogonal Design Experiment - Exploratory Data Analysis for Plutonium Contamination," Methods and Applications of Radioanalytical Chemistry (MARC) Conference, Kona, Hawaii, April 2006

Inn, K.G.W. (co-authors: LaRosa, J., Outola, I., Nour, S., Kurosaki, H., and Crawford, E.), "Radiochemical Measurements Of  $^{237}\text{Np}$  In A Mixed Radionuclides Solution: Experiences In Chemical Separation And Alpha Spectrometry," Methods and Applications of Radioanalytical Chemistry (MARC) Conference, Kona, Hawaii, April 2006

Inn, K.G.W. (co-authors: Kurosaki, H. LaRosa, J., Chang, K.), "Evaluation of the stability of NIST PT Samples," Radiobioassay and Radiochemical Measurement Conference, Chicago, IL, October 2006

Inn, K.G.W. (co-authors: Kurosaki, H., LaRosa, J., Chang, K.), "Evaluation of The Stability of NIST PT Samples," Radiobioassay and Radiochemical Measurement Conference, Chicago, IL, October 2006

Inn, K.G.W. (co-authors: Mille, M., and Nour, S.), "Russian Roulette with a Hot-Headed Phantom," Radiobioassay and Radiochemical Measurement Conference, Chicago, IL, October 2006

Jacobson, D. L., "Neutron Radiography and Tomography Facilities at NIST to Analyze In-Situ PEM Fuel Cell Performance," 8<sup>th</sup> World Conference on Neutron Radiography, NIST, Gaithersburg, MD, October 2006

Jacobson, D. L., "Neutron Radiography and Tomography Facilities and Experiments to Analyze In-Situ PEM Fuel Cell Performance," 2006 Joint International Meeting, 210<sup>th</sup> Meeting of The Electrochemical Society, Cancun, Mexico, October 29 through November 3, 2006

Karam, Lisa, presentation to the Secretary of Commerce (Carlos Gutierrez) and others, "Radiation Detection Efforts for Homeland Security," NIST, January 5, 2006

Karam, Lisa, presentation to the Montgomery County Local Emergency Preparedness Council (LEPC) Annual Meeting, "Work of the Ionizing Radiation Division: Homeland Security and Medical Standards," NIST, January 19, 2006

Karam, Lisa, presentation to members of the Homeland Security Dialogue Forum and Congressional staffers, "Radiation Detection Standards and Validation," NIST, February 22, 2006:

Karam, Lisa, "Efforts in Quantitative Assessment: NIST Ionizing Radiation Division Standards Supporting Health Care," Application of High Resolution CT for Lung Cancer Drug Development, April 2006, Rockville, Maryland.

Karam, Lisa, presentation to Einstein Fellows, "Use of Radiation in Medicine," NIST, May 9, 2006

Karam, Lisa, presentation to the NIST-NSC (National Science Council, Taiwan) Science and Technology delegation, "Metrology in Medicine," NIST, June 6, 2006.

Karam, Lisa, presentation to the DNDO (Domestic Nuclear Detection Office), Office of Acquisition and Deployment, "Technologies and Support for Radiation and Nuclear Detection for Homeland Security," NIST, June 9, 2006

Karam, Lisa, presentation to Sen. Barbara Mikulski, "Quality Assurance in Radiation Measurements: Mammography and Brachytherapy," NIST, August 15, 2006.

Karam, Lisa, presentation to the S&T Directorate, DHS (and CBRNE performers), "Radiation and Nuclear

Detection Standards and Validation,” NIST, August 29, 2006.

Karam, Lisa, presentation to the DNDO (multiple offices), “Technologies and Support for Rad/Nuc Detection and X-Ray Systems for Homeland Security,” Washington, DC, September 20, 2006

Karam, Lisa, “The USMS and Standards in Biomedical Imaging: a NIST Perspective,” DIA Medical Imaging Conference -- Critical Path Opportunities List: From Opportunities to Action, Washington, DC, October, 2006

Karam, Lisa, “Results of the Technical Audit of the SIR Quality System,” BIPM Radionuclide Metrology Laboratory, Paris, France, November 16, 2006

LaRosa, J., “Measurement Evaluation Programs in Environmental Radioactivity at NIST,” NBL Measurement Evaluation Program Meeting, Nashville, TN, July 2006

Minniti, R., “Uncertainty in Primary Air-Kerma Standards from  $^{60}\text{Co}$  Beams”, 2006 Council on Ionizing Radiation Measurements and Standards (CIRMS) Fifteenth Annual Meeting, NIST, Gaithersburg, MD, October 2006.

Minniti, R., “Large-Volume Chambers Used for Calibrating a Low-Level  $^{137}\text{Cs}$  Gamma-Ray Beam Irradiator,” Annual Meeting of the Health Physics Society (HPS), Providence, RI, July 2006.

Mitch, M.G., “Integration of AAPM TG-43 Formalism into a New Plastic Scintillator Dosimeter System”, 48<sup>th</sup> Annual Meeting of the American Association of Physicists in Medicine (AAPM), Orlando, FL, July 2006

Mitch, M.G., “Illustrating Manufacturing Variability in Prostate Brachytherapy Seeds through X-ray Spectrometry and Radiochromic Film Measurements”, 48<sup>th</sup> Annual Meeting of the American Association of Physicists in Medicine (AAPM), Orlando, FL, August 2006.

Mitch, M.G., “Absolute Calibration of Low-Energy Photon Sources – the NIST Approach”, 25<sup>th</sup> Annual Meeting of the European Society for Therapeutic Radiology and Oncology (ESTRO), Leipzig, Germany, October 2006.

Mitch, M.G., “Uncertainties in Air-Kerma-Strength Measurements of Low-Energy Photon Brachytherapy Sources”, Council on Ionizing Radiation Measurements and Standards (CIRMS) Fifteenth Annual Meeting, NIST, Gaithersburg, MD, October 2006.

Nico, J.S., "Neutron Physics at NIST," Nuclear Physics Seminar at the California Institute of Technology, Pasadena, CA, February 2006.

Nico, J.S., "Recent Neutron Lifetime Measurements," Plenary talk at the Conference on Intersections of Particle and Nuclear Physics (CIPANP 2006), Puerto Rico, June 2006.

Nico, J.S., "Neutron Lifetime Experiments," First Summer School on Fundamental Neutron Physics, Knoxville, TN, June 2006.

Nico, J.S., "Measuring the Neutron Lifetime with a Proton Trap," NCNR Expansion Initiative, Bethesda, MD, July 2006.

Nico, J.S., "Neutron Facilities at NIST," Neutron Physics and Fundamental Symmetries Pre-Town Meeting, Pasadena, CA, December 2006.

Nour, S., Inn, K.G.W., Burnett, W., Bohrer, S., Cadieux, J., Moreno, J., Stewart, B., Decker, D., Koski, N., Garcia, S., Burns, K., Volchok, H., G. Kis-Benedek, G., Bunzl, K., Feiner, M., Olson, D., Bowen, V., Livingston, H., Beasley, T., Froggatt, M., "Certification of a New Rocky Flats Soil (RFS-2) Standard Reference Material SRM-4353A," Radiobioassay and Radiochemical Measurement Conference, Chicago, IL, October 2006

Nour, S., Inn, K.G.W. and Filliben, J., "Development of the NIST Rocky Flats Soil-2 SRM 4353A," Methods and Applications of Radioanalytical Chemistry (MARC) Conference, Kona, Hawaii, April 2006

Nour, S., Mille, M., and Inn, K.G.W., "Using Monte Carlo Methods to Estimate Efficiencies of Gamma-Ray Emitters with Complex Geometries," Methods and Applications of Radioanalytical Chemistry (MARC) Conference, Kona, Hawaii, April 2006

Outola, I., Nour, S., Kurosaki, H., Inn, K.G.W., La Rosa, J., Lucas, L., Volkovitsky, P., Koepenick, K., "Investigation of Radioactivity in Selected Drinking Water Samples from Maryland," Methods and Applications of Radioanalytical Chemistry (MARC) Conference, Kona, Hawaii, April 2006

Outola, I., Filliben, J. and Inn, K.G.W., "Searching for a robust reference value from intercomparison exercise data -Seaweed Radionuclide Standard Reference Material (SRM 4359)," Methods and Applications of Radioanalytical Chemistry (MARC) Conference, Kona, Hawaii, April 2006

Pibida, L., DHS Activities for Development of Standards and Test and Evaluation Methods for Radiation Instruments used for Detection of Illicit Traffic of Radioactive Materials. "Final Research Coordination Meeting of the Agency's Coordinated Research Project on "Improvement of Technical Measures to Detect and Respond to Illicit Trafficking of Nuclear and Radioactive Materials," April 2006

Seltzer, S.M., "Memorial Lecture for Robert Loevinger," 48<sup>th</sup> Annual Meeting of the American Association of Physicists in Medicine (AAPM), Orlando, FL, August 2006.

Soares, C.G., "International Standardization of the Clinical Dosimetry of Beta Radiation Brachytherapy Sources: Progress of an ISO Standard," American Physical Society, Baltimore, MD, March 2006.

Soares, C.G., "Beta Particle and Low-Energy Photon Brachytherapy Source Dosimetry," Physics Department Colloquium, Hampton University, Hampton, VA, April 2006.

Soares, C.G., "ANSI/HPS N13.11: Status of Current Update," Panasonic User's Group Meeting, Sun River, OR, June 2006.

Tosh, R.E., "Transfer-Function Characterization of Heat Conduction in Water Calorimetry," 48<sup>th</sup> Annual Meeting of the American Association of Physicists in Medicine (AAPM), Orlando, FL, August 2006

Volkovitsky, P., Yen, J., and Cumberland, L., "Uncertainty Estimation for Detector Energy Resolution", Council on Ionizing Radiation Measurements and Standards (CIRMS) Fifteenth Annual Meeting, NIST, Gaithersburg, MD, October 2006

Zimmerman, B.E. "Results of an International Comparison of Iodine-131 Among National Laboratories: Establishing Measurement Traceability for Radioactivity in Medicine," International Conference on Quality Assurance and New Techniques in Radiation Medicine [QANTRM], Vienna, Austria November 2006



## STAFF CURRICULA VITAE

ARIF, MUHAMMAD, PHYSICS, BS, Dacca Univ., Bangladesh, 76; MS, Ohio Univ., 80; Ph.D., Univ. of Missouri-Columbia, 86; Univ. of Missouri; Post Doc. Fellow, 86-88; Physicist, NIST, 88-03; Group Leader, 03-present. Mem., American Physical Society. Res: Neutron and X-ray scattering, x-ray and neutron interferometry, neutron imaging.

BATEMAN, FRED B., NUCLEAR PHYSICS, BS, Physics, Ohio University, 86; Ph.D., Nuclear Physics, Ohio University, 94; Post-doctoral Research Associate, Nuclear Physics Group, Ohio University, 94-95; Post-doctoral Research Associate, Neutron and Nuclear Science Group, Los Alamos National Laboratory 95-98; Research physicist, NIST 98-present. Res: Nuclear technology, radiation protection and industrial dosimetry, accelerator technology, and accelerator operations.

BERGSTROM, PAUL M., PHYSICS. BS, (Electrical Engineering) Pennsylvania State University, 82; Ph.D., Univ. of Pittsburgh, 92; University of Tennessee Post. Doc. Fellow, 92-94; Lawrence Livermore National Laboratory Post. Doc. Fellow 94-97, Staff Member 97-00; Physicist, NIST 00-present. Res: Radiation interactions, computational dosimetry, computational atomic physics including the interactions of photons, electrons and positrons with atoms. Monte Carlo Methods including the transport of photons, electrons and positrons.

BRANNON, CHARLIE E. JR., HEALTH PHYSICS, BS, Biology, Jacksonville State University, 77; MBA (in progress), Global Management, University of Phoenix, 03; Field Medical Platoon Leader, U.S. Army, 78-80; Chemistry & Health Physics Technician, Farley Nuclear Plant, Alabama Power Co., 80-83; Lead Gamma Spectroscopy and Radiochemistry Counting Room Technician, Waterford III SES (Nuclear), Louisiana Power and Light, 83-88; Chief, Radiation Safety & Nuclear Medicine Science Officer, U.S. Army, 88-95; Chief, Physicist and Radiation Safety Officer, VA Medical Center at Memphis, TN., 95-00; Assistant Radiation Safety Officer, University of Louisville, 00-02; Health Physicist, Department of Energy, 02-03; Physical Scientist, NIST, 03-2006

CESSNA, JEFFREY T., PHYSICS. BS, Washington College, 89; Physicist, NIST, 88-present. Res: Radioactivity standards and testing.

CLARKSON, NOWELL, MACHINIST, AAI Corp., 62-85; Hydraulic Mechanic and Fabricator, 85-92; Owner, Fabrication Machine Shop, 92-98; Engineering Technician, NIST, 98 to present. Res: Equipment design, fabrication, and installation required by staff, guest researchers, and facility users.

CHEN-MAYER, H. HEATHER, PHYSICS, BS, Zhongshan University, China, 82; Ph.D., City University of New York, 89; Research Collaborator, Brookhaven National Lab, 84-89; Research Associate, Argonne National Lab, 89-90; Research Associate, University of Missouri/Guest Researcher, NIST, 91-95; Physicist, NIST, 95-present. Mem: APS, Sigma Xi, MRS. Res: Nuclear analytical techniques, gamma radiation dosimetry, water calorimetry.

COLLÉ, RONALD, CHEMISTRY. B.Sc. Chem. Georgia Institute of Technology, 1969; Ph.D., Nuclear and Radiochemistry, Rensselaer Polytechnic Institute, 1972; MS. Adm., Administration of Science and Technology, 1979, George Washington University. NIST 1976-2003, 2005-present; Research Chemist, Radioactivity Group, Ionizing Radiation Division, Physics laboratory. Res: Radiochemical and radionuclidic metrology as applied to standardization; development and preparation of measurement

standards for radiopharmaceuticals, nuclear medicine, environmental monitoring, and nuclear power applications.

COOPER, SARENÉE L., PHYSICS, BS, Physics, Southern University and A&M College, 00; Physical science technician, NIST 00-present. Res: Alanine pellet dosimetry, alanine film dosimetry, radiation/temperature studies.

COSTRELL, LOUIS, ELECTRICAL ENGINEERING. BS, Univ. of Maine, 39; Graduate work Univ. of Pittsburgh, 39-41; ELECTRICAL ENGINEERING. MS, Univ. of Maryland, 49; Graduate work in physics and mathematics 1948-50; Electrical Engineer, Elliot Co, 39; Westinghouse Elec. Corp., 39-41; U. S. Navy Dept, 41-46; Physicist, NIST, 46-51; Chief Nuclear Instrumentation Section, 1951-81; Research Fellow, University of Michigan & Guest Researcher, NIST, 1995-present. Res: Neutron dosimetry, neutron physics, and hyperfine interactions.

COURSEY, BERT M., PHYSICAL CHEMISTRY. BS, Univ. of Georgia, 65; Ph.D. Univ. of Georgia, 70; Captain, U.S. Army Corps. of Engineers, Engineer Reactors Group, 69-71; Presidential Intern, NIST, 72-73; Research Chemist, NIST, 73-87; Visiting Scientist, Central Bureau for Nuclear Measurements, Geel, Belgium, 83-84. Editor, Int. J. Applied Radiation and Isotopes, 78-present. Editor, Int. J. Nuclear Medicine and Biology, 85-present. NML Program Analyst, Program Office, 87; Staff NIST Office of Quality Programs, 87-88; Group Leader, Radiation Interactions and Dosimetry, 88-94; Chief, Ionizing Radiation Division, 94-present. Res: Radiation physical processes in scintillation detectors, interaction in organic materials, and quality assurance in nuclear power and nuclear medicine.

CUMBERLAND, LONNIE T., PHYSICS B.Sc., Mathematics, Physics, and Astronomy, University of Southern Mississippi, 1998; M.Sc, Computer Science, University of Southern Mississippi, 1999; M.Sc, High-Energy Particle Physics, Wayne State University, Michigan, 2004. 2005; Research Physicist, Radioactivity Group, Ionizing Radiation Division, Physics Laboratory, NIST. Research: internal gas counting, large area alpha and beta source counting, nuclear decay parameters, nuclear & particle physics, numerical methods, computational modeling and simulations, and data analysis

DESROSIERS, MARC F., PHYSICAL CHEMISTRY. BS, Boston College, 78; Ph.D., Univ. of California at Santa Barbara, 83; Argon Natl. Lab. Post. Doc. Fellow, 84-86; Research Assoc. Prof., Univ. of Maryland-Balt. County, 86-89. NIST 1989-present. Program Chairman, Washington EPR Discussion Group, Mem: Radiat. Res. Soc., ASTM, Intl. EPR Soc. Res: Radiation interactions (inorganic to biological), pulse radiolysis, magnetic resonance, with an emphasis on electron paramagnetic resonance.

DEWEY, MAYNARD S., PHYSICS. BS, State University of New York at Stony Brook, 78; Ph.D., Princeton University, 84; Research Associate, Princeton University, 86; Physicist, NIST 86-present. Mem: American Physical Society. Res: Neutron lifetime measurement, neutron fluence measurement, ultra-high resolution gamma-ray measurements.

EARDLEY, DAVID F., ELECTRONICS TECHNICIAN. AA, Commonwealth College, 90; US Army, 80-90; Bell Helicopter Arabia, 90-91; Thomas Jefferson National Laboratory (CEBAF), 92-06; NIST, 06-present. Res: repair and maintenance of electronic equipment, accelerators, and x-ray facilities.

FITZGERALD, RYAN P., NUCLEAR PHYSICS. PhD, University of North Carolina, Chapel Hill, 2005.

MS, nuclear physics, University of North Carolina, Chapel Hill, 2001. B.A., physics, SUNY Geneseo, NY, 1999. 2005; Physicist, Radioactivity Group, Ionizing Radiation Division, Physics Laboratory, NIST, DOC. Research: Developments in Resonance Ionization Mass Spectroscopy (RIMS) for environmental samples.

GENTILE, THOMAS R., PHYSICS. BS, State University of New York at Stony Brook, 79; Ph.D., Massachusetts Institute of Technology, 90; Research Fellow, California Institute of Technology, 90-92; NIST 93-present. Member: American Physical Society. Res: Neutron polarization based on polarized <sup>3</sup>He, neutron tomography.

GILLIAM, DAVID M., NUCLEAR ENGINEERING, PHYSICS; BA, Rice Univ. 64; MS, Rice Univ., 66; Ph.D., U. Michigan, 73; NBS/NIST Neutron Interactions and Dosimetry Group, 73-present; National Measurement Laboratory Analyst, 85; Associate Division Chief, 86-87; Group Leader, 94-03, Physicist, 03-present. Mem. American Physical Society, American Nuclear Society, ASTM E10.05, ANSI E 13.3, Comité Consultatif pour les Étalons de Mesure des Rayonnements Ionisants, Section III, Mesures neutroniques. Res: Absolute neutron reaction rate measurements.

HAMMOND, MICHELLE A., PHYSICS. BS, Southern University, 2000; Physical Science Technician, NIST, 2000-present. Res: Calibration of Radioactive Sources.

HEIMBACH, CRAIG R., PHYSICS, BS, Rensselaer Polytechnic Institute, 68; MS, Nuclear Physics, Purdue University, 70; Ph.D., American University, 76. Nuclear Physicist, Harry Diamond Labs., 72-78; Nuclear Physicist, Aberdeen Test Center, US Army, 78-00; Director, Army Pulse Radiation Facility, 00-03, Aberdeen Test Center, US Army; Physicist, NIST, 03-present. Res: Neutron dosimetry and spectroscopy, radiation transport, radiation shielding, radiation effects on electronics.

HUDSON, LAWRENCE T., PHYSICS, BS, Mississippi College, 83; MS, Vanderbilt University, 86; Ph.D., Vanderbilt University, 89; NASA, Johnson Space Center (work-study program) 79-83; Sandia Nat'l Lab. (Summer) 83; Oak Ridge Nat'l Lab. (Summer) 84; NIST/NRC Post Doc. Fellow, 90-91; Physicist NIST, 90-present. Mem: APS. Res: x-ray metrology, spectroscopy, and applications.

HUFFMAN, PAUL R., PHYSICS, BS, North Carolina State University, 90; MS, Duke University, 1992; Ph.D., Duke University, 1995; Postdoctoral Fellow, Harvard University, 1995-1998; Physicist, NIST, 1998-present. Mem: American Physical Society. Res: Low-energy neutron weak interactions, fundamental symmetries, neutron optics.

INN, KENNETH G.W., RADIO-CHEMISTRY. BA, Univ. of Hawaii, 69; MS, San Diego State College, 72; Ph.D., Univ. of Arkansas, 78; Research Chemist, NIST, 78-present, Group Leader, Office of Radiation Measurements. Mem: ACS, AGS, Sigma Xi, ASTM, ANSI. Res: Environmental level radio geochemistry, low-level radio bioassay, ultra low-level radioanalytical methods, geochronology methods.

JACOBSON, DAVID L., PHYSICS, BA, Westminster College, 90; Ph.D., University of Missouri-Columbia, 96; Post Doctoral Fellow, University of Missouri-Columbia, 96; NRC Post Doctoral Fellow, NIST, 96-98; Physicist, NIST 98-present. Res: Neutron optics and neutron interferometry, neutron imaging.

KARAM, LISA R., BIOCHEMISTRY. BS, Berry College, Georgia, 82; MS, American University, 83; Ph.D., American University, 85; Research Asst., NIH 79; Teaching Asst., Dept. of Chem., Berry

College, 79-82; Graduate Teaching Asst., Dept. of Chem., American University, 82-83; Res. Chemist, NIST, 83-97; Leader, Radioactivity Group, 98-03; Deputy Division Chief, Ionizing Radiation Division, 03-present. Mem: American Chemical Society, AAAS, Tri-Beta, IUPAC. Res: GC/MS, HPLC, DNA and protein damage and repair, radiation induced cross-linking, food post irradiation dosimetry, enzyme isolations.

KING, LYNNE E., A.A., Landscape Technology, Montgomery College, Maryland, 1995; B.A., Environmental Science and Policy, Hood College, Maryland, 1997. Present position: Physical Science Technician, Ionizing Radiation Division, Physics Laboratory, NIST (at NIST since 1998).

LAROSA, JEROME J., CHEMISTRY. BS, University of Rochester, 71; Ph.D., University of Chicago, 84; University of Chicago Research Associate, 84-85; Argonne National Laboratory, Researcher, 85-87; International Atomic Energy Agency (IAEA), Seibersdorf Laboratory (Austria), Staff Member 87-95; Institute for Reference Materials and Measurements (Geel, Belgium), Guest Scientist, 95-96; IAEA Seibersdorf Laboratory, Staff Member 96-97; IAEA, Marine Environment Laboratory (Monaco), Staff Member, 98-2004 Res: Nuclear and radiochemistry research. Radiochemical measurement of production cross sections in high energy proton-target irradiations. Development and application of chemical separation and purification techniques for radionuclides from terrestrial and marine environmental samples. Quantitative determination of radionuclides by means of radioactivity measurements.

LAUREANO-PEREZ, LIZBETH, B.S., Chemical Engineering, University of Puerto Rico Mayaguez Campus, 1998; M.S. Chemical Engineering, West Virginia University, 2000; Ph.D. Chemical Engineering, Michigan State University, 2005. Present Position: Chemical Engineer, Radioactivity Group, Ionizing Radiation Division, Physic Laboratory, NIST. Research: Standards development and dissemination, primarily standardization by liquid scintillation counting.

LUCAS, LARRY L., NUCLEAR CHEMISTRY. BA, Univ. of California at Los Angeles, 65; Ph.D.; Univ. of California at Davis, 73; NAS-NRC Research Associate, NIST, 73-75; Research Chemist, NIST, 75-present. Res: Alpha-particle scattering, high-accuracy direct radioactivity measurements.

McCLELLAND, MELVIN R., ELECTRONICS TECHNICIAN. Univ. of Pittsburgh 67-69, US Navy 69-79, Leasametric Inc., 79-86, NIST 86-present. Res: Repair and maintenance of electronic equipment, accelerators and x-ray facilities.

MINNITI, RONALDO, PHYSICS Licenciate (MS) Univ. of Buenos Aires, Argentina, 1991. Ph.D., Univ. of Tennessee, 1997. NRC Post. Doc. Fellow, NIST, 97-99; Teaching Asst., Dept. of Physics, Univ. of Tennessee, 91-92; Research Asst., Dept. of Physics, Univ. of Tennessee and Oak Ridge National Lab., 92-97. Res: Calibration of X-ray and Gamma-ray measuring instruments, interaction of ions with surfaces and solids, scanning tunneling microscopy, measurement of low energy electrons.

MITCH, MICHAEL G., PHYSICS. BA, Gettysburg College, 88; Ph.D., Penn State Univ., 94; Summer Research Student, Dept. of Phys., Penn State Univ., 87; Teaching Asst., Dept. of Phys., Penn State Univ., 88-90; Research Asst., Dept. of Phys., Penn State Univ., 89-94; Associate Research Scholar, Dept. of Materials and Nuclear Engr., Univ. of Maryland and NIST, 94-98; Physicist, NIST, 98- present. Mem. American Physical Society, AAAS. Res: Production and characterization of radiolabelled fullerenes, brachytherapy source dosimetry.

NICO, JEFFREY S., PHYSICS, BS, Michigan State Univ., 83; MS, U. of Michigan, 90; Ph.D., U. of Michigan, 91; Postdoctoral Fellow, U. of Michigan, 91 and Los Alamos National Laboratory, 91-94;

Physicist, NIST, 94-present. Res: Absolute neutron reaction rate measurements, weak interactions, neutron dosimetry.

NORMAN, BRUCE, PHYSICAL SCIENTIST, University of Kentucky '72-'76, University of South Florida, '77-81. NIST '85-present. Res: radiochemical neutron activation analysis, instrumental neutron activation analysis, and radionuclide metrology.

O'BRIEN, C. MICHELLE, PHYSICS. AS, Chattanooga State, 88; BS, Univ. Tennessee, Knoxville, 90; MS, Univ. Tennessee, Knoxville, 93; Health Physics Tech., Brookhaven National Lab., Summers of 88/89; U.S. Peace Corps, Benin, West Africa, 90; Research Asst., ORNL, 91-93; Physicist, NIST 93-present. Mem: Health Phys. Soc. Res: Instrument calibration, characterization of x-ray calibration mammography range.

PIBIDA, LETICIA, PHYSICS. Licenciata MS Univ. of Buenos Aires, Argentina, 1991. Ph.D., Univ. of Tennessee, 1997. Teaching Asst., Dept. of Physics, Univ. of Tennessee, 1991-92; Research Asst., Dept. of Physics, Univ. of Tennessee, Oak Ridge National Lab. and Brookhaven National Lab., 1992-97; Research Scientist, NIST, 1997-2001; Physicist, NIST 2001-present. Mem: APS, OSA. Res: Development of resonance ionization mass spectrometry system, measurements of low-level environmental samples; and gamma-ray and high-resolution electron spectroscopy.

PUHL, JAMES M., Physical Scientist. AA, Mathematics, Frederick Community College, 90; B.Sc, Computer & Information Science, Univ. of Maryland, 05; NIST 90-present. Res: radiochromic dosimetry, EPR dosimetry, source profilometry.

SCHULTZ, MICHAEL K. PhD, Chemical Oceanography (Actinide Geochemistry), Florida State University, Tallahassee, Florida, 2002; MS, Chemical Oceanography (Actinide Geochemistry), Florida State University, Tallahassee, Florida, 1996; B.A. Russian Language, University of South Florida, Tampa, Florida, 1990. 2005; Physical Scientist, Radioactivity Group, Ionizing Radiation Division, Physics Laboratory, NIST

SHANKLE, ROBERT L., Engineering Science Technician. Frederick High School, Machining 1, 2&3., 1983-1986, Welding 1,2&3., 1983-1986. Frederick Community College, Machine Shop 1., 2001. Res. NIST 2006 – Present Engineering Science Technician, Ionizing Radiation Division, Neutron Interactions and Dosimetry Group.

SELTZER, STEPHEN M., NUCLEAR PHYSICS. BS, Virginia Polytechnic Institute, 62; MS, Univ. of Maryland, 73; Physicist NIST, 62-94; Leader, Radiation Interactions & Dosimetry Group, 95-present. Res. Assoc., Inst. for Physical Science and Technology, Univ. of Maryland, 83-84. Mem: APS, ANS. Res: Radiation transport theory, Monte Carlo methods, radiological physics, dosimetry.

SOARES, C., PHYSICS. George Washington Univ. 67; BS, Univ. of Florida, 71; Ph.D., 76; Graduate Teaching Assist, Dept. of Phys., Univ. of Florida, 72-75; Physicist, Harry Diamond Labs, 73; Physicist, NIST, 75-present. Mem: Health Phys. Soc., American Assoc. of Physicists in Medicine. Res: Photon and electron spectroscopy, thermoluminescence dosimetry, calibration source development, measurement assurance, electron source calibration.

THOMPSON, ALAN K., PHYSICS, BA, Rice U., 86; Ph.D., Mass. Inst. Tech., 91; Research Associate, Harvard U., 91-93; Physicist, NIST, 93-present, Mem: American Physical Society, Res:  $^3\text{He}$  polarization, neutron polarization, tests of fundamental symmetries, structure of the neutron, weak interactions, neutron dosimetry.

TOSH, RONALD E., PHYSICS, BA, Kenyon College, 84; Ph.D., Univ. of Pittsburgh, 92; Univ. of Delaware Postdoc. Fellow, 92-97; Applications Engineer, National Instruments, 97-98; Field Sales Engineer, National Instruments, 98-04; Physicist, NIST, 2004-present. Res: development of primary photon and electron dosimetry standards, non-invasive temperature measurements, laboratory automation.

UNTERWEGER, MICHAEL P., NUCLEAR PHYSICS. BA, Univ. of Buffalo, 63; Ph.D. St. Louis Univ.; Pres. Intern, NIST 72-73; Nuclear Physicist, NIST, 73-present. Mem: ASTM, ANSI, IEEE. Res: Radioactivity, internal gas counting, ionization chambers, microcomputers, micro-calorimetry, alpha-particle counting.

VOLKOVITSKY, PETER, PHYSICS. MS, Moscow State University, Moscow, 69; Ph. D., Institute for Theoretical and Experimental Physics, Moscow, USSR, 73; Doctor of Sciences, Institute for Theoretical and Experimental Physics, Moscow, Russia, 94. Institute for Theoretical and Experimental Physics, Moscow, Russia, staff research physicist, group leader, 73-94; BioTraces, Inc, Herndon, VA, team leader, vice president, 95-03; George Mason University, Fairfax, VA adjunct professor of physics, 95-present; Res. Physicist, NIST, 03-present. Res: Nuclear and radiation physics, particle and X-ray detectors, radiation metrology, applications of radiation detectors for medicine and biology.

ZIMMERMAN, BRIAN E., NUCLEAR CHEMISTRY. BA Chemistry, New College of Florida, 87; Ph.D., Univ. of Maryland, 92; Post-doctoral Research Associate, Nuclear Physics Group, Univ. of Tennessee, 92-5; Research Chemist, NIST 95-03, 06-present; Medical Radiation Physicist, Dosimetry and Medical Radiation Physics Section, International Atomic Energy Agency 03-06, Member: American Chemical Society, Society of Nuclear Medicine, European Association of Nuclear Medicine, International Committee on Radionuclide Metrology, ANSI N42.13, Res: Radionuclide metrology, liquid scintillation counting, quality assurance in nuclear medicine, radionuclide metrology applications in PET/CT, internal dosimetry, applications of Monte Carlo simulation to radionuclide metrology and radiation medicine

**DIVISION ASSOCIATES 2006**

NAMES	SPONSORS	PROJECT
<b><i>Division Office</i></b>		
Caswell, Randall	Self	Radiation transport calculations
<b><i>Radiation Interactions and Dosimetry Group</i></b>		
Al-Sheikhly, Mohamad	University of Maryland College Park, MD	High dose measurement techniques
Berger, Harold	Digitome Corp. Davidson, NC	X ray tomosynthesis, variable depth laminography
Cleveland, Thomas E.	Self	Construction of Ced/Cmos-Based Neutron Imaging Detector
Domen, Stephen	Self	Water Calorimetry
Dryden, John W.	Digitome, Corp, Davidson, NC	Volumetric x-ray imaging
Ganesan, Ramanathan	Australian Radiation Protection & Nuclear Safety Agency	High-energy photon and electron beam absorbed dose measurements with water and graphite calorimeter
Hobbs, Thomas G.	ICRU Bethesda, MD	Health physics and radiation protection
Holland, Glenn E.	SFA, Inc	Advanced x-ray diagnostics for bomb detection
Hubbell, John	Self	Development of new and extended tabulation of critically evaluated photon mass attenuation
Kinnane, Mark N.	University of Melbourne	Precision metrology of absolute x-ray wavelengths
Lamperti, Paul	Self	Brachytherapy calibrations
Massillon, Guerdo	Instituto de Fisica, UNAU	National standards for therapeutic lowe- energy x-ray fields and sources
Morehouse, Kim	Food and Drug Administration Rockville, MD	Study of possible radiolytic products in food
Motz, Joseph	Rayex Gaithersburg, MD	Develop power enhancement of x-ray tubes
Pagonis, Basile	Western Md. College Westminster, MD	Thermoluminescence Dosimetry Meas. & Brachytherapy Sources

Sparrow, Julian H.	Self	Design and fabrication of the Free Air Chamber
Steel, James S.	Rayex Corp. Gaithersburg, MD	Power enhancement of x-ray tubes

***Neutron Interactions and Dosimetry Group***

Black, Timothy C.	University of North Carolina	Neutron Interferometry
Carlson, Allan D.	Self	Neutron cross section standards
Cooper, Robert L.	Univ. of Michigan	Fundamental Physics
Eisenhauer, Charles	Self	Neutron transport calculations and dosimetry studies
Fisher, Brian M.	DHS Post Doc	Homeland Security
Gagliardo, Jeffrey J.	General Motors	Neutron Imaging
Gan , Kangfei	George Washington University	Fundamental Physics
Greene, Geoffrey L.	University of Tennessee	Fundamental Physics
Grundl, James A.	Self	Neutron fluence measurement
Huber, Michael G.	Tulane University	Neutron Interferometry
Huffman, Paul	North Carolina State University	Ultra Cold Neutron
Laptev, Alexander B.	Tulane University	Fundamental Physics
Lee, Seung W.	Korea Atomic Energy Research Institute	Neutron Imaging
Luo, Da	Indiana University	Fundamental Physics
Micherdzinska, Anna	University of Winnipeg	Fundamental Physics
Mumm, Hans P.	University of Maryland	Ultra Cold Neutrons
Opper, Allena	George Washington University	Fundamental Physics
O'Shaughnessy, Chris	North Carolina State University	Ultra Cold Neutron
Owejan, Jon P.	General Motors	Neutron Imaging



Pushin, Dmitry	Massachusetts University of Technology	Neutron Interferometry
Rich, Dennis R.	Indiana University	He-3 Polarization
Schrack, Roald A.	Self	Neutron Cross Section Standards/Data
Schwartz, Robert	Self	Radiation Protection Dosimetry
Snow, Michael	Indiana University	Fundamental Physics
Trabold, Thomas A.	General Motors	Neutron Imaging
Trull, Carroll A.	Tulane University	Fundamental Physics
Werner, Samuel	Self	Neutron interferometer and optics
Wietfeldt, Fred	Harvard University Cambridge, MA	Fundamental physics experiments
Yang, Liang	Harvard University Cambridge, MA	Ultracold neutron research
Yew, Andrew	University of Tennessee	Neutron Radiometry

**Radioactivity Group**

Golas, Daniel	Nuclear Energy Institute Washington, DC	NEI-NIST measurement assurance programs
Hutchinson, J.M. Robin	Self	Development of new radionuclide detection techniques
Kurosaki, Hiromu	University of Maryland College Park, MD	Develop and produce measurement test materials
Nafee, Sherif	Alexandria University Alexandria, Egypt	Advancing Technologies in Gamma Ray Spectrometry
Nour, Svetlana	University of Md. College Park, MD	Develop standards and quality assurance programs in support of Homeland Security
Outola, Iisa	University of Maryland. College Park, MD	Develop test methods and standards for low-level radioactivity measurements related to Homeland Security
Palabrica, Ofelia	Nuclear Energy Institute Washington, DC	NEI-NIST measurement assurance programs

## IONIZING RADIATION DIVISION (846) STAFF

Lisa R. Karam, Deputy Chief  
 Bert M. Coursey (detailed to DHS)  
 Wanda Lease, Secretary  
 Louis Costrell

### RADIATION INTERACTIONS & DOSIMETRY

Stephen M. Seltzer, Group Leader  
 Diana Copeland, Secretary

Fred Bateman  
 Paul Bergstrom  
 Heather Chen-Mayer  
 Sarenée Cooper  
 Marc Desrosiers

**David Eardley**  
 Larry Hudson  
 Melvin McClelland  
 Ronaldo Minniti  
 Michael Mitch

C. Michelle O'Brien  
 James Puhl  
 Christopher Soares  
 Ronald Tosh

### NEUTRON INTERACTIONS & DOSIMETRY

Muhammad Arif, Group Leader  
 Martha Neviaser, Secretary

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 David M. Gilliam  
 Craig Heimbach  
 Daniel Hussey

Thomas Gentile  
 David Jacobson  
 Pieter Mumm

Jeffrey Nico  
**Robert Schankle**  
 Alan Thompson

### RADIOACTIVITY

Michael Unterweger, Actg. Grp. Leader  
 Cecilia Houstis-Beshai, Secretary

Doug Alderson  
*Charlie Brannon*  
 Jeffrey Cessna  
 Ron Collé  
 Lonnie Cumberland  
 Kenneth Inn  
 Jerry LaRosa

Lizebeth Laureano-Perez  
 Larry Lucas  
 Michelle Hammond  
 Lynne King  
 Payam Motobar  
 Bruce Norman

Leticia Pibida  
 Michael Schultz  
 Gavin Spalleta  
 Peter Volkovitsky  
 Brian Zimmerman

**Bold:** Arrived in 2006  
*Italics:* Left in 2006