Council on Ionizing Radiation Measurements and Standards

Fifth Report on Needs in Ionizing Radiation

Prepared by the CIRMS Science and Technology Committee

October 2011

Executive Summary

Mission

The Council on Ionizing Radiation Measurements and Standards (CIRMS) is an independent, non-profit council that draws together stakeholders from government, industry and academia to discuss, review and assess national needs in the field of ionizing radiation to enhance societal benefits.

Vision: CIRMS seeks to inform the national debate on issues involving ionizing radiation by preparing this document, a Needs Report to be presented to the US Congress, to make policy recommendations based on the interplay among fundamental scientific advancement, practical implementation of ionizing radiation technologies and governmental rules and regulations to ensure public safety. To achieve these ends, CIRMS seeks to organize expert opinion in focus areas: 1) medical applications, 2) personnel and environmental radiation protection, 3) homeland security technologies, and 4) industrial applications and materials effects.

Policy Recommendations: CIRMS highlights current deficiencies and suggests informed dialog to address these 2011 Needs in Ionizing Radiation Measurement and Standards:

1. US Congress must find ways to better inform the public perception of radiation or risk reducing scientific advantage, economic advantage and domestic job creation.

2. The Federal Government and associated Regulatory Agencies should immediately prioritize developing 21st century rules and regulations, informed by the scientific community, to enable progress toward elimination of food-borne pathogens/pests, increase shelf life and inhibit sprouting and maturation, while increasing food safety.

3. A virtual national laboratory consortium is needed that can support regulatory, research and development uses and measurement of ionizing radiation to leverage national brick and mortar assets at universities, DoE laboratories and government laboratories.

4. An independent review panel should be established to evaluate all requests for isotopes that are not now currently available from commercial sources, based on recommendations from CIRMS, the National Academies Nuclear and Radiation Studies Board (NAS NRSB) and the Nuclear Regulatory Commission (NRC).

5. National dialog among NIH, NIST, university, and DoE laboratories is needed to better control the supply of the molybdenum-99 isotope.

6. A coherent long-term funding mechanism must be found to support maintenance of the mathematical modeling codes implementing the effects of ionizing radiation on materials.

Metrology Needs: Each year, each of the subcommittees of the CIRMS Science and Technology Committee prepares a series of Measurement Program Descriptions (MPDs). These emerge through data sharing and focused discussion at CIRMS meetings and workshops. The MPDs offer guidelines for scientific funding agencies, corporations or academic investigators with ties to ionizing radiation about issues which the community feels are relevant today. These represent potential target areas for funding research, where federal regulation may soon change, and where new ideas and rules may propel emerging technologies into new markets. These needs are grouped into the 2011 CIRMS focus areas: 1) medical applications, 2) personnel and environmental radiation protection, 3) homeland security technologies, and 4) industrial applications and materials effects.

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Needs in Ionizing Radiation

Contents

Societal Benefits of Ionizing Radiation

Ionizing radiation has a direct effect on materials and life forms. Controlled exposures bring about numerous societal benefits. Careful monitoring of exposure assures the public and personnel working with radiation against unwarranted risks.

In the medical area, ionizing radiation in the form of X-rays, as Roentgen discovered at the end of the nineteenth century, is widely used for diagnostic purposes. Likewise controlled emissions from radioactive isotopes, such as technetium-99m, which is derived from molybdenum-99, is used in diagnostic procedures such as bone scans. Electron beams (EBs), X-rays and the emerging use of proton beams are used in cancer therapy. Localized cancers, such a prostate cancer, are treated with isotopes, such as palladium-103. The medical community has adopted selected beam and isotope use for numerous purposes in both diagnosis and in therapy.

In the area of Homeland Security, X-rays are used to routinely screen airline passenger luggage. Since 2001, electron beam and X-ray treatment have been used to decontaminate some US mail from possible biological hazards, such as anthrax. Irradiation interrogation techniques are being developed for cargo inspection to determine the presence of nuclear or chemical hazards. Personnel working with radiation sources, as in nuclear power plants and radiological departments, commonly wear radiation responsive badges so that their possible exposure can be monitored. These personnel and other radiation monitoring devices are traceable to standards maintained by the US National Institute of Standards and Technology (NIST).

In the industrial area, high current EBs are used in the manufacture of diverse products ranging from crosslinked wire and cable jacketing, as in under-the-hood automotive wiring and in aircraft wiring, heat shrinkable tubing and food packaging films, tire components, and in the drying of inks, coatings and adhesives that are made from reactive materials which "dry" using irradiation and thus eliminate air pollutants very effectively. Long lived isotopes, such as cobalt-60, and alternatively X-rays derived from high powered electron beam accelerators, are used to sterilize medical devices, sanitize food and eliminate food-borne pathogens such as *E. coli* and *Salmonella*, which have caused numerous illnesses resulting in costly recalls of ground beef, vegetables and even eggs. In its first "Needs Report" (1994), CIRMS highlighted the need for continuing studies into the radiation effects on the metals used to house nuclear reactors (see: MPD D.4.2).

Policy Recommendations concerning Ionizing Radiation

In contrast to how science and technology work collaboratively in other countries, such as in other industrialized countries as Japan and the Russian Federation, and in emerging economies, as Brazil and Poland, US science funding and projects are scattered across a diverse array of federal departments and agencies. The provincialism in many of these areas prevents or retards the implementation of sound science and technology for societal benefit. It is beyond the scope of this report to comment upon the Byzantine labyrinths investigators must pursue in order to even find and then attain federal funding for scientific and technological projects that portend societal benefit. The heterogeneity and dispersed array of these highly compartmentalized funding systems leads many in the scientific community to spend well in excess of 25% of their time simply sorting out funding paths and then seeking the funding needed for their efforts. In its second "Needs Report" of October 1998, CIRMS attempted to devise program strategies that would be outlined with roadmaps. However, invariably, the first issue in any roadmap became "obtain funding for ...". In the present circumstances of fiscal restraint, six policy issues, not specifically related to issues of metrology, are germane to the use and development of ionizing radiation measurements and standards.

Policy Consideration 1: US Congress must find ways to better inform the public perception of radiation or risk reducing scientific advantage, economic advantage and domestic job creation.

Many citizens possess a passing knowledge of radiation and develop opinions about the scientific merits of radiation and radiation safety from what they see in the popular media. Many people, some of whom are elected to higher office, make no distinction between the words radiation and radioactive. People fear what they cannot see and cannot understand. Fear and media misrepresentation limit US effectiveness in dealing with issues concerning ionizing radiation. This holds true in food irradiation, homeland security, power and materials processing. This education knowledge gap translates into outdated federal rules and regulations, public mistrust and fear, loss of scientific support for creating safe new technologies that will create jobs, tax revenues and bolster US competitiveness. US Congress must address this issue through national dialog, public service announcements, targeted grant funding, student support, and Regulatory Agency continuing education support.

While there are valid safety and security concerns with numerous projects, proposals and efforts involving radiation of all forms, CIRMS believes that immense good that can be derived from a consistent policy stance toward appropriate concerns in the field based on a fundamentally grounded understanding of actual vs. perceived threats. The focus of the 2011 CIRMS Annual Meeting concerns the "Public Perception of Radiation."

Policy Consideration 2: The Federal Government and associated Regulatory Agencies should immediately prioritize developing 21st century rules and regulations, informed by the scientific community, to enable progress toward elimination of food-borne pathogens/pests, increase shelf life and inhibit sprouting and maturation, while increasing food safety.

The anti-microbial benefits of irradiating food have been known since the start of the twentieth century, when radiation sources themselves were first being discovered. The US Army research laboratories in Natick, Massachusetts, and the US Department of Agriculture laboratories have validated these findings. Limits on the amount of irradiation for various food-stuffs have been developed by the US Food and Drug Administration. As the world's food supply is growing and more food enters the US from all over the world, there is a need to harness this safe and approved technology to protect the food supply and to enhance its quality. For decades, US astronauts have been consuming irradiated foods. Irradiated foods could become a substantial part of the rations for military personnel, especially given the ability of using irradiation to extend the shelf-life of foods. Without an effective pull, food irradiation, as the Executive Director of CIRRPC had discussed fifteen years ago, will remain a talking point, but not an implemented technology.

In his final CIRRPC report of September 1995, Alvin Young (from OSTP and USDA), who had served as CIRRPC's Executive Director for all of its eleven years of existence, inserted a closing section on food irradiation. Food irradiation has been shown to be safe and efficacious. The food safety requirements of the US Food and Drug Administration and of the US Department of Agriculture have, for the most part, been met. There still exist barriers to commercial acceptance for this process, which can eliminate food borne pathogens that cause waste, spoilage and harmful effects on humans, even, in some instances, leading to death. They involve a complex interaction between food producers and experts in food irradiation. Here only a coordinated stimulus or push at the Federal level will help bring about a desirable societal benefit, the elimination of food borne pathogens. What has proven to be good and wholesome for our astronauts (irradiated food) should also be beneficial for our children and families.

Policy Consideration 3: A virtual national laboratory consortium is needed that can support regulatory, research and development uses and measurement of ionizing radiation to leverage national brick and mortar assets at universities, DoE laboratories and government laboratories.

Industrial electron beam accelerator technology has been developed in the United States since the 1930's relying upon free market capitalization. US based companies are responsible for the manufacture of a large share of the over 1700 high current electron accelerators in industrial use throughout the world. Likewise, the dominant markets in which these EB accelerators are used

have been based upon innovations of US entrepreneurs, markets that involve hundreds of billions of dollars of value-added products. These successes have been attained without federal support. However, now in a more competitive global marketplace of the twenty-first century, other nations have more astutely structured their science and technology capabilities to support the industrial use of EB technology. Countries, such as Japan and the Russian Federation, have national laboratories with high current, EB accelerators that are used to foster the deployment of EB technology in industrial areas. Similarly, such coordinated approaches to fostering the use of this energy-efficient process technology are found in the national laboratories of emerging economies as in Brazil, Poland and even Malaysia and Egypt. No comparable national facilities exist in the US. This has facilitated technological developments to be launched outside of the US. For example, the use of EB to eliminate the stack gas contaminants of sulfur dioxide and nitrous oxides was investigated and developed in Japan and Poland and then also scaled up in Poland to commercial use. US industry lacks such a national resource as the Japan Atomic Energy Research Institute (JAERI) in Takasaki, Japan, and its ability to coordinate commercial interests in technology deployment. It is not practical given current funding patterns to build such a brick and mortar facility at any specific agency or laboratory. NIST itself would need an entirely new building to house a facility and other facilities NIST maintains in support of other areas, such as the medical community. Accelerators require specialized shielding and cannot simply be housed or moved to other buildings at NIST. The present building used by the NIST Ionizing Radiation Division has been found to be inadequate by several National Research Council review panels. A consortium of stakeholders with facilities at universities, DoE laboratories and Government agencies across the country should be established to allow NIST the regulatory facilities it needs to develop and maintain effective, modern measures and standards dealing with the ionizing radiation community.

Policy Consideration 4: An independent review panel should be established based on recommendations from the National Academies Nuclear and Radiation Studies Board (NAS NRSB) and the Nuclear Regulatory Commission (NRC) to evaluate all requests for isotopes that are not now currently available from commercial sources.

Said panel should enquire of any investigator, including those in any and all Federal departments or agencies, as to the "need" for such isotope, its fully burdened costs of manufacture (including overheads) and why alternatives, such as available isotopes, cannot be used for given experimentation. In its report on a "Workshop on The Nation's Needs for Isotopes: Present and Future," the Department of Energy's Office of Science listed numerous isotopes that could be needed for various purposes. However, this report (DOE/SC-0107) neglected to quantify such supposed needs. One cannot tell if milligrams, grams or kilograms or more of any given isotope is or could be needed. Of particular concern would be long-lived isotopes which would require heightened security measures. There has been a pattern of force-fitting existing DoE laboratory

facilities into isotope manufacture using accelerators and platforms that may not be appropriate for such functions.

Another policy issue pertains to the use of cesium-137. A 2008 National Academies report on **Radiation Source Use and Replacement** had recommended the discontinuance of the use of the isotope cesium-137 and the implementation of a funded program to facilitate the use of alternative sources (small X-ray devices) for such applications as blood irradiation. This isotope stored in many hospitals and other facilities was deemed to be susceptible to theft and could be used in making a "dirty bomb" which could be detonated in highly commercial areas, such as the Wall Street area in Manhattan, could leave that area inaccessible for centuries. How such Academy recommendations have or have not been implemented are policy matters that need to be brought to the attention of both Congress and the Administration.

Policy Consideration 5: National dialog among NIH, NIST, and university and DoE laboratories is needed to better control the supply of the molybdenum-99 isotope.

Illustrative of an issue related to policy is the need in the US medical community for a reliable source of the isotope, molybdenum-99, that is used to produce the short half-life technetium-99m, which in turn is widely used in diagnostic procedures. The metrology for these isotopes is well known, and protocols for their use have been established, but the critical issue at this time is the need for a sustained, domestic source of supply for molybdenum-99.

With the shutdown of some dated nuclear reactors in Canada, molybdenum-99, which was made as an adjunct, has now a serious supply issue affecting the medical community. As an alternative to using nuclear reactors to produce this isotope, an electrically sourced accelerator could be used. There are over 100 commercial cyclotrons which routinely provide the short-lived isotopes that are needed in nuclear medicine and for medical diagnostics. NIH itself has such cyclotron facilities. In order to overcome potential barriers between users and their source of supply, the oversight for the manufacture of molybdenum-99 could be placed within the charge of the National Institutes of Health (NIH), but this may create an unfunded Federal mandate that would not be sustainable. Molybdenum-99 is needed by the medical community, NIH routinely deals with the medical community and NIH has developed a system for expediting the deployment of proven and promising medical technologies through its fast-track translational medical center. Thus, high level discussion to properly find a sustainable solution will help support the medical community and commercial needs and not continue to retard economic growth and scientific advancement.

Policy Consideration 6: A coherent long-term funding mechanism must be found to support maintenance of the mathematical modeling codes implementing the effects of ionizing radiation on materials.

Outside the United States, these computer codes are more openly shared amongst the radiation community. For example, the International Atomic Energy Agency (IAEA) has recently published a booklet on the **Use of Mathematical Modeling in Electron Beam Processing: A Guidebook** and when purchased in hard copy (42 Euros) includes a disk with the commonly used codes on it. A major code, the ITS Tiger code, was developed decades ago at NIST. However, access and distribution of such codes within the United States is cumbersome with excessive royalties having to be paid to the Oak Ridge National Laboratory (ORNL) to acquire some of these codes. ORNL is not structured as is NIST to deal with the broad base user community, including academia for use in teaching students the use of these codes, as is NIST. The user community would like access to these codes, but code repositories use licensing fees to support database maintenance which severely limits users and retards the growth of a robust community to move this work forward. US Congress must find a coherent long term funding mechanism to support and maintain these vital computational codes and databases to foster continued development and greater participation from younger generations of scientists.

Conclusion:

The United States is losing its competitive edge in science, technology, engineering, and mathematics (STEM) fields. The US Congress can make a small investment into the ionizing radiation community to push forward national education, promote interagency collaboration, reduce redundancies in government systems and develop a joint scientific, industrial, governmental focus to create jobs, encourage high-tech commercial growth and increase US competitiveness. The consequences of inaction are a continued slide in safety measures and lack of interest in this critical area of national security, food safety and industrial relevance. This lack of interest and lack of funding, and frustration regulatory environment causes the best thinkers and problem solvers of the next generation to pursue other non-STEM fields and has dramatic long-term consequences for the United States.

Metrology Needs

Each of the subcommittees of the CIRMS Science and Technology Committee has prepared a series of Measurement Program Descriptions (MPDs) pertinent to their area of expertise. These were arrived at through dialog at CIRMS meetings and workshops. The MPDs are designated by letter apropos to subcommittee areas of interest:

A = Medical Applications
B = Public and Environmental Protection (PERP)
C = Occupational Radiation Protection (merged into PERP)
D = Industrial Applications and Materials Effects (IAME)
E = Homeland Security (combined with PERP)
F = Computational Needs (cross-cutting areas involving modeling)

Numbers are assigned to MDP's as they evolved with the last digit indicating the latest revision of an existing MPD with its first issuance starting at zero. MPDs tend to be living working documents that are changed by the subcommittees of the CIRMS Science and Technology Committee as some aspects are completed and others perceived as in need of attention. MPD A.7.3, for example, is a seventh MPD generated by the Medical Applications subcommittee in its fourth revision. One or two page MPDs for these various areas are presented below.

A. Medical Applications:

The CIRMS Medical Applications subcommittee deals with diagnostic and therapeutic uses of ionizing radiation, whether isotope or accelerator sourced radiation. New topics of interest involve the growing use of proton beam therapy for more targeted cancer treatment and a need for enhanced dosimetry systems to quantify exposure levels in computerized tomography scans (CT scans). An introduction to the overall areas of interest in the medical area in the use of ionizing radiation can be found in Appendix D. This was taken from the fourth "Needs Report" of December 2004. More complete details on all of the MPDs generated by the CIRMS Medical Applications subcommittee can be found in prior "Needs Reports" which are accessible on the CIRMS web site: www.cirms.org .

CIRMS has been very effective in the Medical Applications area by drawing together professionals from the academic and medical communities, from the US FDA's Center for Devices and Radiological Health (CDRH), and by involvement of the National Institutes of Health, in particular the National Cancer Institute, and of inter-agency groups such as the Biomedical Advanced Research and Development Authority (BARDA). One of CIRMS early success stories (MPD A.1.0) was the organization's ability to pull together of various agencies to

cofund a needed radiation target facility at NIST so that air-kerma measurements for mammography equipment could be calibrated. (See Appendix E.)

NIST, through the guidance of the CIRMS Medical Applications subcommittee, has also established radioactivity standards for nuclear medicine (MPD A.2.3) and for determining the absorbed dose-to-water for photon external beam radiation therapy (MPD A.4.1). National standards for the air-kerma measurements of diagnostic X-ray beams (MPD A.5.0) and for the air kerma strength of photons emitted by brachytherapy sources (MPD A.6.0) have also been established. NIST has obtained equipment, such as a medical linear accelerator, to facilitate these activities.

Below is a list of the completed Measurement Program Descriptions prepared by the CIRMS Medical Applications subcommittee. Details of these MPDs can be found in prior issuances of the CIRMS "Needs Reports" that are posted on-line on the CIRMS web site: www.cirms.org. One or two page descriptions of the active MPDs follow. These present the objectives, some background information and needs in each active area.

Medical Applications – Completed Measurement Program Descriptions (MPDs):

A.1.0 **National Air-Kerma Standards for Mammography** (see Appendix E)

A.2.3 **Radioactivity Standards and Techniques for Nuclear Medicine**

A.4.1 **Absorbed-Dose-to-Water Standards for Photon External Beam Radiation Therapy**

A.5.0 **Air Kerma National Standards for Diagnostic X-ray Beams**

A.6.0 **National Air Kerma Strength Standards for Photon Brachytherapy Sources**

Medical Applications -- Active Measurement Program Descriptions (MPDs):

A.3.4 **Dose Mapping Systems for 3D Conformal Radiation Therapy and Intensity Modulated Radiation Therapy**

A.7.3 **Absorbed Dose Standards for Brachytherapy Sources**

- A.7.3a Low dose-rate photon sources
- A.7.3b High dose-rate sources, as iridium-192
- A.7.3c Neutron brachytherapy
- A.7.4d Electronic brachytherapy

A.8.1 **Liquid Based and Micro-Brachytherapy Sources**

Medical Applications -- New Measurement Program Descriptions (MPDs):

A.9.0 **Dosimetry for Proton Beam Therapy**

A.10.0 **External Beam Therapy**

- A.10.0a X-ray beam therapy
- A.10.0b Small photon beam therapy
- A.10.0c Electron beam therapy

A.11.0 **Radionuclides for Imaging**

A.12.0 **Bone Density Measurements**

A.13.0 **Enhanced Dosimetry Systems for CT Scans**

MPD A.3.4: DOSE MAPPING SYSTEMS FOR 3D CONFORMAL RADIATION THERAPY AND INTENSITY MODULATED RADIATION THERAPY

Objective: Establish standards for 3D dosimetry, quality assurance and treatment verification for conformal radiation therapy.

Background: Recent rapid advances of three dimensional (3D) Conformal Radiation Therapy (3D CRT) and Intensity Modulated Radiation Therapy (IMRT) have created an urgent need for the introduction of high-resolution three-dimensional methods of dosimetry, quality assurance and treatment verification. Conformal treatment techniques can deliver escalated doses to the lesion while minimizing the dose to the surrounding tissues, thereby potentially increasing the so-called therapeutic ratio, which is a measure of the likelihood that the disease will be controlled while minimizing radiation-induced complications. Tissue equivalent gels which either undergo color-body formation or an inter-polymer phase change have been found to be effective in indicating conformal dose mapping.

Needs: A single most important objective for new measurement protocols that are needed should be the development of a reliable system of data correlation between the 3D treatment plan and the 3D phantom measurement. The new system should be readily accessible to medical physicists in hospitals, as these measurements would be used on a routine basis to confirm the quality and safety of conformal radiation therapy equipment, typical treatment protocols and possibly even individual treatment plans. These new measurement protocols would have to be standardized and traceable to measurements performed periodically at NIST or at Accredited Dosimetry Calibration Laboratories (ADCLs).

To meet these needs, standards are needed for phantom design and composition and for their calibration to national reference sources. Software capable of easily translating phantom response via instrumental analyses to absorbed dose is needed. This also involves the development of appropriate measurement protocols and their correlation with patient treatment results.

Despite having been noted in previous CIRMS "National Needs Reports," activities in the areas addressed by this MPD have been limited to a few research and development projects funded by the National Institutes of Health (NIH), mostly through its Small Business Innovative Research (SBIR) awards.

Action Items:

1 – Establish a system for gathering data and correlating data between 3D treatment plans and 3D phantom measurements.

2 – Improve 3D phantoms through the use of fiducial markers so that dosimetry can better correlate with treatment plans.

3 – Develop user-friendly computer software for handling data generated by radiation treatment plan (RTP) and 3D dosimetry.

4 – Establish 3D dosimeter calibration protocols such that the absorbed dose response varies <2% in inter-laboratory comparisons.

5 – Develop quality assurance, acceptance testing and commissioning measurement protocols that lead to patient treatment verification.

6 – Conduct workshops and seminars to bring together diverse organizations needed to accomplish the desired goals, including participation from universities, government agencies, e.g. NIH, FDA, NIST, and ADCLs and interested private companies.

Resource Requirements:

1 – A firm commitment to a minimum of 5 person-years, preferably at least 10, over the next four year time period is required to make substantive progress in this area. Resource commitments are needed from government agencies and laboratories, from universities and from private companies working in collaboration with each other.

Figure A.3.4 – Irradiated BANG gel dosimeter (courtesy of MGS Research, Incorporated)

MPD A.7.3: ABSORBED DOSE STANDARDS FOR BRACHYTHERAPY SOURCES

Objective: Develop NIST traceable absorbed dose standards for diverse brachytherapy sources:

A.7.3a Low dose-rate photon sources
A.7.3b High dose-rate sources, as iridium-192
A.7.3c Neutron brachytherapy
A.7.4d Electronic brachytherapy

Background: Brachytherapy sources are coming into wider use for such applications as prostate implants and breast treatments. Presently, NIST offers air-kerma calibrations for these sources. Conversion of the air-kerma strength to a three dimensional dose-distribution in a medium is a long process, involving Monte Carlo analysis and in-air measurements of anisotropy and spectra. Radiochromic film is a convenient tool for some of this work, but requires construction of precise phantoms for each source geometry. Direct measurement of the dose-rate by an ionization chamber in a medium is a more direct method and would serve to tie together the theoretical modeling and the in-air measurements. It will also enable a direct measurement of source anisotropy.

With the increasing acceptance of implants as a leading method of treating cancer as well as a number of common non-cancerous conditions, the brachytherapy source manufacturers are responding by creating new source designs to compete for a part of the large market. Direct measurement of new source designs offers the advantage of increased accuracy and shorter validation times for clinical applications.

An alternative device for brachytherapy applications is a miniature X-ray generator. This device allows radiation to be delivered to small volumes of tissue through a needle-like applicator that can be inserted into the target tissue. Procedures for calibration of this device must be developed and implemented before it can be used in the clinic.

To appropriately address these needs, NIST must have source capabilities equivalent to each of the brachytherapy modalities noted above: a) low dose-rate photon sources; b) high dose-rate sources, as iridium-192; c) neutron brachytherapy sources; and d) an electronic brachytherapy source.

Action Items:

1 – Using three different detector systems, continue to characterize their reliability in measure dose from different brachytherapy sources.

2 – Adapt detector housings and software to enhance absorbed dose measurements for each of the different brachytherapy sources.

3 – Sustain sufficient NIST and industry support to complete the objectives of this MPD.

Resource Requirements:

1 – A minimum of 4 person-years per year over the next three year time period is required to sustain efforts in this area with personnel being provided by both NIST and its industry partner.

Figure A.7.3 – Well-ionization chamber for clinic use (courtesy of NIST Ionizing Radiation Division)

MPD A.8.1: LIQUID-BASED AND MICRO-BRACHYTHERAPY SOURCES

Objective: Develop a NIST traceable standard for liquid-based brachytherapy sources, and micro-brachytherapy sources, and transfer this standard to the ADCLs.

Background: Liquid based and micro-brachytherapy sources are coming into wider use for therapy applications. Recently, NIST developed a "nuclear medicine" standard based upon a contained activity measurement. However, such an activity measurement is not sufficiently precise for use in radiation therapy. A preferred standard would consist of a statement of the emitted radiation from the source.

A critical need in this area is a technique to transfer the calibration from the assay of a sample of an unsealed radioactive source, to the calibration of the unsealed source in the environment used for treatment. In some cases, the unsealed source is introduced by a catheter into a balloon, which is implanted into the target tissue. The effect of the balloon, as well as the specific geometry of the unsealed source, must be addressed.

Action Items:

1 – Adopt the "brachytherapy" model for calibration, assay and dosimetry of liquid-based and micro-brachytherapy sources rather than the "nuclear medicine" model.

2 – Establish a system for calibration of dose calibrators by the ADCLs for liquid-base and micro-brachytherapy sources.

3 – Advance the quantitative, image-based dosimetry for liquid-based brachytherapy and micro-brachytherapy and conduct a consensus building workshop to cover this topic.

4 – Study the conversion from "contained activity" to "emitted radiation" standards for liquid-based and micro-brachytherapy.

Resource Requirements:

1 – A minimum of 2 person-years per year over the next three year time period is required to launch into these objectives. Some partnerships between NIST and industry are warranted in this area.

MPD A.9.0: DOSIMETRY FOR PROTON BEAM THERAPY

Objective: In conjunction with the medical community, develop protocols and techniques to be used to assess absorbed dose from high energy proton beams.

Background: A major advance in the beam treatment of cancers has been the development and adoption by the medical community of high energy proton beams (200+ MeV). While such beams are very expensive installations, the ability to focus proton beams on smaller domains of cancerous tissue has resulted in more efficacious patient treatment by minimizing potential radiation exposure to adjacent healthy tissue. Unlike electron beams or photon beams from isotopes or X-ray sources, proton beams do not attenuate as the distance from the source increases. Proton beams generate a Bragg peak concentrating the ionizing radiation at a distance from the source which is dependent upon the proton beam energy, as illustrated in figure A.9.0.

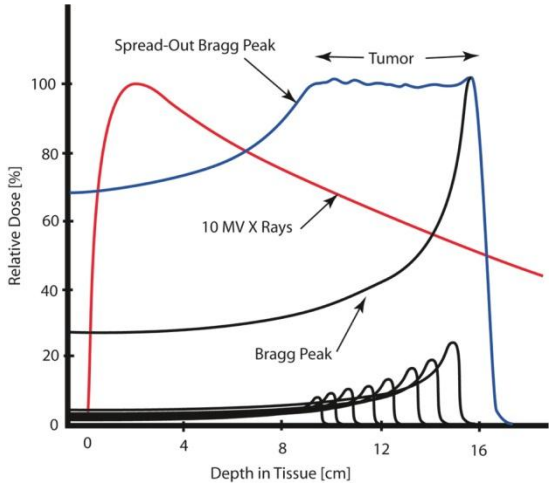


Figure A.9.0 Comparison of proton Bragg peak with X-ray attenuation

Action Items:

1 – In collaboration with proton beam cancer treatment centers, NIST and the ADCL's should harmonize protocols for proton beam dose determinations. This will involve a selection of appropriate dosimeters for use in a clinical environment and studies amongst the existing proton beam treatment center as to the inter-center precision of such dosimeter systems.

Resource Requirements:

1 – A minimum of 2 person-years per year over the next three year time period is required to launch into these objectives. Partnerships between NIST, ADCL's and the medical community are essential in this area.

MPD A.10.0: DOSIMETRY FOR EXTERNAL BEAM THERAPY

Objective: Coordinate the dosimetry protocols and establish new ones if so needed for different modalities of beam sources used for therapy:

A.10.0a X-ray beam therapy
A.10.0b Small photon beam therapy
A.10.0c Electron beam therapy

Background: High energy electron beams (typically 4 to 25 MeV) are used for the treatment of certain cancers, i.e. skin, prostate and breast cancers. X-rays derived for such electron beam sources are also used in these areas for treatment purposes to attain greater depth of beam penetration. Such photon beams can also be delivered by directed gamma sources. Depending upon the cancer being treated, each of the source modalities have been proven to be effective. However, each source differs in dose-rate and a cross-correlation needs to be established amongst the dosimetry protocols developed for each of these modalities.

Action Items:

1 – In collaboration with cancer treatment centers, NIST and the ADCL's should harmonize protocols for external beam dose determinations. This will involve a selection of appropriate dosimeters for use in a clinical environment and studies amongst the existing external beam treatment center as to the inter-center precision of such dosimeter systems.

Resource Requirements:

1 – A minimum of 2 person-years per year over the next three year time period is required to launch into these objectives. Partnerships between NIST, ADCL's and the medical community are essential in this area.

MPD A.11.0 RADIONUCLIDES FOR IMAGING

Objective: Establish a US based source for radionuclides, such as molybdenum-99, which in turn is used to produce technetium-99m, that are essential to certain imaging techniques used in the medical community.

Background: The short half-lived (about 6 hours) isotope, technetium-99m, is used in over 20 million medical diagnostic procedures every year. These range from bone scans in which scintillation counters can depict the image of bone structures through other body internal uses, such as functioning cardiac and brain imaging. Technetium-99m (a meta-stable isotope) is derived from molybdenum-99, which, as noted in the first Policy Consideration above, is now in a critical short supply. Historically, molybdenum-99 has been produced as a by-product from certain nuclear reactors, now being shut-down. At the US Department of Energy conference on "Accelerators for America's Future," held in Washington, DC, in October 2009, it was shown that molybdenum-99 could also be produced using a variation of existing cyclotron technology. This approach would eliminate the US presumed need to construct nuclear facilities for the express purpose of producing molybdenum-99. Such nuclear facilities would be costly and require years of planning, permitting and environmental impact studies.

A network of commercial and of in-house cyclotrons is widely used to produce short half-life isotopes for nuclear medicine. Over 200 such cyclotron facilities exist within the US. As recommended in Policy Consideration 1, the National Institutes of Health (NIH) are familiar with the operation of isotope producing cyclotrons and are in excellent contact with the entire medical community. NIH could take a lead role in alleviating this shortage of a much needed isotope.

Action Items:

1 – The appropriate congressional funding committees and sub-committees need to be clearly informed of this cyclotron approach to producing isotopes for use in medical imaging areas. This would be a far more cost-effective approach than those being presented based on the construction of smaller nuclear reactors.

Resource Requirements:

1 – Volunteers from the non-Federal employee members of CIRMS to address congressional staffs.

MPD A.12.0 BONE DENSITY MEASUREMENTS

Objective: Establish dosimetry and reference phantoms to be used in bone density measurements.

Background: With the increasing life expectancy of the US population, there is greater concern over the loss of calcium and other minerals which constitute bone structure. Such loses can lead to osteoporosis and other debilitating consequences. Periodic bone density tests are now routinely recommended, especially as people age. Dual-energy X-ray absorptiometry (DXA) is used to measure the bone density, as shown in Figure A.12.0 below.

In order to assure consistency of bone density measurements, both dosimeters, which can be used to confirm the output of the DXA equipment and surrogates or phantoms which can be evaluated as Standard Reference Materials are needed. These will assure patients of a consistency of bone density results irrespective of which facility they are conducted.

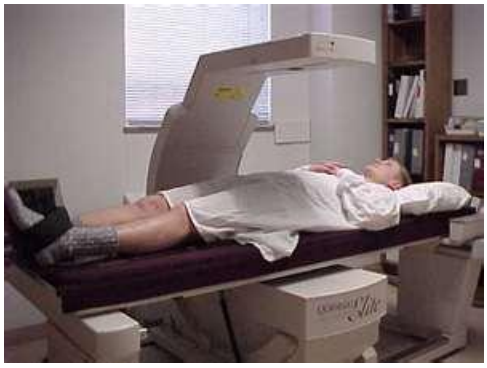


Figure A.12.0 DXA bone density testing

Action Items:

1 – In conjunction with ADCL's and with the appropriate medical associations, such as CIRMS members the American Association of Physicists in Medicine (AAPM) and the American College of Radiology (ACR), NIST traceable dosimeters and standard bone reference materials need to be developed and evaluated in inter-laboratory and inter-institutional tests.

Resource Requirements:

1 – A minimum of 2 person-years per year over the next three year time period is required to launch into these objectives. Partnerships between NIST, ADCL's and the medical community are essential in this area.

MPD A.13.0 ENHANCED DOSIMETRY SYSTEMS FOR CT SCANS

Objective: Develop a coherent dosimetry system based upon NIST traceable dosimeters which can be used routinely in the administration of CT scans.

Background: The enhanced image quality of X-ray generated computerized tomography (CT scans) has lead to a growing use of this diagnostic method in the medical community. For the most part, radiologists conducting CT scans rely upon protocols established by the manufacturers of the CT scanning equipment to set exposure parameters. Supposed corrections are made for body weight and bulk. Because this diagnostic procedure can sometimes lead to the detection of undesired health issues, i.e. detection of cancers, patients can be prone to seek multiple CT-scans from different facilities, shopping around while in denial of an unfavorable result. Studies have shown that excessive, multiple CT scans can themselves be a source of radiation induced malignancies.

To ensure patient safety, industry standards for CT scanning equipment have to be established and then administered by appropriate authorities, such as the US Food and Drug Administration's Center for Devices and Radiological Health. Reliance upon vendor generated protocols does not assure patient safety. In conjunction with this, a database has to be established within the Department of Health and Human Service which will catalog patient exposures with due respect to individual patient privacy rights. Radiologists need to be informed prior to administering a CT scan of how many times a given patient has had this procedure.

Action Items:

1 – In conjunction with the AAPM and the ACR, standards, such as those developed for equipment through the American National Standards Institute (ANSI), have to be established for CT equipment. Such standards should include the use of NIST traceable dosimeters and phantoms that have a high degree of dose sensitivity.

2 – Relying upon its existing database in the Medicare/Medicaid system, the Department of Health and Human Services can begin to establish a database annotating how often an individual is to have a CT-scan. Radiologists need to be informed as to how often a given patient has been subjected to this procedure.

Resource Requirements:

1 – A coordination team of representatives of the appropriate associations, of NIST, of FDA CDRH and of DHHS will take several years to implement this need.

B/C/E. Radiation Protection and Homeland Security

Through the first three CIRMS "Needs Reports" (1994, 1998 and 2001), CIRMS maintained a distinction between its then subcommittees on Public and Environmental Radiation Protection (PERP) and Occupational Radiation Protection (ORP). Measurement program descriptions (MPDs) were generated by both of these subcommittees: PERP's were designated with a "B" and ORP's with a "C." Numerical designations came out of line as different MPDs were generated. One has to go back to these earlier documents which can be found on the CIRMS web site to see these. By the 2004 "Needs Report," CIRMS had melded the PERP and ORP subcommittees into one and augmented their needs with a growing need for metrology as required by the newly formed Department of Homeland Security.

Background information on PERP/ORP, taken from the fourth "Needs Report" (2004) can be found in Appendix F and in the history of CIRMS, Appendix B. The MPDs which the combined PERP/ORP/Homeland Security subcommittee seeks to maintain are listed below:

Radiation Protection and Homeland Security Active MPDs:

B.7.2 **Traceability to NIST for Reference, Monitoring and Service Laboratories**

B.8.2 **Sorption of Radioactive Elements in Contaminated Soils and Sediments and Urban Structural and Other Materials**

B.9.2 **Atom-Counting Measurement Techniques for Environmental Monitoring**

C.3.4 **Intercomparison Transfer Standards for Neutron Source Calibrations**

C.4.4 **Improvements in In-Vivo Radionuclide Metrology**

C.17.3 **Improved Radiation Measurement Infrastructure for Occupational Radiation Protection**

C.20.2 **Implementation of Support for Personnel Dosimetry Proficiency Testing per ANSI N13.11**

E.1.1 **Emergency Radiological Response Metrology Infrastructure**

Radiation Protection and Homeland Security New MPDs:

E.4.0 **Traceability for High Energy Photon Dosimetry for Non-Intrusive Inspection Systems**

E.5.0 **Traceability of Neutron Cross Sections, Measurements, and Detector Development**

MPD B.7.2: TRACEABILITY TO NIST FOR REFERENCE, MONITORING AND SERVICE LABORATORIES

Objectives: Develop a national approach, consistent with ANSI N42.23, for reference, monitoring, and service laboratories to establish and maintain traceability to NIST

Establish NIST traceability for the reference laboratories of sponsored performance evaluation programs

Background: The term "traceability" has become a complex concept having subtle differences in meaning depending on the specific application and the organization effected. In 1996, as a result of the American National Standards Institute (ANSI) process, a national standard was developed for the purpose of clarifying a process of how laboratory measurements can become traceable to NIST. The standard ANSI N42.22–1995, entitled "Traceability of Radioactive Sources to the National Institute of Standards and Technology (NIST) and Associated Instrument Quality Control," was primarily developed to address the needs of the commercial radioactive source manufacturers related to NIST traceability for the materials that they manufacturer, produce or sell. However, the guidance and concepts provided within the standard are applicable to any organization preparing radioactive materials that desires to be traceable to NIST. ANSI N42.23-1996 was developed to address a national concern to establish a national approach to measurement assurance for the radioassay laboratory community, especially for the environmental and bioassay applications. This standard, entitled "Measurement and Associated Instrumentation Quality Assurance for Radioassay Laboratories," was published in 1997 after nearly ten years of preparation. The purpose of the standard was to provide the basis for the creation of a national measurement quality assurance (MQA) process to support the optimization of the quality of radioassays performed by service laboratories in the United States. Within the framework of the national MQA program description is the delineation of the responsibilities and interaction of NIST, the accrediting/administering organization and the reference, monitoring and service laboratories.

Action Items:

1 – NIST should establish a steering committee comprised of NIST and government and commercial laboratory stakeholders. It should work closely with the working group that is being established to revise the current version of ANSI N42.23. This steering committee should focus on:

a) Recommending the program elements required at NIST to support a consistent national approach to Measurement Assurance, and facilitate the necessary working relationship between NIST, reference, monitoring and service laboratories and the administrating agency.
b) Developing a "needs" table of sample matrix, radionuclides, media type and analyte concentration level. Test matrices would have to be specific to the needs of each program. These MAPs will vary greatly, from drinking water standards, to radiobioassay standards, to soil samples, to emergency responder tests. The levels needed would also be program specific.

c) Developing guidelines for the development of measurement quality objectives for the preparation and distribution of performance testing samples by NIST and the reference laboratories.

d) Developing guidelines and criteria for sample preparation procedure verification and validation applicable to test matrices and analyte concentrations prepared by NIST or the reference laboratories.

e) Establishing common testing requirements for NIST traceability between NIST and the reference /participating laboratories.

f) Developing quality assurance assessment criteria for conducting onsite assessments of the reference laboratories.

g) Developing a consistent mechanism for funding NIST support of a national approach to MQA involving government and private testing laboratories.

h) Make recommendations on resources at NIST that would be needed to adequately support this effort. These might include but are not limited to: additional scientific and staff, expanded measurement capabilities, dedicated laboratory facilities, and additional programmatic oversight and management.

Resource Requirements:

1 – For the Radiochemical Intercomparison Program (NRIP), three full-time employees or contractor equivalent at NIST are needed for program administration, development of the necessary technical capability and the preparation and analysis of the test samples of the programs. The scientists will also be responsible for the development and maintenance of the radioanalytical procedures, and the development of the test sample preparation and verification protocols.

2 – Sufficient and dedicated laboratory facilities and resources to conduct the radioanalytical portion of the programs.

3 – Maintenance of calibrated nuclear instrumentation and primary test solutions for the conduct of the programs.

4 – Sufficient resources for programmatic oversight and management to update the programs and meet the community's needs.

NOTE: In the CIRMS "Second Report on National Needs in Ionizing Radiation Measurements and Standards," published in October, 1998, this MPD appeared as MPD B.1. A new MPD number has been assigned, MPD B.7, to avoid confusion with MPD B.1 that had appeared in the first CIRMS "Report on National Needs in Ionizing Radiation Measurements and Standards," published in January, 1995, that covered a different topic.

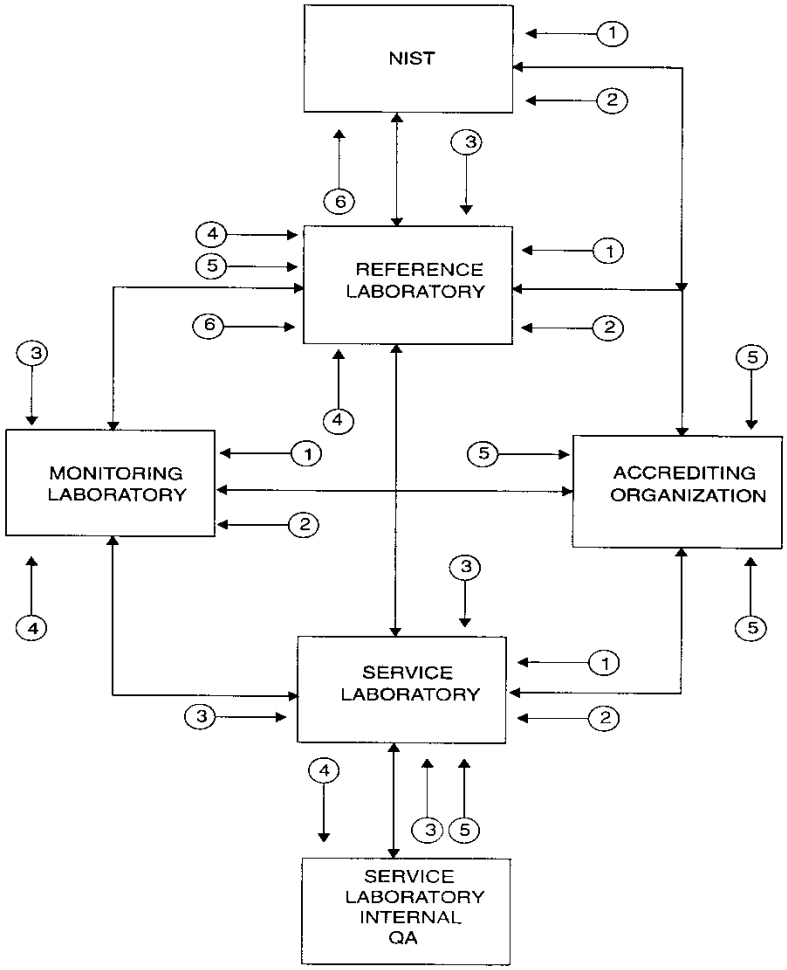


Figure B.7.1 – Diagram of national performance testing program per ANSI N42.23

MPD B.8.2: SORPTION OF RADIOACTIVE ELEMENTS IN CONTAMINATED SOILS AND SEDIMENTS AND URBAN STRUCTURAL AND OTHER MATERIALS

Objectives: Develop a rigorous, standard protocol for sequential extractions of radiologically-contaminated soils, sediments, and urban structural and other materials.

Apply the standard protocol to produce NIST Standard Reference Materials (SRMs) certified for radionuclide fractionation.

Background: Extensive areas of soils and sediments have been documented as having significant radioactive contamination. It is critical to evaluate the sorption of the radionuclides to soils and sediments to assess the potential of mobilization through the ecosystem, evaluate the health risk to man, and to develop cost-effective strategies for environmental remediation. The "environmental transport and biological availability" of the relevant contaminating radionuclide species is a critical issue. There is a more pressing need to remediate sites where the radionuclides may be in more mobile physico-chemical forms than sites where the contaminants are known to be firmly fixed in the matrix. Recent studies have shown that the speciation of contaminating radio-elements plays a very important role in dictating whether a radionuclide may move into the environment and the food chain. How then does one measure environmental transport and bioavailability of contaminant radionuclides? Unfortunately, there is no widely accepted method available for measurement of this parameter. On the other hand, numerous studies have been performed that involve use of various chemical extraction procedures for separating soil samples into several operationally-defined fractions. The interpretation of where an ion appears in such a sequential extraction scheme is often used as a surrogate for the potential mobility of that radioelement in the environment and its bioavailability. In other words, one commonly interprets a species as "mobile" or "labile" if it is present in one of the early, less harsh, treatments in a typical sequential extraction series. A "refractory" label is often assigned should the analyzed material respond to one of the latter, more vigorous, treatments. Although these interpretations are somewhat qualitative in nature, the information is far more useful than simply reporting the total concentration of radioactive elements in samples.

Action Items:

1 – Conduct inter-comparisons using the extraction protocol to evaluate the reproducibility among laboratories.

2 – Initiate the certification of a new line of natural-matrix environmental SRMs for extraction of radionuclides.

3 – In support of the extraction protocol results, develop *ab initio* molecular orbital computations for radionuclides on mineral surfaces and interior planar positions to evaluate the energetics of the interactions.

4 - Develop surface contaminated urban materials (concrete, metal, glass, paper, marble, and other materials).

5 – Develop an expert consensus draft sequential extraction protocol to assess radionuclide mobility from urban materials.

6 – Optimize the sequential extraction protocol for assessing radionuclide mobility from urban materials.

7 – Develop suite of surface and volumetric radionuclide spiked Standard Reference Materials.

Resource Requirements:

1 – Two NIST full-time employees (FTE) are needed to conduct the Action Items above; ICP-MS support for stable element analysis, computational power for the *ab initio* computations. Estimated cost $100,000 per year over a 10 year period.

2 – Two full-time employees (FTE) at NIST to coordinate and conduct the certification of the new line of natural-matrix environmental and urban matrix SRMs for extraction of radionuclides. Estimated cost $350,000 per year over a 20 year period.

The study envisioned would consist initially of a relatively small group of professionals (approximately 4-6 scientists in three laboratories) over a period of 3 years. In the second stages of the investigation, several expert personnel and facilities would be brought into the project in an inter-laboratory comparison to evaluate the efficacy and reproducibility of the recommended protocol in different laboratories. The third phase would consist of the certification of benchmark radioactivity reference materials for community use.

Figure B.8.1 – Soil sampling for radioactive contamination

NOTE: In the CIRMS "Second Report on National Needs in Ionizing Radiation Measurements and Standards," published in October, 1998, this MPD appeared as MPD B.5 and the related MPD B.3. A new MPD number has been assigned, MPD B.8, to avoid confusion with MPD B.5 that had appeared in the first CIRMS "Report on National Needs in Ionizing Radiation Measurements and Standards," published in January, 1995, that covered a different topic, and MPD B.5 in the second report.

MPD B.9.2: ATOM-COUNTING MEASUREMENT TECHNIQUES FOR ENVIRONMENTAL AND RADIOBIOASSAY MONITORING

Objective: Develop the capability and resources to provide NIST traceable reference materials and analytical performance testing of long-lived radionuclides in various media by mass spectrometry.

Background: Certain radiochemical analyses, especially those of the long-lived alpha emitters, can be long, laborious and costly. It is expected that cleanup and site remediation programs related to Department of Defense programs will require millions of assays over a period of 30 or more years, costing many billions of dollars. Furthermore, rapid analysis of radionuclides for emergency response and isotopic ratio determination of source identification are required. Thus, a need exists for reducing the cost of these programs by developing techniques that: (1) use atom-counting to reduce measurement time spent by factors of 10 per assay while increasing sensitivity by a factor of 1000, and (2) extends analytical sensitivity and selectivity over conventional radioactivity measurement techniques, and (3) perform measurements in situ if possible, thus avoiding laboratory analyses.

In addition to environmental sample analyses for the long-lived nuclides, current studies have shown that atom-counting is very applicable for radiobioassay for a number of radionuclides. Recently, the Brookhaven National Laboratory has demonstrated that Plutonium-239 (^{239}Pu) in urine samples can be measured accurately down to the microBq per liter. The technique combines the isolation, concentration and purification steps of qualitative and quantitative chemistry in conjunction with inductively coupled plasma mass spectrometry. Similar mass spectrometric techniques have been developed by the Los Alamos National Laboratory (LANL) and the Lawrence Livermore National Laboratory (LLNL). The application of atom-counting to bioassay will produce cost savings and will enable health physicist to document internal uptakes orders of magnitude better than current levels. In addition, the mass spectrometric technique yields additional isotopic information to that obtained from traditional radioactivity measurement techniques.

Action Items:

1 – Conduct a third intercomparison study to evaluate the capability of various mass spectrometric techniques for the assay of isotopic uranium in synthetic urine specimens.

2 – Provide leadership and program manager to initiate a national program for physical and consensus standards, intercomparisons, and performance evaluations that will serve the needs of the emergency response and cleanup radionuclide mass spectrometric community.

3 – Update the needs of the mass spectrometry community and provide a formal needs report upon which program funding can be based and obtained.

4 – Develop a NIST capability to produce and verify long-lived radionuclide reference materials for various mass spectrometric applications.

5 – Develop a NIST capability to enable NIST traceability for a national performance evaluation program for the testing of laboratories engaged in the MS analysis of environmental and bioassay samples for radionuclides.

6 – Continue research and development of radiochemical separations, source and ionization optimization, and pulse counting optimization.

Resources Required:

1 – One-half full time employee or contractor equivalent at NIST for program development and administration and the development of the necessary technical capability for the funded program.

2 – Enhanced TIMS, RIMS, ICP-MS and MS-MS radionuclide metrology capabilities at NIST.

3 – Sufficient and dedicated laboratory facilities and resources to conduct the analytical portion of developed programs.

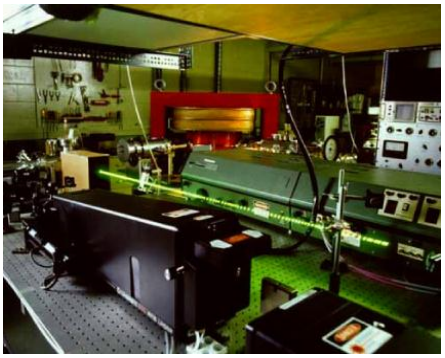


Figure B.9.1 – Resonance ionization mass spectrometry (RIMS) system (courtesy of NIST Ionizing Radiation Division)

NOTE: In the CIRMS "Second Report on National Needs in Ionizing Radiation Measurements and Standards," published in October, 1998, this MPD appeared as MPD B.4. A new MPD number has been assigned, MPD B.9, to avoid confusion with MPD B.4 that had appeared in the first CIRMS "Report on National Needs in Ionizing Radiation Measurements and Standards," published in January, 1995, that covered a different topic, and MPD B.4 in the second report.

MPD C.3.4: INTERCOMPARISON TRANSFER STANDARDS FOR NEUTRON SOURCE CALIBRATIONS

Objectives: Develop and promulgate protocols for the use of thermoluminescent dosimeters as intercomparison standards that will be effective on a national and international level.

Appraise and report on the reliability of other intercomparison transfer standards and instruments for neutron source calibrations.

Background: The calibration of personnel dosimeters and area survey meters used for radiation protection purposes in neutron fields is difficult. The devices used for measurements in neutron fields have dose equivalent responses that are dependent on the neutron energy spectrum and on the scattering environment. In addition, the reference calibration neutron sources maintained by NIST are not available for routine calibration or intercomparison measurements. These measurement services are supplied by secondary calibration laboratories.

In order to ensure the consistency of calibrations performed by secondary calibration laboratories with NIST standards, ongoing measurement quality assurance (MQA) interactions between the laboratories and NIST must take place.

The MQA program for photon (X-ray and gamma-ray) radiations has been in place for many years, and NIST and the secondary laboratories produce consistent results. The situation for neutrons is more complex. NIST maintains neutron reference radiations recommended by ISO 8529-1. The physical characteristics of these sources have been publicly documented. However, the critical elements of a neutron calibration include more than the source spectrum and intensity. The calibration depends upon having knowledge of the interaction of the neutron source with its surrounding material, the phantom (for dosimeters), and the detector itself. The methods required for neutron calibrations are discussed in ISO 8529-1, 2 and 3.

An MQA program for neutron dosimetry needs to incorporate methods that will either incorporate or evaluate the effects of the items mentioned previously. Each neutron calibration facility is virtually unique, and all variables affecting the calibration need to be considered in the design of a method for MQA measurements. Therefore, a method needs to be developed that will permit evaluation of all of the variables or that has a response to the variables that is close to that of the devices calibrated.

The original effort on transfer standards was completed and was not successful at the precision needed. The MPD has been revised to include intercomparisons with both instruments and passive dosimeters. Currently efforts are underway for direct intercomparisons using personnel dosimeters.

Typical personnel dosimeters have been irradiated under nearly identical conditions at NIST and PNNL. The results of this study are presently being evaluated. Follow-on experiments will determine optimal reader parameters and appropriate irradiation and readout protocols for use of the Thermoluminescent Dosimeter (TLD) system as transfer standards in intercomparison measurements and for proficiency testing of calibration laboratories seeking accreditation by National Voluntary Laboratory Accreditation Program (NVLAP) for dosimetry. When the irradiation conditions have been established the study needs to be extended to additional US and foreign laboratories to fully evaluate the technique. Results will be published and presented at a CIRMS meeting or CIRMS workshop.

Additional efforts will be undertaken to evaluate the use of instruments including a survey meter as a transfer standard for general calibrations of neutron survey meters. Another approach that will be further evaluated is the use of the tissue equivalent ion chamber. Current research efforts on electronic dosimeters (ED) will result in detector based methods of neutron dosimetry. The devices under consideration (combinations of diodes, ion chambers, and multi-cell tissue equivalent proportional counters) will have energy responses that are different from conventional dosimeters and different from instruments. Ensuring that the transfer standards are suitable for these devices will require additional investigations in the next 1-3 year time period.

Through participation in ISO standards efforts NIST personnel and personnel from other US secondary laboratories (PNNL) will seek optimization of intercomparison methods and seek international standardization to ensure worldwide consistency of neutron dose measurements for radiation workers throughout the world.
NIST and PNNL will be primary participants in these efforts. Other laboratories and vendors that wish to be involved will need to perform experimental irradiations, establish a pool of transfer dosimeters/instruments and develop capability to analyze and tabulate the results.

Action Items:

1 – Evaluate and establish protocols for the use of thermoluminescent dosimeters (TLDs) to be used in intercomparison studies and as transfer standards.

2 – Extend the results of the TLD program to involve non-US laboratories.

3 – Evaluate neutron survey meters, ion chambers and electronic dosimeters for their reliability as transfer standards for general measurement of neutron dosimetry.

4 – Optimize the intercomparison and standardization protocols for neutron dosimetry through participation in international standardization efforts (ISO) so that they become applicable on a world-wide basis.

Resource Requirements:

1 – The neutron calibration program will require one person-year per year over the next three-year time frame and approximately $150,000 for equipment and supplies.

2 – Funding must provide for personnel to track and participate in international standards efforts. It is estimated that this will require 5-10% of an individual's effort per year plus travel costs $30,000 per year.

MPD C.4.4: IMPROVEMENTS FOR IN-VIVO AND IN-VITRO RADIOBIOASSAY METROLOGY

Objectives: Improve the consistency of measurements for internal radioactivity depositions in humans resulting from occupational or natural exposure.

Develop techniques that can detect and measure lower concentrations of radionuclides in organs and soft body tissues.

Background: Non-invasive in-vivo and in-vitro radiobioassay (whole-body and organ counting, and urine, feces and tissue radioanalysis, respectively) of personnel working with radionuclides or materials with potential radioactive contamination is a primary method dosimetrists employ for routine occupational monitoring and accident assessment.

The variability among "homemade" and de facto reference phantoms can account for up to an 80% difference among measurement laboratory results [Kramer, G. H., Loesch, R. L., and Olsen, P. C. "The Second International *In-Vivo* Intercomparison Program for Whole Body Counting Facilities by Canadian and United States Agencies;" **Health Physics** 80(3), 214-224 (2001)]. Measurement comparability and consistency can be ensured through calibrations based on national standard realistic human-surrogates (calibration phantoms). In addition, site-specific (organ specific) quantitative assessment requires new measurement technology and 3-D tomography. A solution to the problem of measurement differences is the continued development of technological and measurement quality assurance bases for quantitative site-specific in-vivo radiobioassay. This is a recommendation of the International Workshop on Standard Phantoms for In-Vivo Radioactivity Measurements [**Health Physics**, **61**, 893 (1991)].

Similarly, the variability of in-vitro radiobioassay measurements is largely due to sampling heterogeneity and non-equilibrium of chemical yield monitors with the analytes of interest during sample preparation. While sample heterogeneity problems may be improved by taking larger or more samples, problems of completely equilibrating the chemical yield monitors with the analyte in the sample is largely dependent on the chemical speciation of the analyte. For example, refractory plutonium particles in the lung or in fecal samples could be underestimated by 15-50 percent if insufficiently aggressive dissolution methods were used. Even in cases where the analyte is easily solubilized, precision of analysis of radionuclides in synthetic urine and fecal test samples is of the order of 10-15 percent (Wu, et.al., BERM Conference Proceedings). To improve these capabilities, there is a need for the development of new reference materials and traceable Proficiency Testing programs to continue to evaluate and improve the measurement community's capabilities.

Action Items:

1 – Develop calibration systems and quality assurance protocols for radionuclide-labeled organ and phantom surrogates.

2- Facilitate comparison of calibrations with standard phantoms to surrogates in the DoE phantom library and to real animal/human exposures in order to improve measurement techniques and measurement consistency.

3 – Develop 3-D tomography and related computational methods for improved definition of organ/tissue modeling.

4 – Evaluate long-term massic activity stability of radionuclides in synthetic urine and fecal test samples.

5 – Develop certified high fired plutonium performance test samples.

6 – Extend bioassay accreditation programs, possibly through the HPS accreditation program, beyond the current DoE RESL program.

Resource Requirements:

1 – A cumulative expenditure of approximately $3million over the next three-year time frame will be needed to sustain and properly coordinate efforts at NIST, LLNL, the Bureau of Radiation and Medical Devices (BRMD), RESL and PNNL on new phantom materials, ANSI and international standards, techniques for assessing homogeneity and content of phantom inserts, and Monte Carlo calculations.

2 - An investment of 1 FTE to evaluate the long term stability of the synthetic urine test samples, and develop the reliable production and certification of refractory plutonium in bioassay test samples.

3 – Investigation of extending accreditation efforts to sectors other than DoE will require a minimum of 20% of a person year of effort.

MPD C.17.3: IMPROVED RADIATION MEASUREMENT INFRASTRUCTURE FOR OCCUPATIONAL RADIATION PROTECTION

Objective: Improve the occupational radiation measurement infrastructure through development and implementation of measurement standards and accreditation programs on a national and an international level.

Background: The infrastructure that supports radiation measurements for purposes of occupational radiation protection has two major components: *standards* and *accreditation programs*. *Standards* for radiation calibration are required to ensure that calibrations (and interpretation of occupational risk) are consistent on both a national and an international basis. The standards must describe the generation and calibration of radiation fields in terms of standardized quantities and the use of a consistent set of conversion coefficients to interpret the fields in terms of worker risk. The ongoing standards development work of the ISO must be encouraged and expanded. *Accreditation programs* provide a method of ensuring that calibrations, dosimeter processing or test measurements are performed in a quality manner consistent with established standards or criteria, thus providing assurance that the results are consistent with national needs. In addition, it is necessary to ensure that the accreditation programs are consistent, cost effective, and appropriate in terms of national and international needs. Although the critical elements of a complete measurement quality assurance (MQA) program are required for accreditation under each of the four existing secondary laboratory accreditation programs, they do not use the same general or specific criteria to evaluate candidate laboratories. Questions have been raised about the comparability (equivalence) of accreditation granted by the various programs. An obvious major improvement would be the adoption, by all the programs, of the new standard ISO/IEC 17025 (cancels and replaces ISO/IEC Guide 25), which establishes general criteria for laboratory performance. Through meetings and information exchange, CIRMS makes continual progress in this area with recent incorporation of ISO/IEC Guide 25 into the programs. The stage must be set to upgrade to ISO/IEC 17025.

A recent innovation is the consideration of total measurement uncertainty as a basis for dosimetry system approval. Germany has developed pattern tests based on total system uncertainty that will be used for approval of dosimetry systems in the future. The HPS is developing a standard for evaluating dosimeter uncertainty, and the International Electrotechnical Commission (IEC) is working on a standard for evaluating the uncertainty of measurements. These standards consider a greater range of influence quantities than the NVLAP and DOELAP standards and provide a rational basis for evaluating dosimetry against guidance by the International Commission on Radiological Protection (ICRP). CIRMS efforts will include looking at evaluating total uncertainty as a basis for evaluation of measurements in radiation protection.

Currently, a national effort is underway to accredit organizations using ISO Guide 58, "Calibration and Testing Laboratory Accreditation Systems-General Requirements for Operation and Recognition (Revision of ISO/IEC Guides 38, 54, and 55)". CIRMS can assist by providing the technical expertise needed to achieve an orderly acceptance of these efforts. Operating the accreditation programs through an organization that is accredited based on internationally accepted criteria will provide significant benefits: improve acceptance of the programs by the regulators and the customers (an accreditation certificate has not been universally recognized as an indicator of program quality), and provide international acceptance of the accreditation programs. CIRMS acts to improve the technical basis for the programs, as well as facilitates the relationship of users, program developers, and NIST in the development and implementation of accreditation programs and must continue this effort.

CIRMS members need to meet with national/international standards developers to make sure that needed standards are identified and approved for development. CIRMS members have been and should continue to be active in the development and review of conversion coefficients used in ISO standards, as well as in the development of international standards for beta, photon and neutron reference radiations. Review of standards has resulted in changes that ensure compatibility with US practice and US regulations. Information exchanges at CIRMS annual meetings can identify new standards. Special meetings to address implementation of standards and accreditation programs will be needed. An ad hoc working group should be formed through CIRMS to study the pattern testing/type testing philosophy and make recommendations.

Action Items:

1 – Identify and participate in the development of national and international standards that are needed to support the radiation measurement infrastructure for the protection of occupational workers, including providing supporting data such as conversion coefficients.

2 – Seek broader national and international acceptance of existing laboratory accreditation programs, improve upon their inter-comparability and provide guidance and assistance as needed.

Resource Requirements:

1 – Funding to facilitate annual meetings to monitor the progress on the above.

2 – 1/2 person-year per year over a three-year timeframe to study the evolving methodologies and criteria for personnel radiation protection and accreditation of laboratory protocols.

MPD C.20.2: IMPLEMENTATION OF SUPPORT FOR PERSONNEL DOSIMETRY PROFICIENCY TESTING PER ANSI N13.11

Objective: Support the implementation of proficiency testing under criteria developed for ANSI N13.11.

Note: ANSI N13.11-2009 has been recently published and is now in effect.

Background: Proficiency testing of dosimetry systems is required by both the Department of Energy (DoE) and the Nuclear Regulatory Commission (NRC) for dosimetry of record for radiation workers. In the past the criteria and needs for the NRC and DoE have been different and covered in different standards; American National Standards Institute (ANSI) N13.11 for the NRC and an internal DoE standard for DoE. The most recent revision of ANSI N 13.11 incorporates both agencies' requirements thus providing a single set of criteria for proficiency testing in the US for dosimetry systems. The testing requires carefully defined criteria for sources, geometries, irradiation procedures, conversion coefficients, etc. in order to provide a fair test of the candidate dosimeters. It is important that the users, the standards laboratories and the standard developers exchange information to provide a realistic and equitable basis for testing. As the proficiency testing evolves it is important to identify needed studies to improve the technical basis for the program and assist with the implementation. CIRMS has had information exchanges for the two revisions of the dosimetry accreditation program (based on revisions to ANSI N13.11) that have occurred in recent years. It is important that such exchanges continue to occur and identify this need in a separate MPD will provide more visibility for support of the proficiency testing program.

Action Items:

1 – To implement revisions of the ANSI N 13.11 standard, the following must be addressed:

a) Methods for dealing with multiple sources of exposure.

b) Sharing of test data to validate the new test categories in order to shorten the pilot test phase.

c) Ways to deal with the thermal neutron component of exposures.

d) Methods for dealing with low dose exposures and fading.

e) Testing at high energies for both neutrons and photons.

Resource Requirements:

1 – Periodic meeting must be held to follow through on the details involved in implementing ANSI N 13.11. Funding for such meetings should be <$50,000.

2 – To address the issues highlighted above requires one person-year of support over the next three year time frame. Such support can be divided between NIST and the proficiency test laboratories during the implementation of the new criteria. Subsequently, continuing support of 1/4 person-year will be needed.

MPD E.1.1: EMERGENCY RADIOLOGICAL RESPONSE METROLOGY INFRASTRUCTURE

Objective: Develop the metrology infrastructure for the national network of radiological analytical laboratories under ICLN by improving its capabilities for responding to RDD/IND incidents as well as accidental releases of radionuclides.

Background: The Homeland Security Presidential Directive/HSPD-9 on Defense of the United States Agriculture and Food (30 January 2004) called for the development of integrated national laboratory networks for measuring and assessing food, animal, plant and water quality. Both federal and state resources were to be interconnected and harmonized with standard diagnostic protocols and analytical procedures.

In June 2005, the EPA, USDA, DOD, DHS, DOC, DHHS, DOI, DOJ and DOS signed a Memorandum of Agreement for an Integrated Consortium of Laboratory Networks (ICLN). This established the framework for a multi-agency, national laboratory capability that focuses a coordinated response to accidental or deliberate incidents involving chemical, biological, radiological and nuclear agents. The ICLN consists of five major laboratory networks, covering environmental, air, food, water, plant, animal and health domains, as well as the federal systems designated with responsibility for laboratory preparedness and response. With emphasis on both surveillance and operational readiness, each agency is mandated to develop the necessary emergency response network that will look after the safety of responders and population, evaluate the quality of air, food, water and environment, and contribute to the maintenance of civic order. With respect to radiological resources, it requires augmentation and upgrading of existing laboratory facilities for handling non-routine radionuclides and newly relevant matrices, developing rapid methods, and planning for surge capabilities.

The specific agencies have critical roles in ensuring the success of the ICLN in formulating its concerted radiological response effort. A realistic assessment of the present situation indicates that the different agencies have progressed unevenly; furthermore, there are very prominent gaps in the capabilities throughout the ICLN that need to be addressed. A few examples may be cited here.

Action Items:

1. Promote formulation of a consensus standard within ICLN on acceptance criteria for consequence management of radiological incidents.

2. Support development of criteria for and implementation of performance testing exercises to evaluate response capabilities and competence of networks and their laboratories.
3. Advocate the development and validation testing of streamlined, rapid radioanalytical screening methods and procedures.

4. Collect existing methods into a readily accessible, easily searchable radioanalytical emergency procedures manual database (REPMD) to assist networks and their laboratories in selecting appropriate radiological methodologies (e.g., fast screening and analytical methods).

5. Query the radioanalytical community for suggestions about new certified reference materials (radionuclides and matrices) needed for testing the various laboratory networks' response to realistic emergency conditions and samples.

6. In the near future, use newly developed certified reference materials to establish traceability links to NIST by way of routine and emergency performance testing exercises.

Resource Requirements:

1 – Develop consensus performance standard for CM radioanalytical laboratories - $600k first year, $200k/yr for next 4 years.

2 – An appropriate radioanalytical methods database server, software and computer services for the first year of developing the database - $500k for two years.

3 – Ongoing support by computer services - $100 000 annually.

4 – Full-time staff for program administration - $300 000 annually.

5 – Traceable performance and readiness testing program - $630k annually.

6 – Rapid radioanalytical methods development and validation - $200k/yr.

Total: $ 2.33M for two year, $ 1.43M subsequent years.

MPD E.4.0: TRACEABILITY FOR HIGH ENERGY PHOTON DOSIMETRY FOR NON-INTRUSIVE INSPECTION SYSTEMS

Objective: Clear and definitive standards are required to measure the performance of cargo inspection systems employing multi-energy high-energy X-ray photons to detect the presence of explosive materials in large target cargo containers. Standardize measurement methodologies are needed for detection rates for specific quantities of explosive materials.

Background: While standards exist for identifying and mitigating the threat posed by explosives that may be hidden inside of small targets such as check and carry-on baggage, significant standards development is required to assure the detection of explosive threats potentially hidden inside of large targets such as ISO cargo containers.

Next generation baggage inspection systems will employ multi-energy low-energy X-ray photons (100 – 180 KV) generated using traditional X-ray tubes to discriminate explosive threat materials. Cargo inspection systems require much higher energy photons (4 – 10 MeV) to penetrate large cargo containers and multiple pulsed energies to effectively discriminate explosive materials. These multi-energy, high-energy X-ray photons are generated by bremsstrahlung conversion using electron accelerators which are capable of producing multi-energy pulses of high-energy electrons that are then directed onto high-Z targets creating bremsstrahlung photons proportional to the energy of the electron beam.

Next generation and current x-ray inspection systems use density and/or atomic composition as primary indicators to discriminate explosive threats from most benign materials. When both of these attributes are known, they can provide a reasonable identifier of the presence of explosives. The density of potential explosive threat materials inside of a object to be inspected can be calculated based upon attenuated photon flux. However, density alone has limited value because observations correspond to averages over regions of space where a mix of low-, medium-, and high-density non-threat materials may coexist. The effective atomic number (Z_{eff}) or the weighted mean of the atomic numbers of the elements in a compound must be considered. A surrogate material used in the performance standards for the next generation x-ray scanners should possesses the same attenuation properties as its parent compound over the photon energy region of interest. This can only be accomplished with a compound whose density and Z_{eff} are nearly identical. As with density, measurements that average over a large region of space utilizing poorly selected or created surrogates may dilute the explosive signature with surrounding materials.

Low energy inspection systems are widely deployed with well-established performance standards for multiple energy material discrimination of explosive materials. While X-ray

photon signatures required to determine the density and Z_{eff} of explosive materials can be confidently measured at low energies, these signatures are relatively subtle and difficult to confidently measure at the high energies required to penetrate large targets such as a cargo container.

New multi-energy, high-energy LINAC designs and detector materials are being sought to enhance the material discrimination capability in non-destructive imaging air, land and sea cargo inspection systems. The current generation of LINACS have high pulse-to-pulse variability which affects the ability to detect the subtle signature changes that occur when X-rays interact with explosive materials at high photon energies. The needed next generation of imaging interrogation LINACs must have minimal radiation leakage and high pulse-to-pulse reproducibility (low variability in end point energy and integrated pulse energy) to improve the detectability of explosive materials. This next generation of LINACs needs to have high beam on to beam off ratios with very little dark current for high fidelity measurements.
Photon detectors used in these high-energy active interrogation techniques are count-rate limited, often relying on detectors that have fast recovery times and provide poor or no energy resolution. Advancements in detector technologies must facilitate higher count-rates. In addition to measuring precisely the quantity of photons, these new detectors should improve on one or more traditional detector parameters such as efficiency, energy resolution (or energy thresholding), size, cost, and photon/neutron discrimination. Clear and definitive standards are required to measure the performance of cargo inspection systems for the detection of explosives.

Action Items:

1 – Standards, as those being developed for high energy imaging equipment by the American National Standards Institute (ANSI-N45.46) for measuring the performance of imaging X-ray systems for cargo security screening have to be established for explosive detection. Such standards should include the use of NIST traceable detector materials and explosive surrogates that provide X-ray and composition correct signatures for sensitivity analysis.

Resource Requirements:

1 – A minimum of two NIST person-years per year over the next three year time period is required to launch into these objectives.

2 – Access to linear accelerators capable of producing multi-energy high-energy X-ray photons for development and verifications of detector materials and explosive surrogates.

3 - Partnerships between NIST and DHS are essential in this area.

MPD E.5.0: TRACEABILITY OF NEUTRON CROSS SECTIONS, MEASUREMENTS, AND DETECTOR DEVELOPMENT

Objective: Develop a coherent metrology program to meet the diverse and numerous demands of Department of Energy's Advanced Fuel Cycle Initiative involving a plurality of isotopes in conjunction with DoE and university laboratories.

Background: To advance the US transition to a greater use of nuclear power, the Department of Energy (DoE) is engaged in an Advanced Fuel Cycle Initiative (AFCI). This initiative is focused on the development of more cost-effective use of fast reactors. The database on pertinent nuclear reactions requires up-dating and input based upon the best-available detection equipment. Such input data is needed to facilitate and anticipate life-cycle issues that may occur with such fast reactors. Within the AFCI, a cross-agency group was formed, the Nuclear Physics Working Group (NPWG), to be a forum amongst various stakeholders for the sharing of pertinent information. Generated data must be analyzed for its covariance, sensitivity and uncertainties for it to be most useful. Within the AFCI, there are several sub-topics being addressed, these are sometimes called "campaigns."

The specific sub-topics or "campaigns," which will benefit from enhanced nuclear data, are:

The Fast Reactor Research and Development Campaign
The Safeguards Campaign
The Systems Integration Campaign
The Modeling and Simulation Campaign
The Fuels Campaign

Another area of concern is Criticality Safety. Specific sub-sets of data needs for fast reactors require research into fission measurements, research into capture measurements, research into the elastic/inelastic components in interpreting and analyzing measurements, research into the fission neutron spectrum measurements as well as an underlying support for basic nuclear physics.

The kinds of data that need to be generated on a broad plurality of isotopes, some of more interest than others to the defined sub-topic categories or "campaigns," are:

Neutron capture cross-section measurements
Fission cross-section measurements
The elasticity of cross-section measurements
The inelasticity of cross-section measurements
Fission neutron spectrum measurements

Thermal scattering effects

Such measurements will include not only investigations into the reaction components involved in fast reactor thermo-nuclear systems, but also analyses of spent fuel.

To date, the Fast Reactor Research and Development sub-topic has begun to generate some data which will be of value in the other sub-topic categories. Instruments such as the Fission Time Projection Chamber (TPC) and the Lead Slowing Down Spectrometer (LSDS) have come into use. A new device, the Detector for Advanced Neutron Detector Experiments (DANCE), is being considered. The objective is to improve the precision of all the many diverse measurements of radio-activity encountered in nuclear fission reactions.

A multi-faceted team is proposed involving two of the DoE laboratories, the National Institute of Standards and Technology (NIST) and a consortium of eight universities capable of addressing some of these needs, which are involved through the DoE Nuclear Energy University Program (NEUP). To complement these measurement needs, an enhancement of the probability codes used in estimating or simulating these pertinent nuclear reactions is also needed.

Action Items:

1 – To facilitate understanding of the diverse requirements for supporting the fast reactor initiative, a coherent organization structure must be developed integrating all program aspects under a defined person in-charge who has total budgetary responsibility. Supporting institutions may have to assign personnel on a rotational basis in order to expedite completion of these needs. A fragmented approach is not only poor management, but also will delay achievement of desired results.

2 – Neutron cross section measurements and other radioactivity measurements should be implemented with state-of-the-art equipment.

3 – A permanent home for all nuclear measurement data should be established with sufficient continuing funding to enable the US to maintain leadership in this field.

4 – The development of a next generation of neutron detector systems is needed including such as those developed for the neutron induced fission fragment tracking time projection chamber, for the LSDS, for the DANCE, and others.

Resource Requirements:

1 – A minimum of 2 NIST person-years per year over the next three year time period is required to launch NIST into these objectives.

2 – A steady funding source across DoE, DoD, NIST, NSF, or other sources, under a defined unified management structure, at about $30,000,000 per year is required to support these measurement efforts.

3 - Partnerships between NIST and DoE and other committed parties are essential in this area.

D. Industrial Applications and Materials Effects

In the industrial area, high current electron beams are used in the manufacture of diverse products ranging from crosslinked wire and cable jacketing, as in under-the-hood automotive wiring and aircraft wiring, heat shrinkable tubing and food packaging films, tire components, and in the drying of inks, coatings and adhesives that are made from reactive materials which effectively eliminate air pollutants. Long lived isotopes, such as cobalt-60, or alternatively X-rays derived from high powered electron beam accelerators, are used to sterilize medical devices and hold out the long-promised hope for sanitizing food and eliminating food-borne pathogens such as e-coli and salmonella, which have caused numerous illnesses and deaths resulting in costly recalls of meats, produce, eggs, etc.

The CIRMS Industrial Applications and Materials Effects (IAME) subcommittee deals with diverse uses of ionizing radiation in a myriad of industrial processes. For the most part, these are high speed, energy efficient processes. There are over 1700 high current electron beam accelerators used by industry to produce value added products, whose cumulative value has been estimated at least $75 billion US dollars. The insulation and jacketing on wire and cable are EB crosslinked to enhance flame retardency, such as in under-the-hood wiring and aircraft wiring. Tire manufacturers use EB processing in order to control the placement and stability of tire cords when they are molded into a finished tire. Heat shrinkable tubing is used to protect electrical connections; heat shrinkable wrap-around materials protect the connections in the telecommunications industry. Impervious food packaging films that recover their original shape upon heating are produced using EB crosslinking. Low-energy, self-shielded units are used to convert reactive liquid materials to produce dry inks, coatings and adhesives with near-zero volatile organic emissions, a “green” process technology. Pathogens on medical devices or in or on foodstuffs are eliminated by using ionizing radiation from either radioactive cobalt-60 sources or electron beams. The FDA and USDA have approved the use of this technology in order to protect the food supply and increase food safety. The development of very powerful electron beam accelerators has made X-rays derived from these sources a viable alternative to isotope use in the industrial area. Irradiation in the space environment and of the effects of radiation on the containment vessels of nuclear power plants are also concerns of this subcommittee. Background on the overall metrology areas of interest in the industrial area is in Appendix G. The Industrial Applications and Materials Effects MPDs are listed below. One page descriptions of the active MPDs follow in a separate section. These present the objectives, some background information and needs in each active area.

Industrial Applications and Material Effects – inactive MPDs

D.1.0 **High-Dose Calibrations for Electron-Beam Processing**

D.2.0 **Radiation Measurements for Gamma-Radiation Processing**

Industrial Applications and Material Effects – active MPDs:

D.3.4 **Radiation Hardness Testing and Mixed-Field Radiation Effects**

D.4.4 **Neutron Dosimetry for Reactor Pressure Vessel Surveillance**

D.5.3 **Medical Device Sterilization**

D.6.1 **Pollution Prevention (P2)**

D.7.3 **Food Irradiation**

D.8.1 **Low-voltage Electron Beam Dosimetry**

MPD D.3.4: RADIATION HARDNESS TESTING AND MIXED-FIELD RADIATION EFFECTS

Objective: Provide radiation hardness testing capabilities for space environments.

Background: The overall success of future space missions, including spacecraft designed for deep space exploration as well as for extended, near-earth orbits, is strongly predicated on the ability of advanced electronic components utilized in the fabrication of spacecraft and payload instrumentation and control systems to be able to operate at full capacity for extended periods of time within the unique and extremely harsh radiation environment of interplanetary space. Program managers in the National Aeronautics and Space Administration (NASA) desire to qualify high performance technologies for use in future space-based electronic systems. With a declining industrial base of radiation-tolerant (radiation-hardened) electronic components, space systems engineers are forced to turn to commercially-available parts for needed electronics. As such, these commercially-available devices require careful radiation testing, especially since their reduced size and operating power increases their vulnerability to space-borne radiation.

Existing facilities, such as those at the Naval Surface Warfare Center rely upon antiquated accelerator technology. A new facility with a large enough chamber to hold up to a cubic meter of materials and components is needed. Such facility should be able to expose materials concurrently to three types of space radiation: electron, protons and ultra-violet radiation.

Action Items:

1 – In conjunction with NASA and one of its primary contractors (such as Boeing), design and specify a new radiation exposure chamber for the evaluation of materials, including electronics, to simultaneous radiations as will be encountered in the space environment.

2 – In the meantime, promulgate the capabilities of existing facilities capable of doing radiation hardness testing, such as Naval Surface Warfare Center**,** Sandia Laboratory, Rensselaer Polytechnic Institute Gaerttner Laboratory, Kent State University NEO Beam.

3 – Promote the interaction among the different irradiation facilities to perform an intercomparison study regarding fluence measurements.

Resource Requirements:

1 – An engineering team comprised of NASA engineers and tier one space contractors will have to be assembled to do a concept design and cost estimate for a new multi-faceted facility for evaluating materials and electronics to be used in space.

2 – An expenditure of <$500,000 should be sufficient to complete a preliminary design study and cost estimate.

MPD D.4.4: NEUTRON DOSIMETRY FOR REACTOR PRESSURE VESSEL SURVEILLANCE

Objective: Sustain NIST traceable neutron dosimetry protocols for the nuclear power industry.

Background: During power operations of light-water-cooled, pressurized water nuclear power reactors, radiation-induced embrittlement will degrade certain mechanical properties important to maintaining the structural integrity of the reactor pressure vessel (RPV). Specifically, fast-neutron (E > 1 MeV) radiation-induced embrittlement of the RPV steel could lead to a compromise of the vessel integrity, under extreme conditions of temperature and pressure, through a reduction in the steel's fracture toughness. This so-called fast-neutron embrittlement is a complex function of many factors including the neutron fluence, the neutron energy spectrum, and the chemical composition of the steel. Additional factors may also come into play, such as the neutron fluence-rate, whose effects have not been fully investigated. Because of the obvious safety implications brought about by a potential breech in the pressure vessel's integrity, the US Nuclear Regulatory Commission (US NRC) has issued requirements designed to help ensure that the structural integrity of the reactor pressure vessel is preserved. In particular, fracture toughness requirements for power reactors, for both normal operating conditions and anticipated operational occurrences, are set forth in Title 10 of the Code of Federal Regulations, Part 50 (10 CFR 50), "Domestic Licensing of Production and Utilization Facilities." To satisfy the codified fracture toughness requirements, 10 CFR 50 further requires that the operators of all commercial nuclear power stations institute a neutron dosimetry program that provides measurement data for material damage correlations as a function of the fast-neutron fluence. Sustaining such studies is paramount to the US interests in revitalizing the use of nuclear power.

Action Items:

1 – Maintain NIST capabilities for neutron dosimetry.

2 – Enhance NIST's interaction with the nuclear power industry, which itself allocates substantial manpower resources to conform to NRC regulations.

Resource Requirements:

1 – With facilities and protocols in place, NIST requires a sustained commitment of a minimum of one person-year per year over the next three-year time frame.

MPD D.5.3: MEDICAL DEVICE STERILIZATION

Objective: Promulgate NIST traceable empirically verified protocols for gamma and electron beam dosimetry used in medical device sterilization.

Background: The high growth medical device industry relies on a diversity of material constructions to perform unique and sometimes intricate functions. Radiation sterilization has gained increased acceptance as a fast and efficacious means for assuring the absence of any microbial contamination on such devices. Items as mundane as cotton balls and bandages to sophisticated transdermal drug delivery systems, wound care treatment coverings and complex plastic filtration units are being sterilized by radiation processes. Almost all major producers of medical devices and numerous small companies use radiation sterilization in their device manufacturing processes. Although in the United States the Food and Drug Administration's Center for Devices and Radiological Health does not prescribe a preferred means for attaining sterility, it does require that medical devices be made under current Good Manufacturing Practices (GMP) and in doing so requires a complete protocol of record keeping, traceability, written procedures and the like. For sterilization, the FDA has accepted the standards and guidelines established by the Association for the Advancement of Medical Instrumentation (AAMI – see www.aami.org). These along with specific dosimetry test methods and procedures developed by the ASTM International (ASTM -- see www.astm.org) provide guidance to the practitioner of radiation sterilization to justify claims of product sterility and to do so within the context of GMP protocols. ASTM International lists about twelve different dosimetry methods which can be used to infer dose. However, there is no database founded on inter-laboratory testing to confirm the viability of these standards for commercial use and guide the end-user to apropos dosimeter selection based on data. This leaves the user with an incoherent metrology system and renders the user subject to competing vendor claims.

The International Atomic Energy Agency's Collaborating Center for Radiation Processing and Industrial Dosimetry has conducted two inter-laboratory studies involving nine laboratories. These inter-laboratory tests showed that only alanine dosimeters would be suitable as reference and transfer dosimeters amongst laboratories. Other published results have shown that in particular film dosimeters based on photo-chromatic changes of dyes in films to be unstable and are not made to a modicum of industrial film quality. Thus, only alanine, whether in pellet form or coated onto films, is suitable for indicating compliance with any "dose" requirements. Other methodologies may be suitable for internal process control, but not for reference purposes.

The ASTM International committee F04 on Medical and Surgical Materials and Devices has developed a Standard Method of Test which can be used to infer "dose" based upon the development of a transvinylene double bond in polyethylene (ASTM standard F-2381). This technique, the use of infra-red analysis to determine transvinylene double bonds in polyethylene,

is also used as the in-house control method by the two largest users of industrial electron beam processing. The observation of the transvinylene development in polyethylene goes back to the late 1950's when it was first found that polyethylene would crosslink when exposed to ionizing radiation from an electron beam. Since transvinylene infra-red analysis technique has been successfully used by the major users of EB processing and has been adopted as a standard by the medical device community itself, a more broadly based standard should be developed which would be supported by inter-laboratory studies. The infra-red equipment needed for this type of analysis is less costly than the equipment needed to determine the spin resonance in alanine.

Action Items:

1 – In cooperation with the IAEA Collaborating Center for Radiation Processing and Industrial Dosimetry, conduct more broadly based inter-laboratory international studies on the use of alanine as the appropriate reference dosimeter and publish the resulting database.

2 – Broaden the acceptance of a NIST dosimetry e-calibration service which relies upon alanine dosimetry.

3 – Develop an industry recognized, broadly based standard method of test based upon the infra-red analysis of the development of the transvinylene content in polyethylene. This too must be subjected to inter-laboratory studies in order to determine the precision of this method.

4 –Investigate the use of two real-time dosimetry systems currently available in the market ("Monitorad" and "Cdose") and examine the use of transistors as real-time dosimetry systems as well as other possible semiconductor and optoelectronic devices.

Resource Requirements:

1 – A multi-national dosimetry task force should be formed to implement the above action items. This will require several person years of commitment over at least a three year time frame.

MPD D.6.1: POLLUTION PREVENTION (P2)

Objective: Document the concomitant energy savings when using low-energy electron beams to eliminate volatile organic compounds (VOC's) from inks, coatings and adhesives.

Background: There have been numerous research programs, many publications and but a very few demonstration projects showing the efficacy of using electron beams to eliminate air pollutants, such as sulfur and nitrous oxides, from fossil fuel power plants and to eliminate biohazards and toxic chemicals from wastewater. However, by far, the greatest contribution of electron beam processing to pollution prevention (P2) has been the adoption of low-energy electron beams in the printing, converting and coating industries. By eliminating VOC's through the use of EB curable inks, coatings and adhesive, companies readily comply with the US Clean Air Act amendments of 1990. The technology of using reactive diluents has enabled producers to use conventional printing and coating processes, but to complement them with energy-efficient, space saving self-shielded low-energy electron beams.

The US Environmental Protection Agency (EPA) and regional air quality districts, such as the Air Quality Management District in the Los Angeles county area, have acknowledge low energy EB processing as a pollution prevention, point-of-source technique. This contrasts with the EB uses noted above for stack gas and waste water treatment and of alternative technologies, such as solvent recovery and recycling, which are considered "tail pipe" technologies, systems used after the pollutant has been generated. EB processing also eliminates some of these sources for greenhouse gases.

Low-energy electron beams are also very efficient in converting incoming line power electricity into useful ionizing radiation, between 65% to 80% of incoming power results in useful EB output. The Industry Working Group at the US Department of Energy conference on "Accelerators for America's Future" held in Washington, DC, in October 2009, estimated that if just one industry, coil coating, were to adopt EB processing, there would be sufficient energy savings to reduce power demand equivalent to that of a mid-sized power generating facility. Coil coating was selected as a market area of interest in that this was one market segment for which the EPA had published volume usage of coatings. While the US coil coating industry has not yet adopted EB processing, it is being used in a full scale production facility in Europe. Relative to the total market potential in printing and coatings, coil coating is a minor fraction.

Comparative studies are needed to document the energy savings of using EB processing versus historic uses of thermal drying and processing in diverse industrial applications. With EB processing, one can easily measure input power consumption in terms of kilowatt-hours. However, little is known about the total power consumption, including energy transfer

efficiency, for historic systems of thermal curing and drying. Such data can be generated by astute engineering studies.

Action Items:

1. Working with an industrial association, such as RadTech International North America, and its members, some of whom use low-energy EB processing, establish a program to conduct energy consumption studies on processes, thermal and EB, which are being used to make the same or comparable products. Co-funding for such a study could be obtained through the New York State Energy Research and Development Authority (NYSERDA) which is favorably disposed to support low-energy EB processing. Such a study could be conducted through the newly established UV/EB Technology Center at the State University of New York, College of Environmental Science and Forestry, a center co-funded by NYSERDA.

Resource Requirements:

1 – At least one full person-year of a process engineer is needed to define the parameters of such a study, to locate the appropriate industrial facilities to conduct such studies, to monitor energy consumption and to publish the results.

MPD D.7.3: FOOD IRRADIATION

Objectives: Establish NIST traceable protocols to calibrate and verify dosimetry for all aspects of the food irradiation process.

Establish protocols to quantify the biological effects of food irradiation.

Background: Increased concerns about the overall safety of the food supply chain in North America have, in the United States, empowered the US Food and Drug Administration (FDA) and the US Department of Agriculture (USDA) with greater inspection authority and the demand for improved methods of detection of contaminants and pathogens in foodstuffs. Outbreaks of foodborne illness resulting from Listeria, Salmonella and E. coli contamination, have spurred support for these measures from food industry groups. Thus, there is a renewed interest in the use of ionizing radiation as a method to control pathogens in food products.

Action Items:

1 – Catalog current available information on the food irradiation process now available from the USDA, FDA, WHO and other resources and post links to web sites on the CIRMS web page. In so doing, establish a network of collaboration amongst food industry technologists, the irradiation processing industry and academia, to develop a database covering the different levels of sensitivity (injury, recovery, and repair) of food pathogens to the effect of physical chemical variables (pH, temperature, food composition, nutrition, oxygen, dose and dose rate). The complex array of presently available information on the internet warrants a focused coordination. Such focus could be brought with apropos links on the CIRMS web-site.

2 – Conduct a workshop with the food processing industry and those involved in food irradiation to explain the implications of dose on the reduction and elimination of bioburden.

3 – In collaboration with processors currently engaged in irradiating food, assess various dosimetry techniques and prepare a consensus report on a preferred dosimetry method of test for establishing dose for irradiated food and related packaging materials and on dose-mapping techniques that can be used for verifying depth-dose penetration in the broad spectrum of densities encountered in food products.

4 – Include aspects of food packaging materials irradiation in such report, such as work being conducted within the Society of the Plastics Industry (SPI) in its Food, Drug, and Cosmetic Packaging Materials Committee (FDCPMC) on irradiation effects on packaging materials for food that will be irradiated in its package.

5 – Extend the use of the NIST Internet based e-calibration dosimetry service for food irradiation.

6 – Utilize complementary methodologies being developed for dosimetry metrology for medical device sterilization (MPD D.5.3).

7 – Using Monte Carlo calculations, determine the dose distributions for heterogeneous food product packages, such as boxes of chicken wings with their bones for the different modalities which can be used as sources for ionizing radiation, (gamma ray, electron beam and X-ray). Confirm such determinations with empirical dosimetry studies, giving emphasis to the precision of the D_{min} and D_{max} ratios attainable per mass or type of package of food product.

8 - Catalog available information on the characterization of the occurrence and magnitude of a recovery phenomenon for microorganisms following irradiation and, at the research level, investigate the ability to mathematically model the degree of lethal and potentially-lethal injures to micro-organisms due to irradiation, noting such factors as dose and dose rate.

Resource Requirements:

1 – A specific person, possibly within a government or university laboratory, is needed to coordinate and gather information on all of the various aspects of food irradiation, including developments in understanding the fundamental biochemistry underlying of the effects of ionizing radiation on food, as well as implications on dosimetry calibration services posed by the food irradiation process. This should be a full time effort, not taken on as an additional work assignment. A minimum of one person-year per year over the next three year time interval is needed.

2 – Retain outside consulting services as needed to supplement NIST commitments in this area.

MPD D.8.1: LOW-VOLTAGE ELECTRON BEAM DOSIMETRY

Objective: Develop an end-user technique for confirming bio-burden kill when packaging materials are exposed to low-energy electron beams.

Background: The only major new market area for electron beam processing to have emerged in at least the past twenty-five years has been the use of low-energy electron beams to decontaminate the surfaces of food and medicinal packaging materials before they are filled in aseptic environments. In a few years, this has been by far the fastest growing end-use market for EB technology. Attempts to use low-energy electron beams with one-of-a-kind calorimeter systems have not been replicated and have proven to rely more upon modeling calculations than upon test data from which dose could be inferred. Likewise, dosimeters used in higher energy EB processes have been found wanting in the low energy area (80 to 300 keV). At the lower energy range, 80 to 150 keV, the electron beam is partially absorbed in the dosimeter and then the dose measurement is not performed appropriately Albeit, even with only partial beam penetration, alanine coated films offer the greatest sensitivity to very low energy beams, responding at as low as 80 keV and at very low beam currents, less than a milliamp. Other film dosimeters, such as those which rely upon color body formation, have been found to vary in gauge thickness and manufacturing consistency beyond the tolerances normally found in film manufacture. This encumbers end users with having to make corrections for flawed product manufacture.

Other more traditional end use area of low-energy EB processing, such as the curing of inks, coatings and adhesives, have their own specific product performance test methods. For example, ASTM International D-7244, "Standard Test Method for Relative Cure of Energy-Cured Inks and Coatings," is an automated solvent rub test that can be used in the printing and coating areas. In these areas, manufacturing parameters are established with little need to rely upon an inferred dose.

Bio-burdens found on packaging materials would be down in the low micron thickness range, most likely being only a few cells thick. Techniques for assessing cell death have been developed by epidemiologists for the medical community. Such techniques rely upon assessments made of very thin biological matter. Given the limited beam penetration of the very lowest commercially available EB systems (70 to 80 keV), such beam penetration, provided the beam is not lost in an air gap, would be sufficient to affect such biological matter. Radiation effects on cellular matter can show up in changes in the fluorescence of some specific moieties or in the inability of cells to propagate in a polymerase chain reaction (PCR). Microbial fluorescence and real-time PCR are methodologies that have been evaluated in other areas. Here too in these new decontamination uses of low –energy EB one would no longer have to rely upon an inference of dose.

Action Items:

1 – Develop a real-time bio-burden kill methodology based upon epidemiological techniques used in other areas.

2 – Conduct inter-laboratory comparison studies involving low-voltage EB users and equipment suppliers to validate the direct use of biodosimetry for these surface decontamination applications.

3 – Develop dosimetric techniques useful in the electron energy range of 80 keV to 150 keV.

Resource Requirements:

1 –NIST should assemble an inter-disciplinary team to develop the protocols for using bio-dosimetry with low-energy electron beams. This is at least a two person-year effort.

2 – NIST should acquire a low-energy electron beam ($250,000) in order to implement this need in the low-energy EB area.

F. COMPUTATIONAL NEEDS

The use of mathematical modeling underlies many of the diverse uses involving ionizing radiation. The Ionizing Radiation Division in the Physics Laboratory at the National Institute of Standards and Technology (NIST) has been a pioneer in the development of codes widely used in such modeling. These codes are used in medical, industrial and radiation-protection applications. At NIST, Monte Carlo calculations for dosimetry are cross-checked with ionizing radiation measurements. NIST graphite-wall cavity-ionization chambers serve as the national standard for air-kerma (radiation exposure). Wall corrections obtained from Monte Carlo calculations will adjust air-kerma standards world-wide by up to about 1%. Accurate measurements and calculations of absorbed dose play a significant role in industry, ensuring adequate dose in radiation processing (medical device sterilization, bioagent deactivation, etc.). In medical applications, assessing dose rate accurately is critical to effective treatment planning and fulfilling regulatory constraints.

Recognizing this broad-based use of computational methods, a Measurement Program Descriptions has been modified to express current computational needs. In this area, one MPD is presented:

F.1.1. **Improvements to Computational Methods for Radiation Dosimetry**

MPD F.1.1: IMPROVEMENTS TO COMPUTATIONAL METHODS FOR RADIATION DOSIMETRY

Objectives: Modify existing codes so that they are useable on present day computer operating systems.

Provide better end-user access to existing computational codes.

Background: Computations have increasingly become a vital part in the chain of steps that relate measurement to dose or kerma. Dosimetric calculations are rooted in comprehensive evaluations of data that describe the basic physical interactions of radiation with matter. These evaluations are then utilized by computer codes that simulate the macroscopic measurement system under consideration, modeling the system in all necessary detail. These computer codes can be deterministic, but more often employ the Monte Carlo technique of particle transport. In addition to their vital role in the standards and measurement process, such codes find increasing use in radiation protection, medical, industrial and security applications involving dosimetry.

Some existing codes still require users to enter data in older computer languages, such as Fortran. Unlike present day computer operating systems, such as the widely used Windows platform, these older codes are less tolerant of errors in data entry and often generate an abundance of data, much of which is not germane to the specific circumstances being modeled. Often times data output has to be transcribed into another program in order to have graphics that clearly illustrate the output of the probability code. The RT-Office code, for example, has been developed in Eastern Europe which functions on a Windows platform, maintains a database of properties of commonly used materials, and generates easily understood graphics directly.

Within the US, access to codes is inhibited by a complex arrangement with the Department of Energy's Oak Ridge National Laboratory. Royalty fees for alleged maintenance of these codes are charged on a single-user basis. Many of these codes have been developed by taxpayer funded efforts, such as those developed at NIST. It was the opinion of an Industry Working Group at the DoE's 2009 conference on "Accelerators for America's Future," that such intellectual property developed at public expense should be widely available to the public at minimal service costs. In the computational area, this would facilitate the use of these codes in the teaching environment and broaden the end-user use of mathematical simulation. This would bring the US into line with the practice more common in the European Union where laboratories make codes available upon request. The International Atomic Energy Agency (IAEA) has recently published a booklet on the **Use of Mathematical Modeling in Electron Beam Processing: A Guidebook** and when purchased in hard copy (42 Euros) includes a disk with the commonly used codes on it.

With such a diversity of sources for physical data and for simulation codes, there is a wide variety of applications that make critical use of these methods. In recent years, modeling was useful in establishing depth-dose profiles for the US Postal Service as it adopted radiation treatment to decontaminate mail from potential biohazards, such as anthrax (see Appendix H). Simulations have also been used to study of the possible treatment of high-risk passenger luggage in order to mitigate bioagents and pests. In the radiation therapy field, NIST participated in a study of the dosimetry of beta-emitting brachytherapy sources comparing code results with calibration measurements. The medical community is also finding uses for these codes as exemplified in the development of three dimensional (3D) dosimetry techniques (see MPD A.3.4).

There is a vital effort in using simulations in standards, homeland-security, industrial, radiation-protection and medical applications depends on the health of the underlying code-development efforts. These codes, however, must be in a user friendly computer platform and readily available to the end-user community.

Action Items:

1 – Provide adequate computational resources for NIST to translate the most widely use simulation codes into present day computer operating systems.

2 – Since the use of these codes involves a broad base of industry, the medical community, academia and government, the custody and management of these codes should transferred to NIST, where, in fact, some codes originated. NIST, through its Measurement Services, is properly structured to provide fast and competent user response.

Resource Requirements:

1 – In order to translate the major simulation codes into access via present day computer operating systems, maintain current competency, a minimum of two person-years is required.

2 – The transfer of the custody of existing codes from the Department of Energy to the Department of Commerce will require members of the concerned user community to directly address Congress on this issue.

Appendix A

Introduction to CIRMS

CIRMS Mission and Vision

CIRMS Vision Statement

The **Council on Ionizing Radiation Measurements and Standards (CIRMS)** is an independent proactive forum that provides leadership, focus, action, and information dissemination across all aspects of all irradiation disciplines involving a wide range of ionizing radiation measurements and standards topics.

CIRMS is *THE* council that speaks for the ionizing radiation measurements and standards community and works with national and international standards groups to bring consensus, consistency, and commonality in applications involving industry, academia, and government needs.

CIRMS Objectives

- CIRMS is an open FORUM for discussion
- CIRMS seeks to stimulate COLLABORATION amongst:
  Government
  Industry
  Academia
- CIRMS gathers information and then ARTICULATES NEEDS
- CIRMS facilitates PRIORITIZATION of needed work
- CIRMS RECOMMENDS ACTION steps
- CIRMS provides INFORMATION to NIST and other national laboratories in order to promote better, more consistent standards
- CIRMS attempts to provide the SECONDARY LABORATORIES with information and data that will strengthen their capabilities
- CIRMS DISSEMINATES INFORMATION on STANDARDS through its web site: www.cirms.org
- CIRMS holds WORKSHOPS in order to bring specific issues into greater focus
- CIRMS holds annual MEETINGS that challenge its vision

Goals

- Provide a FORUM for the inter-disciplinary exchange (drawn from government, academic, and industrial constituency) of information on ionizing radiation measurements and standards topics.

- Gather INFORMATION, analyze, and build consensus and prioritize information on ionizing radiation measurements and standards.

- Seek to HARMONIZE standards through selection, avoidance of duplication, mutual recognition, verification and comparability.

- Disseminate, coordinate, and RECOMMEND actions on ionizing radiation measurements and standards.

How does CIRMS serve as a forum?

- Through CIRMS annual meetings
- By outreach to national and international organizations
- By dialog with regulators and policy-makers
- Through focused subcommittees
- Through interagency coordination
- By challenging proactive members in cross-cutting disciplines / agencies / industries
- Through teleconferencing processes and use of the Internet

How does CIRMS disseminate information?

- CIRMS Needs Reports
- CIRMS web page and interactive e-mail
- Improved international communications

CIRMS Strategies

- Establish an outside and a champion within the NIST Ionizing Radiation Division for each Measurement Program Description (MPD)
- Determine key interface point-of-contacts for CIRMS
- Determine the resources needed to implement a given MPD
- Determine facilitator roles and choose active facilitators to achieve goals

- Provide fact sheets on major areas
- Establish needed interactions with other organizations involved in ionizing radiation, especially those involved in standards and measurements
- Maintain dialog with the international standards community
- Determine areas of deficiencies and recommend needed actions

Mission Areas for CIRMS

Diagnostic Radiology
Radiation Therapy
Nuclear Medicine
Environmental Radioactivity
Health Physics
Radiation Sterilization
Food Safety
Nuclear Electric Power
Radiation Processing
Homeland Security

CIRMS Operations and its CIRRPC Predecessor

The Council on Ionizing Radiation Measurements and Standards (CIRMS – www.cirms.org) is an independent, non-profit council that draws together experts involved in many diverse areas involving the use of ionizing radiation to discuss, review and assess developments and needs that enhance the societal benefits of this technology. With input from expertise in industry, in academia and in government, including those in national laboratories, Federal agencies and departments, CIRMS now issues its fifth report on "Needs in Ionizing Radiation." To maintain a coordinated effort, CIRMS rotates its officers from among its three main constituencies (industry, academia and government), so that every third year the President of CIRMS rotates among each of these areas. CIRMS Past-Presidents and current officers are listed above. The CIRMS Science and Technology Committee is comprised of four sub-committees: 1) Medical Applications, 2) Personnel and Environmental Radiation Protection (PERP), 3) Homeland Security, and 4) Industrial Applications and Materials Effects (IAME). Details on CIRMS objectives and mission can be found in Appendix A; a brief history of CIRMS is in Appendix B. This information is also on the CIRMS web site: www.cirms.org.

When CIRMS was formed in 1991, one of its objectives was to supplement the coordination functions of the then federally funded Committee on Interagency Radiation Research and Policy Coordination (CIRRPC), which was chartered in April 1984 and which was expected to longer be supported by Federal departments and agencies. Such funding had been mandated by both statute and by Presidential Executive Order but, with the reorganization of Federal science entities in the mid-1990's, CIRRPC cease to exist as of September 1995. CIRMS also sought to provide guidance to the Ionizing Radiation Division of NIST on the metrology issues confronting the use of ionizing radiation in the medical area, in the area of personnel radiation protection, when dealing with Homeland Security requirements and in various industrial uses of ionizing radiation. The first four "Needs Reports" (1994, 1998, 2001, and 2004), delineated such "needs" as Measurement Program Descriptions (MPDs). In recent years, a number of strategic issues have emerged that pose challenges to the use of ionizing radiation and the societal benefits it has and can provide. Some such issues do not involve metrology, but are related to policy and resource allocation issues that demand attention today. Thus, this "Needs Report" also briefly notes some specific policy issues that should be addressed within the context of Congressional oversight and appropriations.

In contrast to its antecedent, CIRRPC, CIRMS is a non-governmental open forum relying upon volunteer efforts to organize its programs and workshops and upon funding through corporate sponsors, organizational, individual and student memberships (at $500, $250, $50 and $25 per year respectively). CIRMS operating budget over its nineteen years of existence has been approximately $10,000 per year. CIRRPC, which had been chartered by the Office of Science and Technology Policy (OSTP), operated on an annualized budget of approximately $1,200,000.

This enabled CIRRPC to maintain a full time staff and to conduct its own studies affecting US policy in radiation research. Twelve cabinet level federal departments and seven federal agencies and federally funded entities formed the CIRRPC membership: CIRRPC was an internal federal government policy coordinating committee. Fortunately, some of these federal departments and agencies have sustained modest support for CIRMS over the years. CIRMS, however, has brought in non-government input from industry and academia into the areas involving the use of ionizing radiation, creating an open forum, although not at the levels of fiscal support that had been attained by CIRRPC.

Appendix B

CIRMS Origin, Background and Operations

BUILDING A FORUM

THE START AND GROWTH OF THE COUNCIL ON IONIZING RADIATION MEASUREMENTS AND STANDARDS

Getting Started:

On January 8, 1991, Randy Caswell, then Chief of the Ionizing Radiation Division at the National Institute of Standards and Technology (NIST), invited a number of representatives from various academic and industrial associations and from different government agencies to attend a meeting at NIST on Tuesday, February 26, 1991. The purpose of this meeting was to discuss the formation of a new group that could bring to the Ionizing Radiation Division some "outside" perspective on the needs and longer-term goals involving almost all uses of ionizing radiation. This group would be patterned after the Council on Optical Radiation Measurements (CORM) that had been formed in 1972 to provide such guidance and commentary to the National Bureau of Standards (NBS), which subsequently became NIST, in the area of optical measurements and technology.

"Letters we have received and many discussions have pointed to the need for a committee to coordinate activities by NIST and others in the area of ionizing radiation measurements and standards."

Randy Caswell, Chief
NIST Ionizing Radiation Division
January 8, 1991

Of concern to those 27 attendees at this meeting was that the budgetary pressures of the time would shrink and diminish the effectiveness of federally funded coordinating committees and councils, such as the Committee on Interagency Radiation Research and Policy Coordination (CIRRPC), chartered in April, 1984. This could leave a void in providing coherent direction to the scientific and technology efforts in ionizing radiation. Also of concern was how the now designated National Institute of Standards and Technology would integrate its added congressionally mandated tasks of supporting the development of commerce and industry to these efforts.

The 16 organizations and associations present at this formation meeting all endorsed the concept of forming such a council, as did others who could not attend. Besides NIST personnel, this included representatives from DOD, FDA, the Federal Emergency Management Agency (FEMA) and NASA. The name of the council, the Council on Ionizing Radiation Measurements and Standards (CIRMS), was decided upon and a short list of possible functions was agreed upon. In addition, an Organizing Committee was formed to develop a structure for this new council and provide an initial slate of officers. This committee was composed of Randy Caswell as Chairman, Tom Heaton from the FDA, Bill Eckelman from NIH and Tony Berejka, from the industrial association, RadTech International North America.

Convening at a June 17, 1991, meeting, the Organizing Committee went about the business of developing DRAFT By-Laws, filing papers for incorporation in Maryland and applying for CIRMS 501c3 tax-exempt status from the IRS, with a substantial amount of detail being handled by NIST retiree, Elmer Eisenhower. A key point all had agreed upon was that the Council would be a distinct, privately funded entity, not dependent upon any specific allocation of government funding. A modest dues structure was developed, separating membership into three categories: corporate, organizational and individual.

In the development of the CIRMS By-Laws, an Executive Committee consisting of the President, a First Vice-President, a Second Vice-President, a Secretary-Treasurer, and a NIST representative were spelled out, with the Vice-Presidents succeeding each other and the President on a one year basis. As a matter of policy, the Organizing Committee felt that it would be best for the Council to rotate the elected officers from amongst the three main constituencies of the Council: industry, academia and government. A committee and subcommittee structure as it still stands was incorporated into the By-Laws.

By early 1992, the Organizing Committee had received acceptance from candidates for the elected offices in CIRMS and met at NIST on March 31, 1992, with these officers:

President: Marshall Cleland, then with Radiation Dynamics, Edgewood, NY.
First Vice-President: Peter Almond, University of Louisville, KY.
Second Vice-President: Tom Bell, DoE in Germantown, MD.
Secretary-Treasurer: Elmer Eisenhower, NIST retiree.

As the first CIRMS President, Marsh Cleland sent out letters of invitation on May 14, 1992, to various organizations, agencies and individuals to officially join CIRMS and to attend CIRMS first annual meeting, to be held at NIST on October 22 and 23, 1992. This inaugural day and one-half long meeting drew 63 participants and focused mainly on what CIRMS was and where it could be most effective. Following opening remarks by Katharine Gebbie, Director of the NIST Physics Laboratory, and Randy Caswell on "The Objectives of CIRMS," President Cleland

chaired the opening day's major session. This was a panel presentation on "The Diversity of Ionizing Radiation Needs." Needs in 1) nuclear medicine, 2) radiation oncology, 3) diagnostic radiology, 4) industrial processing, 5) industrial radiography, 6) nuclear energy radioactivity, 7) nuclear power materials dosimetry, 8) defense, 9) radon, and 10) environmental radioactivity were addressed by a series of distinguished panel members. Bert Coursey followed this with a presentation on "The Commonality of Measurement and Standards Problems." As First Vice-President, Peter Almond then led an open discussion on "Bringing Diverse Uses and Common Interests Together." Elmer Eisenhower closed the day's activities by reviewing the CIRMS By-Laws. Tom Bell, as Second Vice-President, led the following morning's open discussion of the CIRMS committee structure and of what kind of tasks these committees could undertake.

By mid-February 1993, the chairmanships of the various committees had been sorted out. Bill Koch, a retired Chief of the NIST Radiation Physics Division and long-time Director of the American Institute of Physics, now at the University of Colorado, assumed the Chairmanship of the Science and Technology Committee. Tom Heaton, FDA, lead the Medical Subcommittee; Carl Gogolak, EML, the Public/Environmental Radiation Protection Subcommittee (PERP); Ken Swinth, then with Battelle Pacific Northwest Laboratory, the Occupational Radiation Protection Subcommittee (ORP); and Walt Chappas, then at the University of Maryland, the Radiation Effects Subcommittee. These were then and are still the designated subcommittees of the Science and Technology Committee as determined by the Committee Chair in consultation with the Executive Committee. Tony Berejka became Chairman of the Program Committee; Elmer Eisenhower Chair of the Finance Committee; Bill Casson, then at ORNL, Chair of the Communications Committee; and Second Vice-President Tom Bell, Chair of the Membership Committee. The NIST representative on the CIRMS Executive Committee was Randy Caswell (upon Randy's retirement in 1994 he was succeeded by Bert Coursey). With the initial officers in place and the Chairmanships of the Committees spelled out in the By-Laws filled, CIRMS became a functioning organization.

Building an Open Forum:

Annual Meetings: Following the initial meeting in 1992, annual meetings have been held every fall at NIST with the then President presiding over the meeting. Over the years these have evolved from topical presentations to focusing the major portion of the meeting on a single subject. As subcommittee participation has increased and the impact of the subcommittees became more noticeable, more time has been devoted to the subcommittees themselves reviewing and discussing their programs using a workshop format within the context of the meeting.

CIRMS Annual Meetings

Dates	Chair/President	Topic/Emphasis
October 22 and 23, 1992	Marshall Cleland	Formation meeting
November 8 to 10, 1993	Marshall Cleland	Medical Uses
November 16 to 18, 1994	Peter Almond	Measurement Quality (MQA)
November 28 to 30, 1995	Tom Bell	Advanced Techniques
November 12 to 14, 1996	Tony Berejka	Academic Contributions
November 12 to 14, 1997	Larry DeWerd	Secondary Laboratories
October 19 to 21, 1998	Bob Loesch	National Labs/Agencies
October 13 to 15, 1999	Tom Slowey	Subcommittee Activities
October 30 to November 1, 2000	George Xu	Advanced Radiation Measurements
October 29 to 31, 2001	Joe McDonald	Radiation Standards for Health & Safety
October 21 to 23, 2002	Art Heiss	Traceability and Standards
October 27 to 29, 2003	Geoff Ibbott	Radiation and Radioactivity Measurements and Standards in Industry
October 25 to 27, 2004	Jim Deye	Biological Dosimetry Measurements and Standards
October 24 - 26, 2005	R. Craig Yoder	Impact of New Technology on Radiation Measurements and Standards
October 23 - 25, 2006	Mohamad Al-Sheikhly	Implications of Uncertainty in Radiation Measurements and Applications
October 22 - 24, 2007	Shawna Eisele	Measurements and Standards for Radiation Based Imaging
October 6 - 8, 2008	Manny Subramanian	Radiation Measurements and Standards at the Molecular Level
October 19 - 21, 2009	Nolan Hertel	Radiation Standards and Measurements for Incident Response
October 18 - 20, 2010	Kim Morehouse	Ionizing Radiation Sources: Uses, Availability, and Options
October 17 - 20, 2011 (20th annual)	Chip Starns	Public Perception of Radiation

Newsletter/Web Site:

In the spring of 1994, CIRMS launched its own Newsletter. Under the editorial leadership of Bill Casson, the CIRMS Newsletter contained not only summaries of the organization's own efforts and activities, but also featured a broad range of topics of general interest to the entire ionizing radiation community. The CIRMS Newsletter has shifted format and news items are now incorporated and linked into on the CIRMS web site: www.cirms.org . This was inaugurated by Bill Casson and then supported by efforts from Past-Presidents Tom Slowey and Bob Loesch. Bob Loesch has taken on the responsibility of being the CIRMS "webmaster." Using this electronic media, more timely information can be conveyed to the CIRMS membership. Links are provided to CIRMS sponsors, related scientific and technical meetings and to each of the subcommittees of the Science and Technology Committee. CIRMS meeting summaries are also posted as well as links to papers given at CIRMS annual meetings.

In January 2011, CIRMS launched an entirely new web site which has a more complete background on the organization and a library with links to past "Needs Reports" and to other relevant documents available on the Internet.

Needs Reports:

During the CIRMS second annual meeting in 1993, the Science and Technology Committee agreed to prepare what was expected to be a series of regular reports on "National Needs in Ionizing Radiation Measurements." Bill Koch, the Chairman of the Science and Technology Committee worked with the chairmen of the four subcommittees who in turn developed 22 Measurement Program Descriptions (MPDs) in collaboration with their subcommittee membership. These subcommittee chairmen were:

Medical Subcommittee: Tom Heaton
Public/Environmental Radiation Protection: Carl Gogolak
Occupational Radiation Protection: Ken Swinth
Radiation Effects: Roger Clough

The process of developing a format as well as content took a number of months. After full review by the CIRMS Executive Committee, President Peter Almond, and concurrence with all subcommittee chairs, the first report on "National Needs in Ionizing Radiation Measurements" was published in January 1995. This report was widely distributed not only amongst NIST management and CIRMS membership, but also to key decision-makers in other federal agencies. CIRMS decided to periodically review the progress on the programs described in this report and to produce such a report on a triennial basis. Joe McDonald succeeded Bill Koch as the Chairman of the Science and Technology Committee and thus assumed editorial responsibility

for the second report on "National Needs in Ionizing Radiation Measurements and Standards" published in 1998. Progress was noted on various MPDs, some being completed, and new ones being added, with there being 23 MPDs in the new report. More extensive introductory sections were written and some pictures incorporated into the text to show equipment and facilities used in conducting the work needed to meet the objectives described in these program descriptions. Each subcommittee prepared a roadmap for one of the MPDs in their section. The overall text increased from the 62 pages of the first report to 106 in the second. Again, the actual coordination in pulling together these MPDs was lead by the subcommittee chairs:

Medical Subcommittee: Tom Heaton
Public/Environmental Radiation Protection (PERP): Dave McCurdy
Occupational Radiation Protection (ORP): Ken Swinth
Industrial Applications and Material Effects (IAME): Paul Farrell

Following a similar CIRMS review process, this second "National Needs in Ionizing Radiation Measurements and Standards" was released by President Bob Loesch in time for the 1998 annual meeting. These first two "National Needs Reports" have been made available on the CIRMS web site.

The third "Needs Report" was released in October 2001 by President Joe McDonald. Past-President Tony Berejka was the editor, being the Chairman of the Science and Technology Committee. The roadmap concept was dropped in that for many MPDs the first action item was to obtain funding for the program described. It was also difficult to convey such roadmaps in concise graphics. A standardized format for all MPDs was introduced consisting of four sections: 1) the statement of the objective(s), 2) background information, 3) action items needed to meet the objective(s), and 4) resources, both in terms of personnel and equipment, required. Sixteen MPDs were included, reflecting the greater focus attained by reviewing the MPDs during the CIRMS annual meeting. The entire report was 110 pages, including introductory and appendix materials. Graphics were controlled so that the entire report could be easily transmitted over the Internet in a condensed format. The 2001 "Needs Report" was made available in both print and compact disk (CD) format. The subcommittee chairs again pulled together the needed input:

Medical Subcommittee: Tom Heaton and Larry DeWerd
Public/Environmental Radiation Protection (PERP): Dave McCurdy and Ken Inn
Occupational Radiation Protection (ORP): Ken Swinth
Industrial Applications and Material Effects (IAME): Roberto Uribe and Ken Koziol

The fourth "Needs Report" released in 2004 reflected several changes within CIRMS. The word "National" was dropped from the title since there is a growing international involvement in the

radiation standards and measurements community. Three overseas national laboratories, the National Physical Laboratory (NPL) in the United Kingdom, the Austrian Research Centre Seibersdorf (ARC), and the Physikalisch-Technische Bundesanstalt (PTB) in Germany, are organizational sponsors of CIRMS. In addition, representatives from other areas, such as Canada, Denmark (the Risø National Laboratory), and from the International Atomic Energy Agency have been participants in CIRMS meetings, often giving formal presentations. A realignment of the subcommittee structure was brought about by combining the PERP and ORP subcommittees into a single Radiation Protection subcommittee. The CIRMS interests in Homeland Security were included amongst the Radiation Protection MPDs. An independent Homeland Security subcommittee is in its formative stage. At previous CIRMS annual meetings, the critical role of computational methods in a variety of areas became more and more apparent. Thus a section on Computational Needs was developed. Tony Berejka again served as editor with the assistance of the chairpersons of the Science and Technology subcommittees and NIST personnel:

Medical Subcommittee: Larry DeWerd and Geoff Ibbott
Radiation Protection: Ken Swinth, Ken Inn and Carl Gogolak
Homeland Security: Mike Unterweger
Industrial Applications and Material Effects (IAME): Roberto Uribe and Ken Koziol
Computational: Steve Seltzer and Paul Bergstrom

The fourth "Needs Report" was posted on the CIRMS web site and is available only in CD format. This is the fifth "Needs Report" and it too will be on the CIRMS web site and available on a flash drive.

Workshops:

CIRMS sponsorship or co-sponsorship of topical workshops has facilitated the implementation of many of the MPDs. These have been held at NIST or at other appropriate venues. The Medical subcommittee has worked in cooperation with the American Association of Physicists (AAPM). The PERP subcommittee had interacted with appropriate subcommittees within the ASTM International (ASTM) that deal with radioactivity measurements. The ORP subcommittee collaborated with the Health Physics Society (HPS). These interactions are maintained as well as those of the IAME subcommittee members with ASTM International subcommittees dealing with dosimetry. Such collaboration, as well as responsiveness on the part of NIST's Ionizing Radiation Division, has brought some MPDs to successful conclusion and enabled significant progress to be made on others.

Over the years, CIRMS has sponsored or co-sponsored over 40 workshops, averaging three or four per year. These workshops bring together a community of interest in a particular topic and

begin to form the basis for new Measurement Program Descriptions (MPDs) – See Appendix C. The workshop format has been adopted as a forum within the annual meeting with each subcommittee structuring its break-out session as more succinct workshops focusing on the general theme of the meeting.

CIRMS Workshops

Date	Topic	Subcommittee
June 1994	Ocean Studies SRMs	PERP
March 1995	Radionuclide Speciation	PERP
March 1995	New NVLAP Criteria	ORP
September 1995	MQA for Gamma Processing	IAME
April 1996	Absolute Dose Measurements	Medical
April 1996	Mutual Accreditations	ORP
June 1996	Radiation Sterilization of Medical Devices	IAME
July 1996	Mid-year Workshop	PERP
July 1996	Mid-year Workshop	ORP
July 1996	Mutual Accreditations	Medical/ORP
September 1996	Therapeutic Radionuclides for Bone Palliation	Medical
February 1997	NIST Radiochemistry Intercomparison Program	PERP
March 1997	Iodine-125 Brachytherapy	Medical
October 1997	High Dose Electron Beams	IAME
October 1997	Electronic Personnel Dosimetry	ORP
March 1998	NIST Radiochemistry Intercomparison Program	PERP
April 1998	Measurements and Standards for Brachytherapy	Medical
September 1998	Radiation Protection Dosimetry	ORP
April 1999	Low-level Radionuclide Mass Spectrometry and Atom-Counting	PERP
April 1999	Measurements for Prostate Therapy Seeds	Medical
May 1999	µR-level Measurements and Standards	PERP
April 2000	Radiation Measurements in Support of Nuclear Material and International Security	General

April 2000	Computational Radiation Dosimetry	General
May 2000	Estimating Uncertainties for Radiochemical Analyses	PERP
October 2000	Dosimetry for Radiation Hardness Testing	IAME
October 2000	Measurements and Standards Infrastructure for Brachytherapy Sources	Medical
October 2000	Laboratory Accreditation for Personnel Dosimetry	ORP
October 2000	Drum Assay Intercomparison Program	PERP
October 2001	*In vivo* Radiobioassay Phantoms	PERP/ORP
October 2001	Food Irradiation	IAME
October 2001	Intravascular Brachytherapy Sources	Medical
February 2002	Ultra-Sensitive Uranium Isotopic Composition Intercomparison Planning Meeting	PERP
September 2002	Electron Beam Treatment of Biohazards	IAME
October 2002	Traceability and Standards in the Medical Physics Community	Medical
October 2002	Traceability and Standards for Homeland Security	PERP/ORP
October 2002	Traceability and Standards in High-Dose Applications	IAME
April 2003	Advances in High Dose Dosimetry	IAME
October 2003	Annual Meeting Focus: Radiation and Radioactivity Measurements and Standards in Industry Subcommittee break-out sessions	Medical RP HS IAME
October 2004	DHS-EML/CIRMS REALnet (Radiological Emergency Analytical Laboratory Network) workshop	RP/HS
October 2004	Annual Meeting Focus: Biological Dosimetry Measurements and Standards Subcommittee break-out sessions	Medical RP HS IAME

Student Awards:

In order to foster the development of young scientists and technologists in the various aspects of ionizing radiation, during 1999 CIRMS developed a Student Awards program, guided by then First Vice-President George Xu. Since then, CIRMS has awarded 48 Student Awards to cover the costs involved in attending the annual CIRMS meeting to graduate students from 21 different institutions. Each student presents a poster paper and gives a ten minute oral presentation covering his or her project. Summaries of these presentations are posted on the CIRMS web site. This program is an integral part of the annual meetings and flourishes with sustained sponsorship from some of CIRMS members, notably the Thermo-Electron Corporation, IBA Industrial Incorporated, ASTM International and NIST.

Year	Student	Institution	Area of Interest
1999	Ariel Drogin	University of Kentucky	Medical
	Jennifer Smilowitz	University of Wisconsin	Medical
	Oleg Povetko	Oregon State University	PERP
	Ahmet Bozkurt	Rensselaer Polytechnic Institute	ORP
	Kirt Marlow	Idaho State University	IAME
2000	Lesley Buckley	University of Wisconsin	Medical
	Peter Caracappa	Rensselaer Polytechnic Institute	Medical/ORP
	Scott Larsen	State University of New York	IAME
2001	Kurt Stump	University of Wisconsin	Medical
	Brigitte Reniers	Universite Catholique de Louvain	Medical
	Matt Buchholz	Oregon State University	PERP
	Michael Czayka	Kent State University	IAME
2002	Wes Culberson	University of Wisconsin	Medical
	Dickerson Moreno	University of Missouri	PERP/ORP
	Michael Shannon	Georgia Institute of Technology	PERP/ORP
	Ramazan Kizil	Penn State University	IAME
2003	Sheridan L. Griffin	University of Wisconsin	Medical
	Malcolm P. Heard	University of Texas	Medical
	Baodong Wang	Rensselaer Polytechnic Institute	PERP/ORP
	Shannon Helfinstine	Kent State University	IAME

2004	Jennifer R. Clark	University of Kentucky	Medical
	Stephen Davis	University of Wisconsin	Medical
	Carlos Roldan	University of Massachusetts Lowell	IAME
2005	Eric Burgett	Georgia Institute of Technology	Homeland Security
	Mark Furler	Rensselaer Polytechnic Institute	PERP/ORP
	Andrew Jensen	University of Wisconsin	Medical
2006	Kimberly Burns	Georgia Institute of Technology	PERP
	Maisha Murry	University of Cincinnati	Medical/HS
	Karl Benjamin Richter	University of Minnesota	IAME
	Reed Selwyn	University of Wisconsin	Medical
2007	Jianwei Gu	Rensselaer Polytechnic Institute	Medical
	Arman Sarfehnia	McGill University	Medical
	Sarah Scarboro	Georgia Institue of Technology	Medical/HS
	Zachary Whetstone	University of Michigan	PERP/HS
2008	Regina M. Kennedy	University of Wisconsin	Medical
	Matthew Mille	Rensselaer Polytechnic Institute	Medical
2009	Marina K. Chumakov	University of Maryland	IAME
	Ryan Grant	University of Texas M.D. Anderson Cancer Center	Medical
	Jessica R. Snow	University of Wisconsin	Medical
	Walter Voit	Georgia Institute of Technology	IAME
2010	Keith Hearon	Texas A&M University	IAME
	Steven Horne	University of Texas	PERP/ORP
	Regina Kennedy	University of Wisconsin	Medical
	Charlotte Rambo	Texas A&M University	IAME
2011	Austin Faught	University of Texas	Medical
	Gina Paek	Chapman University	IAME
	Adam Paxton	University of Wisconsin	Medical

Distinguished Achievement Awards:

At the annual meeting in 2002, "The Council on Ionizing Radiation Award For Distinguished Achievements in the Field of Ionizing Radiation Measurements and Standards" was initiated.

Randy Caswell, the former Chief of the Ionizing Radiation Division at NIST and the person who help create CIRMS was given this award. Subsequently, the award was renamed in Randy's name. In 2004, H. Thompson Heaton, II, from the Center for Devices and Radiological Health, of the US FDA was the recipient. For many years, Tom had chaired or co-chair the CIRMS Medical Applications subcommittee and was instrumental in its success. In 2004, "The Council on Ionizing Radiation Measurements and Standards 2004 Randall S. Caswell Award for Distinguished Achievements in the Field of Ionizing Radiation Measurements and Standards" went to CIRMS Past-President and longtime Chairman of the Science and Technology Committee, Tony Berejka.

Year	Caswell Award Winners
2000	Randall S. Caswell, NIST
2002	H. Thompson Heaton, II, US FDA
2004	Anthony J. Berejka, Ionicorp^{+}
2006	Kenneth L. Swinth, Swinth Associates
2007	Bert M. Coursey, US Department of Homeland Security
2008	Larry A. DeWerd, University of Wisconsin
2009	Marshall R. Cleland, IBA Industrial, Incorporated
2010	Geoffrey Ibbott, University of Texas, M.D. Anderson Cancer Center
2011	Kenneth G. W. Inn, NIST

Organizing for Achievement:

Dialog:

From its inception, CIRMS implemented several organizational procedures to assure that this new forum, that covers all aspects of ionizing radiation, would remain open and operate smoothly. Monthly conference calls amongst the members of the Executive Committee were immediately initiated. Now the chairs of the subcommittees of the Science and Technology Committee are invited to participate and guide the organization in its day-to-day activities.

Structure:

At the second annual meeting that was held in 1993, Elmer Eisenhower accepted the role of Executive Secretary. His functions as Secretary-Treasurer were then taken over by Ken Inn who was elected by the membership to that post. Ken served in that capacity until the 1998 annual meeting when John Micka was elected Secretary-Treasurer. The functions of Secretary and Treasurer have now been split with Past-President Tom Slowey serving as Treasurer and Sandy

Perle as Secretary. In mid-1995, Elmer Eisenhower expressed his desires to fully enjoy his retirement from NIST. The CIRMS Executive Committee thereupon began to search for a replacement. With good fortune, CIRMS found Katy Nardi and commenced to retain her as the Council's Executive Secretary. As CIRMS has grown, Katy has assumed more and more of the administrative tasks in keeping the organization going. For example, she works closely with NIST's conference management personnel to assure that the annual meetings proceed without flaw.

As CIRMS has grown, the subcommittees of the Science and Technology Committee have found it beneficial to be co-chaired so that there is not that heavy a reliance on any one individual. The Medical Subcommittee is now co-chaired by Past-Presidents Larry DeWerd and Geoff Ibbott. The Public and Environmental Radiation Protection Subcommittee (PERP), formerly co-chaired by Dave McCurdy and Ken Inn, and the Occupational Radiation Protection (ORP), chaired by Ken Swinth, have been merged into one subcommittee, Radiation Protection, dealing with all facets in this area. For now, the interests in Homeland Security are expressed amongst those in the Radiation Protection area, whose subcommittee is now chaired by Ken Inn. A distinct Homeland Security subcommittee is being Co-Chaired by Mike Unterweger from NIST and David Taylor from DHS/ TSA.

Executive Interaction:

On September 11, 1995, CIRMS President Tom Bell held a meeting of the Executive Committee and subcommittee chairs at NIST to review the overall goals and objectives of the organization. By then, having several years of operational experience, CIRMS reformulated its Mission Statement and tightened the language of some of its original goals and objectives. These are now also posted on the CIRMS web site and are presented in the table below. Since then, every year the CIRMS Executive Committee convenes, prior to the annual meeting, to hold its annual retreat. With the chairs of the subcommittees of the Science and Technology committee present recent retreats have focused on the progress being made on the MPDs as spelled out in the "Needs Reports." Operational issues, such as the development of the web site, annual meeting program planning, and the like are also addressed.

Summary:

In a few brief years, the Council on Ionizing Radiation Measurements and Standards has constructed a unique open forum for dialog on all aspects of ionizing radiation. The Council is truly unique with its membership coming from all (3) areas related to ionizing radiation standards; industry, academia, and government. The CIRMS Officers bring leadership with a common goal across all areas. However, the vitality and growth of any organization depends on its membership.

Appendix C

The Effectiveness of CIRMS

RECOGNITION OF CIRMS VALUE BY NIST

UNITED STATES DEPARTMENT OF COMMERCE
National Institute of Standards and Technology
Gaithersburg, Maryland 20899-
OFFICE OF THE DIRECTOR

January 21, 2004

Dr. James Deye
National Cancer Institute
6130 Executive Blvd., MSC 7440
Rockville, MD 20892-7440

Dear Dr. Deye:

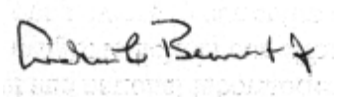
I would like to congratulate you on yet another successful annual meeting of the Council on Ionizing Radiation Measurements and Standards (CIRMS), held recently here at the National Institute of Standards and Technology. The focus of this latest meeting, "Radiation/Radioactivity Measurements and Standards in Industry," clearly aligns with NIST's mission to "work with industry to develop and apply technology, measurements and standards." It is great to have so many representatives from the user community here on-site, and to hear their perspectives on the needs and developments in ionizing radiation research, measurements and standards in health care, homeland security, environmental and personnel protection, and industrial applications.

As an independent council that brings together experts involved in all aspects of ionizing radiation, CIRMS is a vital resource to our Ionizing Radiation Division and to NIST. The expertise within your organization, from government and national laboratories, the academic community and industry, provides us with valuable insight to help in our efforts to maintain the national standards in ionizing radiation and provide our services to our entire customer base. In particular, the CIRMS triennial report on "National Needs in Ionizing Radiation Measurements and Standards," along with its Measurement Program Descriptions, has proven invaluable in the

strategic planning of the Ionizing Radiation Division. This report provides us with a consensus view of the needs in the field and allows the Division to efficiently leverage its resources with the customers' needs in mind.

I would like to commend CIRMS on its extensive efforts in promoting the highest quality of radiation and radioactivity measurements and standards. NIST and I endorse these efforts, and wish you the best success in CIRMS continuing activities.

Sincerely,



Arden L. Bement, Jr.
Director

Appendix D

INTRODUCTION TO MEDICAL MPDs

Medicine was one of the first applications of ionizing radiation as Wilhelm Roentgen himself took an X-ray of a hand within a few days of his discovery in 1895. X-ray tubes became specialized for either diagnostic or therapeutic applications. For diagnostic radiology the tubes had to be designed to handle the high instantaneous energy input from small focal spot tubes, while therapy tubes had to be designed to generate much higher average energy levels for longer periods of time using larger focal spots. To treat tumors at greater depths in the body with external radiation, high-energy accelerators and radionuclide teletherapy units were pioneered in the late 1940s and 1950s. Like X-rays, the radium (Radium-226, 226R) discovered by the Curies in 1898 was quickly used as a therapeutic agent for the treatment of cancer. Radium brachytherapy sources were used for the interstitial treatment of tumors. Newer radionuclides, such as Iridium-192 (192Ir), Palladium-103 (103Pd) and Iodine-125 (125I), have replaced radium for this use. Radionuclides are also used for diagnostic information, as Technetium-99 (99mTc), is commonly used for many nuclear medicine procedures.

Historically, the primary measurement laboratories such as the National Institute of Standards and Technology (NIST) played a major role in developing national standards for measuring the radiation used to treat patients. In the 1920s, the free air chamber was designed to measure the then-new radiation quantity "exposure". Free air chambers with different dimensions were developed to cover the energy range from 10 to 300 keV. In the 1970s graphite cavity ionization chambers were developed to measure the exposure from Cesium-137 (137Cs) and Cobalt-60 (60Co). Recently a wide-angle free air ionization chamber and extrapolation chambers have been used for the measurement of brachytherapy sources, especially those having low energy emissions such as 125I. A recent application of these types of sources is intravascular brachytherapy for preventing or inhibiting restenosis of cardiac vessels.

Today, the only traceable units of radiation quantities are Systeme International (SI) units. To enhance patient safety and minimize the risk of errors, the Medical Subcommittee will only accept SI units. Because the role of CIRMS is to deal with measurement and standards, only the use of SI units is acceptable. In particular, the following units should be used for the quantities listed. This is not intended to be a complete list. For the quantity activity, only Becquerels (Bq) shall be used (not Curies, Ci). The Curie is an antiquated unit of activity based on radium. The new SI unit has as its basis the measurable quantity of disintegrations per second. For brachytherapy sources, the quantity expressing output is air kerma strength, having units of energy transferred per unit time at 1 meter distance ($Gy\text{-}m^2/s$; Gray-meter squared per second). The unit U = $Gy\text{-}m^2/h$ is recognized as it is based on Systeme International (SI) units. Apparent

activity is likewise not an acceptable quantity; it is based upon the output of a source and only vaguely related to the contained activity because it is dependent on the source geometry.

DIAGNOSTIC RADIOLOGY

The national attention to health care and the goal of universal coverage have highlighted the need for cost effectiveness and quality assurance in the care provided to every US resident. Breast cancer is the second leading cause of death by cancer in women. During their lifetimes, one in nine women will develop breast cancer. The Center for Disease Control (CDC) estimates that breast cancer mortality could be reduced by 30% if all women were screened regularly. The best way to prevent deaths from breast cancer is early detection. The best methods of early detection are self-examinations coupled with periodic mammograms. The goal of the Mammography Quality Standards Act (MQSA) was to provide high quality mammograms with the least radiation exposure. When MQSA was passed in 1992 there were no national standards for X-ray tubes commonly found in mammography units. The need for developing mammography air kerma standards was one of the four medical subcommittee Measurement Program Descriptions (MPDs) in the first "CIRMS National Needs Report" (1985). This MPD, the first to be completed, proved highly successful (see Appendix B-2). As a result, national standards are now available for air kerma measurements from molybdenum and rhodium anode X-ray tubes. A network of secondary level laboratories is in place for calibrating the instruments that Food and Drug Administration (FDA) inspectors use in their yearly inspection of mammography facilities, and for calibrating the instruments that medical physicists use in their yearly on-site evaluations of mammography facilities.

Most diagnostic X-ray exams are carried out at X-ray potentials between 80 and 120 kV and use filtration typical of the NIST moderately filtered (M) series of X-ray beams. Another MPD was completed so that NIST now offers M80 and M120, as well as molybdenum beams as standard options. A new international standard is in development whereby there will be a new basis for these X-ray beams.

THERAPEUTIC RADIOLOGY

One of the leading causes of death of Americans is cancer — over 25% of the population will die from some form of this disease. Ionizing radiation is one of the common treatment modalities, with over half of all cancer patients undergoing ionizing radiation treatment either for palliation or for cure (approximately 600,000 patients per year). The total cost of these treatments is in excess of $10 billion per year. The goal of radiation therapy is to kill the cancer while sparing normal tissue. This means using large doses of radiation that must be accurately known and precisely delivered to the tumor. Radiation oncologists have been able to detect clinically

acceptable differences in the responses of patients who experience variations of as little as 5% in the delivered dose.

By far the most common types of radiation presently used to treat cancers are beams of X-ray and gamma-ray photons and electrons, although the use of brachytherapy sources is also common for treating some cancers such as prostate cancer. External electron and photon beams are most frequently produced by electron linear accelerators, although radioactive source teletherapy units still play a role for photon treatments. Photon-emitting radionuclides are the primary sources of photons for brachytherapy treatments. A recent application of brachytherapy sources is in intravascular brachytherapy for the prevention of restenosis of coronary arteries. Other types of radiation used include protons, neutrons, and heavy ions. These latter radiations have features that make them desirable for treating some forms of cancer. For example, as protons are slowed down in tissue, they lose more of their energy per unit distance just before they stop. Thus protons can be used to deliver more dose to the tumor and less to the surrounding tissue.

Historically, ionization chambers used to measure the output of machines used for radiation therapy were calibrated free in air in terms of exposure (or more recently air kerma) from a 60Co unit. A standard protocol was then used to convert the measurement to absorbed dose to tissue. A more straightforward approach is to calibrate the ion chamber in a water phantom in terms of absorbed dose to water since this is reasonably close to the desired absorbed dose to tissue. Thus, an MPD was included in the 1988 "CIRMS National Needs Report" for developing an absorbed dose to water standard based on a water calorimeter. A water calorimeter was developed, which has allowed NIST to provide an absorbed dose to water calibration factor for ion chambers immersed in water phantoms.

An application of brachytherapy radiation is to prevent restenosis following balloon angioplasty. Approximately 40% to 50% of patients having angioplasty experience another obstruction of the arteries within six months. Studies have shown that radiation can slow or eliminate the regrowth of the lining of the injured vessel, delaying or preventing further obstruction. Intravascular brachytherapy involves introducing minute radioactive sources into the artery through a catheter, to deliver radiation directly to the inner surface of the vessel. These sources are in close proximity to the vessels so the determination of the dose at sub-millimeter distances from the source is important. In recent years, drug-eluting stents have largely replaced intravascular brachytherapy as a treatment modality, but the success of brachytherapy was a testament to the careful dosimetry and establishment of standards that supported accurate dosimetry.

The need for high-spatial resolution dosimetry in radiation therapy is important not only for brachytherapy, but also for verifying the predicted dose distribution calculated using radiation

therapy planning software. Modern treatments given using intensity-modulated radiation therapy (IMRT) particularly demand the ultimate in high-precision dosimetry.

With the development of improved methods of implanting brachytherapy sources in a precise manner for treating prostate cancer, there has been a tremendous growth in the use of 125I and 103Pd seeds for this modality. Air kerma strength standards for these brachytherapy sources are developed as new source designs become available, and are subjected to the customary procedures of standardization and comparison. The need for a 103Pd standard as expressed in the 2001 CIRMS Third Report on National Needs in Ionizing Radiation Measurements and Standards has since been met.

Therapeutic application of radiopharmaceuticals with curative intent has been practiced since the early 1950s, mainly with Iodine-131 (131I) and Phosphorous-32 (32P). There are presently about 60,000 nuclear medicine procedures performed per year using radionuclides for therapy. There is considerable current interest in the radiation oncology community and the private-sector radiopharmaceutical industry in developing radiolabelled monoclonal antibodies with, for example, the beta-particle-emitting nuclides Yttrium-90 (90Y) and Rhenium-186 (186Re), used in tissue-specific agents for targeting the primary tumor.

Finally, an exciting new area is palliative radiopharmaceuticals for use in treating pain associated with bone metastases in the later stages of several types of cancers. It is estimated that up to 125,000 cancer patients per year would benefit from treatment with these bone palliation agents. Some of the nuclides already available or under investigation include 32P, Strontium-89 (89Sr), Tin-117 (117mSn), Samarium-153 (153Sm), and 186Re.

NUCLEAR MEDICINE

Nuclear medicine, the use of radioactively labeled pharmaceuticals in diagnostic and therapeutic applications, has undergone enormous growth since its introduction in the late 1940s. The needs for radioactive standards used in both diagnostic and therapeutic nuclear-medicine applications continue to be necessary.

Diagnostic applications for in vivo imaging have grown to 8.2 million procedures annually in the United States alone. The chief reason for the continued growth is that radionuclides provide physiological information, as opposed to anatomical information (e.g., differences in tissue density) provided by the more common diagnostic X-rays and magnetic resonance imaging (MRI). It has been estimated that over 80% of these diagnostic nuclear medicine procedures involve the use of 99mTc, which has a six-hour half-life. The remaining 20% is accounted for by a score of other gamma-ray emitting radionuclides with half-lives from a few minutes to a few days. Some of the most common procedures include coronary imaging, tumor imaging,

renal function studies, and skeletal imaging. Appropriate 99mTc-labeled radiopharmaceuticals have been developed for these and many other applications.

A second class of radionuclides used in diagnostic nuclear medicine is the short-lived positron emitters used for positron emission tomography (PET imaging). These include Carbon-11 (11C) with a 20 minute half-life and Fluorine-18 (18F) with a 2 hour half-life, which are ideal because of the ease with which they can be incorporated into biomolecules. The use of PET is growing at a tremendous rate.

Appendix E

MPD A.1: National Air-Kerma Standards for Mammography

Summary

In 1992, the US Congress passed Public Law 102-530, the Mammography Quality Standards Act of 1992. This Act requires that all screening and diagnostic mammographic facilities be certified by the Secretary of the Department of Health and Human Services by October 1, 1994. This certification process will involve accreditation by an approved nonprofit private organization or approved State organization. There must be a yearly on-site evaluation by a credentialed medical physicist and a yearly inspection by a credentialed government inspector.

Detailed Program Characteristics

Mammographic units used in the United States commonly use molybdenum for both the X-ray tube anode material and the additional filter used to remove unwanted low-energy bremsstrahlung X-rays that contribute to patient dose but not significantly to image quality. One problem in calibrating instruments used to measure the air-kerma rate from mammographic units is that the National Institute of Standards and Technology (NIST) presently does not yet have a national standard for those mammographic beams. In fact, the only national standards laboratory in the world having appropriate national standards is the Physikalisch-Technische Bundesanstalt (PTB), the German standards laboratory. All the reference X-ray beams at NIST are produced by tungsten-anode X-ray tubes. The spectra (and therefore any measure of beam quality) are quite different for these two anode materials. For a tungsten target, aluminum filter system operated at voltages appropriate for mammography, most of the dose results from the thick-target tungsten bremsstrahlung (i.e., low energy X-rays), although the L-fluorescent tungsten X-rays are present. For a molybdenum target, molybdenum filter system, the K-fluorescent X- rays dominate the spectra and there is very little thick-target molybdenum bremsstrahlung. For a reasonable choice of operating voltages, one can match either the half-value layer or the homogeneity coefficient but not both beam quality parameters for molybdenum anodes.

In the United States, the Food and Drug Administration's Center for Devices and Radiological Health (CDRH) is responsible for calibrating all the instruments that the government inspectors will use during the yearly inspection of each mammography facility. The CDRH X-ray Calibration Laboratory is accredited by NIST's National Voluntary Laboratory Accreditation Program. CDRH is establishing a new facility within the Mammography Calibration Laboratory explicitly to calibrate instruments in appropriate X-ray beams. Since there are no suitable

national standards in the United States, CDRH has opted to send its reference ionization chamber to PTB to establish traceability to a national standard.

To perform the annual on-site evaluation, the medical physicists will presumably have their instruments calibrated at one of the American Association of Physicists in Medicine's (AAPM) Accredited Dosimetry Calibration Laboratories (ADCL). One of these laboratories, at the University of Wisconsin, is developing a free-air chamber to measure air kerma from their mammography X-ray units. In principle, the free-air chamber is an absolute device, but in practice it is necessary to determine a number of correction factors. Preliminary comparisons of this chamber with NIST standards have been made in tungsten-anode beams, and measurements of selected mammography chamber response have been made in the molybdenum and rhodium beams at CDRH.

To be able to provide national standards for all secondary laboratories wishing to calibrate mammography probes, it is desirable for NIST to develop suitable reference X-ray beams. An Interagency Agreement has been established with the Food and Drug Administration to develop these national standards. At a minimum, these new reference beams should be identical to the beams recommended by the International Electrotechnical Commission for measuring the characteristics of diagnostic X-ray equipment and for verifying the performance requirements of ionization chambers and semiconductors used in medical radiography.

US Facilities, Staffing, and Funding

The appropriate US facilities can be organized into three groups:

1. NIST: As indicated above, NIST needs major new resources in equipment and personnel to carry out this program. With the tight deadlines of MQSA, this program needs high priority. A minimum requirement is 2 person-years and $250,000 for each of two years.

2. CDRH: Most equipment for the new mammography facility has been ordered. Two additional person-years will be required: one to finish developing the automated computer system and the other to do routine calibrations, maintain in-house quality control, and maintain inventory. Equipment costs are estimated to be about $130,000 for each of two years.

3. ADCLs: To set up laboratories for calibrating instruments to measure air kerma from mammography units, it is estimated that each ADCL will need at least $100,000 for equipment and a person to operate the calibration facility. Two of the ADCLs have expressed an interest in developing mammography calibration facilities.

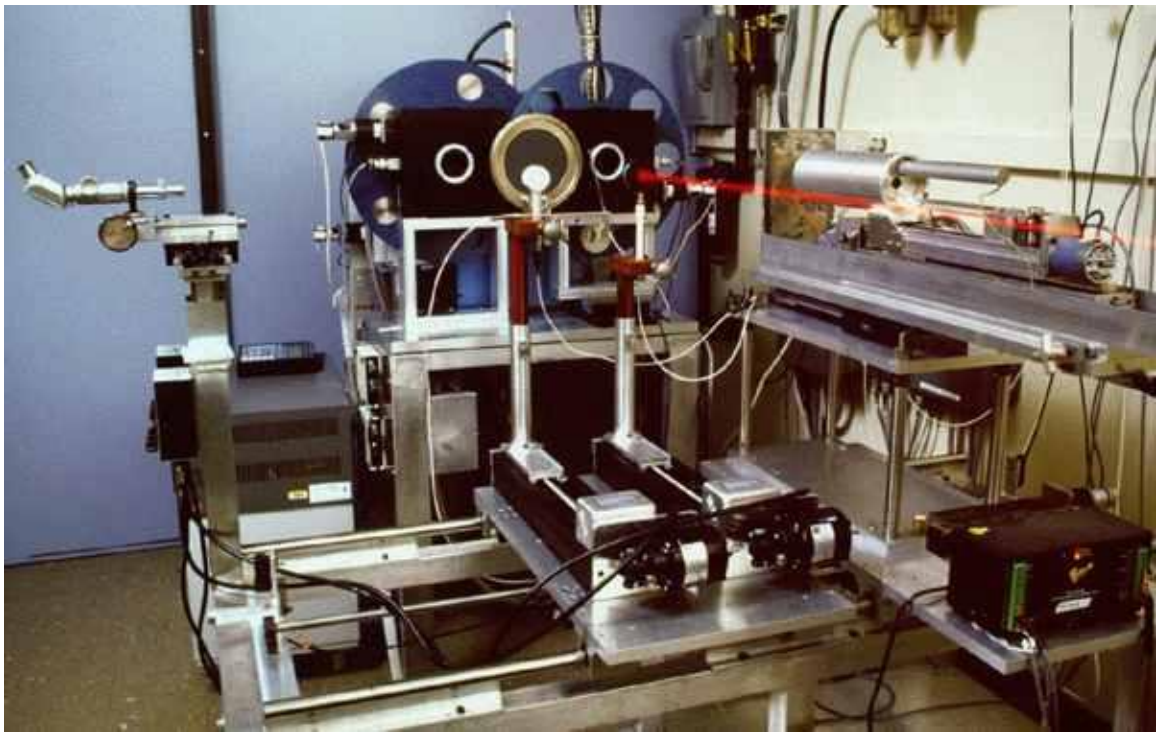


Figure A.1 – National standard calibration range for mammography testing

Appendix F

INTRODUCTION TO RADIATION PROTECTION AND HOMELAND SECURITY MPDs

When CIRMS formed the subcommittees of the Science and Technology Committee, a distinction was made between the radiation measurements as related to radiation protection of the members of the public at-large and the environment and to radiation protection in the workplace. Two subcommittees were formed to address these needs: the Public and Environmental Radiation Protection (PERP) subcommittee and the Occupational Radiation Protection (ORP) subcommittee. Notes A and B at the end of this section provide background information on these two areas. Despite some differences in techniques and in regulations for these two areas, there are a number of overlapping issues in radiation measurement in the two areas and these two groups have worked jointly in several areas. In addition, the emerging concerns over radiation protection of first-responders by the Department of Homeland Security (DHS) also fit into this area in that such concerns also involve worker as well as public radiation protection. While CIRMS has formed an independent subcommittee to deal with Homeland Security interests, this nascent subcommittee's interests are included herein.

Since the public protection from environmental radiation and workplace radiation protection problems share many common characteristics, the two subcommittees a single merged subcommittee was formed, the Radiation Protection (RP) subcommittee. This broader title encompasses both of the previous areas and is more representative of the description of departments or divisions in government, industry or academia that are charged with monitoring and controlling radiation as it would affect persons in a situation where they are or can be exposed to irradiation sources.

The Radiation Protection subcommittee deals with radiation measurement issues for workers in the nuclear industry and in various other end-use areas that deal with radioactive isotopes, such as nuclear medicine, biomedical research and agriculture. Of concern are the protection of the workers and the members of the public at-large. This includes, for example, those engaged in nuclear power generation, nuclear research performed by national laboratories, universities, contractor laboratories in the private sector, environmental protection, nuclear weapons research and development, waste handling, storage, transportation, disposal, decontamination and decommissioning of contaminated sites and structures, and Homeland Security related activities. There are over one million workers employed within the nuclear industry, at Department of Energy facilities and facilities licensed by the Nuclear Regulatory Commission (NRC) and the states. This is a several billion dollar industry and its viability depends on the protection of both these workers and the members of the public and of the environment.

The workplace environment must be fully characterized in order to protect the health of radiation workers. Since radiation cannot be detected by the human senses, workers depend upon measurement tools and techniques to monitor their exposure to radiation. Planning, controlling and monitoring the exposures to ionizing radiation require accurate, reliable instrumentation to establish dose-rates, indicate high exposure areas, and to control the spread of contamination in both the workplace and in the public environment. The day to day prevention and minimization of radiation exposure to workers and members of the public requires the use of sophisticated portable and/or installed instruments whose results are verified by bioassay and dosimetry programs that also rely upon sophisticated instrumentation. The dosimetry and bioassay results constitute the legal record of the worker's exposures. However, measurements made with reliable instrumentation prior to entry and during work in an area of potential radiation exposure are essential to minimizing worker exposures and in complying with applicable federal and state radiation protection regulations and the principal of keeping radiation exposures *As Low As Reasonably Achievable* (ALARA). ALARA is used throughout industry as a guiding principle for the control and monitoring of a worker's radiation exposure.

In recent years, an increasing number of sophisticated instruments and dosimeters have been derived from the increased sophistication and miniaturization of electronics. However, performance evaluations and inter-comparisons have shown the response characteristics of such instruments remain dependent on such factors as the environmental conditions, the dosimeter processor, and the quality of the calibrations, and the skill and experience of the person analyzing results. The reliability of the entire measurement system has not improved with the increasing sophistication of the measurement tools. For example, in the case of personnel dosimeters, recognition of the deficiencies led to the establishment of accreditation programs for dosimetry processors. This program has significantly improved the overall performance of dosimetry processors' measurements in the US. However, maintaining these improvements requires continued diligence.

Although new technology provides more and more information, better sensitivity and analytical speed, the work environment and its regulations require more accurate measurements at lower dose-rates. A large fraction of the workers continue to be exposed to radiation in the medical, nuclear power, and research industries, but must meet regulatory demands for lower worker exposures and improved control of the radiation environment. Today many workers are involved in environmental cleanup activities and these workers encounter a different radiation environment than one would expect in a typical work environment.

Expansion of accreditation programs that also include new measurement techniques, improvement of calibration techniques and capabilities, improvement of the control, or understanding of limitations of different the measurement techniques, and development of better new measurement techniques results in improved measurement accuracy and reliability. In turn,

improved measurement accuracy and reliability assists in protecting the radiation worker within the workplace, and members of the public and the environment. The improved accuracy and reliability of the measurements and the monitoring and control of the radiation environment increase public confidence in the nuclear industry. This will improve public confidence in the industry and will lead to its continued viability and acceptance.

Measurement tools for accurate assessments are fundamental to for addressing the issues of radionuclides in the environment and their impact on humans. While there are many radioanalytical methods, detection systems, and calibration standards available, current metrology needs in nuclear emergency response and routine cleanup require rapid reduced-cost turnkey analytical methods and technologies with higher selectivity and sensitivity that yield technically and legally defensible analyses. The development of these measurement tools, and their calibrations, will be based on pooling multi-disciplined expert teams. This requires considerable resources that can be found only through national initiatives. CIRMS goal is to provide a forum to identify areas of opportunity for reliable new measurements and standards development, to produce a strategic plan, and to initiate cooperative and leveraged funding support to meet current and future needs in occupational, environmental and radiation protection bioassay radionuclide metrology needs. In this regard, many of the interests in the area of Homeland Security, especially as related to the needs of first-responder, fall within this context.

MEASUREMENT PROGRAM DESCRIPTIONS

The following MPDs address measurement and standards needs in radiation protection and Homeland Security areas:

Public and Environmental Radiation Protection

B.7.2 Traceability to NIST for Reference, Monitoring and Service Laboratories
B.8.2 Sorption of Radioactive Elements in Contaminated Soils and Sediments and Urban Structural and Other Materials
B.9.2 Atom-Counting Measurement Techniques for Environmental and Radiobioassay Monitoring

Occupational Radiation Protection

C.3.4 Intercomparison Transfer Standards for Neutron Source Calibrations
C.4.4 Improvements for In-vivo and In-vitro Radiobioassay Metrology
C.17.3 Improved Radiation Measurement Infrastructure for Occupational Radiation Protection
C.19.2 NIST Traceability for Low Dose -Rate Calibrations
C.20.2 Implementation of Support for Personnel Dosimetry Proficiency Testing per ANSI N13.11

Homeland Security

E.1.1 Emergency Radiological Response
E.2.1 Performance Criteria for Service Laboratories Performing Personnel Radiation Exposure Dose Assessment Using Solid Matrix Biological Materials
E.3.1 Performance Criteria for Specialized Teams Supporting Medical Response during Nuclear and Radiological Emergencies including Terrorism Incidents

Within the Homeland Security area, several organizations are working on documents and programs that will assist in dealing with the needs in this area. Below is a table that attempts to summarize the current status of some programs underway as well as to point to major gaps and areas that require future attention. These three MPDs are but a partial focus, and, as the CIRMS Homeland Security subcommittee evolves, it will up-date a consensus matrix that can be posted on the CIRMS web-site for comment.

Measurement Domain	**Initiatives Undertaken**	**Target Document and/or Audience**	**Related Concerns**
Cytogenetic Biodosimetry	IAEA document in DRAFT format	ISO/DIS 19238 balloted in 2003	ISO standard for triage in progress
Biophysical Dosimetry	Intercomparison study of dosimetry methods needed	**Need initiative for an internal standard method**	Correlative *in vivo* research
Radiation Bioassay Whole-Body Counting	REALnet Workshop C IRMS Meeting October 27, 2004	Reference and satellite laboratories	**Need initiative for deployment**
Hematology		Reference laboratories	**Need initiative for deployment**
Clinical Symptoms and Biodosimetry	Training programs	Physicians and Radiological Assessors	**Need to address first responders**
Software Tools	Biodosimetry Assessment Tool (BAT)*	Physicians and Radiological Assessors	**Need to address first responders**

*See: <www.afrri.usuhs.mil/www/outreach/biodostools.htm#software> for details.

Appendix G

INTRODUCTION TO THE INDUSTRIAL APPLICATIONS AND MATERIALS EFFECTS MPDs

The Council on Ionizing Radiation Measurements and Standards (CIRMS) considers all aspects of ionizing radiation which involve radiation effects, including uses in the medical community for diagnostic, therapeutic or palliative purposes, and the monitoring of exposure of persons working with ionizing radiation or the general public from naturally occurring radiation sources. The Industrial Applications and Materials Effects (IAME) subcommittee differs in that it deals primarily with the use of radiation in industrial processes, in contrast to applications related to effects on humans. Four sources of radiation used within the industrial community are taken into account:

Accelerated Electron Beams
X-rays Generated from Electron Beams
Gamma Rays from Radioactive Isotopes
Neutron and Mixed Field Sources

ACCELERATED ELECTRON BEAMS

Many industrial applications rely upon high current, high dose rate electron beam accelerators that provide ionizing radiation to enhance the performance and/or market value of materials or processes. It has been estimated that there are in excess of 1000 such electron beam accelerators now in use in industry. Research to support some of these industrial uses is sometimes carried out using low current accelerators, such as the historic Van de Graaff generators or pulsed linear accelerators.

Electron beam accelerators in the 100 to 500 kV voltage range are sufficiently low in voltage such that they can be housed in lead shielding to provide the needed safety for operators from the resultant X-rays generated when electrons impinge upon target materials. These accelerators utilize elongated filaments or segmented filaments in parallel and have been made at up to three meters in length. The limited penetration of 300 keV electrons (approximately 430 μm or 17 mils in unit density material) constrains these devices to applications involving thin films, such as the surface curing or crosslinking of coatings, inks and adhesives or the crosslinking of polymeric films used in some shrink film applications. However, beam currents as high as 1.3 amps (A) have been achieved. Since product through-put is proportional to beam current, production rates in excess of 700 meters per minute have been noted, depending upon the response of the processed material to ionizing radiation and appropriate under beam handling process equipment. Such low voltage accelerators are mostly used by major corporations capable of marketing the high production output.

Recently, very low voltage accelerators with energies in the range from 70 to 150 keV but with substantial beam currents have been developed for coatings and thin film applications. These units are more compact and should be more affordable for modest sized industrial applications. Even at these very low voltages, there is sufficient beam penetration (80 μm or 3 mils) to cure inks, pigmented coatings, and adhesives and to crosslink thin gauge polymeric films. Some emerging areas of market interest have been in the use of low-voltage accelerators for surface sterilization of food packaging materials and air purification as well as for the curing of coatings that are in compliance with US Food and Drug Administration regulations for direct food contact. In these emerging areas of interest, dosimetry and dose determinations are becoming more important. Low-voltage accelerators are also being explored to implement in-line sterilization of packaged medical devices.

Mid-voltage, high current accelerators have been produced with total beam power (voltage times current) of 200 kW. The predominant use of such high current, mid-voltage accelerators has been to crosslink the jacketing on wire and cable in order to render such insulation resistant to heat distortion and melting, should a short or unusually high current be encountered which would heat the conductor. The most common accelerator for these wire and cable applications is a 1.5 MeV device. The crosslinking of wire and cable jacketing is an accepted industrial practice with formulations having been, for the most part, converted to non-halogen containing flame-resistant materials. The crosslinking of wire and cable jacketing is often the first industrial use of irradiation processing espoused in developing areas, as there is need for such materials to support the development of infra-structure to transmit electricity.

While lead shielding has been used for accelerators up to 0.8 MeV, shielding for mid and higher voltage accelerators is thick walled concrete. The thickness of the concrete or shielding is proportional to the accelerator voltage as prescribed in the National Council for Radiation Protection and Measurements, Report No. 51, Radiation Protection Design Guidelines for 0.1-100 MeV Particle Accelerator Facilities (National Council on Radiation Protection and Measurements – NCRP Publications, Bethesda, MD). The maximum voltage attained at these high beam currents (up to 100 mA) is 5.0 MeV (but at reduced amperage), which implies beam penetration of 1.9 cm (0.8 inches) for unit density materials (per equal entrance – equal exit surface dose).

Many other significant industrial operations rely upon mid-range, high current accelerators as part of manufacturing processes. For example, tire companies (Bridgestone, Goodyear, Michelin, for example) use such electron beam processing to partially cure tire components in extruded form before they are plied into tires, then molded and finally cured. Shrink film used in food packaging applications (CRYOVAC® Division of the Sealed Air Corporation) and heat recoverable tubing (Raychem, part of Tyco Electronics, a subsidiary of Tyco International) used to insulate electrical connectors also rely on such high current accelerators to crosslink materials,

notably polyethylenes and compositions thereof. There are numerous other industrial applications for these high current, mid-voltage accelerators, including some use in the sterilization of medical devices.

For the most part, the higher voltage, high current accelerators are used for market applications wherein their higher beam penetration is of consequence (10 MeV giving 3.9 cm electron penetration in unit density material). These markets include medical device sterilization, food irradiation and some curing of the matrix resins used in fiber reinforced composite plastics. Despite angst over public acceptance, food irradiation is supported by a continuing series of positive results for providing a safe and effective means of eliminating hazardous food contaminants. Regulatory barriers are continually being overcome. More recently, accelerators with high beam currents and high energy (10 MeV) have become available. Heretofore, much high voltage work depended upon low current linear accelerators (linacs). There are (2) operating electron accelerator food treatment commercial facilities; Calavo in Hawaii and Sadex in Iowa. There are a few research electron accelerator facilities (Texas A & M University, Idaho State University, University of Maryland, Kent State University, and Iowa State University).

No specific needs pertaining to accelerator design or development are addressed in this report. For a majority of low and mid voltage electron beam industrial applications, product properties and performance requirements and not dosimetric parameters dictate the needed exposure to ionizing radiation. For example, industry accepted use of solvent rubs is a criterion for indicating the complete cure of a low voltage electron beam cured coating. The modulus of elasticity, which for thermoplastics such as polyethylene is determined above the melt transition of the thermoplastic, is used to indicate the crosslinked state of films, shrink tubing and wire and cable insulation. Only in those areas that must comply with some regulatory requirements, such as in the sterilization of medical devices and in the elimination of potentially hazardous bioburdens from foodstuffs, are dosimetric requirements essential.

X-RAY IRRADIATION

When electrons impinge upon a material target, X-rays are emitted. With the development of high current, high energy (5.0 to 10 MeV) accelerators, the known inefficiencies of energy conversion from accelerated electrons to X-rays has been found to be overcome by substantial increases in available beam current. While only ~6-10% of electron energy is converted to X-rays, with high current sources the X-ray output is sufficient to make X-ray processing a viable alternative to other technologies.

X-ray processing is being used to “sanitize” sacks of mail for the US Postal Service to eliminate any possible biohazard contamination (see Appendix B-c). X-ray processing systems designed around high current, high-voltage accelerators are under investigation for use in food irradiation

as well as medical device sterilization. With X-ray penetration being comparable to that of gamma rays, these devices that are electrically powered are of interest so that there is no concern over the transport and use of radioactive materials. While emerging as a viable technology, no specific measurement needs are perceived for X-ray usage in that the dosimetry systems developed for electron beam and gamma processing can also be used for X-ray sources.

GAMMA IRRADIATION

For the most part, the industrial use of gamma irradiation relies on well-established irradiator designs in which products are exposed to gamma rays generated from the decay of cobalt-60 (^{60}Co) radiation sources. In years past, there had been a modicum of interest in the use of Cesium-137 (^{137}Cs). The use of ^{137}Cs in industrial environments has been limited because of concerns regarding the solubility of cesium chloride in the event of capsule failure.

In contrast to ionizing radiation from an electron beam, gamma irradiation has:

- Significantly greater depth of penetration (product stacks up to approximately one meter are common even at relatively high product densities).
- Dose distribution uniformity in these thick cross-sections.
- The ability to be scaled down for research purposes with a readily available installed base of research scale systems.
- The ability for large scale commercial facilities to increase product capacity by commensurate increases in the cobalt source.
- Lower dose rates of approximately 10 kilograys per hour (kGy/h), in contrast to electron beam dose rates of 10 kGy/s.

According to the preeminent supplier of ^{60}Co and designer of multi-purpose gamma irradiation facilities, MDS Nordion (Kanata, Ontario, Canada), there are over 180 large-scale gamma processing facilities in over 47 countries throughout the world. These facilities are used mainly for the sterilization of medical devices, including syringes, surgical gloves, IV sets, surgical kits and trays. Approximately 45% of the sterile disposable medical devices manufactured in North America are sterilized with gamma irradiation. A number of major suppliers of medical devices own and maintain their own ^{60}Co gamma irradiation facilities.

Within North America, many ^{60}Co irradiation facilities also perform some food irradiation. One such ^{60}Co irradiation processing facility dedicated primarily to food irradiation is Food Technology Services, Incorporated (Mulberry, FL). Other facilities deal with food items such as spices. The use of ^{60}Co for food irradiation is being extended to Mexico with a facility near Mexico City operated by Sterigenics and more recently (2011) a food treatment facility in northern Mexico, operated by Benebion. Research and development is being conducted on food

irradiation involving ^{60}Co irradiation systems at the Canadian Irradiation Centre (Ville de Laval, Quebec, Canada) and at the Canadian Department of Agriculture's Food Research Centre (St. Hyacinthe, Quebec).

Most of the industrial applications relying upon gamma irradiation involve uses for which there are regulatory controls, such as the sterilization of medical devices and food irradiation. Thus, dosimetric release parameters are essential. In addition to the commercial and pilot-scale gamma irradiation facilities, there are many smaller self-contained or panoramic gamma ray facilities used for a variety of other applications including the radiation hardness testing of semi-conductors, materials testing, and dosimetry development studies.

NEUTRON AND MIXED FIELD EFFECTS

Neutron Effects on Steel: There are currently 109 operating nuclear power reactors in the United States that are being used for electric power generation. A principal concern regarding the continued, safe operations of these reactors is the impact of neutron irradiation on the structural integrity of the reactor's pressure vessel. The study of neutron-irradiation effects on pressure vessel steel can only be adequately addressed through a national commitment to a long-term measurement and monitoring program conducted over an extended period of time. Unlike other industrial applications, short-term programs of limited scope, while useful for providing certain engineering data, cannot fully address the strategic and social needs for ensuring nuclear reactor operational safety.

Mixed Field Effects: Of increasing industrial concern and of national security and military importance are the effects of irradiation on components used in the space and commercial environment, in particular sensitive electronic devices. These exposures often involve mixed fields of irradiation, gamma, neutrons and, in space, also high-energy protons. Here unique measurement and radiation effects problems confront the irradiation community.

Appendix H

INVOLVEMENT OF CIRMS LEADERSHIP IN IRRADIATION SANITIZATION OF MAIL FOR THE US POSTAL SERVICE

Background: On October 15, 2001, a letter was opened in the office of then Senate Majority Leader Tom Daschle containing a white powdery substance. In it there was a hand printed note stating "We have this anthrax. You die now." This was postmarked October 9, 2001, from Trenton, New Jersey and processed through the Brentwood postal facility within the District of Columbia. Traces of anthrax were found in other Senate offices resulting from air-borne transmission of this potentially lethal fine powder. A comparable letter with the very refined white powder was found amongst mail addressed to Senator Patrick Leahy, postmarked the same day, from the same post office, processed through the same postal facility and containing a similar note.

As a result of the Daschle letter, numerous Senate personnel were tested for anthrax exposure and the Hart Senate Office Building was closed and quarantined. The use of the mail to transfer anthrax powder was tied into previous incidents of particulate anthrax exposure in Florida and New York, but of more coarse material. Five people died from the inhalation of anthrax, including three postal workers.

Since authorities did not yet know the scope or source of these anthrax transmittals, a pressing concern became the safety of the US mail itself. Radiation processing had long been known as a proven means for dealing with bio-contaminants in food and for the sterilization of medical devices. The US Postal Service (USPS) quickly sought to implement a means of assuring the safety of US mail via radiation processing.

National Academy of Sciences workshop: In response to a November 7, 2001, request from the House of Representatives Committee on Government Reform, the National Academy of Sciences assembled a panel of experts to review various options the US Postal Service had to "Ensure the Safety of the US Mail." This panel convened on November 14 at the National Academy and listened to and discussed various options, including considerations of the volume of mail handled by the postal service, the cost-effectiveness of various processes and the speed in which they could be implemented.

Serving on this eleven member panel were CIRMS Past-Presidents Marshall Cleland and Tony Berejka, then CIRMS NIST representative Bert Coursey and Mohamad Al-Sheikhly of the University of Maryland (subsequently to become a CIRMS President). A presentation on the effectiveness and possible through-put rates for electron beam processing was made by Yves Jongen from Ion Beam Applications (IBA).

Mail Irradiation: Bert Coursey was to lead an inter-agency Task Force under the President's Science Advisor to coordinate efforts amongst NIST, government agencies familiar with bio-hazards, as the FDA, the USDA and the Armed Forces Radiobiology Research Institute (AFRRI) and the US Postal Service (USPS). Preliminary irradiations were conducted at an 18 kW linac facility in Lima, Ohio and demonstrated the effectiveness of electron beam treatment in sanitizing the mail of anthrax. Dosimetry methods espoused by CIRMS for medical device sterilization were implemented by Marc Desrosiers and dose-distribution calculations made by Steve Seltzer from the Ionizing Radiation Division at NIST. It was found that mail could be effectively sanitized at 10 MeV using standard letter-carrying trays (Figure 1).

An alternate facility having a much higher powered 140 kW, 10 MeV electron beam, the IBA (now Sterigenics) facility in Bridgeport, New Jersey, was also found to have better suited logistics for handling the critical federal mail in specific zip codes within the District of Columbia. Mail irradiation has since transferred to this facility which can also do treatment of mail in bulk using its X-ray conversion capabilities (Figure 2 shows schematics of the electron beam and X-ray capabilities at this facility). This operation is still protecting certain mail from contamination using radiation processing.

Continuing Activities: The leadership of CIRMS continues to contribute to the ongoing federal efforts related to mail security. With a series of experiments informed by Monte Carlo calculations, an optimized mail irradiation process was developed that reduces the damage to potentially archive-able documents while maintaining a reasonable margin of safety. Having obtained White House approval, efforts are underway to see that this process is adopted by Congress and fully implemented. Further, it is anticipated that the irradiation of federal mail will be performed in a federal facility in Washington, DC. CIRMS members are actively consulting with the US Postal Service and its contractors to insure adequate technical specifications before construction and process validation and before product release.

Follow-On Irradiation Efforts for Homeland Security: The USPS has donated two Titan 10 MeV, 18 kW, electron beam linacs and associated equipment to the NIST Ionizing Radiation Division. These are intended to be the basis for an irradiation processing test-bed facility that could help in the study of radiation mitigation of other threats, as well as for other industrial processes. The NIST division lacked space and funding for the accelerators, so one unit was donated to the University of Maryland and the other unit was donated to the Idaho Accelerator Center (a division of Idaho State University).

The success of the mail-irradiation efforts led to a project funded by the federal Technical Support Working Group (TSWG) to apply the Division's coupled experimental-computational approach to study the feasibility of the prophylactic irradiation of suspect passenger luggage to mitigate the introduction of agricultural diseases and pests into US agriculture. This study has

shown that detailed Monte Carlo radiation-transport calculations are able to match accurate state-of-the-art experimental dosimetry to within about 10% to 15 %, allowing the use of computational dosimetry to explore the wide spectrum of possible geometrical complications and to accurately estimate requirements for possible airport-based facilities.

Figure 1. Dosimetry studies with mail in trays

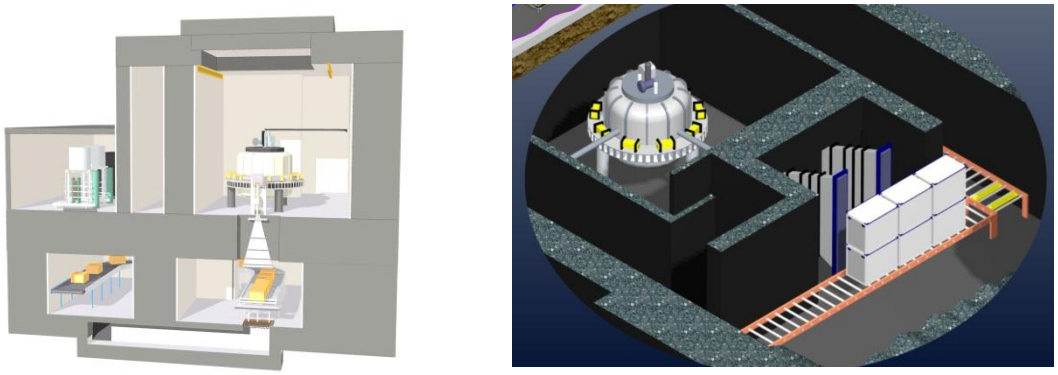


Figure 2. Schematics of IBA electron beam and X-ray irradiation processing facility
Reference: Cole, Leonard A**. The Anthrax Letters**, John Henry Press, Washington, DC (2003).

Appendix I

Acronyms Used in This Report

AAMI—Association for the Advancement of Medical Instrumentation

AAPM—American Association of Physicists in Medicine

ADCL—Accredited Dosimetry Calibration Laboratory

AFCI — Advanced Fuel Cycle Initiative

AFRRI — Armed Forces Radiobiology Research Institute

ALARA—As Low As Reasonably Achievable

ANSI—American National Standards Institute

APL — Applied Physics Laboratory

ASTM—ASTM International

BAT — Biodosimetry Assessment Tool

BNCT — Boron Neutron Capture Therapy

BREL — Boeing Radiation Effects Laboratory

BRMD—Bureau of Radiation and Medical Devices

CAT — Computerized Axial Tomography

CDC — Center for Disease Control

CDRH—Center for Devices and Radiological Health

CERN—Centre European de Recherche Nucleaire

CI — Conformality Index

CIRMS—Council on Ionizing Radiation Measurements and Standards

CIRRPC — Committee on Interagency Radiation Research and Policy Coordination

CORM — Council on Optical Radiation Measurements

CRCPD—Conference of Radiation Control Program Directors

CRT — Conformal Radiation Therapy

CT — Computed Tomography

DICOM — Diagnostic Image Formats

DHS — Department of Homeland Security

DOC—Department of Commerce

DOD—Department of Defense

DOE—Department of Energy

DOELAP—Department of Energy Laboratory Accreditation Program

DOI—Department of the Interior

ED—Electronic Dosimeter

EML—Environmental Measurements Laboratory

EPA—Environmental Protection Agency

EPR—Electron Paramagnetic Resonance

FDA—Food and Drug Administration

FDCPMC — Food, Drug, and Cosmetic Packaging Materials Committee

FEMA—Federal Emergency Management Agency

FSU — Florida State University

FTE—Full Time Employee

GIS — Geographic Information System

GMP — Good Manufacturing Practices

HS — Homeland Security

HPS—Health Physics Society

HPSSC—Health Physics Society Standards Committee

IAEA—International Atomic Energy Agency

IAME—Industrial Applications and Materials Effects

ICP-MS — Inductively Coupled Plasma - Mass Spectrometry

ICRP—International Commission on Radiological Protection

ICRU—International Commission on Radiation Units and Measurements

IEC—International Electrotechnical Commission

IMRT — Intensity-modulated Radiation Therapy

ISO—International Organization for Standardization

LANL—Los Alamos National Laboratory

LLNL—Lawrence Livermore National Laboratory

LS—Liquid Scintillation

MAP—Measurement Assurance Program

MAPEP— Mixed Analyte Performance Evaluation Program

MARLAP—Multi-Agency Radiochemistry Laboratory Analytical Procedures

MARSSIM — Multi-Agency Radiation Survey and Site Investigation Manual

MPD—Measurement Program Description

MQA—Measurement Quality Assurance

MQSA—Mammography Quality Standards Act

MRI—Magnetic Resonance Imaging

NASA—National Aeronautics and Space Administration

NBS — National Bureau of Standards (former name of the National Institute of Standards and Technology)

NCRP—National Council on Radiation Protection and Measurements

NDA—New Drug Applications

NIH — National Institutes of Health

NIRP — NIST Radiochemical Intercomparison Program

NIST—National Institute of Standards and Technology

NPL—National Physical Laboratory (UK)

NRC—Nuclear Regulatory Commission

NRC-Ottawa—National Research Council (Canada)

NRL — Naval Research Laboratory

NSWC—Naval Surface Weapons Center

NVLAP—National Voluntary Laboratory Accreditation Program

NYSERDA — New York State Energy Research and Development Authority

OCT — Optical Computerized Tomography

ORNL—Oak Ridge National Laboratory

ORP — Occupational Radiation Protection

OSL — Optically Stimulated Luminescence

PE—Performance Evaluation

PERP — Public and Environmental Radiation Protection

PET—Positron Emission Tomography

PMMA—Polymethyl Methacrylate

PNNL—Pacific Northwest National Laboratory

PTB—Physikalisch-Technische Bundesanstalt (Germany)

PWR—Pressurized Water Reactor

P2—Pollution Prevention

QA — Quality Assurance

REALnet — Radiological Emergency Analytical Laboratory Network

RESL—Radiological and Environmental Sciences Laboratory

RIMS—Resonance Ionization Mass Spectrometry

RMAP — Radiological Measurement Assurance Program

RP — Radiation Protection

RPSMUG — Radiation Processing Simulation and Modeling User Group

RPV—Reactor Pressure Vessel

RTP — Radiation Treatment Plan

SBIR — Small Business Innovative Research

SI — Système International d'unités

SPECT—Single Photon Emission Computed Tomography

SPI — Society of the Plastics Industry

SRM—Standard Reference Material

TIMS — Thermal Ionization Mass Spectrometer

TLD—Thermoluminescent Dosimeter

TRU—Transuranics

TSWG — Technical Support Working Group

USDA—United States Department of Agriculture

USPS — United States Postal Service

VOC — Volatile Organic Compounds

WHO — World Health Organization