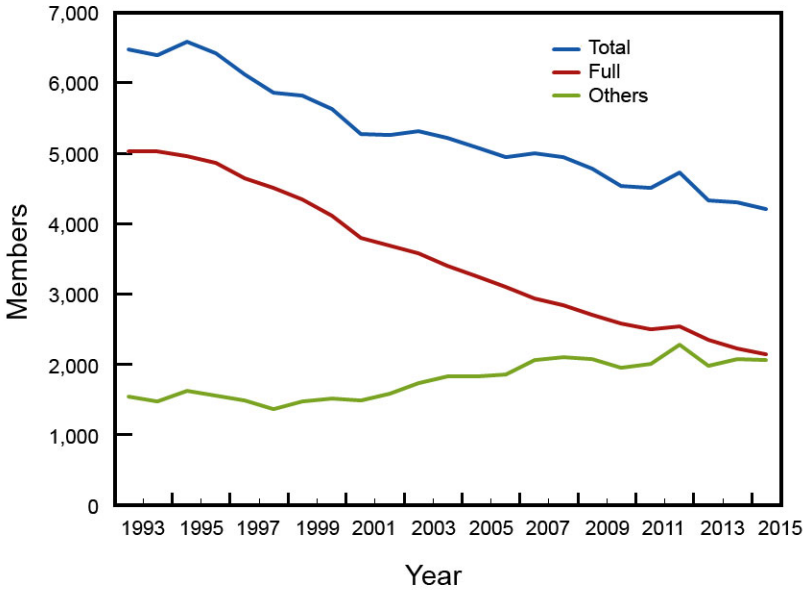
Fifty-Second
Annual Meeting Program

Meeting the Needs of the Nation for Radiation Protection



April 11–12, 2016

Hyatt Regency Bethesda
One Bethesda Metro Center
7400 Wisconsin Avenue
Bethesda, MD 20814

Front cover: Membership of the U.S. Health Physics Society, 1993 to 2015 [NCRP Statement No. 12, *Where are the Radiation Professionals (WARP)?*, issued December 17, 2015]. Statement No. 12 is available for free at http://ncrponline.org/wp-content/themes/ncrp/PDFs/Statement_12.pdf.

NCRP Mission:

To support radiation protection by providing independent scientific analysis, information and recommendations that represent the consensus of leading scientists.

amazonsmile

NCRP Resource Development Committee is launching a series of efforts to increase the financial stability of NCRP. The first effort is to request Council members and friends who shop online at Amazon to make a simple (no cost) modification. Simply register at AmazonSmile (https://smile.amazon.com/), and the AmazonSmile Foundation will donate 0.5 % of the purchase price to NCRP at no charge to you! It's easy!

Follow the directions and be sure to select the National Council on Radiation Protection and Measurements (from the pull down list or searchable request) as the 501(c)(3) public charitable organization to receive the Amazon contribution for each purchase. Donations are anonymous. However, we would like to recognize your support and if you notify NCRP (Laura.Atwell@ncrponline.org) we will add your name to the NCRP list of AmazonSmile contributors.

Introduction

Meeting the Needs of the Nation for Radiation Protection

Fifty-Second Annual Meeting of the National Council on Radiation Protection and Measurements (NCRP)

In June 2013, NCRP hosted a Workshop to address the question of "where are the radiation professionals?" This question regarding the future supply of qualified radiation professionals has been raised by professional societies, the National Academy of Sciences, and the U.S. Government Accountability Office as the largest birth cohort in U.S. history, the so-called "baby boomers" reach retirement age and transition out of the workforce. This issue, known by the acronym WARP, has been considered independently by various entities, and the purpose of the workshop was to bring representatives of professional societies, government agencies, educational institutions, and the private sector together to exchange information and develop action plans to mitigate a dichotomy between the growing use of radiological methods in medicine, research and industry, and the declining numbers of available experts in radiological protection. In addition, the threat of radiological terrorism exacerbates the potential need for a cadre of highly trained radiation experts.

NCRP recently published Statement No. 12, *Where Are the Radiation Professionals?* which summarizes the Workshop proceedings and the actions recommended by NCRP to ameliorate the situation. The Statement can be found on page 3 and the PDF can be downloaded from http://ncrponline.org/wp-content/themes/ncrp/PDFs/Statement_12.pdf. The meeting will take a more in-depth look at the issues raised by the WARP Workshop, featuring presentations by a number of experts from the concerned sectors and providing examples of actions already underway and additional actions needed to ensure that the needs of the United States for radiation protection expertise are met in the future.

The 2016 Annual Meeting Program is divided into three sessions that consider how did we get to where we are now, where do need to be in the future, and how do we get there. The opening session will begin with a consideration of the inexorable effects of population demographics on the future radiological workforce. The declining membership numbers of radiation-related professional societies will then be discussed, and the picture is not pretty. Next, a look at the current and future needs for radiation protection expert in medicine will be reviewed, and finally, the changing roles of health physicists, particularly in state radiation control programs, will be presented.

The second session begins with a look at the differences between education and training, and how both are needed. The next topic is the need for scientific researchers (and of course, research funding) to resolve remaining questions in fundamental radiobiology, such as low-dose and dose-rate effects, and the impact of molecular biology on our understanding of radiation risk. An example of the establishment of a "hub" or perhaps "center of excellence" in radiation protection will be presented, and finally, the needs of federal and state governments for an adequate number of radiation professionals to develop, interpret and enforce radiation protection guidance will be reviewed.

The third session considers concrete steps that need to be taken to ensure the adequacy of radiation protection practice for the United States. A vital first step is knowledge capture and management, to ensure that the lessons learned by present-day experts are not lost with their retirements. The last three presentations then discuss methods to meet future needs in industry, medicine, and emergency response.

The 13th Annual Warren F. Sinclair address will be given by Dr. Richard E. Toohey, who will review the WARP-related activities of NCRP and set the stage for subsequent presentations. The 40th Lauriston S. Taylor Lecture will be delivered by Dr. John W. Poston, Jr. who will discuss radiation protection and regulatory science.

The meeting will conclude with NCRP President Dr. John Boice's presentation of an overview of current NCRP activities and his vision for the future of NCRP.

NCRP and the Radiation Research Society (RRS) are pleased to welcome the fourth NCRP/RRS Scholars to this year's Annual Meeting. The three young scientists below received competitive travel awards made possible by the generosity of RRS. These awards are aimed at encouraging and retaining young scientists in the field of radiation science. Eligible applicants included junior faculty or students in the radiation sciences or junior health or medical physicists:

Daniel Adjei
Military University of Technology, Institute of Optoelectronics, Poland

Shaowen Hu
Wyle Science, Technology & Engineering Group, Houston, Texas

Yuan-Hao (Chris) Lee
Municipal Wan Fang Hospital, Taiwan

Questions can be submitted on cards during each session. Oral questions from the floor will not be accepted. The session chairs and speakers will address as many questions as time permits. All questions and answers will be published in *Health Physics* as part of the proceedings of the Annual Meeting.

NCRP is grateful to the Joint Armed Forces Honor Guard from the Military District of Washington D.C. who will open our Annual Meeting and to Kimberly Gaskins of the U.S. Nuclear Regulatory Commission who will sing our National Anthem.

Where Are the Radiation Professionals (WARP)?

***NCRP Statement No. 12*, December 17, 2015**

Since the discovery of x rays and radioactivity in the 1890s, sources of ionizing radiation have been employed in medicine, academia, industry, power generation, and national defense. To provide for the safe and beneficial use of these sources of radiation, the United States developed a cadre of professionals with the requisite education and experience. Unfortunately, their numbers have diminished alarmingly (AAAS, 2014; GAO, 2014; HPS, 2013; NA/NRC, 2012).

Methods

To study the decline in radiation professionals and potential national crisis, the National Council on Radiation Protection and Measurements (NCRP) sponsored a workshop in June 2013 in Arlington, Virginia to evaluate whether a sufficient number of radiation professionals exist now and into the future to support the various radiation disciplines essential to meet national needs. Attendance at this workshop included professionals from government, industry, academia, medicine, and professional societies. Presentations from over 30 groups (NCRP, 2013) resulted in the recommendations found in this Statement.

Findings

Evidence presented at the workshop revealed that the country is on the verge of a severe shortfall of radiation professionals such that urgent national needs will not be met. Factors contributing to the downturn include the economy, attrition, redirected national priorities, and decreased public funding. The magnitude of this shortfall varies with radiation disciplines and practice area. Radiation biology has already been critically depleted and other specialties are following the same downward spiral. All radiation professionals share the same goals to develop or implement scientific knowledge to protect workers, members of the public, and the environment from harmful effects of exposure to ionizing radiation. Accordingly, the workshop concluded that the current and projected shortfall will adversely affect the public health, radiation occupations, emergency preparedness, and the environment. Major shortfalls have already been observed in day-to-day operations, leaving policy development, regulatory compliance, research and development, environmental monitoring, emergency management, and military applications as unfunded and under-supported mandates.

The dwindling number of professionals will be of particular concern in mounting a response to a catastrophic nuclear or radiological incident, including terrorist attacks. The current concept of operations for response includes surge support from the existing body of radiation professionals to serve as technical subject matter experts to aid in the management of the consequences of such an event. However, as the number of radiation professionals decreases, the nation's resilience and ability to cope and manage a catastrophic nuclear or radiological event is severely degraded.

Deficit of Professionals

Federal, state and local governments employ radiation professionals in broad and diverse areas such as policy development, regulatory compliance, research and development, environmental monitoring and restoration, waste management, emergency preparedness and response, nuclear medicine, radiation therapy, diagnostic radiology, and nuclear forensics.

The U.S. Government Accountability Office (GAO, 2014) estimates that 31 % of the federal workforce will be eligible to retire by September 2017, and the percentage of engineering and technical professionals eligible to retire by September 2017 is even higher at 41 %. Similarly, a survey of the Conference of Radiation Control Program Directors (directors of state agencies that regulate the use of radioactive materials and radiation-producing devices within their states) predicted that over 50 % of the technical staff in the states' radiation control programs will need to be replaced in the next 10 y.

The National Academy of Sciences has expressed concern about the future supply of radiochemists (NA/NRC, 2012). The projected shortfall of skilled technical expertise within government will result in an inability to support day-to-day operations and will have a significant adverse

effect on the ability to manage the consequences of a catastrophic nuclear detonation or nuclear power plant accident in the United States. The basic radiation sciences and their real world applications are part of a vast enterprise that directly and materially benefits the U.S. population. This enterprise must be strategically managed to prevent atrophy of U.S. expertise and loss of world leadership in radiation sciences to Europe and East Asia.

Numerous professional societies represented at the workshop conclude that the current workforce demographics and expected retirements are such that the demand for replacement radiation professionals will substantially increase from 2015 to 2025 (Appendix A; NCRP, 2013).

Within the private sector (*e.g.*, nuclear power, uranium production, consulting services), adequate numbers of some but not all skilled workers are available in the short term (5 to 10 y). However, in the longer term (10 to 20 y), experienced workers will be retiring, and insufficient replacements are projected to be available. Consequently, even outsourcing of traditional government work to the private sector, especially in large-scale incident response and remediation will unlikely be a viable option to cope with the numerous retirements of government workers.

Only two areas appear to have adequate personnel in the short term: medical physics and nuclear power. In medical physics, where radiation and the practice of medicine intersect, there appears to be no current or anticipated deficit, despite the tremendous growth of the use of ionizing radiation in medicine (NCRP, 2009). Unlike most areas where radiation professionals work, the demand is highly visible and the salaries for practice are attractive. In nuclear power, some utilities have begun educational programs in cooperation with local colleges to "grow their own" future staff. Further, military retirees, especially from the nuclear Navy, frequently transition from shipboard to civilian nuclear power operations. Nonetheless a surge of retiring employees, combined with a waning interest in the field by young professionals and a deficit of training programs in general, have contributed to the industry's growing skills gap in the United States and in other countries.

Figures 1 and 2 demonstrate the long-term trends in the declining numbers of students enrolled in academic health physics programs (ORISE, 2015) and the declining number of members in the U.S. Health Physics Society.[1]

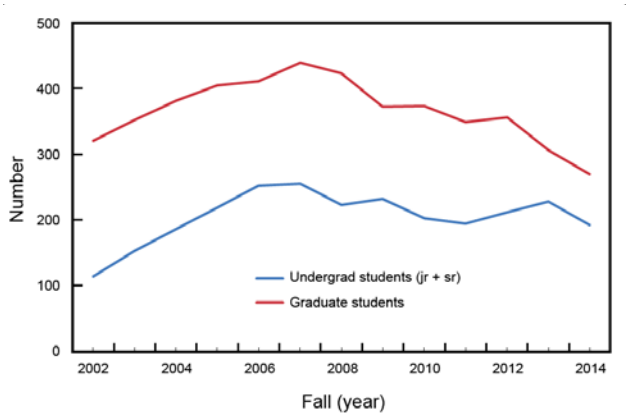


Fig. 1. Health physics enrollment trends, Fall 2002 to Fall 2014 (ORISE, 2015).

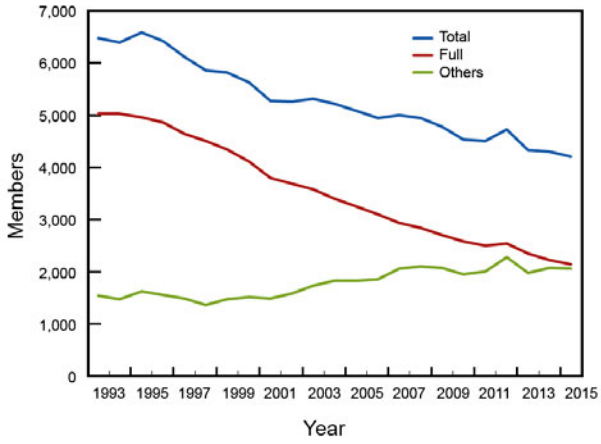


Fig. 2. Membership of the U.S. Health Physics Society, 1993 to 2015.

Deficit of Funding

Federal funding of student scholarships and postgraduate fellow programs have been disappearing. There are only 22 U.S. academic programs with students and staff involved with health physics education, including 12 small programs that graduate fewer than six students per year (ORISE, 2015). Only 12 U.S. programs have sufficient faculty and staff to train future students at B.S., M.S., and Ph.D. levels. Loss of research funding has decimated the ranks of university radiation biologists and other professionals (i.e., the professors needed to teach the next generation of radiation professionals).

1. Health Physics Society (2015). HPS Secretariat (McLean, Virginia).

The Biomedical Advanced Development and Research Authority (BARDA), the National Institute of Allergy and Infection Diseases, and the National Cancer Institute (all parts of the U.S. Department of Health and Human Services) sponsor research in radiological counter-measures, radiation oncology, and radiation epidemiology. The U.S. Department of Energy's (DOE) National Nuclear Security Administration established the Stewardship Science Academic Alliances Program in 2002, to fund academic research in the areas of materials under extreme conditions, low energy nuclear science, radiochemistry, and high energy density physics. One of the goals of the program is to provide hands-on training and experience to students who will be the next generation of scientists and physicists in the areas of interest and potentially be employed at one of our national laboratories (NNSA, 2015). However, these highly focused programs alone cannot support the required faculty and students needed to replace retiring radiation professionals.

Total current federal funding of the radiation sciences (including salaries, grants, contracts) is estimated to be approximately $50 billion annually, including U.S. Nuclear Regulatory Commission training programs, the DOE low-dose radiation research program (before funding was significantly reduced last year), the Centers for Disease Control and Prevention Radiation Studies Branch, the NIOSH Division of Compensation Analysis and Support, the Armed Forces Radiobiology Research Institute, the National Cancer Institute Radiation Epidemiology Branch, and the National Nuclear Security Agency Office of Emergency Operations. NCRP considers it reasonable to provide funding to ensure a continued supply of radiation professionals for these and other programs at a level approaching 10 % of the annual operating costs (*i.e.*, $5 billion annually), judiciously spread across education, training, research, professional development, career management, and development of surge capacity to meet emergency response requirements.

Recommendations

Courses of action to preclude and mitigate the disastrous outcome of not having sufficient radiation professionals to handle the current and future needs of the nation include:

- **Education:** The federal government considers science, technology, engineering and mathematics (STEM) education programs in kindergarten through twelfth grade as vital to the future economic development of the United States (NA/NRC, 2011). Recently the administration published a *Federal STEM Education 5-year Strategic Plan*, with FY15 funding of almost $500 million requested. Support for education of radiation professionals should be considered equally as vital to the health and safety of the United States. University programs must be enlarged and adequately funded to build on STEM learning experiences. The opportunities for higher education in radiation science have been particularly threatened by double-digit budget cuts and higher tuition costs, both of which contribute to decreasing enrollment. Reduced faculty support affects basic research as well as the ability to educate the next generations of radiation professionals. As an example, DOE funds for low-dose radiation research have all but vanished; this hampers acquisition of fundamental knowledge for basic understanding of risk to human populations from low radiation doses needed for radiation protection and for risk management.
- **Research:** Research funding is a necessary condition for education in the radiological sciences. It supports student activities and the faculty who will teach the next generation of students. Without external research support, colleges and universities cannot maintain academic programs in the radiological sciences. Consequently research funding needs to be restored and in fact increased to answer the crucial questions that affect aspects of government operations and policy (*e.g.*, what are the health effects of low-dose radiation exposures comparable to those routinely received from medical procedures, environmental circumstances and occupational endeavors?). The House Committee on Science, Space, and Technology approved the Frontiers in Innovation, Research, Science and Technology (FIRST) Act to prioritize federal investments at the National Science Foundation and the National Institute of Standards and Technology by funding research and development to address national needs (HR, 2014). Maintaining an adequate and well-trained cadre of radiation professionals is one of those needs, as is determining the actual health effects, and magnitude, of low-dose radiation exposures. The importance of public support for radiation research is highlighted in the *Low-Dose Radiation Research Act of 2015* which was passed by the U.S. House of Representatives and awaits approval by the U.S. Senate (HR, 2015).
- **Training:** To provide a significant and guaranteed supply of replacements for radiation professionals lost to retirement, jobs with more opportunities, and

death, new graduates will require months to years of practical, hands-on experience to replace senior professionals. Consequently support must be provided not only for formal academic education, but also for internships, practicums, post-doctoral positions, and similar post-graduate training programs. Such developmental positions at national laboratories and with federal agencies should be funded and guaranteed for the long-term, so that prospective employees can expect career stability. In addition, training grants should be made available to develop a surge capacity of radiation professionals in emergency response to augment the small number of federal and state radiological staff in the case of a potential large radiation emergency involving mass casualties. Competing for emergency response funds has been difficult because of the assumed low probability of such an event. While such events might be low probability, they are of high consequence, and the country cannot afford to be unprepared. Not only are more radiation professionals required for day-to-day activities, but their expertise needs to be leveraged efficiently to train all other responders (*e.g.*, medical, security) about managing such incidents.

- **Joint Program Support Office (JPSO):** The federal government should create a (radiation) JPSO to more efficiently manage radiation professionals in the civil service. The JPSO would: centralize and provide better visibility for the function of radiation professionals; monitor federal staffing levels and needs; enhance mechanisms for interagency collaboration; diminish cross-organizational stovepipes; and centralize recruiting and development of future radiation professionals.
- **Continued monitoring and advocacy:** The status of the availability of radiation professionals, training programs, graduation rates, research opportunities, career opportunities, and professional development obviously needs continued monitoring and follow-up. Consequently, NCRP has established Council Committee 2 specifically to carry out this role and provide advice on this radiation issue to the federal government, consistent with NCRP's Congressional Charter.

Conclusion

The looming shortage of radiation professionals represents a serious threat to the United States: scientific leadership is being lost, competition in world markets is affected, and protection of our citizens and country diminished. NCRP advocates a sequence of activities in the areas of education, training, research, and personnel management to address this urgent national need:

- Restore significant federal and state funding for scholarships, fellowships, and faculty research to increase and sustain a credible workforce of radiation professionals.
- Reinvigorate partnerships among universities, government, and the private sector to ensure undergraduate and graduate programs are adequately resourced to support the training and qualification of radiation professionals, including those who will educate the next generation.
- Establish a Joint Program Support Office (JPSO) for radiation professionals in the federal civil service to manage utilization and career development of personnel more effectively.
- Monitor trends in the supply of and demand for radiation professionals.
- Establish basic and advanced competency profiles to serve as guidance upon which to base the education, training, qualification and appropriate use of radiation professionals.

Public health, radiation safety, emergency preparedness, and the environment are all at risk. The clarion call to act is now!

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Monday, April 11, 2016

Opening Session

8:10 am **Presentation of the Colors**
Joint Armed Forces Honor Guard from the Military District of Washington, DC

Singing of the National Anthem
Kimberly Gaskins
U.S. Nuclear Regulatory Commission

8:15 am **Program Welcome**
Judith L. Bader
Program Committee Co-Chair

8:20 am **Welcome**
John D. Boice, Jr.
President, NCRP

Thirteenth Annual Warren K. Sinclair Keynote Address

8:30 am **WARP: Where are the Radiation Professionals?**
Richard E. Toohey
M.H. Chew & Associates

How Did We Get Here?

Jacqueline P. Williams &
Patricia R. Worthington, *Session Co-Chairs*

9:00 am **Radiation Brain Drain? The Impact of Demographic Change on U.S. Radiation Protection**
Hedvig Hricak
Memorial Sloan-Kettering Cancer Center

9:25 am **Membership Trends in the Health Physics Society: How Did We Get Here and Where Are We Going?**
Kathryn H. Pryor
Pacific Northwest National Laboratory

9:50 am **Q&A**

10:10 am **Break**

10:40 am **Review of the Workforce for Radiation Protection in Medicine**
Wayne D. Newhauser
Louisiana State University

11:05 am **Changing Roles of State Health Physicists**
Ruth E. McBurney
Conference of Radiation Control Program Directors, Inc.

11:30 am **Q&A**

11:50 am **Lunch**

Where Do We Need To Be?

Ralph L. Andersen & Robert C. Whitcomb, Jr.,
Session Co-Chairs

1:15 pm **Commercial Nuclear Power: Assessing and Meeting the Need**
Jerry W. Hiatt
Nuclear Energy Institute

1:40 pm **Education or Training: Does it Matter?**
Kathryn A. Higley
Oregon State University

2:05 pm **Estimating Cancer Risks at Very Low Radiation Doses: What Can be Done?**
David J. Brenner
Columbia University Medical Center

2:30 pm **Q&A**

2:55 pm **Break**

3:25 pm **Developing a Radiation Protection Hub**
Nolan Hertel
Georgia Institute of Technology / Oak Ridge National Laboratory

3:50 pm **Meeting Regulatory Needs**
Michael Weber
U.S. Nuclear Regulatory Commission

4:15 pm **Q&A**

4:35 pm **Break**

Fortieth Lauriston S. Taylor Lecture on Radiation Protection and Measurements

5:00 pm **Introduction of the Lecturer**
Michael T. Ryan

Radiation Protection and Regulatory Science
John W. Poston, Sr.
Texas A&M University

6:00 pm **Reception**
Sponsored by Landauer, Inc.

Tuesday, April 12

8:15 am **NCRP Annual Business Meeting**

9:10 am **Break**

How Do We Get There?

Pamela J. Henderson & Chad A. Mitchell, *Session Co-Chairs*

9:30 am **Critical Issues in Knowledge Management in Domestic Radiation Protection Research Capabilities**
Shaheen Dewji
Oak Ridge National Laboratory

9:55 am **The Business of Health Physics: Jobs in a Changing Market**
Matthew P. Moeller
Dade Moeller

10:20 am **Break**

10:45 am **Meeting the Needs of First Responders: Scientific Experiments to Operational Tactics for the First 100 Minutes After an Outdoor Explosive Radiological Dispersal Device**
Stephen V. Musolino
Brookhaven National Laboratory

11:10 am **Meeting the Needs of the Nation for Radiation Protection: How Do We Get There? Meeting Medical Needs**
Donald P. Frush
Duke University School of Medicine

11:35 am **Q&A**

Session 4: Conclusions

John D. Boice, Jr., *Session Chair*

11:55 am **NCRP Vision for the Future and Program Area Committee Activities**
John D. Boice, Jr.
President, NCRP

12:20 pm **Closing Remarks**
John D. Boice, Jr.
President, NCRP

12:30 pm **Adjourn**

Monday, April 11, 2016

Opening Session

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Presentation of the Colors
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Program Welcome
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Welcome
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National Council on Radiation Protection and Measurements

Thirteenth Annual Warren K. Sinclair Keynote Address

8:30 am

WARP: Where are the Radiation Professionals?
Richard E. Toohey
M.H. Chew & Associates

In July 2013, the National Council on Radiation Protection and Measurements (NCRP) convened a workshop for representatives from government, professional organizations, academia, and the private sector to discuss a potential shortage of radiation protection professionals in the not-too-distant future. This shortage manifests itself in declining membership of professional societies, decreasing enrollment in university programs in the radiological sciences, and perhaps most importantly, the imminent retirement of the largest birth cohort in American history, the so-called “baby boomer” generation. This group comprises those born from approximately 1945 to 1965, the first quarter of whom have already reached the traditional retirement age of 65 y. Each speaker at the workshop presented a “quad chart” that showed “who we are,” “what we do,” “how we do it,” and “our needs.” Consensus emerged that shortages already are, or soon will be felt in government agencies (including state radiation control programs), membership in professional societies is declining precipitously, and student enrollments and

university support for radiological disciplines are decreasing, with no reversals expected. The supply of medical physicists appears to be adequate at least in the near term, although a shortage of available slots in accredited clinical training programs looms large. In general the private sector appears stable, due in part to retirees joining the consultant ranks. However, it is clear that a severe problem exists with the lack of an adequate surge capacity to respond to a large-scale reactor accident or radiological terrorism attack in the United States. The workshop produced a number of recommendations, including increased funding of both fellowships and research in the radiological sciences, as well as creation of internships, practicums, and post-doctoral positions. A federal joint program support office that would more efficiently manage the careers of radiological professionals in the civil service would enhance recruiting and development, and increase the flexibility of the various agencies to manage their staffing needs. NCRP has electronically published the proceedings of the WARP workshop, and NCRP Statement No. 12 has been completed and issued, along with a one-page synopsis. NCRP has also established Council Committee 2, which is charged with continuing to monitor the situation and periodically report to the Council and stakeholders on the issue.

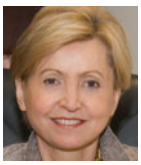
How Did We Get Here?

Jacqueline P. Williams & Patricia R. Worthington, *Session Co-Chairs*

9:00 am

Radiation Brain Drain? The Impact of Demographic Change on U.S. Radiation Protection

Hedvig Hricak
Memorial Sloan-Kettering Cancer Center



Since the discovery of x rays and radioactivity, and especially since the “Atoms for Peace” initiative, the use of radiation has had a significant, beneficial impact in the United States, particularly in medicine, energy production, basic science research, and industrial applications. Radiation protection knowledge and experience are required to continue to develop and implement scientific knowledge to protect workers, members of the public, and the environment from potential harmful effects of ionizing radiation while facilitating the beneficial use of radiation-based technologies. However, several demographic changes are negatively impacting U.S. radiation protection and response capabilities. These changes are most evident in the medical, energy, research, and security arenas.

Demographic shifts in the U.S. population are expected to contribute to substantial increases in the incidence of cancers and other diseases over the coming decades. For example, it is projected that by 2030, 40.5 % of the U.S. population will have some form of cardiovascular disease (CVD), with a tripling of total direct medical costs. While cancer-related and CVD death rates have been decreasing as a result of improved imaging and therapeutic approaches, a significant increase in the beneficial and safe use of radiation in medicine will be needed to continue fighting these diseases in the future. Accordingly, the need for radiation protection for

patients, staff, and members of the public will also increase.

With respect to energy, it is projected that from now through 2040, U.S. consumption will continue to grow while rising costs for electric power generation, transmission and distribution will increase the average price of electricity by 18 %. Given these changes, the increasing concerns about climate effects and the resulting shift toward greater use of renewables, it will be necessary to maintain or increase the availability of nuclear energy in the U.S. as well as to develop new technologies. These endeavors will require excellence in professional and scientific leadership in radiation sciences.

There is also, unfortunately, a real and mounting specter of terrorism that must be dealt with. Terrorists continue to adapt to the challenges of emerging forms of conflict and exploit changes in technology and society. They are developing new capabilities of attack and improving the efficiency of their existing methods. Are we as a nation responding with sufficient speed and commitment? NCRP, the National Research Council, the U.S. Government Accountability Office, as well as the Health Physics Society (HPS) have each clearly stated that responding to a major U.S. radiation accident or terrorist attack will require a huge surge in radiation professionals to manage the consequences of such an incident.

Regrettably, there are significant shortfalls in radiation protection, radiobiology, nuclear expertise, and radiation research infrastructure in the United States. HPS concluded that “[T]he critical human capital shortage in radiation safety is overwhelming the Society's efforts to help respond to this crisis.” A report published by the Oak Ridge Institute for Science and Education reiterated this concern, stating “[I]t is highly likely that the number of job openings for new graduate health physicists will continue to exceed the number of new graduates available in the labor supply.” Indeed, in 2013, the number of graduate-level enrollees in radiation protection programs was the lowest reported since the early 1970s, and it is anticipated that there will continue to be decreases in master's and doctoral degree recipients. A survey of faculty members employed in radiation biology in U.S. and Canadian residency programs revealed similar concerns over the declining numbers of radiobiologists; it showed both that faculty members with degrees in radiation biology are scarce and that those responsible for teaching radiation biology to radiation-oncology and radiology residents are aging. In fact, age distributions for workers in radiation protection, medical physics, and nuclear power are heavily and increasingly skewed toward the higher end of the spectrum. Furthermore, in addition to asking: “Where are the radiation professionals?” it is essential to ask, “Where are the radiation facilities?” Research infrastructure and resources continue to decay and decline.

For public, private and government entities alike, the increasing shortage of radiation scientists and radiation protection specialists as well as the lack of infrastructure stand in sharp contrast to emerging scientific opportunities and the need for new knowledge to address issues of health, growth and security. The radiation brain drain is real and requires immediate attention, as the workforce in radiation sciences will soon be inadequate to fill the multiple roles it occupies in the academic, medical, energy and defense sectors.

While necessity may be the mother of invention, preparation is the father of inspiration. Could it be that such challenges create opportunities for improvement? Though for many years, the United States has been the world leader in radiation protection and radiation sciences, the country clearly lacks a coordinated, long-term,

milestone-driven strategic plan for reversing the radiation brain drain. Addressing the problem will require significantly increased federal and state funding as well as formal partnerships and initiatives amongst academia, research, government, and the private sector. It will also require unique and creative courses of action and may lead to remarkable advances we are, as yet, unable to imagine.

9:25 am

Membership Trends in the Health Physics Society: How Did We Get Here and Where Are We Going?

Kathryn H. Pryor
Pacific Northwest National Laboratory

The Health Physics Society (HPS) has been a diverse body since its beginnings in 1956, encompassing professionals from different disciplines with an interest in radiation safety issues. Health physics was just beginning to emerge as a distinct discipline, initially spurred by the development of the atomic bomb, and amplified by the commercial use of nuclear power. There was a need for a professional group to discuss issues and share ideas and experiences in the field. Both the field of health physics and the ranks of the HPS membership experienced a steady increase in numbers and interest.

HPS continued to grow in numbers and thrive through the mid-1990s, and then began to retract. Concern regarding the "graying" of the HPS was being discussed as far back as the late 1990s. Despite efforts to broaden the base of membership through additional membership categories, the numbers of plenary (now referred to as Full) members continued to shrink.

The "graying" of the HPS is real - although age demographic data are only available for about the past 15 y (and is provided voluntarily), the shift in age distribution over this timeframe is clear. A recent survey indicated that over 50 % of HPS members are over 50 y of age, and over half of the respondents plan to retire within 10 y. As our members age, they convert to emeritus memberships or drop their membership altogether. Some members simply aren't able to continue for financial or health-related reasons. There is now an age gap – members in their 30s and early 40s are missing from the mix.

Potential causes for declining membership may include smaller enrollments in academic programs, reduced employment opportunities, and societal factors. There appears to be reduced employer support for participation in professional activities and travel to conferences. Societal factors include easy access to professional information through the internet, balancing of family commitments, other volunteer opportunities, and a general decline in joining professional groups.

So, what is the fate of the HPS? We are not alone – other professional groups are experiencing the same overall trends in membership to differing degrees. A number of initiatives have been launched or are being considered by HPS in an effort to offset this trend.

9:50 am **Q&A**

10:10 am **Break**

10:40 am

Review of the Workforce for Radiation Protection in Medicine

Wayne D. Newhauser
Louisiana State University

Within the health care industry, several professions share responsibility for the protection of patients and staff from radiation, including the scientific specialties of medical physics and health physics, the medical specialties of radiation oncology and radiology, with important supporting roles played by registered therapy technologists, engineers, and information technologists. This talk will review the current status of the workforces of selected radiation professions in the United States, with emphasis on medical physics, health physics, and radiation oncology, based on a survey of the literature.

The presentation will cover the current size and general characteristics of the workforces. Data will be presented on trends in the supply and demand for entry level positions in various professions. Factors influencing demand for radiation professionals, *e.g.*, changes in number of incident cancers, the utilization of radiation treatments, and changes in health care economic policies will be mentioned.

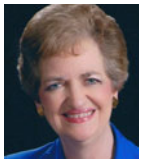
Several education-related topics will be reviewed, including relevant trends in higher education, such as the numbers and types of degree programs, their capacities, graduation rates, and other performance indicators.

The presentation will also mention selected factors that influence the supply of radiation professionals, including the cost of higher education (*e.g.*, tuition), admission and graduation rates degree programs and residency training fellowships, the perceived attractiveness of various professions to students, job duties, job satisfaction, and rates of compensation. Funding for academic programs will also be discussed, including trends in state and federal support for research and education.

11:05 am

Changing Roles of State Health Physicists

Ruth E. McBurney
Conference of Radiation Control Program Directors, Inc.



State radiation control programs are responsible for many aspects of radiation protection under their purview. Although some federal agencies have a specific role in radiation protection at the federal level, radiation control programs have been established in each state, New York City, the District of Columbia, Los Angeles County, and Puerto Rico. Most of these state, local and territorial programs, under legislative authority and mandates, address all aspects of radiation protection for sources of radiation not exclusively under federal control, including the use of some sources of radiation not regulated by the federal government, including industrial and medical uses of x ray (other than mammography) as well as certain types of naturally occurring radioactive material.

The role of state health physicists is ever-evolving, and the scope of their work is constantly expanding. In addition to regulatory duties involved with the control of

radioactive material and radiation machines (x ray and accelerators), as well as sources of nonionizing radiation, such as lasers and ultraviolet radiation, state radiation control staff are also involved in environmental radiation issues and preparing for radiation emergencies.

Those states in the planning zones of nuclear power plants are involved in offsite emergency planning and exercising, including scenario development, accident assessment, contamination control and environmental monitoring. Since the events of September 11, 2001, radiation control programs are also involved in planning for other radiological incidents, including terrorist acts. States and local governments that have experience in emergency planning have been shown to be better equipped and prepared for handling other types of radiological incidents, but preparing for radiological dispersal device and improvised nuclear device events present unique challenges to all programs and their staff.

Emerging technologies, especially in healing arts applications, present ever-changing training needs for radiation control staff. Source security, financial security for decommissioning and disposal of radioactive material are challenges that have come more to the front in the past few years. In addition, new challenges, such as technologically enhanced naturally occurring radioactive material, as well as its associated risk and methods for regulatory control, are adding to the need for health physics resources and knowledge base.

To develop a consistent and scientifically sound approach to radiation protection policies across state and federal agencies, and to avoid unnecessary duplication of effort, the Conference of Radiation Control Program Directors (CRCPD) fosters the exchange of ideas and information among the states and the federal government concerning radiation control. It also provides a forum for state and federal agencies to work together and apply their limited resources to address radiological health issues of mutual interest. CRCPD uses working groups assigned to specific issues, annual meetings for presentations and discussion of issues of mutual interest, new developments in the field, upcoming challenges and recommendations, along with training and workshops to keep state and federal regulatory personnel informed and educated on new technologies, issues, and regulatory procedures.

11:30 am **Q&A**

11:50 am Lunch

Where Do We Need To Be?

Ralph L. Andersen & Robert C. Whitcomb, Jr., *Session Co-Chairs*

1:15 pm

Commercial Nuclear Power: Assessing and Meeting the Need

Jerry W. Hiatt
Nuclear Energy Institute

The purpose of this presentation is to provide an overview of the process used by the commercial nuclear power industry in assessing the status of existing industry

staffing and projecting future supply-demand needs. The most recent Nuclear Energy Institute developed "Pipeline Survey Results" will be reviewed with specific emphasis on the radiation protection specialty. Both radiation protection technician and health physicist specialties will be discussed.

The industry initiated Nuclear Uniform Curriculum Program will be reviewed as an example of how the industry has addressed the need for developing additional resources. Furthermore, the reality of challenges encountered in maintaining the needed number of health physicists will also be discussed.

1:40 pm

Education or Training: Does it Matter?

Kathryn A. Higley
Oregon State University

Radiation protection professionals are an endangered breed. Health physics (HP) as a discipline and vocation is at a critical juncture. We are at a tipping point. Oak Ridge Associated University tracks enrollment and degrees in HP programs. In 2014 there were only 10 PhD, 81 MS, and 61 BS graduates nationwide in health physics. Why are these numbers important? Small programs do not cover their costs to operate. Higher education today is vastly different from what it was even 20 y ago. Every academic program must now make a budget case to justify its existence. Consequently, HP programs, which are by anyone's measure, minuscule, are in very real danger of closing. Given that the country will continue to need radiation protection expertise, we must take immediate steps to reinvigorate the profession and preserve academic programs. We simply cannot train or short-course our way out of this problem. Under routine conditions, individuals trained in basic health physics can be expected to safely manage daily operations. But life is full of the unexpected. When it involves radiation, we need someone grounded in the radiological fundamentals to understand, assess, and safely deal with it.

There are several specific steps that must be taken. The American Board of Health Physics (ABHP) in conjunction with the Health Physics Society (HPS) must identify minimum curriculum content for health physics programs at the graduate and undergraduate level. Academic institutions should share curricular content to make program delivery more cost effective and to minimize redundancies. This should include establishing joint degrees and academic exchanges to enhance student mentoring and faculty experience. ABHP must require applicants for board certification (CHP) to have graduated from an approved academic program.

At the federal level, we need to recognize the discipline of health physics as meeting a "strategic national need." The basic requirements for health physicist in the Office of Personnel Management's Classifications and Qualifications System (job series 1306) need to be revised and strengthened. Applicants for federal HP jobs must have a minimum number of credit hours in HP or radiation safety and have graduated from an approved program or hold CHP certification. At the federal and state level we need to mandate advanced radiation protection degrees and/or CHP for jobs with substantial radiation safety management or assessment responsibility. Federal programs with considerable radiation safety obligations must carve out funds for academic research for faculty from approved HP programs. Internship opportunities for undergraduate

and graduate HP students must be established and sustained.

The Institute of Nuclear Power Operations, a long standing supporter of education, must require accreditation of health physics professionals in the nuclear industry. Industry in general must do more to support knowledge transfer efforts, by teaming with approved academic institutions, to provide student internship opportunities, and support faculty sabbaticals or cooperative research efforts. Industry is best suited to train and produce the job-specific skills needed for competent HPs.

Without these very specific steps, HP will be relegated to a subspecialty footnote within other academic programs, if it survives at all. The broad, interdisciplinary education that is the hallmark of a great health physicist will be lost. HP, as an academic discipline and as a profession represents a strategic national need. But it is in peril, and there is no single, "silver bullet"[1] that will save it. Multiple actions must be taken, and soon.

2:05 pm

Estimating Cancer Risks at Very Low Radiation Doses: What Can be Done?

David J. Brenner
Columbia University Medical Center

Providing realistic estimates of radiation-induced cancer risks at very low doses is of importance in a number of societal arenas. Nuclear power is an obvious case, for example in terms of assessing the significance of, and response to, accidents such as at Chernobyl and Fukushima. Another example is providing the input to benefit-risk analyses for the multiple applications of x-ray imaging in medicine.

Epidemiological studies of populations exposed to low doses of radiation have and will continue to provide value, but as we move to lower and lower doses, to doses where the natural cancer background rate is increasingly dominant, even the largest scale studies will produce results with very wide confidence intervals, and with therefore only limited utility.

The situation is not dissimilar for animal models of radiation-induced cancer where, again, the natural cancer background limits the potential for large-scale radiation-carcinogenesis studies at very low radiation doses.

A third potential approach is use of *in vitro* cellular or molecular models of radiation-induced cancer. A limitation here is the need for *in vitro* endpoints which can act as credible surrogates for radiation-induced cancer in man. Lacking these — and it may be that no single *in vitro* endpoint could fulfill this role — while such studies may be technically feasible at very low doses, their relevance may be questioned.

A fourth approach is the use of models. Among these there are two types of approaches: one relates to the long-discussed goal of providing a complete quantitative description of all the chemical, physical and biological steps involved in radiation-induced cancer on time scales ranging from picoseconds to years. Whilst long a programmatic goal, progress has been slow even for modeling limited subsets of this "grand scheme" approach, reflecting the extraordinary complexities involved at every mechanistic level.

The second type of modeling approach is not focused on providing absolute risk estimates, but is rather motivated by the goal of extrapolating radiation-induced cancer risks from epidemiologically tractable doses down to epidemiologically-intractable low radiation doses. An

example here is the biophysical argument which underlies the linear nonthreshold model. An advantage of these extrapolation motivated approaches is that the assumptions underlying any particular extrapolation model can, at least in principle, be tested without the need for direct cancer-risk measurements at low doses.

A final approach uses the so called "upper limit" technique. Here the goal is to provide statements such as "the radiation-induced cancer risk at dose *D* cannot be more than *R*, because if it were the risks would have been detected in low dose epidemiological studies." Such statements have considerable value for clarifying low-dose radiation risks to the general public, for providing the data for risk-benefit analyses, as well as providing the data needed to design rational responses to large-scale radiological events.

2:30 pm **Q&A**

2:55 pm **Break**

3:25 pm

Developing a Radiation Protection Hub

Nolan Hertel
Georgia Institute of Technology / Oak Ridge National Laboratory

A National Council on Radiation Protection and Measurements (NCRP) committee estimates that in 10 y there will be a human capital crisis in the radiation safety community as a whole. The difficulty in responding to this shortage will be amplified by the fact that many radiation protection (health physics) academic programs will find it difficult to justify their continued existence, since they are low volume programs both in terms of enrollment and research funding compared to more highly subscribed and highly funded academic programs. In addition, radiation protection research groups have been disbanded or dramatically reduced in size across the national laboratory complex. The loss of both of these national resources is being accelerated by low and uncertain government funding priorities.

Borrowing from the U.S. Department of Energy (DOE) research hub model [e.g., the Consortium for Advanced Simulation of Light Water Reactors (http://www.casl.gov)], is it an opportune time to form a consortium that would bring together the radiation protection research, academic and training communities? The goal of such a consortium would be to engage in research, education and training of the next generation of radiation protection professionals. The consortium furthermore could bring together the strengths of different entities in a strategic manner to accomplish a multifaceted research, educational and training agenda. This vision would forge a working and funded relationship between major research universities, national labs, 4 y degree institutes, technical colleges, and other partners. This consortium would differ from the DOE research hub model in that it would incorporate a greater educational and training mission.

An initial goal would be to secure consortium funding for a 5 y period that would be renewable upon satisfactory performance. Such a consortium would need to be structured so that it does not encroach on funding from any contracted radiation protection activities that its members normally would have received. An agenda would be formed that is truly research, education and training driven and not

driven by contracted product development or statutory regulatory needs.

It is envisioned that such a consortium would set up a large summer student intern program where the interns are placed at several national laboratories and other facilities to gain either research or operational radiation experience. The consortium would set up a practicum program where new hires by DOE, their laboratories, and/or other federal agencies are rotated through several facilities to broaden their understanding of operational health physics. The consortium would also serve as a research hub for funding university and national laboratory research that advances the state of radiation protection knowledge and methods. This would require the development of a research agenda would be generated by the scientists and engineers who are part of the consortium in concert with an advisory committee consisting of radiation protection scientists.

It is time to form a Consortium for the Advancement of Radiation Protection.

3:50 pm

Meeting Regulatory Needs
Michael Weber
U.S. Nuclear Regulatory Commission

The world is experiencing change at an unprecedented pace, as reflected in social, cultural, economic, political and technological advances around the globe. Regulatory agencies, like the U.S. Nuclear Regulatory Commission (NRC), must also transform in response to and in preparation for these changes. In 2014, NRC staff commenced Project Aim 2020 to transform the agency by enhancing efficiency, agility and responsiveness, while accomplishing NRC's safety and security mission. Following Commission review and approval in 2015, NRC began implementing the approved strategies, including strategic workforce planning to provide confidence that NRC will have employees with the right skills and talents at the right time to accomplish the agency's mission. Based on the work conducted so far, ensuring an adequate pipeline of radiation protection professionals is a significant need that NRC shares with the states and other government agencies. NRC is working to ensure that sufficient radiation protection professionals will be available to fulfill its safety and security mission and leveraging the work of the National Council on Radiation Protection and Measurements, the Conference of Radiation Control Program Directors, the Health Physics Society, and others.

4:15 pm **Q&A**

4:35 pm **Break**

Fortieth Lauriston S. Taylor Lecture on Radiation Protection and Measurements

5:00 pm **Introduction of the Lecturer**

Michael T. Ryan

Radiation Protection and Regulatory Science

John W. Poston, Sr.
Texas A&M University

It took about 30 y after Wilhelm Konrad Roentgen's discovery of x rays and Henri Becquerel's discovery of natural radioactivity for scientists in the civilized world to formulate recommendations on exposure to ionizing radiation. We know of these efforts today because the organizations that resulted from the concerns raised in 1928 at the Second International Congress of Radiology still play a role in radiation protection. The organizations are known today as the International Commission on Radiological Protection (ICRP) and, in the United States, the National Council on Radiation Protection and Measurements (NCRP). Today, as we have some many times in the past, we honor Dr. Lauriston Sale Taylor, the U.S. representative to the 1928 Congress, for his dedication and leadership in the early growth of NCRP.

The mission of NCRP is "to support radiation protection by providing independent scientific analysis, information, and recommendations that represent the consensus of leading scientists." The developments in science and technology, including radiation protection, are occurring so rapidly that NCRP is challenged to provide its advice and guidance at a faster pace than ever before. The NCRP role has also expanded as the Council considers newer uses and applications of ionizing radiation in research and medicine as well as the response to nuclear or radiological terrorism. In such a technical world, new areas have been established to deal with the nexus of science and regulation, especially in the United States. Lord Ernest Rutherford supposedly said, "That which is not measurable is not science. That which is not physics is stamp collecting." I wonder what he would say if he was alive today as now many embrace a new field called "regulatory science." This term was suggested by Professor Mitsuru Uchiyama in Japan in 1987 and was reviewed in literature published in English in 1996. Some have attributed a similar idea to Dr. Alvin Weinberg, for many years Director of the Oak Ridge National Laboratory (ORNL). He actually introduced the term "trans-science," which he defined as the policy-relevant fields for which scientists have no answers for many of the questions being asked. He was influenced with the heavy involvement of ORNL in developing methods to assess environmental impacts as mandated by the 1969 National Environmental Policy Act. Professor Uchiyama defined regulatory science as "the science of optimizing scientific and technological developments according to objectives geared toward human health." In essence, regulatory science is that science generated to answer political questions.

This presentation will introduce regulatory science and discuss the differences between what some call "academic science" and "regulatory science." In addition, a short discussion of how regulatory science has and will impact the practice of radiation protection and all areas involving the use of radiation and radioactivity.

6:00 pm

Reception in Honor of the Lecturer
Sponsored by Landauer, Inc.

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Tuesday, April 12

8:15 am **NCRP Annual Business Meeting**

9:10 am **Break**

How Do We Get There?

Pamela J. Henderson & Chad A. Mitchell,
Session Co-Chairs

9:30 am

Critical Issues in Knowledge Management in Domestic Radiation Protection Research Capabilities

Shaheen Dewji
Oak Ridge National Laboratory

In response to the severe atrophy of capabilities in health physics identified by the Health Physics Society in 2002, the National Council on Radiation Protection and Measurements created WARP (Where Are the Radiation Professionals?) to assess the “front-end” of the human capital pipeline in university education and training. Over a decade later, the human capital crisis in radiation protection continues to be of paramount concern to address the loss of expertise associated with the loss of radiation protection knowledge on the “back-end,” most notably with respect to research and development (R&D) capabilities of the field. In order to preserve the radiation protection knowledge in R&D that may be lost due to the growing number of retirements in the field of radiation protection, knowledge management, and knowledge capture has become an extremely high priority that must be addressed immediately before the expertise is irreplaceably lost. As a hub of domestic capabilities, Oak Ridge National Laboratory's Center for Radiation Protection Knowledge has a mandate to develop and actuate a formal knowledge management strategy in the transfer knowledge from outgoing subject matter experts in the field of radiation protection. It is envisioned that such an effort will provide one avenue for preserving domestic capabilities to support stakeholder needs in the federal government and the nuclear industry, while continuing to lead and innovate in R&D on a global scale.

9:55 am

The Business of Health Physics: Jobs in a Changing Market

Matthew P. Moeller
Dade Moeller

Health physics is changing. The early legends have long since passed. The first generation of young health physics professionals is now almost gone as well. Today's health physicists are no longer the specialists, scientists and educators who

initially defined, established and developed our profession. To assess what the future holds, it is beneficial to characterize the type of health physics work performed in the past so as to speculate on the needs and jobs of the future. Since 1979, the market drivers have been:

- operating commercial nuclear power plants;
- initiating cleanup activities within the U.S. Department of Energy's weapons complex sites;
- responding to major nuclear accidents and their aftermaths;
- reducing costs through improved instrumentation and computer applications; and
- advancing medical treatments using radioactive materials and radiation-generating devices.

All these activities created jobs for health physicists decades ago. Today, we are a new generation of health physicists challenged with the burden of continuing past traditions while remaining relevant to changing industries and global markets. The business of health physics has changed rapidly in response to a new set of factors and conditions. These include dependence upon advanced technologies, constraints due to reduced budgets and competitive economic pressures, and the expectation that routine operations will always remain routine. Consequently, work once performed by health physics professionals has disappeared rapidly as well. Today, research projects are rarely funded. Radiation protection programs and protocols are already well established and documented. Those professionals with niche expertise in specialized disciplines of health physics are in demand only in unusual circumstances. Today's reality is that generalists are conducting health physics programs and filling the majority of radiation protection jobs. The most fundamental step that should be taken to maintain jobs for health physicists, and to encourage new students to enter our profession, is to establish comprehensive standards specifying the minimum education, training, qualifications and experience necessary to perform the roles, duties and responsibilities of practicing health physics technicians and professionals in today's marketplace. Without such provisions, smart instruments will continue to replace qualified people. With opportunity, health physics jobs will be focused on:

- decommissioning U.S. nuclear power plants;
- commissioning and operating foreign nuclear power plants of new design;
- conducting environmental programs emphasizing virtually no emissions and therefore no harm;
- screening consumer products to detect inadvertent contamination; and
- supporting another generation of diagnostic and therapeutic medical devices.

Waste management, processing and disposal will be an international concern. The role of the health physicist in all of these endeavors will need to evolve from what it is today.

10:20 am **Break**

10:45 am

Meeting the Needs of First Responders: Scientific Experiments to Operational Tactics for the First 100 Minutes After an Outdoor Explosive Radiological Dispersal Device

Stephen V. Musolino
Brookhaven National Laboratory

During radiological or nuclear emergencies, routine decisions and operations for state and local response agencies can become overwhelming. Prompt actions in the first few hours after an incident has occurred require scientifically sound preplanning, and then operational integration, specialized tools, and response tactics to safeguard the public and responders. To answer the questions about what to do in a tactical sense in the first 100 minutes of a response to a radiological dispersal device required many years of explosive aerosolization experiments. This basic work in materials science was turned into pragmatic language of first responders to inform them of the realistic hazard boundaries, and the appropriate response actions in the first "100 minutes" of a response to radiological terrorism. The U.S. Department of Homeland Security has sponsored efforts to improve national planning and response for radiological terrorism through programs such as "The First 100 minutes," which has developed scientifically supported initial tactical response guidance for managing key activities, such as confirming a radiological release, shelter and evacuation, and conducting lifesaving operations in a radiation environment; RadResponder, a smartphone app that allows anyone to collect and integrate geo-positioned field measurements; and the Radiological Operations Support Specialist, which is a National Incident Management System-typed position that will help train, equip and certify radiation experts to assimilate with the incident command system during a radiological response. With the shrinking pool of radiation protection professionals, there will be challenges in the future to continue this support to radiological and response operations. The problem is much larger in the context of a nuclear detonation.

11:10 am

Meeting the Needs of the Nation for Radiation Protection: How Do We Get There? Meeting Medical Needs

Donald P. Frush
Duke University School of Medicine

Radiation and potential risk during medical imaging is one of the foremost issues for the imaging community. Because of this, there are growing demands for accountability including appropriate use of ionizing radiation in diagnostic and image-guided procedures. Factors contributing to this include increasing use of medical imaging; increased scrutiny (from awareness to alarm) by patients/caregivers and the public over radiation risk; and mounting calls for accountability from regulatory, accrediting, healthcare coverage (e.g., Centers for Medicare and Medicaid Services), and advisory agencies and organizations as well as industry (e.g., NEMA XR-29, *Standard Attributes on CT Equipment Related to Dose Optimization and Management*). Current challenges include debates over uncertainty with risks with

low-level radiation; lack of fully developed and targeting products for diagnostic imaging radiation dose monitoring; lack of resources for and clarity surrounding dose monitoring programs; inconsistencies across and between practices for design, implementation and audit of dose monitoring programs; lack of interdisciplinary programs for radiation protection of patients; potential shortages in personnel for these and other consensus efforts; and training concerns as well as inconsistencies for competencies throughout medical providers' careers for radiation protection of patients. Medical care providers are currently in a purgatory between quality- and value-based imaging paradigms, a state that has yet to mature to reward this move to quality-based performance. There are also deficits in radiation expertise personnel in medicine. For example, health physics programs and graduates have recently declined, and medical physics residency openings are currently at a third of the number of graduates. However, leveraging solutions to the medical needs will require money and resources, beyond personnel alone. Energy and capital will need to be directed to:

- innovative and cooperative cross-disciplinary institutional/practice oversight of and guidance for the use of diagnostic imaging (e.g., radiology, surgical specialties, cardiologists, and intensivists);
- initiatives providing practical benchmarks (*e.g.*, dose index registries);
- comprehensive (consisting of access, integrity, metrology, analytics, informatics) and effective and efficient dose monitoring programs;
- collaboration with industry;
- improved imaging utilization such as through decision support combined with evidence-based appropriateness for imaging utilization;
- integration with e-health such as medical records;
- education including information extending beyond the medical imaging community that is relevant to patients, public, and providers…and administration;
- identification of opportunities for alignment with salient media and advocacy organizations to deliver balanced information regarding medical radiation and risk;
- open lines of communication between medical radiation experts and appropriate bodies such as the U.S. Environmental Protection Agency, the U.S. Food and Drug Administration, and the Joint Commission to assure appropriate guidance on documents and actions originating from these organizations; and
- increased grant funding to foster translational work that advances our understanding of low-level radiation and biological effects.

11:35 am **Q&A**

Conclusions

John D. Boice, Jr., *Session Chair*

11:55 am

NCRP Vision for the Future and Program Area Committee Activities

John D. Boice, Jr.
President, NCRP

Remember the popular books “Where's Waldo”? Well, similar to radiation professionals it seems that even allowing GPS location on his smartphone won't help much - if there's no one to answer the call! Where are the radiation professionals (WARP) and where are you? We're losing human capital and the losses are increasing. If you believe we have a national crisis, do you have ideas on how we can avert the impending disaster or mitigate its consequences? NCRP tried with our workshop in 2013 with representatives from government, academia, industry and societies which resulted in a synopsis and now a fuller statement available on the NCRP website (http://ncrponline.org/). We should not be limited by conventional notions of what is practical or feasible. We need to be imaginative and visionary. NCRP advocates a sequence of activities in the areas of education, training, research, and personnel management to address this urgent national need. But more can be done:

- restore significant federal and state funding for scholarships, fellowships, and faculty research to increase and sustain a credible workforce of radiation professionals;
- reinvigorate partnerships among universities, government, and the private sector to ensure undergraduate and graduate programs are adequately resourced to support the training and qualification of radiation professionals, including those who will educate the next generation;
- establish a Joint Program Support Office for radiation professionals in the federal civil service to manage utilization and career development of personnel more effectively;
- monitor trends in the supply of and demand for radiation professionals; and
- establish basic and advanced competency profiles to serve as guidance upon which to base the education, training, qualification and appropriate use of radiation professionals.

NCRP has created Council Committee-2, Meeting the Needs of the Nation for Radiation Protection, where we will continually monitor and make suggestions on ways to address the vanishing professionals. Further this year's 2016 Annual Meeting is similarly titled and new ideas to mitigate the impending disasters are anticipated.

Remember the days when people were smart and phones where dumb? When the call comes will there be anyone home to answer the phone (smart or otherwise)? Public health, radiation safety, emergency preparedness, and the environmental are all at risk. The clarion call to act is now!

And for a snapshot of NCRP recent and planned activities:

- Integration of Biology with Epidemiology (Chairs: Sally A. Amundson, Jonine Bernstein)—Commentary published late 2015;

- Dosimetry for Workers and Veterans (Chairs: Andre Bouville, Richard E. Toohey);
- Million Person Study of Low Dose Health Effects (Coordinator: John D. Boice, Jr.);
- Radiation Protection Guidance for the United States (update NCRP Report No. 116) (Chairs: Kenneth R. Kase, John D. Boice, Jr.);
- Recent Epidemiologic Studies and Implications for the Linear Energy Transfer Model (Chairs: Roy E. Shore, Lawrence T. Dauer);
- Guidance on Radiation Dose Limits for the Lens of the Eye (Chairs: Eleanor A. Blakely, Lawrence T. Dauer);
- Radiation Exposures in Space and the Potential for Central Nervous System Effects (Chairs: Leslie A. Braby, Richard S. Nowakowski);
- Guidance for Emergency Responders (Chairs: Stephen V. Musolino, Adela Salame-Alfie);
- Emergency Response and Preparedness (2017 Annual Meeting; Program Chairs Armin Ansari, Adela Salame-Alfie);
- Radiation Safety of Sealed Radioactive Sources (Chair: Kathryn H. Pryor);
- Radiation Protection in Dentistry (Chairs: Alan G. Lurie, Mel L. Kantor);
- Radiation Safety Aspects of Nanotechnology (Chairs: Mark D. Hoover, David S. Myers);
- Evaluating and Communicating Radiation Risks for Studies Involving Human Subjects (Chair: Julie E.K. Timins);
- Improving Patient Dose Utilization in Computed Tomography (Chair: Mannudeep K. Kalra);
- Technologically Enhanced Naturally Occurring Radioactive Material in Unconventional Oil and Gas Production (at the Radiological Society of North America Annual Meeting in 2015 and a reprise hoped for 2016);
- Bioeffectiveness of Low Energy Radiation (Chair: Steven L. Simon);
- Naturally Occurring Radioactive Material and Technologically Enhanced Naturally Occurring Radioactive Material Hydraulic Fracturing (Chairs: William E. Kennedy, Jr. and John R. Frasier);
- Meeting the Needs of the Nation for Radiation Protection (now CC 2) (Chairs: John D. Boice, Jr., Kathryn H. Pryor, Richard E. Toohey); and
- "Boice Report"—a monthly column since June 2012 in *Health Physics News* intended to provide brief reports on recent activities in radiation protection, measurements, science, and health.

12:20 pm

Closing Remarks
John D. Boice, Jr.
President, NCRP

12:30 pm

Adjourn

Program Committee

Richard E. Toohey, *Co-Chair*
M.H. Chew & Associates

Kathryn H. Pryor, *Co-Chair*
Pacific Northwest National Laboratory

Judith L. Bader, *Co-Chair*
National Cancer Institute

Donald P. Frush
Duke University Medical Center

Pamela J. Henderson
U.S. Nuclear Regulatory Commission

Jerry W. Hiatt
Nuclear Energy Institute

Kathryn A. Higley
Oregon State University

William E. Kennedy, Jr.
Dade Moeller

Chad A. Mitchell
Krueger-Gilbert Health Physics

Wayne D. Newhauser
Louisiana State University

Robert C. Whitcomb, Jr.
Centers for Disease Control and Prevention

Jacqueline P. Williams
University of Rochester

Patricia R. Worthington
U.S. Department of Energy

Registration

Monday, April 11, 2016	7:00 am – 5:00 pm
Tuesday, April 12, 2016	7:00 am – 11:00 am

Register online: http://registration.ncrponline.org

2017 Annual Meeting

Emergency Preparedness for Nuclear Terrorism: What are Remaining Gaps and is There Need for Realignment of National Efforts

Armin Ansari & Adela Salame-Alfie, *Co-Chairs*

March 6–7, 2017
Bethesda, Maryland

Annual Warren K. Sinclair Keynote Address

Dr. Richard E. Toohey will present the 13th Warren K. Sinclair Keynote Address at the 2016 Annual Meeting of the National Council on Radiation Protection and Measurements (NCRP). The Address, entitled "WARP, an NCRP Initiative to Meet the Needs of the Nation for Radiation Protection," will be a featured presentation at the 52nd NCRP Annual Meeting to be held April 11 and 12, 2016. The Address will be given at 8:30 a.m. on April 11, 2016 in the Crystal Ballroom, Hyatt Regency Bethesda, One Bethesda Metro Center, 7400 Wisconsin Avenue. The keynote speaker series honors Dr. Warren K. Sinclair, NCRP's second President (1977 to 1991).

Dr. Toohey has been a member of the Council for 10 y and has served on the Board of Directors since 2010. He has served on the Budget and Finance Committee since 2006 and as Chair since 2007. Dr. Toohey was Chair of the 2012 Annual Meeting Program Committee on "Emerging Issues in Radiation Protection in Medicine, Emergency Response, and the Nuclear Fuel Cycle," a member of the 2014 committee, and Co-Chair of the 2016 committee.

Dick Toohey is Chair of the Council Committee on "Meeting the Needs of the Nation for Radiation Protection" and Co-Chair of SC 6-9 on "U.S. Radiation Workers and Nuclear Weapons Test Participants Radiation Dose Assessment." He was a member of the scientific committees that produced NCRP Report No. 164, *Uncertainties in Internal Radiation Dose Assessment* (2009); Report No. 163, *Radiation Dose Reconstruction: Principles and Practices* (2009); and Report No. 156, *Development of a Biokinetic Model for Radionuclide-Contaminated Wounds for Their Assessment, Dosimetry and Treatment* (2006); and was a participant in the 2013 workshop on "Where are the Radiation Professionals?"

Dr. Toohey received his PhD in physics from the University of Cincinnati in 1973. He spent the first part of his career at Argonne National Laboratory in both research and operational health physics. He is retired from Oak Ridge Associated Universities, where he served as director of the Radiation Internal Dose Information Center, as Senior Health Physicist for the Radiation Emergency Assistance Center/Training Site, Director of Dose Reconstruction Programs, and Associate Director of the Independent Environmental Assessment and Verification Program. He is currently a consultant with M. H. Chew and Associates of Livermore, California.

He is certified in comprehensive practice by the American Board of Health Physics, was the 2008 to 2009 President of the Health Physics Society, is Treasurer of the International Radiation Protection Association, and Chair of the Scientific Advisory Committee for the U.S. Transuranium and Uranium Registries. His specialties are internal radiation dosimetry, dose reconstruction, radiological emergency response, and litigation support.
Dr. Toohey has 125 publications in the open literature, and is a retired Lt. Colonel, U.S. Army Reserve.

Lauriston S. Taylor Lecture

Dr. John W. Poston, Sr. will give the 40th Lauriston S. Taylor Lecture at the 2016 Annual Meeting of the National Council on Radiation Protection and Measurements (NCRP). The lecture, entitled Radiation Protection and Regulatory Science, will be the featured presentation at the 52nd Annual Meeting to be held April 11-12, 2016. The Lecture will be given in the Crystal Ballroom of the Hyatt Regency Bethesda, One Bethesda Metro Center, 7400 Wisconsin Avenue, Bethesda, Maryland at 5:00 p.m. on April 11, 2016. The lecture series honors the late Dr. Lauriston S. Taylor, the NCRP founding President (1929 to 1977) and President Emeritus (1977 to 2004). A reception sponsored by Landauer, Inc. follows the presentation and all are invited to attend.

In 1971, Dr. Poston graduated from the Georgia Institute of Technology (GIT) in Atlanta with a Ph.D. in Nuclear Engineering after receiving an M.S. from GIT in 1969 and a B.S. in Mathematics from Lynchburg College in Virginia.

Dr. Poston is a Professor in the Department of Nuclear Engineering and Associate Director of the Nuclear Power Institute. He has been at Texas A&M University since 1985 and served for 10 y as the Department Head. Prior to Texas A&M, he was on the faculty at the Georgia Institute of Technology and, earlier, at the Oak Ridge National Laboratory and the Babcock & Wilcox Company in Lynchburg, Virginia.

Dr. Poston was elected as a Distinguished Emeritus Member of NCRP in 2002 after serving 12 y on the Council. He served as the Scientific Vice President for Program Area Committee 3, Nuclear and Radiological Security and Safety from 2007 to 2014. John Poston chaired Scientific Committee (SC) 2-1 on Preparing, Protecting, and Equipping Emergency Responders for Nuclear and Radiological Terrorism; SC 2-2 on Key Decision Points and Information Needed by Decision Makers in the Aftermath of a Nuclear or Radiological Terrorism Incident; and SC 46-14, Radiation Protection Issues Related to Terrorist Activities that Result in the Dispersal of Radioactive Material; and has served as a member on 10 additional committees during his tenure included two annual meeting program committees.

He is a Fellow of the American Association for the Advancement of Science, the American Nuclear Society, and the Health Physics Society. He has received several honors including the Robley D. Evans Commemorative Medal from the Health Physics Society in 2005; the Loevinger-Berman Award in 2003 from the Society of Nuclear Medicine; the Glenn Murphy Award in 1996 from the American Society for Engineering Education; and he presented the First Annual Warren K. Sinclair Keynote Address at the NCRP 2004 Annual Meeting.

Biographies

Ralph L. Andersen recently retired from the Nuclear Energy Institute as the Senior Director of Radiation Safety and Environmental Protection. His 45 y career spans a variety of positions in the areas of health physics, low-level radioactive waste management, and environmental protection across the sectors of nuclear energy, education, medical, industrial, research, and regulation. Mr. Andersen continues to practice as a certified health physicist, serving as a consultant to NCRP Council Committee 1, and as an advisor to the Organization for Economic Co-operation and Development Nuclear Energy Agency on estimating the cost of nuclear accidents and the Electric Power Research Institute on low-dose radiation research. He has a BA from the University of Maryland and completed graduate studies in radiology and radiation biology at Colorado State University.

Judith L. Bader was a senior investigator in many cancer clinical trials, genetics and epidemiology research projects, and communications technologies projects during her 22 y in the U.S. Public Health Service at the National Cancer Institute (NCI), National Institutes of Health. She has been the Chief of the Clinical Radiation Branch of the Radiation Oncology Branch at NCI, Chief of Radiation Oncology at the Bethesda Naval Hospital (now Walter Reed), and founding physician of two private radiation oncology practices. Since 2004, Dr. Bader, has also served as a senior medical advisor to various U.S. Department of Health and Human Services (HHS) and interagency entities charged with planning for and responding to medical aspects of mass casualty radiation emergencies. She is the Founding and Managing Editor of the HHS/Assistant Secretary for Preparedness and Response-sponsored website *Radiation Emergency Management*. She has served on various committees for the American Society for Clinical Oncology and the American Society for Radiation Oncology.

Dr. Bader has a BA from Stanford University, MD from Yale University School of Medicine. She has been board certified in Pediatrics, Pediatric Hematology-Oncology and Radiation Oncology. She is the author of scores of publications in various disciplines including clinical cancer trials, genetics and epidemiology, computer usability technology, and planning for and responding to mass casualty radiation emergencies.

John D. Boice, Jr., *NCRP President* and Professor of Medicine at Vanderbilt University School of Medicine, Nashville, Tennessee. He is an international authority on radiation effects and currently serves on the Main Commission of the International Commission on Radiological Protection and as a U.S. advisor to the United Nations Scientific Committee on the Effects of Atomic Radiation. During 27 y of service in the U.S. Public Health Service, Dr. Boice developed and became the first chief of the Radiation Epidemiology Branch at the National Cancer Institute. Dr. Boice has established programs of research in all major areas of radiation epidemiology, with major projects dealing with populations exposed to medical, occupational, military and environmental radiation. These research efforts have aimed at clarifying cancer and other health risks associated with exposure to ionizing radiation, especially at low-dose levels. Boice's seminal discoveries and over 440 publications have been used to formulate public health measures to reduce population exposure to radiation and prevent radiation-associated diseases. He has delivered the Lauriston S. Taylor Lecture at the NCRP and the Fessinger-Springer Lecture at the University of Texas at El Paso. In 2008, Dr. Boice received the Harvard School of Public Health Alumni Award of Merit. He has also received the E.O. Lawrence Award from the Department of Energy - an honor bestowed on Richard Feynman and Murray Gell-Mann among others - and the Gorgas Medal from the Association of Military Surgeons of the United States. In 1999 he received the outstanding alumnus award from the University of Texas at El Paso (formerly Texas Western College). Dr. Boice recently launched the Million U.S. Radiation Workers and Veterans Study to examine the lifetime risk of cancer following relatively low-dose exposures received gradually over time.

Biographies

David J. Brenner is the Director of the Columbia University Center for Radiological Research, which is the oldest and largest radiation biology center in the United States. He is also Principle Investigator of the Center for High-Throughput Minimally-Invasive Radiation Biodosimetry, a multi-institute consortium to develop high-throughput biodosimetry technology to rapidly test individual radiation exposure after a radiological incident.

Dr. Brenner's research focuses on mechanistic models for the effects of ionizing radiation on living systems. He divides his research time between the effects of high doses of ionizing radiation (relating to radiation therapy) and the effects of low doses of radiation (relating to radiological, environmental, and occupational exposures). At low doses, he was the first to quantify potential risks associated with the rapidly increasing usage of computed tomography scans. At high doses, his proposal to use large-fraction radiotherapy for prostate cancer (hypo-fractionation) is increasingly being used in the clinic, with several randomized trials now published.

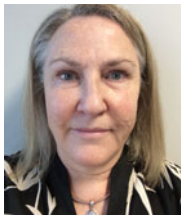
Dr. Brenner has published more than 300 peer-reviewed papers and is the author of two books on radiation for the lay person: *Making the Radiation Therapy Decision* and *Radon, Risk and Remedy*.

Dr. Brenner is a recent recipient of the Failla gold medal, the annual award given by the Radiation Research Society for contributions to radiation research, and the Weldon Prize, from Oxford University for the development of mathematical or statistical methods applied to problems in biology. He is a member of the U.S. National Academies Nuclear and Radiation Studies Board.

Shaheen Dewji is a Radiological Engineer at the Center for Radiation Protection Knowledge (CRPK) at Oak Ridge National Laboratory (ORNL). She received her PhD in the Nuclear and Radiological Engineering Program at the Georgia Institute of Technology, having studied at both the Atlanta and Metz, France campuses. She received her BSc in Physics from the University of British Columbia and has participated in the Education Abroad Program at University of California-Berkeley. She has completed a Masters in Nuclear Engineering at Georgia Tech in assaying internal contamination using hand-held radiation detectors in the event of a radiological dispersion device for the Centers for Disease Control and Prevention. Dr. Dewji's recent work with CRPK at ORNL has included assessment of patient release criteria for 131I patients for the U.S. Nuclear Regulatory Commission, as well as updates to the U.S. Environmental Protection Agency's Federal Guidance Report (FGR) 12 on external exposure to radionuclides in environmental media and FGR 13 on dose coefficients and radiation risk associated with the inhalation and ingestion of radionuclides. Dr. Dewji also holds a certificate in Nuclear Knowledge Management from the National Research Nuclear University MEPhI in Russia, which she obtained through the International Atomic Energy Agency in 2014.

Donald P. Frush is the John Strohbehn Professor of Radiology and Professor of Pediatrics, faculty member of the Medical Physics Graduate Program, and Vice Chair of Safety and Quality for Radiology and Medical Director of the Duke Medical Radiation Center at Duke University Medical Center in Durham, North Carolina. Dr. Frush earned his undergraduate degree from the University of California, Davis; medical degree from Duke University Medical Center; was a pediatric resident at the University of California, San Francisco; and completed a radiology residency at Duke Medical Center and a fellowship in pediatric radiology at Children's Hospital in Cincinnati. He is certified by the American Board of Radiology with additional certification in Pediatric Radiology. Dr. Frush's research interests are predominantly involved with pediatric body computed tomography (CT), including technology assessment, techniques for pediatric multidetector computed tomography examinations, assessment of image quality, and CT radiation dosimetry and radiation protection in medical imaging. Other areas of investigation include CT applications in children and patient safety in radiology. Dr. Frush is or has been a member of various committees and scholarly societies. Committee memberships include past chair of the Commission on Pediatrics, American College of Radiology; Trustee (Pediatrics), American Board of Radiology; past chair of the board and past president

for the Society for Pediatric Radiology; board member, NCRP; chair of the Radiological Society of North America Refresher Course Committee; as well as current chair of the Alliance for Radiation Safety in Pediatric Imaging (Image Gently® Alliance). Dr Frush has also worked internationally with both the World Health Organization and the International Atomic Energy Agency with radiation protection projects in medical imaging. Dr. Frush is a member of numerous associations including the American Roentgen Ray Society, Society of Computed Body Tomography and Magnetic Resonance Imaging (Fellow), Radiological Society of North America, and is also a subspecialty Fellow and Section member for Radiology in the American Academy of Pediatrics.



Pamela J. Henderson graduated from the Georgia Institute of Technology in 1982 with an MS in Health Physics. She served as the Radiation Safety Officer for the University of California, Irvine Medical Center from 1983 to 1991. Ms. Henderson joined the U.S. Nuclear Regulatory Commission in 1991 and currently holds the position of Deputy Director in the Division of Material Safety, State, Tribal, and Rulemaking Programs in Office of Nuclear Material Safety and Safeguards.

Nolan Hertel is a Professor of Nuclear and Radiological Engineering at Georgia Institute of Technology. He received his PhD in Nuclear Engineering from the University of Illinois at Urbana-Champaign and was previously a faculty member at the University of Texas at Austin. He is an expert in radiation protection, shielding and dosimetry and has been actively engaged in education and research for over 36 y.

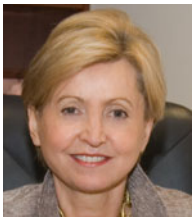
Through a Joint Faculty Appointment at Oak Ridge National Laboratory (ORNL), he is now serving as the Acting Director of the ORNL Center for Radiation Protection Knowledge. That Center is actively involved in internal and external computational dosimetry.

He also currently co-chairs the International Commission on Radiation Units and Measurements committee reviewing external operational dose quantities and is the chair of the Scientific Review Group for the U.S. Department of Energy Russian Health Studies Program. He was recently appointed the co-chair of the Radiation Effects Research Foundation American-Japanese working group being constituted to compute revised and expanded organ doses to for use in Atomic Bomb Survivor Dosimetry System 2002.

Jerry W. Hiatt is a Senior Project Manager - Radiation and Materials Safety for the Nuclear Energy Institute (NEI) and has more than 40 y of nuclear energy experience. He started his career as a radiation protection technician at the Surry Nuclear Station. Since Surry he worked for the U.S. Nuclear Regulatory Commission and a consulting company. Before joining NEI in January 2014 he spent 28 y with BHI Energy where he served in several positions including President and Chief Technical Officer. He is certified in Health Physics by the American Board of Health Physics, served on the Board for 4 y, in 2011 was the second power reactor health physicist to receive the William A. McAdams Award for “sustained and outstanding service to the American Academy of Health Physics,” and has been selected as a Fellow to the National Health Physics Society. Mr. Hiatt has also served on the curriculum advisory board for numerous technical colleges, assisting in the development of radiation protection technician degree programs. He has a BS degree in Biology with a Health Physics emphasis from Virginia Polytechnic and State University.

Biographies

Kathryn A. Higley is a Professor and Head of the School of Nuclear Science and Engineering in the College of Engineering at Oregon State University. Dr. Higley received both her PhD and MS in Radiological Health Sciences from Colorado State University, and her BA in Chemistry from Reed College. She has held both Reactor Operator and Senior Reactor Operator's licenses, and is a former Reactor Supervisor for the Reed College TRIGA Reactor. Dr. Higley started her career as a Radioecologist for Portland General Electric. She later worked for Pacific Northwest National Laboratory as a Senior Research Scientist in the area of environmental health physics. Dr. Higley has been at Oregon State University since 1994 teaching undergraduate and graduate classes on radioecology, dosimetry, radiation protection, radiochemistry, and radiation biology. Her fields of interest include environmental transport and fate of radionuclides; radioecology; radiochemistry; radiation dose assessment; neutron activation analysis; nuclear emergency response; and environmental regulations. She is Chair of Committee 5 (Protection of the Environment) of the International Commission on Radiological Protection, an NCRP Council member, a fellow of the Health Physics Society, and a Certified Health Physicist.



Hedvig Hricak is Chair of the Department of Radiology, Memorial Sloan-Kettering Cancer Center, a member of the Molecular Pharmacology and Chemistry Program, Sloan-Kettering Institute, and Professor, Gerstner Sloan-Kettering Graduate School of Biomedical Sciences. The hallmark of her research career has been the validation of new diagnostic imaging technologies, with a special emphasis on oncology. Her publication record includes more than 380 peer-reviewed original research articles, 18 books, and over 135 monographs and book chapters. She is a member of the National Academy of Medicine [formerly the Institute of Medicine (IOM)] of the National Academy of Sciences (NAS) and a “foreign” member of both the Russian Academy of Science and the Croatian Academy of Arts and Sciences. She has served on the Scientific Advisory Board of the National Cancer Institute, the Advisory Council of the National Institute of Biomedical Imaging and Bioengineering, and the Nuclear and Radiation Studies Board of NAS. She chaired the Committee on the State of the Science of Nuclear Medicine, which produced the highly cited report, *Advancing Nuclear Medicine Through Innovation*. She also served as Vice Chair of the National Academies Committee on Tracking Radiation Doses from Medical Diagnostic Procedures, and as chair of the IOM Committee on Research Directions in Human Biological Effects of Low Level Ionizing Radiation. In addition, she was a member of the National Academies Keck Futures Initiative Steering Committee on The Future of Advanced Nuclear Technologies: Building a Healthier and Safer Planet. Distinguished posts she has held include President of the California Academy of Medicine and President of the Radiological Society of North America (RSNA). She has won numerous awards for her efforts to promote education and international collaboration in imaging, including honorary memberships or fellowships in 12 national or international radiological societies; the Marie Curie Award from the Society of Women in Radiology; the gold medals of the International Society for Magnetic Resonance in Medicine, the Association of University Radiologists, the Asian Oceanian Society of Radiology, the European Society of Radiology and the RSNA; the Beclere Medal of the International Society of Radiology; the Schinz Medal of the Swiss Society of Radiology; the Morocco Medal of Merit; the Jean A. Vezina French Canadian Award of Innovation; and the Order of the Croatian Morning Star of Katarina Zrinska Presidential Award of Croatia. She holds an honorary doctorate from the Ludwig Maximilian University, Munich.

William E. Kennedy, Jr. has extensive experience as a project manager, task leader, and individual contributor covering a broad range of health physics and nuclear engineering topics. He received his BS and MS degrees in Nuclear Engineering from Kansas State University. Mr. Kennedy has been involved in the development of environmental pathway and radiation dosimetry models used to assess potential health and environmental impacts that resulted from releases of radionuclides to the environment.

He specializes in the use of these models in environmental dose reconstruction, radioactive materials transport, radioactive waste disposal, and evaluation of nuclear facility operating practices. Over the past 37 y, Mr. Kennedy has led and contributed to a variety of projects for the U.S. Nuclear Regulatory Commission,

the U.S. Department of Energy, the Electric Power Research Institute, and private industry. He has been involved with development of the technical basis for revised standards and regulations, and serves as the chair of ANSI/HPS N13.12, Surface and volume Radioactivity Standards for Clearance. He served as a consultant to the International Atomic Energy Agency (IAEA), Vienna, Austria, and was a member of the IAEA Advisory Groups to evaluate the Derivation of Exempt Quantities for Application to Terrestrial Waste Disposal and Derivation of Exempt Quantities for Recycle of Materials from Nuclear Facilities.

He was an invited lecturer for IAEA training courses on Management of Radioactive Waste from Nuclear Power Plants at Argonne National Laboratory; on Safety Assessment Modeling for Low and Intermediate Radwastes in Rio de Janeiro, Brazil and in Cairo, Egypt; and on Environmental Monitoring in Kiev, Ukraine. In 1990, he received the Health Physics Society's (HPS) prestigious Elda E. Anderson Award. He served as a member of the HPS Board of Directors from 1998 through 2001 and was selected as a fellow of the society in 2002. He was a member of the U.S. delegation to the 10th Congress of the International Radiation Protection Association in Hiroshima, Japan.

Ruth E. McBurney is the Executive Director of the Conference of Radiation Control Program Directors. In that position, she manages and directs the administrative office for the organization. Prior to taking that position in January 2007, she was the Manager of the Radiation Safety Licensing Branch at the Texas Department of State Health Services, culminating 25 y of service in the Texas Radiation Control Program, most of which involved licensing and standards development. Ms. McBurney has served on the U.S. Nuclear Regulatory Commission's Advisory Committee on the Medical Use of Isotopes and the U.S. Food and Drug Administration's National Mammography Quality Assurance Advisory Committee. She is currently serving as a Member of NCRP, and is also on the Board of Directors. She served as a consultant to the International Atomic Energy Agency in the categorization of radiation sources and recently served on a committee of the National Academy of Sciences regarding replacement technologies for high-risk radiation sources. She has also been a U.S. delegate to the International Radiation Protection Association's 10th, 11th, 12th, and 13th Congresses. Ms. McBurney holds a BS in Biology from Henderson State University in Arkansas and an MS in Radiation Sciences from the University of Arkansas for Medical Sciences. She is also certified in comprehensive health physics by the American Board of Health Physics.

Chad A. Mitchell received his PhD in Biomedical Engineering from Ohio State University and is certified by the American Board of Radiology. His research interests have ranged from retrospective dosimetry to ultra-high field magnetic resonance imaging. After 20 y as a Navy Radiation Health Officer, he recently joined Krueger-Gilbert Health Physics as a medical physicist serving hospitals and clinics in Maryland and neighboring states.

Matthew P. Moeller is Chief Executive Officer and Chairman of the Board of Dade Moeller, a company that he helped found in 1994. His primary responsibilities are to manage the long-term strategic planning and oversee the operations of the company. Mr. Moeller received an AB in mathematics from Cornell University's College of Arts and Sciences and an MS in Environmental Health Sciences (Radiological Health) from Harvard University's School of Public Health. He is certified by the American Board of Health Physics and is a Fellow of the Health Physics Society.

Biographies

Stephen V. Musolino is a scientist in the Nonproliferation and National Security Department at the U.S. Department of Energy's (DOE) Brookhaven National Laboratory (BNL) in Upton, New York. With more than 30 y of experience in Health Physics, his current research interests are in nonproliferation, counterterrorism, and planning for response to the consequences of radiological and nuclear terrorism. Since 1981, he has been part of the DOE Radiological Assistance Program as a Team Captain/Team Scientist and has been involved in developing radiological emergency response plans and procedures, as well as participating in a wide range of radiological and nuclear exercises and field deployments. During the Fukushima crisis, he was deployed in Japan as an Assessment Scientist with the DOE response team that was measuring the environmental consequences of the radioactive material released from the damaged nuclear power plants. Working with the first responder community in the New York metropolitan area, Dr. Musolino was involved with the development of guidance for response to the aftermath of a radiological dispersal device, and served on the scientific committee that developed NCRP Report No. 165, *Responding to a Radiological or Nuclear Terrorism Incident: A Guide for Decision Makers*. Earlier in his career at BNL, he was a member of the Marshall Islands Radiological Safety Program and participated in numerous field missions to monitor the populations living on islands affected by nuclear testing.

Dr. Musolino is a Fellow of the Health Physics Society, Distinguished Alumnus of Buffalo State College, and a member of the editorial board of the journal Health Physics. He earned a BS in engineering technology from Buffalo State College, am MS in nuclear engineering from Polytechnic Institute of New York University, and a PhD in health physics from the Georgia Institute of Technology. He is certified by the American Board of Health Physics.

Wayne D. Newhauser is the Director of the Medical and Health Physics Program at Louisiana State University in Baton Rouge, holder of the Dr. Charles M. Smith Chair in Medical Physics, and Chief of Physics at the Mary Bird Perkins Cancer Center. He is a board certified and licensed medical physicist with specialization in advanced-technology radiotherapies. Dr. Newhauser is an expert in proton radiation therapy, dose reconstructions, and risk estimation and reduction. His current research projects seek to improve long-term outcomes of survivors of childhood and adult cancers. He and his multidisciplinary team of collaborators are known for their early use of Monte-Carlo methods and high-performance computing in proton therapy, including neutron shielding, treatment planning, and estimation of stray radiation exposures. He received the Innovation Excellence Award in 2012 in recognition of his laboratory's research involving in-silico clinical trials to compare advanced-technology radiotherapies. Dr. Newhauser has published more than 85 peer-reviewed journal articles, leads federal research grants, and mentors graduate students and post-doctoral fellows. He has served in leadership roles in the American Association of Physicists in Medicine, the American Nuclear Society, and the Health Physics Society. He serves on the International Advisory Board of the journal *Physics in Medicine and Biology* and is a corresponding member of the European Radiation Dosimetry Group. After receiving a BS in nuclear engineering and MS and PhD degrees medical physics from the University of Wisconsin, he worked at the German National Standards Laboratory, Harvard Medical School and Massachusetts General Hospital, and The University of Texas MD Anderson Cancer Center.

Kathryn H. Pryor currently holds the position of Chief Health Physicist at the Pacific Northwest National Laboratory (PNNL) in Richland, Washington, and has provided management and technical support to the PNNL Radiation Protection Division since 1992. She also served as the Chief Radiological Engineer for the design of the Pit Disassembly and Conversion Project. Ms. Pryor has previously held radiation protection technical support positions at the San Onofre Nuclear Generating Station and the Trojan Nuclear Plant, and was the Radiation Safety Officer at the University of Southern California Health Sciences Campus. Ms. Pryor has been a Council member since 2010 and is currently on the NCRP Board of Directors and is Scientific Vice President of Program Area Committee 2. She received her BS in Biology in 1979 and MS in Radiological Sciences in 1981, both from the University of Washington. Ms. Pryor is a Fellow member of the Health Physics Society (HPS) and served as President-Elect, President, and Past President from 2010 to

2013. She is certified in comprehensive practice by the American Board of Health Physics (ABHP), and served on the ABHP both as a member and Chair from 1998 to 2002. Ms. Pryor was awarded the William McAdams Outstanding Service Award by ABHP in 2007 and the John P. Corley Meritorious Service Award by the Columbia Chapter of HPS in 2003.

Michael T. Ryan is an independent consultant in radiological sciences and health physics. He is an Adjunct Faculty member at Vanderbilt University in the Department of Environmental Engineering and the Texas A&M University in the Department of Nuclear Engineering. He was previously an Associate Professor in the Department of Health Administration and Policy at the Medical University of South Carolina (MUSC). He earned his BS in radiological health physics from Lowell Technological Institute in 1974. In 1976, he earned an MS in radiological sciences and protection from the University of Lowell under a U.S. Energy Research and Development Administration Scholarship. Dr. Ryan received the PhD in 1982 from the Georgia Institute of Technology, where he was recently inducted into the Academy of Distinguished Alumni. He is a recipient of the Francis Cabot Lowell Distinguished Alumni for Arts and Sciences Award for the University of Massachusetts Lowell.

Dr. Ryan is Editor In Chief of *Health Physics*. In 1989, he received the Health Physics Society (HPS) Elda E. Anderson Award, which is awarded each year to the one young member who has demonstrated excellence in research, discovery, and/or significant contribution to the field of health physics. Dr. Ryan has held numerous offices in HPS, including President of the Environmental Section and the Savannah River Chapter. Dr. Ryan served on the Technical Advisory Radiation Control Council for the State of South Carolina for 19 y. He is a member of NCRP. He has served as Scientific Vice President for Radioactive and Mixed Waste Management and Chair of Scientific Committee 87 and a member of the Board of Directors.
Dr. Ryan is certified in the comprehensive practice of health physics by the American Board of Health Physics. In additional to his adjunct appointment at Texas A&M University, Dr. Ryan has taught radiation protection courses on the undergraduate and graduate level at the University of South Carolina and the College of Charleston. In addition, Dr. Ryan has authored and coauthored many refereed articles and publications in the areas of environmental radiation assessment, radiation dosimetry, and regulatory compliance for radioactive materials.

Dr. Ryan is active in his consultancy with a number of national corporations and government agencies. This work generally involves radioactive waste management, radiological health and regulatory compliance for workplace and environmental issues. He most recently served for several years on the independent review panel for decommissioning wok at Brookhaven National Laboratories. He completed a 9 y term as Chairman of the External Advisory Board for Radiation Protection at Sandia National Laboratories in 2007. He is a member of a similar external review board for Lawrence Livermore National Laboratory. He completed 8 y of service on the Scientific Review Group appointed by the Assistant Secretary of Energy to review the ongoing research in health effects at the former weapons complex sites in the Southern Urals. He has also served on several committees of the National Academy of Sciences producing reports regarding radioactive waste management topics. He also served as Chairman for the U.S. Nuclear Regulatory Commission Advisory Committee on Nuclear Waste and Materials. Dr. Ryan has served on Committee since 2002 until it was merged with the Advisory Committee on Reactor Safeguards (ACRS) in 2008. In June, 2008, Dr. Ryan became a member of the ACRS.

Prior to his appointment at MUSC, Dr. Ryan was served as Vice President of Barnwell Operations for Chem-Nuclear Systems, Inc., and had overall responsibility for operation of the low-level radioactive waste disposal and service facilities in Barnwell, South Carolina. Dr. Ryan's area of responsibility included management of a scientific, technical, and support staff; and implementation of the scientific programs to assure the safe and compliant operation of the company's low-level radioactive waste processing and disposal facilities. These programs included facility operations and implementation of policy and procedures for operation, environmental monitoring and regulatory compliance. Prior to this assignment Dr. Ryan served

since 1988 as the Vice President of Regulatory Affairs, having responsibility for developing and implementing the company's regulatory compliance policies and programs to comply with state and federal regulators. Before joining Chem-Nuclear Systems, Inc., as Director of the Environmental and Dosimetry Laboratory in 1983, Dr. Ryan spent 7 y in environmental health physics at Oak Ridge National Laboratory.

Richard E. Toohey received his PhD in physics from the University of Cincinnati in 1973. He spent the first part of his career at Argonne National Laboratory in both research and operational health physics. He recently retired from Oak Ridge Associated Universities, where he served as director of the Radiation Internal Dose Information Center, as Senior Health Physicist for the Radiation Emergency Assistance Center/Training Site, Director of Dose Reconstruction Programs, and Associate Director of the Independent Environmental Assessment and Verification Program. He is certified in comprehensive practice by the American Board of Health Physics, was the 2008 to 2009 President of the Health Physics Society, is a member and director of NCRP, Treasurer of the International Radiation Protection Association, and Chair of the Scientific Advisory Committee for the U.S. Transuranium and Uranium Registries. His specialties are internal radiation dosimetry, dose reconstruction, and radiological emergency response. Dr. Toohey has 125 publications in the open literature, and is a retired Lt. Colonel, U.S. Army Reserve.

Michael Weber has served as the Deputy Executive Director for Operations for Materials, Waste, Research, State, Tribal, and Compliance Programs of the U.S. Nuclear Regulatory Commission (NRC) since May 2010. He strategically leads NRC staff in developing and implementing Commission policy decisions and regulatory programs. Prior to this position, he served as the Director, Office of Nuclear Material Safety and Safeguards (NMSS) beginning in 2007. He represents the United States on the International Atomic Energy Agency's Commission on Safety Standards. In 2014, he led the NRC's Project Aim 2020 strategic transformation project. In addition, he served as Deputy Team Leader of the Integrated Regulatory Review Service Follow-up Mission to the Republic of Korea in 2014.

Mr. Weber joined the NRC in 1982 as a hydrogeologist in NMSS. He held a number of progressively more responsible positions including: Chief, Regulatory Issues Section; Chief, Low-Level Waste and Decommissioning Projects Branch; Chief, Fuel Cycle Licensing Branch; Deputy Director, Division of Waste Management; Deputy Director and Director, Division of Fuel Cycle Safety and Safeguards. In 2002, he was appointed as the Deputy Director of the newly established Office of Nuclear Security and Incident Response (NSIR) following the terrorist attacks on September 11, 2001. In 2006, Mr. Weber was appointed as the Deputy Director, Office of Nuclear Reactor Regulation.

Mr. Weber served as a Technical Assistant to former Chairman Ken Carr and as the Executive Assistant and Director of the Chairman's Office for former Chairman Shirley Ann Jackson. Mr. Weber is a graduate of the Senior Executive Service Candidate Development Program and the Office of Personnel Management's Executive Potential Program for Mid-Level Employees. He received the prestigious rank awards for Meritorious Executive from Presidents Clinton (2000) and Bush (2006). In 1996, he received the William A. Jump Meritorious Award for exemplary service in public administration. He also received NRC's Meritorious Service Award in 1993 for scientific excellence in protecting the environment. Mr. Weber earned a BS degree in Geosciences from the Pennsylvania State University.

Robert C. Whitcomb, Jr. joined the Centers for Disease Control and Prevention (CDC) in June 1993. He is the Chief of the Radiation Studies Branch, Division of Environmental Hazards and Health Effects, National Center for Environmental Health. In this position he serves as Radiation Subject Matter Expert and CDC Spokesperson for technical and public health issues related to environmental radiation and nuclear/radiological emergency response. Previously, Dr. Whitcomb worked with the Illinois Department of Nuclear Safety. His primary area of expertise is the assessment of radionuclides released to the environment and the impact on public health. He has authored or coauthored numerous journal articles and has lectured

nationally and internationally about the public health response in nuclear/radiological emergencies. Dr. Whitcomb is a member of NCRP and the Health Physics Society. He is certified in comprehensive practice by the American Board of Health Physics, and served on the Board of Directors of the Health Physics Society (2004 to 2007). Dr. Whitcomb holds a BS in Biology from Florida Southern College, an MS and a PhD in Environmental Engineering Sciences from the University of Florida.

Jacqueline P. Williams completed her undergraduate degrees at the University of Nottingham, followed by her post-doctoral training in radiation biology at St. Bartholomew's Hospital, University of London, U.K. Shortly after completing her studies, she joined the faculty at the University of Rochester, New York, in the department of Radiation Oncology, and recently in the department of Environmental Medicine. Since that time, Dr. Williams has accrued more than 25 y of experience in radiation biology and related fields and has been involved in a wide range of research areas, including clinically-related oncologic studies and clinical trials, tumor blood flow studies, long-term carcinogenic studies, and pharmacological and toxicological projects. Her current research interests involve identifying mechanisms that underlie the initiation and progression of radiation-induced late normal tissue effects as a consequence of high-dose clinical treatment/accidental exposures or the lower doses associated with either space travel or mass exposures with the goal of developing protection or mitigation strategies. Dr. Williams has served as the President of the Radiation Research Society, the Research Chair on the Board of the American Society for Radiation Oncology, and has been elected to, and is currently serving as, Council Member to the International Association for Radiation Research.

Patricia R. Worthington has 40 y of federal experience, the majority of which has been devoted to promoting and advocating the safety and health of the U.S. Department of Energy (DOE) federal and contractor workers, members of the public living in the vicinity of DOE sites, and advancing the Integrated Safety Management System (ISMS). Dr. Worthington currently serves as the Department's ISM Co-Champion. In this capacity, she works closely with DOE program offices, both headquarters and field, to continually enhance the safe execution of the DOE mission. Her office has responsibility for the DOE Voluntary Protection Program, which encourages and recognizes excellence in occupational safety and health protection and further builds on the continuous improvement component of ISM.

Dr. Worthington is currently the Director of the Office of Health and Safety, within the Office of Environment, Health, Safety and Security (AU) where she reports directly to Associate Under Secretary and supports him in establishing worker safety and health requirements and expectations related to a diverse set of potential hazard exposures, such as chemical, industrial, biological and radiological hazards. Currently, her office is conducting a number of health studies, including: (1) studies to determine worker and public health effects from exposure to hazardous materials associated with Department operations; (2) international health studies and programs in Japan, Spain, the Russian Federation, and medical screening and environmental monitoring in the Marshall Islands; and (3) medical surveillance and screening programs for current and former workers. Her office also plays a critical role in ensuring that DOE makes available worker and facility records and data to support the U.S. Department of Labor in the implementation of the Energy Employees Occupational Illness Compensation Program Act.

A critical aspect of the AU function is assistance. Dr. Worthington's office provides technical assistance to headquarters and field elements in the implementation of policy and resolving worker safety and health issues. Her office supports the DOE Radiation Emergency Assistance Center/Training Site, which provides professional training and medical countermeasures to occupational and nonoccupational exposures to ionizing radiation and in federal agency matters concerning bioterrorism.

Previously, Dr. Worthington served as the Director of the Office of Environment, Safety and Health Evaluations where she worked to improve current management practices for environment, safety, and health programs across the DOE complex and investigated historical operations. As such, she has indepth and

firsthand knowledge of DOE sites, site-specific activities, and operational issues. Prior to joining DOE, Dr. Worthington gained invaluable, extensive experience at the U.S. Nuclear Regulatory Commission where she was responsible for managing the Severe Accident International Research Program, which involved working with over 10 countries to share technical knowledge of nuclear safety. She holds a PhD in Chemistry from Howard University.

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