Study of One Million Radiation Workers & Veterans

Virtual Symposium – November 6, 2020 – 8:30AM-3:00PM

Co-Sponsored by:
Memorial Sloan Kettering Cancer Center; National Council on Radiation Protection and Measurements;
Greater NY, Baltimore-Washington, and New Jersey Chapters, HPS
-Program-

8:30 AM

Kathryn D. Held, National Council on Radiation Protection and Measurements (NCRP) and Massachusetts General Hospital / Harvard Medical School

Kathryn D. Held, PhD, is President of the National Council on Radiation Protection and Measurements (NCRP) and an Associate Radiation Biologist and Associate Professor, Department of Radiation Oncology, Massachusetts General Hospital/Harvard Medical School. At MGH, Dr. Held's research has involved molecular mechanisms for bystander effects in cells and tissues, characterization of photon and charged particle-induced DNA damage responses, and radiation protection and sensitization. She has taught radiation biology for 35 years to radiation oncology medical and physics residents and graduate students and radiology residents at MGH/HMS and MIT and regularly serves as visiting faculty at medical centers around the world. She has served on review panels for numerous federal agencies including the National Institutes of Health, the National Aeronautics and Space Administration, and the U.S. Army Medical Research and Material Command programs and other organizations such as the Radiological Society of North America and Brookhaven National Laboratory and is on the Editorial Boards of several journals. She is a past President of the Radiation Research Society and a member of the Board of the Radiation Research Foundation.

Welcome and Introduction

The critical evaluation of the health effects of low dose and low dose rate radiation exposures in healthy US populations being conducted through the Million Person Study (MPS) is of great value for providing enhanced understanding of the science needed for sound radiation protection policy and recommendations. In partnership with numerous US government agencies and other organizations, the National Council on Radiation Protection and Measurements (NCRP) has been involved in the MPS (also known as the Million Workers and Veterans Study, MWS), under the directorship of Dr. John Boice, for a number of years. NCRP is a Congressionally-chartered, non-government, non-profit organization that has addressed significant science and policy issues related to ionizing and non-ionizing radiations for over 90 years. The NCRP mission is to support radiation protection by providing independent scientific analysis, information, and recommendations that represent the consensus of leading scientists. Hence, the NCRP has supported and fostered the conduct of the MPS epidemiology and dosimetry studies and helped disseminate the important findings of those scientific efforts through NCRP Reports, Commentaries and other published works, as well as at scientific meetings. This Symposium is a superb opportunity to further disseminate the findings from and information on the importance of the MPS. Hence, it is with great pleasure that, on behalf of the other groups involved in this symposium, NCRP welcomes all participants to these proceeding. We look forward to a robust learning experience and stimulating informational exchanges for all.

8:40 AM

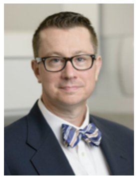
John D. Boice, Jr., NCRP and Vanderbilt University School of Medicine

John D. Boice, Jr., ScD, is past President of the National Council on Radiation Protection and Measurements (NCRP) and Professor of Medicine at Vanderbilt University. He is an international authority on radiation effects and served on the Main Commission of the International Commission on Radiological Protection (ICRP) and on the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR). Boice is the recipient of the DOE E.O. Lawrence Award, the Association of Military Surgeons of the United States (AMSUS) Gorgas Medal, the NCRP Taylor Lecture Award, the IRPA Sievert Award, the MGH Aubrey O. Hampton Award, the NCI Director's Award,

A Million Persons, A Million Dreams – Overview of the MPS

The Million Person Study of Low-Level and Low-Dose-Rate Health Effects (MPS) is designed to address the major unanswered question in radiation risk understanding: What is the level of health effects when exposure is gradual over time and not delivered briefly. Over a million healthy American workers and veterans are being studied to evaluate cancer and non-cancer mortality following low-level low-LET and high-LET exposure, rare cancers, intakes of radioactive elements, and differences in risks between women and men.

The MPS consists of seven categories of persons exposed to radiation from 1913 to the present. The U.S. Department of Energy Health and Mortality study began the Harvard School of Public Health Alumni Award of Merit, and the University of Texas at El Paso (UTEP) Distinguished Alumnus Award. He is a Fellow of the Health Physics Society and is the recipient of the Distinguished Public Health Service Award, the Dade Moeller Lectureship Award, the Distinguished Scientific Achievement Award, and the R.S. Landauer Memorial Lecture Award. He directs the Million Person Study of Low-Level and Low-Dose-Rate Health Effects.



Lawrence T. Dauer, Memorial Sloan Kettering Cancer Center

Lawrence T. Dauer, PhD, DABHP, is an Associate Attending Physicist in the Departments of Medical Physics and Radiology at Memorial Sloan Kettering Cancer Center, and is their Corporate Radiation Safety Officer. He is currently serving NCRP as the Scientific Coordinator for the Million Person Study. He has spent more than 35 years in the field of radiation protection and health physics, including programs for the nuclear energy and industrial sectors as well as operations and research in medical health physics. He is currently a Council and Board member of the National Council on Radiation Protection and Measurements. He served 7 years on the International Commission on Radiological Protection Committee 3, Radiation Protection in Medicine, and has served on several committees for the Health Physics Society (HPS), Greater NY Chapter of the HPS, Radiological and Medical Physics Society, AAPM, ABR, Society for Interventional Radiology, and Radiation Research societies. He has received the Elda E. Anderson and the Fellow Awards from the HPS.

over 40 years ago and is the source of ~260,000 workers. Over 25 years ago, the U.S. National Cancer Institute (NCI) collaborated with the U.S. Nuclear Regulatory Commission to effectively create cohorts of nuclear power plant workers (~150,000) and industrial radiographers (~130,000). For over 60 years, the U.S. Department of Defense collected data on aboveground nuclear weapons test participants (~115,000). At the request of NCI in 1978, Landauer, Inc. began preserving their dosimetry databases which became the source for a cohort of ~110,000 medical workers as well as a source of supplementary workers at nuclear power plants and industrial radiographers. The U.S. Navy has recorded dosimetry information since the 1950s on nuclear submariners (~113,000) and nuclear shipyard workers (~96,000). The study of radium dial painters (~3,200) has been ongoing since the 1920s and was recently reactivated. The MPS is a U.S. national effort and relies on the cooperation and support of federal agencies. The key to excellent epidemiology is comprehensive dose reconstructions for individuals within each of the seven exposure categories.

The MPS vision is to provide broad scientific understandings of health effects following prolonged exposure. Such understanding will improve guidelines to protect workers and the public; improve compensation schemes for workers, veterans and the public; provide guidance for policy and decision makers; and provide evidence for or against the continued use of the linear nonthreshold dose-response model in radiation protection.

A million dreams are keeping me awake
I think of what the world could be
A vision of the one I see
A million dreams is all it's gonna take
A million dreams for the world ***we're*** *gonna make*
— The Greatest Showman

9:10 AM

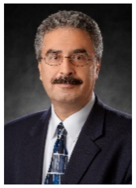
R. Craig Yoder, Landauer, Inc. (retired)

From 1983 until his retirement at the end of 2015, R. Craig Yoder, PhD, directed the technical and scientific research and development programs for Landauer, Inc., a provider of radiation monitoring services throughout the world. He attained the positions of Vice President and Senior Vice President that afforded him at different times the opportunity to direct the operations, sales and marketing, and international business units. His position gave him a unique window to observe the historical patterns of radiation exposure. Dr. Yoder received a B.S. degree from Davidson College and M.S. and Ph.D. degrees in Bionucleonics from Purdue University. Prior to joining Landauer, he was a Senior Research Scientist at Battelle, Pacific Northwest Laboratory in Richland, Washington and was the Radiological Group Supervisor for Pennsylvania Power and Light. Dr. Yoder is a council member of the National Council on Radiation Protection and Measurements (NCRP) contributing to three NCRP reports and recently co-chairing the development of NCRP Commentary No. 30. In 2015, Dr. Yoder was appointed to the US EPA Radiation Advisory Committee. He was certified in Comprehensive Health Physics by the American Board of Health Physics in 1982.

Dosimetry is Key to Excellent Epidemiology

The epidemiological aspects of the Million Person Study depend on estimates of the mean or average absorbed dose to specific organs or tissues in a specific person. Epidemiological analyses require these doses be expressed in both annual and lifetime accumulated values. The average absorbed dose to an organ or tissue cannot be directly measured. Instead, organ doses must be derived from a complex set of correlations and quantitative conversions that attempt to transcribe data from radiological measurements and descriptions of the conditions of exposure into appropriate inputs required by recently developed, advanced computational models that output estimates of the distribution of absorbed doses within the human body. Uncertainties arise from the differences between the real-world radiological exposure environments and the idealized conditions assumed by the models. Changes in the metrological methods and radiation safety quantities over the 50 or so years of interest add complexity. The influence of regulatory requirements on radiation measurements and record keeping impart additional challenges to compiling lifetime organ absorbed dose values such as monitoring to assess the maximally exposed part of the body. Less scientific or technical difficulties arise from identifying the completeness of an individual's dose history and errors affecting the ability to relate radiation safety monitoring results to a specific individual. These issues affect both internal and external dosimetry efforts and vary in importance depending on the specific worker cohort.

9:30 AM



Armin Ansari, Centers for Disease Control and Prevention

Armin Ansari, PhD, CHP, is the Radiological Assessment Team Lead at the Centers for Disease Control and Prevention (CDC) serving as subject matter expert in CDC's radiation emergency preparedness and response activities since 2002. He received both his undergraduate and graduate degrees in radiation biophysics from the University of Kansas, starting his career as a radiation biologist, and did his postdoctoral research in radiation-induced mutagenesis at Oak Ridge and Los Alamos National Laboratories. Prior to joining the CDC in October 2002, he was a project leader with the Environmental Survey and Site Assessment Program at ORISE and a senior scientist with a radiological consulting firm where his work related to radiological site characterization, evaluation of radiation exposure pathways, radiation dose assessments, remedial action activities, and regulatory compliance. He is a fellow and past president of the Health Physics Society and an adjunct associate professor of nuclear and radiological engineering at Georgia Institute of Technology. He serves on the National Council on Radiation Protection and Measurements (NCRP), provides consultancy to the International Atomic Energy Agency (IAEA) and serves as member of the United States delegation to the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR).

Importance of Radiation Epidemiology: CDC Perspective

The practice of radiation protection is based on application of scientific data, together with consideration for ethical principles and societal factors, to provide for health and safety of workers, and members of the public including at-risk populations. During the last hundred years, we have learned a great deal about the biological effects of radiation on cellular and animal models, characterizing its mutagenic and carcinogenic effects in these experimental systems. However, what informs our radiation protection and public heath practice with respect to long-term effects of human exposures to ionizing radiation comes primarily from epidemiologic data on cancer and non-cancer diseases – most notably from the life span study of Japanese atomic bomb survivors. With the exception of occupational accidents, medical overexposures or some acts of terrorism, most environmental exposures (including radon and TENORM), medical exposures, and occupational exposures (including nuclear workers and air crews) are low doses accumulated from protracted low dose-rate exposures. Even in the aftermath of a major nuclear or radiological emergency, critical public health decisions in response and recovery such as evacuation, relocation, embargo of food and agricultural products, waste management, remediation, and long-term monitoring of exposed population are informed by what we know about risk of exposure at low doses and dose rates and uncertainties of those estimates. While direct observation of human health effects by epidemiologic means at low doses remains highly challenging, use of biologically based dose response models can supplement epidemiological data and enhance the estimation of health risks. Ultimately, reliable epidemiological studies help us see the forest for the trees and inform our radiation protection and public health practices.

9:50 AM

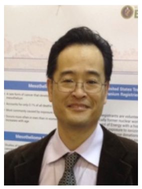
Lawrence T. Dauer, Memorial Sloan Kettering Cancer Center

MPS Cohort: Medical Worker Study

The Million Person Study of Radiation Workers and Veterans (MPS) includes a cohort of workers exposed to radiation as a consequence of performing various medical procedures that involve the use of ionizing radiation (medical radiation workers). Among the different cohort groups studied as part of the MPS, the medical radiation worker group features the highest percentage of female subjects (49%) from which to examine adverse radiation effects that may vary according to sex; particularly the development of lung cancer. NCRP Report No. 178 developed a framework for external radiation exposures along with tables and figures of conversion coefficients for relating measured approximations of the personal dose equivalent, $H_p(10)$ (the dose equivalent at a depth of 10 mm in the body expressed in units of mSv), to selected tissue and organ doses, D_T expressed in mGy (data essential for epidemiology studies). NCRP Commentary No. 30 further and more specifically describes considerations for deriving organ doses for the medical radiation worker cohort that depend on the development of radiation exposure scenarios to describe the radiological and physical conditions to which specific categories of medical workers may have been exposed. Dose-response analyses are based on organ-specific lung doses estimated for each worker based on his or her job-based exposure scenario and calendar years of monitoring. Four medical exposure scenarios were evaluated: general radiology characterized by low-energy x-ray exposure with no lead apron use; interventional radiologists/cardiologists (lead apron wearers); nuclear medicine personnel; and radiation oncologists (mainly nurses and technologists and some medical doctors) receiving high-energy gamma (photon) dose. This presentation will review the MPS medical worker cohort, vital status determination, address dosimetric approaches, and provide preliminary epidemiology results.

10:10 AM **Morning Break**

10:20 AM



Joey Zhou, the Department of Energy (DOE)

Joey Zhou, PhD, MS, MPH, is a senior epidemiologist in the Office of Health and Safety under the Office of Environment, Health, Safety and Security. He is the current DOE program manager for the agency's participation in the Study of One Million U.S. Radiation Workers and Veterans. He also serves as the program manager for the United States Transuranium and Uranium Registries, the Russian Health Studies Program and the Radiation Emergency Assistance Center/Training Site. He has more than twenty years of scientific research and technical program management experience in the U.S. federal government. Prior to DOE, he worked at the Department of Defense, the Environmental Protection Agency, and the Department of Housing and Urban Development.

Importance of Radiation Epidemiology: DOE Perspective

The Department of Energy (DOE) has supported all aspects of the Million Person Study (MPS) since the feasibility study in 2009-2010, funded by the Office of Science and now by the Office of Environment, Health, Safety and Security. 26% (260,000) of the MPS study population comes from former DOE radiation workers. DOE and its predecessors have a long history in conducting and supporting radiation epidemiological studies. The surveillance of radiation exposure and its health effect was implemented shortly after the Manhattan Project began in 1942. The Radiation Exposure Information and Reporting System (now Radiation Exposure Monitoring System) was established in 1968 to serve as the central repository of occupational radiation exposure records. The feasibility studies of using personnel, employment, medical, radiation exposure, and facility records to conduct epidemiologic mortality studies were completed in 1960s. The health and mortality studies of radiation workers across DOE facilities were carried out from the early 1970s. The Epidemiological Records Moratorium, "an agency-wide freeze" on the destruction of all records that might be useful for health studies was ordered in 1990. The Comprehensive Epidemiologic Data Resource (CEDR) was also created in 1990 to allow researchers to access data from the DOE epidemiological studies program. The CEDR became a major source of data used to follow up DOE worker cohorts for the MPS. The DOE has over 650,000 former radiation workers and about 75,000 current radiation workers. The MPS can provide valuable research findings to improve DOE former worker medical screening and compensation programs, and to enhance protection of current radiation workers.

10:40 AM

Sarah S. Cohen, EpidStrategies

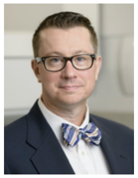
Sarah S. Cohen, PhD, is a Senior Managing Epidemiologist and Associate Practice Leader at EpidStrategies, a division of ToxStrategies, Inc. Dr. Cohen holds a doctorate in Cancer Epidemiology from the University of North Carolina at Chapel Hill as well as a master's degree in Biostatistics from the University of Michigan and has 20 years of experience in the design, conduct, and analysis of epidemiologic studies. Her expertise includes the areas of cancer, cardiovascular disease, diabetes, obesity, nutrition, pharmacoepidemiology, occupational health, and radiation health effects. Dr. Cohen has been a technical contractor to the NCRP for eight

MPS Cohort: Mortality among Workers at the Los Alamos National Laboratory, 1943-1984

Los Alamos National Laboratory (LANL), established in 1942 during the Manhattan Project, continues operations today to solve national security challenges. This study included 26,328 male and female workers employed between 1943-1977 by LANL and Zia, the LANL maintenance contractor for the site. Vital status was determined through December 31, 2017. External radiation monitoring data were included from 1944 through 1990. The greatest potential for elevated doses from internal emitters arising from ^{238}Pu and ^{239}Pu. Doses from internal emitters were based in large part on plutonium urinalyses. External doses were years and a collaborator on the Million Person Study of Low-Dose Health Effects for nearly twenty years, providing data management, statistical support, and coauthoring numerous MPS publications.

received at facilities other than at LANL, and were available from the DOE Radiation Exposure Monitoring System; Nuclear Regulatory Commission Radiation Exposure Information and Reporting System; Landauer, Inc.; US Navy Dosimetry System and the Nuclear Test Personnel Review Program. All available doses including photons, neutrons, tritium, ^{238}Pu, and ^{239}Pu were combined to obtain organ-specific doses received by each worker for each calendar year. Standardized Mortality Ratio (SMR) analyses were conducted as well as internal analyses using Cox proportional hazards models with adjustment for sex, educational attainment, and year of birth. Excess relative risks (ERR) were also estimated. The LANL population was 75% male and 81% white. At the end of vital status tracing, 40% of the workers were alive, 60% had died, and only 89 (<1%) were lost to follow-up. This presentation will include SMRs for lung cancer and leukemia other than CLL, as well as the associated hazard ratios (HRs) from the Cox model and ERRs.

11:00 AM



Lawrence T. Dauer, Memorial Sloan Kettering Cancer Center

MPS Cohort: Nuclear Power Plant Workers and Industrial Radiographers

Two of the largest cohorts considered as part of the Million Person Study are the nuclear power plant workers and the industrial radiography workers. More than 500,000 workers have been employed in U.S. nuclear power plants since the first commercial production of electricity in 1957. The consistent reporting of annual worker doses required by the U.S. Nuclear Regulatory Commission (NRC) for their licensees provides a high-quality dosimetry database that was redesigned in 1994 to facilitate epidemiologic study. Because workers annual recorded dose in the nuclear industry has decreased over the years down to on the order of 2 mSv or less on average, only the workers at nuclear power plants first employed from 1957 through 1985 are considered in the Million Person Study. Cohort members were selected from databases available from the Radiation Exposure Information and Reporting System (REIRS), which is maintained by the NRC, and supplemented with data available from Landauer, Inc., a dosimetry service provider. The number of nuclear power plant workers under study (~135,000) includes nearly three times the number of adults over age 20 years at exposure than the study of Japanese atomic bomb survivors, and over seven times the number of adult males. Most radiation exposures were due to penetrating external gamma rays with only a few neutron exposures or internal exposures.

Industrial radiography is an inspection method to detect fractures and other deficiencies in metallic and other dense materials by exploiting the penetrating ability of higher energy photons to create radiographic images, typically using film, of the defects. The period of greatest external exposure for radiographers is during the time the source (x-ray, ^{192}Ir, ^{60}Co, etc.) is outside its shielded container being transported into and from the material to be radiographed plus the time required to achieve a radiographic image with the appropriate contrast to reveal any defects. For the MPS, a cohort of ~126,000 workers employed as industrial radiographers in the United States as early as 1940 was selected from records within the REIRS database and Landauer dosimetry database. Over 32,000 of the industrial radiographers are known to have worked in naval shipyards.

This presentation will review the MPS nuclear power plant and the industrial radiography worker cohorts, address dosimetric approaches, and provide preliminary epidemiology results.

11:20 AM

Paul K. Blake, Defense Threat Reduction Agency

Paul K. Blake, Ph.D., CHP, is a retired U.S. Navy Captain, currently serving as the civilian program manager of the Nuclear Test Personnel Review (NTPR) Program, Nuclear Technologies Department, Defense Threat Reduction Agency (DTRA), Fort Belvoir, VA. DTRA enables the Department of Defense, the United States Government and International partners to counter and deter weapons of mass destruction and improvised threat networks. DTRA carries out its mission by providing subject matter expertise and material solutions to Combatant Commanders and military Services across a number of mission areas including the nuclear enterprise, building partnership capacity, improvised threats, treaties and on-site inspections, and countering threat networks. Blake leads the Department of Defense's efforts to confirm participation and reconstruct radiation doses for veterans involved in U.S. atmospheric and underground nuclear weapons testing (1945 to 1992), and the post-World War II occupation forces of Hiroshima and Nagasaki, Japan. He also leads DTRA's nuclear detonation human survivability modeling team, and chairs the agency's Radiation Safety Committee. Blake is a 2019 recipient of DoD's highest career civilian award (Distinguished Civilian Service Award).

Importance of Radiation Epidemiology: DoD Perspective

The Department of Defense (DoD) currently employs approximately three million military (active & reserve) and civilian workers. Approximately 70,000 DoD workers (2%) are annually monitored for ionizing radiation exposure. DoD workers and their dependents can also potentially be exposed to ionizing radiation for medical purposes and during nuclear war scenarios or operations other than war. The U.S. military was an early adopter of ionizing radiation. Less than three years after Roengten's discovery of the X-ray, both the U.S. Army and U.S. Navy were employing diagnostic X-ray machines in the war with Spain (1898). However, DoD's existing occupation radiation exposure records programs arose during the Manhattan Project in World War II. These programs expanded with the U.S. development of nuclear weapons and nuclear power applications. The DoD radiation monitoring infrastructure includes three nationally accredited external personal radiation dosimetry programs (Army, Navy, and Air Force), a variety of internal personal monitoring programs, various environmental and food radiological analysis labs, and five radiation dose repositories with records on over 2 million individuals (Atomic Veterans (1945-1992), Army/National Guard, Navy/Marines, Air Force, and Operation Tomodachi Registry (OTR)). The OTR is unique in that it includes dependents, in addition to military and civilian adults. DoD dose repositories also include Coast Guard and Merchant Marine exposures and non-DoD visitor exposures. There have been numerous radiation epidemiology studies of these workers. Most of these studies have been performed by external entities, including the ongoing Million Person Study, which includes approximately 235,000 military personnel who participated at one of 230 U.S. atmospheric nuclear weapons tests from 1945-1962. In summary, radiation epidemiology studies are important to DoD in: (1) understanding the impact of ionizing radiation exposures on the health & safety of our DoD-affiliated population, (2) addressing the credibility of DoD's radiation safety programs, and (3) providing a technical basis for associated radiogenic disease compensation programs.

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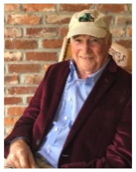
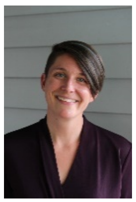


John E. Till, Risk Assessment Corporation

John Till, Ph.D., RADM, USNR (RET) is President of Risk Assessment Corporation (RAC) founded in 1977, a scientific research organization focusing on environmental risk analysis and dose reconstruction. He is a graduate of the U.S. Naval Academy and served in the U.S. Navy Nuclear Submarine Program, retiring in 1999 as a Rear Admiral. He received his M.S. in radiation biology from Colorado State University and Ph.D. in nuclear engineering from Georgia Institute of Technology. He edited the first textbook on radiological risk assessment, Radiological Assessment, in 1983 followed by an updated version in 2008, Radiological Risk Assessment and Environmental Analysis. Dr. Till was a recipient of the Elda Anderson award by the Health Physics Society in 1983 and the E.O. Lawrence Award in the field of Environmental Science and Technology from the Department of Energy in 1995. He is a Distinguished Emeritus member of the NCRP and presented the Lauriston S. Taylor Lecture at the annual meeting of the NCRP in 2013. He is also the 2020 recipient of the Health Physics' Society's Distinguished Scientific Achievement Award. He lives on his farm in South Carolina where he grows corn, soybeans, and long leaf pine.



Emily A. Caffrey, Risk Assessment Corporation

Emily A. Caffrey, Ph.D. is a scientific consultant currently supporting Risk Assessment Corporation in independent environmental dose and risk assessments. Her areas of expertise include dosimetry, statistics, data management and interpretation, and public communication. Dr. Caffrey also teaches Radiation Dosimetry at Georgia Institute of Technology, and serves as the Supervised Practice Coordinator for the Master's in Health Physics program at the University of Alabama at Birmingham. Additionally, she is the Editor in Chief of the Health Physics Society's Ask-The-Expert public education feature, and serves as chair of the Public Information Committee. She was inducted into the Oregon State University Council of Outstanding Early Career Engineers in 2019, and is the 2020 recipient of the HPS' Elda Anderson award.

MPS Cohort: Nuclear Weapons Test Participants

The nuclear weapons test participants form an important component of the Million Person Study. These 14,270 military veterans are of a larger group of approximately 235,000 individuals who took part in one or more atmospheric nuclear weapons tests at the Nevada Test Site (NTS) or the Pacific Proving Grounds (PPG) between 1945 and 1962. The dosimetry for this cohort is of high quality (CV of ~ 0.5) due to the detailed historical records available to researchers, information provided about exposure rate fields, location of ships and units, and the availability of film badge dosimeter readings for about 20% of the participants. The estimated external mean dose for red bone marrow was 6 mGy (maximum of 108 mGy). Two-thirds of the cohort received doses less than 5 mGy and only four individuals received a dose greater than 50 mGy. The 65-year follow-up case-cohort epidemiological study concluded there was no evidence for increasing trends with radiation dose for leukemia (excluding chronic lymphocytic leukemia), myelodysplastic syndrome, multiple myeloma, ischemic heart disease, or cancers of the lung, prostate, breast, and brain. This presentation will briefly review the dosimetry and epidemiological results, focusing on the radiological and non-radiological contributions of this important component of the Million Person Study. Insights into future low dose research gleaned from the nuclear weapons test participants cohort will be discussed, along with ideas on how to combine radioepidemiological studies to expand our practical knowledge of low dose radiation effects for the purposes of radiation protection. It is of note, that a collaborative study comparing biological dosimetry, dose reconstruction, and film badge readings was conducted among 12 other veterans who had received doses in excess of 200 mGy. The correlation between the three dosimetry methods was remarkable especially considering it has been more than 60 years since their exposures.

12:00 PM

Lunch Break

12:30 PM

Steve R. Blattnig, NASA Langley Research Center

Dr. Steve Blattnig has been working on a wide variety of different aspects of space radiation research for the last 20 years. He graduated from the University of Wisconsin - Milwaukee with a PhD in Physics, and his graduate work comprised the development of a pion and muon radiation transport code, including the associated particle production cross section modeling. In January 2003 he began work as a physicist at the NASA Langley Research Center (LaRC). His major areas of research have included the development of space radiation transport methodologies, nuclear and particle physics modeling and their application to mission analysis and vehicle design, and the development of radiation shielding materials. He has also been integral to the development of validation methodologies and on the use of model results in decision making. He is one of the primary developers of the NASA Standard for Models and Simulations, NASA-STD-7009. More recently, his focus has been on the development of probabilistic risk methodology and radiation biology modeling for effects including acute radiation syndrome, cancer, cardiovascular disease, and degenerative central nervous system diseases. He was the project manager for the space radiation transport and measurement project and was the PI of the space radiation risk assessment project.

Importance of Radiation Epidemiology – a NASA Perspective

Radiation is one of the primary risk factors to human health that provides an obstacle to the safe exploration of space. Radiation in space is of a different composition than most exposures on earth consisting of high energy charged particles and resulting particle fragments from collisions with materials in spacecraft and the human body. Exposures can also be relatively high with a mission to Mars estimated to be approximately 0.5 Gy (1Sv). Beyond low earth orbit, it consists of a continuous exposure to Galactic Cosmic Rays and sporadic eruptions from the sun that produce solar particle events. The health risks of primary concern are cancer, cardiovascular and central nervous system diseases. NASA's strategy to mitigate these effects currently consists of the development of permissible exposure limits that effectively limit the time individuals spend in space as well as shielding from solar particle events. Shielding from galactic cosmic rays is of limited effectiveness and so the Human Research Program is currently investigating the potential for biomedical countermeasures. A common theme that runs through this risk mitigation strategy is a need to understand and quantify these health risks so as to counter them cost effectively. Radiation epidemiology provides a primary basis to understand and quantify the response in humans and is integrated with animal and other experimental data to develop risk models for specific disease endpoints. Currently the study of one million radiation workers & veterans is investigating lung cancer risks among women and men and the risks of cognition and dementia following intakes of radionuclides specifically for NASA. However, all the results that improve the understanding of radiation risks in humans can provide benefit to NASA's risk mitigation approach.

12:50 PM

Ashley P. Golden, Oak Ridge Associated Universities

Ashley P. Golden, PhD, is the Director of Worker Health Studies and a Biostatistician for the Oak Ridge Institute of Science and Education (ORISE) at ORAU. She has been ORAU Key Study Personnel on the Million Person Study since 2014. Ashley serves as a biostatistics subject matter expert for numerous epidemiologic studies, medical surveillance programs, and multi-disciplinary projects in the areas of occupational exposure and worker health, with special emphasis on radiation and beryllium exposure in the US Department of Energy (DOE) worker population. She directs the ORISE DOE Data Center which manages multiple worker exposure registries, including: the DOE Radiation Exposure Monitoring System (REMS), the Nuclear Regulatory Commission (NRC) Radiation Exposure Information and Reporting System (REIRS), and the DOE Beryllium Associated Worker Registry. Additionally, she provides statistical peer-review for several journals and is currently a guest editor for a special issue on the Million Person Study for the International Journal on Radiation Biology. She has a number of scientific publications and presentations related to occupational exposure and health risks.

Lung Cancer Risks among Men and Women

The lung cancer risk estimated from Japanese atomic bomb survivors indicate that women are at nearly three times greater risk than men. Since protection standards for astronauts are based on individual lifetime risk projections, this sex-specific difference limits the time women can spend in space. Recently published results from five occupational cohorts within the Million Person Study of Radiation Workers and Veterans (MPS) and the Canadian TB-Fluoroscopy Cohort Study indicated little evidence that chronic or fractionated exposures increased the risk of lung cancer (n=403,067 men and 50,679 women; with no significant differences observed between men and women).

Preliminary results for an additional (approximately) 99,697 men and 75,494 women from four other MPS cohorts (Los Alamos National Laboratory; Tennessee Eastman Corporation; MPS Medical Workers; and the Fernald Feed Materials Production Plant;) are currently being evaluated to provide additional information on lung cancer risk and any sex-specific differences following low dose, low dose rate exposures.

1:10 PM

John D. Boice, Jr., NCRP and Vanderbilt University School of Medicine

Michael Mumma, International Epidemiology Institute and Vanderbilt University School of Medicine

Michael Mumma is the Director of Information Technology at the International Epidemiology Institute (IEI) and Vanderbilt University Medical Center's International Epidemiology Field Station (IEFS). He has over 20 years of experience in developing and conducting epidemiological studies and health investigations, with a focus on determining risk of cancer and other diseases on populations potentially exposed to environmental and/or occupational radiation. He is also heavily involved in the Southern Community Cohort Study (SCCS), a large prospective cohort study investigating environmental, genetic, and lifestyle risk factors on cardiovascular, renal, and pulmonary diseases. He has published on various methodological topics, including geocoding and comprehensive radiation exposure assessment, and is currently developing methods to determining socioeconomic status based on residential history. He earned a BS in Fisheries Science from Frostburg State University and a MS in Ecology from University of Florida.

Cognition and Dementia Following Intakes of Radionuclides

"*It's not going to do any good to land on Mars if we're stupid*." – Ray Bradbury

Relatively high cumulative doses to brain tissue from galactic cosmic rays (GCR) are possible during a mission to Mars. GCR are high-velocity heavy ions (HZE particles) traveling through space. Animal studies have revealed early and late neurological disorders from relatively brief exposures to these high-velocity heavy ions. These studies have raised concern about possible effects on astronauts that might impair performance so that the mission would not be completed or, conceivably, there might be a risk of Alzheimer's or dementia years after the voyage is over. There are no human circumstances on earth that can approximate GCR exposures to brain tissue. If fact, there is no evidence in human studies that low-LET radiation is associated with dementia or Alzheimer's disease, although a recent study of Mayak workers has suggested a link with Parkinson's disease. As a possible though imperfect analogue to high-LET GCR exposure, radium dial painters and DOE workers with intakes of alpha-particle emitting radionuclides are being evaluated for dementia and Alzheimer's disease and for cognitive impairment. The internally-deposited alpha emitters in radiation workers comprise a possible, though imperfect, human analogue for high-LET GCR exposure to brain tissue in space. These epidemiologic studies are intended to provide another line of evidence to consider when making judgments for radiation protection guidance for flight crews on long missions in space.

Studies of alpha particle (He nuclei) exposure to brain tissue and mortality from dementia, Alzheimer's, Parkinson's and motor neuron disease, as well as cognitive impairment have begun, incorporating quantitative scores from neuropsychological testing available from Medicare and Medicaid files and from nursing home files. The cohorts of DOE workers being evaluate include workers at Los Alamos National Laboratory, Mallinckrodt Chemical Works, Mound, Rocketdyne, Rocky Flats, Tennessee Eastman Corporation (TEC), Fernald, Middlesex, Portsmouth Gaseous Diffusion Plant, Paducah Gaseous Diffusion Plant, Oak Ridge National Laboratory (X-10), K-25, Y-12, Savanah River Site and Hanford. Of special note is the possibility that several thousand workers with plutonium burdens could be interviewed and administered the same battery of cognition tests (COGNITION) taken by astronauts on the ISS today (Phase 2).

The strengths of this investigation are:

- the exposure is to humans, and not rodents;
- the exposure is from high-LET radiation at a low dose rate (over years and not minutes or weeks as in the animal experiments);
- the human exposure is to a mixed field of high-LET radiation and low-LET radiation (similar to exposures in space);
- the energy deposition is similar for a wide range of particle types and energies;
- human outcomes of interest can be directly evaluated, i.e., the occurrence of dementia and Alzheimer's disease as well as quantitative measures of cognitive impairment.

While there are some similarities between high-LET alpha-particle exposure to brain tissue and high-LET GCR exposure, there are important dissimilarities, e.g., GCR and alpha particles emitted from radionuclides may share the same LET values, but their track structures and energies are quite distinct.

A critical component of this array of studies of high-LET exposure to brain tissue is accurate assessment of individual worker doses. The next two presentations by Caleigh Samuels (ORNL) and Sergei Tolmachev (USTUR) will cover the comprehensive approach to dose reconstruction.

1:30 PM

Caleigh Samuels, Oak Ridge National Laboratory

Caleigh Samuels is an assistant staff member in the Center for Radiation Protection Knowledge at Oak Ridge National Laboratory. She received her BS in physics from Radford University, her MS in medical physics from Georgia Institute of Technology in 2018 and is currently working towards her PhD in nuclear engineering. Her research focuses on developing and enhancing biokinetic models used in radiation protection and dose reconstruction and application of advanced Monte Carlo techniques in dosimetric modeling. She collaborates on the Million Person Study and is currently focusing on organ dose reconstructions following plutonium intakes at the Rocky Flats nuclear facility.

Brain Dose Estimates for Alpha Emitters at MPS Sites

The Million Person Study (MPS) cohorts studied so far include thousands of workers with elevated intake of alpha emitters, primarily ^{238}Pu, ^{239}Pu, ^{241}Am, ^{226}Ra, ^{210}Po, and U isotopes. Some subset of these alpha emitters generally dominates reconstructed doses to MPS cohorts from internal emitters and, for some sites, from all internal and external sources. In the course of the MPS, the brain has emerged as a tissue of concern due to potential cognitive effects from internal emitters, with emphasis on brain dose from alpha emitters. To this point, the biokinetic models applied in MPS dose reconstructions, which are generally the latest models of the International Commission on Radiological Protection (ICRP), do not explicitly address the brain. Instead, the brain is treated as a mass fraction of a pool of tissues called “Other” that represent the remainder of the body after removal of tissues explicitly identified in the biokinetic model. We are investigating the feasibility of revising the biokinetic models for radionuclides of concern to include brain as an explicitly identified pool with parameter values derived from element-specific biokinetic data. Our initial findings are that: (1) There is generally much less information on the biokinetics in the brain than in visceral organs or bone, for example. (2) For many elements, use of an explicit brain model based on available information should nevertheless provide increased confidence in brain dose estimates compared with current estimates based on the apparently inaccurate assumption that brain kinetics of an element are typical of that of the element’s “Other” tissue. Examples are given to illustrate available data on uptake and retention of elements by the brain, the kinetic models for the brain derived from those data, and comparisons of brain dose estimates based on the explicit and implicit brain models.

1:50 PM

Sergey Y. Tolmachev, Washington State University

Sergey Tolmachev is a Research Professor in the College of Pharmacy and Pharmaceutical Sciences, Washington State University, where he directs the United States Transuranium and Uranium Registries and the associated National Human Radiobiology Tissue Repository. He has over 20 years of experience in the development of analytical methods and in actinide analyses of environmental and biological samples. Dr. Tolmachev is currently a Council member of the National Council on Radiation Protection and Measurements (NCRP) and is a vice-chair of NCRP Scientific Committee 6-12 “Development of Models for Brain Dosimetry for Internally Deposited Radionuclides”. He is a member of the Board of Trustees of the Herbert M. Parker Foundation, a member of the EURADOS (European Radiation Dosimetry Group) working group on internal dosimetry (WG-

Radionuclide Concentrations in Brain Segments: Autopsy Series

The United States Transuranium and Uranium Registries (USTUR) is a federal-grant-funded human tissue research program providing long-term study of actinide biokinetics in former nuclear workers with accidental internal depositions of these elements. The USTUR conducts autopsies and performs radiochemical analyses of the voluntarily donated tissue samples. The National Human Radiobiology Tissue Repository holds all tissues donated to the USTUR, together with specimens acquired from the U.S. Radium Worker Studies. This is a unique resource for retrospective analyses and distribution studies of plutonium, uranium, americium, as well as radium and beryllium in the entire human body as well as specific tissues and organs. This presentation will detail results of plutonium, uranium, beryllium, and radium analyses in brain tissues from occupationally exposed individuals. Distributions of these elements among different segments of

7), and a technical advisor at Kyushu Environmental Evaluation Association (Fukuoka, Japan).

the brain and its impact on brain dosimetry will be discussed. This study was conducted in close collaboration with the Million Person Study of Radiation Workers and Veterans and University of Missouri Research Reactor.

2:10 PM

Afternoon Break

2:20 PM

John D. Boice, Jr., NCRP and Vanderbilt University School of Medicine

Lawrence T. Dauer, Memorial Sloan Kettering Cancer Center

Derek W. Jokisch, Francis Marion University, Oak Ridge National Laboratory

Derek Jokisch, PhD, CHP serves as Professor of Physics and Chair of the Department of Physics and Engineering at Francis Marion University in Florence, South Carolina where he has been a member of the faculty since 1999. Since 2014 he has also held a Joint Faculty Appointment in the Center for Radiation Protection Knowledge at Oak Ridge National Laboratory. He earned his bachelor's degree in nuclear engineering from the University of Illinois and his master's and doctoral degrees in nuclear engineering sciences (health physics) from the University of Florida. He is currently serving as a member of Committee 2 on Doses from Radiation Exposure for the International Commission on Radiological Protection as well as a member of the US Scientific Review Group for the Department of Energy's Russian Health Studies program. Jokisch is a past recipient of the Elda Anderson Award from the Health Physics Society and the J. Lorin Mason Distinguished Professor Award from Francis Marion University.

A Million More Dreams

The vision for the Million Person Study of Low-Level and Low-Dose-Rate Health Effects (MPS) includes a long-term follow-up of all exposure cohorts and an expansion of efforts in radiation biology. Currently, over 800,000 workers and veterans within 25 of the >30 individual MPS cohorts have been followed for mortality, and in the next 2-3 years all will be. At regular 5 to 10 year intervals there will be a new follow-up to update the mortality experience of the MPS and dose-response evaluations.

The power of the MPS is in combining the similar datasets to make strong inferences about low-level health effects. The data will be harmonized recognizing the differences in important variables as defined in different cohorts, such as socioeconomic status. Combined studies will include workers with intake of radionuclides (e.g., plutonium and uranium), and workers exposed primarily to gamma- and x-rays (nuclear power plant workers, industrial radiographers, medical radiation workers, atomic veterans). The dose-response analyses will be organ-specific as the combining of all tumors together has little biological meaning although it has been used for radiation protection. Ways to combine organ-specific dose response relationships will be enhanced. The MPS is a dynamic and evolving program of radiation studies. New inclusions this year are the study of over 113,000 U.S. Navy nuclear submariners starting with service on the Nautilus in 1954, the updated study of 3,200 radium dial painters, and the possible study of 97,000 nuclear shipyard workers. A large study of over 50,000 workers exposed to neutrons is being considered. The new study of ~14,000 women who worked during WWII (1943-47) at the Tennessee Eastman Corporation is unique in that the cohort has never been studied, lung doses from intakes of uranium are up to 1,000 mGy, and the women are recognized by the public as "the girls of the atomic city."

The MPS will change its name to something like the National Center for Radiation Epidemiology and Biology. We have the infrastructure to set up a National Center for Radiation Epidemiology, but the radiation biology component will require a reinvigorated vision and substantial resources. We are encouraged by support from many agencies and the U.S. Congress. For FY20, and for the third year in a row, the Senate Appropriations Bill included a line item to support "the Epidemiologic Study of One Million U.S. Radiation Workers and Veterans…"

The MPS will expand its role in training radiation scientists in epidemiology, statistics and dosimetry and will continue to offer opportunities for collaborative research as well as master and doctoral degrees. In addition to substantially improving knowledge on the potential health effects from low-dose radiation exposures received gradually over time, the MPS will be able to make strong inferences regarding the adequacy (or not) of the LNT model as used in radiation protection.

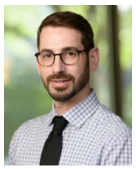
The MPS builds upon 25 years of dreams, some sleepless nights
but no nightmares.

The future belongs to those who believe in the beauty of their dreams.
- Eleanor Roosevelt

2:40 PM **Panelists**

Final Questions/Comments
If you have questions or comments, please submit them via the 'questions' box.

2:55 PM



Brian Quinn, Memorial Sloan Kettering Cancer Center and Greater New York Chapter Health Physics Society
Brian Quinn is a Medical Health Physicist at Memorial Sloan Kettering Cancer Center in New York. He has over 20 years of radiation protection experience, including Health Physics technician work in radiological decommissioning and nuclear power. He has a Master's degree in Applied Physics from Columbia University in New York, where he studied Medical Physics. At MSKCC, he manages a team of Health Physicists in the radiation safety service overseeing operational responsibilities in research labs and hospital. His research interests include radiopharmaceutical and x-ray organ dosimetry. He is currently serving as the President-elect of the Greater New York Chapter of the Health Physics Society.

Virtual Symposium Wrap Up
Note that we hope to have a summary of the virtual symposium presentations and Q&As submitted by end of this year. Look for it in a future Health Physics journal article.

3:00 PM **Virtual Meeting Closes**