CNEC | Consortium for Nonproliferation Enabling Capabilities

Dr. Yousry Azmy, Director
Dr. John Mattingly, PI, Chief Scientist
Stefani Buster, J.D., Assistant Director

CNEC Newsletter

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The Future of Nuclear Nonproliferation

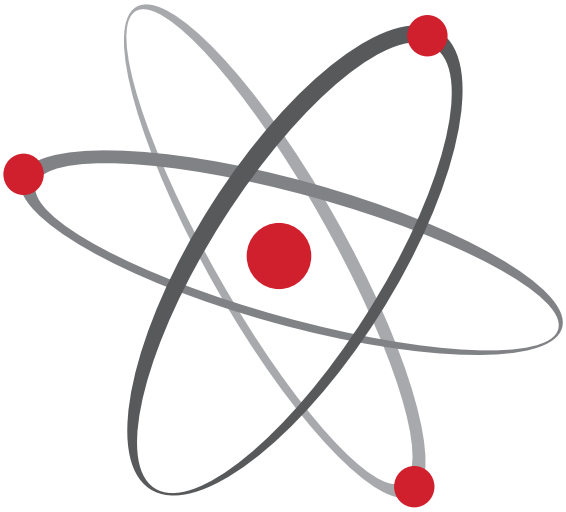
During a visit to CNEC, NNSA Program Manager Dr. Victoria Franques sits with students to talk about opportunities and the future of nuclear nonproliferation

In 2014 NC State was awarded a five-year, $25 million grant by the National Nuclear Security Administration's (NNSA) Office of Defense Nuclear Nonproliferation Research and Development to develop the next generation of leaders with practical experience in technical fields relevant to nuclear nonproliferation. NC State was selected by NNSA over 22 other proposals following a competitive process that began in May 2013.

The Consortium for Nonproliferation Enabling Capabilities (CNEC) was created and comprises seven partner universities (NC State, Georgia Tech, Kansas State University, NC A&T State University, Purdue University, University of Illinois at Urbana-Champaign, and University of Michigan) and four national laboratories (Los Alamos, Oak Ridge, Pacific Northwest, and Lawrence Livermore National Laboratories).

Our Vision

Create a preeminent research and education hub dedicated to the development of enabling technologies and technical talent for meeting the present and future grand challenges of nuclear nonproliferation.



Our Mission

Through an intimate mix of innovative research and development (R&D) and education activities, CNEC will enhance national capabilities in the detection and characterization of special nuclear material (SNM) and facilities processing SNM to enable the U.S. to meet its international nonproliferation goals, as well as to investigate the replacement of radiological sources so that they could not be misappropriated and used in dirty bombs or other deleterious uses.

IN THIS ISSUE

UNIVERSITY PARTNERS

Georgia Tech
Kansas State
NC State
North Carolina A&T
Purdue University
University of Illinois
University of Michigan

NATIONAL LABORATORY PARTNERS

Lawrence Livermore
Los Alamos
Oak Ridge
Pacific Northwest

Dr. Yousry Azmy, Director

Stefani Buster, J.D., Assistant Director

News from the Director

Dr. Yousry Azmy

As CNEC progresses through its fourth year it remains vibrant and productive, with initial investments in new students, in new collaborations, and in novel research ideas maturing and producing first fruits.

Changing times and new demands have brought new blood to the Consortium, while some, mostly graduating students and postdoctoral fellows who completed their terms, have moved on to meet new challenges. At the helm of CNEC, Dr. Robin Gardner has served as Principal Investigator and Chief Scientist since its inception in 2014 and we are very grateful for this. Dr. Gardner resigned these two responsibilities effective June 30, 2017, and with the sponsor's approval Dr. John Mattingly started playing these two leadership roles effective November 16, 2017. As we thank Robin for his service over the past three years, we welcome John wishing him well looking forward to his leadership and providing all the support that he needs to continue making CNEC successful. To be sure, both Robin and John will continue to be engaged in CNEC's technical research just as they have since the very beginning.

Last year CNEC instituted a new policy designed to ensure that the Consortium as a whole meets the sponsor's expectations in terms of annual spending rate. While the details of this policy are beyond the scope of this news piece, the final result of the process that was kicked off late last summer is that we have a few new investigators contributing to CNEC's diverse research portfolio. The new research projects are in line with CNEC's original scope and mission but richly add content that our national lab representatives have judged to be of high value and relevant to NNSA's overall mission as well as the labs' efforts. We welcome to the CNEC family our new collaborators and will endeavor in future issues of this publication to highlight some of their new work.

As always I am grateful to each and every person who is involved, or has previously been involved in CNEC and for their invaluable contributions to our Consortium's success.

Left to right: Dr. Yousry Azmy, Stefani Buster, J.D., Drs. Ge Yang, John Mattingly, Rob Hayes, Victoria Franques

Left to right: Dr. Yousry Azmy, Dr. William Boettcher, Mr. Torry Froscher (retired CIA)

CNEC Thrust Area Highlights

Dr. Alyson Wilson

Data Fusion and Analytic Techniques (DFAT)

DFAT has a new faculty PI. Dr. Raju Vatsavai is a Chancellor's Faculty Excellence Program Cluster Associate Professor in Geospatial Analytics in the Department of Computer Science, North Carolina State University (NCSU). He works at the intersection of spatial and temporal big data management, analytics, and high performance computing with applications in the national security, geospatial intelligence, natural resources, and human terrain mapping. As the Associate Director of the Center for Geospatial Analytics (https://cnr.ncsu.edu/geospatial/), Dr. Vatsavai plays a leadership role in the CGA's strategic vision for spatial computing research. Before joining NCSU, Dr. Vatsavai was the Lead Data Scientist for the Computational Sciences and Engineering Division at the Oak Ridge National Laboratory (ORNL).

DFAT has started a new collaboration with Lawrence Livermore National Laboratory (LLNL). Dr. Alyson Wilson and Katherine Allen, from NCSU, are working with Brenton Blair and Ron Wurtz at LLNL on a project to develop statistical methods for anomaly detection in pulse shape discrimination data. We will be developing unsupervised machine learning methods using a Dirichlet Process Gaussian Mixture Model. Preliminary analyses have demonstrated promise for performance improvements and identifying clusters of anomalous events. We will be exploring the methodology, as well as other unsupervised approaches, to assess whether it is possible to identify anomaly clusters while improving fast neutron detection.

Dr. John Mattingly

Simulation, Analysis, and Modeling (SAM)

The SAM working group continues to make progress on the urban source search challenge problem. They are currently pursuing three parallel research tasks: (1) statistical inference methods for source localization, (2) background estimation, and (3) coupled deterministic/Monte Carlo radiation transport simulation.

Statistical Inference Methods

NCSU completed preliminary analysis of the experiments they conducted with Oak Ridge National Laboratory (ORNL) at the Experimental Gas Cooled Reactor (EGCR) site in May 2017. NCSU demonstrated that they could estimate the location of the source to within ~ 10 meters of its actual location (over a 250 m × 150 m section of the entire EGCR site) from 60 seconds of measurement. NCSU Mathematics is collaborating with Statistics and Nuclear Engineering to develop methods that employ mutual information-based experimental design to optimize the construction of radiation sensor networks for source localization and to enable the analysis of mobile sensors during a dynamic source search. NCSU Profs. Smith and Mattingly were invited to Defense Threat Reduction Agency (DTRA) to brief the Radiation Detection Branch Chief on CNEC's source localization R&D on October 12.

CNEC Thrust Area Highlights

Background Estimation

Purdue University continued to develop machine learning methods to estimate background (a) dynamically, from time-series measurements of background; and (b) statically, from analysis of the gamma spectrum. In the dynamic analysis, future background is predicted based on recent past observations of background; the method predicts the expected gross background count rate, which can be used for anomaly detection. In the static analysis, background is extracted from a spectroscopic measurement where a source may be present, which can be used to estimate the background in an environment where background varies substantially and cannot be measured in the absence of a source.

Coupled Deterministic-Monte Carlo Transport Simulation

University of Michigan (UM) and NCSU began working to couple NCSU's deterministic neutral-particle transport code THOR with a custom Monte Carlo code currently under development at UM. They will implement full two-way coupling to enable efficient simulation of radiation sensor responses in the challenging urban source search problem. The urban environment is essentially a deep penetration problem with streaming (large buildings separated by streets), which is a combination of conditions that individually challenge Monte Carlo and deterministic transport, respectively.

Signatures and Observables (S&O)

North Carolina State University

Rob Hayes published a paper titled "Retrospective Imaging and Characterization of Nuclear Material" in Health Physics: August 2017 - Volume 113 - Issue 2 - p 91–101 http://journals.lww.com/health-physics/Abstract/2017/08000/Retrospective_Imaging_and_Characterization_of.1.aspx

Dr. Katy Huff

Purdue University

Graduate student Paula-Lydia Lagari defended her Masters' thesis on November 15, 2017. Lydia's research is with the Applied Intelligent Systems group (https://engineering.purdue.edu/~aisl/current.html). Her work is related to training neural networks to conduct isotope identification.

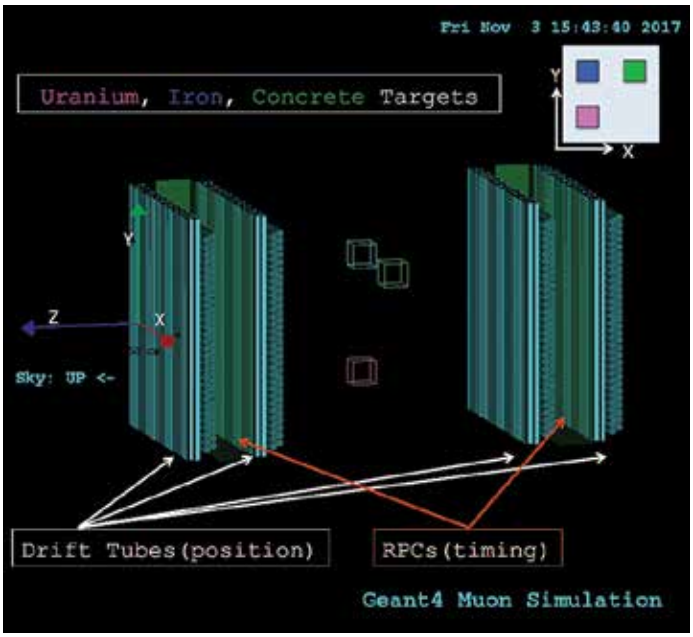
University of Illinois

Robert Brigantic (PNNL) arranged a CNEC Outreach visit to UIUC in November 2017. PNNL scientist Deborah Fagan visited along with Illinois CNEC alum Michael Cheng who is now a PNNL post-graduate intern. Deborah gave a seminar, held a PNNL information session with ANS students, and held meetings to learn about current research being conducted by CNEC students Karl Roth, Aric Tate, and Erik Medhurst. The flyer for her seminar appears on the next page.

CNEC Thrust Area Highlights *Continued from page 5*

University of Illinois

New graduate student Aric Tate joined CNEC this semester. His work is related to improving muon tomography with resistive plate chambers for passive scanning of hidden materials at portal monitors and similar monitoring stations.



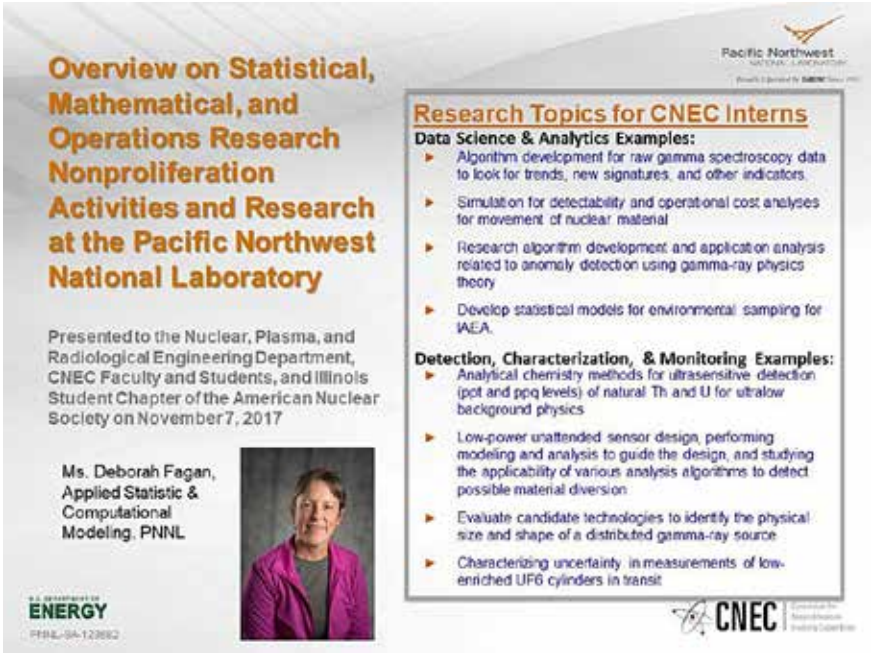
- Cosmic ray muons can be used to passively scan the contents of shipping containers via multiple Coulomb scattering. By adding high precision timing detectors (RPCs) to current methods, the muon's momentum can be used to better identify the composition of contents within opaque containers.
- The figure to the left illustrates how the Geant4+Comsic Ray Muon (CRY) Library is used to construct a proof of concept and create a reconstruction algorithm for scattering density of various materials. Aric Tate, Dhruv Desai. Dr. Matthias Perdekamp. 'Improving Muon Tomography with Resistive Plate Chambers (RPCs)', Nov. 7, 2017.

Laboratory Highlights

Pacific Northwest National Laboratory (PNNL)

Dr. Bobbie-Jo Webb-Robertson

PNNL scientist Debbie Fagan visited University of Illinois Urbana-Champaign on November 7 and presented "Overview on Statistical, Mathematical, and Operations Research Nonproliferation Activities and Research at the Pacific Northwest National Laboratory". She met with faculty and students and participated in a question and answer session with the University student chapter of the American Nuclear Society. Ms. Fagan was accompanied by Michael Cheng, a previous CNEC fellow and current Research Assistant at Pacific Northwest National Laboratory.



Special Lectures and Visits

Dr. Lassina Zerbo of CTBTO Presents Lecture at Georgia Tech

Jacob Inman

In the 21 years since the groundwork of the Comprehensive Nuclear Test ban Treaty Organization (CTBTO) was laid by the United Nations General Assembly, the preparatory commission has installed a data monitoring system fully capable of fulfilling the requirements of the treaty even prior to its ratification. These advances on the part of the preparatory commission were the subject of a presentation by Dr. Lassina Zerbo, the Executive Secretary of the preparatory commission, on September 18, 2017 at Georgia Tech. Dr. Zerbo's talk traced the history of the CTBT, from the political issues that have kept ratification at bay for over two decades to the technical work on the test monitoring and verification systems that has continued despite the roadblocks to ratification. While the talk highlighted the encouraging early results from the verification and monitoring system, Dr. Zerbo's perspective on the future of the CTBT provided a measure of hope, focusing on the success of the Joint Comprehensive Plan of Action (JCPOA) as a sign that resistance to ratification may be eroding. Despite these hopes, however, the lack of IAEA cooperation and the refusal of the US (as well as regional nuclear rivals in Asia) to ratify the treaty leave its future uncertain. In all, Dr. Zerbo describes a treaty with robust and proficient technical achievements, but remains hindered by interstate political gridlock.

Jim Walsh Speaks At NC State

Stefani Buster, J.D.

On September 27, 2017, Dr. Jim Walsh of Massachusetts Institute of Technology's Security Studies Program visited the NC State University and gave a presentation entitled Nuclear Weapons and War: Is this for real US. The presentation addressed the Democratic People's Republic of Korea (commonly known as "North Korea"), the United States of America, and the notion of confrontation. Dr. Walsh started by providing geopolitical context for his presentation including North Korea's historical relationship with the former Soviet Union and the role of nuclear weapons. Dr. Walsh went on to discuss North Korea's reasons for developing a nuclear weapons program, policy options, sanctions, preventive war, diplomacy, China's role, the deter and contain policy, and the posture of delaying resolution. Dr. Walsh covered the Trump administration's policy on North Korea, recent public comments about the country's leadership, and thoughts about the possibility of war. Finally, Dr. Walsh fielded several questions from the audience on topics including: North Korea's possibilities for strategically launching nuclear weapons—in the region vs. to the US, policy options, the current role of Russia, sanctions, the threshold for nuclear war under current conditions, and the Trump administration's efforts to reassure allies in the region.

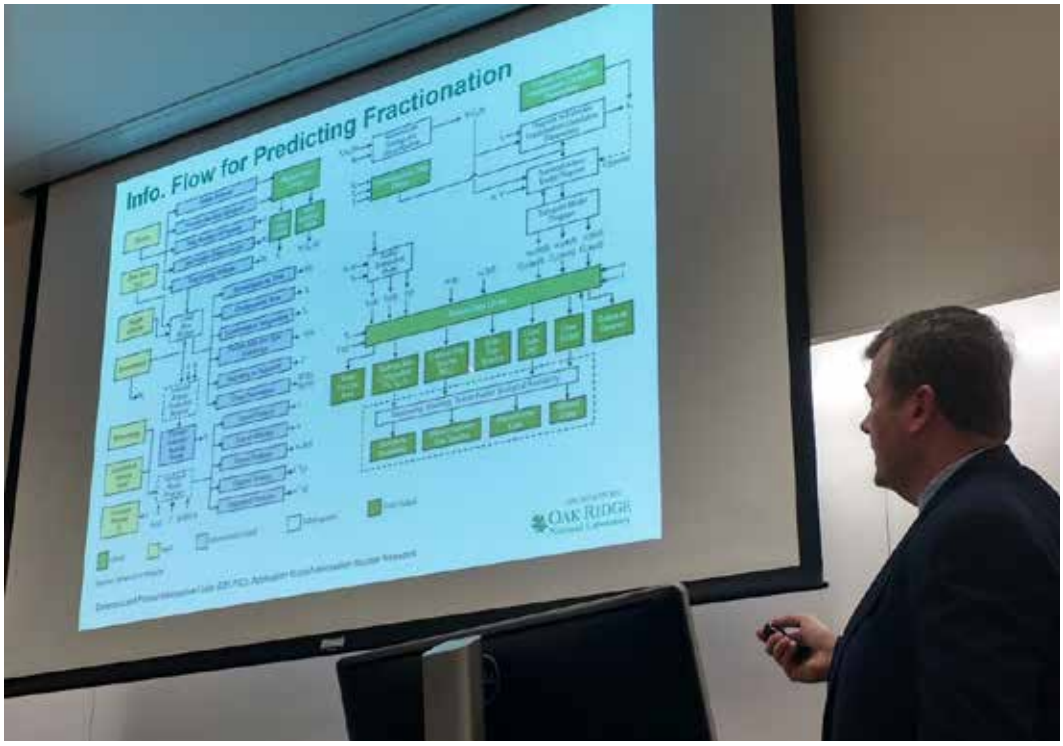
Special Lectures and Visits

Dr. Vince Jodoin of Oak Ridge National Laboratory Gives Lecture at NCSU

Dr. Robert Hayes

On October 26, 2017, Dr. Vince Jodoin, the group leader for the Oak Ridge National Laboratory Nuclear Security Modeling Group presented a lecture on, "Defense Land Fallout Interpretive Code (DELFIC): Application to post-detonation nuclear forensics".

The talk reviewed the application of DELFIC to the National Technical Nuclear Forensics interagency ground sample collection team. The collection team needed a fast running, portable mission planning tool to allow them to robustly respond to emerging nuclear device post-detonation situations. DELFIC is a validated, physics-based, research reference, fallout prediction software package. It has been implemented into the Fallout Planning Tool and is used to predict the expected isotope concentration of fallout, particle sizes, fractionation ratios, dose rate and integrated dose over the planned collection routes—information vital to ensure quality samples for nuclear forensic analysis while predicting dose to the sample collectors. DELFIC includes dynamic cloud rise, diffusive transport, and output processor modules. It also contains a particle activity module which models the radiochemical fractionation of the condensing elements in the cooling fireball into and onto particles to predict the activity size distribution for a given scenario. DELFIC's cloud rise module produces a definition of the stabilized cloud which accounts for particle settling and advection during cloud rise which causes a physical fractionation of the particles. The use of Google Maps and Google Earth with the DELFIC Fallout Planning Tool provides a familiar, user-friendly interface for mission planning and visualization.



Dr. Vince Jodoin of ORNL presenting his lecture on strategic software capabilities for predicting fallout characteristics and its associated measurement parameters

Special Lectures and Visits

Stimson Center Staff Visit ESI and CNEC

Dr. Bill Boettcher

On Wednesday, November 29, 2017, NCSU's Energy and Security Initiative (ESI) and CNEC hosted a brunch from 10-11:30 a.m. in the Talley Student Union, Room 3222. Visiting were Stimson Center Project Manager Lovely Umayam and Research Assistant Jacqueline Kempfer. A presentation and discussion of their recent report "RE-ENERGIZING NUCLEAR SECURITY: Trends and Potential Collaborations Post Security Summits", were held. See https://www.stimson.org/content/re-energizing-nuclear-security-report

On Thursday, November 30, 2017, ESI and CNEC also hosted a donuts and coffee roundtable from 10-11:30 a.m. on "Careers in Nuclear Nonproliferation" in Caldwell Hall Room 217. Umayam and Kempfer discussed Stimson Center programs and their own experiences in the field.

Nuclear Chemistry Invited Talk

Dr. Robert Hayes

Associate Professor Robert Hayes from the North Carolina State University's Nuclear Engineering Department presented a Key Note lecture at a nuclear chemistry conference on the topic of "Nuclear cameras, isotopic identifiers and retrospective thermometers currently in your bathroom, kitchen and office (and yes, pretty much everywhere, past, present and future whether you know it or not)". The content of the lecture demonstrated how using thermoluminescence, optically stimulated luminescence and electron paramagnetic resonance that all insulating materials effectively serve as low resolution integrating spectral gamma cameras. Effectively turning all building materials into dosimetric materials able to be measured retrospectively and so image historical sources and obtain gross isotopics. In principle capable of discriminating historical uranium enrichment, spent fuel measurements and even historical thermometry. The scientific program is available online https://d2cax41o7ahm5l.cloudfront.net/cs/pdfs/nuclear-chemistry-2017-scientific-program.pdf but slides from the presentation should be requested directly from Rob (rbhayes@ncsu.edu).

The 2017 2nd International Conference on Nuclear Chemistry was held in Las Vegas, November 15-16, 2017 at the Renaissance Hotel and Conference Center. The conference was put on through conferenceseries.com and by the Journal of Nuclear Energy Science & Power Generation Technology (Open Access).

Instrumentation used in this research to measure ubiquitous materials for their integrated dose. On the left is the electron paramagnetic resonance spectrometer and on the right is the combined thermoluminescence and optically stimulated luminescence spectrometer

Workshops

CNEC MCNP Workshop for the NC State Nuclear Engineering Department

Dr. Robert Hayes

A weeklong introductory MCNP training workshop was held on the North Carolina State University campus December 11-14, 2017. The agenda started with the basics of MCNP® and Monte Carlo radiation transport theory and then went over code syntax and formalism. How to specify sources, material and cells, conduct tallies and criticality calculations was all covered. Introductory variance reduction methods were also reviewed along with student specific topics. The course was held during the last 3 days of finals so there was some stepping out for mandatory academic requirements.

The course was taught by a pair of lab staff who are in the MCNP code team at Los Alamos, these were Michael Rising and Jennifer Alwin. Michael has been at LANL for almost 10 years and joined the MCNP team in 2013. Jen has been at LANL for over 20 years doing radiochemistry and nuclear criticality safety and recently joined the MCNP team in 2016. They both got to tour the RDNA labs (https://www.ne.ncsu.edu/rdna/) during their visit and issued attendance certificates to attendees. Both very much enjoyed seeing Raleigh, NC State and most importantly, our students!

Honors and Awards

University of Illinois' Katy Huff Wins American Nuclear Society's Mary Jane Oestmann Professional Women's Achievement Award

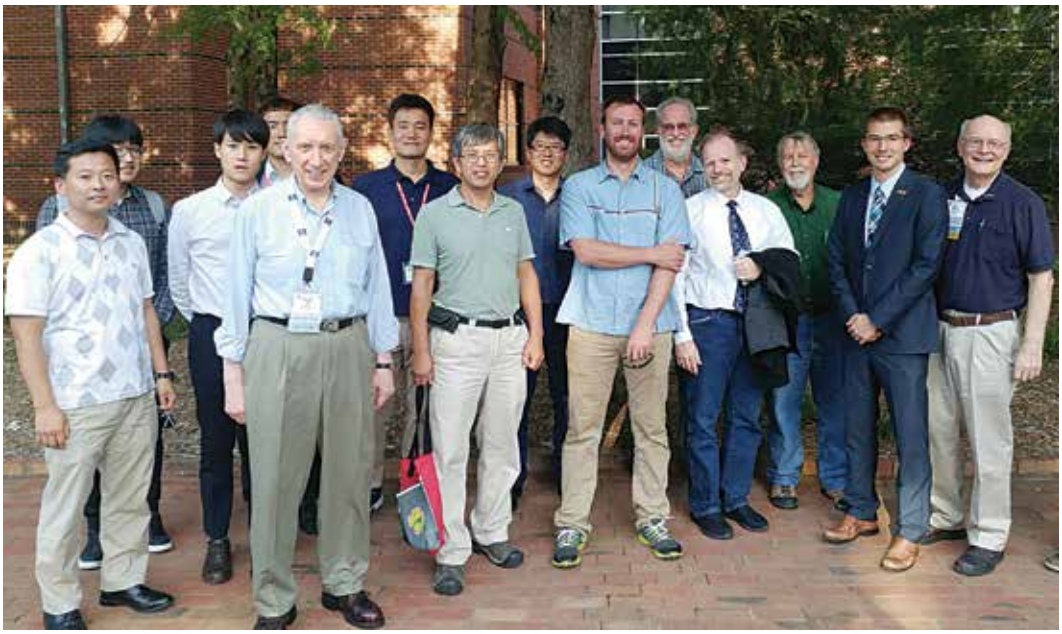
Dr. Katy Huff, Assistant Professor in Nuclear, Plasma, and Radiological Engineering at Illinois, is the 2017 winner of the American Nuclear Society Mary Jane Oestmann Professional Women's Achievement Award. The award recognizes outstanding technical achievement by a woman in the nuclear industry.

Dr. Katy Huff receives the award from ANS President Robert N. Coward

Joseph Cope wins a Health Physics Society (HPS) Award

Dr. Robert Hayes

Samuel Joseph Cope, CNEC Fellow and PhD candidate, was selected as recipient of the 2017-2018 Robert S. Landauer Sr. Fellowship by the Health Physics Society (HPS). The award was established honoring Dr. Landauer (http://hps.org/aboutthesociety/people/landauer.html), a prominent teacher of radiological physics. Joseph presented at the 2017 HPS Annual Meeting in Raleigh, NC, on research related to his Master's of Nuclear Engineering. He continues in the PhD program under Dr. Robert Hayes in air monitoring for radiological emergency response. The award includes a stipend along with travel grant to the 2018 HPS Annual Meeting in Cleveland, Ohio.



Tour of Dr. Hayes labs during 2017 HPS Annual Meeting in Raleigh, NC

Sigma Xi Best Graduate Engineering Poster

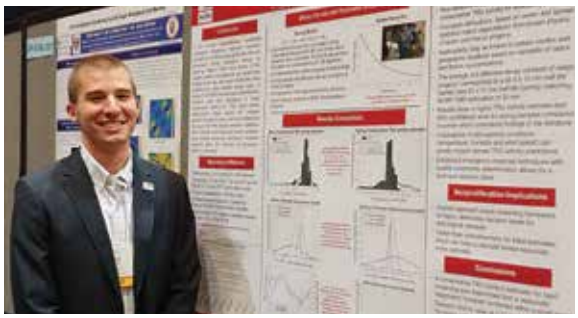
Dr. Robert Hayes

Samuel Joseph Cope, CNEC Fellow and PhD candidate under Dr. Robert Hayes, was awarded best graduate engineering poster at the Sigma Xi Student Research Conference. Cope presented recent work on the seasonal differences of "NORM Air Sampling for Radiological Emergency Response." The award includes a free year of society membership, a Sigma Xi medal and cash award. Sigma Xi, The Scientific Research Honor Society is the international honor society of science and engineering. One of the oldest and largest scientific organizations in the world, Sigma Xi has a distinguished history of service to science and society for more than one hundred and twenty five years. Scientists and engineers, whose research spans the disciplines of science and technology, comprise the membership of the Society, and more than 200 Nobel Prize winners have been members.

https://www.ne.ncsu.edu/news/2017/cope-phd-student-presents-2017-sigma-xi-student-research-conference/

Sigma Xi awardee induction ceremony and poster presentation from student research conference

Award presentation to Joseph from both the president and executive director of Sigma Xi



Joseph during the presentation and judging of the posters standing next to his as yet awarded poster for best in the graduate engineering section

Dr. Timothy Burke is the 2017 Recipient of the Mark Mills Award

Dr. Brian Kiedrowsk

Tim Burke receives award from ANS President Robert N. Coward

Dr. Timothy Burke is the 2017 recipient of the Mark Mills Award for his paper entitled "Kernel Density Estimation of Reaction Rates in Neutron Transport Simulations of Nuclear Reactors" published in Nuclear Science and Engineering for his doctoral research. During his graduate studies at the University of Michigan under the supervision of Professors Brian Kiedrowski and William Martin, Burke developed innovative techniques for performing large collections of pointwise estimates of reaction rate responses in Monte Carlo particle transport calculations. Upon graduation, Burke joined CNEC as a postdoctoral researcher at the University of Michigan working with Kiedrowski. During his postdoc, Burke applied the techniques he developed during his doctoral work and created a novel and efficient approach for estimating the response sensitivities of interface locations in Monte Carlo calculations, which has applications in subcritical benchmarks and quantifying the needed resolution in hidden source search models. Burke is currently a Nicholas C. Metropolis Fellow at Los Alamos National Laboratory in the Computational Physics Division.

Featured Research

Localization in an Urban Environment

Jason Hite, North Carolina State University

In this article, we describe a Bayesian approach to determining the location and intensity of an unknown source of radiation in a heterogeneous urban environment. A source is assumed to exist in the search area and is observed by a network of radiation detectors, which records counts due to both the source and from natural background radiation present in the scene. Using these measurements, we seek to predict the location of the source, as well as to quantify the uncertainty in our predictions.

In previous work we demonstrated an algorithm based on Markov-Chain Monte Carlo to perform the localization. These results were based on a simulated city block, with synthetic measurement data generated using a simplified model for the transport of gamma rays from the source to the detector in a heterogeneous medium. In May 2017, and with the assistance of Oak Ridge National Laboratory, we performed a series of outdoor measurements intended to serve as a field test for our localization algorithm. These measurements were designed to simulate a real-world search scenario in an urban setting and serve as a basis for further development of our techniques.

Figure 1

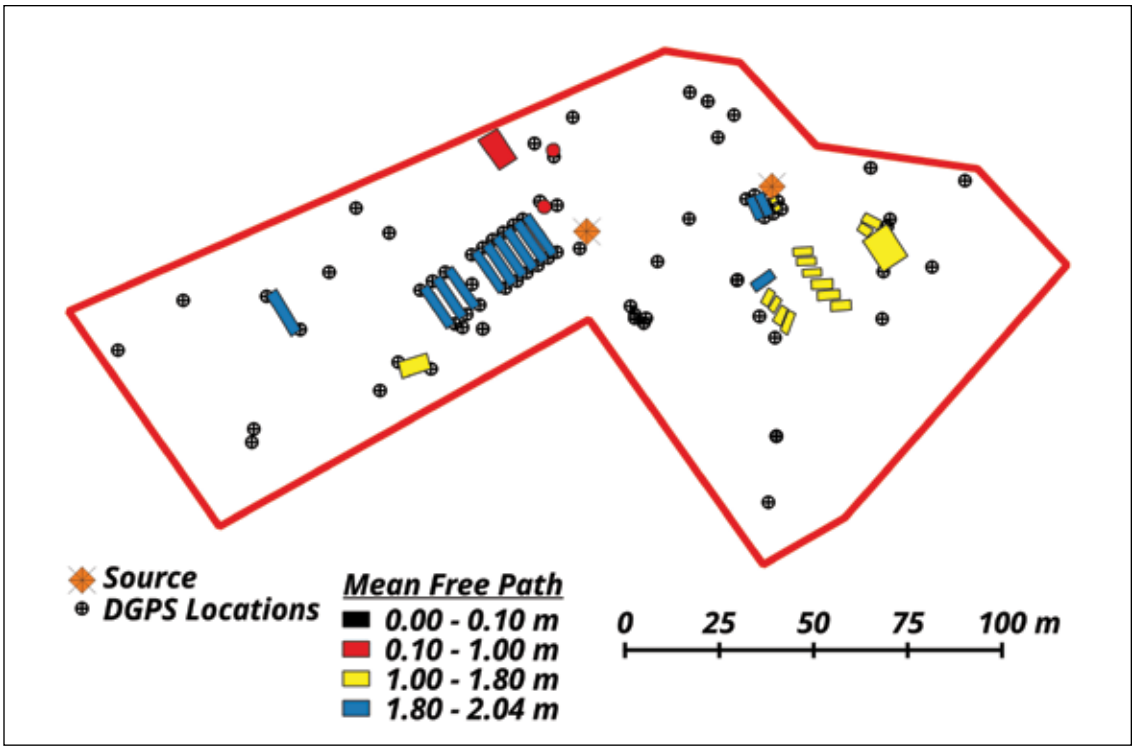


Figure 2

Field Test

In May of 2017, we performed a full-scale measurement campaign at the Energy Systems Test Complex at Oak Ridge National Laboratory, also known as the former site of the Experimental Gas-Cooled Reactor. The measurement campaign took place outdoors in a cluttered environment and was chosen to mimic a real-world search in an urban setting. We placed a Cs-137 source with a nominal activity of approximately 37 microcuries (μCi) in two different locations, shown in orange in fig. 1. These source placements divided the measurement campaign into two separate experiments, referred to as experiment 1 and experiment 2.

As part of the measurements we performed a detailed survey of the site using photography and precision differential global positioning system (DGPS). This data was used to reconstruct a simplified representation of the geometry of objects in the experiment area, which is shown as the polygons in fig. 2. Material cross sections were then selected on a best-estimate basis, using the dimensions of the objects and assumed compositions. These cross sections are shown in terms of mean-free path by the colors in fig. 2, grouped into four categories ranging from weak (blue) to strong attenuators (red/black).

Results and Analysis

The Bayesian Metropolis algorithm we use infers the source location by accumulating the posterior probability that any given source location is statistically consistent with the measured detector responses. The mode of the posterior distribution corresponds to the best estimate of the source's location, while the spread in the posterior distribution characterizes its uncertainty. The joint likelihood of any given set of detector responses is estimated using a highly simplified ray-tracing model, which assumes gammas that scatter while traveling from source to detector are unlikely to reach that detector.

Our algorithm also accounts for uncertainties in the cross section of the objects in the scene, which are difficult to estimate precisely in situ. We employ a Metropolis sampler that is modified to propagate fixed parameter uncertainties onto the posterior density and assign large uncertainties to all material cross sections that are representative of our imprecise knowledge of the true cross sections. These cross section uncertainties are reflected in the spread of the posterior, however our work has consistently shown that the effect of cross section uncertainties is small and the method still produces useful results even with highly uncertain information on the material composition of objects in the scene.

Figure 3 shows the joint posterior for the source location in the first experiment for a 60 s measurement time and uniformly distributed cross section uncertainties of ±50% relative to their estimated nominal values. We see that the method is able to localize the source to within ≈15 m, with fig. 4 showing that the localization error decreases as the measurement time is increased. We note, however, that there is a persistent bias in the posterior distribution which exceeds the predicted uncertainty. Future work is focused on reducing this bias and we currently attribute it to the detector response model not accounting for the orientation of the detectors.

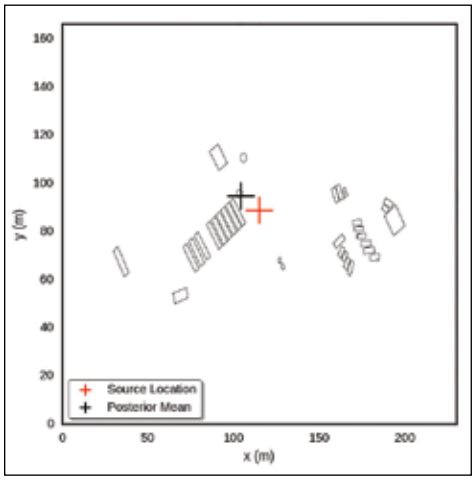


Figure 3

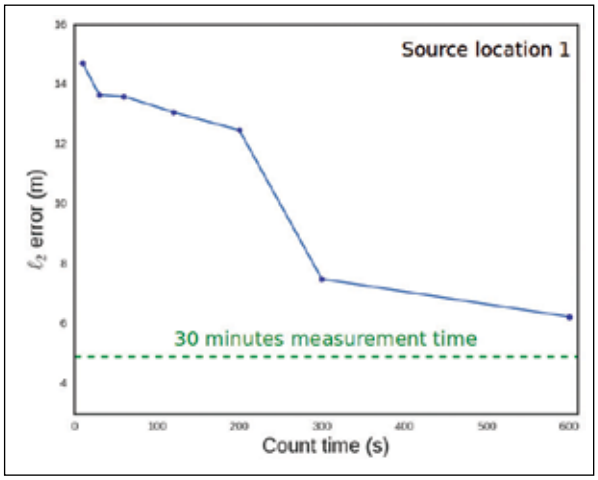


Figure 4

Upcoming Events

Event	Date	Location
CNEC Annual Workshop and Advisory Board Meeting	February 8-9, 2018	NC State, Raleigh, North Carolina
Distinguished Lecture Series Mr. Alain Lebrun	February 22, 2018	NC State, Raleigh, North Carolina
Distinguished Lecture Series Dr. Manoj Prasad	March 22, 2018	NC State, Raleigh, North Carolina
University Program Review	June 5-7, 2018	Sheraton Hotel, Ann Arbor, Michigan
American Nuclear Society Annual Meeting	June 17-21, 2018	Marriott Philadelphia Downtown, Philadelphia, Pennsylvania

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