CNEC | Consortium for Nonproliferation Enabling Capabilities

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CNEC Newsletter

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Pacific Northwest

CNEC Holds First Annual Workshop

Stefani Buster

From February 6th to 7th, over 70 CNEC PIs, national laboratory representatives, students and postdoctoral fellows, administrators, sponsor representatives, and other area experts attended the first annual CNEC Workshop. The event was hosted in conjunction with CNEC's annual Advisory Board (AB) meeting at NC State's campus in Raleigh, NC. Additionally, representatives of the Consortium for Verification Technology, and the Nuclear Security Science Consortium attended the CNEC Workshop.

CNEC Advisory Board

The workshop featured 26 oral presentations by CNEC students and researchers, and provided an opportunity for them to get feedback from the wider CNEC body, national laboratory partners, sponsor representatives, and the CNEC AB. The presentations covered projects related to CNEC's four Thrust Areas: Signatures and Observables; Simulation, Analysis, and Modeling; Data Fusion and Analytic Techniques; and Replacement of Dangerous Radiological Sources. The event also included presentations that covered CNEC's policy and education efforts, national laboratory collaborations, and outreach.

Student Poster Session

A poster session followed by dinner at the Park Alumni Center concluded the first day of the workshop. During this time, 24 CNEC Fellows and students presented their work at the poster session and engaged the visitors in fruitful discussions.

When the workshop ended, CNEC's AB began its meeting and evaluation of the consortium's work. CNEC's AB comprises six leading researchers with a combination of technical and policy backgrounds in nuclear nonproliferation applications. The AB members are affiliated with academia, government labs, and industry research: Dr. Christine Anderson-Cook, Project Leader, Statistical Support for Design & Analysis for Nuclear Forensics (NTNFC), Los Alamos National Laboratory; Dr. Al Carnesale, Chancellor Emeritus and Professor, UCLA; Dr. Elmer Lewis, Professor Emeritus in Service, Northwestern University; Dr. Robert Mayo, Principal Professional Staff, Applied Physics Laboratory; Mr. William Tobey, Senior Fellow, Belfer Center for Science and International Affairs; and Dr. Nick Tsoulfanidis, Adjunct Professor University of Nevada-Reno, Chemical & Materials Engineering Department.

NC State Hosts Dr. Michael Koehl

Robert Hayes

Dr. Michael Koehl of NNSA, who oversees radiological emergency response, search and consequence assessment, visited the CNEC labs at Research Building II (RBII) on Wednesday January 18, 2017 along with a tour of the PULSTAR reactor. During this visit, he toured the research laboratories of both Dr. John Mattingly and Dr. Robert Hayes.

Purdue University Hosts Dr. Robert Beimler

Miltos Alamaniotis

The Purdue University CNEC team hosted Dr. Robert Beimler, Proponent Manager, US Army Nuclear and Countering WMD Agency, Fort Belvoir, Virginia on March 27, 2017. Dr. Beimler had the chance to interact with the CNEC affiliated faculty at Purdue and identify some common interests.

University News

NC State Offers New Nonproliferation Graduate Certificate

Stefani Buster

North Carolina State University (NC State) has created an interdisciplinary graduate certificate program in Nuclear Engineering and Political Science focused on *Nuclear Nonproliferation Science and Policy*. The objective of the program is to educate students and post-graduate professionals about nuclear nonproliferation from both the social science and the engineering perspectives. The program cultivates an in-depth understanding of the technical and policy challenges to developing and implementing robust international nuclear nonproliferation regimes. This 12-credit (four classes) certificate program is open to degree-seeking students at NC State, students at other institutions of higher education, and post-graduate professionals seeking to expand their educational credentials.

For more information, visit https://www.cnec.ncsu.edu/2016/11/10/1343/.

ANS Student Conference 2017

Lisa Marshall

The 2017 ANS Student Conference, hosted by the University of Pittsburgh Nuclear Engineering Program, drew approximately 500 attendees. CNEC participated in its two-day career fair. Ms. Lisa Marshall, educational outreach director, gave her annual workshop on graduate school where CNEC is an integral part of the discussion - CNEC fellowship, nuclear security/non-proliferation research, integrating public policy and national laboratory internships/positions. Future CNEC students are being cultivated through the educational pipeline - pre-college to graduate studies. Again this year CNEC participated in pre-college summer programs, special thanks to Dr. Robert Hayes and his graduate students. This past academic year there were information sessions and individual advising on what CNEC represented to undergraduate students. More recently, at Duke University's Pratt School of Engineering, Ms. Marshall spoke to nuclear related topics including nuclear safety and security.

Lisa Marshall and Brian Burns (NC State) with alumnus Jesse Holmes

CNEC Booth with NC State students

News from CNEC National Laboratories

Pacific Northwest National Laboratory

Bobbie-Jo Webb-Robertson & Robert Brigantic

Dr. Karl Pazdernick and Michael Cheng to Join PNNL

The Applied Statistics & Computational Modeling group in the National Security Directorate at the Pacific Northwest National Laboratory invited two CNEC associated individuals to join the laboratory. Dr. Karl Pazdernick, currently a postdoctoral research associate in the department of statistics at North Carolina State University working under Professor Alyson Wilson, accepted a position as a Machine Learning & Computational Statistics Research Scientist. Mr. Michael Cheng, currently a graduate research assistant in the Radiation Detection & Isotope Identification (RDII) research group headed by Professor Clair J. Sullivan at the University of Illinois at Urbana-Champaign, accepted a position as a Post Master Research Associate.

PNNL Staff Visits

Jennifer Tanner, PNNL, was invited to give a seminar at the Georgia Institute of Technology (GIT) by Dr. Nolan Hertel, the GIT point of contact for the Consortium for Nonproliferation Enabling Capabilities (CNEC). The seminar was part of the Nuclear & Radiological Engineering/Medical Physics Programs Seminar Series. The title of the seminar was "Radiation Detection and Arms Control" and the goal was to introduce the students to the different roles radiation detection technologies could play to meet verification objectives under potential future arms control treaties and agreements. The functional areas of warhead monitoring (warhead confirmation, chain of custody, and monitored dismantlement) were summarized while warhead confirmation was explored in more detail using the application of radiation mapping technology as an example. The presentation concluded with a description of the educational opportunities available at PNNL as part of the CNEC and the Consortium for Verification

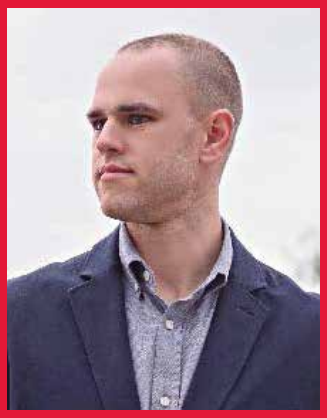
Technology. The seminar was attended by both graduate and undergraduate students as well as several faculty members. Prior to the seminar, Ms. Tanner met with Dr. Hertel and Dr. Anna Erickson, coordinator of the seminar series, and she was able to meet with several of Dr. Hertel's students before and after the seminar.

Oak Ridge National Laboratory

Dave Williams

Dr. Vladimir Sobes of ORNL Visits Purdue University

The Purdue CNEC team had the pleasure to host Dr. Vlad Sobes for a seminar this past February. Dr. Sobes, who is currently a Research and Development Staff Member in the Nuclear Data and Criticality Safety group at ORNL, gave a seminar entitled "The Future of Nuclear Data: Quantum Physics, Machine Learning, and Scattering Experiments". In his talk, Dr. Sobes stated his vision on the integration of machine learning with nuclear data. Details of his talk may be found at the following link: https://engineering.purdue.edu/NE/academics/seminars/2017/seminar-detection



Dr. Vladimir Sobes

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Dr. Sobes Visits Purdue University

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The seminar was attended by all Purdue graduate students. The talk was welcomed by the students, who expressed their interest with a series of well-thought out questions.

During his visit, Dr. Sobes had the chance to meet the Purdue CNEC team and closely interacted with them. Common interests were found and avenues for collaborations were identified. It should be noted that Dr. Sobes mentored a Purdue CNEC student (Mrs. Lydia Lagari) during her internship at ORNL in summer 2016 and again in 2017.

Los Alamos National Laboratory

Jeffrey Favorite

Dr. Brendt Wohlberg Visits NC State

Dr. Brendt Wohlberg of LANL visited NC State University on March 17, 2017. He met with Professor Hamid Krim's research group and several of his students, and he gave a seminar entitled 'Convolutional Sparse Representations for Imaging Inverse Problems' to the Electrical and Computer Engineering Department.

Professor Brian Kiedrowski of University of Michigan Visits LANL

Dr. Brian Kiedrowski visited LANL on March 22, 2017 and gave a seminar to the Monte Carlo Methods, Codes, and Applications group (XCP-3) entitled "Monte Carlo Particle Transport Activities in CNEC at the University of Michigan."

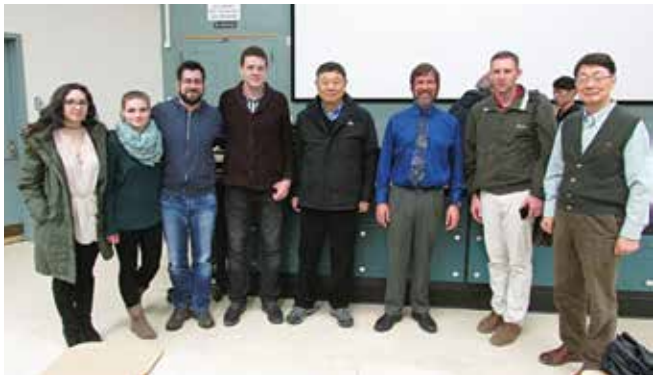
Dr. Jeffrey Favorite Visits Purdue

Dr. Jeffrey Favorite was hosted by the CNEC team of Purdue University, Professor Lefteri H. Tsoukalas, Professor Chan Choi and Dr. Miltos Alamaniotis. Dr. Favorite gave a seminar entitled: "Jezebel: Reconstructing a Critical Experiment from 60 Years Ago". The abstract of his talk may be found at: https://engineering.purdue.edu/NE/academics/seminars/2017/seminar-jezebel-reconstructing-a-critical-experiment-from-60-years-ago

His seminar was open to faculty, graduate and undergraduate students of the School of Nuclear Engineering, and had a high attendance rate.

During his visit, Dr. Favorite had the chance to interact with the Purdue CNEC team, see their work, and have fruitful discussion with the CNEC affiliated faculty. In addition, he had meetings with several other members of the NE faculty who were interested in his work.

Dr. Favorite demonstrates the size of the Jezebel assembly by displaying a red cabbage with a similar circumference



Dr. Favorite with CNEC faculty and students at Purdue

Honors and Awards

Dr. Ralph Smith

Recognition of Simulation, Analysis and Modeling (SAM) Professor Ralph Smith

Dr. Ralph Smith of the NC State Department of Mathematics and participant in SAM was recipient of the SPIE 2017 Smart Structures and Materials Lifetime Achievement Award in recognition of his sustained contributions to the advancement of "Smart Structures and Materials Technologies" and the 2016 ASME Adaptive Structures and Material Systems Award for extraordinary contributions in the development of smart materials and adaptive structures through constitutive model development, modeling and nonlinear control, and uncertainty analysis; and for modeling research that has been validated across a broad range of smart materials.

Dr. Nolan Hertel

Professor Nolan Hertel Named President Elect of Health Physics Society

Dr. Nolan Hertel, Professor of Nuclear and Radiological Engineering (NRE) in the George W. Woodruff School at the Georgia Institute of Technology, was voted president-elect of the Health Physics Society (HPS). He will assume HPS presidency in July 2018. HPS membership is about 4000 individuals and is the largest radiation protection society in the world.

Dr. Hertel is a research participant in the Signatures and Observables (S&O) thrust area of CNEC.

Dr. Hertel is the Interim Nuclear & Radiological Engineering Associate Chair at Georgia Tech.

Dr. Robert Hayes

Recognition of Professor Robert Hayes' Research on Radioisotope Dating

Dr. Robert Hayes' publication in Nuclear Technology (NT) on a key flaw in widely used radioisotope dating technique received special mention in NC State News (https://news.ncsu.edu/2017/01/radioisotope-dating-flaw-2017/) and the DOE Office of Science University Research News (https://science.energy.gov/universities/university-research/?fiscalYear=undefined&program=undefined&searchTerm=key%20flaw&page=&sort=&order=). The NT paper looks at differential mass diffusion such as used in enrichment and how it applies to geological dating. Current work involves its application to trinitite sample assays. Hayes is working with Dr. Vincent Jodoin of ORNL on this latter study.

ANS International Conference on Mathematics and Computational Methods (M&C) 2017

Special Sessions on Nonproliferation at M&C 2017

John Mattingly

Professor John Mattingly of NC State and Professor Imre Pazsit of Chalmers University organized the special topic "Solving Inverse Problems for Nuclear Nonproliferation Applications" at the American Nuclear Society's International Conference on Mathematics and Computation (M&C 2017) held in Jeju, South Korea from April 16-20, 2017. There were other sessions under the topics: Sensitivity Analyses for Safeguards, Multiplicity Counting for Nuclear Material Characterization, Solving Inverse Problems for Safeguards, and Analysis of Safeguards Measurements. The sessions were co-chaired by John Mattingly, Imre Pazsit, James Peltz of NNSA, and Chen Dubi of Nuclear Research Center Negev, Israel.

The special sessions covered recent developments in parameter estimation, model calibration, sensitivity analysis, and uncertainty quantification applied to problems relevant to monitoring states' compliance with nonproliferation obligations and detecting incipient proliferation activities. A total of sixteen talks and two posters were presented by researchers from diverse institutions, including universities in the US,

Dr. Imre Pazsit (left), Dr. John Mattingly (center), Dr. James Peltz (right) at M&C 2017

Sweden, Israel, and Brazil; national laboratories in the US and Belgium; and NNSA, Japan Atomic Energy Agency, and International Atomic Energy Agency. The technical content included mathematical analyses, deterministic and stochastic modeling, and statistical inference methods to estimate system inputs and parameters from experimentally measured system responses. The sessions served to introduce the ANS M&C community to mathematical and computational methods being developed to support nuclear nonproliferation, and it introduced many of the presenters to the advanced methods being developed by the broader M&C community.

CNEC Students Participate in M&C 2017

Several NC State students participated in M&C 2017- Noel Nelson, Nate Hart, and Xiaoyu Hu, all students advised by Professor Azmy. Noel is CNEC funded and Nate is a Nuclear Energy University Program (NEUP) fellow. Nate and Xiaoyu work on CNEC-related research at NC State.

Two CNEC Fellows, advised by Professor Yousry Azmy participated in the "Massively Parallel Transport" session of M&C 2017.

Dylan Hoagland (pictured here presented his paper titled "Iterative Properties of Parallel Jacobi-Integral Transport Matrix Method with Source Iteration Pre-Conditioning".

Raffi Yessayan (pictured here) presented his paper titled "Development of a Parallel Performance Model for the THOR Neutral Particle Code".

CNEC fellow, Joel Kulezsa, who is advised by Dr. Brian Kiedrowski at the University of Michigan (UM), presented a paper titled "Performance Assessment of Cost-Optimized Variance Reduction Parameters in Radiation Shielding Scenarios". CNEC postdoc, Tim Burke from UM, also presented a paper titled "Acceleration of Monte Carlo Methods on Heterogeneous CPU-GPU Platforms Using Kernel Density Estimators".

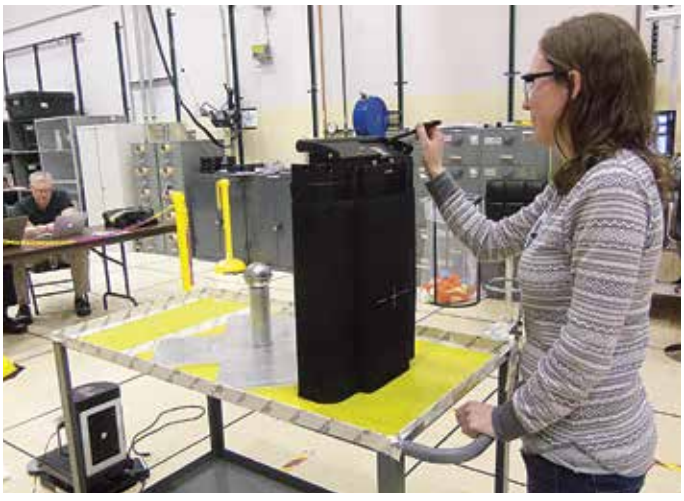
Featured Research

Advanced Critical and Subcritical Neutron Multiplication Measurements for Nuclear Data and Computational Methods Validation

Jennifer Arthur, CNEC Fellow, University of Michigan

Predictive Monte Carlo (MC) radiation transport simulations of special nuclear material (SNM) are extensively used in the fields of nuclear safeguards and nonproliferation for applications such as SNM identification and characterization, experiment planning, and detection system development. Both reliable MC simulation codes and accurate nuclear data knowledge are necessary in order to precisely predict the results of SNM measurements. The purpose of my work is to advance the state-of-the-art of sub-critical neutron multiplication benchmark measurements in order to validate fundamental nuclear data (e.g. Pu-239 $\bar{\nu}$) and newly developed computational methods (e.g. FREYA). Furthermore, by providing novel comparisons between measured and simulated neutron multiplication measurements, we can further identify deficiencies and quantify uncertainties in sensitive nuclear data quantities.

While working towards my thesis I plan to design, execute, and analyze advanced benchmark quality neutron multiplicity measurements and compare the results to MC simulations using a variety of codes (MCNP®6.2, MCNP®6.2-FREYA/CGMF, PoliMi, MCATK, MORET etc.). I am comparing both the computational methods performance (e.g. sampling routines) and nuclear data impact (e.g. underlying fission models) of codes that take into account the correlated physics of fission. I also plan to carry out a preliminary analysis of the applicability of the Total Monte Carlo (TMC) physical uncertainty propagation method to benchmark neutron multiplicity measurements.



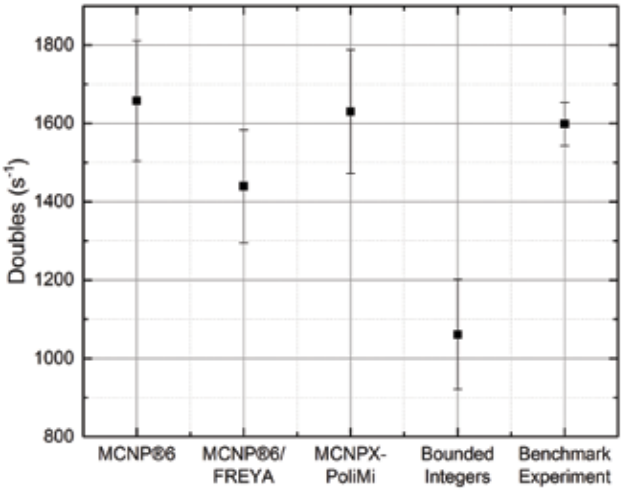


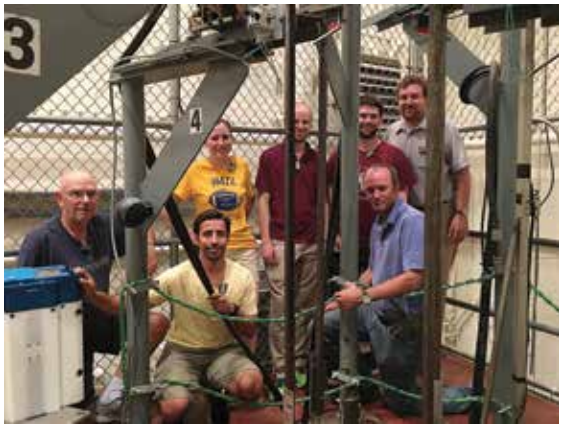
Figure 1.

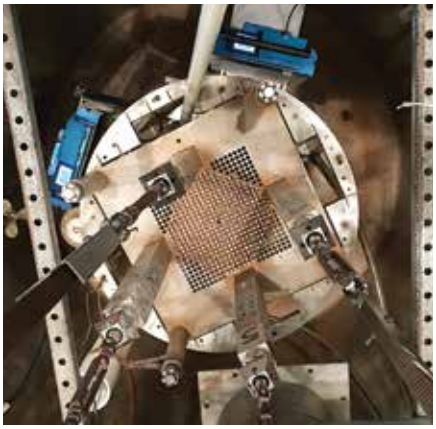
Performing benchmark quality subcritical neutron multiplication measurements with a LANL multiplicity detector on WGPu at the National Criticality Experiments Research Center in Nevada (left).

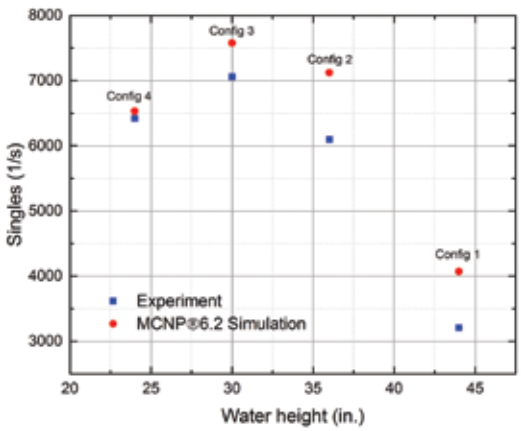
Example result comparing the doubles rates obtained from different MC codes (right).

Advancing the State-of-the-Art for Neutron Multiplication Measurements

My currently completed goals include the design and execution the Critical and Subcritical 0-Power Experiment at Rensselaer (CaSPER). CaSPER was designed to establish a protocol for neutron multiplicity measurements on research reactors as the next step in advanced subcritical neutron multiplication measurements.







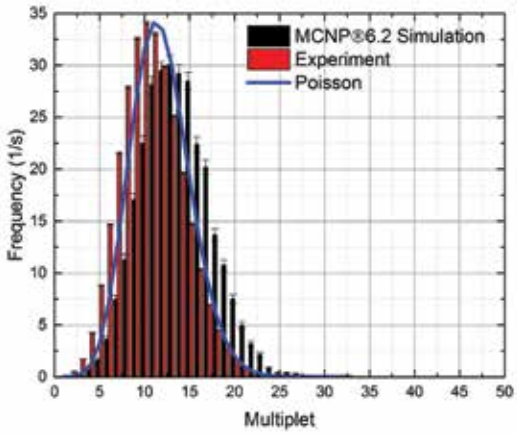


Figure 2.

Pictures taken during the CaSPER measurement, including two MC15 detection systems and the RPI Reactor Critical Facility (RCF) core with the water drained from the tank.

Preliminary comparison of measured and simulated data are also shown.

Nuclear Data and Code Validation with Recent/Upcoming Subcritical Benchmarks

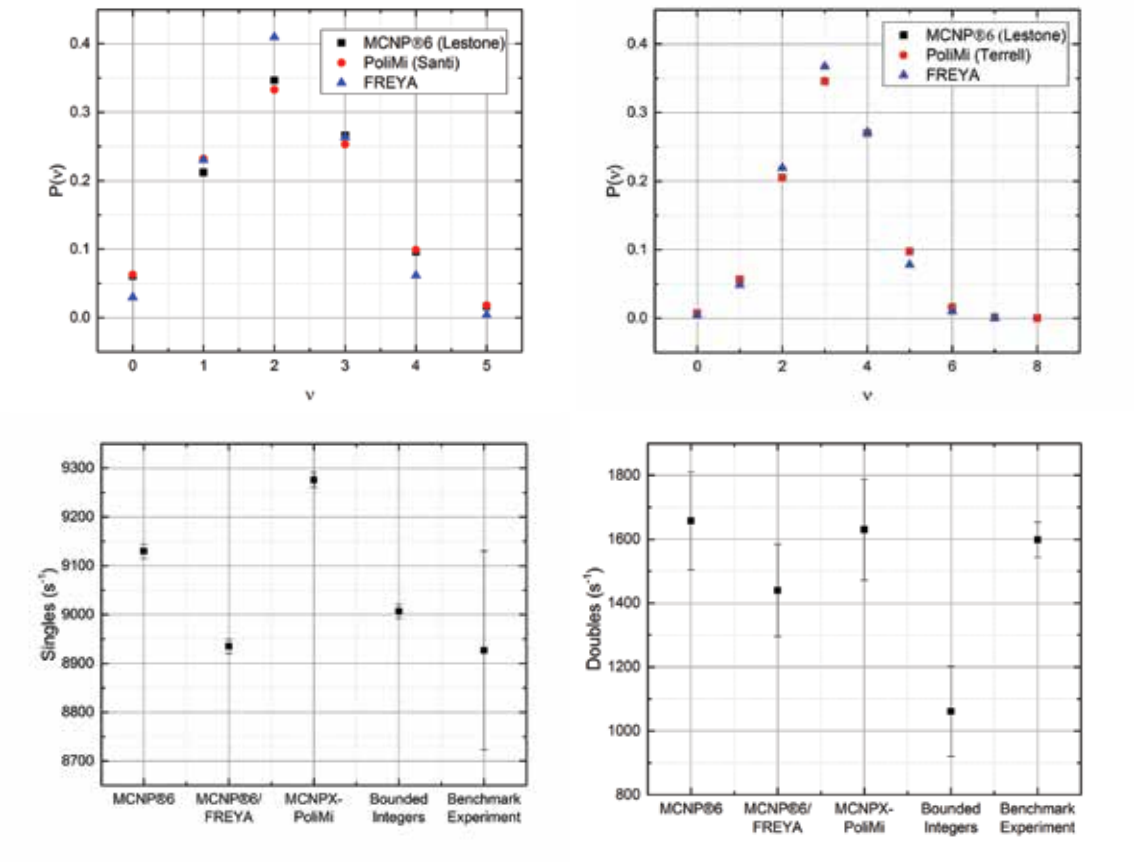
I participated in the newest LANL benchmark measurement intended for the International Criticality Safety Experiment Benchmark (ICSBEP) handbook, the Subcritical Copper-Reflected α-phase Plutonium (SCRαP) experiment. Currently I am working on creating the detailed SCRαP benchmark MCNP®6 model and will in the future perform uncertainty analysis on the physical parameters of interest.

I have simulated a configuration of the nickel-reflected plutonium ball BeRP-Ni benchmark measurement using various MC codes that take into account the correlated physics of fission. The BeRP-Ni benchmark is included in the most recent release of the ICSBEP handbook. Both the results and the underlying neutron multiplicity models applied by the codes have been compared. In the future I plan to expand the comparison to include various BeRP benchmark cases, including all BeRP-Ni and BeRP-W configurations, and the upcoming MCNP®6.2 release.

Figure 3.

Comparison of spontaneous (upper left) and induced (upper right) multiplicity distributions used or produced by various codes.

Comparisons of singles and doubles rates (bottom left and right) are also shown.



Iterative Convergence Properties of Parallel Block Jacobi - Integral Transport Matrix Method with Source Iteration Preconditioning

Dylan S. Hoagland, CNEC Fellow, North Carolina State University

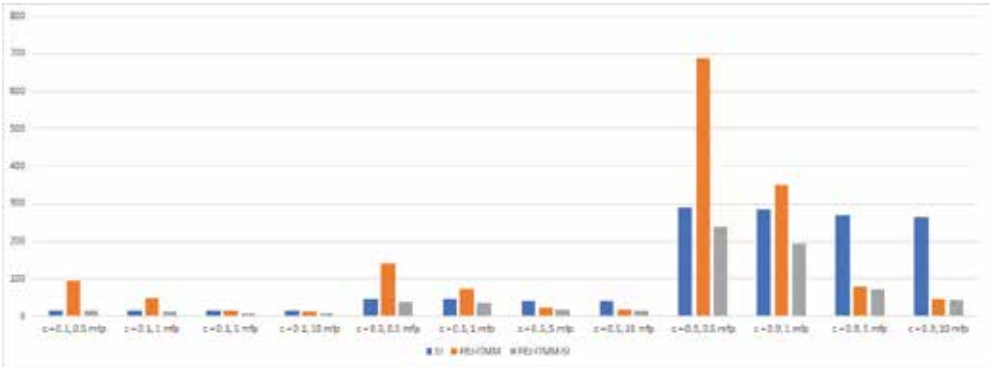
Dylan Hoagland at UITI 2016

My research lies in the Simulation and Modeling thrust area of CNEC, providing improved iterative methods for neutron transport simulation on massively parallel computer systems. Traditionally, transport calculations employ the *Source Iteration* (*SI*) method. The *SI* iterative method relies on a mesh sweep procedure, moving, or "sweeping", across the computational mesh that is superimposed on the physical geometry of the transport problem. When this mesh is comprised of only rectangular cells (a structured mesh) the *SI* method can be executed with reasonable efficiency on a massively parallel computer system using the Koch, Baker, Alcouffe (KBA) spatial domain decomposition. However, when the mesh comprises arbitrarily shaped tetrahedrons (an unstructured mesh), this mesh sweep becomes extremely complex to execute on a multiprocessor system, as the sequential order in which the cells must be swept is no longer trivially deductible.

Parallel Block Jacobi - Integral Transport Matrix Method (PBJ-ITMM) was developed to allow transport problems to be solved on unstructured grids using massively parallel computer systems without the use of these complex sweep algorithms.

PBJ-ITMM splits the problem up into multiple spatial sub-domains. During an iteration, these sub-domains are solved for their angular fluxes independently of all other sub-domains, assuming the flux of particles passing into a sub-domain from neighboring sub-domains based on the outgoing solution of those sub-domains in the previous iteration. Iterations are then executed until convergence of these sub-domain interface fluxes is achieved. This method suffers iterative slowdown when a problem's cells are optically thin though, as many iterations are required to simulate particles which stream across many sub-domains before suffering a collision on average. To reduce this shortcoming of *PBJ-ITMM*, I investigate the use of a *PBJ-ITMM* iteration followed by an *SI* iteration. Previous analysis has shown that an *SI* iteration simulates particles until their next collision, which can be used to eliminate the cause of *PBJ-ITMM's* iterative slowdown in optically thin cells. The combined iterative method is termed *PBJ-ITMM-SI*. The clear disadvantage of this method is that the SI step in the iterative sequence is not executed in parallel, but this will be addressed with the implementation of a hybrid method as well as future research.

To theoretically study the convergence properties of this iterative method, I employ a Fourier analysis. This is a mathematical analysis technique which transforms the problem into the Fourier (frequency) domain. In this domain, the scaling of the iterative error due to the action of a single iteration can be determined as a function of the Fourier variables. The maximum magnitude of this function is termed the spectral radius, as it will be the slowest converging mode, and will hence dictate the convergence rate. If the spectral radius is less than unity, the method will converge, as the error being multiplied by this spectral radius will cause a monotonic reduction of that error mode. It has been shown that *PBJ-ITMM's* spectral radius approaches 1 as the cell optical thickness approaches 0, indicating that the required number of iterations grows without bound. Upon conducting the Fourier analysis for *PBJ-ITMM-SI*, I have shown that SI preconditioning eliminates this undesirable behavior. To demonstrate this improved iterative robustness, the following chart shows the required number of iterations to converge a problem using *SI, PBJ-ITMM*, and *PBJ-ITMM-SI* at a variety of cell sizes (*mfp*) and scattering ratios (*c*).



Although the results shown in this table show significant improvement over *PBJ-ITMM* in optically thin cells, note that there is only slight improvement over *SI* in optically thin cells and only slight improvement over *PBJ-ITMM* in optically thick cells. Since each *PBJ-ITMM-SI* iteration comprises one of each type of iteration, this makes PBJ-ITMM-SI only advantageous over a small range of cell sizes. However, these results are for the homogeneous test problem, which I use for comparison to

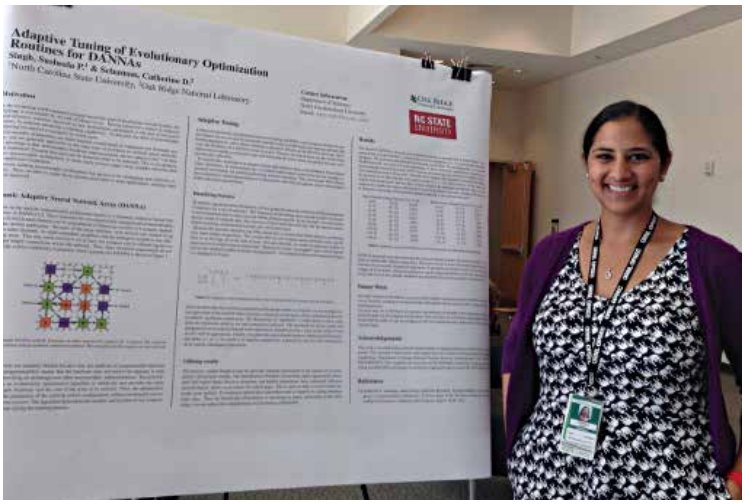
the theoretical Fourier analysis, and is not representative of realistic problems. As realistic problems will contain cells of a variety of thicknesses, I theorize that *PBJ-ITMM-SI* has the ability to show significant reduction of iteration count over each of the individual methods in realistic problems. To test this conjecture, I developed a heterogeneous stripe problem with alternating stripes of thick and thin cells.

Additionally, as I see *PBJ-ITMM* to converge optically thick cells with little assistance from *SI*, and vice-versa for optically thin cells, I propose a hybrid method of the two iterative schemes, termed *PBJ-ITMM-SI-SH*. This hybrid method only runs *SI* in optically thin cells and only runs *PBJ-ITMM* in optically thick cells. In addition to a potentially dramatic reduction in iteration runtime, this hybrid method decouples the *SI* regions from each other, allowing them to be executed in parallel. This addresses the primary disadvantage of *SI* preconditioning, as it prevents the full, serial mesh sweep that is otherwise required. The following table contains the required iterations of all of the discussed iterative methods to converge this heterogeneous stripe problem.

c	*SI*	*PBJ-ITMM*	*PBJ-ITMM-SI*	*PBJ-ITMM-SI-SH*
0.1	14	113	12	13
0.2	20	132	16	16
0.3	26	150	19	20
0.4	33	169	22	24
0.5	43	191	26	28
0.6	58	217	31	33
0.7	82	252	37	39
0.8	130	305	46	49
0.9	272	414	67	71
1.0	N/C	N/C	N/C	N/C

From these iteration counts (N/C stands for not converged in 1000 iterations), I see that *PBJ-ITMM-SI* showed a significant reduction in iterations over each of the individual methods, especially as the scattering ratio becomes large, which are the more costly simulations. Additionally, the hybrid method causes only a slight increase in iterations compared to *PBJ-ITMM-SI*, with each of the iterations being far less costly. From these results, I conclude that *SI* preconditioning provides a viable solution to *PBJ-ITMM's* lack of iterative robustness in optically thin cells, and that with the implementation of the hybrid method, this can be achieved with a much smaller penalty to the parallel execution of the solution.

The novelty of my new approach to transport acceleration lies in employing two high-order transport solution methods as opposed to coupling a high-order solution method with a low-order acceleration method. My current research now aims at performing in-depth studies on the hybrid method including an investigation into multiple approaches for its formulation. Additionally, I am beginning to test *PBJ-ITMM-SI* and *PBJ-ITMM-SI-SH* against state of the art serial transport iterative methods for a quantitative comparison of my developed methods to the current standard. Once we confirm the computational efficiency of our new scheme on structured Cartesian meshes we will seek to implement and test it on unstructured tetrahedral meshes via the THOR code.



Upcoming Events

Event	Date	Location
University Program Review	June 6-8, 2017	Walnut Creek, California
American Nuclear Society	June 11-15, 2017	San Francisco, California
Industrial Radiation and Radioisotope Measurement Applications	July 9-13, 2017	Chicago, Illinois
Institute of Nuclear Material Management	July 16-20, 2017	Indian Wells, California
Device Assembly Facility	July 31-Aug 11, 2017	Nevada
Distinguished Lecture Series	August 24, 2017	Raleigh, North Carolina