

NUCLEAR ENGINEERING

Missouri S&T | Fall 2017



RESEARCHER ENLISTS S&T REACTOR TO
BUILD BETTER CANCER DRUGS

SUMMER CAMP SUCCESS

For the past 17 years, Missouri S&T's nuclear engineering program has hosted a weeklong summer camp to introduce fundamentals of nuclear engineering to interested high school students and incoming college freshmen. This year's camp featured 21 campers from 11 U.S. states.

Campers enjoyed a wide range of academic and recreational activities during the camp, touring, a number of facilities both on campus and off. They got to see Missouri S&T's research reactor, radiation detection and spectroscopy laboratory, and benchtop CT scanner in action at Missouri S&T. Off campus, the students visited the Delbert Day Cancer Institute at Phelps County Regional Medical Center and the Callaway nuclear power plant near Fulton, Missouri. Campers attended a series of talks about radiation measurement, nuclear power, biomedical science, and "a neutron story" delivered by nuclear engineering faculty. Students performed experiments in nuclear engineering facilities to acquire a hands-on experience on nuclear instrumentation. This year, the nuclear engineering program introduced a new activity to its summer camp — Nuclear Expo. Nuclear engineering faculty tailored activities that introduced parts of their research. A thorough Q&A session concluded the set of academic activities. Campers were engaged in these sessions to enhance their knowledge and camp experience.

Each day of camp ended with recreational activities designed for the campers to get to know each other and the nuclear engineering faculty, staff and counselors. Campers enjoyed these activities at The Center (recreational complex in Ber Juan Park, Rolla), Kokomo Joe's Family Fun Center, Alex's Pizza and Lion's Club Park.

The summer camp has proven to be an outstanding recruitment tool. We thank Ameren for continually allowing the nuclear engineering program to arrange a tour of the Callaway nuclear power plant facility for summer camp. Touring a commercial nuclear power facility allowed campers to see first-hand that nuclear energy is clean, safe and affordable. Finally, we would like to thank the faculty, staff and counselors who made this year's camp a resounding success.

NE PROGRAM PULLS IN MAJOR DOE GRANT

In February, Joseph Graham, Hank Lee and a former graduate student now an MIT postdoc, Muhammad Abir, submitted a proposal to the Department of Energy's Nuclear Energy University Program, a competitive funding program that supports research in nuclear energy and the nuclear fuel cycle. The program was soliciting ideas for advanced pool-side fuel characterization techniques for nuclear test reactors, such as the Advanced Test Reactor at INL and the High Flux Isotope Reactor at Oak Ridge.

The team presented a concept for a compact, submersible, high-resolution gamma-ray tomography system. The system will be able to reveal correlated structural and chemical information in three dimensions through a combination of transmission and emission tomography. This facility, and future designs that grow out of it, will greatly extend the suite of fuel characterization capabilities available to users of test reactors. It will help produce data that gives the fuel development community a better understanding of how restructuring, deformation and fission product migration occur at different stages of burnup in advanced fuels.

In June, the Idaho operations office announced that the project was one of those selected to receive funding. In total, this project, which begins later this fall, will receive roughly \$800,000 over the next three years. Graham and Lee will be working with a team of graduate students, undergraduates, a postdoc, and facility engineer to design, model, optimize, construct and finally test the system in the ATR canal. Through the tasks laid out for the team, this project will help generate theses, papers, patents, expertise, job opportunities for our students and a closer connection between S&T and INL.



DEAR ALUMNI, COLLEAGUES AND FRIENDS

I hope all of you are enjoying this time of year when summer turns into fall. The past 12 months passed so quickly — and produced many achievements, which I would like to share.

Our student enrollment remains strong, with 188 undergraduates and 46 graduate students enrolled in 2016-17. Thirty-six students received B.S. degrees during this time, while three graduate students (Fahima Islam, Edward Norris and Huseyin Sahiner) received Ph.D. degrees, and nine students (Andrew Bingham, Raymond Fanning, Eric Feissle, Varun Kalra, Benjamin Prewitt, Saima Rashid, Bader Almutairi, Jay Joshi and Carissa Richardson) received their M.S. degrees.

Our faculty are working hard in their research, teaching and service. Graham and myself, together with Muhammad Abir (our former Ph.D. student, now a postdoc at MIT) recently received a major and very competitive grant from the Department of Energy. With this three-year, \$800,000 grant, we will develop a novel imaging system to non-destructively investigate characteristics of used nuclear fuel. A patent is also under preparation. Joseph Graham also received another five-year grant from the National Science Foundation as a co-PI along with several ceramic engineering professors at Missouri S&T.

Faculty members Carlos Castano, Joshua Schlegel and Xin Liu received a Missouri S&T Innovation Grant for their research of radionuclides for medical applications. I also received an internal grant from the Center for Biomedical Science and Engineering for a simulation study of a new type of small-scale X-ray tube that I am developing. With the help from a Nuclear Regulatory Commission Faculty Development Grant, Liu's group has developed a simulation software, DOCTORS (Discrete Ordinate

Computed Tomography Organ-dose Simulator), which simulates patient absorbed radiation doses during a CT scan. This is much faster than MCNP, a traditional radiation simulation software, and will be freely available to the public. We also received additional grants totaling \$600,000 from NRC this year which will be used to support undergraduate and graduate students in nuclear engineering.

Two of our faculty, Ayodeji Babatunde Alajo and Liu, passed promotion and tenure procedures successfully and are now associate professors. Please join me in extending them our congratulations. As you know, it means a lot to be tenured.

Our graduate students also produced great achievements. Edward Norris was awarded the College of Engineering and Computing Dean's Ph.D. Scholar award. He was also selected as a National Nuclear Security Administration fellow and will work for DOE after completing his Ph.D. Kyle Paaren, a Ph.D. student, was awarded the Integrated University Program fellowship of the DOE Nuclear Energy University Program over three years.

The activities of our student organizations, the American Nuclear Society and Women in Nuclear, are tremendous. They actively participated in the ANS national student conference and hosted trips to nuclear facilities. You can read more about their activities in this newsletter. On November 4, the ANS student chapter here will celebrate its 50th anniversary at Hasselmann Alumni House. All Missouri S&T nuclear engineering alumni are invited to this historic event.

While we are striving to become a top-notch nuclear engineering program in the U.S. and in the world, we are suffering from a gloomy financial situation. The state of Missouri has cut funds for the University of Missouri System significantly, and we foresee difficulties in managing the program, including hiring teaching assistants. We are also short on funds for scholarships to freshmen and sophomores. Although we have been successful in attracting scholarship grants from the NRC, these funds are only for juniors and seniors. As you well know, scholarships are necessary to attract first-year students with high caliber into nuclear engineering and train them to be the next generation of nuclear engineers. With that in mind, I want to thank you very much for your support of our program in previous years, and would greatly appreciate your continued help. We look forward to hearing from you.

Thank you and God bless you all!

Hank Lee, Ph.D.
Associate Professor and Associate Chair of
Nuclear Engineering



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Missouri S&T doctoral student in nuclear engineering is using the campus' research reactor in hopes of refining the process used to synthesize the nanoparticles.

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RESEARCH UPDATE FROM CARLOS CASTANO: FROM NUCLEAR BAR CODES TO SPACE IRRADIATION



This past year has seen the initial work on designing and building the CO₂ reduction experiment, an initiative with Joseph Graham and graduate student **Lewis Rauschelbach**, NucE'16. We will be soon be able to tell if the idea of direct reduction of CO₂ with nuclear has substantial merit, and if we can design a nuclear reactor around the idea.

If so, nuclear reactors optimized for conversion of nuclear to chemical energy may become an eventual reality, unshackling our overwhelming dependence to fossil fuels. We are working under the auspices of the Graduate Assistance in Areas of National Need (GAANN) program, energy being an area of national need.

Last year, we obtained a Missouri S&T Innovation Grant (innovate.mst.edu) to develop the protocols for the creation of radionuclides (radioisotopes in nanoscales), obtain a mice colony and integrate it with the gamma imaging facility that **Xin Liu** currently has in Fulton 227. The objective of this project is that we will be able to produce and test new types of radioisotopes that can be used for new cancer treatments. The team for this effort include **Maria Camila Garcia Toro**, MS NucE'16, **Jenna Slocum**, **Joshua Schlegel**, Liu and myself. If successful, we may be able to track and image accumulation of nanocompounds in the biological models (mice), study damage to some of the chemicals used to functionalize nanoradioisotopes, and determine the therapeutic dose (lethal/therapeutic

amount) of some of these compounds. This is a required preliminary step before any new cancer treatment drug can be tested in humans. This year, I am trying to consolidate the main thrust to apply for grants for these two initiatives. However, other initiatives are ongoing, including the idea of the nuclear bar code, for which we are about to obtain a provisional patent with **Catherine Johnson** and **James Seman**, MS MinE'14. Also ongoing is the design and testing of new shielding materials that saw **Raul Florez**, MS NucE'16, earn his master's degree.

With the generous support of the nuclear engineering program, seniors were able to conduct a variety of interesting experiments in reactor laboratory II. This experimental class is a valuable ground to give all our students a research experience, as well as a testbed for many interesting research concepts that might eventually become full-fledged research areas. While there is no space to put all initiatives, here are the most interesting and successful:

Abigail Dare, **Jacob McFarland**, **Mikayla Molnar** and **Sven Olberg** for the first time generated boron nanoparticles using the radiation reduction method. The nanoparticles appear to be approximately 150nm in diameter. Medical applications probably will favor 50nm, so more work is planned.

Wil Fors, **Philip Honnold**, **Tom Korenak** and **Joshua Nixon** produced in the foundry samples of 709 stainless steel, a new steel being tested for high-temperature systems.

Making samples is usually expensive and only possible to do in big batches. We casted and tested only a few pounds of steel in our campus facility.

Dalton Akley, **David Clark**, **Trevor Rucker** and **Jacob Stueck** tested the effect of voids in the worth of the Reg Rod in the Missouri S&T Reactor. In a paper we published this year, we used the worth of the reg rod to find the value of void coefficient of reactivity. One of the reviewers pointed to the possible effect of the void in the reg rod worth itself. We tested this, and found that indeed, depending on the position of the void, the worth of the reg rod can change by as much as 15 percent. Another paper will be prepared to explain this oversized and unexpected effect.

Payton Bruckmeier, **Ben Foster**, **Bryant Kanies** and **Sara Thompson** studied the expected effect of eight years of space irradiation on LEDs used in spacecraft. This project was conducted with hardware and help from the Naval Research Lab. Interestingly, LEDs are little affected by this amount of dose.

Mitchell Manley, **Luke Moehlenbrock**, **Austin Schrum** and **Benjamin Turpin** studied fatigue in nuclear materials using Krouse bending specimen prepared on campus. The values obtained were comparable to known fatigue values in the materials, pointing to the benefit of this technique for testing fatigue of small specimens that fit high flux research reactors (e.g. HFIR, ATR).

NUCLEAR ENGINEERING HIGHLIGHTS



Catherine Johnson is a professor of explosives engineering at S&T. We are in the same department but in different programs. She and I are collaborating on the development of a “nuclear bar code” which is basically the microscopic addition of rare earths to sensitive materials (explosives, special material) such that even after catastrophic events or interdictions the material can be attributed.



Henry Colorado is a professor of mechanical engineering and materials at the University of Antioquia in Colombia. Our cooperation extends many years on ceramic materials for structural and shielding applications that can resist fire and shock conditions possibly to be encountered in transportation of nuclear material accidents. We have also published a book chapter on the application of chemically bonded phosphate ceramics for nuclear waste applications, and have co-advised several students.



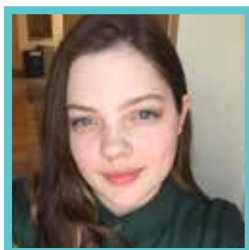
Maria Camila Garcia Toro obtained her M.S. degree by making radioactive nanoparticles with suitable characteristics to be used in cancer diagnosis and treatment. The synthesis process was conducted by irradiating with gamma and neutron at the same time. This technique has the advantage of producing well-characterized radioactive nanoparticles in a single step, reducing the complexity and cost of producing specialty drugs for cancer treatment. This study included metallic and bimetallic nanoparticles (see page 7). Garcia Toro is now pursuing her Ph.D. degree here at S&T.



James Seman, MS MinE'14, is pursuing his Ph.D. in explosives engineering and is conducting research with Johnson and myself. He is actively testing the concept of the nuclear bar code and is exploring the interfering of contaminants as well as detection limits as part of the implementation of the concept.



Lewis Rauschelbach, a GAANN fellow, is working to demonstrate the concept of reducing CO₂ using nuclear radiation. This is the equivalent of converting nuclear energy directly to chemical energy.



Jenna Slocum helped as an undergraduate with our research on radioactive nanoparticles and presented our work at the Undergraduate Research Day at the Capitol. She is currently an Undergraduate Research Ambassador representing S&T in Jefferson City. She is interested in continuing the work with radioactive nanoparticles in-vivo systems (mice), and becoming an academic senator.



NORRIS RECEIVES CEC DEAN'S SCHOLAR AWARD

Ph.D. candidate **Edward Norris**, CSci'13, NucE'13, was recently awarded a College of Engineering and Computing Dean's Scholar award. The award is very competitive, all nine academic departments in the college could submit up to three candidates each. From those candidates, only 10 awards are distributed, selected by the dean based on their academic merit, publication history, and other factors. All 10 individuals who received an award were honored with a plaque given during an award ceremony.

Norris' work focuses on computational analysis of the dose (a measure of radiological risk) patients receive from computed tomography (CT), a common medical diagnostic procedure. To compute the dose, he uses a discrete ordinate method to solve the linear Boltzmann equation which governs uncharged particle transport (including x-rays used in CT). The solution is generated using a phantom made from the CT scan itself which provides detailed, patient-specific dose information. Leveraging GPU computing, he greatly reduced the time necessary to compute the dose from existing methods.

FEMALE NUCLEAR ENGINEERS FOR THE WIN

Women in Engineering is a group of women who focus on outreach, professional development and networking. For years our chapter has tried to help our students get hired after school. To encourage that we host the Nuclear Career Fair, an event for our nuclear engineering students to see how many companies hire nuclear engineers, what to do to get that job, and what they look for.

Our students understand nuclear energy, but not everyone else does. For the freshman class as a whole we offer guest speakers to talk about their company and why they chose nuclear. For all students we host tours of the nuclear reactor on campus or trips to nuclear facilities. This past year we went to the Callaway nuclear power plant and Curium, a nuclear medicine company in St. Louis.

Without community support we would not be here, so we wanted to give back. So in the last year we started our annual fundraiser "Flaming Flocking." In the month of October we take garden flamingos and put nuclear facts on them, then "flock" certain groups or people. Through this we raised \$1,000 that went to the American Cancer Society.



Monica Gehrig (second from left) earned second place among 43 interns in a poster competition at Oak Ridge National Laboratory Nuclear Engineering Science Laboratory Synthesis program this summer. With Gehrig are (from left) Phil Ferguson, NucE'88, MS NucE'93, PhD NucE'95, and ORNL mentors Arnold Lumsdaine and Dennis Youchison.

GAANN FELLOWSHIP ENCOURAGES 2017 GRAD TO PURSUE PH.D. IN NUCLEAR ENGINEERING

Monica Gehrig graduated in 2017 with cum laude honors, a bachelor of science degree in nuclear engineering and minors in mathematics and Spanish. She's now begun the Ph.D. program as a GAANN fellow in the nuclear engineering program here at Missouri S&T.

Throughout her four years as an undergraduate, Gehrig participated in a variety of activities. During her freshman and sophomore years, she focused on campus involvement and networking and professional development by joining a design team and several different professional societies. She was heavily involved with the award-winning Mars Rover Design Team, serving as the science team lead for a semester. Gehrig also presided over the campus chapter of Women in Nuclear for one year, then served as the chapter's vice president the following year. She also participated in the school's chapter of the American Nuclear Society as outreach officer. During the summer between her freshman and sophomore years, she worked as an intern with Enercon Services Inc.

Throughout Gehrig's junior and senior years, she focused primarily on academics, including service as a peer learning assistant with Learning Enhancement Across Disciplines, a campus tutoring effort. During her senior year, she acted as the fluid mechanics and heat transfer subgroup lead in her senior design class and represented the group at the 2017 American Nuclear Society student conference in Pittsburgh. In the summer between her junior and senior years, Gehrig worked as an intern in the Irradiation Testing Department at the Idaho National Laboratory. Her summer work involved creating a repository of information about positions and experiments in the Advanced Test Reactor in order to make planning and designing experiment irradiation more efficient. Her summer project was presented at the Idaho National Laboratory Intern Expo, where Gehrig's work took first place in the Digital Poster Category.

With the assistance of Division Director **Phillip Ferguson**, NucE'88, MS NucE'93, PhD NucE'95, Gehrig spent this past summer as an intern at the Oak Ridge National Laboratory's Nuclear Energy Science Laboratory Synthesis program. She earned second place in a poster contest working with her Missouri S&T Ph.D. advisor, **Gary Mueller**, and ORNL mentors Arnold Lumsdaine and Dennis Youchison in the Fusion and Materials for Nuclear Systems Division to continue a computational fluid dynamics project investigated by a previous Ph.D. student, **Emily Clark**.

Her project involved modeling a scraper element to optimize heat removal in the experimental stellarator reactor, Wendelstein 7-X, built in Greifswald, Germany, by the Max Planck Institute of Plasma Physics. This research will help engineers better understand the technical requirements needed to remove thermal energy from a fusion reactor, which will ultimately be used to generate electrical power.

RESEARCHER ENLISTS S&T REACTOR TO BUILD BETTER CANCER DRUGS

The use of radioactive gold and silver nanoparticles to target certain deadly cells is a promising step in the painstaking process of cancer research and treatment.

Now a Missouri S&T doctoral student in nuclear engineering is building on that promise — with the help of the campus' research reactor — in hopes of refining the process used to synthesize the tiny specks.

Maria Camila Garcia Toro's research is part of a larger vision by her former advisor, **Carlos Henry Castano Giraldo**, of an integrated facility in which radioisotopes created at the Missouri S&T reactor could be tested on laboratory mice colonies maintained by the university's biological sciences department. The project's promise led to the award of an Innovation Grant from the university earlier this year.

Rather than separately create the nanoparticles using either gamma radiation or chemical methods before activating them through neutron radiation, Garcia Toro's work focuses on combining those two disparate processes into a single step that could reduce production costs while also increasing effectiveness.

"The novel part of my process is that we use gamma radiation at the same time as we're using neutrons," she says. "So it's possible to create nanoparticles that are already radioactive in one single step."

In June, Garcia Toro presented her research findings at the Cancer Nanotechnology Gordon Research Conference in Vermont. The Colombia native earned her master's degree in nuclear engineering from Missouri S&T in 2016, and a bachelor's degree in chemical engineering from the National University of Colombia at Medellin, the same campus where her Rolla mentor also studied as an undergraduate.

Castano Giraldo is an associate professor of nuclear engineering and S&T faculty member since 2008. His initial interest in nanoparticles stemmed from earlier work on hydrogen fuel cell storage inside carbon nanotubes created with gamma radiation.

"I later realized we could produce nanoparticles of many materials with radiation," he says.



HOW IT WORKS

The single-step synthesis involves the irradiation of aqueous solutions at different concentrations of the metallic precursors, which are activated using the nuclear reactor. Controlling the time and dose rate of the irradiation process has allowed Garcia Toro to determine the optimal nanoparticle size for cancer treatment.

"The size distribution of nanoparticles used in cancer treatment is a key element to improve tumor retention, interstitial interaction inside of the body and the cancer cell-killing process," she explains. "Nanoparticles with approximately 50 nanometers of diameter exhibited greater sensitization and higher cell uptake compared with other sizes."

Project collaborators include Dr. Joshua Schlegel, an assistant professor of nuclear engineering who plans to study modifications to the irradiated nanostructures and the corresponding biological paths; and Dr. Xin Liu, an assistant professor in the mining

and nuclear engineering department who oversees a specialized facility for gamma radiation imaging that will be used to determine the distribution of nano-radioisotopes in mice.

Once a promising treatment is identified, the next step, says Castano Giraldo, is a possible collaboration on human clinical trials with the Mallinckrodt Institute of Radiology at Washington University in St. Louis.

"There is still much work to be done before a new treatment is FDA-approved," he notes.

The 200-kilowatt nuclear reactor where Garcia Toro is working to streamline the production of irradiated nanoparticles has been in operation since 1961.

In addition to its irradiation facilities, the reactor's research capabilities include a graphite thermal column, a key source of slow neutrons, and a beam port that can be positioned between the reactor floor and the ground floor for experiments involving high-energy neutrons.

CELEBRATING OUR STUDENTS

By Ayodeji Babatunde Alajo

“Education is the passport to the future, for tomorrow belongs to those who prepare for it today.” — Malcolm X

There is a theme on which we as a program and institution at large have focused: getting the best and brightest students amongst our peer institutions. It's one thing to have the best and brightest students, it's another to help them learn as much as they can absorb. This got me thinking about how well we have done with the students who pass through our tutelage. We have many post-graduation metrics to evaluate this: percentage of students with jobs, average starting salaries, percentage of students enrolled in graduate school, percentage of students in nuclear and allied industries, etc.

As a scientist/engineer, I love metrics for their quantitative nature. However, some things lend themselves to qualitative evaluations, rather than quantitative measures. I like to focus on evaluations that provide actionable information on how much our students have learned during their time with us. The evaluations are completely rooted in two senior-year courses: Nuclear Systems Design I & II — colloquially known as Senior Design.

In the spring semester of 2013, I took over as the instructor for Senior Design. Since then, I have overseen the courses each semester either exclusively or in collaboration with other professors. Through Senior Design, we have the opportunity to evaluate several aspects of learning, which are indicative of the real-world science and engineering skills our students have acquired. The yearlong tandem of courses tests the students in technical, professional and ethical knowledge applicable to everyday engineering decisions. Our students completed amazing projects. They were well prepared for a life in engineering and other endeavors. One thing I wished we did was to showcase the projects; provide visibility of the work to other nuclear engineering stakeholders. It is okay to blow your own trumpet in this case. So I decided to celebrate the success of our students in Senior Design over the years. Here we go!

Academic Year 2012–13

25 MWe small modular reactor for industrial and microgrid applications with at least 10-year refueling cycle

The A-Team: Missouri S&T Advanced Reactor (MSTAR). Members: Amanda Baker, Heather Beard, Lindsay Brandt, Jonathan Cordz, Matthew Crinnian, Nicholas Detrich, Kelsey Freedline, Dustin Green, Brandon Lahmann, Paul O'Larte, Stony Reid, Jonathan Scott, Dustin Specker, Matthew Storts, Casey Tompkins, and Teresa Wilk.

The LFR Team: Small Modular LBE Cooled Breeder Reactor (SMoL-R). Members: Stephen Banks, Anthony Blust, Christopher Buehler, Joshua Fagnant, Thomas Forland,

Alberto Gomez, Benjamin Heider, Zezhong Huang, Solomon McNeal, Adam Miller, Edward Norris, Yusef Rahaman, Jonathan Schatke, Brian Seawright, Adam Stensland, Christopher Swisher, and Reece Wall.

Academic Year 2013–14

60 MWe reactor suitable for microgrid deployment

Team Nuke: Prismatic Modular Helium-cooled Reactor (PMHR). Members: Michael Acton, Desiree Beardmore, Robert Chisholm, Garrett Gable, Gabriel Harlan, Nancy Janssens, Keith Landers, Chandler Mills, Benjamin Prewitt, Kelsey Salzman, and Daniel Watson.

Ocean's 11: Ocean's Eleven Microgrid Applications Reactor (OMAR) — A Brayton Cycle Very High Temperature Reactor.

Members: Kathryn Krev, Steven Anderson, Clyde Beers, Shauntay Coleman, Sarah Gregg, Brianne Heisinger, Brett Mercer, Wesley Munie, Katherine Reid, Katie Siebert, and Joseph Wieland.

Project Tango: Tango's Supercritical Water Reactor (TSWR). Members: Ethan Barth-Taber, Brandon Bringer, Raymond Fanning, Annessa Griffen, Randall Homan, Matthew Kruse, Andrew Mills, Katie Murphy, Paul Rodriguez, Devin Valmores, and Megan Will.

Academic Year 2014–15

Nuclear Space Propulsion

The Handi Team: High Altitude Nuclear Drone Initiative (HANDI). An unmanned, gas-cooled, fast-reactor-powered aircraft for global reconnaissance. Members: Erica Bay, Andrew Bingham, Eric Feissle, James Jackson, Christopher King, Ethan Margherio, Ian McGhee, Charles Moore, Connor O'Dea, Laurel O'Reilly, Robert Reynolds, and Trenton Wilshusen.

Team SpaceSLAM: Titan Explorer, Nuclear-Thermal (TENT). A modular nuclear propulsion system utilizing liquid methane propellant; for applications in Titan (a Saturn moon) scientific exploration missions. Members: Kyle Acker, Zachery Aniszko, Matthew Courtney, Dylan Prevost, Michael Pride, Chase Roberts, Benjamin Roesch, John Schreiner, Manika Sharma, Cody Stuchal, Michael Unnerstall, and Michael Watts.

The Truckers: Space TRansport Using nuCear Kicked ElectRic System (Space TRUCKERS). A nuclear-electric propulsion system with a primary purpose of unmanned deep space cargo transport. Members: Josh Burks, Eric Carlson, Krista Corvey, Jason Dorrel, Nick Hutton, Ray Larimore, Jacob Luetzow, Brian Mills, Minh-Thuy Nguyen, Ethan Niehaus, Erica Tucker, Steven Wessels, and Brendon Young.

Academic Year 2015–16

Gen-IV Reactor Applications

Team ThRx [T-Rex]: Molten-Salt-Fueled Thorium-Breeder Reactor (MSBR). A

commercial closed-cycle molten salt reactor to be situated in the site of Zion Nuclear Power Station, Illinois. Members: Wayne Brewster Kevin Bruns, Jeff Bush, Matt Caddell, Seth Kilby, Chris Lohff, Sean Prideaux, Lewis Rauschelbach, Carissa Richardson, Nick Spitznagel, Wes Tucker, and Steve Wagstaff.

The Narwhals: North American Reactor cooled With Hot Alloyed Lead System (NARWHALS). A lead-bismuth cooled fast reactor sited on a ship to supply power to coastal cities in need of electricity. Members: Bryan Adams, Patrick Garavaglia, Ben Gibson, Garrett Jones, Montgomery Jones, Kyle Paaren, Joshua Rhodes, Steven Rohan, Mitchell Smith, Keith Sponsler, Nicholas Takacs, and Anthony Tedeschi.

Modern Day Alchemists (MDA): Small Modular Molten Salt Reactor (SMMSR). An economical baseload provider with small footprint and possible deployment in micro-grid systems. Members: Anthony Alchin, Aaron Dayan, Ethan Fischer, Wesley Freeman, Reice Golden, Natalie Jones, Nicholas Jordan, Jonathan Roth, Jessica Seals, Ryan Steere, Alex Swearingen, Logan Turk, and Justen Vinyard.

Academic Year 2016–17

Choice of MSTR Uprate to IMW or Fast flux facility for nuclear cross section measurement experiments

Group One: Externally driven Fast Neutron Flux Facility. Members: Dalton Akley, Taylor Copeland, Benjamin Foster, Sean Hunter, Kate Kruggel, Jacob, McFarland, Sven Olberg, Zachary Schoenfeld, Sara Thompson, and Greg Westphal.

Group Two: Missouri S&T Reactor Power Uprate. Members: Payton Bruckmeier, Abigail Dare, Devon Gallagher, Kelly Jacobs, Adam Lampe, Luke Moehlenbrock, Nishant Pillai, Austin Schrum, Ben Turpin, and Demetrius Williams

Group Three: NaK-cooled Fast Reactor (NaKFR). Members: Saif Alqahtani, Michael Carter, Benett Fetters, Monica Gehrig, Bryant Kanies, Joseph Loesche, Mikayla, Molnar, Kelly Stevens, John Watkins, and Chris Wilson.

Group Four (Nerf): MSTR Uprate Project. Members: David Clark, Eric Fors, Philip Honnold, Thomas Korenak, Mitchell Manley, Joshua Nixon, Philip Rexing, Trevor Rucker, Jacob Stueck, Alex Watson, and Jaron Winans.

All the projects listed here are testaments to the quality of our undergraduate students. I reckon some of the readers who find their names in this article would look back at their time in our program and share the same conclusions. I also hope you will share this article with your colleagues in order to extend the reach of our nuclear engineering program. In conclusion, I should point out that the NaK Fast Reactor Project was presented at the 2017 American Nuclear Society Student Conference. The project was well received; the presenters received positive feedback on the design and significance of the project. The event provided good visibility for our nuclear engineering program. We will encourage more of such presentations in subsequent years.



MISSOURI S&T AMERICAN NUCLEAR SOCIETY
50TH ANNIVERSARY

Saturday, November 4 | 6–8 PM
Hasselman Alumni House
1100 N. Pine St. Rolla, MO 65409
RSVP to ans@mst.edu

PAAREN RECEIVES IUP FELLOWSHIP AWARD

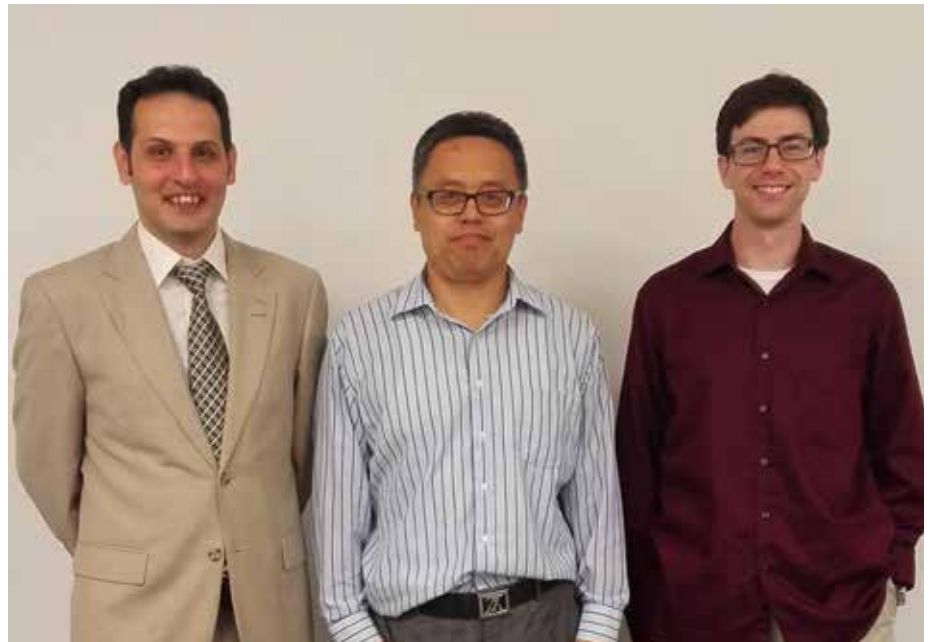
Kyle Paaren, NucE'16, received the Integrated University Program fellowship award through the Nuclear Energy University Program from the Department of Energy. The award is \$155,000 over three years. The funds will go towards his graduate studies, consisting of the development of switchable radioisotopes to be used for gamma and neutron imaging. The radioisotope development will be used in conjunction with nuclear reactor components to test for defects and irradiation damage.

This award was received due to the requirement of Kyle's Chancellors Distinguished Fellowship, where he had to apply for another fellowship within his first year of graduate school.

ANS NEWS

This past year has been a tremendous growing period for our organization. We have focused our attention on outreach and member expansion. In the last year, we have almost doubled the number of students who have been able to attend the ANS national conference. We would like to continue this trend and give our members more opportunities to network, volunteer and explore the vast and interesting world of nuclear science!

In the upcoming semester we plan to work with places like The Magic House in St. Louis during nuclear science week. Our goal is to replace the stigma and fear of nuclear science with facts and understanding. This event will be primarily directed towards young children and their parents.



XIN LIU'S ACTIVITIES

This past academic year has seen several notable accomplishments on my part. First and foremost, I am now tenured and hold the rank of associate professor. I am very grateful to the nuclear engineering program and the mining and nuclear engineering department. Everyone has been so supportive during the past six years. I am also grateful to the university, which provides considerable resources to the new faculty and help them in many possible ways. To me, this is the best place to work. In addition, I must say thanks to the Nuclear Regulatory Commission, which provides the majority of financial support to my research group. Being a tenured professor means more responsibility in teaching and research. I will continue to work hard in those areas and not to fail the trust the department and university have placed in my hands.

Secondly, two of my students, **Edward Norris** and **Huseyin Sahiner**, successfully defended their dissertation and received their doctoral degrees. The topic of Norris' dissertation is mathematical modeling of medical patients' radiation dosage. The topic of Sahiner's dissertation is the gamma spectroscopy by neural network coupled with MCNP. Norris now heads to Washington, where he will work for DOE as a National Nuclear Security Administration fellow. Sahiner is returning to Turkey to become a professor in a university. Look at how happy they are after defending their theses!

In addition Norris was named a Dean's Ph.D. Scholar by the university's College of Engineering and Computing in recognition of his scholarly excellence and research productivity. Norris was one of 10 doctoral students who received the CEC award. The award winners were nominated by professors in their home departments and honored at an end-of-semester campus reception in May. The competition for this award is very intense. As a group, the 10 winners produced a total of 152 technical publications and reports, with another 26 publications under review.

Lastly, I would like to take this chance to advocate an open software developed by our group that is known as DOCTORS (Discrete Ordinate Computed Tomography Organ-dose Simulator). DOCTORS utilizes a GPU-accelerated ray tracer and discrete ordinates solver to compute photon flux distribution in the patient who received a CT scan. The photon flux is then converted to the radiation dose the patient received.

The software was benchmarked against MCNP6 and found to have good agreement using both a water phantom and a realistic patient phantom. DOCTORS was also found to be much faster than MCNP6; MCNP takes hours to compute flux profiles that take less than a minute using DOCTORS. A GPU algorithm was implemented that speeds up the DOCTORS by a factor of up to nearly 40 for large problems. The main user interface of DOCTORS is shown in the following pictures. The executable version of DOCTORS will be freely available to the public for testing and benchmark. I hope to receive more feedback from users and we will continuously make DOCTORS a better software as a teaching and research tool.



UPDATES FROM JOSEPH GRAHAM

It baffles me how quickly a year passes. The day in the life of a professor is filled with such a variety of activities, tasks and little details that it is sometimes hard to see the forest but for the trees.

That said, I have two general impressions from my short time here: (1) I love working in this department (2) our nuclear engineering program is on the rise. I hope that as we continue to work together as faculty, staff and students, S&T will become a premier global institution for nuclear engineering research and education.

In the realm of teaching, I have covered three classes this past academic year: Nuclear Materials, Interactions of Radiation with Matter and Fusion Fundamentals. Interactions of Radiation with Matter and Fusion Fundamentals, which I taught this past spring, were effectively brand new classes in the curriculum. Although they have been listed in the course offerings, these classes hadn't been taught in many years (over 30 years for the fusion class!). I found out that simultaneously preparing lectures for two classes can be quite a time investment, but in the end, the students who were brave enough to be my guinea pigs had generally favorable reviews. Hopefully I will be able to polish off the rough edges in future iterations.

Within my research, I was fortunate to get lab space in McNutt Hall in the fall semester. In that space, I am now working with students to develop a suite of experimental facilities for characterizing radiation effects in nuclear materials. The first piece of major apparatus to go in was a confocal Raman microscope. Instead of imaging a specimen's texture or microstructure, this piece of equipment can create a 3D map of the atomic and molecular vibrations within a specimen. For this reason, confocal Raman microscopy is a powerful technique for characterizing phase, crystal structure, defects and strain within a variety of materials.

In February **Hyoung-Koo Lee**, **Abir Muhammad** (a former graduate student in our program) and I submitted a proposal to the Department of Energy's Nuclear Energy University Program, a competitive three-year grant supporting research in nuclear energy and the nuclear fuel cycle. We were very fortunate to be selected for this award in June. In July I was also awarded part of a five-year National Science Foundation grant as a co-PI along with **Greg Hilmas** and **William**

Fahrenheitz in ceramic engineering. In that project, we will look at the fundamental thermal properties of zirconium carbide (ZrC), an ultra-high temperature ceramic with attractive nuclear applications in TRISO fuel and accident tolerant fuel.

So far in 2017 I have published in *Journal of Physics D: Applied Physics*, have one accepted manuscript in *Journal of Physical Chemistry* and several other papers on their way.

I have been working with a number of graduate and undergraduate students over the past year. Here is a summary of their projects.

Raul Florez, MS NucE'16, a Ph.D. student, has been synthesizing ZrC carbide ceramics, characterizing their composition and structure, and performing high-temperature ion beam irradiations to understand how they are damaged in the extreme conditions found in nuclear fuel.

Salah Al-Smairat, a Ph.D. student, is performing fundamental quantum mechanical modeling studies of electron-phonon coupling in silicon carbide to try and help us understand how electronic stopping power helps anneal radiation damage created by neutrons.

Alaa Milibari, MS NucE'15, a Ph.D. student, and **Jessica Seals**, NucE'16, a master's degree student, are developing a modulated photothermal radiometry (PTR) system which uses a modulated laser source to measure thermal diffusivity in thin films, coatings and ion irradiated steels.

Nicholas Spitznagel, NucE'16, a master's degree student, is also developing an apparatus for measuring thermal diffusivity but using a resistive heating technique called the three-omega method. Spitznagel will use this technique to characterize irradiated nuclear ceramics.

Seniors **Reagan Dugan** and **Michael Coday** are performing some preliminary design and radiation transport modeling work as part of the Department of Energy grant. This work will also be part of an OURE project.

Sophomore **Eric Dalgetty** successfully built a vacuum chamber and electron gun from second-hand parts as part of an OURE project for which he received a third place prize for the poster competition. Dalgetty is currently on internship at the Research and Development division of Gamma vacuum.

Sophomore **Karl Fahrenheitz** is helping develop an angular correlation positron annihilation spectrometer in Graham's lab and also characterizing the total ionizing dose in the MSTR.



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