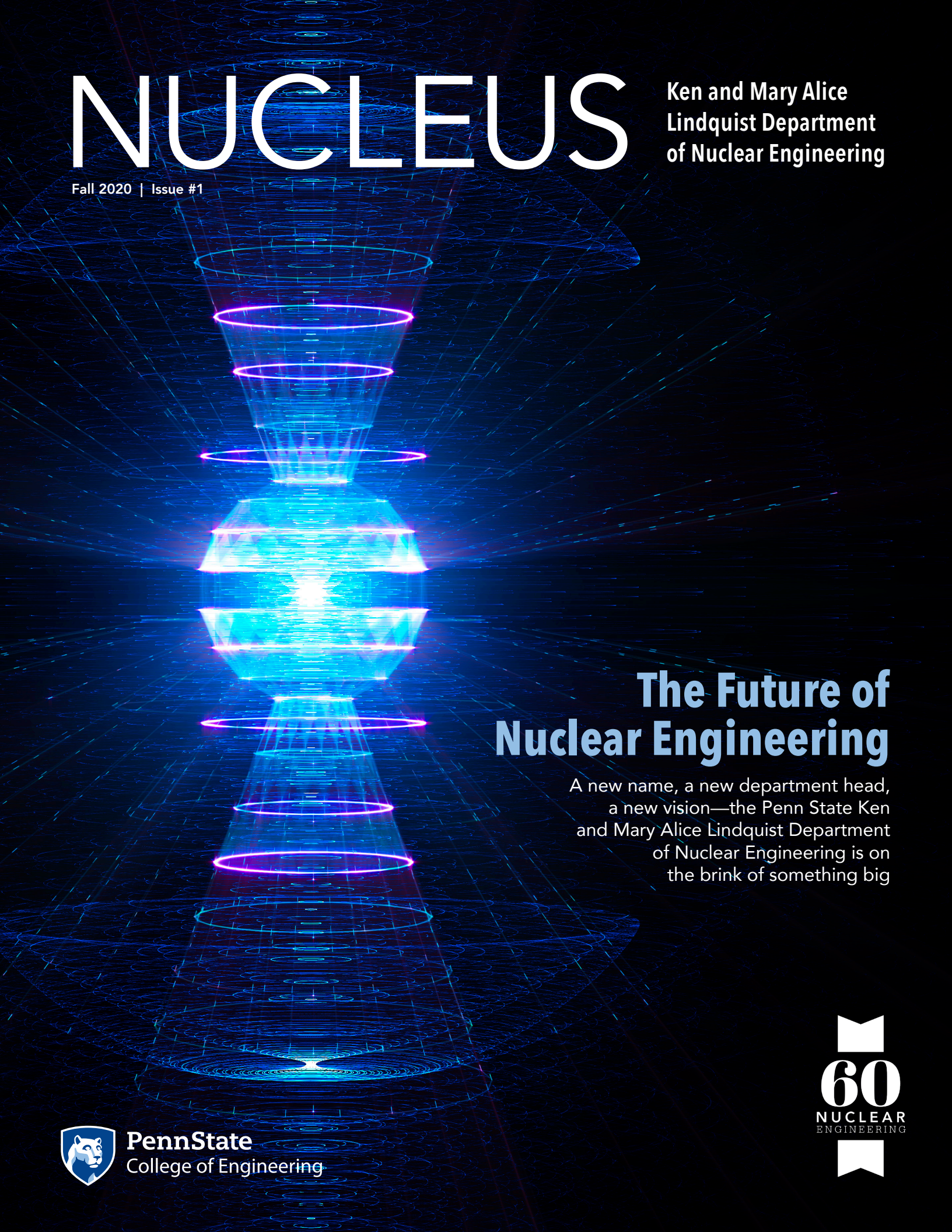
NUCLEUS

Ken and Mary Alice Lindquist Department of Nuclear Engineering

Fall 2020 | Issue #1



The Future of Nuclear Engineering

A new name, a new department head, a new vision—the Penn State Ken and Mary Alice Lindquist Department of Nuclear Engineering is on the brink of something big

PennState
College of Engineering

60 NUCLEAR ENGINEERING

From the department head:

The power of nuclear engineering

In the year since the nuclear engineering program at Penn State became the independent Ken and Mary Alice Lindquist Department of Nuclear Engineering, our faculty, students, and staff have accomplished excellent work.

Penn State nuclear engineering has a prestigious history in the field, particularly in nuclear power and nuclear safety. Nuclear engineering is one of the most multidisciplinary areas in all of engineering, especially when we reflect on the field's origin in the study of how radiation interacts with matter. Beyond nuclear power, radiation is used in cancer treatment, as radio tracers to identify and treat disease, in food science to disinfect materials, in applications related to climate change, water desalination, industrial heating to scale, and so much more.

We are transforming nuclear engineering. Our department and Penn State as a whole will play a key role in the impact nuclear energy will have on the climate, sustainable development, and beyond. This is arguably one of the most important decades for nuclear science and engineering, and, at Penn State, we intend to lead the way in the convergence of nuclear technology and humanity.

To support these efforts, we are modernizing and expanding our facilities. Our faculty and student numbers are growing, and we are building the space for interdisciplinary research efforts and cross-cutting educational experiences. In these pages, you will read more about the Nuclear Innovation Commons and the expansion of our department—both of which are critical efforts to not only grow our physical space, but also to attract more top-notch students and exceptional researchers to Penn State.

These spaces aren't only for our current students and faculty, though. They are also for our alumni. In the Nuclear Innovation Commons, for example, we will have the capabilities to invite alumni guest speakers, virtually or in person, from all over the world to share their work with current students and to collaborate with faculty. And we are working to identify even more opportunities for alumni and friends to engage with the department.

This was an unprecedented year. In the midst of a global pandemic, our faculty was successful in winning key grants, hired fantastic new faculty, and continued guiding the growth and education of our students.

In closing, please remember that my position is one of service. It is my privilege to support and serve the members of our community. Our discipline is intrinsically global, and it's imperative that we seek inclusive and diverse perspectives that enrich our learning, research, and innovation. Please peruse these pages of our inaugural issue to learn more about how we are extending beyond what nuclear has been and innovating what nuclear can become.

We Are! Penn State, and We Are! Nuclear!

Jean Paul Allain
Professor and Head
Ken and Mary Alice Lindquist
Department of Nuclear Engineering
allain@psu.edu

In October 2020, Jean Paul Allain was invited by the National Academy of Sciences, Engineering, and Medicine to speak at a panel discussion on the key goals and innovations needed for development of the first fusion energy pilot plant in the country. His contributions closely mapped his vision for the Ken and Mary Alice Lindquist Department of Nuclear Engineering.

Read more, including his full remarks.

Ramp up your nuclear engineering career with a professional graduate degree online

The master of engineering degree program at Penn State World Campus is nationally recognized and one of the longest-running online master's programs in nuclear engineering, with resident instructors also teaching the online courses. As part of the master's in nuclear engineering online program, students who do not have a bachelor of science degree in nuclear engineering are required to participate in a "ramp-up" course—NUCE 497: Fundamentals of nuclear engineering—that aims to prepare them for the nuclear engineering graduate program.

Massimiliano Rosa, assistant teaching professor of nuclear engineering, teaches this introductory course. The course acts as an introduction to the 30-credit, non-thesis professional master's program conducted entirely online. Other course topics include radiological safety, radioactive waste control, design principles of reactor systems, reactor engineering, nuclear fuel management, heat transfer, and other current subjects.

Ken and Mary Alice Lindquist commit estate gift, honored with named department

Nuclear engineering alumnus Ken Lindquist and his wife and fellow Penn State alumna, Mary Alice Lindquist, made a transformative estate gift in 2018 to support Penn State's nuclear engineering program.

The University named the department, which became a separate entity in 2019, the Ken and Mary Alice Lindquist Department of Nuclear Engineering in the donors' honor.

The estate gift supports a range of programming within the department, which serves to enhance the department's ability to recruit, retain, and reward high-achieving faculty.

The commitment also supports programming related to addiction prevention and awareness, and funds a range of scholarships and programs across the University, including student-athlete scholarships in football, men's basketball, and women's volleyball.

We are very thankful for the commitment and generosity by the Lindquists," said Jean Paul Allain, department head. "Their gift is already making an impact, which is reflected in the inaugural issue of Nucleus, which we dedicate to them.

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205 Hallowell Building
University Park, PA 16802-4400
nuce.psu.edu

Writers: Mariah Chuprinski, Tessa Pick, Gabrielle Stewart, Ashley J. WennersHerron

Introducing the Ken and Mary Alice Lindquist Department of Nuclear Engineering

Newly independent, the Ken and Mary Alice Lindquist Department of Engineering is growing quickly, with six new faculty members hired since July 2019. Their research interests cover the spectrum of nuclear engineering, from fundamental understandings of materials in plasma reactors to applied developments for cleaner and safer future energy.

Jean Paul Allain

Professor and Head of the Ken and Mary Alice Lindquist Department of Nuclear Engineering; Director of the Radiation Surface Science and Engineering Laboratory; Lloyd and Dorothy Foehr Huck Chair in Plasma Medicine, Huck Institutes of the Life Sciences; Professor of Biomedical Engineering by Courtesy; Faculty Fellow, Institute for Computational and Data Sciences; Affiliate Faculty, Materials Research Institute

As director of the Radiation Surface Science and Engineering Laboratory, Allain conducts research on the design and manufacturing of self-organized nanostructures inspired by forms in nature. He applies directed irradiation synthesis and directed plasma nanosynthesis techniques to promote multiscale, multifunctional properties on the surfaces and interfaces of dissimilar material systems, such as polymers and metals or ceramics and biomaterials.

Marek Flaska

Assistant Professor

Flaska conducts research with the goal of designing radiation detection systems for nuclear nonproliferation, safeguards, forensics, and fundamental physics applications.

Amanda Johnsen

Assistant Professor

Johnsen works at the intersection of radiochemistry and neutron irradiation techniques to engage with challenges in the areas of nuclear power generation, nuclear security and safeguards, medical treatment and diagnostic tools, and environmental stewardship. Current projects include measurements of fundamental properties of short-lived fission products, modeling of molten salt reactors for nuclear safeguards, and improved production and separation methods for medically relevant radioisotopes.

Hojong Kim

Associate Professor of Materials Science and Engineering, College of Earth and Mineral Sciences; Associate Professor of Nuclear Engineering by Courtesy

Kim investigates the electrochemical recovery of fission products from molten salts previously used for recycling spent nuclear fuel and the potential materials corrosion applications for these products in extreme molten salt environments. His experiments evaluate several fundamental properties of molten salts, such as redox potentials, diffusion, materials environment interactions, and reference electrode development.

Saya Lee

Assistant Professor

Lee researches thermal fluid applications for maintaining the light-water reactor fleet's safety as well as design and development of advanced reactors. He has contributed to the development of several measurement techniques and tools, including particle image velocimetry (PIV), laser-induced fluorescence, laser Doppler velocimetry, ultrasound velocimetry, fiber-optic temperature sensor, infrared image thermometry, and electric circuit-based sensing methods. Most recently, he has worked with Sulzer Mixer Reactor heat exchangers, molten salt natural convection, heat pipes for microreactors, annular flow boiling, and neural network-based PIV code development.

Azaree Lintereur

Assistant Professor

Lintereur's research is focused on radiation detection, with an emphasis on homeland security and nuclear safeguards applications. In addition to system development, she is also interested in advanced data analysis methods.

Elia Merzari

Associate Professor

Merzari's research relies on predictive large-scale simulations of turbulence to improve the physical understanding of complex flows and, ultimately, to design safer and more efficient energy systems, including nuclear reactors. He develops numerical methods and tools to bridge the gap between supercomputing-based simulation and engineering practice.

Arthur Motta

Professor and Graduate Program Chair

Motta's research focuses on the behavior of nuclear materials in the reactor environment. He employs advanced characterization techniques such as transmission electron microscopy and synchrotron radiation diffraction and fluorescence to examine degradation of nuclear materials performance, particularly for nuclear fuel cladding.

Kenan Ünlü

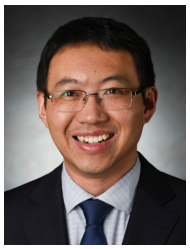
Professor and Director of the Radiation Science & Engineering Center

Ünlü has over 30 years of experience in research reactor administration and has contributed to the development and implementation of nuclear engineering techniques and technologies such as neutron depth profiling, prompt gamma activation analysis, and cold neutron sources. He led the establishment of a nuclear security research and education program at Penn State and has assisted in creating other education, research, and service initiatives at the Radiation Science & Engineering Center.

William Walters

Assistant Professor

Walters investigates the development of computational methods and software for modeling radiation transport and reactor physics using deterministic, hybrid, and Monte Carlo methods. He also examines these models for potential applications in a variety of nuclear engineering areas, including reactor design, shielding, nuclear safeguards, and detector modeling.



Xing Wang

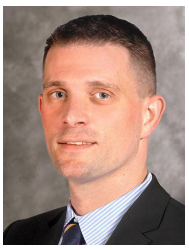
Assistant Professor

Wang focuses on understanding the radiation-induced structure and composition evolutions in materials by combining transmission electron microscopy, atom probe tomography, and multiscale materials simulation. His research goal is to develop radiation-resistant materials for applications in advanced nuclear reactors.

Leigh Winfrey

Associate Professor and Undergraduate Program Chair

Winfrey's research focuses on plasma-material interactions, exploring the effect of extreme heat flux on materials in a plasma environment and the consequent transfer of energy between plasma and material. She also investigates the behavior of reflectors and moderators in hot hydrogen environments for nuclear thermal propulsion systems, design of new materials for extreme environments, and improving the longevity of fusion reactor plasma-facing components.



Douglas Wolfe

Professor of Materials Science and Engineering, College of Earth and Mineral Sciences; Professor of Engineering Science and Mechanics, Professor of Nuclear Engineering by Courtesy, College of Engineering; Metals, Ceramics, and Coatings Processing Department Head, Applied Research Laboratory

Wolfe's research activities include the synthesis, processing, and characterization of ceramic and metallic coatings. His recent work is on titanium nitride and titanium aluminum nitride multilayer coatings for accident-tolerant nuclear fuels used in pressurized water reactors. He is the project manager for the Defense Threat Agency's Interaction of Ionizing Radiation with Matter University Research Alliance, a collaboration among 12 universities and national laboratories.

A new collaborative space for the future of nuclear engineering

By Gabrielle Stewart

The Ken and Mary Alice Lindquist Department of Nuclear Engineering recently began construction on a new commons space on the first floor of the Hallowell Building. The 5,000-square-foot Nuclear Innovation Commons (NIC) will serve as collaborative space for students, faculty, and staff to create and innovate nuclear science and engineering of the future.

Projected to be complete in spring of 2021, the commons will feature a variety of spaces to promote interaction and collaboration within the department:

- Three group ideation rooms equipped with large touch-screen displays
- A state-of-the-art instructional digital laboratory for remote learning nuclear labs
- An office suite for staff supporting student and facility services
- Hot desks for undergraduate research and a NuclearMakr space
- A video wall for remote learning and connecting with nuclear scientists from around the world
- Flexible learning and meeting space with a tech bar, collaboration booths, writable walls, and a digital touch-screen Chart of the Nuclides

"The vision for our Nuclear Innovation Commons is to create a vibrant and collaborative space where students and faculty are inspired to innovate in some of the most emergent areas in nuclear science and engineering," said **Jean Paul Allain**, department head and professor of nuclear engineering.

A nuclear-inspired look

The NIC was designed with nuclear science and engineering in mind, with aesthetics and architecture that represent nuclear facilities and technologies on the leading edge.

Glass with a glow

The space is accented with several dark blue glass panels designed to evoke the blue glow emitted by a nuclear reactor core. This phenomenon is an example of Cherenkov radiation—where charged particles move faster than the speed of light through a medium containing a static electric field. The resulting interactions radiate blue. Visitors to Penn State's own Breazeale Nuclear Reactor may observe real Cherenkov radiation.

Fissionable fuel ceiling

The NIC's wood block ceiling mimics a nuclear fuel assembly, giving a sense of the inner workings both of conventional and future reactor cores. The ceiling

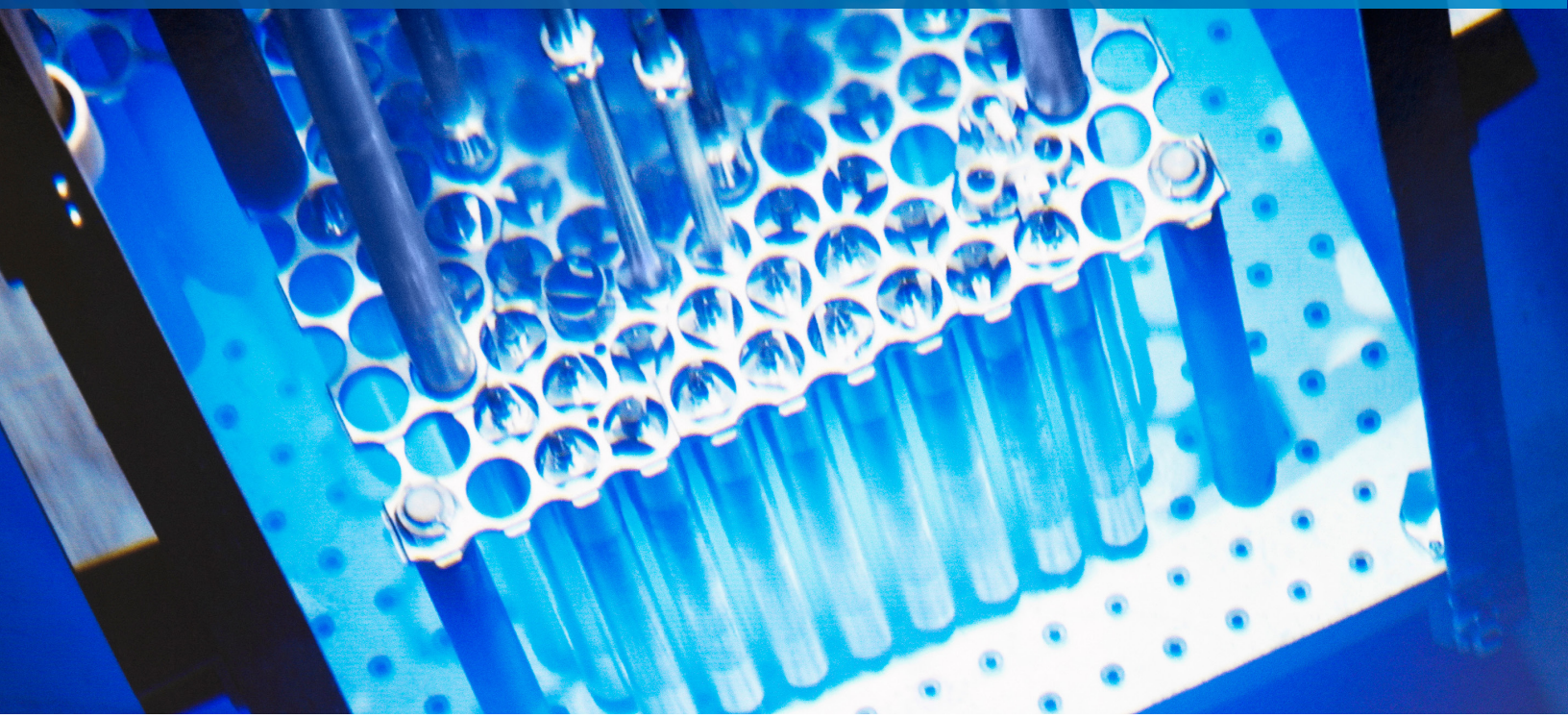
captures the imagery of a bundle of metal tubes containing fuel pellets, the fuel assembly providing energy for fission reactions. The gaps in the ceiling represent the spaces in the structure where other instruments or control rods can be vertically inserted in a conventional reactor. The ceiling also symbolizes the hexagonal arrangement of fuel assemblies that may be found in future advanced nuclear reactors. The instructor demonstration station in the instructional digital laboratory (shown below) is also designed in a similar hexagonal shape. The ceiling wood blocks also resemble the "Chart of the Nuclides," the graph mapping the nuclear behavior of atoms characterized by their nuclear energy states.

Inclusive academic community
Open spaces will encourage collaboration across interests in nuclear engineering, reflecting the department's values of transparency, inclusivity, and diversity. Students, faculty, and staff will be able to see what others are working on and be encouraged to partner to develop advanced solutions to nuclear challenges. The convergence of nuclear and advanced computing in these spaces will foster further collaborative innovation.

The Nuclear Innovation Commons will provide several naming opportunities for those interested in contributing to the department's innovative future. For more information, contact Melissa Showalter at mus41@psu.edu.

A BRIGHT FUTURE

for nuclear science and engineering at Penn State



By Ashley J. WennersHerron

Penn State's Radiation Science & Engineering Center (RSEC), home to the Penn State Breazeale Reactor—the nation's first licensed and longest continuously operating nuclear research reactor—is expanding to facilitate more advanced neutron beam research as well as the growth of nuclear engineering at Penn State. With the support of the College of Engineering, in partnership with the Ken and Mary Alice Lindquist Department of Nuclear Engineering, RSEC's expansion will launch a joint initiative to support novel studies in fundamental and applied research for Penn State faculty and students, industry, and collaborative universities and institutes.

"This is a very exciting time for RSEC, the nuclear engineering department, and many other disciplines at Penn State," said **Kenan Ünlü**, director of RSEC and professor of nuclear engineering. "Having access to an operating research reactor is a key strength for Penn State and allows us to harness research and educational opportunities rarely available in the U.S."

The Breazeale Reactor was established in 1955 after U.S. President Dwight D. Eisenhower launched the "Atoms for Peace" initiative to use the relatively new-found control of the atom to benefit human life. An enormous number of neutrons are generated per second via fission reactions in a reactor core. Enabling many different types of research, the Breazeale Reactor has the capability to allow a vast number of these neutrons to pass through a moderator and be carried outside of the reactor's biological shields through hollow tubes called beam ports.

"The Breazeale Reactor has had several upgrades since its founding," Ünlü said. "A significant redesign and installation of five new beam ports were completed in 2018, but we needed a new neutron beam laboratory

with an expanded beam hall to make full use of the reactor's capabilities and to establish state-of-the-art neutron beam facilities."

One of five neutron beam ports will be outfitted with an extremely cold moderator that allows more effective transportation to the experimental sample location via neutron guides. These cold neutrons will be used in such techniques as neutron depth profiling, prompt gamma activation, and small angle neutron scattering. Three other beam ports will provide neutrons for a student scattering spectrometer, neutron imaging, and neutron transmission studies. The last beam port will be designated for exploratory research involving thermal neutrons.

"Neutrons are an ideal probe for the investigation of complex materials, including biological materials at the atomic scale," said **Jean Paul Allain**, department head and professor of nuclear engineering.

The planned expansion also demonstrates a deep commitment to further develop the newly independent Ken and Mary Alice Lindquist Department of Nuclear Engineering, which is experiencing an unprecedented growth of faculty and students since its establishment in the summer of 2019, according to Allain.

"The expansion will include not only the new beam hall, but also office spaces for RSEC staff, nuclear engineering faculty, graduate students, and visiting scientists who will collaborate with Penn State faculty," Allain said.

The 10,000-square-foot expansion is a $9 million investment for the College of Engineering. According to Allain, it is a worthwhile endeavor that will reap benefits for the University and beyond. He noted that the expansion of facilities for nuclear science and engineering at Penn State will also welcome industry stakeholders for collaborative research projects, as well as serve as a key attraction in recruiting top faculty and students.

"The education and research mission of the nuclear engineering department and RSEC have enjoyed a strategic partnership for many decades in the College of Engineering," Allain said. "Strengthening already close ties, the college is making a significant investment in both the department of nuclear engineering and RSEC."

According to **Justin Schwartz**, Harold and Inge Marcus Dean of Engineering, the expansion will reap benefits beyond the college.

"The collaboration between Drs. Ünlü and Allain to not only organize the physical upgrades but to also initiate truly transformative research and curriculum efforts is a stellar example of the interdisciplinary work that positions Penn State as a leader in nuclear research," Schwartz said. "Penn State is becoming one of the nation's premier neutron science destinations—a vibrant hub of students and researchers engaged in multidisciplinary education and research."

There are philanthropic opportunities for both individuals and companies to support the growth of nuclear science and engineering at Penn State. Please contact the Ken and Mary Alice Lindquist Department of Nuclear Engineering for more information. For more information, contact Melissa Showalter at mus41@psu.edu.

"Penn State is becoming one of the nation's premier neutron science destinations—a vibrant hub of students and researchers engaged in multidisciplinary education and research."

Penn State leads $30 million university research alliance

By Ashley J. WennersHerron

The Department of Defense's Defense Threat Reduction Agency (DTRA) awarded a combined total of $51.1 million to two university research alliances to counter threats of destruction, with a specific focus on improving current and developing future warfighter technology. Penn State is leading the Interaction of Ionizing Radiation with Matter University Research Alliance, which was awarded $30 million for the next five years, with the potential of extending the alliance for a total of nine years and $54 million of funding with additional funding opportunities available.

Led by **Douglas Wolfe**, head of the Department of Metals, Ceramics, and Coatings Processing in the Applied Research Laboratory (ARL), professor of materials science and engineering, professor of nuclear engineering by courtesy, and professor of engineering science and mechanics, Penn State's efforts are focused in ARL, the College of Engineering, and the College of Earth and Mineral Sciences. The alliance includes three other permanent members: the University of Michigan (UM), Massachusetts Institute of Technology (MIT), and the University of Florida (UF). The rest of the alliance includes eight other universities and several national laboratories and industry partners.

"We have a very strong, multidisciplinary group who proposed transformative research addressing DTRA's needs," Wolfe said. "Our collaboration consists of extremely talented investigators from a variety of institutions and disciplines with a wide range of technical expertise."

"Fundamental to every stage of research is education."

Primary Penn State contributors include Meghan Flannery Hayes, head of the Department of Complex Systems Monitoring at ARL; **Marek Flaska** and **Azaree Lintereur**, both of whom are assistant professors in the Ken and Mary Alice Lindquist Department of Nuclear Engineering; Aman Haque, professor of mechanical engineering and engineering science and mechanics; and Saptarshi Das, assistant professor of engineering science and mechanics and law, policy, and engineering.

The team is investigating how ionizing radiation interacts with matter. According to Wolfe, this research could lead to higher-resolution radiation detectors capable of identifying dirty bombs or concealed radiation materials. By understanding the material interactions, the researchers plan to design low-cost, high-efficiency room-temperature detectors that would eliminate the need for extreme temperatures to control detecting materials. They also plan to develop electronics and systems that would be secure against radiation damage.

"Current electronics, including banking and satellite systems, could not withstand a nuclear explosion," Wolfe said. "We hope to develop devices and systems that would be insensitive to radiation. In the event of a bomb explosion, we would still be able to communicate with one another."

University Research Alliance team members are focusing on the basic research of ionizing radiation interactions over three research areas, with research area leads from MIT—materials, UM—devices and device integration, and UF—survival and response. The rotating alliance members will contribute via shorter-term projects that explore specific sub goals of the larger aims.

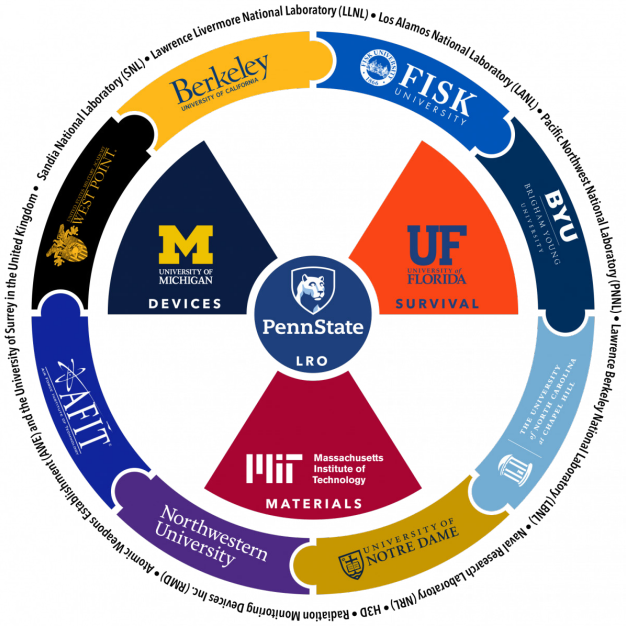
Beyond the primary research goals, the alliance has also established a workforce development program that gave the team their competitive edge, according to Wolfe.

"Fundamental to every stage of research is education," Wolfe said.

The team aims to foster an inclusive academic community to recruit and train undergraduate students, graduate students, and postdoctoral fellows to become the next generation of researchers and engineers.

"This is a landscape-changing opportunity for nuclear engineering at Penn State," said Jean Paul Allain, head of the Ken and Mary Alice Lindquist Department of Nuclear Engineering. "Our team has already demonstrated their collaborative research strengths through a variety of other projects, and now they are combining forces to elevate ionizing radiation interaction research in a way that will transform how we protect against radioactive threats, as well as how we innovate and design digital devices and radiation-hardened electronic systems. Scholars at all levels will come to Penn State to contribute to this project."

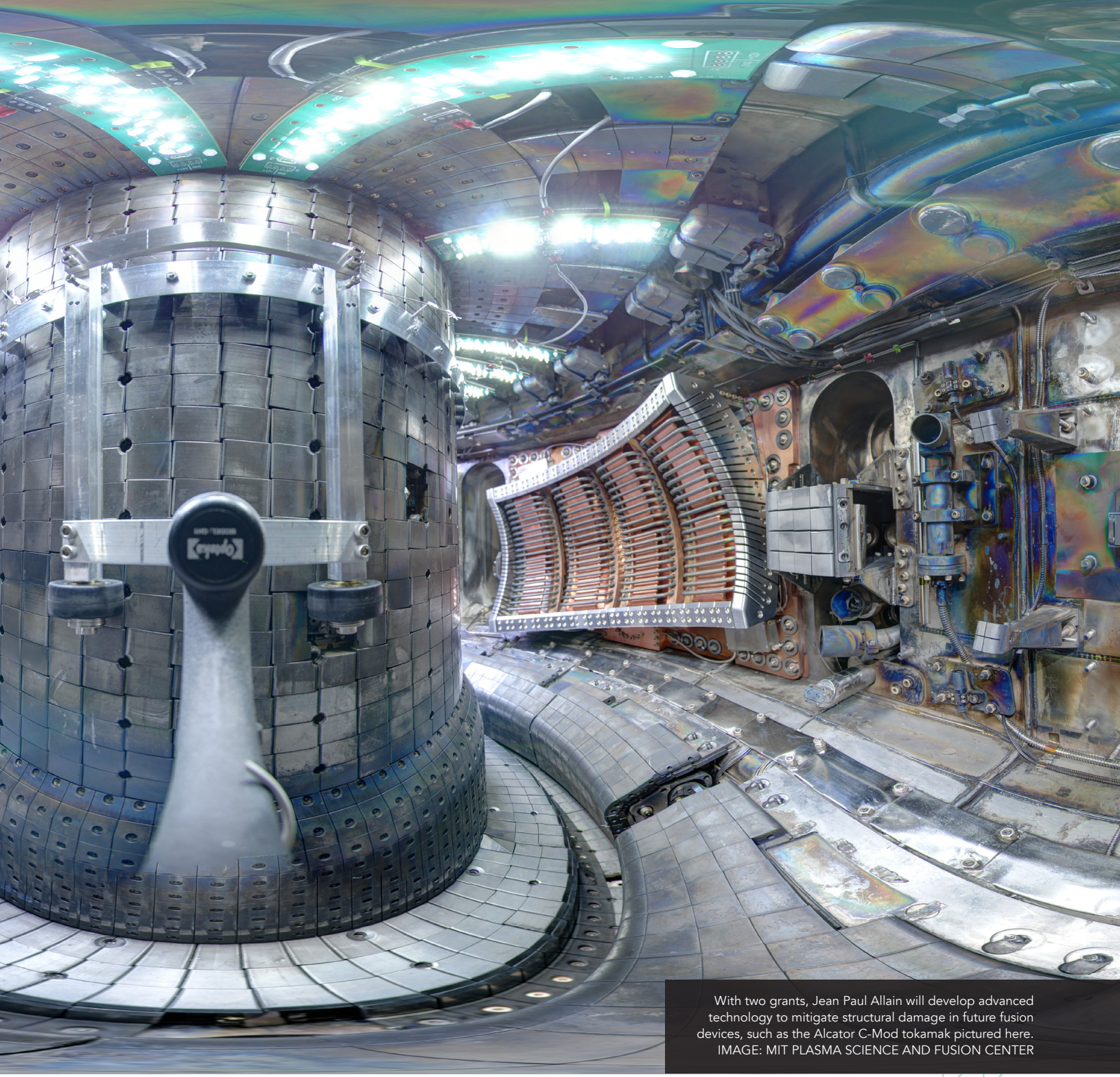
"Our collaboration consists of extremely talented investigators from a variety of institutions and disciplines with a wide range of technical expertise."



Permanent alliance members:
Penn State
University of Michigan
Massachusetts Institute of Technology
University of Florida

Current alliance members:
Brigham Young University
University of California at Berkeley
University of Notre Dame
Northwestern University
FISK University
University of North Carolina at Chapel Hill
Air Force Institute of Technology
United States Military Academy at West Point
Sandia National Laboratory
Lawrence Livermore National Laboratory
Los Alamos National Laboratory
Pacific Northwest National Laboratory
Lawrence Berkeley National Laboratory
Naval Research Laboratory
H3D Inc.
Radiation Monitoring Devices Inc.

"This is a landscape-changing opportunity for nuclear engineering at Penn State."



With two grants, Jean Paul Allain will develop advanced technology to mitigate structural damage in future fusion devices, such as the Alcator C-Mod tokamak pictured here. IMAGE: MIT PLASMA SCIENCE AND FUSION CENTER

How to harness the power of the sun

Nuclear engineer receives $3.6 million in grants to strengthen reactor walls against plasma heat

By Ashley J. WennersHerron

"Finding solutions to the challenges of how to deal with high thermal and particle wall loads is a critical area of fusion research."

In nuclear fusion reactors, the nuclei of atoms fuse to generate more energy than is consumed. This energy-producing plasma is roughly the temperature of the sun, which is powered by the same fusion energy principles. The sun, however, does not need to be confined in the way fusion plasma requires on Earth.

Jean Paul Allain, professor and head of the Ken and Mary Alice Lindquist Department of Nuclear Engineering, has received two grants from the U.S. Department of Energy (DOE) totaling $3.6 million to study how to improve the effectiveness and survivability of reactor materials responsible for containing the plasma.

"Finding solutions to the challenges of how to deal with high thermal and particle wall loads is a critical area of fusion research," Allain said. "The plasma temperature is so high at the boundary of the wall, it will melt any solid. You either need to develop a liquid metal that can't be damaged or a solid that self-heals."

To explore the first option, the DOE awarded Allain, in partnership with Princeton University and the Massachusetts Institute of Technology (MIT), $2.5 million over five years. Allain will work with Penn State colleagues in the College of Engineering, the Materials Research Institute, and the Applied Research Laboratory to build a porous scaffolding, over which lithium-based liquid metal could move.

"The biggest challenge is how do we deliver the liquid metal into the reactor," Allain said. "We're going to mimic how trees get water from their roots to their leaves: capillary force."

A series of tiny tube-like structures run through the tree. Tension between the water droplets and the surface of the structures propels the water up, against gravity. Allain and the research team will mimic those same principles by using capillary force to drive the liquid metal up a porous but solid scaffold and deliver it to the surface wall of the reactor. As plasma in the reactor heats and touches the wall, ideally the liquid metal will flow over the affected area, immediately healing any damage.

"Liquid metal has issues: how does it hold together, for example?" Allain said. "A huge plasma force could splash the liquid and force the reactor off. Luckily, in this type of reactor, there is not a risk of melt down—the plasma just turns off. Our design of a pore structure should help address this concern."

Allain's research team will test different materials and develop small 3D prototypes. Bruce Koel, professor at Princeton University, will lead a team that plans to examine surface interactions on the prototypes, while MIT scientist Kevin Woller and his group will test the prototypes in the conditions found in a plasma reactor. The goal, according to Allain, is to determine the best combination of scaffolding material and lithium liquid metal to scale up for use in reactors.

At the same time, Allain will also explore another option—a solid that self-heals. The DOE awarded Allain $1.1 million over three years to develop a self-healing plasma reactor wall.

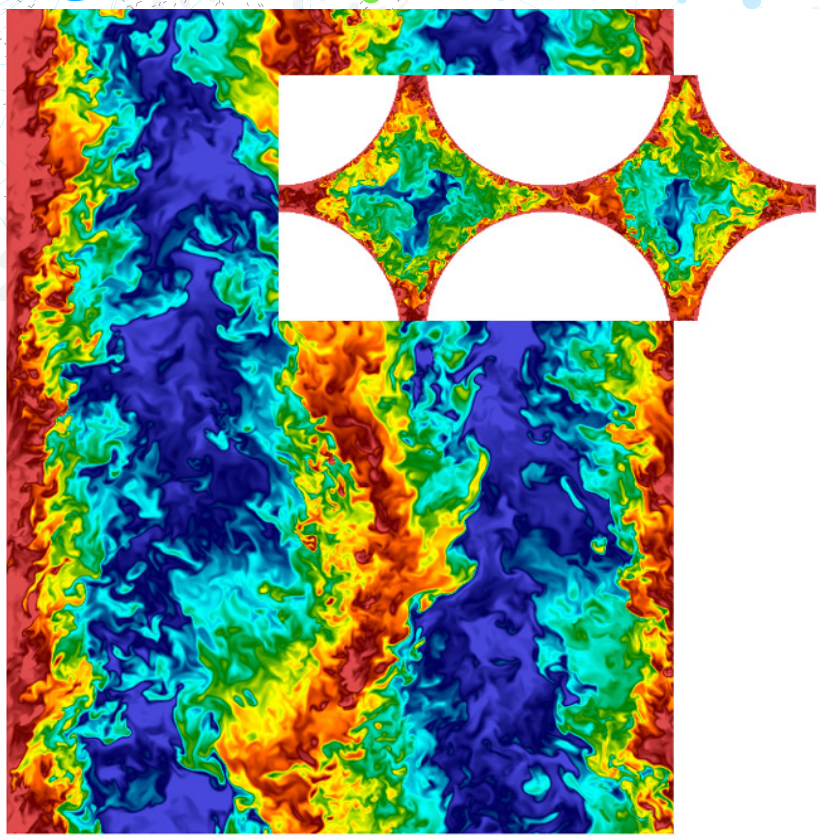
"A solid wall is the more obvious plan, as it can hold itself together," Allain said. "But it could be so greatly damaged by extreme heat fluctuations and neutrons that the structure becomes so weak it fails."

In collaboration with **Xing Wang**, assistant professor of nuclear engineering at Penn State, who will also contribute to the first grant project, Allain will develop a tungsten alloy that contains ultrafine particles that identify and restructure to repair damages.

"The biggest challenge is how do we deliver the liquid metal into the reactor. We're going to mimic how trees get water from their roots to their leaves: capillary force."

Most damage from the fusion reaction to solid walls involves both surface and deep penetration of subatomic particles that displace the atoms in the wall. At that quantum level, the atoms of the wall—namely, the ultrafine particles dispersed throughout—rearrange to alleviate the weak points in the material. The wall heals itself.

"We have our hypotheses, but we just don't know how a self-healing solid or a liquid metal structure will actually perform under extreme conditions," Allain said. "We've assembled two great teams, and we're going to find the answers."



Penn State receives $3 million to contribute to national Center of Excellence

Elia Merzari, associate professor of nuclear engineering, joins national consortium to research and develop advanced nuclear reactors

By Ashley J. WennersHerron

Elia Merzari, associate professor of nuclear engineering, is leading a university consortium to better model temperature flows in nuclear reactor cores in an effort to design safer and more advanced reactors. IMAGE: ELIA MERZARI, PENN STATE

The national Center of Excellence (COE) for Thermal Fluids Applications in Nuclear Energy at Idaho National Laboratory and Argonne National Laboratory has a new member. **Elia Merzari**, associate professor in the Penn State Ken and Mary Alice Lindquist Department of Nuclear Engineering, received $3 million to lead a university consortium in partnership with the COE and industry members to accelerate the deployment of advanced nuclear reactors.

The grant, awarded by the U.S. Department of Energy, funds collaborative work with scientists from Massachusetts Institute of Technology, University of Michigan, Texas A&M University, North Carolina State University, Liberty University, Kairos Power, Westinghouse, General Atomics, and TerraPower, as well as Idaho National Laboratory and Argonne National Laboratory.

"This team is exceptional," Merzari said. "This collaborative group has the best people in the field. It'd be very hard to do better. I think we're going to do some excellent work."

The group will focus on advancing thermal-hydraulic modeling, simulation, and experimentation of leading-edge reactor designs.

"Advanced reactors have received a great deal of attention in recent years, with a wave of remarkably innovative designs introduced on the market," Merzari said. "However, the unique design of advanced nuclear reactors presents many fluid-flow problems that hinder safety and performance."

> "This team is exceptional. This collaborative group has the best people in the field. It'd be very hard to do better. I think we're going to do some excellent work."

By better understanding how temperature changes within the fluid, the researchers can design better and safer advanced reactors, Merzari said.
In nuclear fission reactors, neutrons collide with heavy atoms, causing a release of energy and excess neutrons. The excess neutrons trigger a chain reaction that can be moderated with cooling fluid circulating through the reactor core, as well as with chemical and mechanical controls. The fission reaction inside the core produces complex layering of ever-changing temperature profiles in the coolant fluid and the fuel. Such shifting temperatures cause material stresses that need to be understood and predicted to mitigate potential damage, according to Merzari.

Simulations of these phenomena, used to improve reactor design and ensure safe operation, are traditionally performed with empirical data that may not consider a wide range of designs and scenarios.

Individual research teams have attempted to study and mitigate these issues, but ad-hoc efforts can be expensive, ineffective, and time consuming, according to Merzari. The COE's approach is to define specific thermal-hydraulic challenge problems, with industry input, and experimentally assess them. The results will contribute to a knowledge base for models and simulations that can be used as a standard reference while the thermal-hydraulic performance of advanced reactors is studied further.

"Thermal flow phenomena are essential in the safety analysis and design of advanced reactors," Merzari said. "This is of key interest for the U.S. Department of Energy and the country as a whole. Our contribution promises to be important for the accelerated deployment of [advanced] reactors while also improving economic competitiveness."

Merzari was also named as a collaborator on two other national projects, one led by Texas A&M University and one led by University of Michigan. The first focuses on computationally and experimentally understanding how material flows near the wall of a pebble bed reactor, while the second aims to improve traditional reactor models to better understand and mitigate potential design-based reactor accidents.

"All three of these projects are founded in evaluating the safety of reactors," Merzari said. "They're all tied to advancing reactor technology while improving safety and decreasing cost."

Merzari's contributions to these projects helps cement Penn State's position in the field of nuclear engineering, according to **Jean Paul Allain**, professor and head of the Ken and Mary Alice Lindquist Department of Nuclear Engineering.

"Elia's work is exceptional; his expertise is sought across the country," Allain said. "His home research program at Penn State contributes to the University's place as a leader in advanced thermal-hydraulic modeling for advanced reactors."

Making nuclear engineering more inclusive

By Tessa Pick

Candace Davison (left), assistant director for education and outreach at the Penn State Radiation Science & Engineering Center (RSEC), has spent many years of her career advising and engaging with programs that focus on bringing inclusivity to the STEM fields.

As the first woman to become a licensed senior reactor operator at the Penn State Breazeale Reactor, Davison knows the essential role that women and underrepresented groups play in the STEM fields and nuclear engineering specifically.

"I feel that it is so important to have role models," Davison said. "I do what I can to encourage women and underrepresented students to stay in the STEM fields."

Davison was an adviser for Women in Science and Engineering (WISER) and Minority Undergraduate Research Experience (MURE) at Penn State. These two programs are a part of the PA Space Grant Research Internship Program, which is supported by the NASA Pennsylvania Space Grant Consortium and gives Penn State undergraduate students research and mentorship opportunities through collaboration with faculty research teams and Penn State's state-of-the-art research facilities.

As an adviser for these initiatives, Davison has mentored several undergraduate students, mostly first-year students. She provided these students with hands-on experiences for their projects in radiation and nuclear technology and connected some of them with upper-level nuclear engineering students. According to Davison, this mentorship is aimed at creating retention within the STEM disciplines at Penn State.

"If the students decided to become nuclear engineers, great," Davison said. "However, my goal is to help them see how engineers solve problems and if the field and major is right for them. The programs help incoming students understand why they need to go through the required classes to build a strong foundation in problem solving skills in diverse areas. Research has shown that there is better retention when connecting students in programs like this."

In collaboration with Arthur Motta, professor and graduate program chair of nuclear engineering, Davison developed the Nuclear Science and Engineering Research Internship—formerly known as the Women in Nuclear Internship—at RSEC. This program is focused on getting more students—primarily women and underrepresented groups—engaged with Penn State's reactor facilities.

"My experience with WISER and MURE demonstrated the importance of engaging students early in college courses," Davison said. "So we developed this internship program to engage more women and underrepresented students at the facility while providing an experience that is hands-on, outside of the classroom, but very pertinent to the major."

Davison is also involved in numerous organizations outside of Penn State that focus on building inclusivity in STEM. She has contributed to the American Nuclear Society, American Association of University Women, Graduate Women in Science, Women in Nuclear, and the Society for Women Engineers. She has also developed and conducted many programs for pre-college students and educators and organizations such as the Boy Scouts and the Girl Scouts.

In addition to her work with many nuclear engineering student programs and organizations, Davison is the coordinator of the Gamma Irradiation Facility at the RSEC. She focuses on the many types of applications of gamma rays including chemical, reactions, material or genetic changes, and sterilization. Specifically, she uses gamma rays to sterilize materials that cannot be sterilized using heat or chemicals. Most recently, she contributed to the Manufacturing and Sterilization for COVID-19 (MASC) initiative at Penn State by using gamma irradiation to sterilize medical gowns.

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KEN AND MARY ALICE LINDQUIST DEPARTMENT OF NUCLEAR ENGINEERING

Faculty highlights

Some nuclear engineering faculty and staff gathered for an off-site retreat to discuss goals for the department in early 2020.

Collaborative partnership highlights

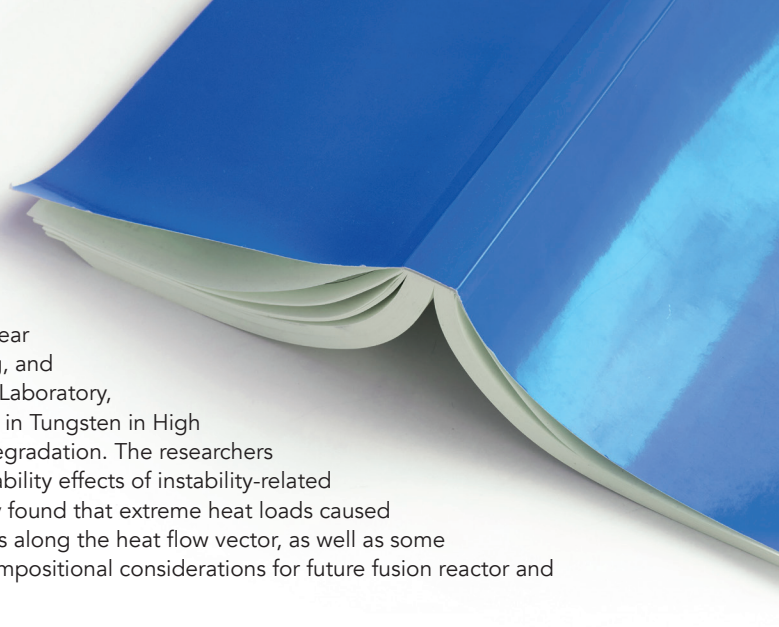
Penn State nuclear engineering faculty are partnering with agencies, laboratories, and universities around the world to advance research in nuclear power, safety, climate change, poverty, water desalination, advanced technologies in plasma and nuclear space physics, nuclear fusion, plasma medicine, and space nuclear propulsion—to name a few. Some of these partners are listed below.

U.S. Department of Energy
- National Nuclear Security Administration
  - Sandia National Laboratories
  - Lawrence Livermore National Laboratory
  - Los Alamos National Laboratory
- Office of Science
  - AMES Laboratory
  - Argonne National Laboratory
  - Lawrence Berkley National Laboratory
  - Oak Ridge National Laboratory
  - Pacific Northwest National Laboratory
- Idaho National Laboratory

U.S. Department of Defense
- Defense Threat Reduction Agency
- Naval Nuclear Laboratory

Universities/Institutes:
- University of Michigan
- Massachusetts Institute of Technology
- University of Florida
- Brigham Young University
- University of California at Berkeley
- University of Notre Dame
- Northwestern University
- FISK University
- University of North Carolina at Chapel Hill
- Air Force Institute of Technology
- United States Military Academy at West Point
- Texas A&M University
- University of Wisconsin-Madison
- Liberty University
- Chalmers University (Sweden)
- University of Manchester (England)
- Imperial College London (England)
- Paul Scherrer Institute (Switzerland)
- University of Tennessee at Knoxville

Industry:
- Électricité de France
- Kairos Power
- Westinghouse
- General Atomics
- TerraPower



Publications in 2020

Penn State nuclear engineering faculty have collectively published nearly 60 peer-reviewed papers in 2020 alone. One of the most recent papers is from Minsuk Seo, doctoral candidate in nuclear engineering, Leigh Winfrey, associate professor of nuclear engineering, and John Echols, a postdoctoral research associate at Oak Ridge National Laboratory, who published their study, "Morphological, Nanomechanical Changes in Tungsten in High Heat Flux Conditions" in the Nature Research Journal npj Materials Degradation. The researchers exposed tungsten to high heat loads to investigate the long-term durability effects of instability-related damage on waste disposal repositories buried at shallow depths. They found that extreme heat loads caused partial melting, increased porosity, and the creation of grains and voids along the heat flow vector, as well as some plasma hardening effects. The study provides novel insights on the compositional considerations for future fusion reactor and material development. Read more

Xing Wang, an assistant professor who joined the department in January, recently published a paper in Nature Materials on radiation-induced segregation in ceramics. First author on the paper, Wang and the researchers found that radiation can induce notable segregation of one of the constituent elements to grain boundaries in ceramics. They also found that the temperature dependence of this radiation-induced segregation is different than what is demonstrated in metallic systems. Read more

Here is a selection of other published works from the nuclear engineering faculty:

Azaree Lintereur
- "Implementation of Machine Learning Algorithms for Detecting Missing Radioactive Material" in Journal of Radionuclide and Nuclear Chemistry
- "Optimization of a K-Nearest Neighbors Regression Algorithm for Improved Pulse Shape Discrimination of Gamma Rays and Neutrons in Organic Scintillators" in Proceedings of the INMM 61st Annual Meeting
- "Machine Learning Approaches to Determine Missing Material from Nuclear Fuel Assemblies" in Proceedings of the INMM 61st Annual Meeting
- "Sandia National Laboratories Early Career University Faculty Mentoring Program in International Safeguards" in Proceedings of the INMM 61st Annual Meeting

Hojong Kim
- "Electrochemical Separation of Alkaline-Earth Elements from Molten Salts Using Liquid Metal Electrodes" in ACS Sustainable Chemistry & Engineering
- "Thermodynamic Properties of Rare-earth Alloys by Electrochemical EMF Measurements" in Journal of Materials Research
- Rare Metal Technology 2020, published by Springer Nature

Xing Wang
- "Radiation-induced Segregation in a Ceramic" in Nature Materials
- "Origin of Increased Helium Density Inside Bubbles in Ni(1-x)Fex Alloys" in Scripta Materialia

William Walters
- "Fission Matrix Homogenization and Iterative Convergence in RAPID" in Progress in Nuclear Energy
- "Validation of Coupled Fission Matrix – TRACE Methods for Thermal-hydraulic and Control Feedback on the Penn State Breazeale Reactor" in Progress in Nuclear Energy
- "Development of RAPID Transport Calculation with Heterogeneous Temperature Distribution" in Annals of Nuclear Energy
- "An Ecopath with Ecosim Model for the Pacific Coast of Eastern Japan: Describing the Marine Environment and its Fisheries Prior to the Great East Japan Earthquake" in Ecological Modeling

Amanda Johnsen:
- "Nuclear Data Uncertainty in Molten Salt Reactors Safeguards" in Transactions of the American Nuclear Society
- "Verification of Molten Salt Reactor Modeling Capabilities in Serpent" in International Conference on Mathematics and Computational Methods Applied to Nuclear Science and Engineering (M&C 2013)

Marek Flaska
- "Characterization of a Mixed-sinusoid Multiplexing Scheme with Silicon Photomultipliers and an Inorganic Scintillator" in Nuclear Instruments and Methods in Physics Research
- "Development of an Efficient Multiplexing Scheme for Multichannel Detection Systems based on Organic Scintillators and Silicon Photomultipliers" in Nuclear Instruments and Methods in Physics Research
- "On the Fabrication and Characterization of Heterogeneous Composite Neutron Detectors with Triple-pulse-shape-discrimination Capability" in Nuclear Instruments and Methods in Physics Research

Elia Merzari
- Merzari contributed to 17 publications so far in 2020. Visit his Google Scholar page to see the full listing.

Arthur Motta
- "The Effects of Introducing Elasticity Using Different Interpolation Schemes to the Grand Potential Phase Field Model" in Computational Materials Science

Jean Paul Allain
- Allain contributed to 22 publications so far in 2020. Visit his Google Scholar page to see the full listing.

Kenan Ünlü
- "Toward the Implementation of Self-powered, Wireless, Real-time Reactor Power Sensing" in Annals of Nuclear Energy

Faculty honors and awards:

Saya Lee was awarded a Nuclear Energy University Program grant in August of 2020. The project, titled, "Experiments for Modeling and Validation of Liquid-Metal Heat Pipe Simulation for Micro-Reactors," is in partnership with Los Alamos National Laboratory and Idaho National Laboratory through the Nuclear Energy Advanced Modeling and Simulation program.

Elia Merzari was elected vice-chair (chair-elect) of the Thermal-Hydraulic Division of the American Nuclear Society. He has previously served as the division's secretary, treasurer, program chair, assistant program chair, webmaster, and executive committee member. He is also the technical program chair for the upcoming 19th International Meeting on Nuclear Reactor Thermal Hydraulics in 2021 in Brussels, Belgium.

In addition, Merzari received an Advanced Scientific Computing Research Leadership Computing Challenge (ALCC) award for 150,000 hours on Summit, the fastest supercomputer in the United States and second fastest in the world. The hours will be used to complete a project in collaboration with Argonne National Laboratory and Idaho National Laboratory, titled, "Toward Full Core Multiphysics High Fidelity Calculation."

Merzari was also awarded the 2020 Lewis F. Moody Award by the fluid engineering division of the American Society of Mechanical Engineers (ASME). He and five co-authors were recognized for their paper on novel heat exchangers for potential use in nuclear reactors, published in the Journal of Fluids Engineering. They were honored in a virtual ceremony at the ASME Fluids Engineering Division Summer Meeting on July 15, 2020.

Student highlights

Scott-McCabe named ROTC student marshal

ROTC student marshal Diego Scott-McCabe, who graduated in 2020 with a bachelor of science in nuclear engineering, was named student marshal by the College of Engineering for the Reserve Officer Training Corps (ROTC). Scott-McCabe, who chose to study nuclear engineering to start his submarine career, plans to serve on submarines in the Navy after completing Navy Nuclear Power School in Charleston, South Carolina.

Reger named nuclear engineering student marshal

Student marshal David Alan Reger, who graduated in 2020 with a bachelor of science in nuclear engineering and a bachelor of science in mechanical engineering, was honored by the College of Engineering as student marshal for the Ken and Mary Alice Lindquist Department of Nuclear Engineering. Reger will continue his education at Penn State, aiming to obtain his doctorate in nuclear engineering, and plans to focus his research on the application of high-performance computing to nuclear thermal hydraulics.

Awards and recognitions

In spring of 2020, the department awarded several students and alumni recognitions:

- John J. Brennan Excellence in NucE Award: **Joshua May**, junior
- Beecher Loftus Leadership and Service Award in NucE: **Christopher Balbier**, senior
- Edward H. and Deborah R. Klevans Scholarship in NucE: **Jake Eichenlaub**, 2020 graduate, **Diego Scott-McCabe**, 2020 graduate
- Monty Schultz Memorial Scholarship in NucE: **David Reger**, graduate student, **Devon Gerstein**, senior
- Bernadette and Warren Witzig NucE: **Jocelynn Kelly**, senior
- Exelon Corporation Endowed Scholarship in NucE: **Melissa Morgan**, junior; **Katie Hawkins**, 2020 graduate; **Garrett Wendel**, 2019 graduate

Nuclear engineering students have also received recognition from outside the University:

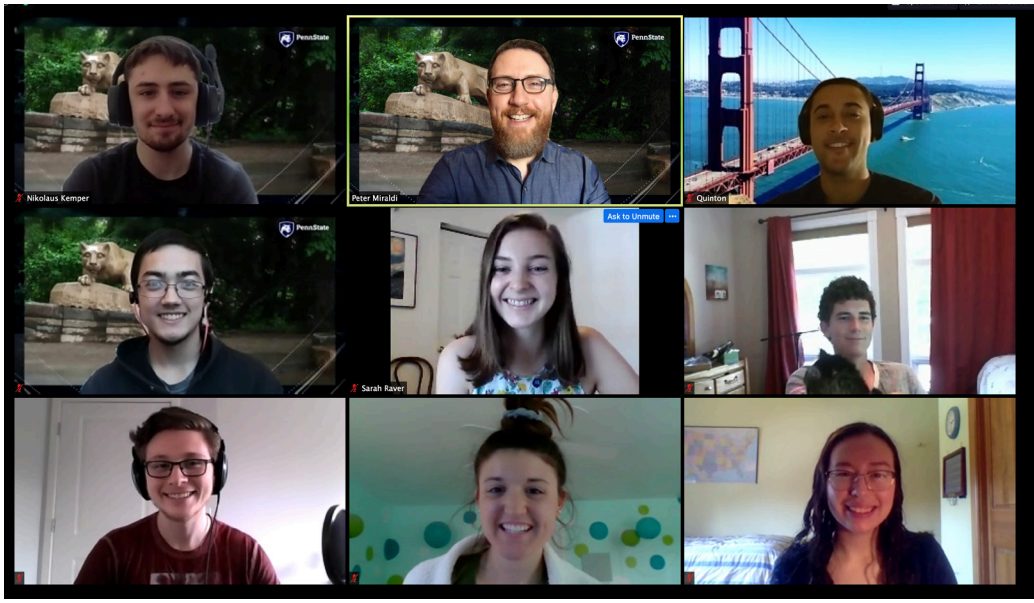
- **Matthew Durbin**, doctoral candidate: J.D. Williams Student Paper Award for Best Poster, Institute of Nuclear Materials Management Annual Meeting
- **Stephanie Castro Baldivieso**, doctoral student: Graduate Fellowship, U.S. Department of Energy Nuclear Energy University Program
- **Victor Coppo Leite**, doctoral student: Graduate Scholarship from American Society of Mechanical Engineers Fluids Engineering Division
- **Thomas Nigl**, doctoral student: Intercollege Graduate Student Outreach Award, Penn State
- **Adam Kraus**, doctoral candidate: Best Paper, ASME Nuclear Engineering Conference

Nuclear engineering students participate in Westinghouse Fellows Program

By Tessa Pick

Over the course of the summer, the Penn State Ken and Mary Alice Lindquist Department of Nuclear Engineering hosted the 11th annual Westinghouse Fellows Program, funded by a grant from Westinghouse Electric Corporation.

Eight undergraduate students from various engineering programs were selected to virtually collaborate with Penn State faculty mentors and graduate students to conduct research and complete professional development activities. At the end of the program, students presented their research via Zoom to Westinghouse engineers and executives.



From left to right, top down: Fellow Nikolaus Kemper; Peter Miraldi, teaching professor in communication arts and sciences at Penn State; fellows Quinton Williams, Jordan Northrop, Sarah Raver, Daniel Roth, Alex Hauck, Danielle Johnson, and Rachel Bartuska.

Alexander Hauck from Rensselaer Polytechnic Institute and Quinton Williams from Oregon State University were advised by **Xing Wang**, assistant professor of nuclear engineering, to develop a model that uses machine learning concepts to automatically identify helium bubbles in transmission electron microscope images with high accuracy.

Under the mentorship of **William Walters**, assistant professor of nuclear engineering, Daniel Roth from University of Wisconsin Madison and Jordan Northrop from Oregon State University studied the design of a gamma heated capsule that will be used in the Penn State Breazeale Reactor. The capsule is used to test material durability in high temperature conditions and resistance to fast neutron damage.

Marek Flaska, assistant professor of nuclear engineering, advised Danielle Johnson from Brigham Young University for her project that focused on finding inexpensive, accurate, and portable methods to detect radon. Flaska also advised **Rachel Bartuska** from Penn State as she contributed to a government-funded project—Consortium for Monitoring, Technology, and Verification—that is aimed at preventing nuclear weapons proliferation.

Amanda Johnsen, assistant professor of nuclear engineering, advised Nikolaus Kemper from University of Massachusetts–Lowell and **Sarah Raver** from Penn State as they conducted research in the field of radiochemistry that focused on building a model for the Szilard-Chalmers effect in order to understand what materials should be used to produce the highest yield of the desired radioisotopes. Throughout the course of the program, Peter Miraldi, teaching professor in communication arts and sciences, led the professional development activities for the fellows. The sessions focused on developing the students' skills in team building, scientific presentation, resume writing, interviewing, conflict management, and impromptu speaking.

Additionally, the students had the opportunity to learn about the Penn State nuclear engineering graduate program and its research areas from faculty guest speakers, **Jean Paul Allain**, professor and head of the Ken and Mary Alice Lindquist Department of Nuclear Engineering, **Leigh Winfrey**, associate professor of nuclear engineering, and Wang, assistant professor of nuclear engineering. Students also heard from **Candace Davison**, assistant director for education and outreach in the Radiation Science & Engineering Center, who spoke about the Breazeale Reactor and Westinghouse employees, and Penn State alumni **Abdul Dulloo**, **Hilary Ruby**, and **Jason Beebe** who spoke about the nuclear power industry.

Staff and alumni highlights

Alumnus Tom Sambolt honored with 2020 Outstanding Engineering Alumni Award

Tom Sambolt, a 1989 graduate of nuclear engineering, was selected to receive the 2020 Outstanding Engineering Alumni (OEA) Award for the Ken and Mary Alice Lindquist Department of Nuclear Engineering. Currently the director of new design for the Naval Nuclear Laboratory (NNL), Sambolt oversees the design of naval nuclear propulsion plants in submarines and aircraft carriers. He was involved in the first nuclear-powered Ford-class aircraft carrier, named USS Gerald R. Ford after the former president.

Sambolt is the executive sponsor for NNL student recruitment efforts at Penn State, working to pair students with internships, co-ops, graduate fellowships, and networking opportunities. He also serves as a judge for the Undergraduate Teaching and Research Experiences in Engineering public speaking competition, and he is a member of the Industrial and Professional Advisory Council for the nuclear engineering department.

As an undergraduate, Sambolt served as a leader in his fraternity, Phi Delta Theta, through which he met his wife, Jane. They reside in Pittsburgh and have three daughters.

Marc Wonders, a 2020 Penn State doctoral alumnus of nuclear engineering, was awarded a 2020 Graduate Fellowship from the National Nuclear Security Administration.

Mark Dorn, a 2009 alumnus of nuclear engineering, was awarded the Penn State Nuclear Engineering Society Early Career Award.

Supporting the Ken and Mary Alice Lindquist Department of Nuclear Engineering

Since July 1, 2019, the Ken and Mary Alice Lindquist Department of Nuclear Engineering has received 80 gifts totaling over $86,000. In addition, the department is sharing in a $50,000 fund from Exelon to support student scholarships. We'd like to thank all of our donors for their generous support.

For more information on how to support the department, please contact Melissa Showalter, associate director of major gifts in the College of Engineering, at mus41@psu.edu or 814-865-9031.

Ken and Mary Alice Lindquist Department of Nuclear Engineering staff

Erin Blumsack
External Relations Coordinator
erinblumsack@psu.edu

Mattie Dutrow
Facilities Representative
mlr5128@psu.edu

Jaime Focht
Department Head Staff Assistant
jlb402@psu.edu

Beth Huber
Graduate Support Assistant
bah41@psu.edu

Melissa Price
IT Support Specialist
map11@psu.edu

Danielle Snyder
Administrative Support Coordinator
dlh65@psu.edu

Corby Williams
Financial Assistant
cjw33@psu.edu

Matthew Zerphy
Chief Administrative Officer
mxz206@psu.edu

Letter from the Penn State Nuclear Engineering Society president:

Opening the door for improved collaboration

These days, we're experiencing many changes to the lives we once knew. Whether it's in traveling, going to work, sending your kids off to school, or heading out to a party or event—we are working and interacting differently these days.

In our Penn State Nuclear Engineering Society (PSNES) alumni organization, we are making the same changes. While we find some challenges ahead during these changing times, we also see many new opportunities to connect with NucE alumni and faculty to provide enriching developmental and mentorship opportunities for students.

This year, PSNES has many exciting plans, and we hope to involve even more of our alumni! Our board is eager to grow the society and expand our impact as nuclear engineers. As president of this organization, I look forward to the continued energy, perspective, and knowledge of our diverse membership.

In the coming year, PSNES will focus on the following imperatives: virtual presence, the PSNES Mentorship Program, a monthly podcast series, and continued student engagement.

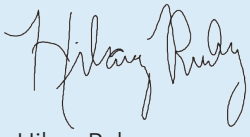
While COVID-19 might limit in-person events, it certainly opens the door for improved virtual collaboration. Keep an eye out for invitations to events designed to promote fellowship and communication among members and students. This virtual presence provides a rich foundation to begin exploring new and creative ways to connect with today's students through our mentorship program.

Beyond live events, we are also developing recorded monthly podcasts to foster a connection with those who may not be able to attend events. These podcasts on a wide variety of topics related to the nuclear industry, featuring alumni, students, and faculty, will also contribute to the legacy of lasting advice we want to leave for generations of nuclear engineers to come.

Building upon our society's 17-year history, PSNES commits to working diligently to provide enriching experiences for students and to continue to support the Ken and Mary Alice Lindquist Department of Nuclear Engineering.

PSNES looks forward to seeing what the coming year will bring. We Are!

Sincerely,



Hilary Ruby
PSNES President
NucE '09, '12 M.Eng.

Connect with the Penn State Nuclear Engineering Society on LinkedIn.

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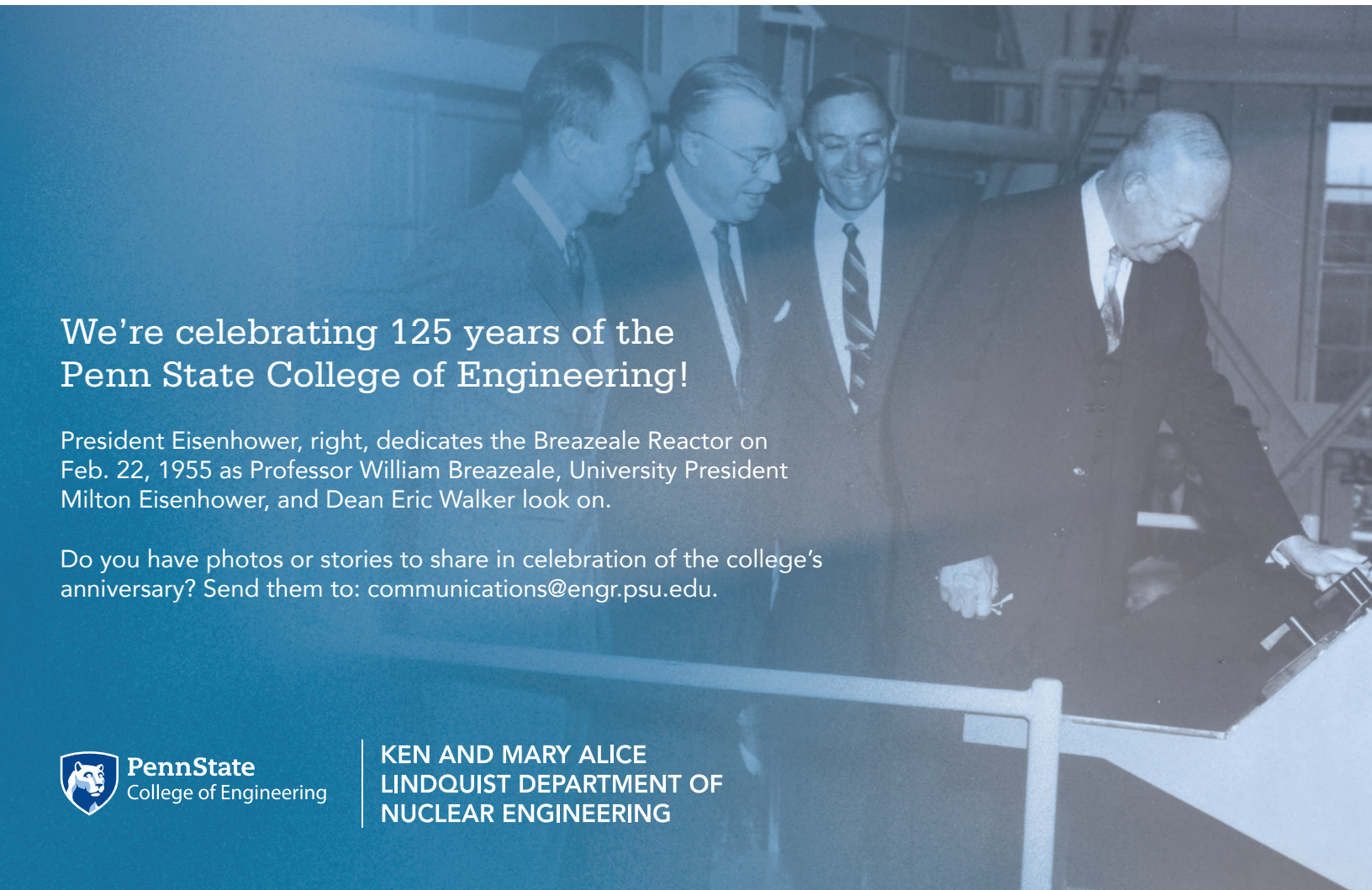

We're celebrating 125 years of the Penn State College of Engineering!

President Eisenhower, right, dedicates the Breazeale Reactor on Feb. 22, 1955 as Professor William Breazeale, University President Milton Eisenhower, and Dean Eric Walker look on.

Do you have photos or stories to share in celebration of the college's anniversary? Send them to: communications@engr.psu.edu.

PennState College of Engineering

KEN AND MARY ALICE LINDQUIST DEPARTMENT OF NUCLEAR ENGINEERING