FALL 2019

ENGINEERING PHYSICS

UNIVERSITY OF WISCONSIN-MADISON

PREPARING TOMORROW'S LEADERS WITH HANDS-ON LEARNING

CHAIR'S MESSAGE

Greetings from Madison!

As some of you may have already heard, I took over as department chair this summer. I joined the EP faculty in 2001 with a research portfolio in modeling and simulation for nuclear energy systems—both fission and fusion—and have brought much of that to the classroom in our nuclear engineering programs. As part of the energy systems and policy cluster, I also connect to the broader energy community across the UW-Madison campus.

I have big shoes to fill in the chair's office. I'm fortunate to have known all of the previous chairs and appreciate the important legacy they have left behind. I may be the first chair who was not hired by Max Carbon, but I have been lucky to know him for more than 25 years. It is still easy to see the impact he had in creating a department that focuses on a rare combination of excellence and collegiality. These principles have guided us in hiring eight new faculty in the last four years, including the newest addition, Yongfeng Zhang, joining us in fall 2019 from Idaho National Laboratory. You can read about two other recent additions in this issue. The department is abuzz with the energy of new young faculty setting up their labs, recruiting outstanding students, and winning their first grants as they establish themselves as leaders in their fields.

We are all thankful, as well, for the leadership of Douglass Henderson over the last five years. He jumped in quickly when Jake Blanchard moved on to the dean's office and provided excellent leadership through an important period of setting strategic direction for the future of the department while overseeing turnover of about a third of our faculty. His work as chair has set me up for success and we look forward to having him and Jake back from their administrative roles.

In other transitions, Professor Ray Fonck has retired and become an emeritus faculty member. He has been a leader in plasma physics and fusion research on campus and beyond, including a stint as the director of the U.S. Department of Energy's Office of Fusion Energy Sciences in Washington, D.C. Most recently, he has secured funding and support for Urania, an upgrade to the Pegasus experiment that Ray began about 20 years ago. While we will miss Ray's wisdom and experience among our faculty, we expect to still see him around the department as Urania's expansion is completed and new rounds of data collection begin.

A vibrant ecosystem of new companies in nuclear science and technology has created opportunities for increased industrial engagement. Near Madison, Phoenix LLC is building a new center for neutron imaging, and Shine is building a new facility for producing medical isotopes. Both companies—which are led by EP alumni—are interested in leveraging the capabilities of our research reactor as we focus on expanding its role in research and irradiation services.

Farther afield, new nuclear reactor designers like Kairos Power, among others, are funding research and hiring our graduates to continue the work they begin here. Some alumni are making an impact in a different way with new inventions to make working in nuclear science and technology safer and more efficient (see the Bakshi story in this issue).

If you'd like to stop by and chat, my door is always open. Or you can look for me most Fridays at 7 a.m. at Mickies Dairy Bar with a group of students, continuing a 27-year tradition. Thank you for your continued support of our department.

ON, WISCONSIN!

Paul Wilson
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BENEFITS OF NUCLEAR ENGINEERING GRADUATE EDUCATION ARE CLEAR

Jayeesh Bakshi's (MSNEEP '14) graduate studies at UW-Madison inspired him to develop a new type of transparent radiation shielding. And not only is his invention benefitting the nuclear industry, but it also is transforming treatment for neuroblastoma, a rare cancer that affects infants and young children.

Bakshi's invention, ClearView Radiation Shielding, overcomes big drawbacks associated with conventional shields made of lead.

As an undergrad at Thapar University in India, he first stepped foot in the nuclear industry through a six-month internship with the Atomic Energy Regulatory Board (AERB), the Indian equivalent of the Nuclear Regulatory Commission in the United States. The experience fueled his passion for nuclear, and he started applying to graduate programs for nuclear engineering.

Although he was accepted to several graduate programs, Bakshi says choosing UW-Madison was an easy decision, given the EP department's overall excellence and many renowned faculty.

At UW-Madison, he found an invigorating academic environment and inspiring faculty who were highly dedicated to his success. Courses taught by Professor Douglass Henderson, especially NE 408 on ionizing radiation and NE 555 on reactor dynamics, played a crucial role in his training as a nuclear engineer.

"My career is in radiation protection, and to be successful you need to understand how radiation works and how it interacts with matter and different materials," Bakshi says. "Professor Henderson's courses provided me with essential skills and knowledge in these areas."

Jayeesh Bakshi at the Grand Gulf Nuclear Station in Port Gibson, Mississippi.

In addition, Bakshi says the opportunity to do hands-on work with the nuclear reactor on campus enhanced his educational experience. "Having access to the reactor allowed me to apply all the theory I'd been reading about and actually see the real results, which was incredibly valuable," he says. "UW-Madison is one of very few programs in the country that have a working reactor, and it's a phenomenal resource for educating students."

Presented with a career opportunity at Radium Inc., a Virginia-based company specializing in working in locked high radiation areas, Bakshi capitalized on his graduate training to take on an exciting challenge: Devise a better, safer alternative to conventional radiation shields made of lead.

"Lead does a good job for radiation protection, but it's a nasty material; it's toxic and not easy to deal with," says Bakshi, who lives in Palo Alto, California. "Nuclear power plants, hospitals and national labs spend significant amounts of money on treatment and disposal."

At Radium, working closely with company president Cam Abernethy, Bakshi led the development of a transparent radiation shield that's as effective as lead in attenuating radiation while being 50% lighter in weight. The patented ClearView Radiation Shielding is made of non-hazardous materials, allowing for simple disposal without any special treatment.

Since Radium's shielding is completely see-through, it provides much greater visibility in high-radiation areas. Bakshi says that has enabled increased efficiency at nuclear power plants by making it much easier for workers to safely see what they're doing as they complete important tasks, maintenance and inspections.

MORE: go.wisc.edu/engrnews-072219

ClearView Radiation Shielding in use at a nuclear power plant. The see-through shielding provides much greater visibility for workers in high-radiation areas, which has helped increase efficiency at nuclear power plants. *Photo courtesy of Jayeesh Bakshi.*

2019 Engineers' Day Distinguished Achievement Award Recipient

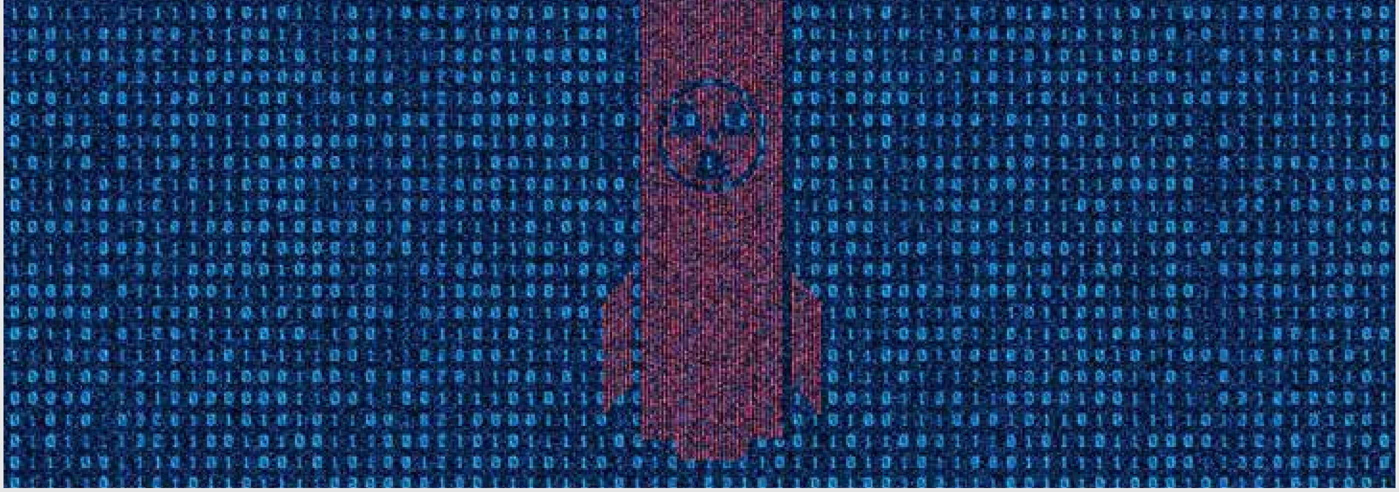
Annie Caputo
Commissioner, U.S. Nuclear Regulatory Commission (BSNE '96)

When Annie Caputo graduated from UW-Madison in 1996, job prospects for nuclear engineers were less than stellar. However, armed with additional experience in communications, she accepted a position in Chicago as an engineer and executive assistant with Commonwealth Edison. She leveraged that experience into quickly becoming a congressional affairs manager for the company.

That experience set the course for her career. She and her family relocated to Washington, D.C., where she later took a position on professional staff for the U.S. House Committee on Energy and Commerce, focusing on nuclear energy issues and supporting development of the Energy Policy Act of 2005.

For 13 years, Caputo served on Capitol Hill as staff for the House Energy and Commerce Committee and the U.S. Senate Environment and Public Works Committee. In May 2018 she was sworn in as a Commissioner on the U.S. Nuclear Regulatory Commission.

The college is honoring Caputo as an industry leader whose policy work and dedication make a difference nationally and inspire young engineers.



STRENGTHENING NUCLEAR SECURITY WITH COMPUTATIONAL TOOLS

Arrielle Opotowsky

In the event of a nuclear security incident—for example, if investigators were to discover stolen nuclear material—a number of pressing questions would arise.

Chiefly, who is responsible for the illicit activity? Is it state-sponsored or the work of terrorists?

To help answer these questions, and ultimately hold the perpetrators accountable, experts in nuclear forensics try to learn as much about the nuclear material or weapon as quickly as possible.

One way to start is by measuring the gamma rays produced by the material.

These measurements reveal important information about the material's composition, such as the type of isotopes present, which is instrumental in guiding an investigation.

"Knowing these details about a material helps investigators deduce how it could've gotten into someone's hands to make a bomb," says Arrielle Opotowsky, a PhD student in nuclear engineering and engineering physics. "Analyzing these measurements points you to the reactor technology that created the material, and that's specific enough to individual countries that you can really narrow down who is responsible just from that one piece of information."

Scientists perform these measurements on a sample of the material in a lab, but it can take months to complete this complex analysis. In her nuclear forensics research, which is supported by a U.S. Department of Homeland Security fellowship, Opotowsky is exploring a way to potentially speed up this process using a computational approach rather than physical experiments.

Specifically, she's researching machine learning methods that could allow us to quickly determine where a nuclear material came from based on measurements of that material. This machine learning approach could ultimately enable investigators to rapidly assess the material using a small instrument out in the field.

"It won't replace an actual scientist doing experiments, but it might be good enough to give some preliminary results quickly, and that can help guide an investigation in the right direction sooner," says Opotowsky, a member of Grainger Professor of Nuclear Engineering Paul Wilson's research group.

Computational tools are also a powerful resource for preventing the spread of nuclear weapons—and EP PhD student Katie Mummah's research promises to aid international nonproliferation efforts.

Mummah is also a member of Wilson's research group, which has developed nuclear fuel cycle simulation tools. Mummah is harnessing those software tools to provide additional insight into how nuclear material is passing through various pathways, from one facility to another, throughout its lifecycle. This information, such as how quickly material is accumulating in a certain pathway, can help alert the nonproliferation community to possible red flags.

Now, the EP department is growing its research and education footprint in nuclear security by participating in two new consortia—the Consortium of Enabling Technologies and Innovation (ETI), and the Consortium for Monitoring, Technology and Verification (MTV).

The U.S. Department of Energy's National Nuclear Security Administration (NNSA) is funding both consortia, which link basic research at universities with the capabilities of the U.S. national laboratories to advance the NNSA's nuclear science, security and nonproliferation goals and educate its future workforce.

Paul Wilson

Katie Mummah

In the ETI consortium, composed of 12 universities and 10 national laboratories and led by Georgia Tech, Wilson is leading the data science research area.

Researchers in this area will investigate methods for combining and analyzing many different kinds of data to detect behaviors and anomalies in the actions of both nation states and non-state actors that telegraph nuclear weapons proliferation.

Wilson says that data could come from a wide variety of places, including satellite images, U.S. intelligence services, process data measured at nuclear facilities, data from news stories and social media feeds, and nuclear safeguards put in place by mutual agreement of the countries.

Additionally, Wilson is participating in the MTV consortium as a principal investigator. That consortium, a partnership of 14 universities led by the University of Michigan, seeks to improve U.S. capabilities to monitor the nuclear fuel cycle.

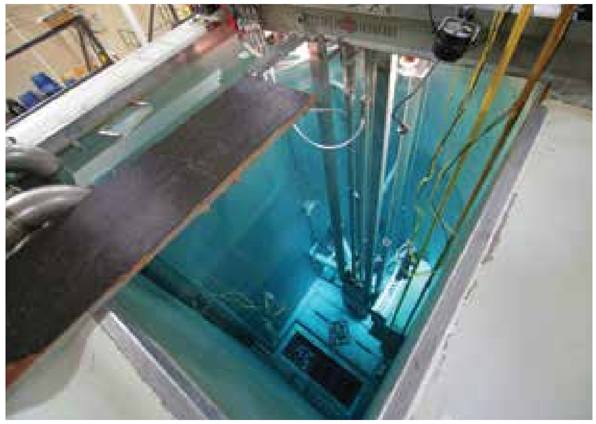
In his cross-cutting role as the nuclear policy lead, Wilson's goal is to ensure the students understand how their fundamental research is relevant to the actual monitoring and detection of nuclear nonproliferation. In particular, he will provide insight on how policy issues play a key role in determining what technologies will ultimately be implemented.

"Every time a new technology is available doesn't necessarily mean it's going to be deployed in the field," he says. "That's because international safeguards are put in place through an open, negotiated process, and the countries and companies that are being monitored have to agree to certain technologies being deployed in their facilities. And they may have legitimate reasons, such as protecting proprietary business information, for opposing a technology. So I want to help the students understand that these policy issues matter and it's not just a purely technical pursuit."

MORE: go.wisc.edu/engrnews-091319

A BROADER REACH:

Expanded role for UW-Madison reactor adds value to industry



With the growth of such companies as Phoenix and Shine Medical Technologies, Wisconsin is rapidly becoming a center for technology development in neutron sources and medical isotope production, and UW-Madison is poised to play in important role in fostering these advances.

As it looks toward the future, the university is building on a nearly 60-year tradition of leadership in nuclear engineering with an expanded role for its research-and-teaching nuclear reactor that extends the facility's expertise into industry.

"We see it as continuing to play an important part in the education of our students and in research," says Ian Robertson, dean of the College of Engineering. "In the spirit of the Wisconsin Idea, industrial sponsorship and usage also are important, because we can leverage the reactor to provide a service to a broader community."

Working toward becoming the world's leading medical isotope producer, Shine is building its first manufacturing facility just south of Madison, in Janesville, Wisconsin. When it's complete, it could produce one-third of the world's demand for medical isotopes, but will serve primarily the U.S. market. Founder and CEO Greg Piefer (BSEE '99, MSNEEP '04, PhDNEEP/MedPhys '06) says the UW-Madison nuclear reactor can fill a need even before his facility is ready. "The reactor can provide a radiation environment similar to that found in our plant, and so we can test some components in that radiation field prior to startup," he says. "If we find any issues, we will have a head start on resolving them. Typically, you wouldn't be able to do that type of testing before the plant starts up."

He says a future collaboration with the reactor might be in producing certain medical isotopes through a process called neutron capture. "These isotopes have an emerging role in treating, and perhaps even curing, cancers in some patients," he says. "This is an extremely exciting field that may substantially change the way we approach the treatment of various cancers. We're excited to evaluate with the UW nuclear reactor if there is a feasible path to work together and get these life-saving products to market more quickly."

Founded in 2005, Phoenix (formerly Phoenix Nuclear Labs) has become an internationally recognized manufacturer of neutron generators, and its state-of-the-art imaging center, currently under construction in Fitchburg, Wisconsin, will be the first facility of its kind to offer commercial neutron imaging services. CEO Ross Radel (BSNE '03, MSNEEP '04, PhDNEEP '07), says the company can draw upon the reactor's capabilities to help test and validate components of Phoenix products. "There are only a couple of dozen places in the country that have neutron fluxes the reactor can produce," he says.

An additional benefit, notes Radel, is that the reactor is closely tied to one of the best nuclear engineering programs in the country. "The professors and staff are really great to work with, not just for providing services, but also because they offer intellectual horsepower," he says. "If Phoenix comes to them with a technical challenge we are trying to solve, there are people to help us do that. There are only a handful of places in this country you can go to find that sort of expertise."

MORE: go.wisc.edu/engrnews-090519

FOCUS ON NEW FACULTY

BENEDIKT GEIGER, STUDYING PLASMA PHYSICS FOR FUSION ENERGY

It's an exciting time for fusion research at UW-Madison, which already has an international reputation for leadership in fusion science and plasma physics. For one, major upgrades to the College of Engineering's Helically Symmetric eXperiment, or HSX, will take that one-of-a-kind fusion experiment to new heights.

Adding to this "fusion energy" is Benedikt Geiger, who joined the EP department as an assistant professor in spring 2019.

Motivated by the ultimate goal of achieving fusion energy, Geiger's research focuses on high-temperature plasma physics. Fusion, the process that powers our sun, holds potential for providing an abundant source of environmentally friendly energy.

But first a number of challenges need to be overcome. One of these big challenges involves finding ways to limit and control turbulence in the plasma as it's magnetically confined in fusion devices.

In a fusion device, plasma fluctuations will develop turbulence, which can cause particles and energy to flow out of the plasma. That's a problem because such strong transport will reduce the energy confinement of the fusion experiment and limit the temperatures that can be achieved in the fusion plasma.

"In my research I'm trying to gain a better understanding of turbulent transport in fusion devices in order to find ways to reduce it, which will ultimately help improve the feasibility of fusion energy," Geiger says.

After earning his master's degree and PhD in physics from Ludwig Maximilians University in Munich, Germany, Geiger was a postdoctoral scholar at the Max-Planck Institute for plasma physics in Garching, Germany, and then joined the institute as a senior staff scientist. He went on to lead a young investigators group there and conducted experiments at the Wendelstein 7-X stellarator before coming to UW-Madison.

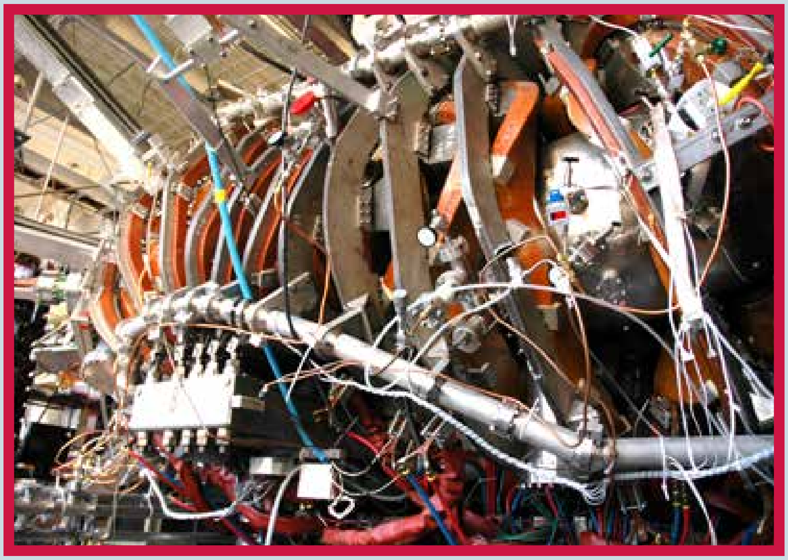
Earlier in his career, Geiger's research focused on tokamaks, the most prevalent and well-developed type of fusion-research devices. He now primarily studies stellarators, which are widely viewed as the main alternative to tokamaks for fusion reactors.

"I'm excited by stellarator research because these devices haven't been excessively studied for long and there's still a lot to explore," he says. "With stellarators, we can work with smaller, less expensive devices and do interesting physics. And we have ideas on how to maybe get stellarators to perform better than tokamaks in terms of transport properties."

At UW-Madison, Geiger will be heavily involved in research with the HSX stellarator, which is housed in the ECE department. His experimental research involves injecting trace particles into the plasma and then following their movement.

"By looking at the trace particles' movement from the plasma edge to the core, and measuring how long that takes, you can get really important information on the transport processes," he says. "In order to explain the behavior of the plasma, we first need to measure the behavior, and one key measurement we can take involves the particle transport."

In addition, Geiger will be contributing to HSX upgrades by implementing a new heating system that he brought over from Germany. "With this upgrade, we'll be able to operate HSX with 10 times higher heating power, which will allow the machine to operate in a completely new parameter space and really give a boost to our fusion research at UW-Madison."



Geiger says the EP department's outstanding reputation in plasma physics and fusion science attracted him, as well as the resources available for plasma research at UW-Madison overall.

"It's not only the EP department, but also the ECE department and the physics department, which together have four plasma physics experiments at the university," he says. "UW-Madison has a really great community with a lot of brilliant professors and talented students, who have shown they can build their own devices and really make an impact. There's a lot of excellent work happening here that drew my attention."

MORE: **go.wisc.edu/engrnews-090519a**

The Helically Symmetric eXperiment (HSX).

CURT BRONKHORST, SHEDDING LIGHT ON HOW MATERIALS DEFORM AND FAIL

Curt Bronkhorst developed his love of mathematics and physics as an undergraduate engineering student at UW-Madison. Now, he's excited to return to the university as a professor to help prepare the next generation of engineering leaders to address important problems.

Bronkhorst, who joined the department as a full professor in spring 2019, specializes in theoretical and computational mechanics of materials.

"I focus on developing theory to describe the way materials deform," he says.

He implements his theoretical models in computer code, such as in standard engineering software, to provide simulations of engineered structures.

"My goal is to give engineers better tools through computational simulation to aid in their design and engineering assessment work," he says. "With these improved tools, engineers wouldn't have to overdesign structural components to avoid failure—saving material and weight."

Bronkhorst focuses primarily on metallic materials in his research. It's an effort that has far-reaching implications for components made of metal, including in vehicles, aircraft and countless other structures.

For practical use, metal needs to be deformed into a desired shape—and this irreversible deformation is known as plasticity. For example, think of a solid, straight piece of metal being bent permanently into a circle.

By studying the physics of plasticity, Bronkhorst aims to learn more about the optimal conditions under which materials will deform without failing.

> **"Moving into an educator role will allow me to make a greater impact … ."**
> — Curt Bronkhorst

"Improved understanding in this area will allow us to design new materials for specific applications, and to more rapidly design those new materials using computational tools," he says.

He is also particularly interested in investigating material damage and failure. "It's a very complex physical process and we're still not able to predict very well when and where materials fail, so that's a large focus area in my work," he says.

After earning bachelor's degrees in mechanical engineering and mathematics from UW-Madison, Bronkhorst earned a master's degree and PhD in mechanical engineering from the Massachusetts Institute of Technology. Then he worked as a senior research scientist at Weyerhaeuser Company, a timber, land and forest products company in Seattle, Washington, where he researched fibers, composites and material manufacturing processes.

After 11 years at Weyerhaeuser, Bronkhorst joined Los Alamos National Laboratory as a scientist. During his 16 years at Los Alamos, he worked on many projects with national security and defense applications and ascended to a senior scientist position.

"Serving our country, in the context of preserving our national defense capabilities, was a distinct honor and privilege of working at Los Alamos," he says.

At this stage in his career, Bronkhorst says he was looking to contribute in new ways, and the opportunity to return to Madison and teach students was too exciting to pass up.

"Moving into an educator role will allow me to make a greater impact," he says. "I'm especially excited to work with students and prepare the next generation of engineers and scientists to make a difference."

Bronkhorst remains a guest scientist at Los Alamos and maintains some activities and collaborations there. He looks forward to leveraging his connections at Los Alamos and other national and DOD labs to provide educational opportunities for his students.

He says the excellence of the EP department, with its unique combination of disciplines, was also a big draw. "Engineering mechanics is really my core discipline, so the mechanics side of the department is a very strong fit for me," he says. "But I've also worked on projects with nuclear materials, such as researching fuel rod materials and radiation-induced damage in metallic material, that are relevant for the department's nuclear engineering program, and I look forward to collaborating with faculty in the department and beyond."

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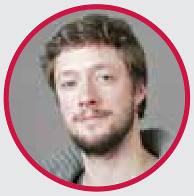
ENGINEERS WIN DOE GRANTS TO ADVANCE NUCLEAR ENERGY TECHNOLOGY


Adrien Couet


Mark Anderson


Douglas Henderson

The U.S. Department of Energy recently awarded more than $28.5 million through its Nuclear Energy University Program (NEUP) to support nuclear energy research and development projects, including a total of about $1.6 million in grants for UW-Madison engineers.

Assistant Professor Adrien Couet is leading a $800,000 project to predict component service lifetimes and design limits. He is studying, in-situ, the individual and synergistic effects of corrosion, irradiation and mechanical stress on material removal by corrosion and erosion in 316 stainless steel tubes exposed to a molten chloride flow. He will conduct the work collaboratively with Oak Ridge National Laboratory and Terrapower LLC, all with a leadership role in research and commercialization of molten salt reactors.

Mechanical Engineering Assistant Professor Mark Anderson, an EP affiliate, is leading a $800,000 project to explore three different areas that will help to improve commercialization of sodium-cooled fast reactors and to aid in testing for the DOE's versatile test reactor. These areas include obtaining detailed heat transfer measurements in sodium to develop more precise heat transfer relations with highly resolved temperature sensors; testing and analyzing compact heat exchangers for use with sodium; and developing, testing and calibrating in-pool submersible flow meters with modern materials and technologies.

In addition, Professor Douglass Henderson received a $211,294 infrastructure award to develop new high-throughput capabilities for the entire nuclear materials community. The UW-Madison nuclear engineering program has unique strength in experimental programs to develop nuclear technology, and Henderson will develop an automated high-speed surface imaging and chemical analysis capability for additively manufacturing high entropy alloys. He and his collaborators will also develop high-throughput irradiation capabilities at the University of Wisconsin Ion Beam Laboratory to investigate radiation damage resistance of high entropy alloys.