

# ENGINEERING PHYSICS



NEW  
**AEROSPACE  
OPTION**

helps launch careers



### Greetings!

There are few single engineering feats that come as close to representing the breadth of the Department of Engineering Physics than the Feb. 18, 2021, landing of the NASA Perseverance rover on Mars. Some department alumni have leadership positions on the engineering team that designed and safely delivered the rover to the planet's surface, and others have performed safety analysis of the radioisotope thermal generator that powers the rover as it starts its

exciting mission. Watching the landing was a thrilling escape from the long and difficult year that many have endured.

Another thrill has been welcoming new faculty member Ben Lindley, who quickly got to work on his first DOE Nuclear Energy University Program (NEUP) project only six weeks after starting, exploring new aspects of integrating nuclear energy with renewables for a variety of clean energy products. Lindley brings a wealth of experience from the nuclear energy industry, where he has both contributed to the development of novel reactor physics approaches and overseen system integration for new reactor designs. After only six months, he is already making an impact on how we engage with a vibrant ecosystem of new companies pursuing innovative nuclear energy systems.

This has been the first year that our aerospace engineering option (formerly the astronautics option) has been in place for the engineering mechanics program. Not only does the change better reflect the focus of the curriculum and the expertise of the faculty who support it, but it resonates more strongly with high school students looking to pursue their passions. A highlight of this program for many students is the experimental course based in the wind tunnel, and the high demand for this course combined with safety protocols due to the ongoing pandemic has resulted in offering lab sections every day instead of twice a week.

A point of pride across all of our undergraduate programs is the career versatility that our alumni have following their deep exposure to fundamental physics and math. For example, in fall 2020, we honored engineering mechanics alumna Amy Warner with the college Distinguished Achievement Award. Amy arrived as an undergraduate with dreams of becoming an astronaut and has built a career in the IT sector. She began in a role that directly applied her engineering mechanics knowledge to the design of computer hard drive components. Today she is a vice president at Intel Corp., where she leads its IT digital business solutions and is corporate director of accessibility.

### On, Wisconsin!

Paul Wilson

Chair, Department of Engineering Physics and Grainger Professor of Nuclear Engineering  
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# FOCUS ON NEW FACULTY: BEN LINDLEY

## Designing advanced nuclear reactors



Photo: iStock.com/vchal

Even as industry moves forward with developing next-generation nuclear reactors, there are a variety of scientific and technological questions that still need to be answered.

“With these new reactor types, there are many different physics phenomena going on, as well as different materials and components,” says Assistant Professor Ben Lindley. “And so we need different methodologies to analyze new reactor designs and understand how they perform.”

Lindley’s expertise is in reactor physics, and his research focuses on designing and analyzing new nuclear reactors. To perform those analyses, he develops and applies cutting-edge computational methods.

His research also involves studying ways to integrate nuclear reactors with variable renewable energy sources to harness the advantages of both while mitigating their drawbacks.

**“I’m interested in how we design nuclear reactors as a complete system, and how we can come up with better components to make reactors more economical, improve their performance and make them even safer,” says Lindley, who joined the faculty in fall 2020.**

Lindley earned a bachelor’s degree and master of engineering degree in mechanical engineering and his PhD in nuclear

engineering, all from the University of Cambridge in England.

After his PhD, Lindley worked as a senior nuclear engineer and reactor physicist at Jacobs (formerly Wood, Amec), a research and development consultancy in the United Kingdom, from 2014 to 2020. At Jacobs, he was part of a team that developed software so that his industry clients could analyze their nuclear reactors. His role also allowed him to conduct research and take part in major national and international research and development programs.

“I feel fortunate to have worked in an environment where I could learn about how the industry functions and understand how some technology is applied in practice while also maintaining my research career,” he says.

When he saw the open faculty position at UW-Madison, he says the opportunity was too exciting to pass up.

“The United States is widely seen as the world leader in nuclear engineering research, and UW-Madison has a reputation as one of the best programs in the country, so it’s a real privilege to be able to teach and do my research here,” he says. “It’s a great opportunity to apply some of the knowledge and skills I’ve learned in industry back into an academic environment, where I’m also excited to work with students.”

At UW-Madison, Lindley is already leading a research project to design and model an integrated energy system that can co-produce electricity and clean water through desalination. A grant from the U.S. Department of Energy Nuclear Energy University Program is funding the work.

The multidisciplinary team is studying how to combine concentrating solar power and an advanced nuclear reactor (in this case, a lead-cooled fast reactor) to maximize the benefits of both. Nuclear energy is most economical when reactors constantly generate power at a fixed level. On the other hand, concentrating solar power production varies with the sun, but this technology also provides thermal storage and thus flexibility.

By integrating these systems, Lindley says, utility operators could produce more electricity when it is in high demand or most expensive. Then, when electricity demand is low, the plant could switch to making best use of the thermal storage, and also produce more clean water by using heat for desalination.



# NEW AEROSPACE OPTION HELPS LAUNCH CAREERS

The aerospace industry offers many career opportunities for engineers, who can apply their skills to challenges involving rockets, spacecraft, airplanes and more.

Now, undergraduate students in the UW-Madison engineering mechanics degree program can focus their education on this field by selecting the new “aerospace engineering option.”

In fall 2020, the department changed the name of its longstanding astronautics option to the aerospace option.

“When the astronautics option was created it was focused on space and so the name fit,” says Professor Matt Allen. “And while many of our graduates still go to work on launch vehicles, satellites and other space-related technologies, the program now includes some great courses regarding aircraft, and the jobs that our students get reflect this shift. The new name better reflects the courses that we now teach and the jobs that our students get.”

Department Chair Paul Wilson says another reason for the name change is that the term “aerospace” has much better name

recognition for both students and employers. “So the aerospace label will make it easier for our students to connect with companies at career fairs and elsewhere,” Wilson says.

And because the aerospace option is based in the department’s highly regarded engineering mechanics degree program, students receive a well-rounded education and develop versatile skills. For example, in the engineering mechanics degree program, students learn the fundamentals of mechanics and dynamics—topic areas that are key for aerospace applications but also for a broad range of other applications and industries.

While the aerospace option at UW-Madison is not a full ABET-accredited aerospace engineering degree, Professor Riccardo Bonazza says UW-Madison’s program has a strong track record of launching students’ careers.

**“Our students find great jobs in the aerospace industry and they are very successful,” Bonazza says.**

UW-Madison engineering mechanics graduates have gone on to work at NASA, Lockheed Martin, Boeing, United Launch Alliance, GE Aviation, the NASA Jet Propulsion Laboratory, Joby Aviation, and ATA Engineering, among others. An EMA graduate even founded his own company, Dark Aero, together with his two brothers, also graduates of the College of Engineering.

When Bonazza keeps in touch with students after they graduate, he always asks if their education prepared them well for their jobs, and if the program missed any important areas. “And the students say, ‘Our UW-Madison education was very effective and covered all the right areas. We’re able to perform at a high level and really contribute when we join these companies,’” Bonazza says.

Because the engineering mechanics program has a relatively small number of students, Bonazza says there is a close-knit community feel and smaller class sizes, which enables faculty to have more direct interaction with students and develop a good rapport.

“I think that’s one of the great advantages of this program,” Bonazza says. “The students and faculty pretty much know everyone’s name, and the students study together and really benefit from these interactions. It’s an effective, highly positive learning environment that the students enjoy participating in.”



# A History of Academic Excellence

Department Chair Paul Wilson says renaming the option also made sense because aerospace is a more fitting label for the astronautics option's evolution as new faculty joined the department and created courses focused on aerospace topics.

Astronautics refers to the science and technology of vehicles that travel beyond the Earth's atmosphere into space—rockets, spacecraft and satellites, for example. On the other hand, aerospace engineering refers to the study of navigation both inside and outside of the Earth's atmosphere—so it encompasses both the science of airplanes and flight as well as technology for outer space.

Professor Riccardo Bonazza has played a crucial role in shaping the aerospace curriculum into what it is today. In the 1990s, Bonazza took over teaching EMA 521: *Aerodynamics*, after Professor Alois "Bud" Schlack retired, and he revamped the course.

Then, in 1996, Ron Thompson, a faculty associate and instructor, helped acquire a wind tunnel for the college through a donation from Greenheck, a company based in Schofield, Wisconsin. The wind tunnel was designed by two undergraduate students (Matthew Orzewalla, currently at NASA's Jet Propulsion Laboratory, and Marty Gissel, who started his career at Greenheck right after graduating).

With the new wind tunnel on campus, Bonazza jumped at the chance to harness it to provide vital hands-on learning opportunities for students. He developed a new course, EMA 522: *Aerodynamics Laboratory*, which was first offered in spring 1999. In the lab course, students conduct experiments in the wind tunnel—for example, taking measurements of lift and drag on a wing—and analyze their data.

"The aerodynamics lab is very popular with the students, who say they really value the hands-on experiences they get through working with the wind tunnel," Bonazza says.

Then, Bonazza developed another new course, EMA 523: *Flight Dynamics*, which was introduced in 2002. Most recently, Bonazza created EMA 524: *Rocket Propulsion*, a course that debuted in fall 2013.

Some of the distinctive course requirements of the aerospace option include advanced mechanics of materials, vibrations, advanced dynamics, and controls.

Popular electives in the aerospace option include flight dynamics, rocket propulsion, satellite dynamics, astrodynamics, experimental vibrations.

## Amy Warner

### 2020 Distinguished Achievement Award recipient

Amy is an IT leader whose professional adaptability and commitment to empowering those of all abilities make her an example for future engineers.



Amy Warner (BSEM '91)

*Vice president and general manager of IT digital business solutions and corporate director of accessibility, Intel Corp.*

#### How did your experience in the College of Engineering shape your career path?

It's the foundation of analytical thinking, solving complex problems, learning how to collaborate with others, and also just discipline. It was a challenging curriculum and it shaped my perseverance and passion for solving complex problems with technology.

#### How did you choose to attend UW-Madison?

My dream was to be an astronaut and at that time aerospace engineering was a distinction within engineering mechanics. My other passion was to be a collegiate soccer player, and I was offered a scholarship for soccer. Madison was the perfect opportunity. It was a top engineering school and I could pursue my passion for athletics.

#### What are some of your fondest memories of your time at UW-Madison?

We went to the Final Four NCAA championships my sophomore year, and in my senior year, we were in the NCAA championship game. We ended up No. 2 in the nation. To this day when I meet people from Wisconsin, we talk about walking up Bascom Hill backward in the middle of winter, and those amazing days when I would be sitting outside in the sunshine looking over the lake studying. And then of course, sporting events. I'm a huge sports fanatic. So all of the basketball, volleyball games, hockey—a lot of the winter sports, I could actually attend. Football games, of course, were fun, when I was in town.

#### What advice would you give students today?

I went into this to be an astronaut—and now I'm focused on accessibility, and all the things I've done in between. There are just so many opportunities and transferable skills when you have those great fundamentals. So be open to that, to following your passion, and to getting uncomfortable to try new things.

#### If you could go back to school today, what would you do?

I'd still be an astronaut. I think now there's far more opportunity to be deaf and go to space as an astronaut than in the past. I also probably would go into gaming. There wasn't gaming as a profession when we went to school—whether it's designing and creating new video games or just being in eSports. I could see competing in eSports.

#### Any hobbies?

Today I'm passionate about golf. I had a knee replacement, and that ended my soccer career. But I love hiking and any outdoor sports. And I'm still a tech geek, so I like technology.

#### Any family you'd like to mention?

I have been with my husband, Dennis, for 20 years. We love living in sunny Scottsdale, Arizona. And of course I have an amazing family who all are still up in Minnesota, and I visit often, but mainly in the summer!



# ADVANCE TAKES ITER FUSION EXPERIMENT TO A NEW LEVEL

A significant advance in numerical fusion energy sciences by UW-Madison researchers provides a new tool for solving pressing challenges for ITER, the international fusion experiment under construction in France.

As the largest fusion experiment ever built, the ITER reactor aims to demonstrate a fusion energy output that is 10 times as large as the energy required to heat its plasma, an ultra-hot ionized gas. Ultimately, researchers hope to harness fusion, the process that powers the stars, to develop a virtually unlimited, environmentally friendly energy source. The United States is a main shareholder on this device, which is considered an essential experiment within the recently adopted new national strategy to a fusion pilot plant in the 2040s.

The research team, led by Associate Scientist Heinke Frerichs and Professor Oliver Schmitz, developed a computational modeling approach that, for the first time, allows them to model specific conditions for ITER, including how 3D plasma boundaries will affect the fusion system. The researchers detailed their advance in a paper in the journal *Physical Review Letters*.

"This is a major step forward in our modeling and predictive capabilities for plasma

regimes that are relevant for ITER," Frerichs says. "For example, this tool will be highly useful for understanding the interaction between the plasma and material surfaces."

As a tokamak fusion device, the ITER reactor is shaped like a doughnut and will use powerful magnetic fields to confine the plasma. But even with this magnetic confinement, heat and particle loads will bombard the plasma-facing reactor components. And, left unmitigated, these power fluxes can melt or heavily erode material surfaces, reducing material lifetimes and degrading the fusion device's performance.

To control transient power fluxes in tokamak devices such as ITER, researchers apply external 3D magnetic control fields to the plasma. However, this 3D control field breaks the toroidal symmetry of the tokamak's magnetic confinement system, inducing a 3D plasma edge topology and turning it into a 3D system. Applying the control fields causes the smooth surface of the doughnut-shaped plasma to become wiggly. This stabilizes transient particle and heat flux ejections, which would reduce the lifetime of the plasma facing components, but at the same time requires

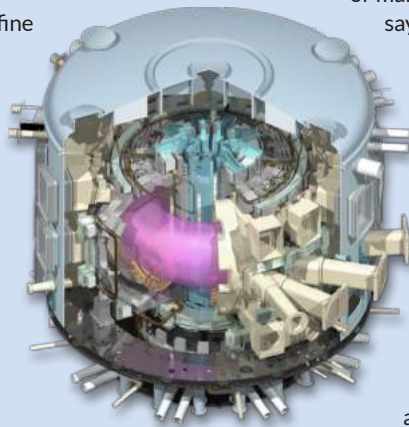
researchers to investigate this new state as fully 3D system. Modeling a 3D system is computationally much more challenging.

"When a fusion device is toroidally symmetric, researchers can apply two-dimensional models to characterize or make predictions," Frerichs says. "But we can't apply those two-dimensional models anymore when we're dealing with a 3D system. So, for ITER, that means we can't really predict what will happen when we apply the 3D magnetic control fields."

To address this challenge, Frerichs and his collaborators developed a model that allows researchers to analyze how ITER will perform as a 3D system. They drew on computing resources

from the Center for High Throughput Computing at UW-Madison in addition to a computing cluster at ITER. "Going from 2D models to 3D models adds a lot of computational demand," Frerichs says.

Frerichs says this new modeling capability could enable researchers to develop an integrated solution for optimizing the control of steady state and transient power fluxes in the ITER reactor. "We need to bring these power fluxes to a sustainable level for ITER," he says. "There's more work to do to solve this problem, but this advance puts us on a good path forward."



ITER Tokamak.  
Credit: US ITER.



Heinke Frerichs

The ITER fusion experiment facility in France in November 2020.  
Credit: ITER Organization/EJF Riche.



# Professor Emeritus Noah Hershkowitz passes away

Obituary courtesy of the Hershkowitz family



Irving Langmuir Professor Emeritus Noah Hershkowitz died at UW Hospital on Nov. 13, 2020, at the age of 79.

Hershkowitz was born in 1941 in the Williamsburg neighborhood of Brooklyn, New York. He grew up in Kew Gardens, New York City, and graduated in 1958 from the High School of Music and Art, where he met Rosalyn, his future wife of 58 years.

He joined the UW-Madison faculty in 1981. Hershkowitz began his career in nuclear physics, but soon changed to plasma physics because “it looked like it would be more fun (and it was).” Not only did he make groundbreaking contributions to his chosen field, but he gained the respect and admiration of his colleagues, both as a physicist and a human being.

Hershkowitz had a profound impact on the education, careers and lives of many undergraduate and graduate students, including more than 50 who received their PhDs. Retiring from UW-Madison in 2012, he remained active as an emeritus professor in engineering physics, continuing to collaborate on papers and to supervise students with whom he shared his love of physics.

“Physics,” he once explained, “is like a jigsaw puzzle that’s really old. All the pieces are worn down. Their edges are messed up. Some of the pieces have been put together in the wrong way. They sort of fit, but they’re not actually in the right places. The game is to put them together the right way to find out how the world works.”

Hershkowitz made a significant impact with his research, which broadened the understanding of the fundamental properties of plasma. His work covered a wide range of plasma phenomena, including low-temperature plasmas, semiconductor fabricating plasmas, fusion plasmas, and space plasmas. His groundbreaking

contributions to understanding solitons, sheaths and pre-sheaths have impacted semiconductor etching, as the plasma sheath plays a major role in the linear acceleration of ions that results in the small features of modern microelectronic circuits.

His pioneering work on emissive probes resulted in the development of a new technique for determining plasma potential by analyzing emissive probe emitted current. In 2002, he was the first to measure plasma potential throughout the pre-sheath and sheath at the boundary in a weakly collisional plasma.

Hershkowitz received numerous awards during his career. Among them was the James Clerk Maxwell Prize in Plasma Physics in 2004, the highest honor afforded by the APS Division of Plasma Physics (DPP), in which he was cited for his fundamental contributions to the physics of low-temperature plasmas. In 2015, he was presented with the IEEE Marie Skłodowska-Curie Award for innovative research and inspiring education in basic and applied plasma science.

Diagnosed with primary progressive multiple sclerosis at the age of 40, Hershkowitz never let MS slow him down. His acceptance of his disability was an inspiration to his family, friends, students and colleagues. He was a member of several disability awareness committees, including the APS Task Force on Disabilities, the Wisconsin Council on Physical Disabilities, and Access to Independence, but he also raised awareness simply by getting on with the work he loved, teaching, doing research, and traveling to conferences around the world even after he had to use a wheelchair full time. He continued to work until his final hospitalization and was a co-author on three papers presented at the APS DPP conference the day before he died.

**Read more:** <https://www.engr.wisc.edu/news/ep-professor-emeritus-noah-hershkowitz-passes-away/>

## Surprise twist Chiral material reveals new phenomenon

UW-Madison engineers have made a unique, asymmetric material that behaves in a new and unexpected way: When this “chiral” material is squeezed or stretched, it also twists.

“What we found with the squeeze-twist coupling in this material has implications for a wide range of materials,” says Professor Roderic Lakes.

For example, it could help advance actuator technology or lead to high-toughness materials that are immune to stress concentration.

Lakes studies unusual materials that behave in unanticipated or extreme ways—in other words, they defy the standard theory of elasticity—to develop a greater understanding of the fundamental physical laws of nature.

And this standard theory of elasticity—which is what engineers use to predict the behavior of most ordinary materials, including steel, aluminum and concrete—doesn’t predict the squeeze-twist phenomenon.

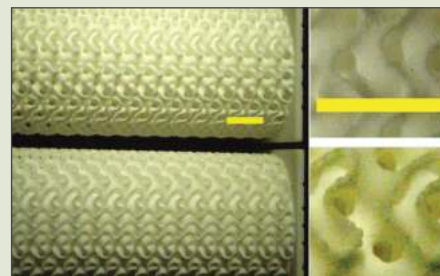
In his latest work, described in a paper published Nov. 13, 2020, in the journal *Physical Review Letters*, Lakes set out to investigate the elastic behavior of a chiral material.

Chirality describes an object that is non-superimposable with its mirror image, such as our right and left hands. For example, a glove for the right hand will not fit a left hand.

“Materials, called chiral materials, can have right-handed and left-handed forms as well,” Lakes says. “For instance, sugar is chiral at the molecular level. But materials such as aluminum and steel are not chiral and cannot take right or left-handed forms.”

Lakes and former graduate student Dan R. Reasa (BSEM ’18, MSEM ’19) used 3D printing to make gyroid lattices in chiral

and non-chiral form. Gyroids are infinitely connected periodic minimal surfaces containing no straight lines. The researchers found that when a gyroid with chiral asymmetry is squeezed or stretched, it also twists. By analyzing this chiral asymmetry, the researchers developed an understanding of the material’s behavior, including the squeeze-twist coupling.



A gyroid lattice created by Professor Roderic Lakes using 3D printing. Credit: Roderic Lakes.

“The nice thing about the gyroid we made is that it’s structurally very stiff and strong, making it useful for substantive applications,” Lakes says.





## Senior among finalists for 2021 Rhodes Scholarship



UW-Madison senior Alex Plum competed as a finalist for the 2021 Rhodes Scholarship, the oldest and most celebrated college award for postgraduate international study.

"The Rhodes Scholarship is the very pinnacle of undergraduate achievement, and to be among the finalists is a huge honor," says Provost Karl Scholz. "During his time with us, Alex has been a scholar

of extraordinary ability and a leader inside and outside the classroom. He is poised to become an intellectual leader who makes a broad impact on the world."

Plum, of Whitefish Bay, Wisconsin, is earning a double major in mathematics and engineering physics, with honors in the liberal arts and certificates in physics and computer science. He will graduate in spring 2021.

As an undergraduate at UW-Madison, Plum has been the recipient of a Wisconsin Academic Excellence Scholarship, a four-year, partial-tuition scholarship for top Wisconsin high school graduates. In addition, he has received over a dozen departmental and campus-wide scholarships, including a Sophomore Research Fellowship and a Hilldale Research Fellowship, UW-Madison's top campus-wide undergraduate research awards. Since his freshman year, Plum has worked with botany Professor David Baum on research projects investigating the origin of life.

Plum has sought numerous off-campus research opportunities. In summer 2018, he worked with a team of ecologists in Uruguay to develop computational models to investigate the effects of environmental policy on a water reservoir. During spring and summer 2020, he worked with physical biologist Christopher Kempes, a professor at the prestigious Santa Fe Institute, the world's leading research center for complex systems science.

Beyond coursework and research, Plum tutors at the Undergraduate Learning Center and volunteers with a science outreach program. He is also the president of the Socratic Society, a philosophy club where students discuss topics at the intersection of philosophy, the sciences, and current events. Plum has helped broaden the appeal of the organization to a wider audience.