OAK RIDGE NATIONAL LABORATORY

Review

Mission first, people always:

OAK RIDGE National Laboratory

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Review
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Contents

ORNL's longest-serving director, Alvin Weinberg, sitting at the controls of the Molten Salt Reactor Experiment. Image credit: ORNL

On the Cover

Sandra Davern of ORNL's Nuclear and Radiochemistry Group leads the lab's Next Generation Radiotherapeutics and Bioassessment Platforms project. Image credit: Carlos Jones, ORNL

ORNL is a laboratory of leaders

Our laboratory is often associated with facilities and instruments that researchers cannot find anywhere else. We are home to one of the world's fastest supercomputers, its most powerful pulsed neutron source, a world-renowned research reactor, and manufacturing capabilities that draw partners from industry, academia and across the public sector.

None of it works without the talented scientists, engineers and other professionals who keep Oak Ridge National Laboratory running and use these unparalleled tools to solve some of the nation's most pressing problems.

For our science missions, leadership means setting the vision, providing the resources, and offering the development opportunities that enable researchers to apply their passions to common goals.

In operations, it is reflected in the relentless pursuit of effectiveness that keeps a large and complex institution running without interruption, allows us to recruit skilled professionals, and identifies continual improvements that enable research.

ORNL's leadership commitments extend outside our gates, too. Staff members are deeply involved in their communities, introducing children of all backgrounds to the wonders of science and improving the lives of neighbors in need.

Our leadership on all fronts was challenged this spring by the COVID-19 pandemic, which required rapid adjustments in our operations and a shift of scientific focus to the fight against this deadly virus. The first story in this issue provides an overview of our initial efforts (see "ORNL is in the fight against COVID-19" on the next page), and we talk with our medical director, Dr. Bart Iddins, in "Experts enable ORNL to keep going strong" (see page 18).

While responding to the emergent needs of the pandemic, we also continued advancing our research, and in this issue of *ORNL Review*, we focus on the people who are creating the lab of the future:

- Researchers who make certain that ORNL effectively addresses America's biggest challenges (see "Scientific leadership begins with people," page 8, "Highly cited research inspires insight and collaboration," page 14, "ORNL researchers shine in professional societies," page 16).
- Professionals who help to make ORNL a welcoming and inclusive community that offers opportunities for growth and provides an attractive environment for peers from around the world (see "People with purpose power ORNL," page 30).
- Volunteers who help make our communities the wonderful places where we raise our families ("Staff members bring ORNL to the community," page 26).

As we do in each issue, we feature an interview with our recent Wigner lecturer. John Martinis was our collaborator in demonstrating the superiority of quantum computers at solving certain problems (see "Distinguished Lecturer," page 36), a breakthrough discovery in which we were proud to play a part.

Finally, our "Time Warp" feature looks back at the pivotal leadership of Alvin Weinberg, ORNL's longest-serving director, whose vision and steady guidance made the lab what it would become today (see "Weinberg's legacy of leadership," page 40).

I hope this issue of *ORNL Review* illuminates how the leadership of our staff members continues to prepare the lab for whatever challenges may come.

Thomas Zacharia
Laboratory Director

ORNL is in the fight against COVID-19

by Morgan McCorkle
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In the race to identify solutions to the COVID-19 pandemic, ORNL researchers have joined the fight by applying expertise in computational science, advanced manufacturing, data science and neutron science.

ORNL is providing remote access to its world-leading supercomputing and neutron facilities for researchers around the world to conduct scientific studies on severe acute respiratory syndrome coronavirus 2, or SARS-CoV-2, the novel coronavirus that causes COVID-19.

Computational science. ORNL's Summit, the United States' most powerful supercomputer, is accelerating COVID-19-related research aimed at improving our understanding of the virus' structure and biology, with the goal of developing targeted therapies and vaccines.

ORNL researchers are also employing artificial intelligence to study the systems biology and molecular mechanisms of the coronavirus; deliver "self-driving" ventilators; model hospital infrastructure; and mine past publications to advance our understanding of challenges related to COVID-19 diagnosis, treatment, epidemiology and management.

"America's national labs are designed specifically to tackle the world's most complex scientific challenges, and our continued investments in high-performance computing and cutting-edge data analysis have proven critical in tackling this global pandemic," said ORNL's Gina Tourassi, director of the National Center for Computational Sciences.

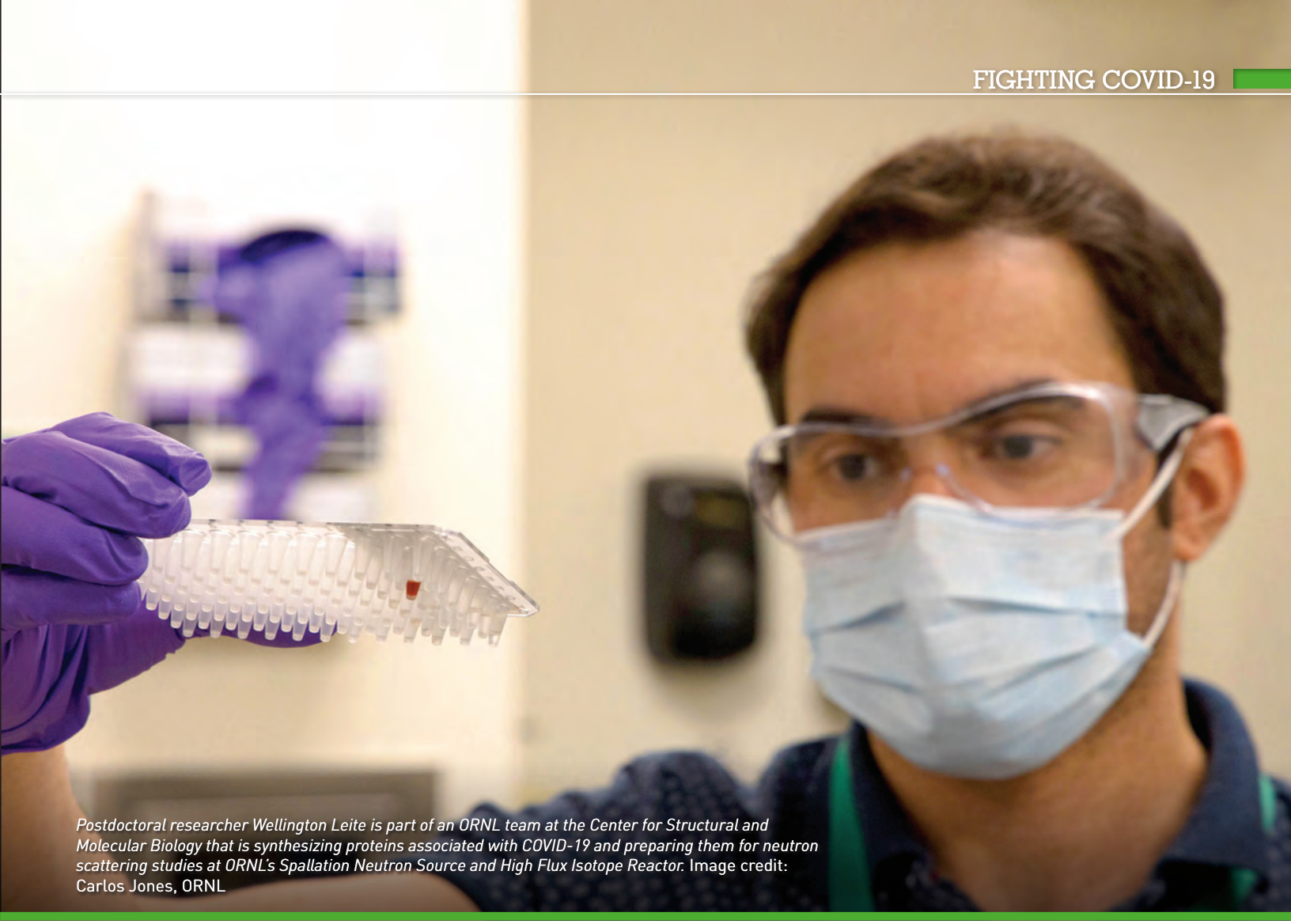
Neutron scattering. ORNL is providing remote rapid access to its advanced neutron facilities—the Spallation Neutron Source and the High Flux Isotope Reactor—to support research related to the pandemic. Neutron research has the potential to yield vital insights into the structure, dynamics and function of viral proteins found in SARS-CoV-2.

"By studying the structures of the individual viral proteins and understanding how they form complexes with each other, and also in the viral RNA, that will give us clues on how to develop therapeutics that can disrupt the life cycle of the virus and essentially stop it in its tracks," said Hugh O'Neill, team lead for the bio-labs within the Neutron Sciences Directorate.

Advanced manufacturing. ORNL researchers are exploring ideas for improving existing personal protective equipment such as new designs for reusable masks and face shields. This work includes using additive manufacturing to significantly reduce tooling costs and production time, coordinating with both medical suppliers and the manufacturing supply chain to speed and expand production capabilities, and establishing plans to reverse engineer and rapidly manufacture and distribute tooling for critical components.

"The Department of Energy's Manufacturing Demonstration Facility and

COVID-19 is the disease caused by the virus SARS-CoV-2. The virus is constructed with "spike" proteins on its outer membrane that anchor and fuse with host cells. Once attached, the genetic material inside the virus hijacks the machinery of healthy cells, creating new proteins that enable the virus to reproduce.
Image credit: Jill Hemman, ORNL



Postdoctoral researcher Wellington Leite is part of an ORNL team at the Center for Structural and Molecular Biology that is synthesizing proteins associated with COVID-19 and preparing them for neutron scattering studies at ORNL's Spallation Neutron Source and High Flux Isotope Reactor. Image credit: Carlos Jones, ORNL

Carbon Fiber Technology Facility at ORNL are developing innovative solutions to the COVID-19 challenge at an unprecedented pace," said Lonnie Love, ORNL's lead researcher on COVID-19 manufacturing efforts. "From rapidly producing filter material to designing and printing mask molds and creating tooling sets for face shields, our researchers are focused on delivering industry the necessary resources to scale up and mass-produce personal protective equipment for those on the front lines in this fight: our health care experts."

Pandemic modeling and analysis. Oak Ridge, Argonne, Los Alamos and Sandia national laboratories are developing integrated COVID-19 pandemic monitoring, modeling and analysis expertise, leveraging the labs' collective strengths in scalable data and computing.

"Our goal is to provide improved situational awareness and insight into what is happening in different regions of the country and how different areas and populations are responding and reacting to conditions and interventions," said Budhu Bhaduri, director of ORNL's National Security Emerging Technologies Division. "Epidemiological prediction of disease progression and modeling consequent stresses on health care infrastructure and economic activities are major emphases."

No matter their area of expertise, researchers across the lab have rapidly responded to address an unprecedented scientific and societal challenge.

"I could not be prouder of our staff who have stepped up to offer their scientific and technical expertise to address this international pandemic," said ORNL Director Thomas Zacharia. "It is during times of crisis that we have the greatest opportunity to distinguish ourselves in service to the nation. That is our legacy at Oak Ridge; it is who we are."

COVID-19 research at ORNL is supported by the DOE Office of Science through the National Virtual Biotechnology Laboratory, a consortium of DOE national laboratories focused on response to COVID-19, with funding provided by the Coronavirus CARES Act.

Researchers at DOE's Manufacturing Demonstration Facility at ORNL developed a reusable face mask prototype with injection molding that will enable rapid manufacturing by industry. Image credit: Carlos Jones, ORNL

Tokamak assembly to begin at ITER

The international ITER fusion project, the world's largest scientific collaboration, is about to begin assembly of the largest fusion device ever built: a 25,000-ton doughnut-shaped reactor known as a tokamak.

Assembly began in May with transfer of the 1,370-ton cryostat base to the lower concrete crown of the tokamak pit. This delicate operation took two days to complete and was the largest single lift during ITER tokamak assembly.

The 29-by-29-meter cryostat is essentially a giant refrigerator. It is the largest stainless-steel high-vacuum chamber ever built and will provide a vacuum environment for various cold components of the tokamak, including 11,000 tons of superconducting magnets operating at 4 Kelvin, or –452 degrees Fahrenheit. The magnet systems will confine plasmas up to 150 million degrees centigrade, or 10 times hotter than the core of the sun.

To support a path to fusion energy, ITER aims to build and operate a burning, self-heated plasma device that can operate for up to an hour at a time and demonstrate reactor-scale power up to 500 megawatts. A typical coal plant today can produce around 600 megawatts, which is considered enough electricity for a small city. Fusion energy has the potential to provide carbon dioxide–free baseload electricity without generating long-lived radioactive waste.

ITER is scheduled to begin operations in the mid-2020s. ITER's partners—China, Europe, India, Japan, South Korea, Russia and the United States—are all contributing components and financial support to the ITER fusion research facility. ITER will ultimately provide partner scientists a chance to understand burning plasmas and prepare for a future fusion power plant. US ITER, managed by ORNL with partners Princeton Plasma Physics Laboratory and Savannah River National Laboratory, is responsible for 9 percent of ITER construction, including 12 hardware systems.—*Lynne Degitz*

Construction crews are beginning to fill the ITER tokamak pit with major components, starting with the cryostat base. Image credit: ITER Organization

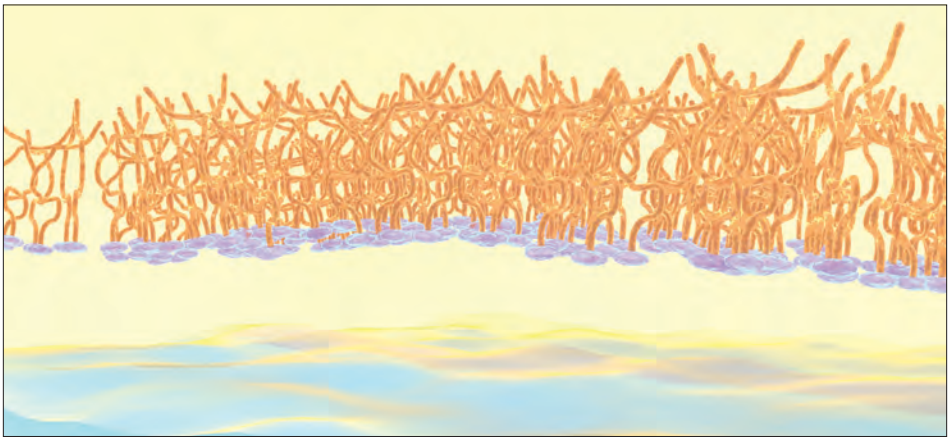
Scoping out polymers at the oil–water interface

Researchers at ORNL and the University of Tennessee have taken a rare look at the inner workings of polymer self-assembly at an oil–water interface to advance materials for neuromorphic computing and bioinspired technologies.

Results published in the *Journal of the American Chemical Society* provide new insights on the way molecules pack and order themselves into "tunable" interfaces, single-layer-thick surfaces with structures that can be modified for specific functionalities.

"Understanding the design rules of the chemistry happening at the liquid–liquid interface ultimately informs how we can make new materials with custom properties," said Benjamin Doughty of ORNL's Chemical Sciences Division.

The study expands interest in the use of soft materials to mimic lipid bilayers, selective membranes with important biological functions such as processing signals across the brain's neural network and transporting ions, proteins and other molecules across cells.



Researchers at ORNL and the University of Tennessee tracked polymer self-assembly at the liquid–liquid interface in real time. Image credit: Michelle Lehman, ORNL

The co-authors previously designed biomimetic membranes using lipid-coated water droplets in oil and demonstrated their potential as sensory components for neuromorphic, or brain-like, computers with natural information processing, learning and memory.

"Because lipids are inherently fragile and decay, we are interested in developing polymer-based counterparts that offer stability and can also give us a range of natural functionalities," said Pat Collier of ORNL's Center for Nanophase Materials Sciences, a DOE Office of Science User Facility.—*Ashley Huff*

For more information:
go.usa.gov/xdSdN

Smart traffic lights can save truck fuel

Large trucks lumbering through congested cities could become more fuel efficient simply by not having to stop at so many traffic lights.

A proof-of-concept ORNL study shows the promise of a potential new system to direct traffic lights to keep less-efficient vehicles moving and reduce fuel consumption.

A preliminary study by ORNL and GRIDSMART shows the promise of a new system to keep trucks moving through intersections and reduce fuel consumption.
Image credit: Thomas Karnowski, ORNL

In collaboration with traffic-management services company GRIDSMART, researchers used smart cameras to collect real-world data from images of vehicles as they move through select intersections.

The team used artificial intelligence and machine learning techniques to "teach" these cameras how to quickly identify each vehicle type and its estimated gas mileage, sending the information to the next intersection's traffic light.

ORNL's Thomas Karnowski said early results from the computer simulation could lead to more comprehensive research.—*Sara Shoemaker*

Taking a gentle look at biomaterials

ORNL scientists have developed a new method to peer deep into the nanostructure of biomaterials without damaging the sample. This novel technique can confirm structural features in starch, a carbohydrate important in biofuel production.

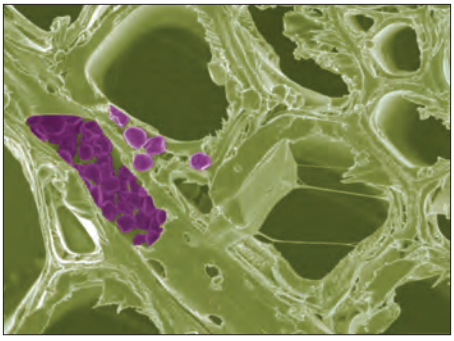
The research team used the sharp probe tip of an atomic force microscope, or AFM, to precisely punch tiny holes into a soft surface such as a biological membrane, creating a detached layer that can be gently peeled away.

Using the new, nonintrusive soft mechanical nanoablation, or sMNA, technique, the team accessed starch granules without altering the nanostructure. Existing observation methods require damaging or destroying the starch's outer layers, which can affect the physical properties of the granules.

"Our technique basically lifts the outer membrane," said Ali Passian of ORNL's Quantum Information Science group. "This leaves the interior structures almost untouched."

As described in a paper published in the journal *ACS Omega*, sMNA allowed the team to observe interior properties of starch granules from stem samples of poplar trees.

In the United States, most biofuel comes from starch in corn kernels broken down into ethanol, but poplars have been longtime biofuel candidates because they grow quickly and produce lots of biomass. Though poplar biomass contains only 3 to 10 percent starch, a biological energy storage unit, the tree has abundant sugars wrapped up in polymeric materials such as cellulose, hemicellulose and lignin—important structural components that make up cell walls of tree trunks, branches and leaves.



While exploring poplar cells using a scanning electron microscope, researchers observed sack-like structures, shown in purple, that were later identified as starch through Raman spectroscopy.
Image credit: ORNL and CINaM, Aix Marseille Université

Researchers want to learn more about the native, nanoscale properties of both starch granules and structural materials to grow productive poplars and best use them as biofuel feedstocks.—*Abby Bower*

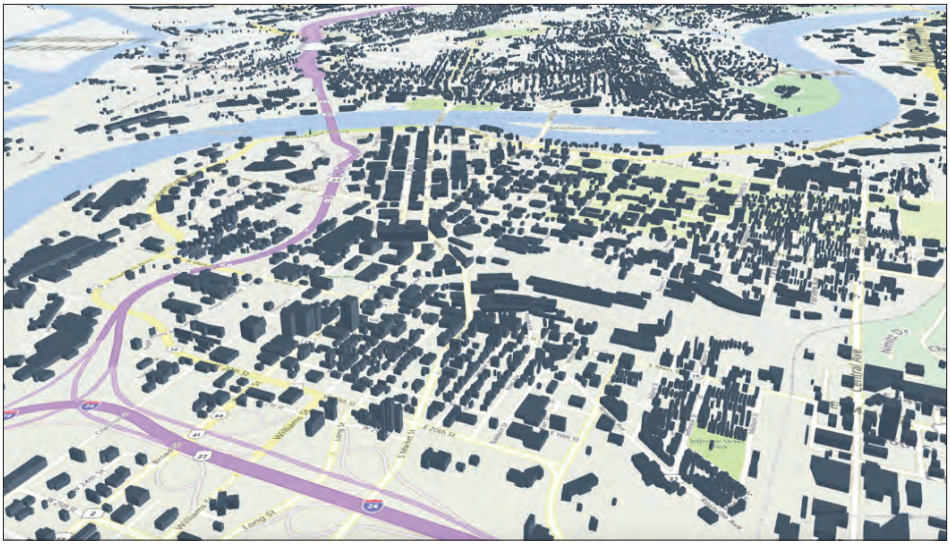
For more information:
go.usa.gov/xdSdx

Building analysis tool IDs energy savings

ORNL researchers have developed a modeling tool that identifies cost-effective, energy-efficiency opportunities in existing buildings across the United States.

Using supercomputing, the energy-modeling method assesses building types, systems, use patterns and prevailing weather conditions.

"Manually collecting and organizing data for energy modeling is a time-consuming process and is used in only a small percentage of retrofit performance projects," ORNL's Joshua New said.



ORNL's modeling tool simulates the energy efficiency of buildings by automating data received from satellite images. The tool was tested on buildings in the Chattanooga area. Image credit: Joshua New, ORNL

The team's modeling approach applies automation to extract a building's floor area and orientation parameters from publicly available data sources such as satellite images. Researchers tested the tool on more than 175,000 buildings in the Chattanooga, Tennessee, area, demonstrating energy-saving opportunities.

"We can model a building in minutes from a desktop computer," New said. "This is the next level of intelligence for energy-saving technologies."

Future plans include making the tool openly available to help reduce energy demand, emissions and costs for America's homes and businesses.—*Jennifer Burke*

Fusion diagnostic system uses off-the-shelf parts

The techniques Theodore Biewer and his colleagues are using to measure whether plasma has the right conditions to create fusion have been around awhile.

The specialized lasers and off-the-shelf components they're working with are nothing new, either.

But assembling them into a portable diagnostic system that can be loaded in a cargo van and driven on a cross-country tour of experimental fusion reactor prototypes? Biewer thinks his team will be the first to successfully do that—this fall.

For about a year, Biewer, a researcher in ORNL's Fusion Energy Division, has been thinking of a way to build a portable system, using only commercially available components, that can accurately measure electron temperature, ion temperature and electron density in fusion prototypes funded by DOE's Advanced Research Projects Agency-Energy, or ARPA-E.

ARPA-E is funding nine projects under its 2015 ALPHA program that, if successful, could serve as a technological basis for new reactor designs. But the agency needed a way to tell whether the plasma in the prototypes is hot enough, dense enough and contained well enough in the magnetic field to produce fusion. In January 2019, the agency asked for additional proposals to build portable diagnostic systems to measure key parameters in these new machines. Biewer's team's proposal was selected last summer and received a little more than $1 million in funding in November 2019.

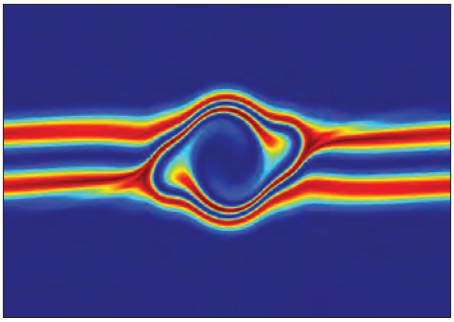
By that time, Biewer, who is principal investigator, had already researched the commercially available components for optical emission spectroscopy, a technique that uses light to measure which types of ions are present in what concentrations and at what temperatures, and Thomson scattering, which uses lasers to measure electron density and temperature by scattering laser light off electrons in the plasma.—*Kristi Nelson Bumpus*

For more information: go.usa.gov/xdSdC

ORNL team developing a virtual fusion device

The prospect of simulating a fusion plasma is a step closer to reality thanks to a new computational tool developed by scientists in fusion physics, computer science and mathematics at ORNL.

Postdoc Nischal Kafle positions a component for a portable plasma-imaging diagnostic device built from off-the-shelf parts. Image credit: Carlos Jones, ORNL



This simulation of a fusion plasma calculation shows the interaction of two counterstreaming beams of super-heated gas. Image credit: David Green, ORNL

Harnessing fusion power on Earth requires strong magnetic fields to hold and squeeze a super-heated gas, and the large-scale experiments capable of such extreme conditions can take decades to build.

Through simulation, a team led by ORNL's David Green hopes to perform virtual investigations of how fusion devices behave using high-performance computing.

"The mathematics underlying a fusion plasma are so complex that traditional approaches test the limits of even today's largest supercomputers," Green said.

The team has tested a new approach on ORNL's Summit supercomputer, and they expect that a combination of Summit and ORNL's upcoming exascale Frontier supercomputer will make a virtual fusion device possible.—*Sara Shoemaker*

Satellite image analysis faster with new technique

A novel approach developed by ORNL scientists can scan massive data sets of large-scale satellite images to more accurately map infrastructure such as buildings and roads in hours rather than days.

Comprehensive image data helps stakeholders make informed decisions. The new computational workflow uses deep learning techniques to train and deploy models to better address location, environmental and time challenges when mapping structures.

"We developed a framework that divides the labor of characterization among several models, each tasked to learn to detect specific objects under near-homogeneous contexts versus one model attempting to detect objects under diverse conditions across a collection of images," said ORNL's Dalton Lunga, who led the study.

The team tested the approach on 21 terabytes of image data—one terabyte covers about 12,085 square miles—and reduced the computing time from 28 days to about 21 hours.

Next, they will characterize even larger image data sets on ORNL's Summit supercomputer.—*Sara Shoemaker*

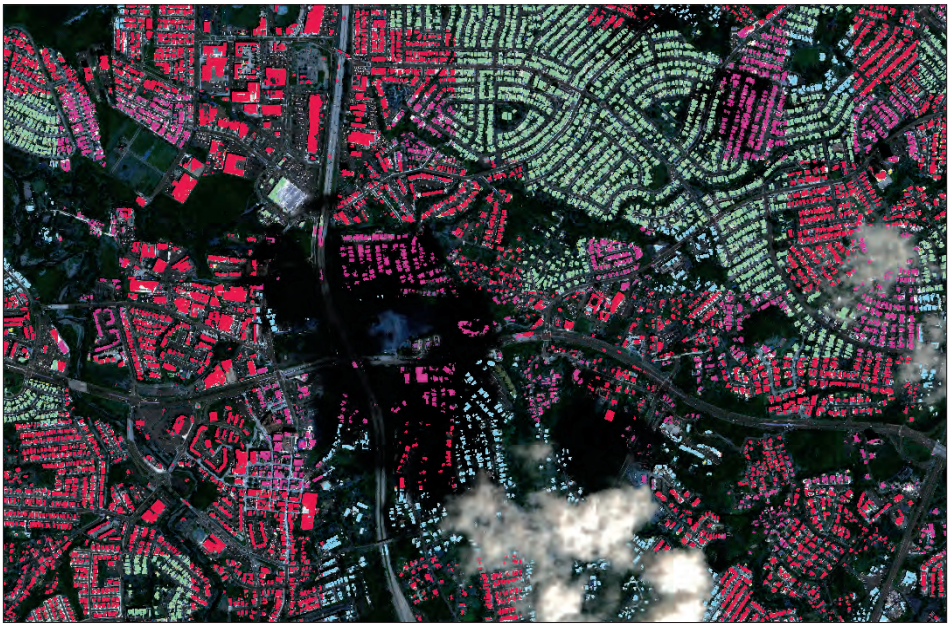
ORNL's Erwin receives mathematics fellowship

ORNL's Samantha Erwin has received a Society for Industrial and Applied Mathematics Science Policy Fellowship.

Erwin's work in the Computational Science and Engineering Division involves characterizing diseases through high-dimensional data analysis and mechanistic modeling techniques. Her research interests range from differential equations to parameter estimation, and she has studied biomedical phenomena including immune responses and antibiotic resistance.

Samantha Erwin

As a SIAM fellow, Erwin will have numerous opportunities to represent the scientific community on a national scale by attending events such as the biannual meetings of the SIAM Committee on Science in Washington, D.C. Program participants serve two-year terms to learn about the processes behind policy decisions, communicate with legislators and advocate for federal investments in various fields of research.—*Elizabeth Rosenthal*



A new computational approach by ORNL can more quickly scan large-scale satellite images, such as these of Puerto Rico, for more accurate mapping of complex infrastructure such as buildings. Image credit: Maxar Technologies and Dalton Lunga, ORNL

Scientific leadership begins with people

by Leo Williams
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It's easy enough to see why ORNL is looking forward to the coming decade and beyond.

As the largest national laboratory devoted to open scientific discovery, ORNL is home to leading research programs in areas ranging from physics and chemistry to engineering and environmental science.

Not only does it host the United States' most powerful scientific supercomputer (Summit) and two of the most powerful neutron scattering facilities (the Spallation Neutron Source and the High Flux Isotope Reactor), it is preparing for Summit's far-more-powerful successor and for major upgrades to SNS. The lab is a leading contributor in 3D printing and carbon fiber production, microscopy and advanced materials research, climate science and isotope production. In fact, ORNL is home to 23 of 24 core capabilities important to its sponsor, DOE's Office of Science, which is itself the country's principal supporter of research in the physical sciences.

"We have responsibility for scientific instruments and infrastructure that enable breakthroughs not possible anywhere else," said Lab Director Thomas Zacharia, who came to ORNL as a postdoctoral fellow in 1987.

"The impact of these capabilities is felt in all areas of our lives—in the energy that powers our businesses, homes and transportation; in the materials that enable our technologies; in medicine, the environment and our fundamental understanding of the universe," Zacharia continued.

"The difference we make at Oak Ridge National Laboratory is not due to our facilities alone, however. Our impact year after year is driven by some of the best scientists, engineers, technical and support staff in the world. They come from all over the country and from dozens of nations, and they find solutions together they could never find alone."

ORNL Review talked with a dozen researchers who have taken on leadership roles around the lab in recent years, asking them what scientific leadership means at ORNL, what prepared them for their roles and what they see in the future for their own fields and for the lab as a whole.

Focusing on individuals amid the big picture

Research leaders at ORNL are challenged to support the goals of some 2,000 staff scientists and engineers while achieving the labwide goals necessary to fulfill national missions in energy, security and scientific discovery.

"We cannot do the research if the people are not inspired," said Juan Carlos Idrobo, leader of the Electron and Atom Probe Microscopy Group within the lab's Center for Nanophase Materials Sciences. "I have my scientific vision, but that is *my* mountain. My job is to inspire and help my group members climb their own mountain. However, only together, as a team, will we be able

to tackle big challenges and climb the Mount Everest of electron microscopy."

Idrobo's personal mountain is the ability to advance materials research by using an electron microscope to measure the spin and orbit of individual atoms. He expects to scale this particular summit in the next decade, an achievement that will spur research into the hard drives that maintain long-term data storage.

> *"My background is technical, very technical. Having grown up in the technical ranks, I feel the pain points of our staff. I view my job right now as being to enable the growth of capabilities by growing our staff.*
>
> — ORNL Energy and Transportation Science Division Director **Xin Sun**

Across the laboratory, research teams strive to maximize the unique capabilities of the advanced instrumentation at their fingertips. It requires both passion and teamwork, said Bianca Haberl, who coordinates the high-pressure science initiative in ORNL's Neutron Sciences Directorate.

"If you have exciting science projects, and the people you work with get equally excited about them, you all achieve more, because you all enjoy then what you're doing," she said.

Fortunately, Haberl's specialty generates plenty of exciting projects. By taking advantage of ORNL's neutron scattering facilities, scientists can, among many other tasks, replicate the conditions found deep within the Earth and other planets. Furthermore, materials show new behaviors when they are subjected to high pressure, including materials that hold promise as high-temperature superconductors.

In fact, Haberl noted, neutron scattering is ideal for studying these promising materials because the highest-temperature superconductors are rich in hydrogen, an element that, when it is next to heavier elements, is practically invisible to probing with electrons and X-rays.

While ORNL gives talented researchers the means to follow their passions, they must also be able to work together. Scientific leaders across the lab agree that a major part of their jobs involves getting people to move in the same direction.

This cooperation is especially important in up-and-coming fields like quantum computing.

See SCIENTIFIC LEADERSHIP BEGINS WITH PEOPLE, page 10

Xin Sun. Image credit: Carlos Jones

"I think in five years, 10 years, we'll answer questions around how our microbial communities in freshwater systems influence water quality, for example—how these communities change in their composition, what their function is, how they impact metal speciation.

— ORNL Earth Sciences Group leader **Eric Pierce**

SCIENTIFIC LEADERSHIP BEGINS WITH PEOPLE, page 9

"When quantum computing first popped into existence, it lacked a clear connection to the rest of the laboratory," said Travis Humble, who heads the lab's Quantum Computing Team. "Strong leadership has meant defining the direction of the science, navigating the many corridors necessary to stand up a high-profile program in a new technical area, and living at the intersection of physics and computers and engineering."

Even in fields that have been around for decades, coordination is necessary for researchers to meet long-term goals. This is a challenge noted by Sarah Cousineau, who leads SNS's Beam Science and Technology Group.

Cousineau's group focuses on the proton beam that drives SNS and the cutting-edge neutron science taking place there. That beam is top-of-class now, she said, but there's no guarantee it will stay in that position.

"Strong leadership to me means the ability to get a group of people to work together toward a common goal," she said. "Right now, we have the most powerful proton beam in the world right here. If we want to maintain that edge, we need strong vision to keep us moving forward, to keep us on the frontier."

Preparing future leaders

It takes a lot of work to get to the positions that these individuals occupy. Not only must they go through the years of schooling it takes to earn a Ph.D., they must also develop the skills to manage and lead talented colleagues.

Energy and Transportation Science Division Director Xin Sun stresses the need for research leaders to have a deep understanding of their fields.

"My background is technical, very technical," she said. "Having grown up in the technical ranks, I feel the pain points of our staff. I view my job right now as being to enable the growth of capabilities by growing our staff."

Sun uses that expertise to guide a division that encompasses a wide swath of ORNL's research efforts, including those in transportation, building technologies, advanced manufacturing, energy efficiency, carbon fiber manufacturing and 3D printing.

Experience working in a variety of research settings is helpful, said Sandra Davern of the Nuclear and Radiochemistry Group. Davern leads the lab's Next Generation Radiotherapeutics and Bioassessment Platforms project, which aims to expand the

> *"I took on opportunities that would help me grow my career both in terms of research and helping others to do research. When you're a young staffer, that's things like organizing a session at a conference or a research journal club—where you organize small groups of people to do things. That's a great way to get leadership experience, but still it's all part of your research.*
>
> — ORNL Computational Sciences and Engineering Division Director **Kate Evans**

cancer-fighting usefulness of radium-223—an isotope that is produced at ORNL.

"I've had quite a diverse background," she said. "I've worked in everything from medical research to plant biology to radioisotope research. I've carried out research at universities, medical institutions and this national lab, so I feel my career trajectory has allowed me to have a very holistic view of the development of research ideas, from the seed idea right through to where it can actually be an advantage to the general public."

For young researchers interested in rising through the ranks of scientific leadership, a background in the nitty-gritty of running an organization is also invaluable. Not only does that involvement provide skills that don't necessarily come with a Ph.D., but it provides a great opportunity to network and even find potential mentors.

Computational Sciences and Engineering Division Director Kate Evans, for example, served on Georgia Tech's Graduate Student Senate while she was working on her Ph.D., and when she was a junior researcher at ORNL she ran her division's seminar series. She encourages her young colleagues to take a similar approach.

"I took on opportunities that would help me grow my career both in terms of research and helping others to do research," she said. "When you're a young staffer, that's things like organizing a session at a conference or a research journal club—where you organize small groups of people to do things. That's a great way to get leadership experience, but still it's all part of your research."

The benefits of a large national lab

A large, scientifically diverse institution like ORNL provides a unique environment for developing scientific leadership, both in finding partners for interdisciplinary collaborations and in broadening one's own expertise.

Hector Santos-Villalobos

"I would say that ORNL is Disney for scientists," said Hector Santos-Villalobos, national security researcher and leader of the Multi-Modal Analytics and Architectures Group. "Take me as an example. I came here to work

See SCIENTIFIC LEADERSHIP BEGINS WITH PEOPLE, page 12

"At Oak Ridge we have an entire pipeline from materials synthesis to characterization to fabrication to understanding, and we are using it to address the myriad of different national energy and national security challenges facing us today.

— ORNL Materials Science and Technology Division Director **Sean Hearne**

SCIENTIFIC LEADERSHIP BEGINS WITH PEOPLE, page 11

at HFIR, doing neutron imaging. Then I had another job doing machine learning for medical imaging. Then I moved into biometrics. Now I do face recognition through windshields and see inside walls via ultrasound reconstruction."

For researchers considering a move to ORNL, the lab's reputation makes for a powerful draw. Materials Science and Technology Division Director Sean Hearne, for example, came to ORNL in early 2019, serving as CNMS director before taking on his current position.

Hearne says he was attracted by the lab's history of solving critical challenges, especially in materials science.

"Oak Ridge is an international leader in materials science," he said. "Being part of that team is a tremendous opportunity."

Hearne noted that his division focuses on materials characterization, while Sun's division—the Energy and Transportation Science Division—works to build the materials into structures.

"At Oak Ridge we have an entire pipeline from materials synthesis to characterization to fabrication to understanding, and we are using it to address the myriad of different national energy and national security challenges facing us today," he said.

ORNL's embrace of both basic and applied research also places it in a bright spot between academia and industry, according to Arjun Shankar, director of the lab's Compute and Data Environment for Science and leader of the Advanced Data and Workflow Group.

"We have, in my opinion, the best of both worlds," he said. "We can play a fantastic translational role collaborating with academics who focus on foundational work. And while industry has its market role, we can work with them to convert our foundational ideas of discovery and translate them to be commercially effective.

"Our ability to focus on the next big mission the country gets behind has been inspiring and a lot of fun."

ORNL faces the future

ORNL's size, scientific diversity and world-class staff also position it to be a major player in solving the country's problems in the coming years. There will be no shortage of challenges in the foreseeable future, and no shortage of ORNL researchers keen to overcome them.

One important goal is to bring manufacturing back to the United States, noted Merlin Theodore, director of ORNL's Carbon Fiber Technology Facility.

> *"If you have exciting science projects, and the people you work with get equally excited about them, you all achieve more, because you all enjoy then what you're doing.*
>
> — ORNL neutron sciences researcher **Bianca Haberl**

"It is very important for advanced manufacturing, especially given the fact that we're trying to increase American competitiveness so that we can be the leading nation," she said. "There's a lot of things that we rely on internationally that we really shouldn't have to, because we have the expertise and the sources here."

Research organizations across the lab are preparing for future technologies. CSED director Evans noted that ORNL's future in computing includes quantum as well as other seemingly futuristic technologies such as artificial intelligence and neuromorphic computing, which uses attributes of the human brain to make systems more efficient and less power intensive. As a result, she sees scientific computers being created for specific purposes.

"I have a feeling it might become more specialized," she said. "Quantum computers will probably be very good and far superior to other computers at solving certain problems, but not all of them. Same with neuromorphic computers; they will be very good at solving certain problems, but not all of them."

Cousineau and her colleagues at SNS will be getting ready for proton beams that are massively more powerful than any now in existence. For example, while the lab is preparing to upgrade the neutron source's accelerator, beam scientists will be planning for future accelerators that are several times more powerful still.

"We are a 1.4-megawatt facility, and we're going to go to 2.8," she said. "But we need to start having a conversation about 10 megawatts. What does that look like? We're starting research efforts where we say, 'How are we going to remove this hurdle? How are we going to remove that barrier?' These are the things we are aiming at."

Sarah Cousineau

For Earth Sciences Group Leader Eric Pierce, future upgrades to SNS and other facilities around the world will help him and his colleagues better understand the behavior of metals such as mercury in the environment.

"I think in five years, 10 years, we'll answer questions around how our microbial communities in freshwater systems influence water quality, for example—how these communities change in their composition, what their function is, how they impact metal speciation," Pierce said.

See SCIENTIFIC LEADERSHIP BEGINS WITH PEOPLE, page 17

Highly cited research inspires insight and collaboration

by Jim Pearce
pearcejw@ornl.gov

Every year since 2002, the Web of Science Group has announced its list of Highly Cited Researchers, ostensibly the most influential scientists and engineers in their respective fields. Their influence is gauged by how often their publications are cited by other researchers worldwide.

This year's list includes nine scientists from ORNL.

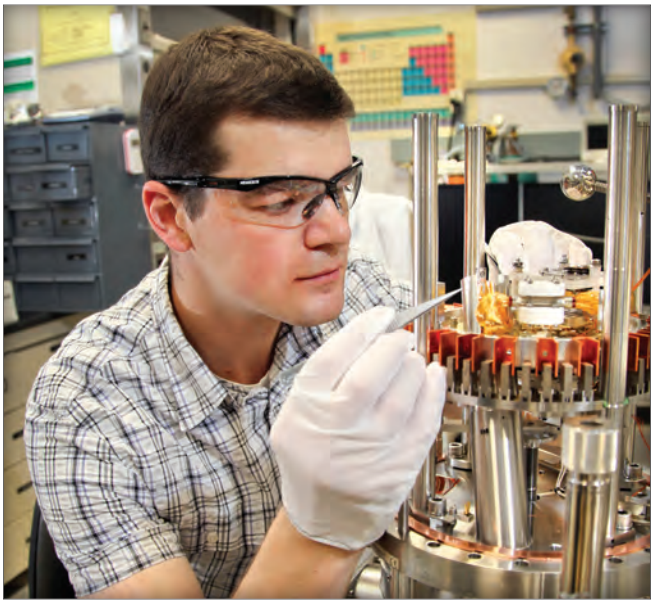
One of these researchers, materials scientist Michael McGuire, notes that a research paper becoming highly cited has a lot to do with timing—being at the forefront of research, or a little ahead of it.

> *"One of the reasons other scientists cite research from ORNL is that the laboratory has a very strong reputation for producing transferable knowledge—knowledge that stands the test of time.*
>
> — ORNL microscopist **Petro Maksymovych**

"The key to success in this field," McGuire said, "is being able to see the one result among many that really has potential for further investigation and then presenting it to the research community in a way that gets them excited about it."

McGuire and his colleagues look for materials with interesting qualities, although sometimes they're interesting for unexpected reasons.

"Sometimes we're looking for superconductors and we find a new magnetic material, or we're looking for a magnet and we find a new superconductor," he said. "As a result, a lot of our research doesn't produce papers in *Nature* or *Science*, but it does produce novel materials that become the foundation that other scientists build on to advance their research, both here and outside of ORNL."



Petro Maksymovych analyzes a sample using a customized, variable-temperature scanning probe microscope at ORNL's Center for Nanophase Materials Sciences. Image credit: Jason Richards, ORNL

Ecosystem ecologist Colleen Iversen, another of the laboratory's highly cited scientists, also maintains that many benefits of the science produced at ORNL are accrued by sharing those insights.

"I don't think that where something gets published makes it good science or not," Iversen said. "Good science is good science—and if you do good science, people will find it.

"I spend a lot of time thinking about how to communicate my work to the broader community of scientists and to the public. Our work is funded by taxpayer dollars, so we need to make that information available as widely as we can," she added.

To that end, Iversen has helped to develop the Fine Root Ecology Database, or FRED, maintained by ORNL's Climate Change Science Institute, as a way to share scientific data across institutions.

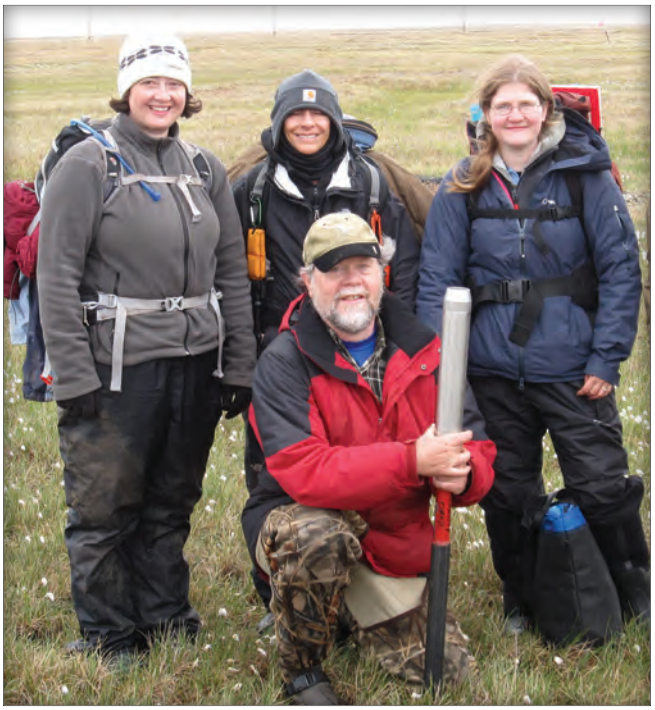
"FRED contains information from 100,000 locations across the world that root and rhizosphere ecologists are freely sharing," she said, "and the data is being used to build mathematical models and to inform the next generation of studies in the field.

> *"I don't think that where something gets published makes it good science or not. Good science is good science—and if you do good science, people will find it.*
>
> — ORNL ecosystem ecologist **Colleen Iversen**

"This kind of data-sharing makes me feel that I'm making a difference. It makes me feel like I'm contributing to a conversation that's bigger than me."

When it comes to contributing to a larger conversation, ORNL microscopist Petro Maksymovych, another of the lab's highly cited scientists, can point to the continuing interest in papers on ferroelectric materials that he and his collaborators published 10 or more years ago.

For decades, scientists suspected that rearranging the atomic structure of these materials under applied fields should give rise to new properties such as metal–insulator transition. However, the community could not confirm that behavior until he and his colleagues were able to apply advanced microscopy techniques to the problem.



Colleen Iversen's (left) ecosystem research has taken her to Alaska as part of the NGEE Arctic project to study Arctic ecosystems in a changing climate. Also shown, from left, are ORNL's Joanne Childs, Rich Norby (kneeling) and Victoria Sloan. Image credit: ORNL

Materials scientist Michael McGuire specializes in exploring the structure and properties of complex materials, with an emphasis on magnetism. Image credit: Jason Richards, ORNL

"This work started out as a collaboration with University of California physicist and former ORNL Deputy for Science and Technology Ramamoorthy Ramesh," he said. "Then we went on to work with a number of people at ORNL's Center for Nanophase Materials Sciences, where we were able to observe the process directly and subsequently control it."

More recently, attention to this research has peaked again because of the discovery of ferroelectricity in hafnium dioxide. Because this material is also compatible with processes used to manufacture many electronic components, it could open the door to the development of faster, smaller computer memory chips.

Like his highly cited colleagues, McGuire and Iversen, Maksymovich stresses the importance of sharing knowledge with the broader scientific community, as well as being a part of an institution that is known for producing high-quality scientific research.

"One of the reasons other scientists cite research from ORNL is that the laboratory has a very strong reputation for producing transferable knowledge—knowledge that stands the test of time," he said.

ORNL researchers shine in professional societies

by Sean Simoneau
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More than 100 professional societies are represented at ORNL, and chances are good that in each there is an ORNL staff member stepping up to make a difference.

In just the past few years, ORNL scientists have received prestigious awards, served on committees or been elected fellows of professional societies; many of these scientists also hold leadership positions at the lab.

> *"Professional societies give staff members the chance to interact directly with other researchers, practitioners and possible collaborators. There have been an incredible number of collaborative ideas and proposals developed in the session rooms and hallways of our annual meetings.*
>
> — ORNL Nonproliferation Program Office Director **Larry Satkowiak**

"Professional societies are, by their nature, people from different organizations each with their own unique perspective, looking for solutions to common sets of challenges and problems," said Larry Satkowiak, director of ORNL's Nonproliferation Program Office.

Satkowiak joined the Institute of Nuclear Materials Management early in his career as a way to interact with others in the nuclear community, develop collaborations and learn more about what was going on in the field.

"My first annual meeting was eye-opening and mind-expanding," he said.

He initially took on a leadership role as a way to reinvigorate his local chapter and has since held positions within the INMM, including president of the institute and Technical Division chair. He is a senior fellow of the INMM and serves as chair of its Annual Meeting Committee.

Larry Satkowiak

"The lab develops you technically and allows you to shine as a scientific or technical professional," Satkowiak said. "Professional societies give staff members the chance to interact directly with other researchers, practitioners and possible collaborators. There have been an incredible number of collaborative ideas and proposals developed in the session rooms and hallways of our annual meetings."

Joining multiple professional societies allows researchers to engage with other domains working on the same issues and strengthen their scientific leadership in their field.

Gina Tourassi, director of the National Center for Computational Sciences and the Oak Ridge Leadership Computing Facility, is an elected fellow of three professional societies and a senior member of two others.

"As my scientific interests evolved over time, I joined several different societies, which helped broaden my knowledge and understanding of the various scientific communities with which my own work intersected," she said.

Taking on a leadership role in a society taught Tourassi how to inspire, how to encourage and achieve cooperation and how to guide processes and complete tasks, while her experience at ORNL has helped her see the broader impact of the lab's work in the world.

"Every professional society is part of a bigger ecosystem," she said. "To be effective in its mission, a professional society needs to be able to communicate and coordinate effectively with many scientific communities."

Society leaders learn how to take on new responsibilities, organize large events, hone their interpersonal skills and

forge meaningful collaborations both inside and outside their field. Researchers who step up early can establish their bona fides and set themselves up for future acknowledgments, such as awards and named fellowships, said Karren More,

> *"Every professional society is part of a bigger ecosystem. To be effective in its mission, a professional society needs to be able to communicate and coordinate effectively with many scientific communities.*
>
> — ORNL National Center for Computational Sciences Director **Gina Tourassi**

director of the Center for Nanophase Materials Sciences and fellow of the Microscopy Society of America and the American Ceramic Society.

"By getting involved, early career researchers can get their name out there and start to be recognized not only for their

> *"It is, after all, the staff who bring recognition to the lab as a world-leading research institution, one that supports its staff in their desire to broaden their engagement in their scientific field.*
>
> — ORNL Center for Nanophase Materials Sciences Director **Karren More**

scientific contributions, but also their service to the society and community," More said. "It is a great way to earn a reputation as a person who gets things done."

Having ORNL leaders in professional societies promotes the lab's reputation as an organization with staff who help professional societies thrive while also producing great science—both of which are vital to scientific advancement

"It is, after all, the staff who bring recognition to the lab as a world-leading research institution, one that supports its staff in their desire to broaden their engagement in their scientific field," More said.

Gina Tourassi

Karren More

When ORNL researchers serve in leadership positions, they get the chance to influence scientific directions and programs. Some leaders, like Tourassi, take the opportunity to develop an environment of diversity and inclusion and act as mentors for other researchers.

"My goal is to lead by example and inspire the next generation of scientific leaders," she said. "I appreciate how these memberships have enabled my career growth. I consider it as part of my social responsibility to give back."

SCIENTIFIC LEADERSHIP BEGINS WITH PEOPLE, page 13

"Answering those questions is fundamental to understanding how metals cycle in the environment and how that impacts drinking water quality, the quality of our lakes and streams."

For her part, the Nuclear and Radiochemistry Group's Davern is looking to a future where radiation therapy is more effective and its effects less catastrophic.

"The opportunities are there for us to work together in cross-disciplinary teams to make better radiotherapeutics," she said. "If we can have more targeted therapies that localize where you want them to be and don't travel systemically as much throughout the body, then you can decrease those effects. There will never be none, but hopefully they will be less."

For ETSD Director Sun, the future is an opportunity for the lab to live up to the reputation it has built over its seven-plus decades—a reputation built on the achievements of the Manhattan Project, the discovery of messenger RNA and the identification of the Y chromosome's role in determining an individual's sex.

"Right now we are positioned to do the big science that will have huge societal impacts," she said. "If you look at ORNL's history, in the end it really has societal impact."

Experts enable ORNL to keep going strong

ORNL's world-class researchers get plenty of well-deserved attention, but the lab also owes its success to the people behind the scenes.

It takes hundreds of skilled technicians, craft workers, and administrative personnel to keep the lab's buildings and utilities well-maintained and available 365 days a year, to attract the best possible new staffers and ensure they hit the ground running, to keep equipment running, respond to emergencies, and pay the bills. Whatever their jobs, ORNL could not get by without them.

ORNL Review sat down with a few of these exceptional supporting players and asked them about their roles and their views on leadership. Unsurprisingly, they stressed the importance of mentoring, and they see a bright future for the lab.

Dr. Bart Iddins: Managing COVID-19 on site

COVID-19 was a new enemy this year, but ORNL Health Services Director Dr. Bart Iddins was already as prepared as possible for a pandemic.

Iddins's background as a decorated military officer, physician, veterinarian and public health officer plays into how he views his current mission: to ensure COVID-19 doesn't prevent ORNL staffers from continuing the lab's missions.

> *"Since January, my complete focus has been on defending this operation from SARS-CoV-2. I am in full battle mode to defend this nationally important mission and its most important asset, its people, from this deadly virus.*
>
> — ORNL Health Services Director **Dr. Bart Iddins**

"Before January 2020, my time was divided among health care management and administration, medical program management, occupational risk assessment, occupational health risk surveillance and patient care," Iddins said. "Since January, my complete focus has been on defending this operation from SARS-CoV-2. I am in full battle mode to defend this nationally important mission and its most important asset, its people, from this deadly virus."

For Iddins, who joined the lab 18 months ago after retiring from the U.S. Air Force, that means drawing on his medical background, which taught him the importance of considering diseases in terms of not only

Dr. Bart Iddins at ORNL's 2019 Veterans Day celebration. Image credit: Carlos Jones, ORNL

the health of each individual, but also the health of the entire herd.

It also means making use of his military background, especially combat experience.

"It is clear to me after numerous contingency deployments and combat tours that the key to successful military campaigns is logistics," Iddins said. "Whether we are talking about procurement of required cleaning supplies, computers for teleworking, COVID-19 test kits, cloth face masks and any number of other necessary supplies and equipment, logistical support is a cornerstone to management of a pandemic at the local, state, national and international levels."

Another military principle he's applied to ORNL's COVID-19 strategy: a layered defense. Working from home, strict social distancing, home quarantine, contact tracing, COVID-19 testing and travel restrictions all are part of ORNL's in-depth defense, which is evaluated daily, he said.

"The greatest challenge is that many aspects of the pathogenesis of SARS-CoV-2 are unknown," Iddins explained. "As a result, ORNL's COVID-19 strategy is in a constant state of adaption as new viral research data becomes available."

As more employees return to campus, Iddins will continue to evaluate the best courses of protective action.

"I love all aspects of my job in normal times and in these 'new normal' times," Iddins said. "I enjoy being part of this incredible team of like-minded people."—*Kristi Nelson Bumpus*

Kory Miike: Great leaders come from great mentors

When you have an organization responsible for 350 research, office and support facilities covering 4 million square feet, you need strong leadership throughout. Fortunately, says Kory Miike, wise leaders can build leadership within their organizations.

Miike, who serves as director of ORNL's Facilities Management Division, leads a staff of about 300. The division performs facility-related functions ranging from fixing leaky faucets to engineering and installing state-of-the-art equipment for researchers.

> *"You want your circle of influence to be as big as it can be. You can accomplish more that way. You can grow your circle of influence by how you perform, how your attitude resonates, how you network, and how you respond to people.*
>
> — ORNL Facilities Management Director **Kory Miike**

According to Miike, the No. 1 job of a leader is to create more leaders.

"Taking quality time to mentor others is necessary for the organization and for its future leaders," he said.

Miike's first experience with a strong mentor was nine years ago—four assignments and 15 positions into an Air Force career.

"He took the time to make sure I was fully involved with the issues," Miike said. "He would say 'You are coming to this meeting with me; you will see what I see.' He would bring everyone together to collaborate. He wanted to know our thoughts about the issues."

Miike came to ORNL in 2016, serving as deputy director and director of the Logistical Services Division before taking the helm at the Facilities Management Division in 2019.

Before joining the lab, he had a fruitful Air Force career in which he eventually became deputy group commander over four squadrons and more than 1,500 personnel at the 305th Maintenance Group at Joint Base McGuire-Dix-Lakehurst in New Jersey. He emphasizes what he calls "the circle of influence" as a key leadership principle.

Kory Miike

"You want your circle of influence to be as big as it can be," Miike said. "You can accomplish more that way. You can grow your circle of influence by how you perform, how your attitude resonates, how you network, and how you respond to people."

All individuals have a circle of influence that needs to be nurtured, he said.

"When you are out there doing a job, the minute you take a shortcut, your circle of influence shrinks."—*Ed Bodey*

Jessica Langstaff: Ensuring utilities are always available

Strong leadership for Jessica Langstaff is about quick decision-making and facing challenges head-on.

Langstaff is an operations manager for ORNL's Mechanical Utilities Complex, an organization staffed around the clock, 365 days a year, to provide many of the vital

See EXPERTS ENABLE ORNL, page 22

OAK RIDGE National Laboratory

ORNL BY THE NUMBERS

ORNL has been an important national resource for more than 75 years and provides leadership in supercomputing, nuclear and neutron science, advanced materials, manufacturing, isotope production, environmental science and many other fields.

1943
ESTABLISHED

$2.1B
BUDGET (2019)

60+
NATIONALITIES REPRESENTED ON STAFF

ORIGINAL NAME:
CLINTON LABORATORIES

9
USER FACILITIES

3,200
GUEST RESEARCHERS ANNUALLY

WORLD'S FASTEST SUPERCOMPUTER

2 NOBEL LAUREATES

CONTRIBUTED TO THE DISCOVERY OF

11 PERIODIC TABLE ELEMENTS

Pm No Lr Rf
Db Sg Fl Mc
Lv Ts Og

194
JOINT FACULTY WITH UNIVERSITY OF TENNESSEE

818
U.S. PATENTS (2007-2019)

2,000+
JOURNAL PUBLICATIONS (2019)

5,000+
TOTAL STAFF

2,000+
STAFF SCIENTISTS/ENGINEERS

WORLD'S MOST INTENSE PULSED NEUTRON SOURCE

150
ACTIVE LICENSES

200+
COMMUNITY ORGANIZATIONS SUPPORTED (2019)

EMPLOYEE GIVING TO UNITED WAY:
$650,000
(2019)

Jessica Langstaff

EXPERTS ENABLE ORNL, page 19

utilities—like water and steam—that keep ORNL operating.

"I can receive a call any time, day or night, telling me that we experienced a problem in one of our systems, like a water line break," Langstaff said. "Our ability to face the issue head-on and to rapidly respond is critical for us in meeting our primary mission of providing uninterrupted service to our research customers."

The ORNL water distribution system, for example, is essential to the operation of world-class research facilities such as the Spallation Neutron Source, the High Flux Isotope Reactor and the Summit supercomputer. Langstaff's organization distributes nearly 770 million gallons of water each year to customers throughout the campus. It operates large industrial systems that chill nearly 60 million gallons a year to meet the cooling needs of research facilities and to provide building temperature control.

> *"I can receive a call any time, day or night, telling me that we experienced a problem in one of our systems, like a water line break. Our ability to face the issue head-on and to rapidly respond is critical for us in meeting our primary mission of providing uninterrupted service to our research customers.*
>
> — ORNL Mechanical Utilities Complex manager **Jessica Langstaff**

One incident that required quick decision-making and what Langstaff calls "a head-on response" occurred in 2016, when a 20-inch water main that serves the HFIR complex ruptured, spewing 50 to 75 gallons of potable water a minute.

Langstaff and the Mechanical Utilities team raced to respond, working day and night in harsh winter conditions to repair the leak before water supplies to HFIR were interrupted. Their success prevented a potential reactor shutdown and the interruption of important research activities.

> *"Rapid growth can potentially introduce confusion and stress. We want new staff to be successful. One key to their success is understanding ORNL's research and safety culture.*
>
> — DOE Center for Bioenergy Innovation Chief Operating Officer **Renae Speck**

For the 11 years that she has been a member of Mechanical Utilities, Langstaff's personal leadership philosophy has been to capitalize on lessons learned and the decision-making skills that come with them.

Her leadership philosophy also drives her to spend a significant amount of time in the field, where she experiences the work firsthand. This, she says, allows her to maintain direct and consistent contact with the systems she manages and the highly skilled tradespeople—electricians, millwrights, power equipment operators and others—who perform the hands-on work.—*Ed Bodey*

Renae Speck

Renae Speck: Helping staff prepare for a growing lab

Renae Speck spends much of her time as chief operating officer of DOE's Center for Bioenergy Innovation at ORNL ensuring that incoming researchers and other staff adjust well to a growing laboratory.

"Rapid growth can potentially introduce confusion and stress," she said. "We want new staff to be successful. One key to their success is understanding ORNL's research and safety culture."

Speck has been at ORNL for over a decade, serving as COO of CBI and as operations director for DOE's National Alliance for Water Innovation, led by Lawrence Berkeley National Laboratory.

She sees a bright future at ORNL, with researchers increasingly working together under the lab's "One ORNL" philosophy.

"I see more collaboration now than ever before," she said. "I think it will continue to strengthen ORNL's scientific output."

Speck brings a diverse background to her position. She started at ORNL as a commercialization manager in the Partnerships Directorate and, before that, held positions at Western Kentucky and Vanderbilt universities.

Her wide experience has taught her that leadership isn't just one style.

Instead, she said, different people require different approaches, and leaders must know when to lead and when to let others lead.

"We need to have multiple styles to adapt to diverse situations," Speck said.—*Clint Keeton*

Marilyn Foxall: Helping the next generation

A native Californian with almost 30 years of experience in human resources, Marilyn Foxall agrees that strong mentoring is critical to a successful organization.

Foxall is director of the lab's Talent Services Division, where she oversees Human Resources managers, business partners and administrators. But when she first started working, she was an emergency room receptionist with dreams of entering the police academy and pursuing a career in law enforcement.

The course of her career changed the day she was asked to answer phones for the hospital's personnel department.

"Sandra Davis, who was the senior vice president of Human Resources, had been watching me and told me I should be in HR," Foxall said with a laugh, "but I couldn't do that. I had other plans!"

Once Davis mapped out her own career and explained what was possible, however, Foxall was persuaded to change those plans, and a decades-long mentorship began.

"Every couple of years, Ms. Davis would call me to check in on me and tell me it was time to move," Foxall said.

Noting that career advancement wasn't the only benefit of a good mentor, she added, "The thing about a great mentor is that they will always tell you the truth. Sometimes that truth may be rough, but they will always have the courage to be authentic with you because they care."

> *"The No. 1 tenet I step out on every day is courage. Everything you do that propels you forward starts with courage.*
>
> — ORNL Talent Services Division Director **Marilyn Foxall**

Courage is an aspect of leadership with which Foxall is well acquainted. Ever since she was a little girl, she said, her parents and grandparents—"the village that raised me," she calls them—have always counseled her to be courageous.

These teachings have served her well in a career that has moved from the private sector to the DOE national laboratory system.

"The No. 1 tenet I step out on every day is courage," she said. "Everything you do that propels you forward starts with courage."—*Christy White*

Marilyn Foxall

Gary Worrell: Making sure we attract the best talent

ORNL has many impressive research facilities, notes Gary Worrell, but they can't reach their potential without skilled scientists, engineers and other staff members. As director of the Talent Acquisition Division, Worrell is deeply involved in making certain ORNL recruits the best possible candidates to fill job openings.

"Research organizations have a lot of great equipment," Worrell said, "but we need people to use that equipment and publish findings."

See EXPERTS ENABLE ORNL, page 25

New workshops let participants face uncomfortable truths

by Katie Jones
joneske1@ornl.gov

Through Courageous Leaders Summits, ORNL is providing leaders and staff with meaningful guidance on how to welcome differences in order to work together most effectively. The summits give participants the opportunity to confront uncomfortable truths about diversity and inclusion.

> *"A diverse and inclusive culture takes everyone at the lab. The summits are one way to expand our understanding of others' experiences.*
>
> — ORNL Office of Diversity Director **Deborah Bowling**

"Courageous Leaders sessions facilitate an open dialogue to talk about the things that are different for each of us," said Deborah Bowling, director of the lab's Office of Diversity.

Each summit is two half days of activities that explore "insider" and "outsider" cultures in the workplace that can create unconscious bias and impact diversity and inclusivity.

"Opening the sessions, people are asked to read real, anonymous experiences that happened at ORNL," Bowling said. "Every company has a unique culture—and the conversations are unique to each company and to each summit, because the participants drive the conversation."

Deborah Bowling

More than 500 ORNL managers and staff have attended Courageous Leaders Summits since the program was first offered in 2018, and eight to 10 sessions are on the books for 2020, which could reach another 1,000 employees.

"A diverse and inclusive culture takes everyone at the lab," Bowling said. "The summits are one way to expand our understanding of others' experiences."

ORNL's Courageous Leaders Summits, Bowling added, help staff understand each other because a variety of experi-

ences come up in conversation that on their own they might not think about.

Bowling described a recurring discussion about different travel experiences for employees. "For example, men may not have reservations about landing at an airport at midnight and taking a taxi in a strange city, but some women have voiced that they do have reservations."

The summits have led to conversations about navigating differences of gender, race, sexual orientation, age, physical ability and other characteristics.

"Some people are asking questions they've never been able to ask before in a group setting," Bowling said. "Simply opening the conversation is a notable success of the Courageous Leaders Summits."

EXPERTS ENABLE ORNL, page 23

Worrell, who has been in his position about a year, has been working with the lab's communications organization to establish ORNL's brand and send the message to researchers that ORNL is an employer of choice. The job takes an A-plus game, given there is steep competition for potential recruits.

One challenge is that private industry is changing.

"More and more organizations are hiring Ph.D.-level talent, beyond just the universities and research institutions," Worrell said. He noted, for example, that companies such as Google and Amazon are hiring their own Ph.D.-level staff to address data mining challenges.

So far, Worrell's group has achieved its A-plus game: ORNL hired more people in 2019 than in any other year in its history.

But it's not just about putting warm bodies in vacant positions. Since his early days as a software sales rep, Worrell has gotten his sense of fulfillment from helping clients reach their goals.

"If I help an organization execute their business plan," he said, "it's rewarding to me to be a part of that success."

And success, says Worrell, is better together. "You can go it alone or you can build a team. In my experience, you're going to get farther, faster by teaming up."—*Christy White*

> *"Research organizations have a lot of great equipment. But we need people to use that equipment and publish findings.*
>
> — ORNL Talent Acquisition Division Director **Gary Worrell**

Gary Worrell

Staff members bring ORNL to the community

Candice Halbert, a scientific associate at SNS, leads an activity focused on germs and proper handwashing during a STEM Saturday event. Image credit: Amir Noble

by Abby Bower
ornlreview@ornl.gov

The contributions of ORNL staff members in their communities range from donating to United Way and other nonprofits to volunteering for service and fundraising events with Team UT-Battelle, to—on occasion—even founding a nonprofit.

No matter the scale or complexity, their community leadership most often starts with a simple sentiment: "I want to help."

Answering the call

That's how Candice Halbert, a scientific associate at the Spallation Neutron Source, got the idea to start Girls in STEM, or gSTEM, a science outreach program based at Knoxville's Vine Middle School. Halbert found herself at Vine Middle on an unrelated mission. She'd collected water and supplies—mostly from ORNL staff—to send to Flint, Michigan, during the peak of the city's water crisis in 2016. The donation drop-off was at the school.

> *"When you ask a person the majority of the time what a scientist looks like, they're not going to say, 'Someone that looks like me.'*
>
> — ORNL scientific associate **Candice Halbert**

When she noticed that Vine is a science, technology, engineering, art and math, or STEAM, school, Halbert asked whether she could help out in a science capacity. She received an unexpected reply: Would she be willing to start a new afterschool science program for girls?

Halbert agreed, and gSTEM was born, with the mission to give girls at Vine, a majority black school, the opportunity to do hands-on experiments and to have high-level interactions with STEM professionals who look like them.

"When you ask a person the majority of the time what a scientist looks like, they're not going to say, 'Someone that looks like me,'" said Halbert, who notes that in her field, she often finds

Thomas Proffen of the Neutron Sciences Directorate explains how objects hit the top of the screen while leading a session on video game app creation for Girls Inc. in Oak Ridge, a nonprofit dedicated to empowering girls. Image credit: Yvonne Dalschen

herself the only woman and the only person of color in a room. "So in order to change this mindset, we need more people of color, women and LGBTQ+ people in the room to associate as STEM professionals."

The program's success pushed Halbert to start a nonprofit, Youth Outreach in STEM, or Yo-STEM, which has tripled in size from the original eight girls and four mentors. It includes broader activities such as public STEM Saturdays and a coed Build-a-Drone program.

From the beginning, overwhelming buy-in from the Neutron Sciences Directorate's leadership and monetary support from Team UT-Battelle helped gSTEM operate at no cost to the school, Halbert said. The mentors were then—and still are—mostly ORNL staff.

The volunteer spirit

"Recruiting volunteers when you have the lab in town is not a big problem," said Thomas Proffen of ORNL's Neutron Sciences Directorate, who started his own STEM nonprofit for girls.

While working with his daughter's FIRST Lego League team, as part of an international robotics competition program, Proffen noticed that even in a setting with an equal boy–girl mix and a female coach, kids split up according to gendered tasks. After his daughter competed in an all-girls computer science competition, he decided to create a space in tech education just for middle school girls.

His idea came to life as Oak Ridge Computer Science Girls. Through the program, he hosts free coding classes every other Saturday and longer camps during school breaks. Since it started in 2017, the program has given hundreds of girls the confidence to tackle tough technical challenges. Finding volunteers never takes much more than an email to several women's organizations at the lab, he said.

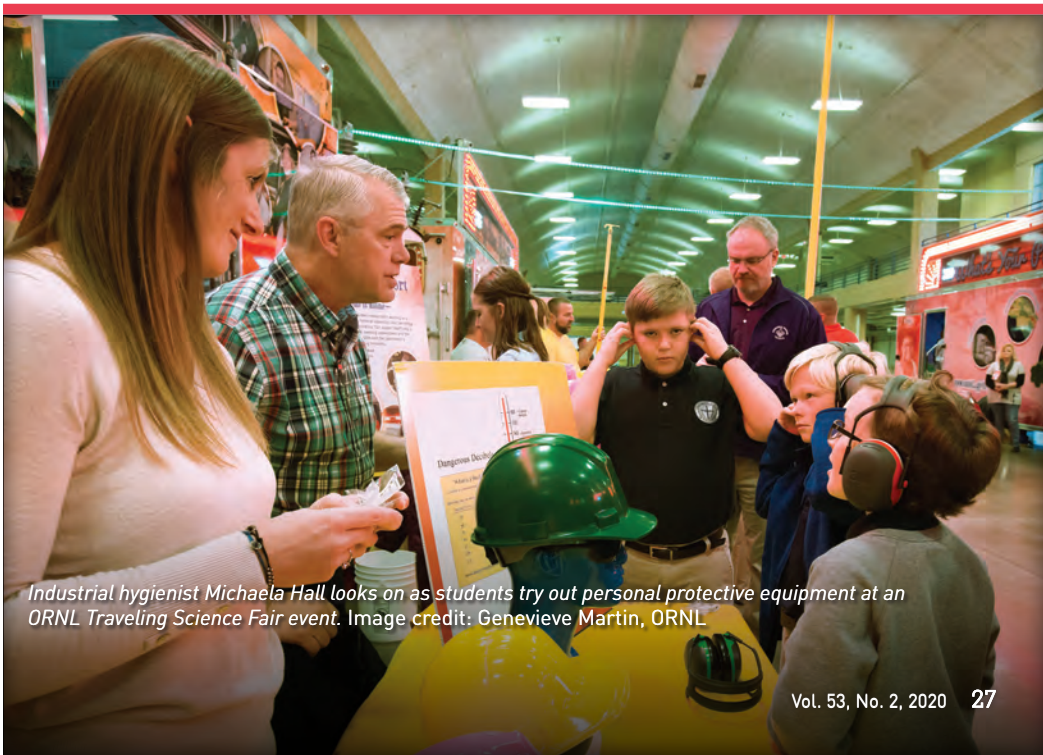
> *"Recruiting volunteers when you have the lab in town is not a big problem.*
>
> — **Thomas Proffen** of ORNL's Neutron Sciences Directorate

Outreach is a passion for Proffen, who also spearheads ORNL's annual Hour of Code efforts. During a week in December, lab volunteers visit area schools to talk to students about ORNL and computer science, leading kids through hands-on coding activities designed to inspire. In 2019, 43 lab staff members visited 27 local schools.

Science for schools

Proffen is also a technical trailer lead for ORNL's Traveling Science Fair, a unique outreach effort that gives kids across the region a chance to see first-hand the amazing science happening at ORNL through interactive exhibits held in six trailers—one each for five of the

See STAFF MEMBERS BRING, page 28



Industrial hygienist Michaela Hall looks on as students try out personal protective equipment at an ORNL Traveling Science Fair event. Image credit: Genevieve Martin, ORNL

John Powell, director of the Environment, Safety, Health and Quality Directorate, helps build a home with Team UT-Battelle and Habitat for Humanity. Image credit: Ed Bodey, ORNL

STAFF MEMBERS BRING, page 27

lab's science directorates and one for mission support.

The Traveling Science Fair is where Michaela Hall, an industrial hygienist at ORNL, found her place. In addition to co-leading the mission support trailer, which represents the Facilities and Operations Directorate and the Environment, Safety, Health and Quality Directorate, Hall leads setup and safety oversight for the fair, which visits schools, festivals and events between six and 10 times a year.

prevent kids from getting the kind of up-close science exposure the fair offers, especially in underserved communities.

"Those communities are the ones in my mind where you see the kids get the most excited," Hall said. "They show up and the looks on their faces are awesome, like they are beaming with excitement."

She's been involved with the fair for about six years, but it was started long before that by numerous creative and dedicated ORNL staff members who made

> *"Those communities are the ones in my mind where you see the kids get the most excited. They show up and the looks on their faces are awesome, like they are beaming with excitement.*
>
> — ORNL industrial hygienist **Michaela Hall**

Her shifts are long. Leading the setup crew means spending four to five hours setting up the day before. On the day of the fair, her team arrives two to three hours before the event begins and leaves two hours after it ends. But to Hall, it's worth it. The fact that the Traveling Science Fair is free and mobile means it breaks down access barriers that otherwise could

the effort possible, Hall said. Though Idaho National Laboratory has been working with ORNL staff to launch a similar effort, ORNL remains at this time the only national lab with a Traveling Science Fair.

'Simultaneous excellence'

This type of forward-thinking outreach is just one example of ORNL management contractor UT-Battelle's management philosophy of "simultaneous excellence" in action. The principle behind simultaneous excellence, according to ESH&Q Director John Powell, is that for the company to really achieve excellence, it must excel not only in science and technology, but also in operations and community service.

> *"It's not just extra credit. It's why we're here. If we don't pay attention to operations and community, we might not get to even do the science.*
>
> — ORNL Environment, Safety, Health and Quality Director **John Powell**

"It's not just extra credit," Powell said. "It's why we're here. If we don't pay attention to operations and community, we might not get to even do the science."

Powell is a leadership sponsor for Team UT-Battelle, an employee service organization that helps allocate resources and volunteers to community service efforts ranging from national park cleanups and charity races to collecting Angel Tree donations.

One dear to his heart is ORNL's involvement with Habitat for Humanity of Anderson County, where Powell regularly volunteers. ORNL donations and volunteers showing up on Saturday mornings have helped build homes and assisted families in need with a "hand up" on vital repairs.

"But if pounding nails isn't your thing, that's OK," Powell said.

The lab's community outreach is as diverse as its more than 5,000 employees. And the best way to keep it growing, according to Candice Halbert, is to ask communities what they need and answer the call.

"We don't want to tell people what to do," Powell said, "but we can make it so whatever you want to do, you're not going in alone."

Polymer physics pioneer pushes women in STEM

By Abby Bower
ornlreview@ornl.gov

Dame Julia Higgins doesn't mind being a pioneer, but only if it means she's truly paving the way for the next generation.

An expert in neutron scattering for polymer research, Higgins's work has earned her titles including Dame of the British Empire, Fellow of the Royal Society and President of the United Kingdom's Institute of Physics. During a September 2019 visit to ORNL, she walked audiences through her key research and landmark initiatives promoting diversity in STEM.

"When I came into polymer science, there were a number of questions that couldn't be answered with the techniques of the time," Higgins said. Researchers wanted to know how a polymer's unique, chainlike molecules behaved when melted or stretched.

Higgins had attended Oxford University's Somerville College in the 1960s, one of only 10 women studying physics in a class of around 200.

> *"When I came into polymer science, there were a number of questions that couldn't be answered with the techniques of the time.*
>
> — Imperial College London polymer scientist **Dame Julia Higgins**

She was recruited to Oxford's chemistry department for her doctorate by an enthusiastic young researcher who wanted to use neutrons, a subject that capitalized on Higgins's physics background. Newly developed neutron scattering tools pioneered at ORNL's Graphite Reactor had given researchers a new analytical capability to complement more widely available tools like light and X-ray scattering.

Dame Julia Higgins. Image credit: Genevieve Martin, ORNL

At the University of Manchester, France's Institut Laue-Langevin and later at Imperial College London, Higgins sought fundamental answers about polymer behavior through neutron scattering techniques. She was fortunate, she said, that whenever a new technique was developed, she was frequently among the first to use it.

But that wasn't the only way she broke barriers.

When she became a professor of chemical engineering at Imperial College in 1989, she joined only one other female professor. As her own career advanced, she became increasingly involved in management and science policy. She noticed a lack of senior women within Imperial College, especially in STEM departments.

"I thought it's all very well being a pioneer, but where are the people behind you?" she said.

See POLYMER PHYSICS, page 31

People with purpose power ORNL

by Jim Pearce and Kelley Smith
pearcejw@ornl.gov

Liane B. Russell fellow Christa Brelsford studies how social systems interact with physical systems and the implications of that relationship for infrastructure and emergency planning.
Image credit: Carlos Jones, ORNL

Uniquely powerful scientific instruments don't sustain global leadership without a diverse research and technical staff from across disciplines, ready to solve the world's most pressing challenges.

"We have amazing facilities, but we also make sure we have the programs and opportunities expected by the people leading our extraordinary research," said Mardell Sours, ORNL's director of human resources. "Everyone wants to work for an organization that values its people and pursues solutions for the good of humanity—and that's what we do at ORNL."

Sours' team works with the lab's scientific leadership to identify and recruit the most talented professionals in their fields, to support development of staff members across the lab, and to provide the "total rewards" they expect—not only in compensation and traditional benefits but in growth opportunities, training, flexible work arrangements and amenities such as an on-site medical clinic and fitness center.

She views diversity and inclusion as vital ingredients in fulfilling the lab's science and technology mission. "Diverse and inclusive organizations are more innovative, productive, safe, collegial, and enjoyable places to work," she said.

In the next few years, ORNL aims to hire up to 1,000 more new employees.

> *"You can tell professors and university leadership teams how amazing ORNL is all you want, but to really appreciate the laboratory, they have to come and see it.*
>
> — ORNL Director of Research Excellence **Moody Altamimi**

"We are taking a much more proactive approach to meeting the talent needs of the lab," said Gary Worrell, ORNL's lead talent acquisition partner. "We have partnered with every organization across

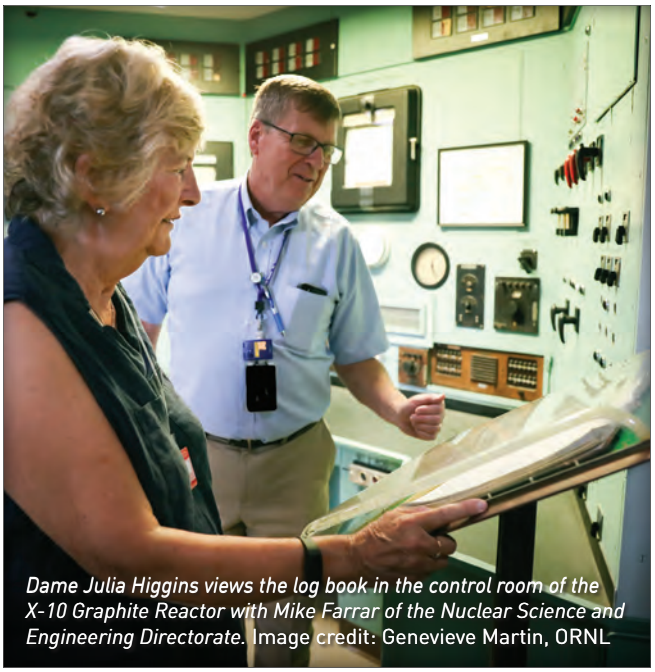
POLYMER PHYSICS, page 29

To ensure others could follow in her footsteps, Higgins helped start two initiatives for women: at Imperial, the Academic Opportunities Committee, and, nationally, the Athena Project.

The committee's internal activities included educating female academics on promotion opportunities and providing funding for those returning from maternity leave to spend a full year on research before resuming lecturing and administrative duties.

The Athena Project gave accreditation, awards and grants to departments working to increase the number of women in senior roles. The project's success came from involving top leaders and demanding accountability, Higgins said. To receive Athena accreditation, departments and institutions had to demonstrate their progress with data rather than merely recording the problem, a requirement that increased the number of women in leadership.

For women in STEM, she said, "The leaky pipeline is changing, but very slowly."



Dame Julia Higgins views the log book in the control room of the X-10 Graphite Reactor with Mike Farrar of the Nuclear Science and Engineering Directorate. Image credit: Genevieve Martin, ORNL

the lab to identify talent needs; we are collaborating with more organizations like Historically Black Colleges and Universities (HBCUs) and the Society of Women Engineers, and our talented team of recruiters is working closely with hiring managers to ensure we find diverse, high-quality talent—people who aspire to the science mission of ORNL."

In addition, recruiters are working to improve the recruitment experience.

"Whether or not a person gets the job, I want them to say, 'I had a really good time meeting the team. I learned a lot, and I would love to work there someday,'" said ORNL recruiter Stephanie Baird. "I want ORNL to be set apart, not just in terms of our research excellence, but in how we treat people. Each person is important—they're not just another name in a pool of applicants."

This new approach has led to an increase in the volume and diversity of applicants. Most notably, the applicant pool has increased from an average of roughly 15,000 a year to over 50,000 in 2019.

Cultivating promising undergrads

Moody Altamimi, ORNL's director of research excellence, oversees efforts to offer underrepresented minority students the opportunity to develop skills that will enable them to pursue advanced degrees in science and engineering. She makes it clear that the ultimate goal of the lab's involvement with organizations like the National Graduate Degrees for Minorities in Engineering and Science, Inc. (GEM) Consortium is finding and encouraging exceptional talent.

"These are high-quality, carefully selected students who just happen to be diverse," Altamimi said. "I have been working with GEM students for two years, and our goal has been to engage with them as early as possible. We want to move the process upstream by identifying talented candidates early on and inviting them to spend the summer doing research at the laboratory.

"Our long-term strategy is to provide these students with a successful internship experience that encourages them to consider the laboratory as a potential employer or collaborator."

Building faculty relationships

Another way the lab identifies promising students is by building relationships with their teachers. That's the thinking behind the HBCU Minority Educational Institution (MEI) Faculty Summer Research Program at ORNL. The lab sponsors summer research appointments for faculty at HBCUs and MEIs, with an eye toward increasing research collaborations and fostering long-term relationships between ORNL research staff and faculty members.

"You can tell professors and university leadership teams how amazing ORNL is all you want," Altamimi said, "but to really appreciate the laboratory, they have to come and see it. When the Faculty Summer Research Program participants

See PEOPLE WITH PURPOSE, page 32

PEOPLE WITH PURPOSE, page 31

were here last summer, we created an environment that enabled them to engage with our science and technology staff, and they were blown away by the opportunities that were available, as well as by the incredible science that takes place here."

Student research assistant Alydia Young discusses the poster "Thermal Vibration Contribution to Atomic-Level Stress" during last December's ORNL Collaboration Workshop, which was attended by 14 Historically Black Colleges and Universities and Hispanic Serving Institutions. Image credit: Megan Jamerson, ORNL

Faculty members are also asked to identify one or two students who could come to ORNL for an internship over the summer.

"Typically, the summer research experience gives students the confidence and the desire to go on to get a Ph.D.," Altamimi said. "The research produced by undergraduate students who have had internships at any national lab is much more mature, much more refined, so their Ph.D. applications are naturally stronger." We know they will hit the ground running when they get into a Ph.D. program."

Developing leadership potential

In addition to recruiting talented individuals, ORNL puts a premium on developing the potential of staff members throughout their careers at the laboratory.

Eric Benson, an organizational development and training consultant at ORNL, designs, develops and delivers training programs that promote individual and organizational improvement.

"Our goal is to enhance performance," Benson said. "Performance is a combination of our relationships and our results. The programs we provide help people to get along and get great things done."

One of the laboratory's most effective training courses has been the Developing Leadership Potential program.

"To be a leader in science, you need to demonstrate a mastery of science," Benson said. "But being a leader of scientists requires learning to lead in a different way. It requires a mastery of working with and motivating people. That's what Developing Leadership Potential is all about."

The weeks-long program is conducted once a year for about 20 people. To attend the course, individuals must be nominated by their manager.

"We ask managers to consider whether these individuals are on a succession plan, whether they are up-and-comers, whether they have demonstrated an exceptional level of performance and are looking to take on larger leadership roles," Benson said.

"It's a wonderful opportunity for them to begin to network with people who will be on the same leadership level. They forge bonds with one another, so there's good collaboration across the lab, not only from a scientific standpoint, but also when they need to discuss a situation or get advice.

"We're seeing an uptick in participation in all of our programs, so the professional development opportunities at the lab are being taken advantage of more and more. We're encouraged by it, and we'd like to see the numbers continue to increase."

Attracting world-class early-career scientists

Another of the many tools the laboratory uses to attract top next-generation scientists is research fellowships. For example, the Liane B. Russell Fellowship, named for the groundbreaking ORNL geneticist, attracts world-class, early-career researchers from all fields of science and engineering. The fellowship's three-year appointments allow recipients to conduct high-quality research with the goal of pursuing long-term careers at ORNL.

One recent recipient, Christa Brelsford, works in ORNL's Human Dynamics Group. She says that the fellowship has given her the opportunity to build a collaborative network across the national lab system while still maintaining her strong connections to academia.

Brelsford has been studying the concept of "community detection" and trying to develop tools to measure how social systems interact with physical systems.

Undergraduates from underrepresented communities attended the GEM Grad Lab event in September 2019 at ORNL. Participants learned about opportunities to develop skills that will enable them to pursue advanced degrees in science and engineering. ORNL organized the event with University of Tennessee and the National Graduate Degrees for Minorities in Engineering and Science, Inc. (GEM). Image credit: Genevieve Martin, ORNL

"For example," she said, "Suppose a hurricane hits a major city—where do the people go? In an emergency, we need to understand both the vulnerabilities of the physical infrastructure like roads, transportation systems, power and water, and we also need to understand how people make choices. People are not just going to uniformly move to the next closest community. People go to other cities. People go to places where they have relationships and contacts and community."

Brelsford noted that, historically, researchers haven't had very good tools for measuring or understanding how these choices are made.

"This idea of community detection is a very early-stage effort to try to answer these questions by using publicly available data from Twitter that contains geographic information—like place names and, occasionally, GPS-type information," she said. "That gives us information about where people are tweeting from and where the tweets are directed to."

By accumulating these social media interactions, Brelsford and her colleagues can begin to build pictures of communities whose boundaries are defined by person-to-person interactions, rather than by lines on a map. Eventually, she hopes that this knowledge can be applied to helping cities determine where people are likely to go in the event of a natural disaster and to apply that knowledge to infrastructure and emergency planning.

> *"To be a leader in science, you need to demonstrate a mastery of science. But being a leader of scientists requires learning to lead in a different way. It requires a mastery of dealing with people. That's what Developing Leadership Potential is all about.*
>
> — ORNL organizational development and training consultant **Eric Benson**

"I have always considered the purpose of a scientific career to be doing good in the world," Brelsford said. "So the guiding, practical question of my work is: 'Is this going to help? Is it going to make somebody's life better?' I'm not a classical economist or a classical geographer or a classical anybody. I have always been prone to saying, 'That's a cool question; I'm going to work on that.' And if I don't have the expertise to answer the questions myself, I go find a collaborator who does. This fellowship at ORNL has allowed me to pursue that kind of research and to build those kinds of relationships."

> *"For me it's about seeing everyone's perspective on how the labs work, their missions, how they work together, because they're coming from all different backgrounds.*
>
> — ORNL computational nuclear scientist **Tara Pandya**

Tara Pandya. Image credit: Carlos Jones, ORNL

Oppenheimer program shapes ORNL leaders

By Abby Bower
ornlreview@ornl.gov

For ORNL's Tara Pandya, a computational nuclear scientist, 2020 will be a crash course in learning how to lead within a national laboratory.

Pandya joined the 2020 cohort of DOE's prestigious Oppenheimer Science and Energy Leadership Program at the start of the year, becoming the second ORNL staff member accepted since the program launched in 2017.

She follows Eric Pierce, a group leader in the Environmental Sciences Division, who was a member of the 2019 cohort.

"It's a really big honor," Pandya said. "It's very rare that someone gets the opportunity to do what we get to do."

The yearlong program was developed to introduce the next generation of leaders to the breadth and depth of the national laboratory system. This year's cohort, whose 18 members bring diverse backgrounds from within all 17 national laboratories, will tour the country's national labs and write "think pieces" based on their experiences that address specific improvement areas for the DOE lab system.

"For me it's about seeing everyone's perspective on how the labs work, their missions, how they work together, because they're coming from all different backgrounds," Pandya said.

For Pierce, the experience provided unparalleled working-level and big-picture views of how the system works, including challenges labs face daily. And he already had a unique background, having spent a year with DOE in Washington, D.C., during a federal administration change.

"Even having all that insight after a year in D.C., the year of traveling around the complex and seeing the different labs and the different missions through the Oppenheimer program still offered a unique perspective that I don't think you can get any other way," he said. "The breadth and depth of the science at each institution is amazing, and that is probably an understatement."

The highlights are too numerous to list, but among the "coolest" things Pierce saw during the program was the National Ignition Facility at Lawrence Livermore National Laboratory, where 192 lasers focus on a point the size of a pencil eraser to imitate conditions found in stars, planets and nuclear weapons. Hearing from national leaders including former Energy Secretary Ernest Moniz was also memorable, he said.

The program had a lasting impact for Pierce. It taught him how to navigate systems within and outside the lab and support staff members in his group, and it gave him insight into interlab teaming opportunities and a renewed appreciation of the entire system.

"Overall if I was to sum it up, you hear people say all the time that 'the national labs are a crown jewel,'" he said. "It often sounds like it's just kind of a cliché, but having been at two, having been able to go to at least 14 ... they really are the crown jewel.

"The things they do for the country and the way the complex has the ability to focus resources on a really, really difficult problem is quite unique—so unique that every other country is trying to recreate it."

John Martinis is a former research scientist at Google and holds the Wooster Chair in Experimental Physics at the University of California, Santa Barbara.

In 2019, he led a team of researchers from Google, NASA Ames Research Center and ORNL that demonstrated that a quantum computer can outperform a classical computer at certain tasks, a feat known as quantum supremacy. The quantum system, dubbed Sycamore and built by Google, consisted of 53 quantum bits, or qubits. The classical system against which Sycamore was evaluated was ORNL's Summit supercomputer. The team's results were published in the journal *Nature*.

Martinis earned a Ph.D. from the University of California, Berkeley, in 1987. His Ph.D. thesis was a pioneering demonstration of quantum-bit states in superconductors.

On February 18, 2020, Martinis delivered the Eugene P. Wigner Distinguished Lecture on the topic "Quantum supremacy: Checking a quantum computer with a classical supercomputer." This is an edited transcript of our conversation preceding his lecture.

Distinguished

John Martinis

1 · What is quantum computing?

So, people are familiar with computers. Computers are based on storing and manipulating information using bits, which are [given the value of] zero or one. You can think of it maybe as a coin on a table, heads and tails.

This is very powerful; we can do many things with it. But nature allows us to store and process information in another way, using the laws of quantum mechanics. Quantum mechanics usually describes how atoms and nuclei—very small physical systems—work, but what was realized in the early 1980s was that you could use quantum mechanics to store and manipulate information in a way that's much more powerful for certain problems than what we can do now with regular computers.

It's all based on the fact that in quantum mechanics you have something called a superposition state. If you generalize quantum mechanics to information, this kind of superposition can be applied to a bit—zero or one—so you can encode a certain quantum state as a zero and another quantum state as one, and then nature allows you to be in zero and one at the same time.

The advantage to this is you can do information processing on that zero-and-one state—that superposition state—effectively making a parallel computer.

If you look at Summit here, CPU processors are processing data in parallel, which gives us its enormous power. With quantum mechanics, you do that just with one state. By building a big machine, you get massive parallelization that grows exponentially with the number of qubits. The parallel processing power doubles every quantum bit—zero-plus-one superposition state—you have. So, by the time you get up to 50 qubits, which is what our experiment has done, you're parallel processing 2 to the 50 states. It's an enormous number. And thus you get this extreme amount of parallel computing power.

2 · What is quantum supremacy?

The easy way to describe quantum supremacy is, we ran our quantum computer for about 200 seconds to take a million data points running the quantum computer. And to check if the quantum computer actually gave us the right answer would have taken—in the hardest case we did—about 10,000 years on a classical computer.

Of course, at 10,000 years, we can't check it, so we made an easier case—fewer qubits—where we were able to check it. And then we project for the largest data set we had.

Why is it important? We're on a long road to build a quantum computer that can do useful problems. The idea has been around for 35 years or so. It should be very possible. We thought about doing the simplest experiment

Lecturer

we can imagine, to show that the quantum computer has this extreme amount of power.

3. Where do we stand in the field of quantum computing?

We've been working on this a long time. I've known about it and in fact did some initial experiments on superconducting qubits in the mid-1980s. I call those initial experiments prehistoric qubit experiments, because the word qubit hadn't been invented. So it's been a very long road to understand all the physics and build it. We just have to keep working on the technology to understand the physics better and build bigger and bigger systems. And for me, this is the beginning of a long series of devices and quantum computers we'll build to try to solve useful problems.

4. Why is Google interested in quantum computing?

Google has a lot of classical computing power in their data center. Everyone's familiar with using their cellphones, and of course the cellphone is a very powerful computer in itself. But most of the processing and connecting to the external world and searching and using social media, etc., is done through these giant data centers.

These data centers have a huge amount of computing power, and they continue to be important, but they are expensive and consume a lot of power. Google and many other companies want to know if you can use quantum computing to accelerate some of the processes there. It'll never replace a lot of the things that a data center does, but for certain tasks it might be more efficient and more powerful.

5. Why was it important for you to come here, visit the lab, meet with researchers and participate in this lecture series?

On our quantum supremacy paper, we benchmarked how the classical algorithms would work using the Summit computer here, so it's nice to meet people here and see the supercomputer. In a sense, we're trying to make a supercomputer, too, and we're scoping out the competition. It's nice to know about what's going on here.

Actually I'm going to get a little bit of information to help put building a quantum computer in context for people at Google. And we're very interested in the DOE using the machine. They're a natural user for our machine, and we want to meet people and talk about what we're doing.

The Eugene P. Wigner Distinguished Lecture Series in Science, Technology, and Policy gives scientists, business leaders and policymakers an opportunity to address the ORNL community and exchange ideas with lab researchers. The series is named after Eugene Wigner, ORNL's first research director and recipient of the 1963 Nobel Prize in Physics.

ORNL is proud of its role in fostering the next generation of scientists and engineers. We bring in talented young researchers, team them with accomplished staff members, and put them to work at the lab's one-of-a-kind facilities. The result is research that makes us proud and prepares them for distinguished careers.

We asked some of these young researchers why they chose a career in science, what they are working on at ORNL, and where they would like to go with their careers.

Julie Chaves

Postdoc, Biosciences Division
Ph.D., Comparative Biochemistry, University of California, Berkeley
Hometown: Placerville, California

What are you working on at ORNL?

I study how genes work in bacteria and develop methods to engineer bacteria to make useful products. I currently work on engineering soil bacteria to metabolize wood feedstock into fuels and chemicals.

What would you like to do in your career?

Ultimately, I would like to work in the commercial microbial strain engineering industry, designing and implementing microbial solutions to environmental problems.

Why did you choose a career in science?

I enjoy learning how living systems work, the process of problem-solving and the translation of that knowledge into novel technology.

Chanaka Kumara

Postdoc, Materials Science and Technology Division
Ph.D., Analytical Chemistry, University of Mississippi
Hometown: Kurunegala, Sri Lanka

What are you working on at ORNL?

My research at ORNL focuses on exploring nanomaterials—metallic, ceramic and carbon-based—as advanced lubricant additives and protective coatings. I am working on tuning nanomaterials characteristics so that they can be used in lubrication technologies with a focus on automotive efficiency and durability.

What would you like to do in your career?

As a chemist, I focus on understanding the behaviors and interactions between atoms and molecules. I want to improve the connection between bench-scale nanomaterials researchers and applied industrial-scale production to take full advantage of the fascinating properties of nanomaterials.

Why did you choose a career in science?

I always enjoyed experimenting and trying out different things, and science helps me understand and explain. A science career is exciting when we solve fundamental questions to understand nature.

Jasmine Kreig

Graduate student, Environmental Sciences Division
Ph.D. student, Energy Science and Engineering, University of Tennessee (Bredesen Center)
Hometowns: Seattle, Washington; Raleigh, North Carolina

What are you working on at ORNL?

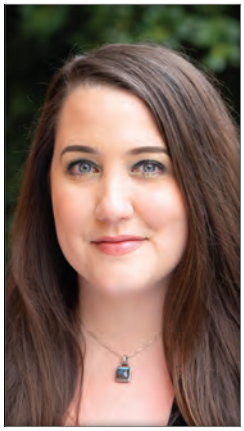
I am examining biodiversity in bioenergy landscapes in Iowa. For part of this project, I am investigating landscape design that incorporates bioenergy crops at the fuel-shed scale. The other aspect of my project seeks to create an optimal spatio-temporal harvesting strategy for both biomass and wild game.

What would you like to do in your career?

I would like to stay in research. I have enjoyed immensely my time—first, as a post-bachelor's researcher and then as a graduate student—at ORNL and would be happy continuing to do research at a national institution.

Why did you choose a career in science?

Science was always the subject in school that challenged me the most. Even though I found it to be incredibly frustrating, I also found that eventually figuring out whatever had stumped me gave me the most pleasure. I wanted a job where I could continue to learn and be challenged.



Tyler L. Spano

Postdoc, Nuclear Nonproliferation Division
Ph.D., Uranium Mineralogy, University of Notre Dame
Hometown: Middlesex, New Jersey

What are you working on at ORNL?

I study the basic chemistry of materials in the nuclear fuel cycle by synthesizing and characterizing uranium compounds. The Fuel Cycle Materials Characterization Group is particularly interested in determining the chemical and structural origins of what we observe using vibrational spectroscopy and other analytical techniques.

What would you like to do in your career?

I want to continue to explore the complexity of actinide materials and contribute to understanding processes relevant to the nuclear fuel cycle. Along the way, I hope to empower students and young scientists to be creative and excited about research, especially uranium chemistry.

Why did you choose a career in science?

I chose a career in science because I am curious about the world around me. Growing up, I loved rocks and minerals and was fascinated by radioactivity and the Manhattan Project. I feel lucky that my job is to investigate and be curious about science that I find exciting.

Saiid Kassaee

Graduate student, Energy and Transportation Science Division
Ph.D. student, Mechanical Engineering, University of Tennessee
Hometowns: Dallas, Texas; Tehran, Iran; Knoxville, Tennessee

What are you working on at ORNL?

My work focuses on heat transfer during operation of a liquid-piston compressed-gas energy storage technology invented at ORNL called GLIDES. Based on our studies done on the GLIDES system, we are working to develop a constant-temperature gas compressor by employing spray cooling, increasing the compression efficiency.

What would you like to do in your career?

I would like to continue research to develop efficient building equipment and advance energy storage technologies and grid modernization.

Why did you choose a career in science?

I liked to play with tools when I was a kid. In the Iranian culture, this is a sign that the kid will become an engineer. I chose science because science gives us the knowledge to think outside the box, think of new ideas and help humanity.

Michelle Gervais

Graduate student, Physics Division
Ph.D. student, Nuclear Physics, University of Kentucky
Hometown: Hamburg, Wisconsin

What are you working on at ORNL?

I am working with the "neutron a and b" collaboration at ORNL. We are studying free neutron decay to get a precision measurement of the "little-a" and "little-b" terms in the standard model.

What would you like to do in your career?

I haven't fully decided where I want to go when I graduate, whether academia or industry. I have several years left with research, so I'm going to decide the traits of my research that I enjoy the most and find a job that emphasizes those things.

Why did you choose a career in science?

I originally decided to study physics because I really enjoyed solving problems in my math classes, and I loved the tangible, real-world uses physics had to offer. I also double-majored in art in undergrad, so I enjoyed turning sometimes hard-to-comprehend physics ideas into paintings that can get people who normally avoid science.

Weinberg's legacy of leadership

by Tim Gawne
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When we at ORNL consider the value of leadership, we hold Alvin Weinberg, the lab's longest serving director, in particularly high regard.

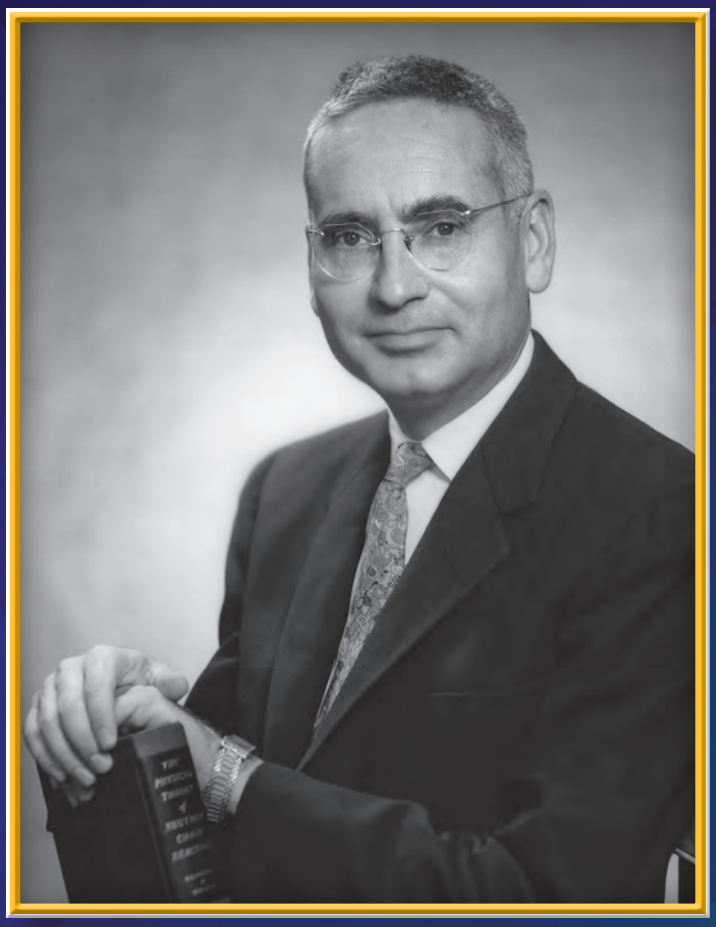
Oak Ridge wasn't much to look at when Weinberg arrived as a scientist in 1945. Hastily erected to support the Manhattan Project's mission to create the world's first nuclear weapons, the town was all muddy roads and temporary housing. But like other self-proclaimed Oak Ridgers, Weinberg stayed to see what the lab—and the community—could become.

As Weinberg expressed in his book *The First Nuclear Era: The Life and Times of a Technological Fixer*, the function of management is "first, to maintain standards, and, second, to show that it cares." He soon got the opportunity to put this philosophy into practice, becoming director of the lab's Physics Division in 1946 and associate director of the lab two years later.

In the years following World War II, ORNL's future was very much in doubt. The Atomic Energy Commission had decided late in 1947 that nuclear reactor development would be consolidated at Argonne National Laboratory, successor to the University of Chicago's Metallurgical Laboratory and home of the world's first nuclear reactor. As a result, Oak Ridge's ongoing mission was unclear.

Weinberg carved out that mission in a 1948 agreement with Argonne's director, Walter Zinn. Argonne would continue its work developing power reactors while the Oak Ridge site—dubbed Oak Ridge National Laboratory earlier that year—would take on more exotic test and research reactors.

During Weinberg's time at ORNL—including his tenure as director from 1955 to 1973—the lab would build 12 research and test reactors, in addition to the Graphite Reactor built during the war. Weinberg pursued the idea of a reactor that would power aircraft engines, not because he thought the idea was feasible—he in fact called the concept a "contradiction in terms"—but because it represented an opportunity. The Aircraft Nuclear Propulsion project would lead to one of the world's first molten salt reactors, a concept that has attracted renewed interest in recent years.



Alvin M. Weinberg. Image credit: ORNL

Weinberg would also shepherd the lab through a major realignment of ORNL's core capabilities, launching a process that would expand the lab's research portfolio and make it the most diverse of America's national laboratories, with leadership today in supercomputing, neutron science, advanced manufacturing, clean energy research and a host of other areas in addition to our ongoing missions in nuclear science and technology.

In his illustrious career, Weinberg served on the President's Science Advisory Committee for both the Eisenhower and Kennedy administrations. He also joined a delegation to the Soviet Union to open a dialogue between East and West on matters of science and energy.

Weinberg shared his belief in the lab's potential in an article published in *The ORNL News* in 1948. In it, he said:

"I firmly believe that if we persevere and if we have fortitude, Oak Ridge National Laboratory will fulfill its promise as a successful laboratory, a national institution, and a happy place in which to work."

That belief turned out to be prescient, largely because of Weinberg's own creative leadership and steady guidance over the years. We will always owe him our gratitude.

Weinberg speaks with then-Sen. John F. Kennedy and Jacqueline Kennedy at the Homogeneous Reactor Experiment No. 2 during a 1959 visit at ORNL. Image credit: Ed Westcott, ORNL

Weinberg at the controls of the Molten Salt Reactor Experiment. Image credit: ORNL

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