ARGONNE NOW

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From Stagg Field to Supercomputers

THE PHYSICS EXPERIMENT THAT CHANGED THE WORLD

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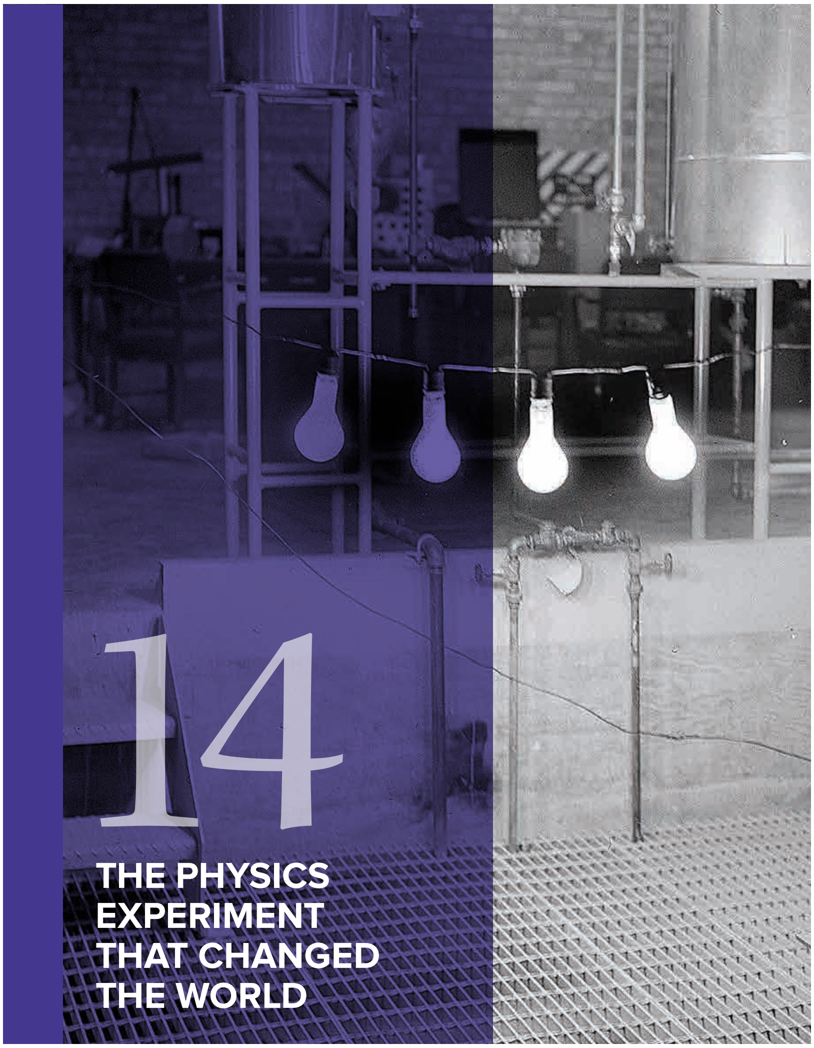

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Scientists in Sync

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ARGONNENOW

ON THE COVER

This image represents the temperature in a natural circulation toroidal loop, where red and its shades are hot, and blue and its shades are cold. Natural convection loops represent the prototype for safety systems that are important for new nuclear reactor designs.

EDITOR
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CREATIVE DIRECTOR
Abby Miesen

EDITORIAL BOARD
Paul Kearns
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PHOTOGRAPHY
Wes Agresta
Mark Lopez
Andrew Orr

DESIGN
Cara Hotz
Lidia Hernandez

ILLUSTRATION
Rich Lo
Robert Corwin

CONTRIBUTORS
Jo Napolitano
Brett Hansard
John Spizzirri
Vic Comello
Steve Koppes
Kathryn Jandeska
Joan Koka
Louise Lerner

COPYEDITING
Carolyn Steele
Andrea Manning
Katherine Obmascik

PRODUCTION
Gary Weidner
John Schneider

Argonne NATIONAL LABORATORY

Send correspondence and questions to:
ArgonneNOW
Communications & Public Affairs
Argonne National Laboratory
9700 South Cass Avenue, Building 201
Lemont, IL 60439
argonnenow@anl.gov
630-252-5526

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U.S. DEPARTMENT OF ENERGY

Argonne is a U.S. Department of Energy laboratory managed by UChicago Argonne, LLC. The laboratory's main facility is outside Chicago at 9700 South Cass Avenue, Lemont, Illinois 60439.

DIRECTOR'S NOTE

Dear readers,

It is an honor to bring you more stories of Argonne National Laboratory, where our science changes the world. Every day our 3,200 employees build on our proud history of discovery and innovation, helping us to be known for our ideas and for safely delivering lasting impact on society through our exemplary research and operations.

Exemplary research begins with exemplary leadership. In this issue, we introduce you to five women recently chosen to lead the laboratory's Environmental Science, Mathematics and Computer Science, Physics, Chemical Sciences and Engineering, and Nuclear and Waste Management divisions. They are driving discoveries in next-generation materials and energy, unlocking the mysteries of the cosmos, advancing artificial intelligence, and supporting safe and compliant research. They're also opening new doors for women and minorities who seek to work in their respective fields.

Exceptional research also demands world-class facilities. Learn how an upgrade to Argonne's Advanced Photon Source (APS) will revolutionize knowledge of materials' structures and propel progress in science, medicine, and technology. With a beam already a billion times more powerful than a doctor's X-ray, the APS has helped researchers find better ways to use energy, sustain the nation's technological and economic competitiveness, and fight disease. Imagine along with us the kind of scientific impact a beam 500 times brighter will have.

In this issue, we also tell you about our laboratory's role in the U.S. Department of Energy's (DOE's) Exascale Computing Project. The Argonne Leadership Computing Facility (ALCF) is the future home of Aurora, an exascale system being developed by Intel in partnership with Cray for deployment by 2021. Argonne scientists are developing applications, systems, software, and hardware to take advantage of tremendous new computing power and overcome grand challenges in energy, materials, climate, medicine, and more.

All that we do here at Argonne supports the DOE mission. See scenes from a January visit by U.S. Secretary of Energy Rick Perry, who toured the APS and ALCF as well as our unique facilities that enable battery advancements and support American industrial success by producing innovative materials for energy. Secretary Perry inspired our employees with a message of Argonne as an "influential" and "consequential" place. We could not agree with him more.

Keep up with the laboratory at www.anl.gov and talk to us — you can continue the conversation online with @argonne on Twitter and on the Argonne National Laboratory page on Facebook.

Enjoy this issue of **ArgonneNOW**.

Paul K. Kearns

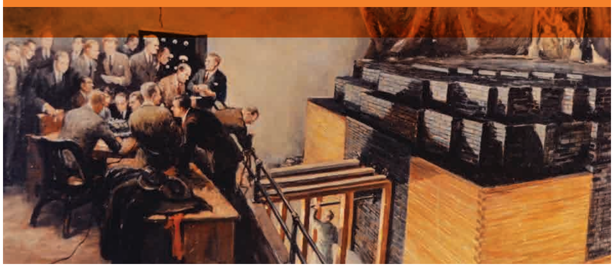
PAUL KEARNS
Director, Argonne National Laboratory

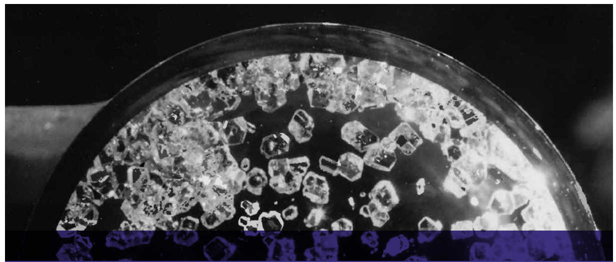
This Year in Science History

1942

76 YEARS AGO

On December 2, a group of 49 scientists led by Enrico Fermi created the world's first controlled, self-sustaining nuclear chain reaction under the west stands of the University of Chicago's Stagg Field.





1962

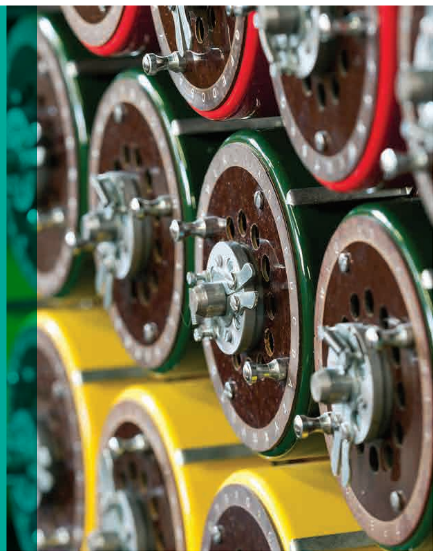
56 YEARS AGO

Argonne researchers created xenon tetrafluoride, the first molecule based on xenon, a noble gas thought previously to be chemically inert. The creation led to a major shift in the way chemical bonds are studied.

1982

36 YEARS AGO

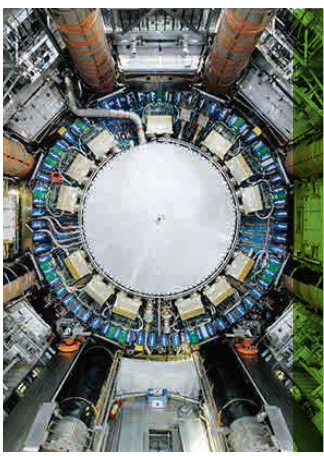
An Argonne researcher laid the theoretical foundation for quantum computing by developing the first model of a Turing machine based on quantum mechanics. Quantum computers promise to solve certain computing problems far faster than today's computers.



1992

26 YEARS AGO

Designed and managed by Argonne scientists since its deployment in 1992, the DOE's Atmospheric Radiation Measurement Southern Great Plains observation site continues to provide important data to scientists worldwide for use in climate research.



2012

6 YEARS AGO

Contributions by Argonne scientists enabled the ATLAS experimental collaboration at the Large Hadron Collider to yield data that helped confirm the discovery of the Higgs boson, a previously elusive elementary particle.

Highlights

BIG BANG – THE MOVIE

If you have ever had to wait those agonizing minutes in front of a computer for a movie or large file to load, you'll likely sympathize with the plight of cosmologists at the U.S. Department of Energy's Argonne National Laboratory. But instead of watching TV dramas, they are trying to transfer the huge amounts of data that make up movies of the universe — computationally demanding and highly intricate simulations of how our cosmos evolved after the Big Bang.

In a new approach to enable scientific breakthroughs, researchers linked together supercomputers at the Argonne Leadership Computing Facility and the National Center for Supercomputing Applications at the University of Illinois at Urbana-Champaign. This linkage enabled scientists to transfer massive amounts of data and run two different types of demanding computations in a coordinated fashion — referred to technically as a workflow.

What distinguishes the new work from typical workflows is the scale of the computation, the associated data generation and transfer, and the scale and complexity of the final analysis.

For cosmology, observations of the sky and computational simulations go hand in hand, as each informs the other. Cosmological surveys are becoming ever more complex as telescopes peer out more deeply into space and time, mapping out the distributions of galaxies at farther and farther distances and at earlier epochs of the evolution of the universe.

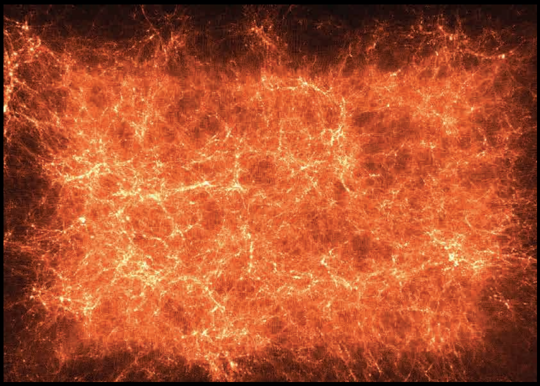
The very nature of cosmology precludes carrying out controlled lab experiments, so scientists rely instead on simulations to provide a unique way to create a virtual cosmological laboratory. "We talk about building the 'universe in the lab,' and simulations are a huge component of that," said Argonne cosmologist Katrin Heitmann.

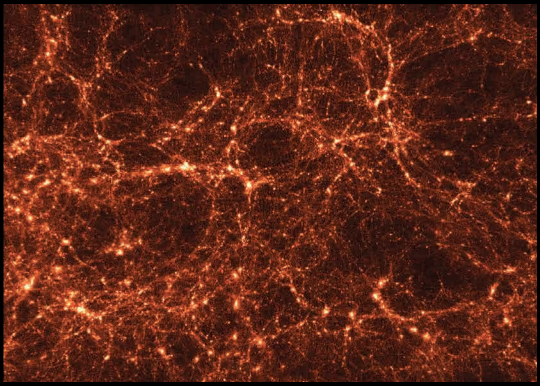
Not just any computer is up to the immense challenge of generating and dealing with datasets that can exceed many petabytes a day. "You really need high-performance supercomputers that are capable of not only capturing the dynamics of trillions of different particles, but also doing exhaustive analysis on the simulated data," Heitmann said.

Adapted from an article by Jared Sagoff and Austin Keating. Research was funded by the U.S. Department of Energy's Office of Science and the National Science Foundation. The team used resources of the Argonne Leadership Computing Facility, the Oak Ridge Leadership Computing Facility, the Energy Science Network, and the National Energy Research Scientific Computing Center, which are DOE Office of Science User Facilities, during their research.

CHECK OUT ARGONNE'S VIDEO AT youtu.be/-oCtLJmFXng

These images show a simulated sky image of galaxies produced by running Argonne-developed high-performance computing codes and then running a galaxy formation model.





Highlights

FORGET ABOUT IT

Even as the power of our modern computers grows exponentially, biological systems — like our brains — remain the ultimate learning machines. By finding materials that act in ways similar to the mechanisms that biology uses to retain and process information, scientists hope to find clues to help us build smarter computers.

Inspired by human forgetfulness — how our brains discard unnecessary data to make room for new information — scientists at the U.S. Department of Energy's Argonne National Laboratory, in collaboration with Brookhaven National Laboratory and three universities, conducted a recent study that combined supercomputer simulation and X-ray characterization of a material that gradually "forgets." This approach could one day be used for advanced bio-inspired computing.

"The brain has limited capacity, and it can only function efficiently because it is able to forget," said Subramanian Sankaranarayanan, an Argonne nanoscientist and study author. "It's hard to create a nonliving material that shows a pattern resembling a kind of forgetfulness, but the specific material we were working with can actually mimic that kind of behavior."

The material, called a quantum perovskite, offers researchers a simpler non-biological model of what "forgetfulness" might look like on an electronic level. The perovskite shows an adaptive response when protons are repeatedly inserted and removed that resembles the brain's desensitization to a recurring stimulus.

Quantum simulations performed at the Argonne Leadership Computing Facility probed the origin of this adaptive response.

As the material responds to protons that scientists add and subtract, its ability to resist an electrical current can be severely affected. This behavior allows the material to be effectively programmed, like a computer, by the proton doping. Essentially, a scientist could insert or remove protons to control whether or not the perovskite would allow a current.

The perovskite material and the resulting neural network algorithms developed by Sankaranarayanan and his team could help create more efficient artificial intelligence capable of facial recognition, reasoning, and human-like decision making. Scientists are continuing the research to discover other materials with these brain-like properties and new ways to program these materials.

Adapted from an article by Savannah Mitchem. Research was funded by the U.S. Army Research Office, U.S. Air Force Office of Scientific Research, C-SPIN, Intel Corporation, and the Vannevar Bush Faculty Fellowship. The team used resources of the Center for Nanoscale Materials and the Argonne Leadership Computing Facility, both DOE Office of Science User Facilities, during this research.

From left to right: Badri Narayanan, Hua Zhou, Subramanian Sankaranarayanan, and Mathew Cherukara

AIR FORCE FELLOWS AIM HIGH AT ARGONNE

Science, technology, and national security come together in a personal and powerful way through the U.S. Air Force Fellows program at the U.S. Department of Energy's Argonne National Laboratory, which over the summer became a second home to Lt. Col. Chris Snyder and Maj. Sean "Skeet" Richardson.

Snyder and Richardson were chosen for the prestigious one-year national program after a rigorous selection process based on merit, rank in their respective career fields, and education and experience relevant to the Argonne mission. The program promotes open communication between the Air Force and Argonne and encourages collaborations to benefit the Departments of Energy and Defense.

"The fellowship is an opportunity for both participants to expand their knowledge and experience with the basic and applied sciences at which Argonne excels," said Argonne's Keith Bradley, who leads the lab's National Security Programs.

The Air Force, like all branches of the military, depends heavily on science, technology, engineering, and math, including hallmark research conducted at Argonne. For example, stealth aircraft employ some of the most advanced composite materials, made possible in part because of discoveries by scientists and facilities at Argonne and other national laboratories.

This program, which began in 2003, is aimed at bringing the Air Force and the broader scientific community together to foster greater collaboration and understanding.

ARGONNE WELCOMES DEPARTMENT OF ENERGY SECRETARY PERRY

U.S. Department of Energy Secretary Rick Perry visited Argonne National Laboratory in January, getting a first-hand view of the multifaceted and interdisciplinary laboratory.

In his first stop at Argonne since his confirmation as Secretary of Energy last year, Perry toured two of the laboratory's standout national user facilities: the Advanced Photon Source (APS) and the Argonne Leadership Computing Facility (ALCF).

The APS, which annually hosts thousands of users from around the world, is currently slated for an upgrade, which will dramatically increase the brightness of X-rays it produces for use in a wide range of different experiments.

The ALCF, which like the APS is a DOE Office of Science User Facility, hosts one of the nation's fastest computers, called Mira. The ALCF is scheduled to be the future home of a new exascale high-performance supercomputer — called Aurora — by 2021.

"The combination of world-leading expertise and state-of-the-art facilities found at Argonne keep America at the forefront of scientific discovery and technological breakthroughs," Perry said. "Argonne and the other 16 Department of Energy National Laboratories sit at the heart of America's innovation engine."

Perry also toured Argonne's Electrochemical Discovery Laboratory, where researchers work to develop next-generation beyond-lithium-ion batteries. Perry spent time at the Materials Engineering Research Facility as well, where energy storage and other materials are scaled up for potential commercialization.

"Argonne leads discoveries in countless scientific fields — from developing novel imaging and X-ray technology to introducing the exascale era of computing," said Argonne director Paul Kearns. "The laboratory also fosters open and productive partnerships with a range of industries to ensure the future competitiveness of our nation's businesses and enhance national defense and cybersecurity."

In an open town hall meeting with Argonne staff, Perry said that he valued the laboratory's pursuit of energy breakthroughs that have produced economic benefits while making America more secure.

He was joined on his tour of Argonne by Rep. Bill Foster (D-IL), as well as representatives from local DOE site management and the University of Chicago.

Adapted from an article by Jared Sagoff.

Secretary of Energy Rick Perry (right) and Eric Isaacs (center), Executive Vice President for Research, Innovation and National Laboratories at the University of Chicago, discuss materials scaled up at Argonne's Argonne's Materials Engineering Research Facility.

Snyder, a distinguished graduate of the Air Force Test Pilot School, is the executive officer for the Test and Evaluation Directorate of Headquarters Air Force in Washington, D.C. His current research at Argonne involves how the Air Force should invest to speed up the qualification and certification process for additively manufactured metal parts intended for aviation or space use.

Richardson is an F-16 experimental test evaluator pilot and assistant director of operations at the 416th Flight Test Squadron, Edwards Air Force Base, California. He is working with Argonne colleagues to better understand the capabilities and limitations of machine learning, so the Air Force can formalize an effective and efficient acquisition process for systems that include machine learning.

Adapted from an article by Ron Walli. Funding for the Air Force Fellowship program is provided by the U.S. Air Force.

Lt. Col. Chris Snyder and Maj. Sean "Skeet" Richardson were selected for a prestigious one-year national program to promote open communication between the Air Force and Argonne and encourage collaborations to benefit the Departments of Energy and Defense.

Highlights

CHICAGO QUANTUM EXCHANGE TO CREATE TECHNOLOGICALLY TRANSFORMATIVE ECOSYSTEM

The University of Chicago is collaborating with the U.S. Department of Energy's Argonne National Laboratory and Fermi National Accelerator Laboratory to launch an intellectual hub for advancing academic, industrial, and governmental efforts in the science and engineering of quantum information.

This hub within the Institute for Molecular Engineering, called the Chicago Quantum Exchange (CQE), will facilitate the exploration of quantum information and the development of new applications with the potential to dramatically improve technology for communication, computing, and sensing.

Quantum mechanics governs the behavior of matter at the atomic and subatomic levels in exotic and unfamiliar ways compared to the classical physics used to understand the movements of everyday objects. The engineering of quantum phenomena could lead to new classes of devices and computing capabilities, permitting novel approaches to solving problems that cannot be addressed using existing technology.

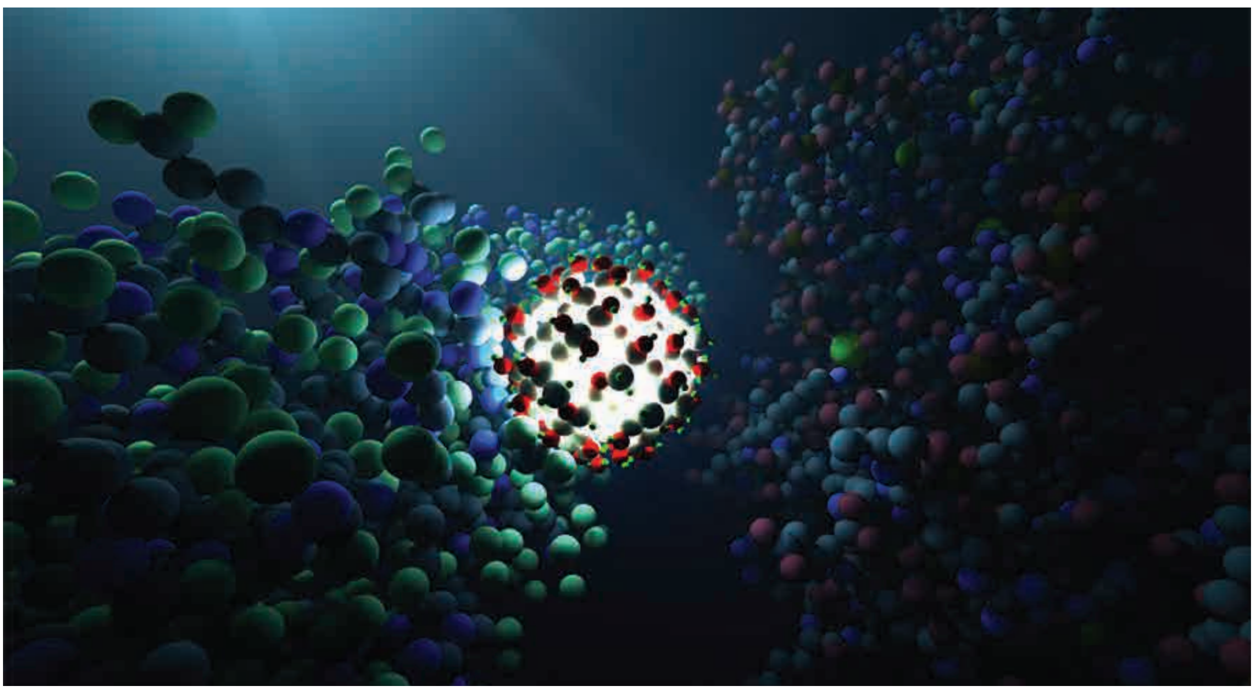
"The combination of the University of Chicago, Argonne National Laboratory, and Fermi National Accelerator Laboratory, working together as the Chicago Quantum Exchange, is unique in the domain of quantum information science," said Matthew Tirrell, dean and Founding Pritzker Director of the Institute for Molecular Engineering and Argonne's deputy laboratory director for science.

The collaboration will benefit from UChicago's Polsky Center for Entrepreneurship and Innovation, which supports the creation of innovative businesses connected to UChicago and Chicago's South Side. The CQE will have a strong connection with a major Hyde Park innovation project that will enable the transition from laboratory discoveries to societal applications through industrial collaborations and start-up initiatives.

This new quantum ecosystem will provide a collaborative environment for researchers to invent technologies in which all the components of information processing — sensing, computation, storage, and communication — are kept in the quantum world.

This contrasts with today's mainstream computer systems, which frequently transform electronic signals from laptop computers into light for internet transmission via fiber optics, transforming them back into electronic signals when they arrive at their target computers, finally to become stored as magnetic data on hard drives.

Adapted from an article by Steve Koppes.



Argonne, the University of Chicago, and Fermilab are launching an intellectual hub called the Chicago Quantum Exchange to advance academic, industrial, and governmental efforts in the science and engineering of quantum information. Above: An illustration of a blinking quantum dot in its 'on' state. (Image courtesy of Nicholas Brawand.)

ARGONNE'S REUSABLE SPONGE COULD REVOLUTIONIZE OIL AND DIESEL CLEANUP

When the Deepwater Horizon drilling pipe blew out seven years ago, beginning the worst oil spill in U.S. history, those in charge of the recovery discovered a new wrinkle: the millions of gallons of oil bubbling from the sea floor weren't all collecting on the surface where they could be skimmed or burned. Some of it was forming a plume and drifting through the ocean under the surface.

Now, scientists at the U.S. Department of Energy's (DOE) Argonne National Laboratory have invented a new foam, called the Oleo Sponge, that addresses this problem. The material not only easily absorbs oil from water, but is also reusable and can pull dispersed oil from the entire water column — not just the surface.

"The Oleo Sponge offers a set of possibilities that, as far as we know, are unprecedented," said co-inventor Seth Darling, a scientist with Argonne's Center for Nanoscale Materials and the Director of the Institute for Molecular Engineering at Argonne.

Previously, Darling and fellow Argonne chemist Jeff Elam had developed a technique called sequential infiltration synthesis, or SIS, which can be used to infuse hard metal oxide atoms within complicated nanostructures.

After some trial and error, they found a way to adapt the technique to grow an extremely thin layer of metal oxide "primer" near the foam's interior surfaces. This serves as the perfect glue for attaching the oil-loving molecules, which are deposited in a second step; they hold onto the metal oxide layer with one end and reach out to grab oil molecules with the other.

The result is Oleo Sponge, a block of foam that easily adsorbs the oil from the water. The material, which looks a bit like an outdoor seat cushion, can be wrung out to be reused — and the oil itself recovered.

"The material is extremely sturdy. We've run dozens to hundreds of tests, wringing it out each time, and we have yet to see it break down at all," Darling said.

Adapted from an article by Louise Lerner. Research was funded by the U.S. Coast Guard and the Bureau of Safety and Environmental Enforcement. The team used resources of the Center for Nanoscale Materials, a DOE Office of Science User Facility, in the development of the material.

CHECK OUT ARGONNE'S VIDEO AT youtu.be/zCx5bzLIRmc

Argonne postdoctoral researcher Ed Barry wrings out a sheet of Oleo Sponge during tests at Argonne.

Argonne scientists tested the material's performance in saltwater at Ohmsett, the National Oil Spill Response Research & Renewable Energy Test Facility, a massive outdoor seawater tank in New Jersey for testing cleanup technology.

Argonne scientist Seth Darling, who co-invented the material, helps wring out the Oleo Sponge during testing. The Oleo Sponge can be wrung out, the oil collected, and the material reused — it has stood up to dozens of cycles so far without breaking down.

Around the Labs

NEWS + DISCOVERIES FROM OUR SISTER NATIONAL LABORATORIES

COMPILED BY JOAN KOKA

BURROWING NEUTRINOS

Fermi National Accelerator Laboratory
Batavia, Illinois

Tiny, invisible particles known as neutrinos travel through our bodies and our universe every single day, yet we still don't have a clear picture of what they do or their role in the creation of the universe. To understand them better, Fermilab will be projecting these tiny particles through 800 miles of underground rock as part of a leading-edge international experiment. These particles will be captured by a detector in the Sanford Underground Research Facility in South Dakota, and the measurements recorded will provide transformative insights into neutrino properties, as well as the formation of black holes and the possibility of proton decay.

RECREATING DIAMOND SHOWERS ON FAR-FLUNG PLANETS

SLAC National Accelerator Laboratory
Stanford, California

The high-temperature and high-pressure conditions on Neptune and Uranus may be causing diamonds to rain down on these giant planets. At SLAC, researchers have observed this "diamond rain" for the first time by simulating these extreme planetary conditions in the lab with the help of lasers. Their technique caused tiny diamonds to form over fractions of a second. X-ray snapshots captured their formation and will help researchers understand the structure and formation of these distant planets.

COOKING UP FUEL USING SOLAR POWER

Lawrence Berkeley National Laboratory (LBNL)
Berkeley, California

Researchers at Lawrence Berkeley National Laboratory have led the creation of a light-activated material that can chemically convert carbon dioxide into carbon monoxide, without generating unwanted waste products like methane. The carbon monoxide gas generated can be further engineered to make liquid fuels, solvents, and other useful products. Their achievement represents a critical step toward generating solar-powered fuels for mass consumption and stemming emissions of greenhouse gases.

DISSECTING THE GLUE THAT HOLDS THE UNIVERSE TOGETHER

Thomas Jefferson National Accelerator Facility
Newport News, Virginia

The beam of the newly upgraded Continuous Electron Beam Accelerator Facility at the Jefferson Lab now has double the energy, and has begun running its first experiments. The facility collides electrons and atoms to enable researchers to study the particles that make up the atom's nucleus, and the forces that mediate how these particles interact. With the new upgrade, researchers can apply new methods for studying these forces and interactions to uncover how the universe came to be.

SENDING SOFTWARE TO SCAN THE SKIES

Pacific Northwest National Laboratory (PNNL)
Richland, Washington

Offshore wind turbines can provide a huge source of energy for the nation, but may pose a risk to neighboring creatures. To encourage the safe deployment of these technologies, while promoting environmental safety, PNNL has developed a new open-source software program called Thermal Tracker to categorize and track birds and bats using a thermal camera and basic computer. With it, developers and regulators can track compliance with environmental monitoring requirements, better assess proposed locations for a wind farm, and evaluate how the potential presence of birds or bats nearby might affect its operations. Such tools aid in accelerating the safe adoption of renewable wind technologies while supporting wildlife along the way.

REFINING METAL POWDERS FOR MANUFACTURING

Ames Laboratory
Ames, Iowa

Ames Laboratory scientists have perfected a technique for creating consistently sized metal powders to use in manufacturing processes. The patented technique, known as gas atomization, involves the application of high-pressure gas molten metals, which causes metals to disintegrate into particles. This approach enables manufacturers to create customizable and consistently sized powders for all kinds of metals, including iron, nickel, tin, and titanium, while minimizing waste. The laboratory plans to scale up these capabilities to increase support for laboratory research and industry needs.

CAPTURING LIVE FUNCTIONS ON A TINY SCALE

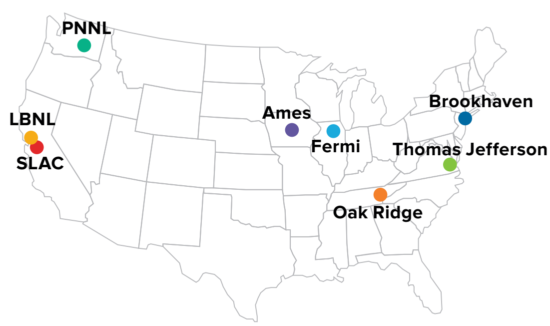
Oak Ridge National Laboratory (ORNL)
Oak Ridge, Tennessee

Imaging already tiny cellular components, such as cell membranes, at extremely small scales is difficult to do without interrupting their biological function. But researchers at Oak Ridge National Laboratory have figured out a way to do so. Their technique, which combines genetic and chemical labeling, enabled them to successfully complete the world's first scan of a living cell membrane at nanoscale resolution. Without disrupting the membrane's functions, researchers put together a detailed picture of a bacterial cell's outer layers, uncovering new details about how such membranes actually function; this technique has the potential to revolutionize how researchers study nanoscale structures in living things.

RAMPING UP DISEASE-FIGHTING TREATMENTS

Brookhaven National Laboratory (BNL)
Upton, New York

Radioisotopes — radioactive forms of chemical elements — play a lead role in tracking and treating diseases like cancer, and in imaging physiological processes, like the flow of blood. Yet not all are easy to produce — some require the use of high-energy accelerators, like the one at Brookhaven National Laboratory. To accelerate the production of these radioisotopes, laboratory researchers have incorporated a new scanning system. The system is designed to increase the production of a variety of radioisotopes, helping to meet the needs of health practitioners and patients across the nation.



From Stagg Field to Supercomputers

THE PHYSICS EXPERIMENT THAT CHANGED THE WORLD

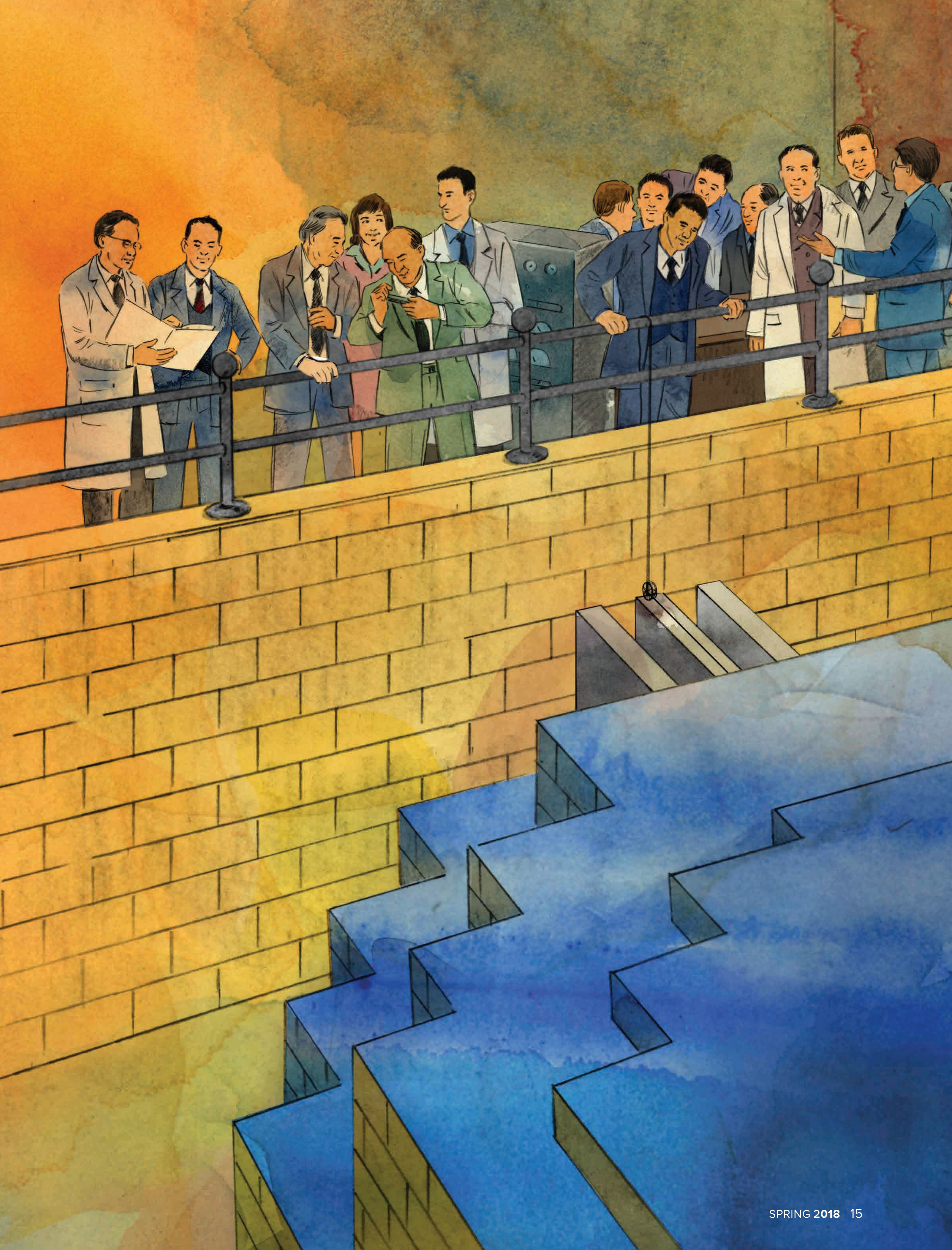
BY LOUISE LERNER AND DAVE BUKEY

Illustrations by Rich Lo

On December 2, 1942, as World War II raged, a small group of scientists gathered beneath the football stands of the University of Chicago for a physics experiment that would very literally change the world.

The site of the world-changing physics experiment — The University of Chicago's Stagg Field in 1942.

Enrico Fermi (lower left) and a dozen or so team members who helped him achieve the world's first controlled atomic chain reaction.



In utmost secrecy, they had constructed a pile of uranium and graphite that would soon become the very first nuclear reactor. Led by Enrico Fermi, the scientists hoped to split uranium atoms and create the world's first self-sustained, controlled chain reaction.

Seventy-six years later, the implications of that physics experiment still reverberate around the world. Besides shaping the outcome of the Second World War and the following half-century of international foreign policy, it has continued to shape the way the world views and uses energy, medicine, and scientific research.

CP-1, as the reactor was called, was not a particularly impressive engineering feat at first glance. It looked like a 20-foot-high mass of bricks; that's where the name "Chicago Pile-1," or CP-1, came from. But it was actually 6 tons of uranium metal, 50 tons of uranium oxide, and 400 tons of graphite bricks laid in an arrangement painstakingly and precisely calculated by some of the greatest scientific minds in the country.

At 3:25 p.m., Fermi gave the final signal. The counters ticked, and the pile achieved criticality. The atomic age had begun.

As part of the nation's Manhattan Project, Fermi's team was expected to determine the likelihood that larger versions of CP-1 could breed plutonium to produce an atomic bomb. But greater plans for the discovery were already in place: the newly discovered atomic energy could be employed for peaceful uses, such as generating inexpensive electrical power.

That was the mission of Argonne — the lab that grew from Fermi's experiment — when the federal government and the University of Chicago moved it west and designated it the first national laboratory in the United States.

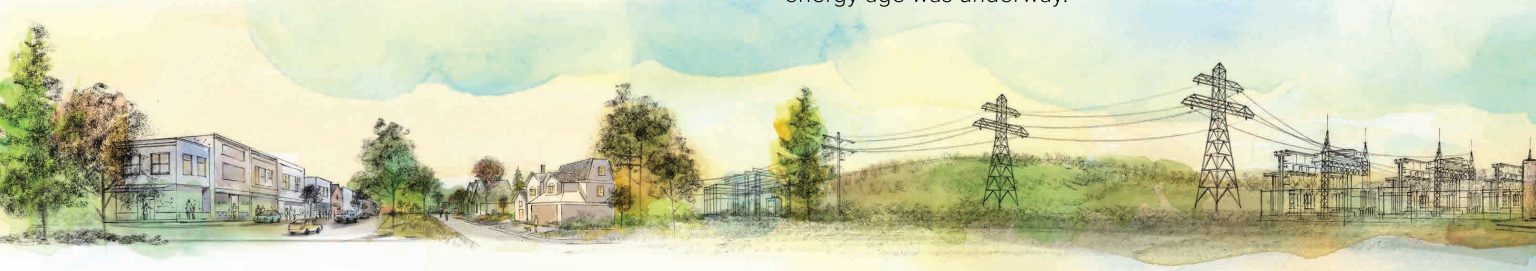
In December 1951, Argonne's Experimental Breeder Reactor-1 lit up four lightbulbs with the word's first usable electricity from nuclear energy.

The Atomic Energy Commission funded scientific work at Argonne, Oak Ridge, Brookhaven, and other national laboratories which led directly to the rise of nuclear power in America. The history of nuclear energy is a story of the partnership between government and science at its best. Virtually every nuclear reactor operating around the world today is based on technology and designs developed by U.S. national laboratories.

It's not often that we discover an entirely new way to produce electricity. The prospect required an enormous amount of scientific and engineering work, from developing the underlying theoretical physics calculations to creating materials that could withstand the intense conditions inside a reactor.

The Atomic Energy Commission also established a new site, the National Reactor Testing Station, in southern Idaho, far from densely populated areas, and developed a new Argonne branch, Argonne National Laboratory-West (now the Materials & Fuels Complex at Idaho National Laboratory) to build prototype reactors to test emerging ideas.

It was there, on December 20, 1951, just nine years after that wartime experiment in Chicago, that Argonne's Experimental Breeder Reactor-I lit a string of four lightbulbs with the world's first significant amount of electricity generated from nuclear power. The nuclear energy age was underway.



“At 3:25 p.m., Fermi gave the final signal. The counters ticked, and the pile achieved criticality. The atomic age had begun.”

Following preliminary design studies by Oak Ridge engineers, Argonne engineers designed and built a test reactor that Westinghouse and the U.S. Navy used to build the reactor for the first atomic-powered submarine, the USS Nautilus, which was launched in 1954. The Nautilus could run for 50,000 miles without refueling, and it became the first submarine to travel underneath the polar ice cap; its success demonstrated that nuclear power was both safe and reliable. In 1955, another test reactor in Idaho powered the entire nearby town of Arco. The next step was to prove the value of nuclear energy to utilities by producing electricity on a larger scale. Planning began for an operating prototype at Argonne, the Experimental Boiling Water Reactor. Commonwealth Edison watched closely, collecting data from the tests; the utility was poised to roll the reactor out for business if the tests were successful.

In December of 1956, this reactor produced its first electricity, ramping up to produce 100 megawatts shortly thereafter. Soon Commonwealth Edison was building an almost identical reactor in nearby Dresden, Illinois, which would become the first large-scale power plant built entirely by private industry. The era of commercial-scale nuclear energy had truly begun.

Over the following years, reactor research from the U.S. national laboratories became the basis for nearly every nuclear reactor around the world. “The dominant types of nuclear reactors that power the world all have their origins in Argonne research,” says Laural Briggs, a nuclear engineer at Argonne.

For example, Argonne designed reactors and built and tested the early prototypes. Oak Ridge developed principles of reactor control and protection systems still used today.

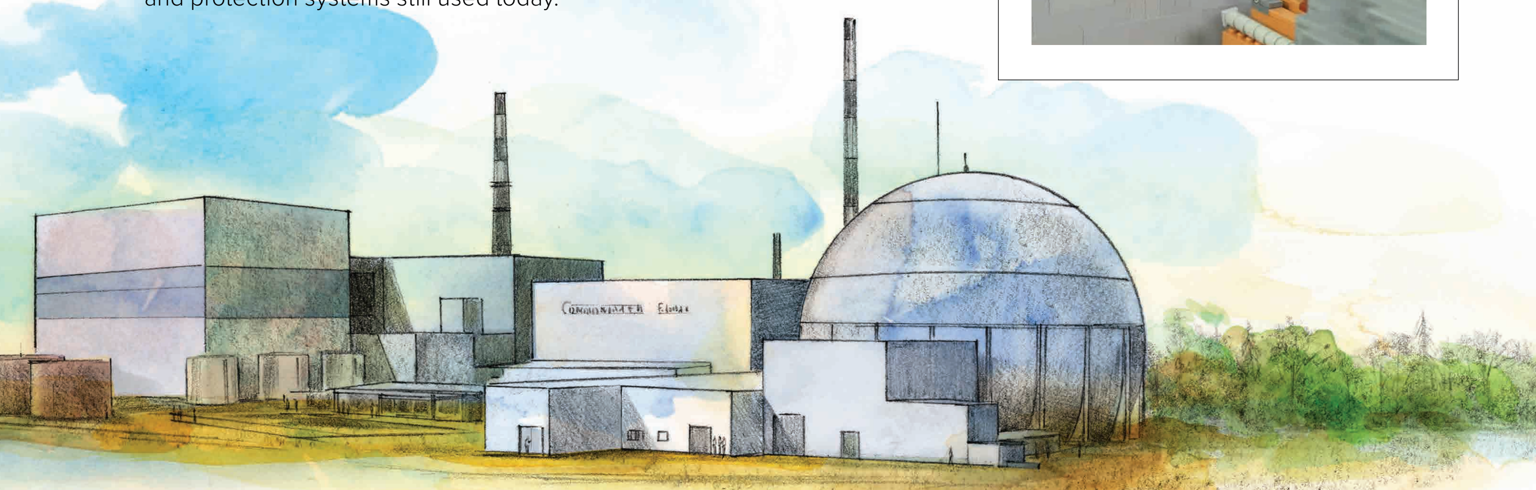
CHICAGO PILE-1: A BRICK HISTORY

Argonne National Laboratory commemorated the 75th anniversary of the first self-sustained, controlled nuclear chain reaction under the west stands of old Stagg Field by commissioning an animated video that portrayed the historic event.

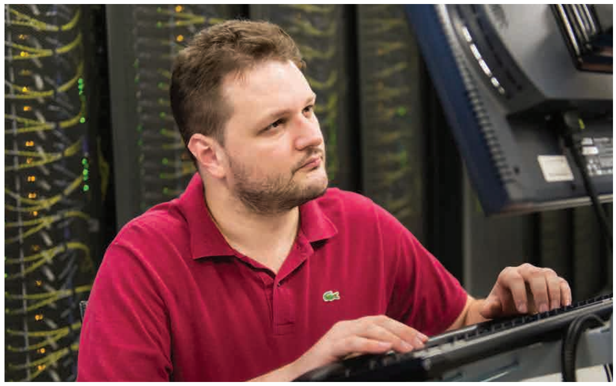
The result was a modern take on this historic experiment. The 2-minute, 30-second video faithfully renders such details as the exterior of Stagg Field, the rackets court where Enrico Fermi and his team built Chicago Pile-1, and even the Hutch Commons dining room at the University of Chicago where scientists had lunch the afternoon of their crowning achievement.

The video was produced in consultation with Argonne scientists by Brick 101, a digital media company owned and operated by UChicago alumnus Dave Pickett.

CHECK OUT ARGONNE’S VIDEO AT
youtu.be/mTPiTJ2bKS0



“We can simulate turbulence in great detail, thanks to the computing power of machines like the Mira supercomputer”



Merzari uses Argonne’s Mira supercomputer to conduct modeling and simulation experiments that have the potential to make nuclear reactors safer, more efficient, and economically more competitive.

Today, more than 400 reactors provide about 11% of the world’s electrical power.[1] The national laboratories continue to research and develop advanced nuclear reactors and how to handle spent nuclear fuel. They also work closely with the Nuclear Regulatory Commission to develop safety standards and practices, train industry professionals in the United States and abroad, and provide expertise on decommissioning older reactors.

There were many other seismic shifts in the scientific landscape caused by the 1942 atomic chain reaction. The field of computer science, for example, broke through the surface as scientists built some of the first computers to model the physical phenomena — i.e., how the fuels were functioning and how the structural materials, which were under stress, were holding up — inside nuclear reactors.

Researchers can better solve thorny challenges, like those posed by nuclear physics, by breaking them down into smaller tasks. They tackle each with many processors that work together. This insight, known as parallel computing, lies at the heart of today’s supercomputers and the field of high-performance computing.

“You have a lot of parameters to juggle. But high-performance computing can be very helpful” in the right circumstances, says Argonne’s Briggs.

That’s where Elia Merzari, principal nuclear engineer at Argonne, and his colleagues come in. Merzari is a member of an Argonne team that simulates how heat and fluids flow and create turbulence within nuclear reactors. To do this, the team must understand how heat and fluids behave under any simulated conditions — a field known as computational fluid dynamics.

“We can simulate turbulence in great detail, thanks to the computing power of machines like the Mira supercomputer” located at the Argonne Leadership Computing Facility, says Merzari.

To harness Mira’s full processing power, Argonne researchers developed an award-winning programming code, known as Nek5000. The code allows Mira to run on all cylinders to handle “the largest-scale calculations for fluid flow in nuclear reactors,” says Merzari.

The setup and the team’s expertise will “ultimately help design a new generation of more economically viable reactors,” he says.

Take, for example, small modular reactors, a new concept for a self-contained source of nuclear power about as wide as a hot tub (one-quarter the size of a standard pressurized water reactor). These reactors could run nonstop for seven to 20 years and generate a total of 50 to 200 megawatts of power. They would be small and cost-effective enough to build in a factory and safely deliver to utility customers or scientific laboratories.

Researchers at Argonne and other U.S. national laboratories are refining the designs of these mini reactors by simulating via supercomputers how they might operate. This step can bolster safety, control costs, and promote efficiency because the researchers glean key insights before conducting real-world experiments. These benefits will multiply as Argonne and the other national laboratories move toward exascale, an era in which supercomputers will be 50 times faster than today.

The chain reaction Fermi started that day in 1942 has gathered steam, rolled back scientific frontiers, and continues to improve our lives in surprising ways.

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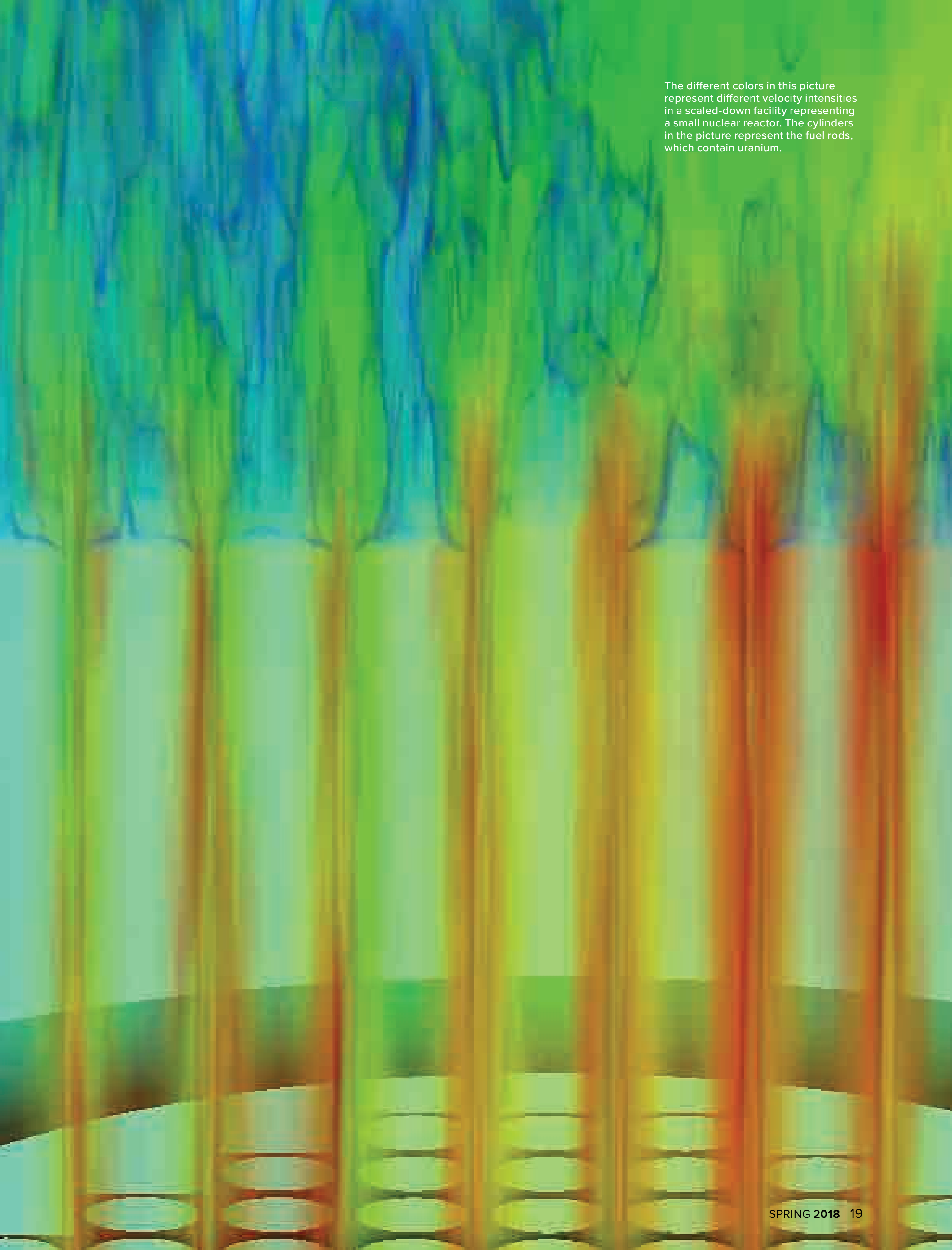
[1] ***How Nuclear Power Helps Meet Global Energy Demand / The Role of the IAEA, pub. IAEA Feb. 2017.***



The different colors in this picture represent different velocity intensities in a scaled-down facility representing a small nuclear reactor. The cylinders in the picture represent the fuel rods, which contain uranium.

VALERIE TAYLOR

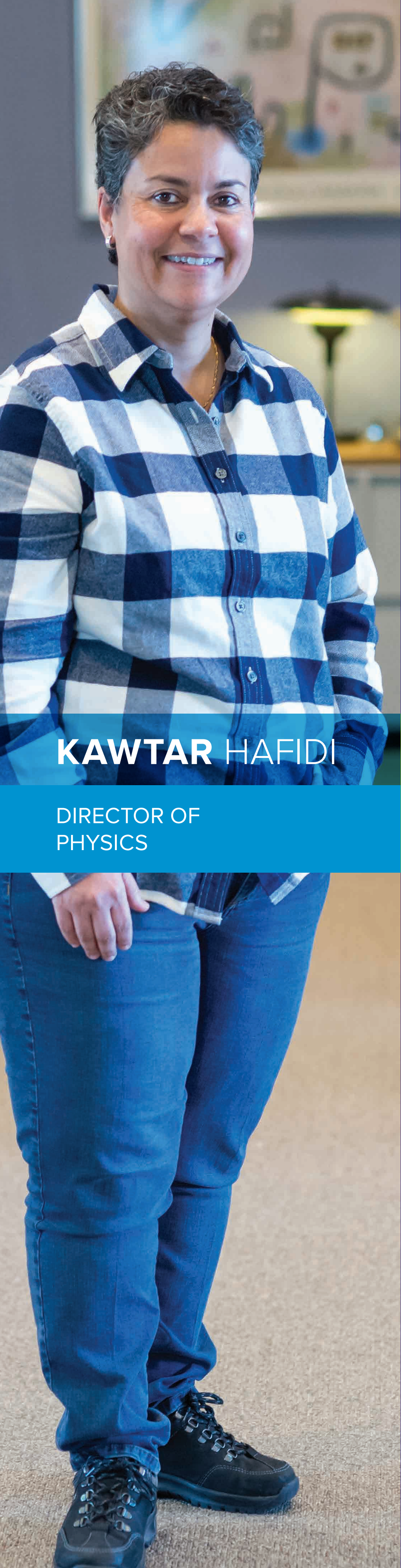
DIRECTOR OF MATHEMATICS AND COMPUTER SCIENCE

CYNTHIA JENKS

DIRECTOR OF CHEMICAL SCIENCES AND ENGINEERING

CRISTINA NEGRI

DIRECTOR OF ENVIRONMENTAL SCIENCE



KAWTAR HAFIDI

DIRECTOR OF PHYSICS

How will the next generation of scientists overcome challenges in physics and energy storage?

How will artificial intelligence transform scientific inquiry?

SCIENTISTS IN SYNC

BY JO NAPOLITANO

Four of Argonne's newest division directors look to the future.

When U.S. Department of Energy Secretary Rick Perry visited Argonne in January, Nuclear Engineer Heather Connaway asked if he had any advice for early career scientists. "Don't be afraid to get outside of your comfort zone," urged Secretary Perry. Feel free to collaborate, he advised.

That collaborative spirit thrives at Argonne as scientists and engineers — early career or not — in different areas team up to tackle scientific challenges and, ultimately, improve lives as well as our nation's security and economy. That collaborative spirit also shines in four of Argonne's newest division directors: Valerie Taylor (Mathematics and Computer Science), Cynthia Jenks (Chemical Sciences and Engineering), Cristina Negri (Environmental Science), and Kawtar Hafidi (Physics).

When scientists work together, "we really make an impact because the frontier of science shifts towards complex systems and complex competencies," says Negri. "We have the potential for new discoveries, new technology, new anything."

U.S. Department of Energy Secretary Rick Perry visited Argonne in January and urged scientists and engineers to step outside their comfort zone.

These four renowned researchers and leaders eschew barriers and are changing the face of science across the laboratory. We recently sat down with them to discuss why collaboration is vital, the roles technology and young people play in shaping science, and the need for greater outreach to women and minorities.

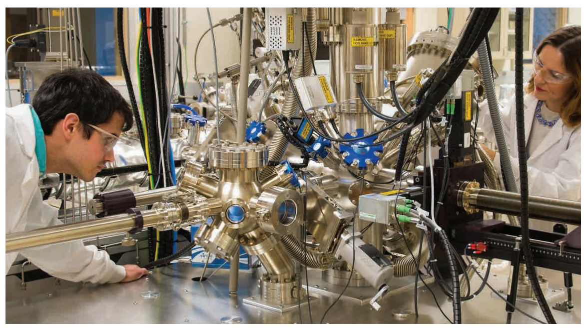
ArgonneNOW: Argonne strives to solve the world's greatest scientific challenges. What does that mean for your division and how might technology play a role?

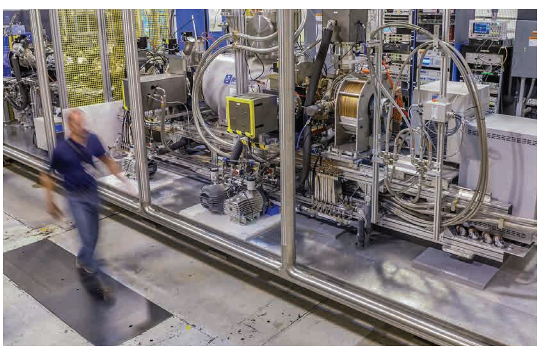
Cristina Negri: The Environmental Science Division is charged with many tasks, one of which involves climate science. As part of our work in this area, we are also developing the science to better understand how major weather events impact energy systems. For this, we need to create more detailed mapping, including finer-resolution modeling of dramatic precipitation. Our goal is to focus on specific parts of the country — to better understand weather patterns in an area as small as a single county or metro area. This is an enormous challenge, but the more information we have, the more we can act on. We are currently working with Argonne's Energy and Global Security Directorate to develop the comprehensive inputs we need for this purpose.

Valerie Taylor: The Mathematics and Computer Science Division provides the math and computing methods and tools needed to solve some of our nation's most critical scientific problems. Because the data generated from simulations and instruments have increased significantly, there is growing interest in using machine learning for science and engineering. Advances in machine learning, an application of artificial intelligence in which computers have the ability to learn without being programmed, and deep learning — an area within machine learning in which computers process data in such a way as to create patterns to aid in decision-making — will greatly benefit all areas of scientific study, such as understanding major weather events.

In an effort to satisfy the world's computational needs and rise up to its greatest challenges, scientists are focusing on quantum computing and neuromorphic computing to meet specific needs. Quantum computing will use the power of atoms and molecules to perform specific memory and processing tasks far faster than traditional computers can. Neuromorphic computing gets its inspiration from the human brain, specifically its neural networks. Such computers would have the ability to infer, deduce, or make conclusions based on evidence and reasoning.

Cristina Negri: If we want to protect the environment or extract more resources from it, we must first





Clockwise from upper left: The Mira supercomputer is a stepping stone toward the next great goal of supercomputing: exascale speed, where computers will calculate quintillions of floating point operations per second; scientists collaborate on next-generation battery research in the Electrochemical Discovery Laboratory; Cristina Negri collects poplar samples to measure the pollutants sucked from the earth; workers install the Electron Beam Ion Source at the Argonne Tandem Linac Accelerator System in the laboratory's Physics Division.

understand it. We also must gain a better understanding of all of the functions that, say, a forest or other ecosystem can provide, before we determine what to do with it. For example, what is the benefit of the clean water or air that it yields?

Until now, this has been pretty expensive to monitor. New computing opportunities and capabilities will take environmental research to a much higher level. Whether we are trying to learn more about climate, weather, biogeochemistry, ecology, or population shifts, all of these areas will greatly benefit from improvements in the way we compute and handle data.

Cynthia Jenks: Right now, a major focus is on energy storage. How do we store energy for the grid? We are also working to create more advanced batteries that would enable electric vehicles to make that next jump.

On the more fundamental side, I've been talking a lot about the science of complexity. Major advances in molecular design, characterization tools, and computing now allow us to tackle incredibly complex problems. In chemistry, there is now a large knowledge base about how to take one chemical and convert it to another. But in industrial processes, there are so many more variables to consider. There are multiple components that need to be converted simultaneously and impurities in the system that can hinder these efforts. So how do you handle this? That's what we need to know.

Kawtar Hafidi: There are still many puzzles being explored in nuclear physics: from understanding highly unstable nuclei that are critical to nucleosynthesis in stars and supernovae to describing how matter is formed from quarks when we can never see quarks individually — only bound together to form protons, neutrons, and other hadrons. The difficulty of answering these fundamental questions drives us to develop new tools to study these fascinating objects. While our mission is to better understand the nature of visible matter that makes up the universe, the techniques we develop to address these difficult questions have important applications outside of nuclear physics, giving us many opportunities to leave our comfort zone and think outside the nuclear physics box.

For example, our work building accelerators and understanding reactions in atomic nuclei led us to work with the Nuclear Engineering Division to develop improved production techniques for isotopes needed for medical imaging and treatment. Our interest in extremely rare nuclei led us to develop techniques for trapping and detecting single atoms of a specific isotope. After we perfected trapping for our nuclear physics

SAFETY IN NUMBERS

The collaborative spirit drives not only scientific discoveries, but also breakthroughs in safety, says Cynthia Rock, the newest director of Argonne's Nuclear and Waste Management Division. Rock, who excelled as a point guard in collegiate basketball, attributes her biggest Argonne achievements to teamwork.

"Collaboration is a huge part of why my division has been so successful," she says. "We regularly tap into Argonne's scientific experts to help solve some very big problems."

One issue Rock faced here at Argonne was how to remove nuclear material from the laboratory and store it safely underground at the Waste Isolation Pilot Plant, in southeastern New Mexico. Back in 2009, Rock led a multi-million-dollar program that decommissioned six nuclear facilities and went a long way toward emptying four others — steps that ensured Argonne's safety, reduced maintenance costs, and added 90 combined Argonne and subcontractor jobs.

"It felt great to help Argonne and employ people who had been laid off" in the financial crisis, Rock says. Her team's decommissioning work also led to several honors, including the U.S. Department of Energy Secretary's Achievement award in 2012. Rock will also receive a humanitarian award this summer from Northwestern Oklahoma State University, her alma mater. (She already earned a spot in the school's basketball hall of fame.)

In her new role, Rock is focused on safety and modernizing Argonne's facilities. "I welcome the challenge and enjoy the creativity and passion that's needed to develop sustainable solutions," says Rock.

CINDY ROCK

Director of Nuclear and Waste Management

"When scientists work together, we really make an impact because the frontier of science shifts towards complex systems and complex competencies."

measurements, we applied this highly sensitive and selective technique to trap and count other rare atoms. Just as carbon-14 allows us to date samples of organic matter, counting isotopes of krypton and argon allows us to date groundwater, glacial ice, and water from deep ocean currents, providing a powerful new tool for environmental studies and geosciences.

ArgonneNOW: What are the obstacles you might face moving forward with your research?

Cristina Negri: In terms of the environment, there is a lot of information to gather and analyze, but consensus is a different story. Agreeing on what should be done is an enormous challenge — but we have an even greater challenge in making people understand why this research is important. We must have an active and vibrant research program in this area. That's the only way we will fully understand the impact of all of our actions on the world we live in.

Kawtar Hafidi: It's tempting for scientists and researchers to drill down in one particular area of study. It's very hard to let go and start something new. That's human nature. We have to find the balance between allowing someone to become an expert in one particular area and pushing them to think long term, to stay relevant.

ArgonneNOW: Valerie, could you expand on Argonne's efforts in the area of quantum information science?

Valerie Taylor: The area of quantum information science includes quantum computing, quantum communications, and quantum sensing. The laboratory has many efforts in quantum information science, as interdisciplinary efforts are critical to advances in this area.

I will focus on our efforts in quantum computing in the Mathematics and Computer Science Division. Currently, quantum computing is in its early stages with the availability of quantum processors with a small number — about 50 — of quantum bits, or qubits. We are engaged in work in the area of quantum algorithms, leveraging our depth and breadth in optimization, as well as work with parallel methods to extend the work with quantum simulators. Further, we are actively searching for a strategic hire in quantum computing.

There's also the Chicago Quantum Exchange, launched by the University of Chicago, in collaboration with Argonne and Fermi National Laboratories, which aids academic, industrial, and governmental efforts in the science and engineering of quantum information. We are engaged in research with the Chicago Quantum Exchange in the area of quantum networks. It's a very exciting time.

ArgonneNOW: What are some of Argonne's top priorities?

Cynthia Jenks: Among the top priorities is Argonne's Materials and Chemistry Initiative. The Chemical Sciences and Engineering Division will play a large role in advancing this initiative. As part of this, for example, we'll focus even more on catalysis (the study of how different materials — catalysts — can help accelerate chemical reactions). We will look at methods for designing catalysts that, for example, perform reactions in confined spaces. We can design catalysts in which, say, one part of the catalyst produces a particular chemical, and then another area takes that chemical and turns it into something else.

Fundamental science needs that are the foundation of new energy storage technologies continue to be a key focus for Argonne. Along with applied aspects of energy storage, battery recycling is another important focus. So, we have all of these batteries in the world. How can they be recycled? There are a few divisions working together on advancing this area.

ArgonneNOW: How does collaboration across departments benefit the laboratory?

Cristina Negri: That's the great thing about working at Argonne. I may be doing my environmental research here and Valerie can be doing her computer work two floors down from me. Both are worthy ventures, but when you put them




Clockwise from upper left: Division Directors Valerie Taylor, Cynthia Jenks, Kawtar Hafidi, and Cristina Negri discuss scientific priorities with their teams.

together, you get a lot more than the sum of the two parts. That's our edge here at Argonne.

It's pretty remarkable to have all of these different competencies, areas of expertise, resources, and facilities all in one place.

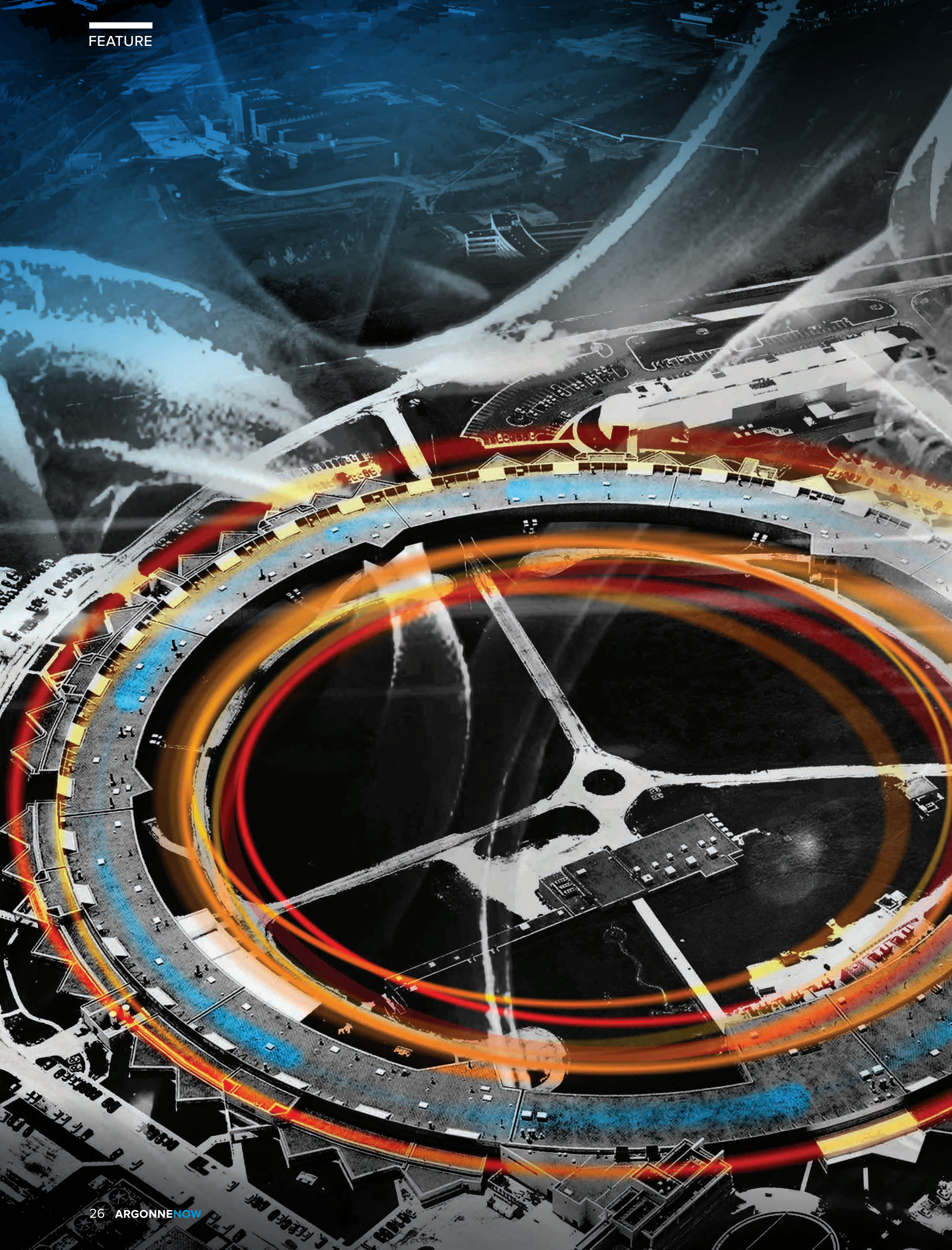
Valerie Taylor: Not only does the laboratory attract world-class researchers, it also provides state-of-the-art equipment and facilities to advance the science — and then there's the focus on excellence. Argonne has extraordinarily high standards for staff.

ArgonneNOW: Can you talk about Argonne's efforts to reach out to young people, women, and minorities?

Cristina Negri: We all should strive to become role models to the young people who visit or work at the laboratory and we must remember that everything we do also provides an example to those looking to us for guidance and support. We have to be vigilant in creating and maintaining an atmosphere in which all people, including women and minorities, are encouraged to step up and meet the challenge of working at a place like Argonne. All of our scientists and researchers should feel emboldened, confident in meeting the laboratory's goals and objectives.

Kawtar Hafidi: Young people are open to new ideas, which is great. I saw that this past year in the area of quantum information. The Department of Energy's Office of Science encouraged many offices to start thinking about it, including the Office of Nuclear Physics. I asked around my division to gauge people's interest and was met mostly with silence — except for two people who are among the younger folks on staff. Now we have a plan for how our department can add to this conversation. I was so glad to see their enthusiasm about building a bridge between these disciplines.

Valerie Taylor: We are constantly mindful of the need to help find and foster the next generation of scientists. We have a very welcoming environment for everyone, especially underrepresented groups like women and minorities. I recently attended a work-life balance workshop for women in high performance computing. I'm overjoyed at the notion that such a topic is being addressed — and that that panel was staffed by both men and women. That was great to see.



Ultra-bright X-ray beams expanding the boundaries of research.

BEAM US UP

BY STEVE KOPPES

Illustration by Robert Corwin

An F-15 fighter jet flies only 60 times faster than the world's fastest human, Usain Bolt, can run. But the upgrade of the U.S. Department of Energy's Advanced Photon Source, or APS, at Argonne National Laboratory in Illinois will make it 500 times brighter than it is today.

"A fighter jet is different from a human being, but that factor of 500 is such a big change, it's going to revolutionize the types of science that we can do," said Stephen Streiffer, Argonne Associate Laboratory Director for Photon Sciences and Director of the APS.

"We'll be able to look at the structure of materials and chemical systems in the interior of things — inside a turbine blade or a catalytic reactor — almost down to the atomic scale. We haven't been able to do that before. Given that vast change, we can only dream about the science we're going to do."

The APS upgrade has been in the works since 2010. The upgrade will reveal a new machine that will allow its 5,500 annual users from university, industrial, and government laboratories to work at a higher spatial resolution, or to work faster with a brighter beam (a beam with more X-rays focused on a smaller spot) than they can now.

"Sometimes it's called the ultimate X-ray microscope," said Dennis Mills, Argonne Deputy Associate Laboratory Director for Photon Sciences. It will open opportunities for closer-up views of materials and, for experiments involving the evolution of phenomena over time, the collection of data at more rapidly occurring intervals.

In operation since 1996, APS's electron storage ring, measuring two-thirds of a mile across, is large enough to encircle a major-league baseball stadium. Its beams are a billion times more powerful than the X-rays at a doctor's office. The 7 giga-electron-volt (GeV) facility is one of the world's highest-energy synchrotron radiation sources.

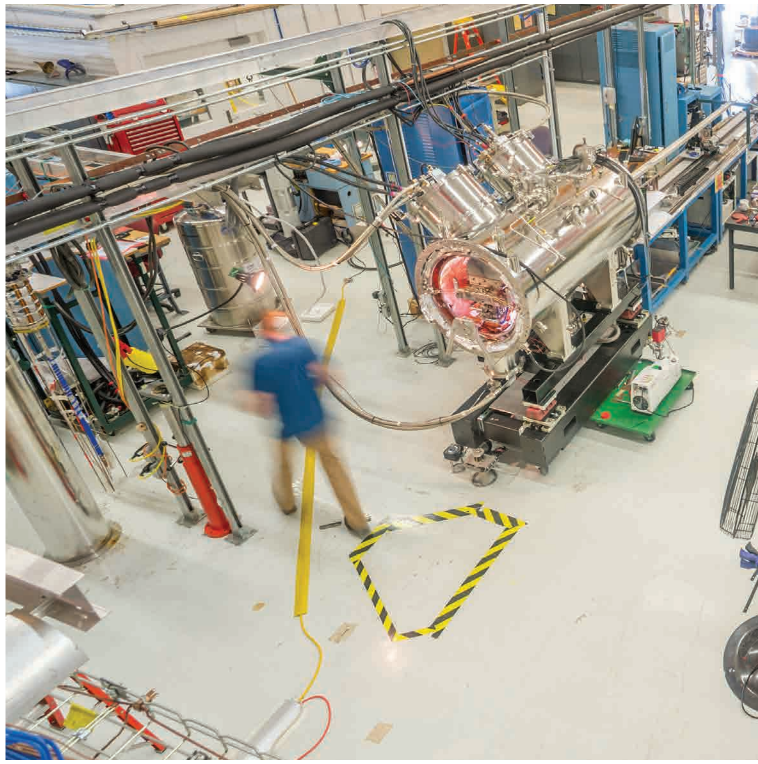
"An important aspect of what we do with the APS isn't big science. It's small science at a very large scale," said Streiffer. Fifty to 60 experiments get underway and generate data every day.

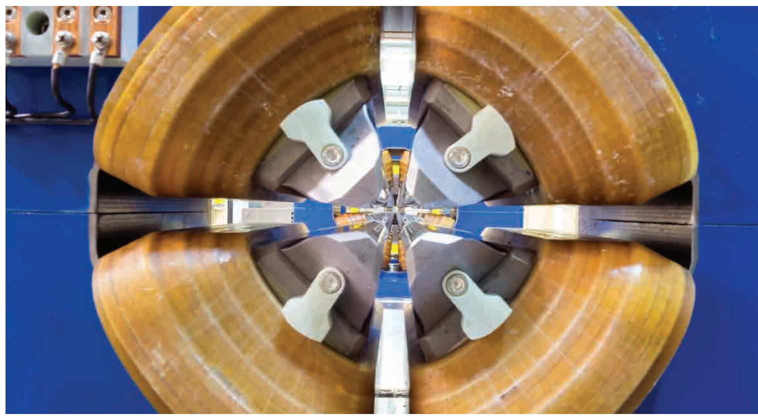
Scientists from across the country and around the world use the powerful, versatile, invisible light of the APS to study the arrangements of molecules and atoms, probe the interfaces where materials meet, determine the interdependent form and function of biological proteins, and watch nanoscale chemical processes. They need these capabilities to develop better ways to use energy, sustain the nation's technological and economic competitiveness, and push back the ravages of disease.

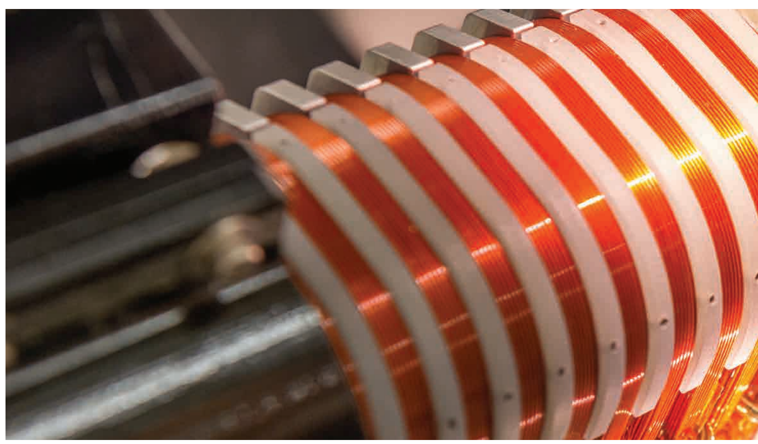
A NOBEL HISTORY

Research at the APS has contributed to two Nobel Prizes in chemistry, both pertaining to protein crystallography, a method used to investigate the features of proteins.

The 2009 Nobel Prize in chemistry went to Venkatraman Ramakrishnan, Thomas A. Steitz, and Ada E. Yonath for their study of the structure and function of the ribosome. All three laureates completed key aspects of their work at the APS. Ribosomes work as protein factories in all organisms, from humans to bacteria. The improved knowledge about ribosomes, especially in bacteria,

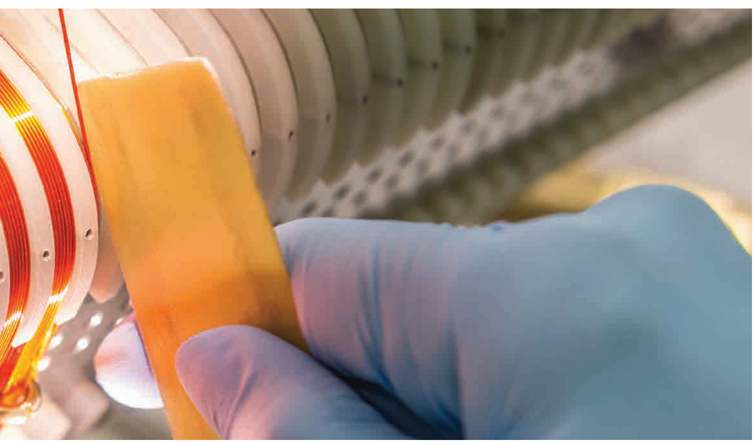






Counter clockwise from top: Physicists and engineers build and test new APS components, a closeup of the magnets that will drive the upgraded APS beams, a technician installs other magnets that will propel the beams.

> “An important aspect of what we do with the APS isn’t big science. It’s small science at a very large scale.”



opened a new avenue of medical research as scientists worked to identify antibiotics that can interfere with bacterial protein synthesis.

In 2012, Brian Kobilka shared the Nobel Prize in chemistry for work he had done on G-protein-coupled receptors, or GPCRs, a large family of proteins that play a key role in how cells interact with their environments. In his research, Kobilka passed extremely bright X-rays through crystallized proteins. By watching how the X-rays scattered, he revealed the three-dimensional structure of the proteins in great detail.

Many of today’s pharmaceuticals target GCPRs. Kobilka performed a study at APS that led to the first discovery of the structure of a human GPCR. Kobilka and other scientists bring their protein crystals to the APS with the goal of defining their structures.

“That can then help us understand the function of the molecule, which is what the biologists really want to know,” Mills said. Getting the proteins to crystallize is often difficult, sometimes resulting in rather small protein crystals. But the APS offers tightly focused beams. “You can use a small crystal at the APS and still get the data that you just couldn’t get at most other places.”

BEND, REFOCUS, REPEAT

The lattice of bending magnets currently used at the APS causes the electron beam to spread horizontally. But after the APS upgrade, a more advanced magnetic lattice, called the multi-bend achromat, will gently bend the beam, refocus it, and bend it more — over and over again until the horizontal beam’s size and shape become much smaller than what the facility currently produces.

“Right now, the APS operates with a beam that very much looks like a flat pancake,” Streiffer said. “It’s large in the horizontal dimension and rather small in the vertical dimension.”

In its typical operational mode, the APS beam measures approximately 15 microns in diameter vertically (much less than the diameter of a human hair) and 207 microns horizontally. But after the upgrade, the beam will measure approximately 10 microns in diameter vertically and 20 microns horizontally.

“By installing this more complicated magnetic lattice — the multi-bend achromat, which achieves this bend, refocus, bend, refocus, bend, refocus — you make the horizontal dimension of the beam similar to the vertical dimension, which improves its properties very substantially,” Streiffer said.

The theory behind multi-bend achromats is well established, but the challenge for photon scientists is making them work in practice. Streiffer compared the current APS magnetic lattice to a sedan and the proposed upgrade to a sports car. The sedan is affordable and reliable; the sports car offers higher performance, but also is more temperamental.

APS UPGRADE PROJECT **GETS NEW LEADER**

Robert O. Hettel arrived at Argonne this past fall to direct the upgrade of the laboratory's Advanced Photon Source, known to its users as the APS.

Hettel, a veteran accelerator designer and expert on storage-ring light sources, comes to Argonne from SLAC National Accelerator Laboratory.

In his new role as director, Hettel will oversee the planning, construction, and implementation of the upgrade. This project will create the world's ultimate three-dimensional microscope and enable researchers to view and manipulate matter at the atomic level, to solve complex science problems across multiple disciplines.

"Robert has a unique background that makes him the ideal person to lead the APS upgrade during its next critical phase," says Paul Kearns, Argonne's Laboratory Director. "He has balanced an impressive list of scientific and engineering achievements with a wonderfully nuanced eye for the bigger picture. We are looking forward to his leadership and perspective on this major project."

Hettel was attracted to the APS to work on a project that, once finished, will be at the forefront of scientific discoveries and engineering advances for the next generation.

"The APS is already a major force in the world of light sources, and the APS upgrade will truly lead the world in storage-ring light source performance," Hettel says. "I am looking forward to working with Argonne and the APS to build this fantastic machine."

ROBERT O. HETTEL

Director of the Advanced Photon Source Upgrade Project

Each new generation of light source has involved something of a leap into the unknown. The same applies to multi-bend achromats, a fourth-generation synchrotron radiation technology.

"It's only been in the last five or 10 years that computational techniques for simulating accelerators have evolved to where people are becoming convinced they can actually make this high-performance lattice work," Streiffer said.

The APS upgrade involves a technique called swap-out injection to introduce beams into a storage ring. Swap-out is the next outgrowth of the current technology's top-up injection technique. In top-up mode, the weakest of the decaying electron bunches receive an added charge as they circulate, while all existing bunches stay in place.

"That works in third-generation machines. In fourth-generation machines, where you're really pushing the performance, that doesn't work so well," said Michael Borland, Associate Director of Argonne's Accelerator Systems Division and an Argonne Distinguished Fellow. "You get rid of the bunch that's there and you inject a new one. You swap in a full-current bunch for a weakened one."

FEWER DONUTS AND SANDWICHES

The APS upgrade will require scientists to remove the current machine, install the new one, and re-open the facility to users, all within a year.

"To achieve this goal, we are simulating the process of commissioning the new machine," Borland said.

Vadim Sajaev, group leader in accelerator operations and physics at the APS, has developed a complex simulation code that will evaluate 100 or more possible configurations of the machine and consider potential operational differences that could emerge between its intended design and its actual construction.

Using this simulation, Borland said, "We can make fairly confident statistical predictions about the performance of the machine after we've commissioned it. We also plan to apply this software to our existing machine." In that exercise, they will pretend to commission the existing machine as a way to further test and develop the software.

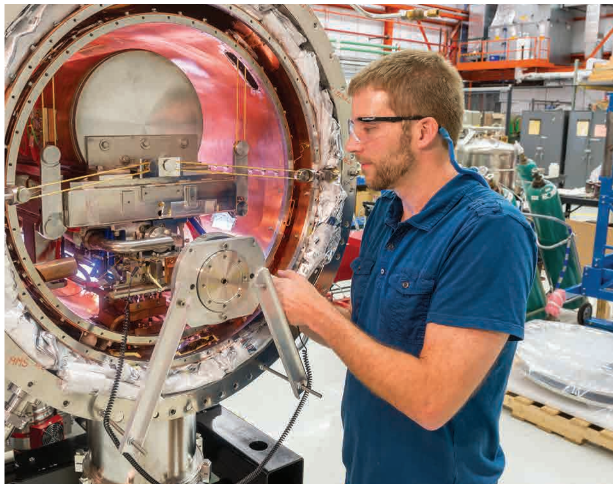
"Usually commissioning is a bunch of physicists in a control room with donuts and sandwiches for weeks getting the machine to work," Borland said. "We need to use more sophisticated technology to help us do that more quickly."

APS physicists have also been optimizing their magnet configurations through advanced computer simulations that emulate biological evolution. They were among the first to apply the technique to accelerator design on a large scale. In 2010, Borland received 36 million processor hours from the U.S. Department of Energy to conduct simulations based on the technique at the Argonne Leadership Computing Facility, which houses one of the world's fastest supercomputers.

"We continue to use Argonne facilities for that sort of calculation," said Borland.

The calculations were performed using something called a multi-objective genetic algorithm, which starts with a given configuration of magnets in a possible accelerator. The simulations then

“Each new generation of light source has involved something of a leap into the unknown.”



Clockwise from top left: Argonne technician Susan Bettenhausen builds a magnet designed to push the APS into new territory, engineer Matthew Kasa works on equipment for the APS upgrade, engineer Chuck Doose ensures new magnets slated for the APS upgrade are calibrated correctly.

determine how easy it will be to inject an electron beam into the accelerator, and how long the beam will last once it arrives.

“Then you make basically random tweaks to different parameters of the magnets and re-evaluate, to ask ‘How good is that configuration?’” Borland said.

After simulating an entire generation of a hundred or so randomizations from the starting point, the algorithm will find the ones that perform the best.

“Then you run the simulation on those so-called ‘rank one’ configurations. Basically, you take different properties from those configurations and you mix them together using random numbers. Then you re-evaluate all those ‘children’ of the previous generation and repeat. Eventually, the algorithm can find solutions that you never would have thought of yourself and that you couldn’t really get from any more deterministic technique,” Borland said.

The APS team has used this method both to improve the existing accelerator and to design new ones.

“It sometimes finds things that don’t seem right. And then you look in more detail and understand it did something really clever that you didn’t consider.”

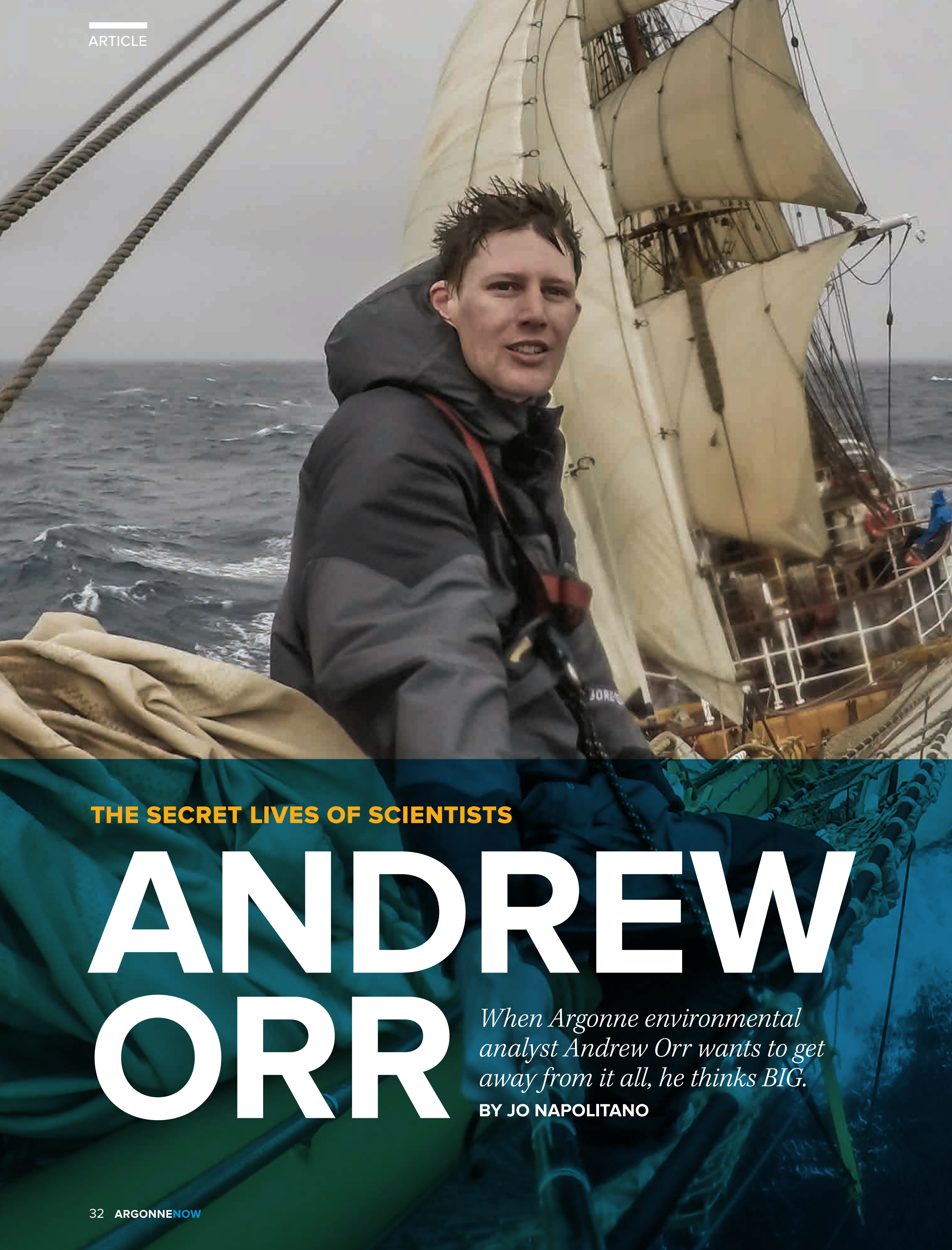
FINE TUNING A STICKY NOTE

Other simulation codes also help Argonne scientists understand and tune the APS electron beam’s properties. The continuously evolving ELEGANT code, which Borland and collaborators developed, has become a mainstay of accelerator design and simulation at APS and other light sources worldwide. These include the world’s first free-electron laser, the Department of Energy’s Linac Coherent Light Source at SLAC National Accelerator Laboratory.

“The basic equations that govern the electron beams are pretty simple. You can probably write them on a sticky note,” Borland said. Nevertheless, the configurations to create high-quality electron beams are quite complicated.

“You need simulation codes to help improve the electron beam’s quality,” Borland said. The outcome: APS beams that shine more brightly than ever.

The APS upgrade is funded by the U.S. Department of Energy’s Office of Science.



THE SECRET LIVES OF SCIENTISTS

ANDREW ORR

When Argonne environmental analyst Andrew Orr wants to get away from it all, he thinks BIG.

BY JO NAPOLITANO

In February 2015, Andrew took a 52-day trip partway around the world, sailing 6,000 miles on a 100-year-old tall ship. The vessel, which took off from Argentina, went on to Antarctica and then to Cape Town, South Africa, by way of South Georgia Island and Tristan da Cunha, the most remote inhabited archipelago in the world.

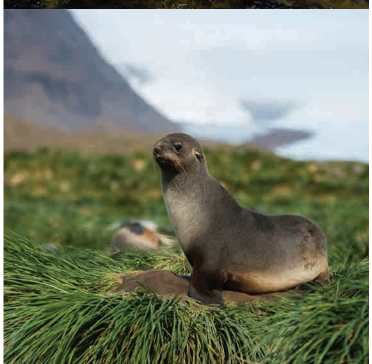
What do you do at Argonne?
AO: I analyze geographic and spatial data and make maps for environmental impact statements and atmospheric and climate modeling. When I first arrived at Argonne, I helped build a mapping tool that would allow individual states to determine the best locations in their state for clean energy technologies such as wind, solar, and geothermal energy.

What is your hobby?
AO: Travel and photography. I took about 7,000 still shots aboard the ship and about 1,800 video clips.

How did you first hear about this trip?
AO: A few years ago, a former coworker took a trip on the same ship, Europa. It sails around the world throughout the year. Every winter — for us in the Northern Hemisphere — the ship sails to the Southern Hemisphere. My friend spent 22 days on the ship, which was not nearly long enough for her. To improve upon that, I chose the 52-day trip.

Did you have much experience at sea?
AO: I never had any sailing training. At first, the crew breaks the group into three teams. Each team works a 4-hour shift and then has 8 hours off. When you are on watch, you get to steer the ship. You get to work the sails, go up in the rigging, go up to the top of the mast. There are actually two mandatory positions: watch and lookout. They always have two people on lookout while the ship is sailing.

Did your prior knowledge of mapping come in handy?
AO: Yes, but only a bit. The crew taught us celestial navigation with a sextant. It is tough because it is cloudy almost all of the time so you never have a good view of the sky.



What was the most memorable part of the trip?
AO: When we first arrived on land in Antarctic waters, we walked through a penguin colony. I was taking hundreds of pictures because it was my first time seeing penguins up close. I have loved them my entire life, so this was a dream come true. I know their main predator down there is the leopard seal, and I saw one actually eat a penguin. I was maybe 200 feet away.

Anything else stand out?
AO: I was at the helm late one night somewhere in the Scotia Sea between South Georgia and the Antarctic peninsula. I looked up and saw the Southern Cross, which is a recognizable constellation. I then spotted what was probably a large satellite in low orbit. It was incredible to be standing on a 100-year-old tall ship sailing in Antarctic waters and looking at a constellation as a manmade spacecraft passed by.

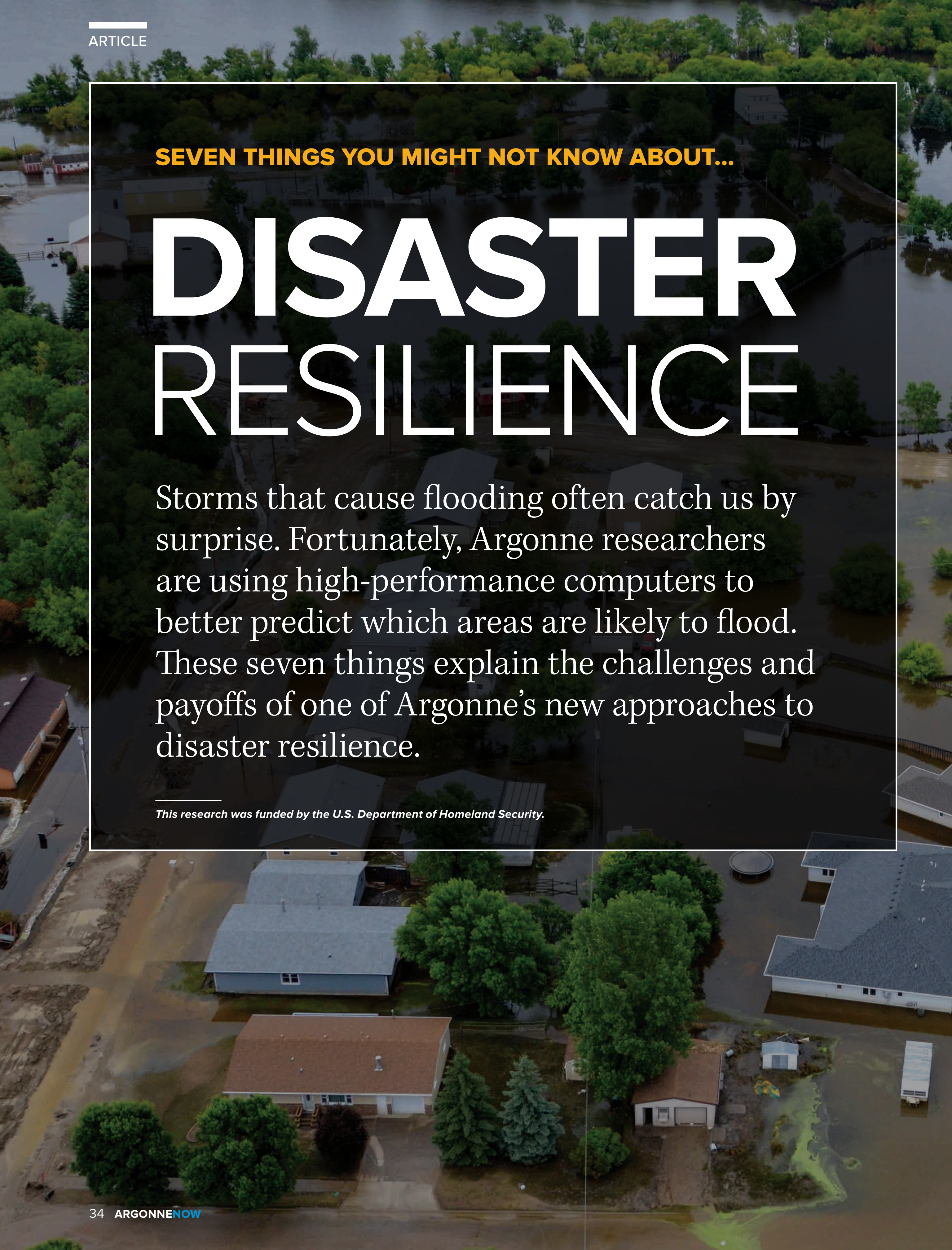
You were sailing in some uniquely remote areas. How dark was it?
AO: There is no light other than the moon and stars. We saw only two other boats the whole trip. Several times I saw planets, really bright planets that would reflect off the sea.

Where there any scary moments?
AO: Yes, definitely. We were sailing in the Drake Passage — between the Antarctic Peninsula and South America — when an intense storm arose with 27-foot high waves and winds stronger than 45 miles an hour. The Passage is one of the most dangerous waterways in the world, known for almost constant extreme weather. The crew did not let anyone on deck because we might fall overboard. I was worried, but the ship handed it well.

Where will you go next?
AO: I would love to go to Patagonia at the southern end of South America. I am also interested in going north to the Arctic Circle, to the Svalbard set of islands midway between continental Norway and the North Pole. I'm hoping there is a tall ship that does that route at some point.

To see more of Andrew's photos, visit www.aretephotograph.com.

ARTICLE



SEVEN THINGS YOU MIGHT NOT KNOW ABOUT...

DISASTER RESILIENCE

Storms that cause flooding often catch us by surprise. Fortunately, Argonne researchers are using high-performance computers to better predict which areas are likely to flood. These seven things explain the challenges and payoffs of one of Argonne's new approaches to disaster resilience.

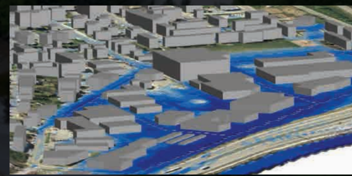
This research was funded by the U.S. Department of Homeland Security.

FLOODS ARE ONE OF THE MOST COMMON — AND DESTRUCTIVE — NATURAL HAZARDS IN THE WORLD

According to the World Economic Forum, one recent study found that in a 20-year period from 1995 to 2015, flooding accounted for 43 percent of all recorded global natural disasters — making it the most common by far. (Storms were second, at 28 percent, and earthquakes third at 8 percent.)

BUT ACCURATELY PREDICTING FLOODS, ESPECIALLY IN URBAN AREAS, IS EXCEEDINGLY DIFFICULT

This is because rainfall patterns can vary across small areas and can often escape detection by patchy rain gauge networks. Predictions must also account for unique landscape features that could affect flooding, as well as how fast the rain is falling. (For example, rain that falls in 6 hours could have very different flood effects than the same amount of rain spread out over 24 hours.)

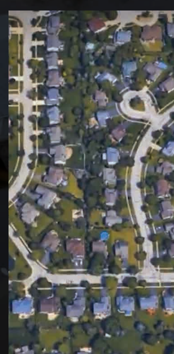


A NEW TOOL DEVELOPED AT ARGONNE CAN PREDICT FLOODS MORE ACCURATELY THAN EVER BEFORE

It offers a new way to analyze weather data, taking advantage of the laboratory's unique, high-performance computing resources and overcoming important limitations of previous approaches. It is the most comprehensive flood-predicting tool for urban areas to date.

IT'S THE EQUIVALENT OF DEPLOYING MILLIONS OF RAIN GAUGES THROUGHOUT AN AREA

The tool takes data from Doppler radar sites and analyzes it with a powerful collection of mathematical equations. Then it combines the data with a detailed model that incorporates geographic features and urban buildings.



USING THEIR NEW MODEL, RESEARCHERS CAN NOW PREDICT FLOODING WITHIN FEET, NOT MILES

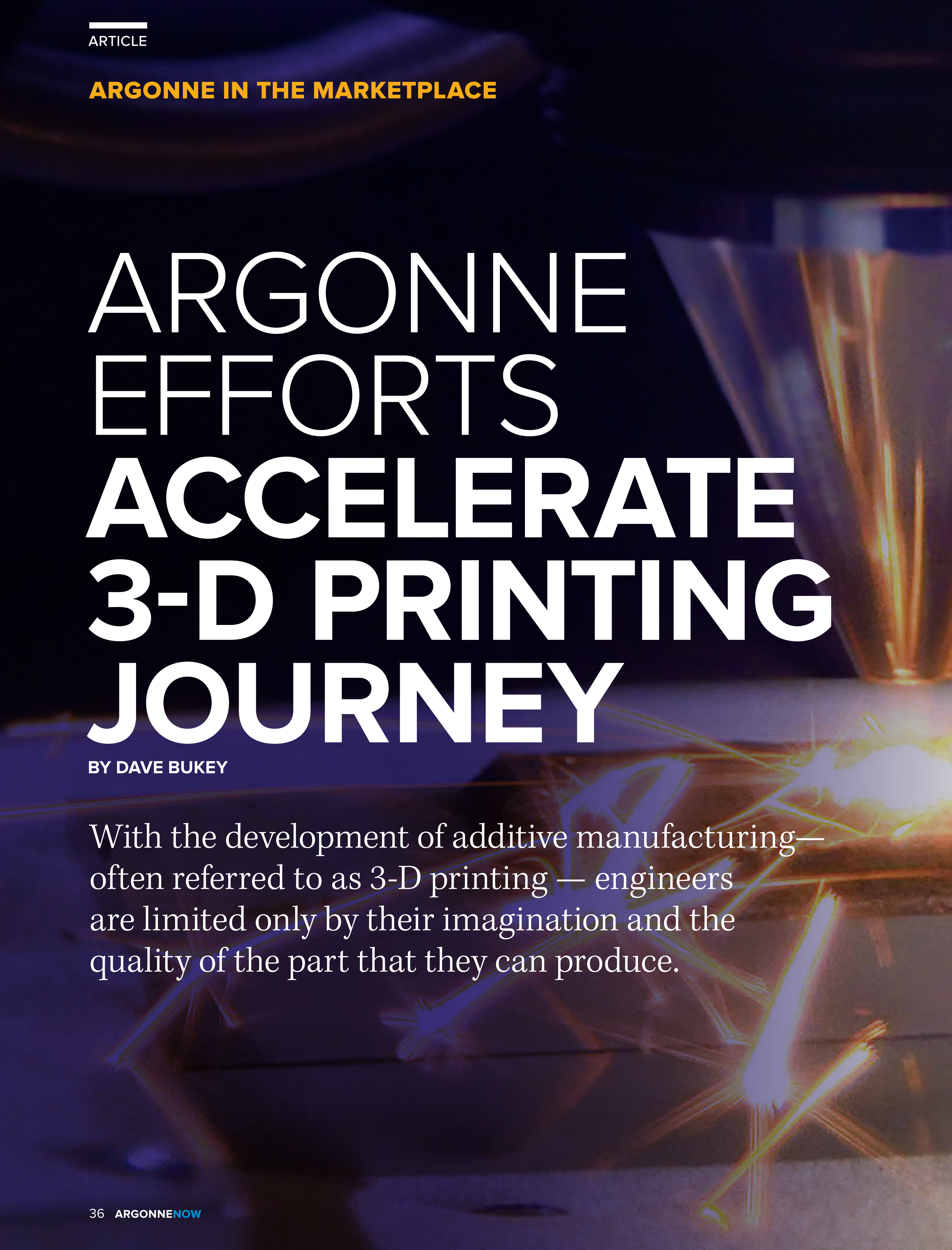
That's important, because storms that produce the highest rainfalls tend to be in small areas; the intensity of the rain can vary considerably between areas less than 100 feet apart. Studying past storms shows that predicted flood depths from a single rain gauge can be off by up to a foot and a half compared to radar-based rainfall data.

ARGONNE SCIENTISTS ARE ACTING LOCALLY, AND THINKING GLOBALLY

Argonne initially developed and deployed this tool as part of a Department of Homeland Security resilience program in Portland, Maine. Despite the regional focus at the beginning, the collaborative work and the information it yielded could reach far beyond Maine, with resulting benefits for science and society.

ACCURATELY PREDICTING FLOODS WOULD REDUCE THEIR HUMAN AND ECONOMIC TOLL

By understanding how extreme storms will affect areas, city planners, local communities, and business coalitions can make better decisions about how to improve storm drainage and flood preparedness. Other benefits could include using land more strategically and decreasing damage with various flood-reducing methods — potentially saving countless lives, homes, and businesses.



ARTICLE

ARGONNE IN THE MARKETPLACE

ARGONNE EFFORTS **ACCELERATE 3-D PRINTING JOURNEY**

BY DAVE BUKEY

With the development of additive manufacturing—often referred to as 3-D printing — engineers are limited only by their imagination and the quality of the part that they can produce.

By heating plastic or metal powders with lasers, scientists have already built cars, pedestrian bridges and even artificial jawbones layer by layer. This technology has the potential to transform manufacturing as engineers use titanium and other metal alloys to tap raw materials more efficiently, which in turn will reduce product costs and weight and shorten supply chains.

Yet metal additive manufacturing faces roadblocks. Printed materials often contain structural defects and vary from their designs, forcing engineers to repair their finished pieces or start over from scratch. And not all physics behind the process are well understood. Much of the research in this area involves trial and error — a costly and time-consuming way to innovate.

To address these problems, scientists from the U.S. Department of Energy's (DOE) Argonne National Laboratory, Carnegie Mellon University, and Missouri University of Science and Technology are investigating the entire 3-D printing process, including the material properties of the metal powders and how the laser "melts" and shapes those powders into the desired components, to discover both how defects form and methods to avoid them.

For the first time, scientists recently peered inside materials formed by 3-D printing in real time as the laser molded the metal powders into shapes. As the laser "prints" metal components, Argonne physicist Tao Sun and his collaborators have a front-row seat to its inner workings via the intense synchrotron X-rays at the Advanced Photon Source, a DOE Office of Science User Facility located at Argonne.

"The laser-metal interaction happens very quickly," said Sun. "Fortunately, we captured the process at 50,000 frames a second using the high-speed X-ray instrument at the Advanced Photon Source. We can study the resulting movie frame by frame to examine how the material's microstructure, especially defects and pores, form."

The team showed they can observe and quantify many metal 3-D printing characteristics — including melt pool size/shape, powder ejection, solidification, porosity formation, and phase transformations.

Sun will share his conclusions with partners in academia and other national laboratories who are building models to reliably predict the characteristics of the printed materials. These models also predict the dynamics of the process — such as how the laser melts the powder, when the powder changes into gases and liquids, and so on.

Meanwhile, Aaron Greco, a principal materials scientist at Argonne and project co-leader for Argonne's additive manufacturing effort, enhances the models from a different angle. "After printing, we examine the product's resulting microstructure and defects," said Greco. "We use a variety of techniques including optical and electron microscopy and even tomography at the Advanced Photon Source, to validate the models."

The result is a virtuous loop in which the experimental data feeds into models of additive manufacturing, and then the improved models are tested by more elaborate and insightful experiments. This interplay between modelers and experimentalists is essential to clearly and accurately understanding the underlying materials physics required to make 3-D printing truly reliable.

Although this loop is vital to their fundamental understanding of additive manufacturing, the researchers' ambitions extend further.

"Our goal is to explore new possibilities," said Greco. "Industries are currently limited to a certain set of metal alloys. But what about new ones? If you understand the physical properties related to how to print new alloys, you can adopt these into the process and speed up the reliability of printing."

Industries are also limited by the extremely detailed models currently required to define the printing process for complex parts. By reducing these models to just the handful of elements that affect quality and reliability, the team hopes to make the models faster and more suitable for industry.

Ultimately, Argonne's efforts will achieve the best of both worlds: Scientists will uncover the dynamic mysteries of metal additive manufacturing, while industries will thrive with blueprints to rapidly print cost-effective and reliable products.

"Our work will not only help industries improve efficiency and performance, but also increase the likelihood that metal additive manufacturing will be more widely adopted in other applications," Greco said.

Sun's research was reported in the *Scientific Reports* article, "Real-time monitoring of laser powder bed fusion process using high-speed X-ray imaging and diffraction." The experiments were performed at the Advanced Photon Source's 32-ID-B beamline.

This research was supported by Argonne National Laboratory; the U.S. Department of Energy's Office of Science, National Nuclear Security Agency, and Office of Energy Efficiency and Renewable Energy; the Grumman Corp.; and the University of Missouri Research Board.

EDUCATION

AFTER-SCHOOL ENERGY RUSH

BY KATHRYN E. JANDESKA

How can high school students help develop plans to clean the air in major U.S. cities? The U.S. Department of Energy's Argonne National Laboratory is finding out.

Argonne partnered with the University of Chicago in the summer of 2017 to sponsor "All About Energy," a six-week program that gives Chicago public high school students an up-close look at careers in science, technology, engineering, and mathematics (STEM) and a chance to learn what it means to be a scientist. Now in its second year, the program ran from July 5 through August 15.

According to Shaz Rasul, director of community programs at the University of Chicago, "All About Energy" has been a hit with students, who participated under the auspices of After School Matters, a Chicago not-for-profit that provides opportunities to more than 15,000 teens each year.

Founded in 2000, After School Matters creates public–private partnerships to provide enrichment opportunities for students in Chicago's public high schools, where resources are scarce and such opportunities are limited.

"All About Energy" drew more than 100 applicants, Rasul said, with the Neighborhood Schools Program, one of the university's community outreach programs, interviewing more than 60 candidates for the 30 spots available.

"We were excited to partner with the University of Chicago on this program," added Meridith Bruozas, Argonne's manager of Educational Programs and Outreach. "We built the curriculum here and designed it after a recent Argonne OutLoud event that dealt with building an energy plan."

Students were organized into six five-member teams, with each team assigned a different Chicago neighborhood for study. One of their first tasks was to learn about the City of Chicago's sustainability plan, which calls for reducing carbon dioxide emissions 20 percent by 2020. Students met with the city's chief sustainability officer, who described the plan and answered questions.

Students spent four and a half weeks studying different kinds of alternative energy, learning the pros and cons of each and how they worked.

The program also included field trips. Students made biofuel at Argonne and visited Chicago's famed Museum of Science and Industry, where they met with the museum's sustainability officer. They also attended Argonne's Learning on the Lawn event, where they joined poster presentations by the laboratory's undergraduate interns.

Teams spent the last week and a half of their program formulating an energy plan for their assigned neighborhood, implementing alternative energy practices with the goal of reducing greenhouse gas emissions by 20 percent. The program culminated in an August 15 poster session in which students described their energy plans. Guests included officials from the City of Chicago; members of Argonne, the University of Chicago, and After School Matters; and students' families.

"This program provides an opportunity for students to try on the identity of a scientist," Bruozas said. "There are few, if any, programs like this."

Argonne's Educational Programs Department aims to enrich STEM education through programs that advance the laboratory's strategic energy, environment, and security initiatives. Argonne also seeks to develop new educational programs based on transforming discoveries that further the Department of Energy's mission of workforce development and science literacy.

"It was really an opportunity like no other," said Daniel Arenas, an Argonne summer intern who participated in the 2016 STEM program. "The STEM program last year enabled me to network with people who helped me attain a summer internship this year. I worked with chemists and engineers at a level I never thought possible as a high-school graduate. Everyone at Argonne, the University of Chicago and After School Matters shows great interest in every single participant and genuinely wants the best for us."

"This program provides an opportunity for students to try on the identity of a scientist. There are few, if any, programs like this."

Argonne and the University of Chicago partnered to help these Chicago high school students study different kinds of alternative energy; Middle: Chicago high school students made biofuel at Argonne as part of a summer partnership between the laboratory and the University of Chicago.

ARTICLE

CROWDSOURCE

WHAT IS THE BIGGEST SURPRISE NATURE HAS HANDED YOU?

JACK GILBERT

Microbial Ecologist

MICROBIAL ECOLOGY

"The biggest surprise nature handed me is the discovery that microbes in your gut could influence brain development and behavior. That was astounding to me. When my son was diagnosed with autism, I wanted to figure out a potential solution to his problem. Instead, I uncovered a whole research field to which we are now actively contributing. Microbial 'dysbiosis' (imbalance) seems to play a role in so many facets of our health. The fact that it could be influencing disorders such as depression, anxiety, and even cognition fascinates me. I am desperate to uncover this link and figure out how to use it to help people."

LINDA YOUNG

Atomic and Molecular Physicist

PHYSICS

"The biggest surprise to me has been the creative, explosive growth of lasers and their applications in science and society. As a graduate student working with homemade tunable infrared lasers, it was hard to imagine that lasers would one day be responsible for so many things: examining the difference between matter and antimatter, quantum key distribution (a new approach to cryptography) to satellites, telecommunications, grocery checkout, 3-D manufacturing, and even eye surgery. Argonne has expanded the frontiers of novel laser applications with the invention of atom-trap trace analysis, a method of counting individual rare atoms in a sea of a trillion isotopic sisters to calculate the age of groundwater.

These applications use long-wavelength lasers, but the quest for an X-ray laser was always a dream for scientists. Finally, in 2009, the U.S. Department of Energy successfully developed the first hard X-ray free-electron laser at the SLAC National Accelerator Laboratory — and Argonne contributed to this feat by demonstrating the single-pass saturation mechanism and building the undulator."

Argonne scientists from different disciplines provide a perspective on a complex question.

RICK STEVENS

Associate Laboratory Director for Computing, Environment and Life Sciences

COMPUTING, ENVIRONMENT AND LIFE SCIENCES

"The biggest recent happy surprise is how well machine learning is working on problems in cancer. Predicting cancer drug response now seems to be an achievable goal in the near term. Computers are already reliably more accurate and more consistent than humans in most areas of cancer diagnosis. This did not require fundamental breakthroughs specific to cancer. Instead, it required the careful organization of data from thousands of patients and just enough computing power. Of course, there has been recent progress in machine learning across the board. This seems to be the effect of good algorithms, large amounts of data, and teraflop-level computing (performing trillions of operations per second). The future is very bright for applying machine learning to many problems in medicine, science, and engineering. We dreamed about this 30 years ago, but now it seems that it will happen in our lifetime."

SANTANU CHAUDHURI

Director of Manufacturing Science and Engineering

MANUFACTURING SCIENCE AND ENGINEERING

"The grand challenge at the core of manufacturing at Argonne is the holy grail of manufacturing science at large: How do we develop the science behind the art of making many copies of the same thing, over and over, with minimal defects, and at a very frugal energy budget in the shortest time possible?

As we learn more about how nature synthesizes or manufactures inorganic, organic, and composite materials, we cannot help but be amazed by nature's sophisticated machinery. Nature manages to maintain a tremendous degree of control over the mesoscale architecture of materials and chemicals. In manufacturing science, we are beginning to build the science and tools needed to understand and control the manufacturing genome — nature's blueprint — and move beyond intuition-driven engineering to predictive control of synthesis and assembly at the molecular level."

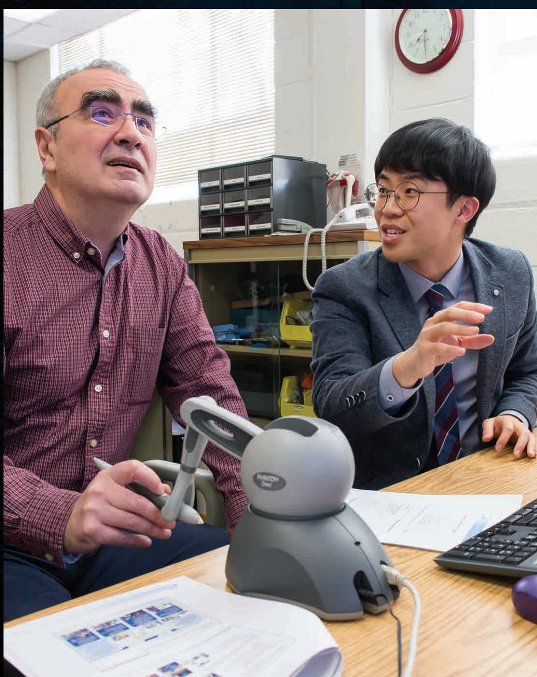
ARTICLE

SCIENCE BEHIND THE FICTION

NOT A STRANGER THINGS DOPPELGÄNGER

BY JO NAPOLITANO

The opening scene of the hit Netflix series "Stranger Things" takes place inside the fictional Hawkins National Laboratory, which is shown to conduct clandestine work related to the supernatural.



Argonne's Marius Stan (left) and Donghyeon Lee (right) discuss ways to collaborate.

The made-up site, alleged to be run by the U.S. Department of Energy, opened a portal to another dimension, one that might be connected to the disappearance of a 12-year-old boy — and the discovery of a young girl with otherworldly powers. The first of the show's two seasons focused on the boy's recovery while the second followed his family and friends as they grappled with all that had happened.

The made-up laboratory at the heart of the story, set deep inside a pitch-dark forest, is said to resemble Argonne — so much so that the real U.S. Department of Energy released a tongue-in-cheek comparison between the two. The missive came out this past summer.

"We don't mess with monsters," the announcement said. "But the Energy Department is in the business of detecting invisible dangers."

Marius Stan, interim director of the Systems Science Center in the Global Security Sciences Division, has long been delighted by the intersection of the real and the imagined. Stan is not only an acclaimed computational physicist and chemist but also won a recurring role in the hit AMC series "Breaking Bad." The Emmy-winning crime drama ran for five years, ending in 2013.

Stan said that while the main laboratory building depicted in "Stranger Things" might be eerily reminiscent of some of Argonne's older edifices — or even of the Department of Energy building in Washington, D.C. — the similarities are only superficial.

"The type of work we do helps society," Stan said. "We don't torture people, though some of my postdocs might say I torture them with physics and math."

Indeed, he said, the national laboratories constantly strive to solve some of the great problems of our age, particularly in the area of energy production, energy storage, and energy transportation. The U.S. Department of Energy also has a strong focus on high performance computing.

Argonne, its people, and its world-class facilities are key to this mission, he said.

"The laboratory is home to some extraordinary facilities, including the Advanced Photon Source, a tremendous X-ray machine that we use to look inside materials, to learn how they are made — and to design better ones," Stan said. "We also do significant work in support of national security."

The real laboratory, set in the Argonne Forest, was established in 1946 following the first sustained nuclear reaction conducted at the University of Chicago as part of the Manhattan Project. It has had 14 directors since then: Paul K. Kearns was appointed in November 2017 to lead Argonne as it upgrades the Advanced Photon Source, enters the era of exascale computing, explores the universe, and helps transform manufacturing and energy storage.

Stan said he understands why the national laboratories have attracted the attention of the show's creators. The public does not entirely understand the work that goes on at the sites and that makes the labs appear to be mysterious, he said. In an effort to help change this, Stan is giving a series of presentations on science, art, and society in the Chicago area. At these events, he talks at length about the tremendous benefits of scientific research and engineering innovation, particularly in the area of artificial intelligence.

"Many people don't know about the research we do," he said. "We must always work to connect with the public to demonstrate the laboratory's value and positive impact on society."

As for "Stranger Things," Stan would like to thank the show's creators for shining a light on the national labs.

"It's a good thing in itself," he said. "It brings attention. Some of the people who watch the show might look up national laboratories. They won't find the Hawkins lab, but they might stumble upon Argonne."

Argonne's Marius Stan and Young Soo Park inspect a Baxter robot. Both researchers are examining how robotics and artificial intelligence can help deactivate and decommission nuclear power plants.

ARTICLE

ASK A SCIENTIST

HOW ADVANCED COULD ARTIFICIAL INTELLIGENCE BECOME?

PRASANNA BALAPRAKASH
Computer Scientist

How do computers learn for themselves?

PB: They don't, actually. When it comes to machine learning, the approach that is currently gaining the most attention is "supervised learning," in which we (humans) have to teach them (computers). It's similar to how we learn from our parents, teachers, and mentors. We have developed algorithms for this purpose based on the way humans process information. For example, we can now teach machines the association between the images and labels based in part on how we ourselves have come to understand the world around us.

How efficient or accurate is machine learning?

PB: That all depends on the data that we provide. We need good training data from the start. Machine learning is not magic. Machines cannot perform tasks outside what they are given or how they are trained.

Can a machine learn incorrect information?

PB: It can if the training data are wrong. Let's say you give a machine an image of a cat and tell the machine it is actually a dog. It doesn't have a way to learn the truth. But if you give a machine hundreds of cat images and 10 are actually dogs, the algorithm will use the majority of the images to determine which is a cat and which is not.

Who is leading the field?

PB: Speaking of AI in general, several countries are taking this very seriously and are trying to lead the field. Of course, the United States is one of them. But let's not forget that AI is already a part of our everyday life in the form of Siri and self-driving cars. As the technology improves, there will be infinite ways to use it to advance science, find new materials, create better drugs, and understand data from cosmology, for example. In fact, scientific experimentation has created so much data that humans could not possibly process all of it. Computers will sort it for us, using AI.

Will Artificial Intelligence ever get to the point where humans won't be able to tell the difference between AI and human thinking?

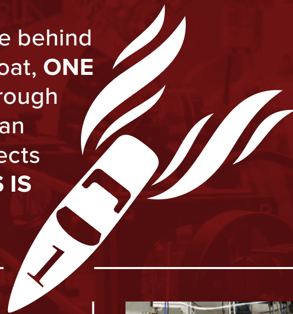
PB: Let's narrow the idea of "thinking" to simply problem solving. AI is already able to do this — and in some cases, to outperform humans. This is particularly true in the areas of language translation, image classification, palliative care, and radiology, where machines can solve problems with greater accuracy than humans. But when we look at general intelligence, there is no problem-solving algorithm that can perform well on all possible tasks. Humans cannot solve all problems, but we can solve many of them. It is for this reason that I don't believe computers will ever overtake humans outside of specific, narrow tasks. So our fears here are misplaced. Nevertheless, AI has great potential to deliver impacts in a wide range of applications, from those that improve our quality of life to those that enhance our understanding of the universe.

Prasanna Balaprakash is a computer scientist. His research interests include AI, machine learning, optimization, and high-performance computing.

BY THE NUMBERS

ARGONNE **WAKEFIELD ACCELERATOR FACILITY**

Just like a boat leaving a wake behind it affects a skier behind the boat, **ONE ELECTRON BEAM** moving through a conducting pipe generates an electromagnetic field that affects a trailing electron beam. **THIS IS A WAKEFIELD**.



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TWO BEAMS are employed in wakefield acceleration. An electron **DRIVE BEAM** generates the wakefields, which are used to accelerate a second trailing beam, called the **WITNESS BEAM**.

100 MEV

Wakefields provide a high-energy boost to the trailing witness beam. Because wakefield acceleration can generate very intense fields, the energy increases rapidly over a short distance, with an acceleration gradient upward of **100 MEGA-ELECTRON-VOLTS (MEV)** per meter.

The Argonne Wakefield Accelerator facility is building the capacity to reach accelerating gradients in the range of **200–300 MEV** per meter and to dramatically improve the energy efficiency. Such progress could establish wakefield acceleration as a powerful scientific tool, with its smaller footprint and lower cost.

This effect was first demonstrated in **1988** (30 years ago), when J.B. Rosenzweig and Wei Gai, et al., first observed wakefield acceleration in a plasma at Argonne National Laboratory's Advanced Accelerator Test Facility.

1988

ARGONNE OUTLOUD
PUBLIC LECTURE SERIES

This year's lecture series will highlight a variety of Argonne research activities that shed a bright light on challenges facing our evolving world and how science is helping to advance effective solutions.

May 31
SCIENCE AND THE TRANSFORMATION OF CITIES
Ralph Muehleisen

June 16
THE SOIL BENEATH OUR FEET
Umakant Mishra

July 12
NAVIGATING RISK DUE TO EXTREME EVENTS
Rao Kotamarthi

September 20
THE NEW ENERGY CRISIS: ENERGY INNOVATION IN A WORLD WHERE ENERGY IS CHEAP AND PLENTIFUL
John Carlisle

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Argonne National Laboratory
9700 South Cass Avenue
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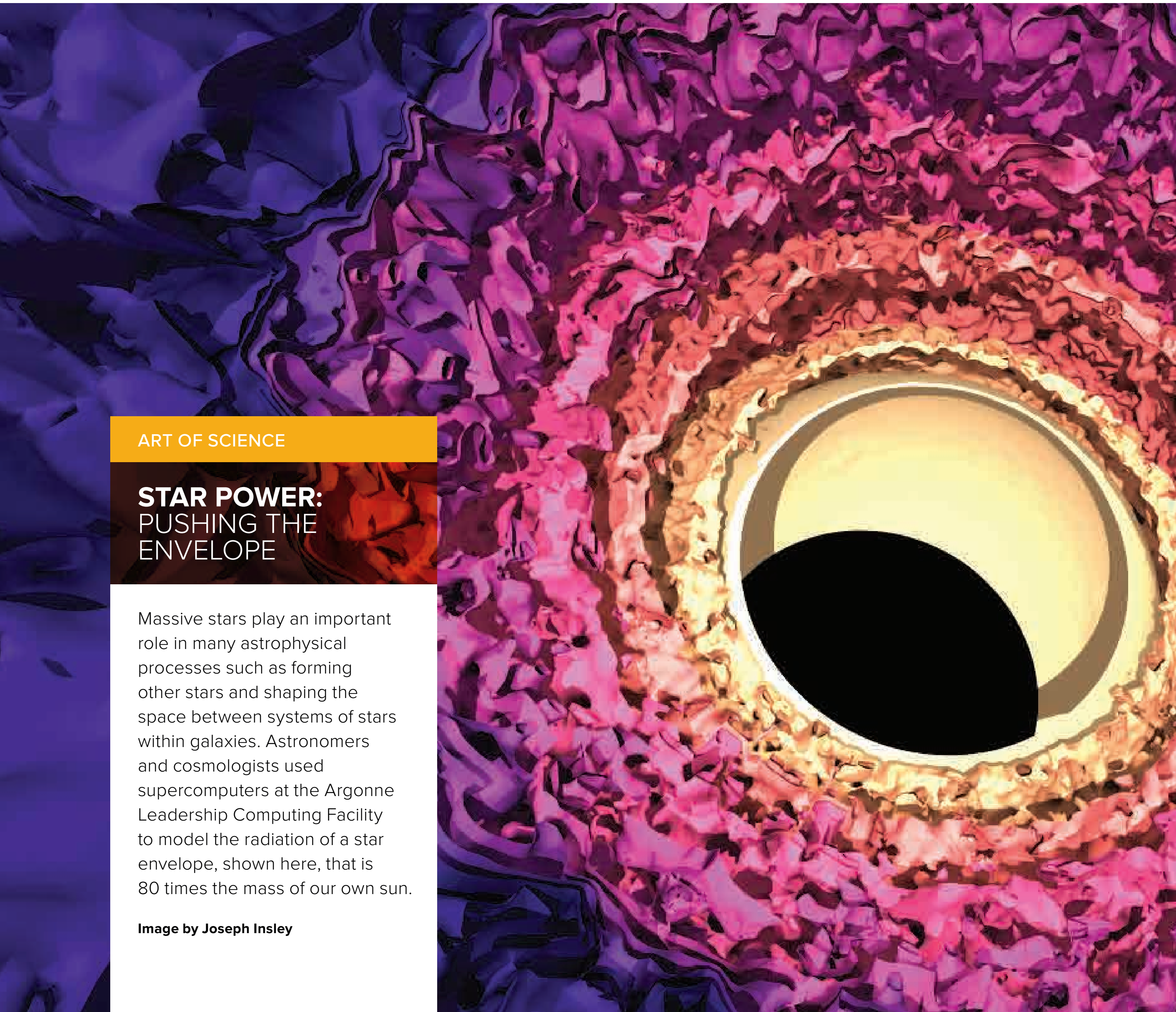

ART OF SCIENCE

STAR POWER: PUSHING THE ENVELOPE

Massive stars play an important role in many astrophysical processes such as forming other stars and shaping the space between systems of stars within galaxies. Astronomers and cosmologists used supercomputers at the Argonne Leadership Computing Facility to model the radiation of a star envelope, shown here, that is 80 times the mass of our own sun.

Image by Joseph Insley