ARGONNE NOW

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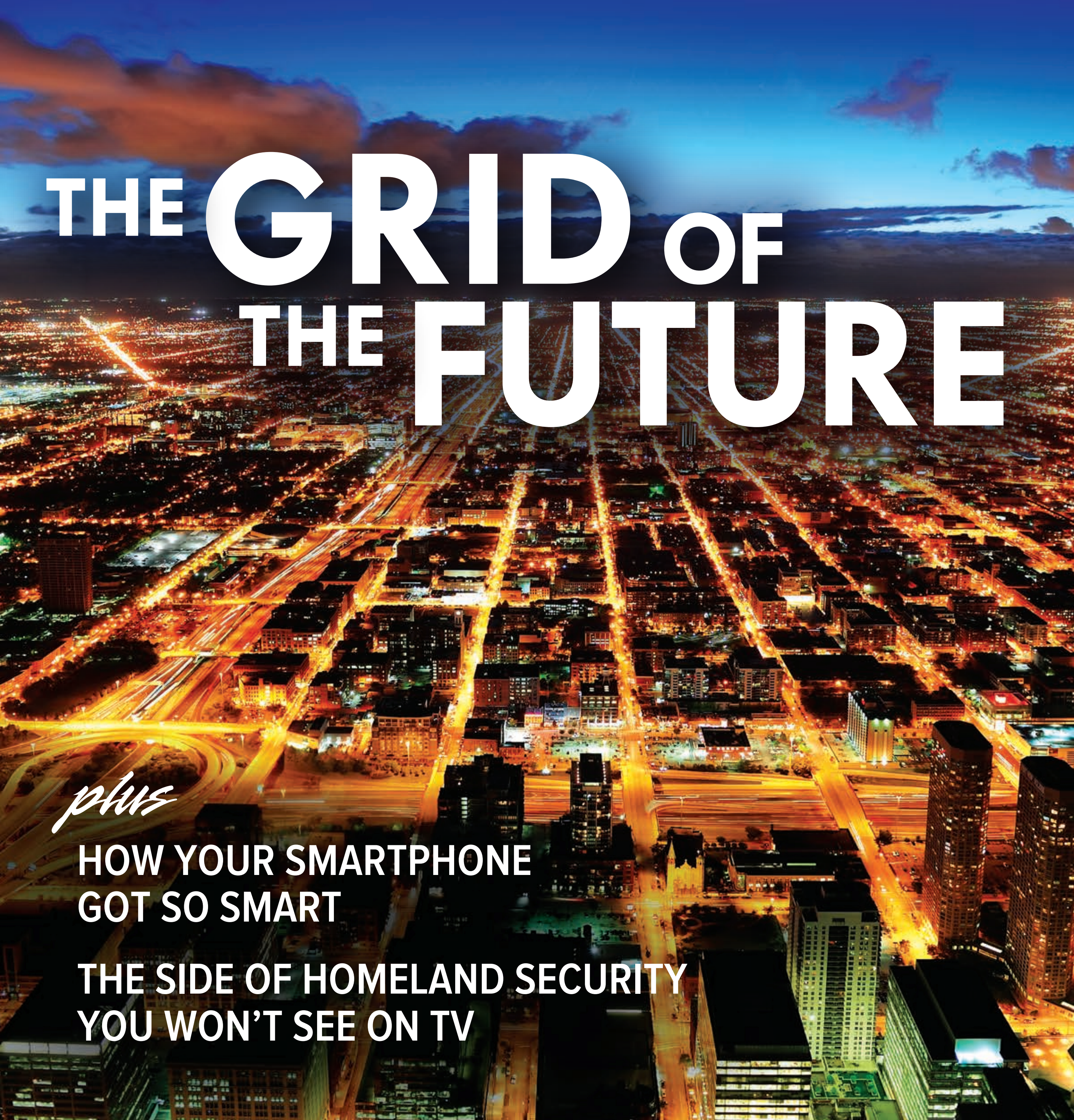


THE GRID OF THE FUTURE

plus

HOW YOUR SMARTPHONE GOT SO SMART

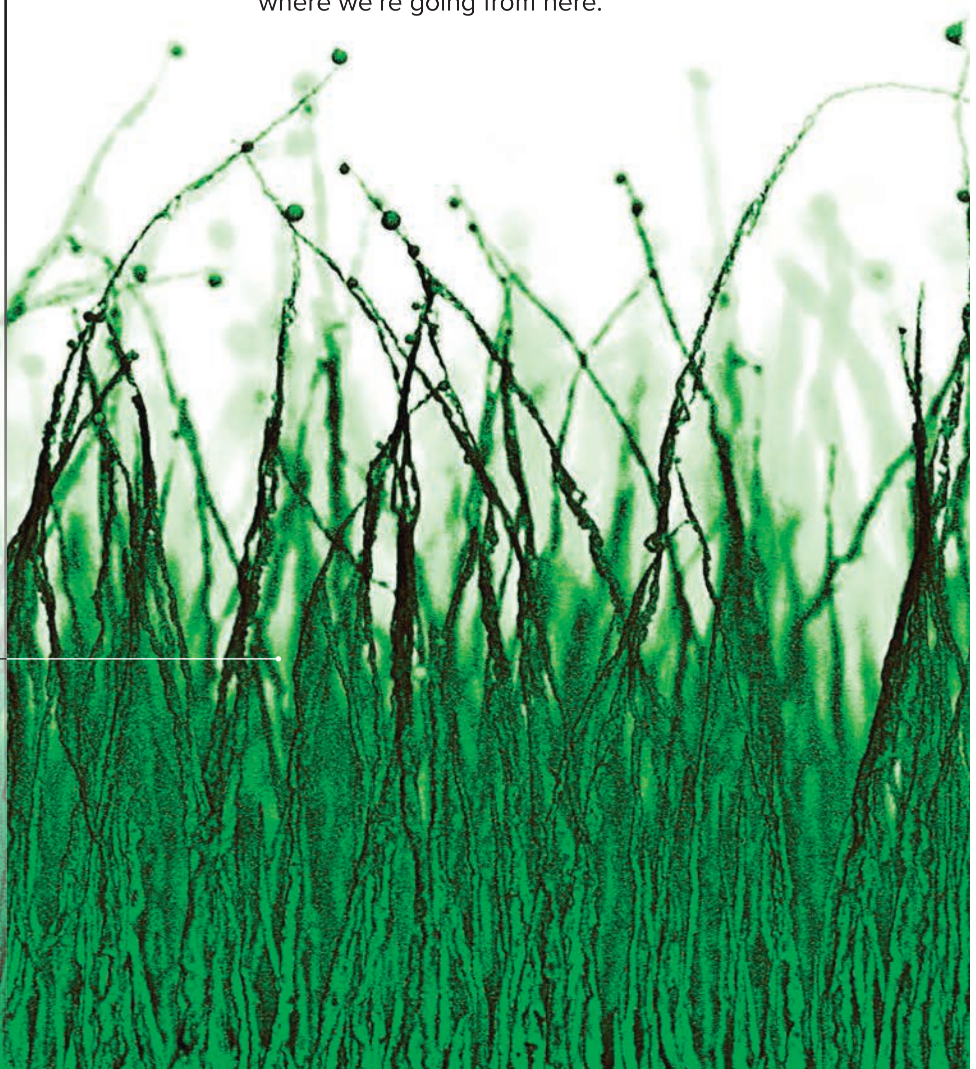
THE SIDE OF HOMELAND SECURITY YOU WON'T SEE ON TV

editor
Louise Lerner

editorial board
Ed Daniels
Emilio Bunel
Robin Graham
Matt Howard
Denny Mills
Steve McGregor

photography
Wes Agresta
Mark Lopez
art and design
Sana Sandler
production
Gary Weidner

send correspondence and questions to:
Argonne Now
Communications & Public Affairs
Building 201
Argonne National Laboratory
9700 S. Cass Avenue
Argonne, IL 60439
argonnenow@anl.gov
630 252 5526



Image

Scientists are studying these tiny silica nanowires for energy storage devices like batteries. Image by M. Bettge, D. Abraham (Argonne National Laboratory); S. MacLaren, S. Burdin, R. Haasch, I. Petrov, M. F. Yu, and E. Sammann (University of Illinois at Urbana-Champaign).

Argonne NATIONAL LABORATORY

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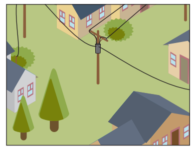

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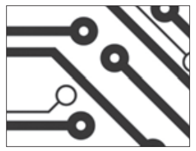

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Dear Reader,

When we invest in scientific research, we invest in the future of our nation. New technologies drive our economic growth; in fact, some analysts believe that discoveries in science and technology have led to more than half of America's economic growth over the last century. So as director of Argonne National Laboratory, I know that the work we do here every day plays an important role in creating new products, building new industries, and keeping our economy healthy.

As a Department of Energy laboratory, we focus much of our research on a broad portfolio of sustainable and clean energy technologies. Our cover story for this issue, "The Grid of the Future" (page 20), looks at the work we are doing to improve a key component in our nation's economic future: the intricate network that delivers our electricity. For the last 50 years, the pattern of Americans' electricity use has remained relatively constant, so the current grid has been mostly adequate for our needs. But today, we are facing some transformational changes: Innovative new technologies, such as electric cars, could shift our consumption from gasoline to electricity, while wind and solar offer more renewable (but intermittent) generation. Today's electric grid wasn't built to handle these types of challenges. Fortunately, our scientists here at Argonne are using our world-class supercomputer to develop a smarter, more flexible grid that will deliver electricity affordably and securely while meeting consumer needs.

Our story on the basic science behind the smartphone ("How Your Smartphone Got So Smart," page 30) offers a case study focused on one of our laboratory's most important missions: How can we create new materials that will improve our lives? At Argonne, we are developing new materials to make more powerful batteries, more efficient solar panels, and more effective pharmaceuticals. As you'll read in this article, we're also working on new materials that will help us take the next great leap beyond the transistor—the electronic device that is the fundamental building block of all modern electronics. The semiconductor material in the transistor helped to take us from the room-sized computers of the 1950s to the smartphone in your pocket today; our goal is to create new materials that will have an equal impact.

You'll also read about a side of homeland security that we don't see on TV: the researchers who use science and analytics to make our nation safer ("A True Sense of Security," page 26). For example, our staff built a network of sensors that can be used to detect chemical weapons in city subway systems, providing early warning to commuters and giving instant notice to first responders—potentially saving many lives.

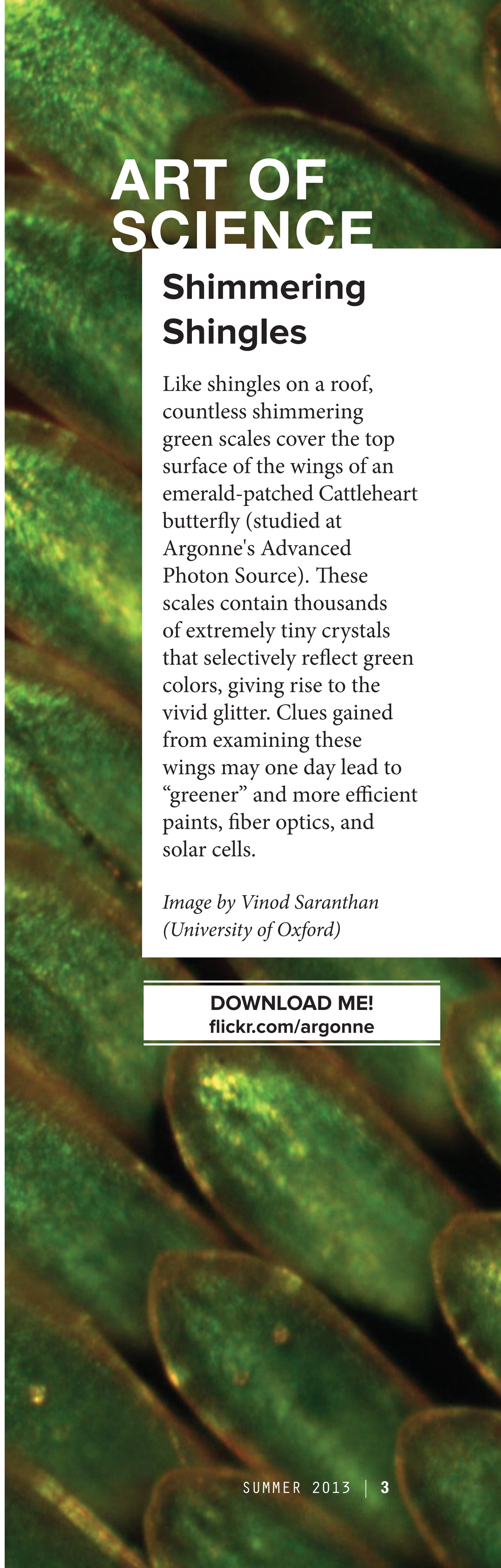
Here at Argonne, we are proud that our scientists and engineers are among the best in the world, tackling some of the biggest energy, environmental, and national security challenges facing our nation. But we're equally proud of the impact of our research, which helps to create new jobs and strengthen our economy.

We appreciate your interest in our work, and we hope you enjoy reading this latest issue of *Argonne Now*.

Sincerely,

Eric D. Isaacs

Eric D. Isaacs, Director



ART OF SCIENCE

Shimmering Shingles

Like shingles on a roof, countless shimmering green scales cover the top surface of the wings of an emerald-patched Cattleheart butterfly (studied at Argonne's Advanced Photon Source). These scales contain thousands of extremely tiny crystals that selectively reflect green colors, giving rise to the vivid glitter. Clues gained from examining these wings may one day lead to "greener" and more efficient paints, fiber optics, and solar cells.

Image by Vinod Saranthan (University of Oxford)

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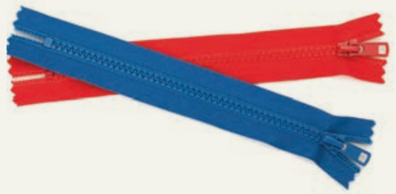
SCIENCE HISTORY

1913 — 100 YEARS AGO

Modern zipper invented
Gideon Sundback created the modern zipper in late 1913, adding the unlocking slider and the little nibs that keep the metal teeth aligned. His basic design has remained virtually unchanged a century later.



1963 — 50 YEARS AGO

A banner year in physics

SEPTEMBER
Construction is completed at Argonne's new Zero Gradient Synchrotron, a proton accelerator for high energy physics. It was cutting-edge for its time, but today the Large Hadron Collider smashes protons at eight trillion electron-volts—energies more than 600 times higher!

Looking down the accelerator cavity at Argonne's Zero Gradient Synchrotron.

DECEMBER
Argonne scientist Maria Goeppert Mayer becomes the second woman to win the Nobel Prize in Physics for her work on atom structure. Her discovery, a phenomenon called "spin-orbit coupling," showed that protons and neutrons spin in their own axes while moving in a larger orbit, much like Earth rotates on its axis while spinning around the sun.*

Argonne scientist Maria Goeppert Mayer won the 1963 Nobel Prize in Physics.

1988 — 25 YEARS AGO

First "worm" on the Internet
Until 1988, the fledgling Internet was a friendly place. 21-year-old Robert Morris wrote a software "worm" that replicated itself from machine to machine—but accidentally made computers hosting it crash. A quarter century later, global cyber crimes cost more than $100 billion per year; meanwhile, Morris is now a professor at MIT.

In 1988, the first malicious Internet worm disabled thousands of computers.

**Research at the lab is still earning Nobel Prizes today. Turn to page 16 for the story.*

by Jared Sagoff

SONGS IN THE KEY OF SEA

Soft horns and a tinkling piano form the backbone of "Fifty Degrees North, Four Degrees West," a jazz number with two interesting twists: it has no composer and no actual musicians. Unless you count bacteria and other tiny microbes, that is.

The song is the brainchild of Peter Larsen, a biologist at Argonne. Larsen, it turns out, has no musical training at all; his interests run less towards the blues and more towards blue-green algae.

When faced with an avalanche of microbial data collected from samples taken from the western English Channel, Larsen recognized he needed a way to make sense of it all. "Thinking of interesting ways to highlight interactions within data is part of my daily job," he said.

In the case of the western English Channel data, however, Larsen decided that a visual representation of the data would not be as effective as one he could hear.

"There are certain parameters like sunlight, temperature, or the concentration of phosphorus in the water that give a kind of structure to the data and determine the microbial populations," he said. "This structure provides us with an intuitive way to use music to describe a wide range of natural phenomena."

A colleague of Larsen's suggested that classical music could effectively represent the data, but Larsen wanted any patterns inherent in the information to emerge naturally and not to be imposed from without.

"For something as structured as classical music, there's an insufficient amount of structure that you can infer without having to tweak the result to fit what you perceive it should sound like," Larsen said. "We didn't want to do that."

While this is not the first attempt to "sonify" data, it is one of the more mellifluous examples of the genre. "We were astounded by just how musical it sounded," Larsen said. "A large majority of attempts to converting linear data into sound succeed, but they really don't obey the dictates of music—meter, tempo, harmony. To see these things in natural phenomena and to describe them was a wonderful surprise."

Data collection in the English Channel was supported by the U.K.'s National Environmental Research Council and the Center for Ecology and Hydrology.

MORE
Listen to samples of microbial bebop at www.anl.gov/articles/songs-key-sea

battery hubbub

From left: Chicago Mayor Rahm Emanuel, Illinois Governor Pat Quinn, and U.S. Secretary of Energy Steven Chu speak with Argonne scientists George Crabtree and Jeff Chamberlain in downtown Chicago late last year. The three met to announce that Argonne and a team of partners won funding of up to $120 million over five years to establish a new Batteries and Energy Storage Hub. The Hub, called the Joint Center for Energy Storage Research (**jcesr.org**), will combine the R&D firepower of five national laboratories, five universities, and four private companies to make revolutionary advances in battery performance. The goal is 5-5-5: batteries five times more powerful at a fifth of the cost in the next five years.

NEW ISOTOPE MEASUREMENT COULD ALTER PICTURE OF EARLY SOLAR SYSTEM

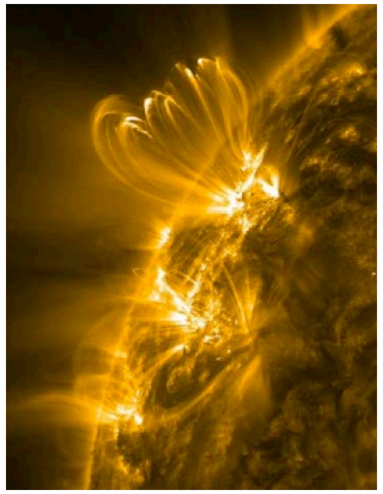
| by Louise Lerner

The early days of our solar system might look quite different than previously thought, according to research at Argonne. The study used more sensitive instruments to find a different half-life for samarium, one of the isotopes we use to chart the evolution of the solar system.

"It shrinks the chronology of early events in the solar system, like the formation of planets, into a shorter time span," said Argonne physicist Michael Paul. "It also means some of the oldest rocks on Earth would have formed even earlier—as early as 120 million years after the solar system formed, in one case of Greenland rocks."

According to current theory, everything in our solar system formed from star dust several billion years ago. Some of this dust was formed in giant supernovae explosions, which supplied most of our heavy elements. One of these is the isotope samarium-146.

Samarium-146, or Sm-146, is unstable and occasionally emits a particle, which changes the atom into a different element. Using the same technique as radiocarbon dating,



Scientists have calculated a new value for the half-life of samarium, an isotope used to track how our solar system came into being. Above: Superheated plasma loops on the surface of the sun following a solar flare eruption. (Photo credit NASA/GSFC/SDO.)

scientists can calculate how long it's been since the Sm-146 was created. Because Sm-146 decays extremely slowly—on the order of millions of years—many models use it to help determine the age of the solar system.

The number of years it takes for an isotope to decrease by half is called its half-life. Since Sm-146 emits particles so rarely, it takes a sophisticated instrument to measure this half-life.

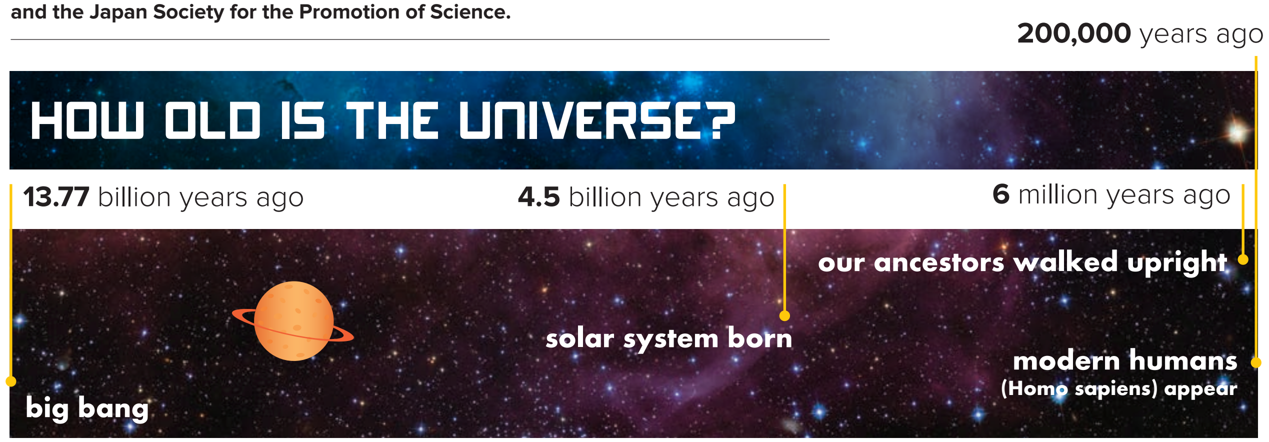
The Argonne Tandem Linac Accelerator System, or ATLAS, a Department of Energy national user facility for the study of nuclear structure and astrophysics, is just such an instrument. "It's easy for the ATLAS, used as a mass spectrometer, to pick out one Sm-146 atom in tens of billions of atoms," said physicist Richard Pardo, who manages the facility and participated in the study.

By counting Sm-146 atoms with ATLAS and tracking the particles that the sample emits, the team came up with a new calculation for its half-life: just 68 million years.

This is significantly shorter than the previously used value of 103 million years.

The new value patches some holes in current understanding, according to Paul. "The new time scale now matches up with a recent, precise dating taken from a lunar rock, and is in better agreement with dates obtained with other chronometers," Paul said.

This research was supported by the U.S. Department of Energy's Office of Science and the Japan Society for the Promotion of Science.



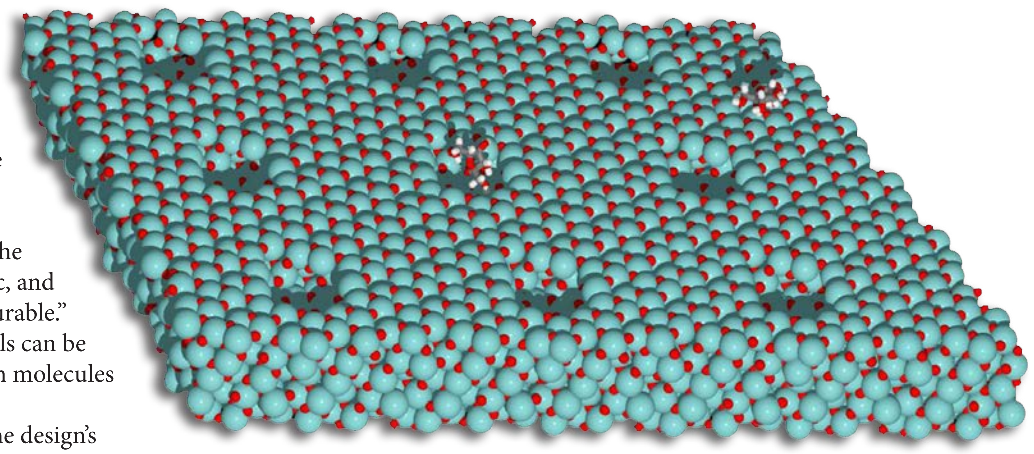
NANOSCALE 'Goldilocks' PHENOMENON COULD IMPROVE BIOFUEL PRODUCTION

| by Jared Sagoff

In a case of the Goldilocks story retold at the molecular level, scientists at Argonne and Northwestern University have discovered a new path to the development of more stable and efficient catalysts.

The research team sought to create nanobowls: nano-sized bowl shapes that allow inorganic catalysts to operate selectively on particular molecules.

Catalysts are vitally important substances that perform many manufacturing processes for us, including turning algae or corn stalks into biofuels. In nature, enzymes do this job. But enzymes can be fragile things. "The extremely harsh conditions necessary for biomass conversion would cause the enzyme proteins to unravel," said Argonne chemist Jeff Elam. "In contrast, the nanobowls are inorganic, and this makes them very durable." Like enzymes, nanobowls can be tailored to accept certain molecules and reject others.



This computer graphic shows a set of zirconium oxide nanobowls. The center nanobowl has captured a fructose molecule (white, gray, and red chain-like structure). Image by Argonne scientist Larry Curtiss.

According to Elam, the design's effectiveness correlates with the size and depth of the bowl; if the bowl is too large or shallow, practically any molecule can access the catalyst, which can lead to uncontrolled and often undesirable side reactions. Likewise, if the bowl is too small or deep, even the intended molecule will not fit into the bowl. However, if the nanobowl structure is "just right," only the intended molecule will reach the catalyst and react.

The trick to building a nanobowl with a specific shape and depth is to use a nano-sized template. In the first proof-of-concept nanobowl experiments, bulky organic molecules called calixarenes were used as the template. They were grafted onto a titanium dioxide surface that served as both the catalyst and the "table" for the nanobowl to rest on. Next, the walls of the bowl were built around the template, one atomic layer at a time, using atomic layer deposition, a technology borrowed from the semiconductor industry. Once the scientists grew the nanobowl to the proper height, they burned away the organic template, leaving behind a cavity with the same shape.

Read more about atomic layer deposition on page 44.

Since the titanium dioxide is in the form of a nanopowder with lots of surface area, the experiment required the scientists to create millions of these nanobowls. Fortunately, the processing techniques that Elam and his colleagues employed can be scaled up so that successful nanobowls identified in these bench-scale studies can eventually have a real-world impact.

The next step, Elam said, involves applying the knowledge gained in these studies to make nanobowl catalysts tailored for biofuel production. "The overarching problem in these reactions is to selectively remove oxygen without breaking carbon-carbon bonds."

MORE

This research was supported as part of the Institute for Atom-Efficient Chemical Transformations, an Energy Frontier Research Center funded by the U.S. Department of Energy's Office of Science. Elam and colleagues used the laboratory's Advanced Photon Source, also funded by the Office of Science, to characterize the structure of the nanobowls.

HAWAII-BOUND IN SEARCH OF GLOBAL CLIMATE DATA

by Brian Grabowski

While the idea of a cruise to Hawaii may sound like paradise, making that same journey 25 times back and forth in a year might start to lose its appeal.

But for a climate data-gathering machine called AMF2, perched aboard the ship, every trip is a chance to gather more data that is critical to understanding the Pacific Ocean's role in the global climate.

The machine is the Department of Energy's second Atmospheric Radiation Measurement (ARM) mobile facility, operated and managed by Argonne scientists. It carries a suite of instruments to measure properties of clouds, the ocean, precipitation, aerosols, and radiation. As you read this, the AMF2 is traveling back and forth between Hawaii and Los Angeles, taking data aboard the Horizon Spirit in the first official ARM marine deployment of its kind.

The AMF2's mission is to capture data so that scientists can get a better picture of the way that clouds, aerosols—particles in the air, like dust or smog—and Earth's energy and water balance interact over the Pacific. All of these variables are important in piecing together how the Earth's climate works as a whole.

AMF2 is particularly well adapted to gather data in regions of the world that don't have much data yet, or are difficult to get to—like the open ocean.

"We were very excited to see the AMF2 deployed," said AMF2 technical operations manager Michael Ritsche, an atmospheric scientist at Argonne. "The launch represented the culmination of four years of hard work in designing, building, and preparing to deploy aboard an ocean-going vessel."

The Argonne-managed AMF2 team spent months adapting the instruments, which had been last deployed on land in the Maldives, to life aboard a ship. For example, they have to stay stable despite the rolling of the ship's deck as it plies the waves. (Feeling seasick yet?) The researchers installed special tables to correct for the motion.

Collecting data on atmospheric conditions over an entire year, including the transitions among cloud types along this particular route, will provide an enormous amount of new data to help refine and validate models of Earth's climate.

The mission is called MAGIC, which stands for the Marine ARM GPCI Investigation of Clouds; GPCI is a project comparing results from the major climate models. MAGIC is a collaborative effort involving Argonne and Brookhaven National Laboratory, as well as the Department of Energy, ARM, and others. When the campaign is complete, the data will be made available to the scientific community through the ARM data archive located at Oak Ridge National Laboratory.

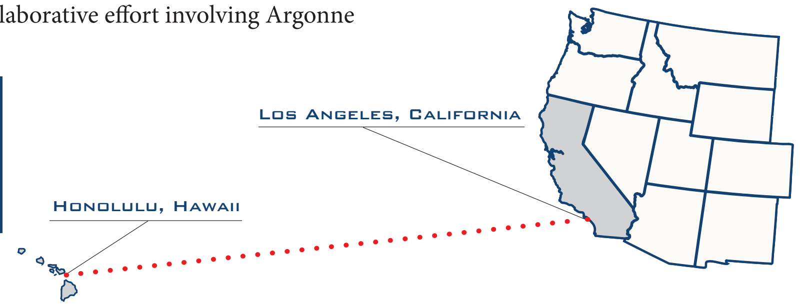
The campaign is funded by the Department of Energy's Office of Science.

MORE Brookhaven National Lab's Ernie Lewis blogs on MAGIC's progress: http://1.usa.gov/Rx4KXd

Where in the world is the Horizon Spirit? Check out the live ship tracker: http://bit.ly/WV9REc

Distance between Los Angeles, California and Honolulu, Hawaii

- 2558.25 miles
- 4116.99 kilometers



NEW TECH COULD BE "MR. FUSION" FOR BIOFUEL

| by Else Tennessen

A new technology from Argonne may remind viewers of Mr. Fusion of *Back to the Future* fame, only with a biofuel twist: put in your waste and out comes diesel fuel.

The Endurance Bioenergy Reactor is a simple, easy-to-use portable system that puts bacteria to work on a variety of biological waste to produce fuel that can go directly into diesel engines and generators.

A team of Argonne scientists led by biophysicist Phil Laible has developed bioengineered photosynthetic bacteria capable of producing an alcohol called phytol from a variety of sources, including wood pulp, leftover corn stalks, food waste, and latrine waste. Once separated from the fermentation broth, phytol serves as a surrogate for diesel fuel that can be used alone or in blends to power generators or vehicles.

With chemical and physical properties similar to diesel fuel, phytol is considered a "drop-in ready" biofuel, meaning it is ready to go directly into diesel engines and generators without any further refinement.

With insight from Air Force Fellow Major Matthew Michaud, Argonne researchers incorporated this groundbreaking discovery into the design of the Endurance Bioenergy Reactor. The process begins in a large fermentation vessel tank; once it's filled, the engineered organism begins converting waste to energy. The bacteria are freeze-dried and shipped along with the reactor hardware, so the operator can simply open the package of bacteria and drop them into the main tank. The reactor can use a variety of carbon and energy sources to make fuel. >>

Argonne bioscientist Phil Laible engineers bacteria to produce biofuels from waste.

The bacteria can produce phytol, similar to diesel fuel, from wood pulp, corn stalks, food waste, or latrine waste.

A single reactor takes between two and four days to convert waste into fuel, but the system can be modified to generate fuel continually. The system can produce 25 to 50 gallons of biofuel a day.

This promising technology provides a viable alternative for military and civilians who need reliable power sources when they are not near a power grid. For military applications, the reactor prolongs operations, reduces costs, and improves safety by decreasing reliance on supply chains and eliminating dangerous convoy missions to deliver more fuel. According to an Army study, one in eight U.S. military casualties in Iraq happened during fuel convoys.

The system's mobility and simplicity also make it a logical choice for energy in remote and disaster areas. The Endurance Bioenergy Reactor is a rapidly deployable tool for humanitarian activities around the world, providing energy when and where it's needed.

"If the idea of converting on-site waste into a drop-in ready fuel with a small mobile unit seems outrageous, then why does moving refined fuel through a weak infrastructure make sense?" said Laible and Michaud. "Plentiful components to make convenient fuel are already at hand. The day has come for something as sensible as the Endurance Bioenergy Reactor."

MORE

Watch the video: **http://1.usa.gov/U8I5Cx**

Visit the Endurance Bioenergy Reactor website: **http://1.usa.gov/SJ3iVF**

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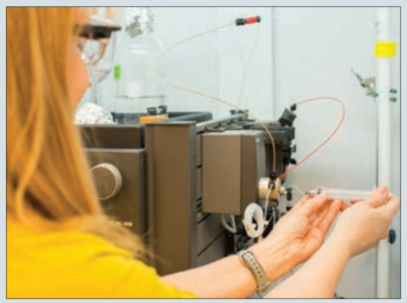
ANTIBODY **BUILDERS**

Antibodies are often the first line of defense against the body's invaders. Built to recognize and attack foreign bacteria and viruses, antibody molecules are released by cells to do battle with microbial hostiles as part of the body's natural immune response.

Because antibodies are naturally so good at recognizing a host of different pathogens, Argonne biologist Rosemarie Wilton has spent much of her career working to better stabilize antibodies and prevent them from degrading over time.

In one possible scenario Wilton described, a soldier might want to use antibodies to detect any biological agents in the environment. However, in the high temperatures of the field environment, antibodies tend to degrade. Wilton and her colleagues have developed several methods to prolong the shelf life of antibodies.



Argonne biologist Rosemarie Wilton tests antibodies.

Wilton and her colleagues at Argonne's Center for Nanoscale Materials have also begun to explore combining antibodies with inorganic nanoparticles that can selectively attack and destroy cancer cells.

In a third study—funded by the National Institutes of Health—Wilton and a collaborator at the University of Cincinnati are testing antibodies to prevent relapse in cocaine addicts. "By using antibodies, we're able to prevent addicts from getting high even if they happen to relapse and use cocaine, which hopefully makes it easier for them to kick the habit in the future," Wilton said. "The antibody binds to the cocaine molecule and prevents it from acting in the brain."

The anti-cocaine antibody study is especially promising because that particular antibody has a relatively long half-life—about three weeks, Wilton said.

— Jared Sagoff

Simulating core melt accidents helps improve nuclear reactor safety

| by Louise Lerner

When a massive tsunami knocked out power to the Fukushima Daiichi reactors in Japan two years ago, Argonne personnel combed the countryside to measure radiation levels around the reactors. Other Argonne scientists consulted for the Department of Energy, lending their expertise in the very scenario that experts believed took place at Fukushima: nuclear fuel eroding the concrete floor beneath the reactor.

In all modern nuclear reactors, there are three barriers to contain the uranium fuel. The first is a layer of metal "cladding" directly around the uranium; the second is a thick steel reactor vessel; and the third is a sturdy concrete containment building with walls, floors, and ceiling several feet thick.

If a disaster, such as a tsunami, knocks out power to a reactor, all reactors have safety systems that shut down the reactor. However, the core continues to generate heat, and has to be continuously cooled. If backup generators fail and can't cool the core—which is what happened at Fukushima—the uranium rods of the core and their cladding can melt together into a substance called "corium." During a full meltdown, this material may leak through the steel vessel and pour out onto the thick concrete floor below.

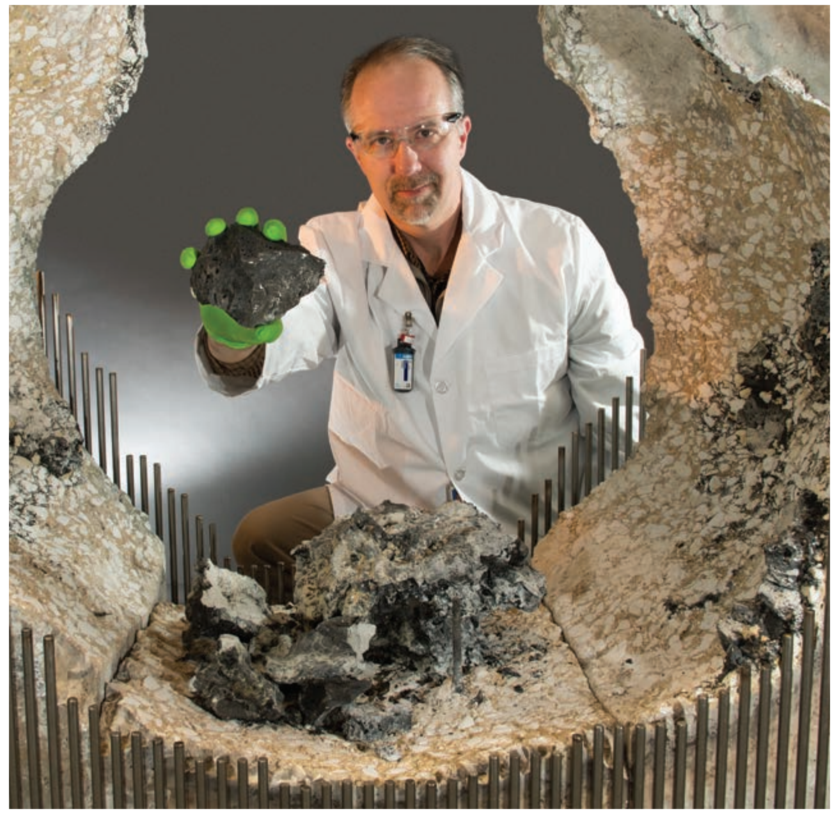
To make sure that the final concrete barrier can withstand the stress of any failure at a reactor, Argonne nuclear engineers have been conducting tests for decades to simulate the effects of partial and full meltdowns on concrete materials.

Typically, researchers produce a large pool of molten corium via a chemical reaction and then run an electric current through it to mimic the heat produced in the fuel during a meltdown. Next, they examine how the corium interacts with the concrete beneath.

Argonne does the largest experiments of this type in the world, thanks to its early history as the U.S. Atomic Energy Commission's primary lab for developing reactors for peaceful energy generation.

One of the lab's most secure facilities lets a team of scientists safely conduct these experiments. The walls are three feet thick, built decades ago to contain experiments on fully functioning nuclear reactors; the air is heavily filtered and the thick steel doors seal shut.

The building is now one of the only places in the national lab system rated strong enough to conduct these types of tests. >>



To improve safety standards for nuclear reactors, Argonne nuclear engineer Mitchell Farmer leads a team that studies reactor core melt accidents in which molten core debris erodes concrete.

Nuclear energy companies often cosponsor the tests to improve safety at their plants. "We partner with both U.S. as well as international organizations in countries like France, Japan, and Korea," said Argonne nuclear engineer Mitch Farmer, who leads the team. "We're often testing unique cooling systems that can be placed in the concrete floors at plants in order to cool core material if it fails the reactor vessel, and this enhances reactor safety."

Different types of concrete have unique chemical properties that can resist the corium, and can also affect how the corium erodes into concrete.

The experiments provide data for validating computer models that simulate corium-concrete interaction. These codes are widely used to support design improvements for nuclear reactors in safety and cost.

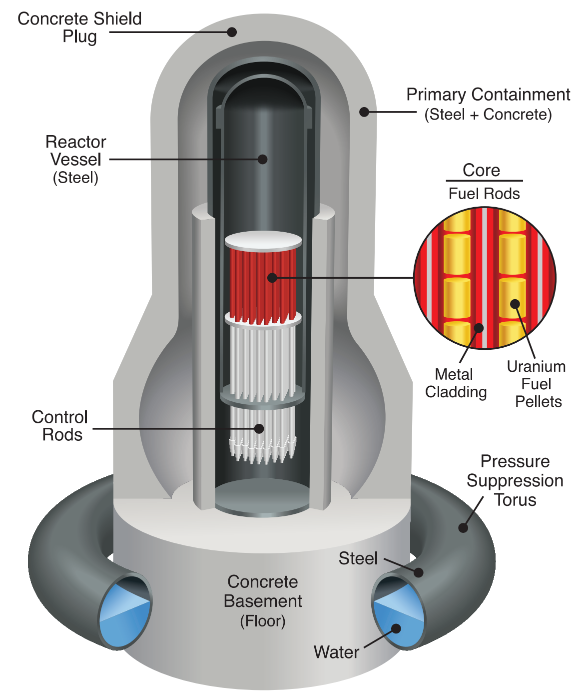
"This type of work is important because it both helps us understand what happened at Fukushima and how to minimize the impact of incidents in the future," Farmer said.

Argonne nuclear engineers have been conducting tests for decades to simulate the effects of partial and full meltdowns on concrete.

This research was supported by the U.S. Nuclear Regulatory Commission, Électricité de France, and the Institut de Radioprotection et de Sûreté Nucléaire (French Institute for Radiological Protection and Nuclear Safety).

MORE
Learn more about Argonne's nuclear energy work at www.ne.anl.gov.

MARK I BWR CONTAINMENT



DID YOU KNOW?

Almost every commercial reactor today is a light-water reactor. These reactors are cooled by water, which is cheap, easy to get, and well-understood. But many of the newest generation of reactor designs are "fast" reactors, which are interesting because they can burn recycled nuclear fuel. They are also designed to have passive safety mechanisms — if the power goes out, as at Fukushima, the reactor cools itself down without any electricity or human intervention.

A PRESIDENTIAL VISIT

President Barack Obama announced a major energy proposal during a visit to Argonne National Laboratory on Friday, March 15.

After touring lab facilities and speaking with researchers about their work, the President held a news conference in which he revealed his proposal for an Energy Security Trust.

Under the President's proposal, the U.S. would set aside $2 billion over 10 years to support research into a range of cost-effective technologies, such as advanced vehicles that run on electricity, homegrown biofuels, fuel cells, and domestically produced natural gas.

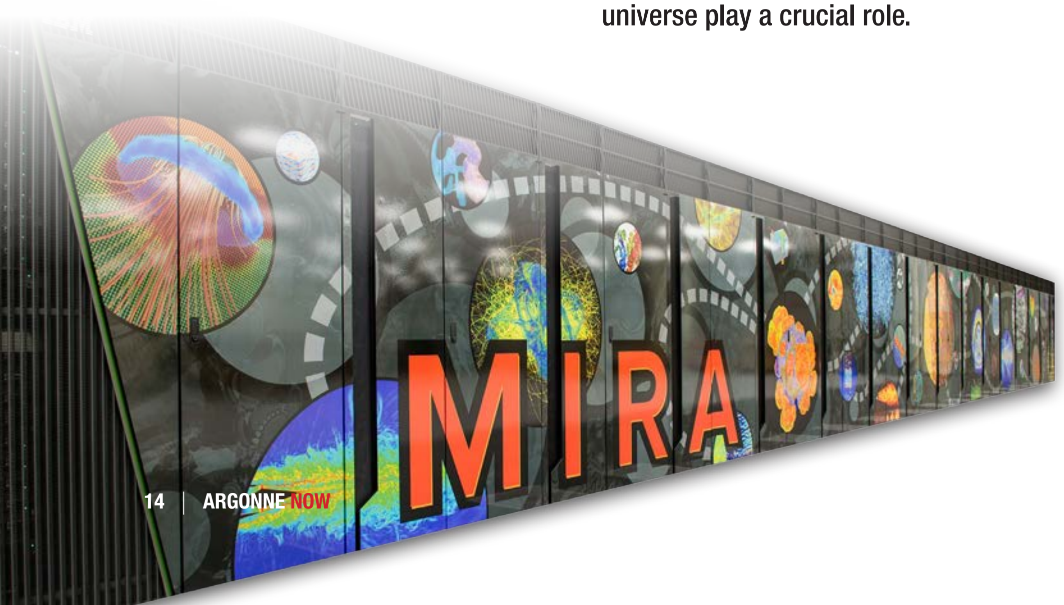
Senator Dick Durbin of Illinois (at left) and Argonne director Eric Isaacs (at right) speak to reporters.

See more photos and watch his address at http://1.usa.gov/10iztuk

EXPLORING THE DARK UNIVERSE AT THE SPEED OF PETAFLOPS

An astonishing 95% of our universe is made of up dark energy and dark matter. Understanding the physics of this sector is the foremost challenge in cosmology today. Sophisticated simulations of the evolution of the universe play a crucial role.

by Laura Wolf and Gail Pieper



The primary lens through which scientists look at the night sky is no longer only a telescope—it's also a supercomputer. The new and coming generations of supercomputers will finally be capable of modeling the universe in the detail and volume required by astronomical surveys of the sky that are now underway, or soon will be.

Scientists use large cosmological simulations to test theories about the structure of the universe and the evolution of the distribution of galaxies and clusters of galaxies. State-of-the-art supercomputers let cosmologists make predictions and test them against data from powerful telescopes and space probes.

Two decades of surveying the sky have culminated in the celebrated Cosmological Standard Model. Yet two of the model's key pillars—dark matter and dark energy, together accounting for 95% of the universe—remain mysterious. A research team led by Argonne is tackling this mystery, aided by some of the world's fastest supercomputers.

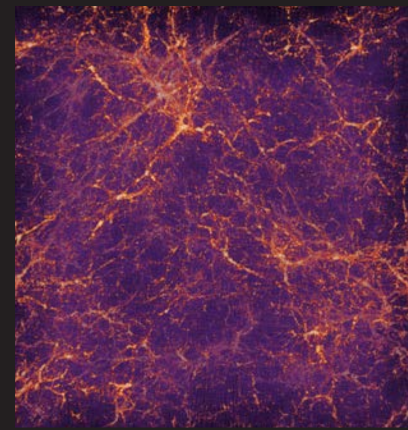
To model the distribution of matter in the universe, the researchers are running some of the largest, most complex simulations of the large-scale structure of the universe ever undertaken.

The Argonne team has run a 1.1-trillion-particle simulation on half a million processor cores of Mira, Argonne's new Blue Gene/Q supercomputer. The team was among a few science teams from across the country to gain early access to the system, which is now online.

Watch the visualization online: http://1.usa.gov/15H4Es5

The power and speed of supercomputers and simulation codes have significantly advanced over the past decade. Mira enables cosmology runs with greater resolution and accuracy on much larger simulation volumes—giving researchers the ability to confront theory with observational data from wide-area cosmological surveys.

Exploring the cosmic structure of the dark universe is an enormously complex problem. As the universe expands, gravitational attraction causes matter to coalesce and form structures—first sheets, then filaments where the sheets intersect, and then clumps where the filaments meet. As time progresses, one can begin to see more clearly the basic structure of an enormous web of voids, filaments, and clumps. Simulations at Argonne have calculated this web-like structure, the so-called cosmic web, in a cube of simulated space more than 13 trillion light-years across.



This visualization, part of a 1.1-trillion-particle simulation run on Argonne's supercomputer Mira, shows the complexity of cosmological structure formation. (Image by H. Finkel, S. Habib, K. Heitmann, K. Kumaran, V. Morozov, T. Peterka, A. Pope, T. Williams, M. Papka, M. Hereld, and J. Insley, Argonne National Laboratory; D. Daniel, P. Fasel, N. Frontiere, Los Alamos National Laboratory; Z. Lukic, Lawrence Berkeley National Laboratory.)

"Because these trillions of particles are meant to trace matter in the entire universe, they are extremely massive, something in the range of a billion suns," said Argonne computational physicist Salman Habib, the project's director. "We know the gravitational dynamics of how these tracer particles interact, and so we evolve them forward to see what kind of densities and structure they produce, as a result of both gravity and the expansion of the universe. That's essentially what the simulation does: it takes an initial condition and moves it forward to the present to see if our ideas about structure formation in the universe are correct."

Next-generation sky surveys will map billions of galaxies to explore the physics of the "dark universe." Science requirements for these surveys demand simulations at extreme scales in order to resolve galaxy-scale mass concentrations over the observational volumes of sky surveys. A key aspect of the Argonne project involves developing a major simulation suite covering approximately 100 different cosmological scenarios and combining them in a framework that can generate predictions for any scenario within the range covered by the original runs.

WHAT IS DARK MATTER?

Scientists studying distant galaxies noticed that something we can't see is exerting a huge gravitational force on things we can see—like stars and supernovae. We named this "dark matter" because it doesn't emit or absorb light. But is it ordinary matter that we don't have a way to measure, or is it a truly new substance?

WHAT IS DARK ENERGY?

This one's a bit trickier. In 1998, two teams of astronomers (one from Lawrence Berkeley National Lab) discovered that not only is the universe expanding, it's expanding faster and faster as time goes on. This means that some other force than gravity is acting on the universe. We understand very little about this mysterious force, but sky surveys and computational simulations can help bring us closer.

THE DARK ENERGY SURVEY

Built at Fermilab and installed in the Chilean mountains, the Dark Energy Camera is now investigating the universe for clues about dark energy. It's the most powerful survey instrument of its kind, able to see light from more than 100,000,000 galaxies up to eight billion light years away in each snapshot.

This research is supported by the U.S. Department of Energy's Office of High Energy Physics, Advanced Scientific Computing Research, and Argonne's Laboratory Directed Research and Development program.

MORE

For more information on computing at Argonne, visit alcf.anl.gov

HACCing away at the code

Few supercomputers in the world have the muscle to simulate complex problems in a reasonable time span. The Blue Gene/Q belongs to an elite class of machines now coming online at DOE national laboratories for this express purpose.

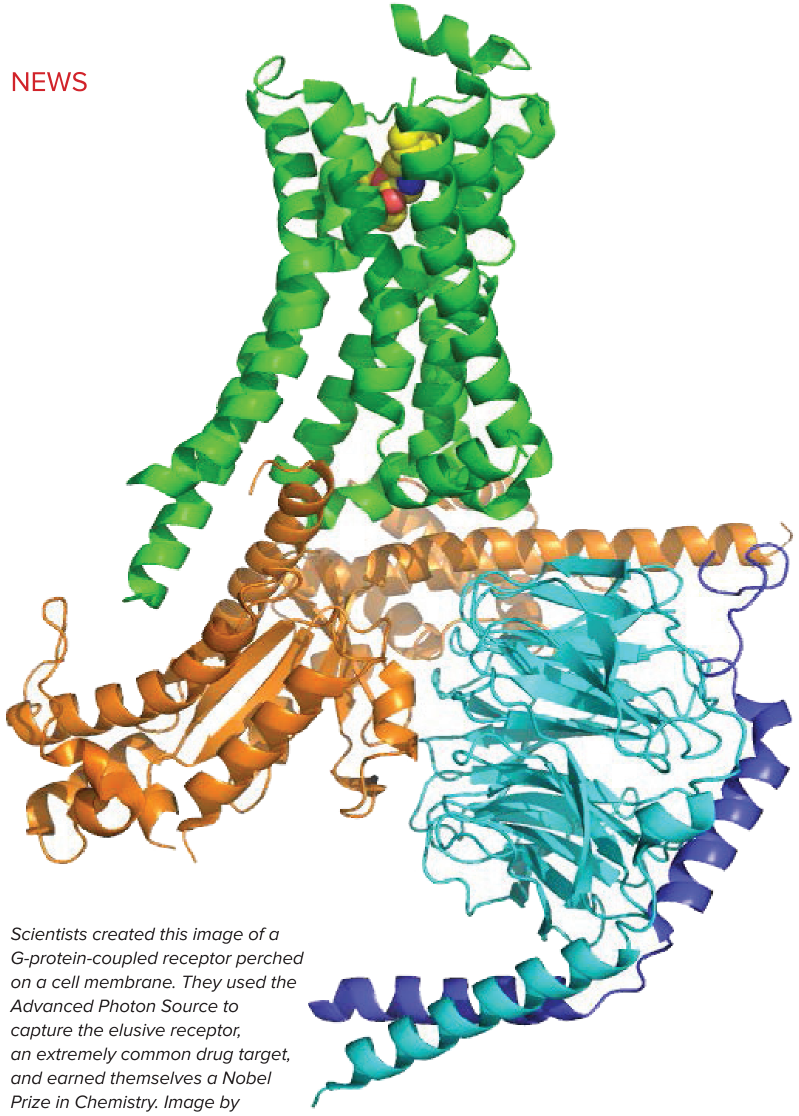
The recent trillion-particle science run conducted on Mira used 32 racks of the computer, which is two-thirds of its total size.

Essential to these simulation runs is the team's simulation code framework called HACC, short for Hardware/Hybrid Accelerated Cosmology Codes. HACC is similar to other codes written to study how the individual particles of a complex system move and interact over time. Unlike those codes, however, HACC is designed for extreme performance and in a way that easily adapts to different computers.

HACC's performance relies on its ability to accurately and efficiently calculate the forces applied to a large number of interacting particles. Cosmology simulations can use more than hundreds of billions of particles.

"The Blue Gene architecture allows an experienced user to program it with a reasonable level of effort and get a good performance," said ALCF performance engineer Vitali Morozov.

The team was recently awarded 40 million core-hours on Mira through the U.S. Department of Energy's Innovative and Novel Computational Impact on Theory and Experiment program, which is supported by the Office of Science's Office of Advanced Scientific Computing Research and provides access to computing power and resources to support computationally intensive, large-scale projects to researchers from industry, academia, and government research facilities. Another 150 million core-hours were awarded under the Early Science Project program.



Scientists created this image of a G-protein-coupled receptor perched on a cell membrane. They used the Advanced Photon Source to capture the elusive receptor, an extremely common drug target, and earned themselves a Nobel Prize in Chemistry. Image by Kobilka et. al, Nature 447, 549 (2011).

ARGONNE X-RAYS POINT WAY TO NOBEL PRIZE, BETTER MEDICINE

| by Tona Kunz

You may not know what research earned the 2012 Nobel Prize in Chemistry. But chances are that it will impact your life or that of someone you know.

New pharmaceuticals and improvements to existing ones will likely grow out of this research, which helps scientists better understand how the body responds to drugs. More than half of all pharmaceuticals on the market work by stimulating or blocking responses from biological messengers called G-protein-coupled receptors. 791 GPCRs exist in the human body, and they work in 791 different ways.

The prize-winning research mapped out how these GPCRs trigger a domino effect among molecules to trigger reactions, from breathing to the production of chemicals thought to impede depression.

You've experienced GPCRs in action if you've used caffeine, allergy medicine, nasal sprays, eye drops, insulin, or high blood pressure medicine. Yet in many cases, scientists don't fully understand how the drugs produce their beneficial reactions.

"This is the type of work where it is easy to see why it was honored with a Nobel Prize, because it is really going to have a big impact on developments in medicine," said Brian Stephenson, director of the Advanced Photon Source at Argonne.

Scientists have been trying to unravel the inner workings of GPCRs since they were first proposed to exist more than 100 years ago, but the technology to do that wasn't available until a major advancement at the Advanced Photon Source. Scientists at the National Institute for General Medical Sciences and National Cancer Institute Collaborative Access Team started developing a micro X-ray beam that allowed researchers to study smaller and more fragile GPCR samples. That new technology attracted Brian Kobilka, of Stanford University, and he used it to conduct nearly all of the X-ray work that helped earn the Nobel Prize.

The prize traces the long arc of the research, which began in the 1970s with Robert Lefkowitz's discovery of the adrenaline GPCR. In the 1980s and 1990s, Lefkowitz and Kobilka isolated and sequenced the GPCR's DNA. Finally, Kobilka worked with X-rays at the APS to determine the 3-D structure of the adrenaline receptor caught in the act of signaling. It provides the first clear picture of GPCR structures—which ball up like confetti strings and thread in and out of a cell's membrane in an intricate pattern—and how drugs interact with them.

"The field is still digesting the research," said Argonne's Robert Fischetti, who led the development of the micro X-ray beam. "However, the implications are far-reaching."

The APS beamline is funded by the National Institutes of Health's National Institute of General Medical Sciences and the National Cancer Institute. The APS is funded by the U.S. Department of Energy's Office of Science.

MORE

Watch a lecture on Argonne's role in the 2012 Nobel Prize in Chemistry: http://bit.ly/Y5WiAE

NOBEL ENDEAVORS The Advanced Photon Source also played a role in the 2009 Nobel Prize in Chemistry. Awardees Thomas Steitz (Yale University), Ada Yonath (Weizmann Institute), and Venkatraman Ramakrishnan (Medical Research Center) used the APS to tease out information on the ribosome, which makes proteins. The new knowledge of the ribosome—especially in bacteria—has opened up a new avenue of medical research as scientists try to identify antibiotics that can interfere with the bacteria's ability to make proteins.

From left to right: Charlie Catlett, director of the new Urban Center for Computation and Data; Brett Goldstein, chief data officer at the City of Chicago; Douglas Pancoast, architect and School of the Art Institute at Chicago professor. (Photo: Robert Kozloff / University of Chicago)

New center to analyze urban data

The next several decades will see the population of the world's cities nearly double. At the same time, cities are beginning to collect more and more data about everything from traffic patterns to crime. If we could analyze this data, we could optimize how cities grow to serve their citizens.

Hence the new Urban Center for Computation and Data—a center funded by a grant from the National Science Foundation and uniting researchers from several Chicago institutions, city officials, and companies with the Computation Institute, a joint initiative between the University of Chicago and Argonne.

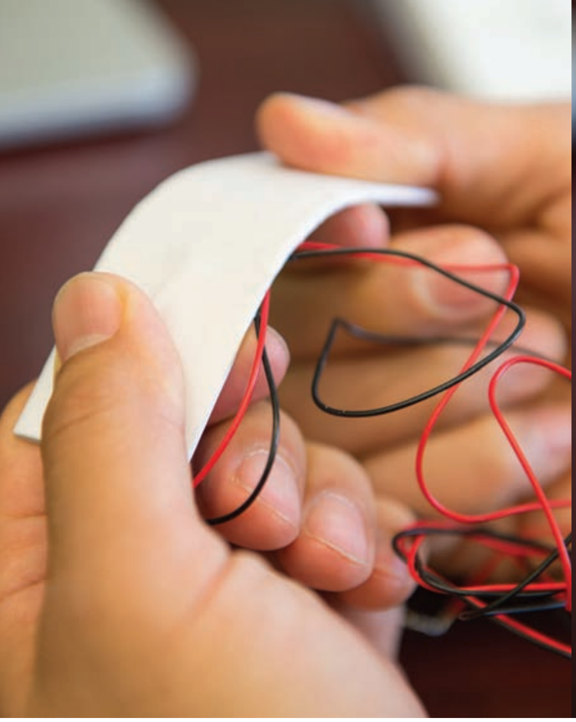
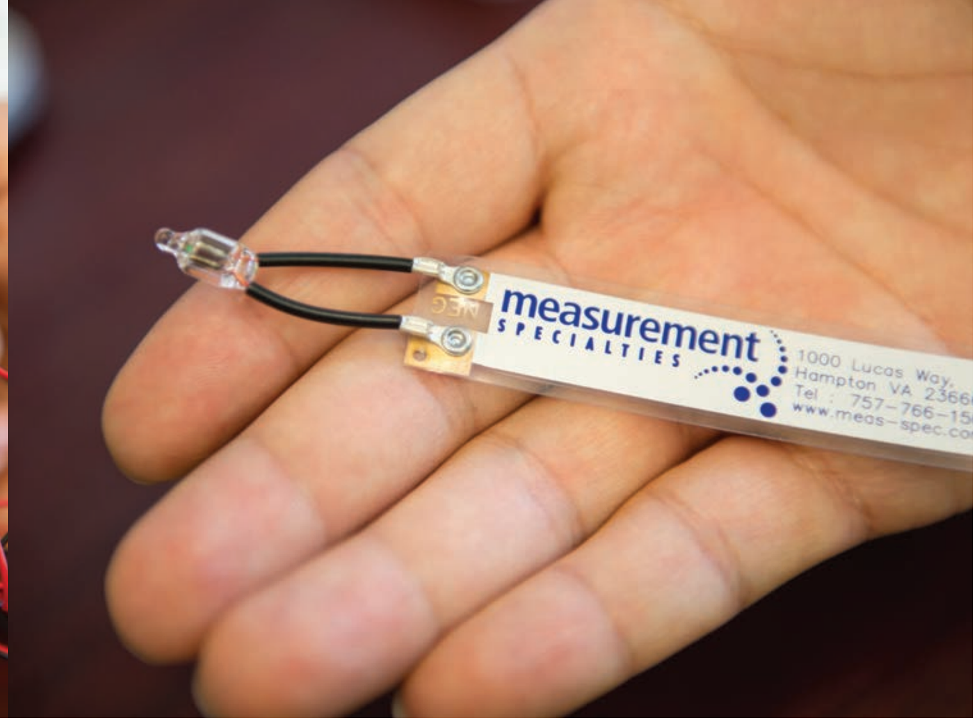
"We're seeing accelerated urbanization globally, outpacing traditional tools and methods of urban design and operation," said director Charlie Catlett. "There is an urgent need to apply advanced computational methods and resources to both explore and anticipate the impact of urban expansion and find effective policies and interventions."

The center will start off with hundreds of datasets published by the City of Chicago Data Portal, an initiative dedicated to open government data. By building computer models of cities, researchers can simulate, say, adding or removing a bus line from a particular neighborhood: what happens to crime, unemployment, and access to health care?

Using this information, city officials can plan for maximum efficiency, health, job growth, and greenhouse gas reductions as their populations grow.

For more information, visit the UrbanCCD website at www.urbanCCD.org.

— Compiled with information from Rob Mitchum, Computation Institute

Special materials called piezoelectrics can generate energy when they are bent or squeezed (above).

BATTERIES NOT ~~INCLUDED~~ NEEDED

by Jim Collins |

The day is coming when heartbeats power pacemakers, sneakers charge cell phones during a jog, and tires power their own pressure sensors as they rotate.

But the science is not quite there yet. The principle behind these future self-powered gadgets is called piezoelectricity; when certain types of crystals are squeezed, they generate electricity. Piezoelectric materials are already the magic behind self-igniting barbecue lighters, but the technology is limited by its low power output. Currently, most piezoelectric devices only produce power on the order of microwatts. (For comparison, a typical laser pointer shines about a 1000-microwatt light.)

piezo·electric
Piezo is Greek for "squeeze" or "press." When these crystals are squeezed, they produce electricity.

"Piezoelectric materials have attracted little attention thus far due to the small amount of power they create," said Argonne materials scientist Seungbum Hong. "But if we can improve this by a factor of 10 or 20, I envision it will change the game."

Hong is leading an effort at Argonne to do just that. The research team is using atomic force microscopy to probe the internal structure and properties of piezoelectric materials, also known as "energy-harvesting materials." Hong believes their work will result in improved materials that open the door to new applications in medicine, consumer electronics, and more.

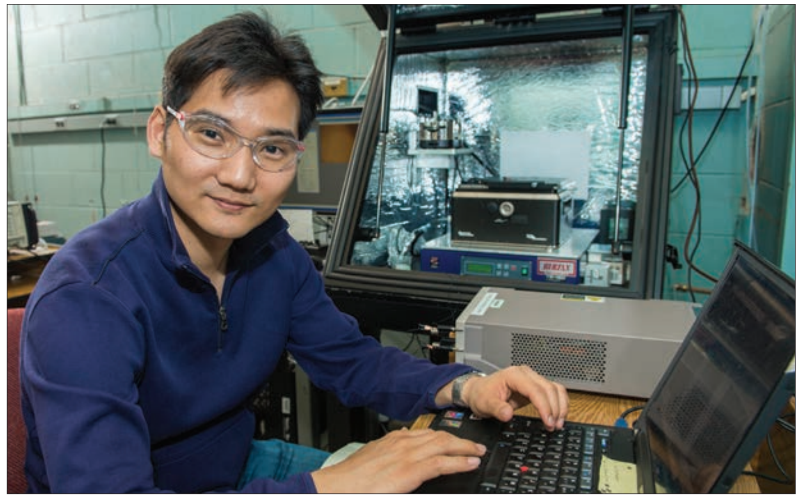
The piezoelectric effect enables materials to convert "wasted" mechanical energy (like human motion, low-frequency vibrations, or acoustic noise) into electrical energy. Upping the power potential could eliminate the need to replace batteries in small devices, resulting in technologies that are more energy-efficient, user-friendly, and environmentally friendly.

In the case of pacemakers, for example, this would mean doing away with the surgeries patients must undergo every five to seven years to replace batteries; hearing aid users wouldn't have to buy new batteries every few weeks. On tires, a piezoelectric-powered sensor could monitor the tire's pressure for the lifetime of a vehicle.

According to Hong, piezoelectric technology could also power wireless sensor networks to monitor the structural health of bridges and buildings.

"Mechanical engineers don't like wires," Hong said. "Going wireless would be more stable and likely less expensive."

For large applications such as vehicles and bridges, these devices would be comprised of springs coated with an energy-harvesting polymer to capture and convert vibrations into electricity. Tiny biomedical devices need very small machines called microelectromechanical systems that use tiny polymer-coated levers to harness mechanical energy.



Argonne materials scientist Seungbum Hong studies the internal structure of piezoelectric materials.

The Argonne team, in collaboration with researchers at the Massachusetts Institute of Technology and the Korea Advanced Institute of Science and Technology, is focusing on a ferroelectric polymer called polyvinylidene fluoride because of its strong piezoelectric response.

The piezoelectric effect enables materials to convert "wasted" mechanical energy into electrical energy.

Researchers also plan to use Argonne's state-of-the-art tools at the Center for Nanoscale Materials and Advanced Photon Source to provide further insight into the behavior of these materials.

"One of the simplest ways to improve poor performance is to identify and understand the strong and weak building blocks inside of materials," Hong said. "By looking at the structure of atoms at the nanoscale, we can figure out how to get to a material that has the properties we need to increase power output."

This research is supported by the U.S. Department of Energy's Office of Basic Energy Sciences and the Brain Korea Program.

HIDDEN PIEZOELECTRICS

Piezoelectric materials are already tucked into a variety of everyday objects.

WATCHES Digital clocks and watches have piezoelectric quartz crystals to keep time.

BARBECUE LIGHTERS Gas stoves, grills, and fireplaces use piezoelectric crystals to create a spark.

SONAR & ULTRASOUND MEDICAL IMAGING When you apply current to piezoelectric crystals, they create sound waves that bounce off objects and can be used to create an image.

SINGING BIRTHDAY CARDS When you open the card, a circuit activates a tiny speaker that contains a piezoelectric crystal making vibrations that are translated into sound.

THE GRID OF THE FUTURE

What will the electric grid look like in 10 years?

by Jared Sagoff

The outlet in your living room doesn't know a lot—yet.

Unaware of whether they are drawing power from wind, solar, gas, or coal plants, the electrical lines that bring us power in many ways still resemble the chaotic, tangled, unidirectional network that has been in place for a century.

With new and better electronic communication technologies, scientists and engineers from around the country have begun to discuss its replacement: a more adaptable, efficient, reliable, and responsive national electrical network called the "smart grid."

"Ideally, the grid of the future should be one that gives the consumer as much flexibility as possible," said Argonne energy systems analyst Guenter Conzelmann.

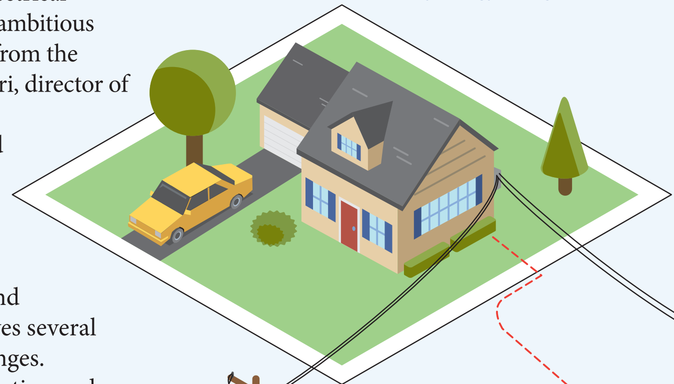
Conzelmann and his colleagues at Argonne have started an initiative to develop better and more powerful modeling capabilities to help us improve how electricity is generated and distributed.

"There are many positive changes to the grid that we have already started to see, such as some families using their own small wind turbines or solar panels to generate power, and this will only continue to spread," Conzelmann said. As consumers start generating their own energy, sometimes in significant quantities, utilities and electrical engineers have begun an ambitious restructuring of the grid from the bottom up, said Mark Petri, director of the Iowa Energy Center.

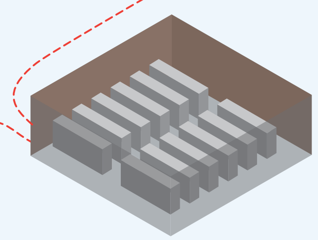
"The task we're charged with doing is closer to reconstructive surgery than a mere facelift," he said.

Creating an efficient and reliable smart grid involves several opportunities and challenges.

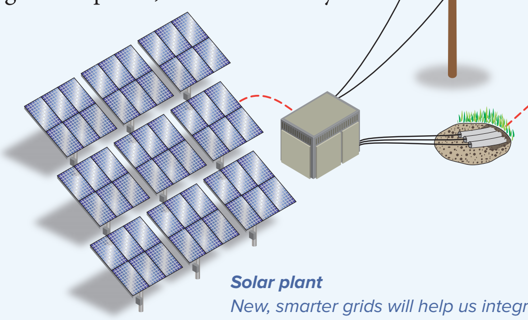
On one hand, as computing and algorithms get better and more available, researchers have been able to build intricate simulation models that give utilities a much clearer picture of the grid—which they can use to make the grid run more efficiently and reliably.



Single-family house *A smart meter in the house improves energy efficiency and reduces the family electricity bill. The electric car battery serves as temporary energy storage.*



Energy storage station *Big battery installations can store energy from renewables to save for when the wind doesn't blow or the sun isn't out.*



Solar plant *New, smarter grids will help us integrate intermittent electricity sources like solar panels.*

On the other hand, operators have to figure out how to integrate new breakthroughs in renewables and technology into a network more than a century old, and whose reliability we've come to depend on for everything from traffic lights to toast.

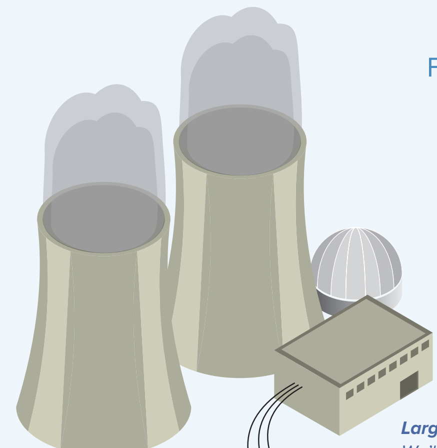
Improving the grid also means protecting its vulnerabilities. "A national smart grid would represent one of the biggest and most complex networks in the world—one in which even a rogue washing machine might be able to start problems if we didn't have safeguards," Conzelmann said.

Talking about "the grid" as it currently exists is something of a misnomer. There are actually several different electrical grids separated around the country by region: one that spreads from the heartland to the East Coast, one for the West Coast and Rockies, and a smaller one for most of Texas. Each of these "grids" contains not only large-scale power plants (like nuclear and gas plants) and end-line consumers, but also smaller installations for on-site generation, as well as the entire distribution and transmission infrastructure.

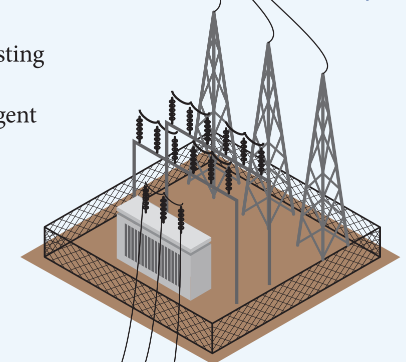
But even taking that approach looks at only half the picture. "In order to bring about the kind of transformation we envision, we need to face both scientific and economic questions at the same time," Petri said. "In an ideal situation, we'd be able to provide, well in advance, information to the markets so that companies can predict how much power their customers are going to need and how much electricity will be available. But the current grid can't do that without sizeable uncertainties."

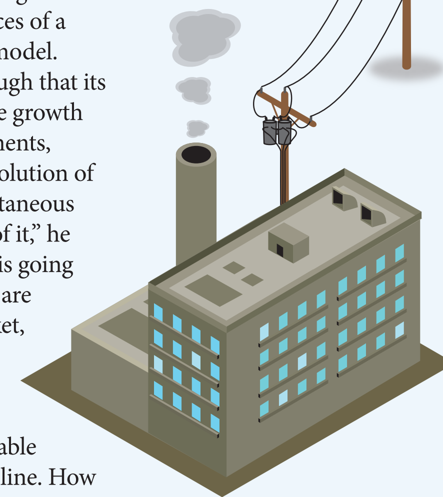
Argonne scientists have already started an effort to improve forecasting for wind and solar power, both of which are obviously highly contingent on meteorology. Solar forecasting in particular is in its infancy—the difference between a mostly cloudy and a mostly sunny day can result in an output prediction error of more than 50%. Developing a more robust solar or wind model requires rapidly analyzing tremendous amounts of data, and researchers have only just begun to put together the initial pieces of a comprehensive real-time model.

The grid is complex enough that its future will be shaped by the growth of several different components, according to Petri. "The evolution of the grid includes the simultaneous evolution of all the pieces of it," he said. "Consumer behavior is going to change, electric vehicles are going to come on the market, coal power plants are retiring and natural gas-plants are replacing them, and more and more renewable energy is going to come online. How do you understand the behavior of the >>



Large power plant *We'll still need big conventional power plants like nuclear, coal, and gas to provide constant, round-the-clock electricity.*





Factory *Industrial factories tend to be predictable, but not as flexible—they need a lot of power at the same time every day—so they aren't good candidates for intermittent sources like wind.*

whole system, how do you manage it, how do you respond to new kinds of threats like climate change and terrorism?"

Math On Demand

It seems only fitting that some of the best work on the fledgling smart grid is being done by one of the Department of Energy's brightest young stars. Victor Zavala started his career as a chemical engineer, but has emerged as one of the United States' top computational mathematicians in the power grid domain.

Last year, Zavala received an Early Career Award for his work at Argonne to improve the efficiency of the power grid and to understand the limits of its flexibility. This is no easy task. "The complexity of the grid is such that it pushes the status quo of mathematics and computer science," he said. "It's no longer enough to look at averages of power flows and demands every hour; with the advent of renewable power and electric cars, now we have to take snapshots every five minutes or less. This generates a massive amount of data and adds significant source of uncertainty that the grid has never seen before."

While researchers have devised effective and accurate methods to forecast demand for electricity, the real challenge from a computational standpoint lies in changing the nature of the real-time operation of the grid. "Operators need to change their way of thinking, which tends to be reactive instead of proactive," Zavala said.

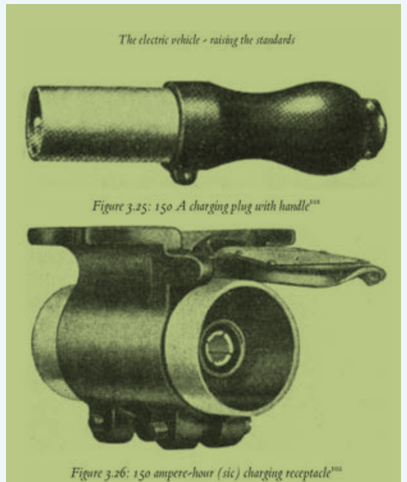
"In order to make power flow smoothly, we have to be immediately aware of problems and possible scenarios within the system," Petri added.

Although highly efficient algorithms and new supercomputers like Mira, Argonne's IBM Blue Gene/Q, have given scientists a new window into complicated grid dynamics, the problem of uncertainty has made Zavala and his colleagues change their approach to the most serious problems. "We're focusing much more on taking a probabilistic attitude when we're dealing with forecasting," he said. "At a certain point there's no real way of making absolute statements of what's going to occur, so we have to prepare for multiple outcomes using limited information."

Unfortunately, making decisions about how much power to draw from any particular plant is not always as easy as just turning on a switch. Certain types of plants, especially coal and nuclear, are all-or-nothing—bringing them on- or off-line involves significant cost. This process, called "ramping up" or "ramping down," takes a great deal of time so flipping the switch is not something to be done lightly, given the uncertainties in other generation sources and in consumer demand.

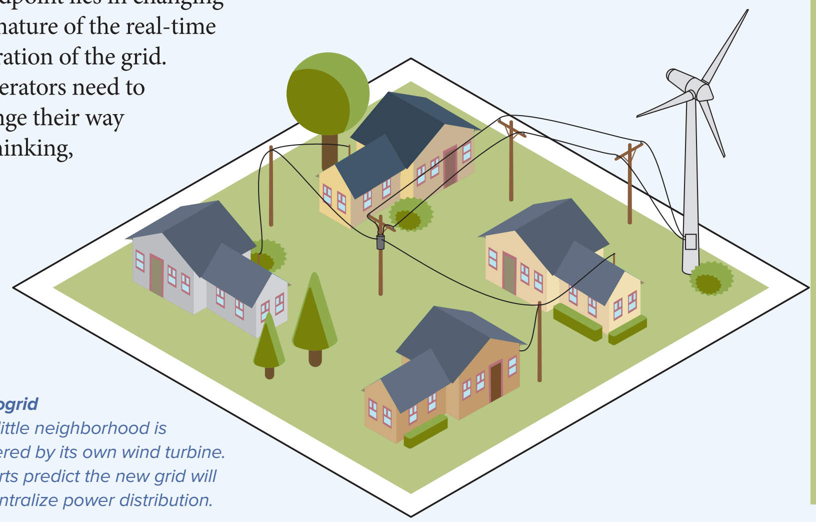
"Grid operators still don't yet have a good way to account for the costs of ramping," Zavala said.

The inelasticity of these parts of the grid causes unpredictable price spikes. The volatility in the power market creates unwelcome uncertainty for everyone in the chain, from power plant operators to distributors to consumers. "There's a huge inefficiency here that is crying out to be fixed," Petri said. "Everyone suffers from the inability of the current grid to respond quickly and nimbly to changes in demand, and that's one of the big changes that will likely take place in the coming five or 10 years."



YOUR GREAT-GRANDPARENTS' ELECTRIC CAR

Via smart grid technology, you could plug your car and your home appliances into the electric outlet to "talk" with electricity suppliers to arrange the most convenient or cheapest way to power your home. Manufacturers are working on a standard plug for the home hub, cars, and appliances. But it turns out that American manufacturers already agreed on a standardized electric vehicle plug—in 1913! In the early days of cars, electric vehicles seemed a likely competitor for gasoline-powered engines and 30,000 were on the road; thus the plug seen here, complete with wooden handle.



Microgrid
This little neighborhood is powered by its own wind turbine. Experts predict the new grid will decentralize power distribution.

Staying Power

The grid's inflexibility stems in large part from the fact that scientists have yet to discover a cost-effective method to store a lot of electricity at once. Currently, the best we have is pumped-storage hydropower—pumping a lot of water to a higher elevation with electricity, then releasing it through a hydroelectric plant to get that electricity back when needed—but that only works in places with the right geography. Most power has to be consumed as soon as it's generated, which is inefficient and limits how much renewable energy we can use.

"One of the major obstacles confronting solar is that you can generate a lot of energy on a sunny day, but you can't keep that power around for nighttime or a cloudy day," Conzelmann said.

Until there's a breakthrough in grid storage technology, an unexpected new resource could be an initial step in the grid's evolution. Plug-in hybrid electric vehicles like the Chevrolet Volt and the Nissan Leaf could give consumers a way of drawing power from the grid as well as feeding energy back. It's a bit like having thousands of car-sized batteries stored around the country in garages.

"Using cars as a form of grid storage is an intriguing idea because it allows individuals to buy and sell power to each other, but we're still years away from having enough capacity to make a real dent in the problem," Zavala said.

Automobiles can offer another benefit: they alleviate the problem of ramping, as power can be drawn from or fed into car batteries on a minute-to-minute basis.

Although nowhere near enough electric cars have yet been sold to make this a realistic solution today, improvements in battery technology will hopefully lead to cost reductions that will make plug-in cars more economically competitive with gasoline engines. >>

DID YOU KNOW?

The electricity you're using right now was generated just a few seconds ago.

7% Electricity lost in transmission in the U.S.

12% U.S. energy generated from renewable energy

40% CO_2 emissions in the U.S. come from generating electricity

11,496 Kilowatt-hours used by an average American home in a year

37,290,374 Smart meters in the U.S. in 2011

Source: U.S. Energy Information Administration

How do we make our electric grid more efficient?

Ted Bohn
Electrical Engineer
"Most grid inefficiency comes from the fact that utilities are required to provide lots of unused capacity that could be required in the event of peak load—often during a hot day in the summer. Usually, however, the demands on the grid are much lower. The smart grid will enable utilities to manage their loads better by allowing for more efficient and intelligent design of systems."

Guenter Conzelmann
Environmental Systems Engineer
"We need the smart grid to radically transform how we produce and consume electricity. The integration of large amounts of variable renewable resources and electric vehicles critically depends on a smarter grid. We want the grid to be able to withstand and recover from shocks such as storms like Hurricane Sandy much faster."

Victor Zavala
Mathematician
"We need a market design that creates incentives to deploy automated energy management technologies at a large scale. We also need a more integrated view of the grid that captures the interactions between an astronomical number of cyber and physical components."

Zavala predicts that as it evolves, the new grid will progressively decentralize how power is generated and used. Because solar and wind installations have lower capacity but greater flexibility than coal and nuclear plants, they are ideal for the creation of "microgrids"—small power networks to supply surrounding neighborhoods instead of bigger cities.

"The microgrid approach has the potential to give consumers vastly more flexibility, and grid operators can still treat them as a single individual unit," Conzelmann said. "We're getting a chance to rewrite the rules for how we generate and distribute electricity." Petri is similarly optimistic. "The day is not too far off when we have a more responsive, adaptable, and secure network that easily incorporates new energy resources and technologies," he said.

The Department of Energy has deployed more than 12 million smart meters in the U.S. so far.

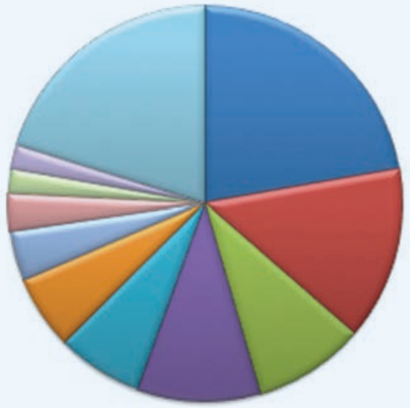
The U.S. Department of Energy's Office of Science and the Office of Energy Efficiency and Renewable Energy support grid research at Argonne.

MORE

For more on federal initiatives for a smart grid: smartgrid.gov

For more on Argonne's work: www.anl.gov/energy/smart-grid or watch a lecture: http://1.usa.gov/ZPUuBd

How Does The Typical Home Use Energy?



NO MAGIC SHOW

by Jared Sagoff

Real-world levitation to inspire better pharmaceuticals

Argonne X-ray scientist Chris Benmore levitates drops of liquid as part of research on pharmaceutical drug development.

MORE

Watch the levitation at www.anl.gov/videos/acoustic-levitation

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It's not a magic trick and it's not sleight of hand—scientists really are using sound-wave levitation to improve the drug development process. Levitating the drugs could eventually yield more effective pharmaceuticals with fewer side effects.

"One of the biggest challenges when it comes to drug development is in reducing the amount of the drug needed to attain the therapeutic benefit, whatever it is," said Argonne X-ray physicist Chris Benmore, who led the study.

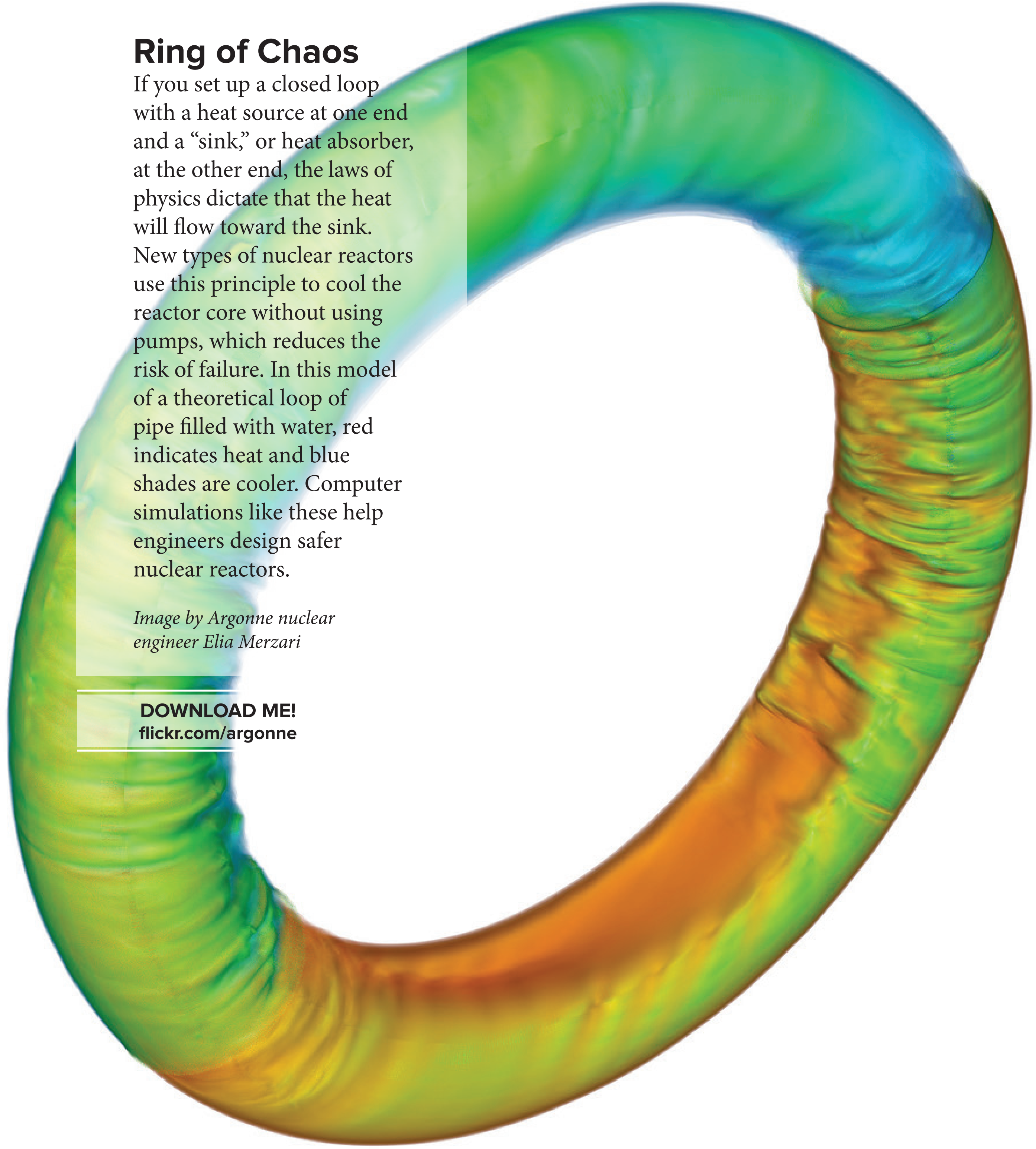
Most drugs on the market are crystalline—they don't get fully absorbed by the body and thus we aren't getting the most efficient use out of them. Part of the drug manufacturing process involves evaporating a liquid solution. If the solution evaporates while it's touching part of a vessel, it is far more likely to solidify in its crystalline form.

To evaporate a solution without it touching anything, Benmore turned to an acoustic levitator. It uses two speakers to generate sound waves at frequencies slightly above the audible range. When the top and bottom speakers are precisely aligned, they create two sets of sound waves that perfectly interfere with each other. At certain points, the acoustic pressure from the sound waves is enough to overcome the effect of gravity, and light objects can levitate when placed at the nodes. The researchers can then examine the samples with high-energy X-ray beams at Argonne's Advanced Photon Source.

A Universal Flu Vaccine?

Read more about drug development at the APS on page 48.

ART OF SCIENCE



Ring of Chaos

If you set up a closed loop with a heat source at one end and a "sink," or heat absorber, at the other end, the laws of physics dictate that the heat will flow toward the sink. New types of nuclear reactors use this principle to cool the reactor core without using pumps, which reduces the risk of failure. In this model of a theoretical loop of pipe filled with water, red indicates heat and blue shades are cooler. Computer simulations like these help engineers design safer nuclear reactors.

Image by Argonne nuclear engineer Elia Merzari

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FEATURES

A TRUE SENSE OF SECURITY

by Louise Lerner

Five men got on the Tokyo subway on a March morning in 1995. It was the peak of morning rush hour. They all carried packets of a tremendously toxic nerve agent called sarin. Each rode several stops, then dropped the packets to the floor and punctured them with the sharpened tip of an umbrella. Then they quickly got off the train.

Sarin was first developed in Nazi-era Germany as a pesticide; it evaporates almost instantly into a gas that seeps into the body through the skin and eyes and interferes with the body's electrical signaling. Victims die because important muscles, including the lungs, become paralyzed.

Some of the trains rode for miles before anyone stopped them. Hospitals were overwhelmed. 12 people died in the subways that day, and thousands more were poisoned.

As Japanese authorities tracked down the men, who were members of the religious cult Aum Shinrikyo, other countries around the world looked at the security of their own subways and public transportation. Subways are an attractive target for chemical and biological attacks because they cram a lot of people into small, enclosed spaces, and as they move from stop to stop, they spread the agent quickly. Before Aum Shinrikyo, no independent group had really succeeded in using chemical or biological weapons. The paradigm had shifted a little.

The United States asked the Department of Energy, which had expertise in radiological and chemical sensing, to begin looking into a network of sensors that could detect chemical weapons released in an enclosed space like the subway or a building.

"Each minute that you can shave off the response time saves lives in these kinds of situations," said Argonne systems engineer Pat Wilkey, who oversees the resulting initiative, called PROTECT, now fully deployed in several major cities.

As Argonne engineers worked on the fledgling system, the U.S. encountered disaster from another route. After the September 11th attacks, President George W. Bush stepped up funding for projects like PROTECT and consolidated several agencies into the Department of Homeland Security, tasked with protecting the nation from disaster.

But the way the department is often portrayed in popular culture—surveillance and secret agents—leaves out a crucial aspect of its role. It also works on technology to detect attacks as they're happening, like PROTECT, and helps federal and local governments prepare for all kinds of disasters, from hurricanes to accidental chemical spills to anthrax attacks.

Argonne, equipped with scientists, engineers, and analysts who had been working on security and protection for decades with the U.S. Departments of Energy and Defense, stepped up to lend support. In addition to PROTECT, the lab has helped local and state governments form emergency plans, run drills for a pandemic flu outbreak in the city of Chicago, and analyzed ways to enhance security at plants and factories across the country.

Argonne works to give federal agencies and local officials answers to questions like these: What geographic area might be affected by an earthquake? How fast can a utility get electricity back online after a hurricane? What should a city do if pandemic flu strikes? How fast does a chemical weapon spread through the subway? How long would it take to empty a stadium in case of an attack?

In the aftermath of 9/11, mindful of the subway attacks in Japan, researchers at Argonne continued to work on the early warning system PROTECT.

Engineers had already invented good chemical sensors; the team built them into a control system that would alert a human monitor and, ultimately, save lives.

Next, they wanted to find the best places to put the sensors. The scientists knew that airflow in the subways is affected by everything from the day's weather to how many people are moving through the stations. They also knew that trains and subways aren't airtight and that some gas would make its way to the surface. To get a map of exactly how a chemical agent would behave in these complex systems, the team released a harmless gas into several subway systems and tracked it as it moved.

They incorporated the data from the tests into the computer system that runs PROTECT. If there is a crisis, an operator sees lists of options pop up to recommend next steps: stopping the trains, closing or opening the ventilation shafts, or ordering evacuations. Once the fire department or other agencies arrive, they can plug into the system to get the latest data.

Since the system also incorporates security cameras in strategic locations, police find it valuable even beyond chemical release situations. "In a crisis, you need eyes on the scene," Wilkey said.

In 2007, Argonne licensed PROTECT to a private company, Smiths Detection, which maintains the systems currently deployed in several major cities. Plans are underway to build PROTECT-based systems elsewhere.

BOUNCING BACK

The other half of protecting the nation is making sure that once a catastrophe happens, we know what to do. Much of the Department of Homeland Security's focus is on helping communities prepare ahead of time for any disaster. >>

Modern security's watchword is "resilience." Resilience describes how quickly a system—a community, a power plant, an airport—recovers from a major blow, be it from terrorist or tsunami.

Resilience efforts tend to focus on infrastructure, which includes everything that keeps the country running behind the scenes. Most people take little notice of train lines, electric grids, cell phone towers, or water treatment plants until they're interrupted by an earthquake or attack. Losing one or all of them throws a town into chaos. What's worse, they tend to depend on each other.

"Failure in one infrastructure can cascade to another," said Jim Peerenboom, director of Argonne's Infrastructure Assurance Center, which performs analysis and helps federal, state, and local agencies run many of the exercises. "Say an earthquake ruptures a natural gas pipeline. Without fuel to produce electricity, the power plants shut down and the region may lose power. Without power, pumps can't deliver water, stoplights go out, and once the backup generators at the phone company run out, there's no phone or cell reception, either. Without communication, it's harder to organize relief efforts."

If a system is resilient, it contains fewer points where one thing going wrong leads to everything going wrong. Whether they are coaching city officials on what to do in case of a chemical spill or modeling what authorities should fix first in disasters, Argonne experts are thinking about how to reduce cascading effects.

Most people take little notice of train lines, electric grids, cell phone towers, or water treatment plants until they're interrupted by an earthquake or attack.

In one study, Argonne engineer Steve Folga led a team that analyzed how a major explosion in a metropolitan downtown area would affect power, gas, phone lines, and other essential infrastructure.

"Natural gas pipelines run throughout urban areas," Folga said. "An explosion could fracture them, and gas could leak into basements of nearby buildings and homes. And unfortunately, turning off the gas is not a simple task. It may take out gas delivery to a large area, and in winter, that means people without heating."

"You can never anticipate every single thing that might go wrong, but the more details are worked out in advance, the smoother the operation if disaster does strike," Folga said.

Folga's team also recently modeled an earthquake-tsunami combination in both Puerto Rico and the Pacific Northwest coastline. When a fault line north of Anchorage, Alaska, began causing tremors, they studied the potential effects of an earthquake there.

The exercises are useful for getting leaders in contact with one another—which can solve problems that might pop up down the line.

"Often we discover potential conflicts that no one's thought about yet,"

TIPS FOR EMERGENCIES

MAKE EMERGENCY PLANS. Make sure loved ones know what to do and how to contact each other in an emergency. www.ready.gov has excellent information on how to prepare ahead of time for a disaster.

KEEP PHONE CALLS BRIEF. If you need to use a phone, try to use it only to convey vital information to emergency personnel and/or family. Better yet:

TEXT INSTEAD OF CALL. In earthquakes, floods, or other disasters that disrupt cell phone service, text your loved ones instead of calling then. Texts use less bandwidth, so you're more likely to connect, and it leaves room on the network free for emergency responders.

IF YOU BECOME AWARE OF A SUSPICIOUS SUBSTANCE: Quickly get away. Protect yourself. Cover your mouth with layers of fabric that filter the air, but still allow you to breathe—such as a T-shirt, handkerchief, or towel. Wash with soap and water. Contact authorities. Tune in to TV and radio reports for information. If you become sick, seek emergency medical attention.

What can I do?

The U.S. Citizen Corps trains regular citizens in first aid and emergency skills and organizes volunteers to support local emergency responders, disaster relief, and community safety. Learn more at **www.dhs.gov/citizen-corps**

Peerenboom said, describing a scenario where a hospital is asked about its plans for evacuating critical patients in case of total power failure. "They'll say, 'We'll call Private Ambulance Company A,' and when we ask the other hospitals in the area, they name the same company in their plans. Obviously Company A only has a limited number of ambulances. In an emergency that knocks out power to the whole area—which is quite likely—they can't transport everyone at the same time."

Argonne also helps regional Homeland Security advisors evaluate threats. The department assigns at least one Protective Security Advisor, or PSA, for each state, according to population; Illinois has three. They serve as a link between local agencies (like fire and police departments), private security forces, and the federal government.

Argonne helped develop tracking tools that the PSAs can use to organize data to make better judgments. For example, one tool is designed for special events.

"Take the city where the Super Bowl is going to be held," said Dave Dickinson, who leads a team at the Infrastructure Assurance Center. "That means there will also be a media tent, hotels for the players, and practice fields at local universities. Each one of those needs its own security assessment."

The PSA collects data and works with other agencies to determine vulnerabilities at each site. With the help of Argonne's data and special event tools, they offer guidance on where a community can send the resources they have—such as police, ambulances, and private security—to maximize protection and recovery.

While everyone recognizes the value of having procedures to help communities recover from any calamity, Peerenboom noted the paradox of working on systems that will hopefully never have to face a real-life threat.

"The work we're doing is both essential and ideally invisible," he said. "Our job goes on behind the scenes, but it's absolutely vital so that we can avoid catastrophes and ensure quick recoveries."

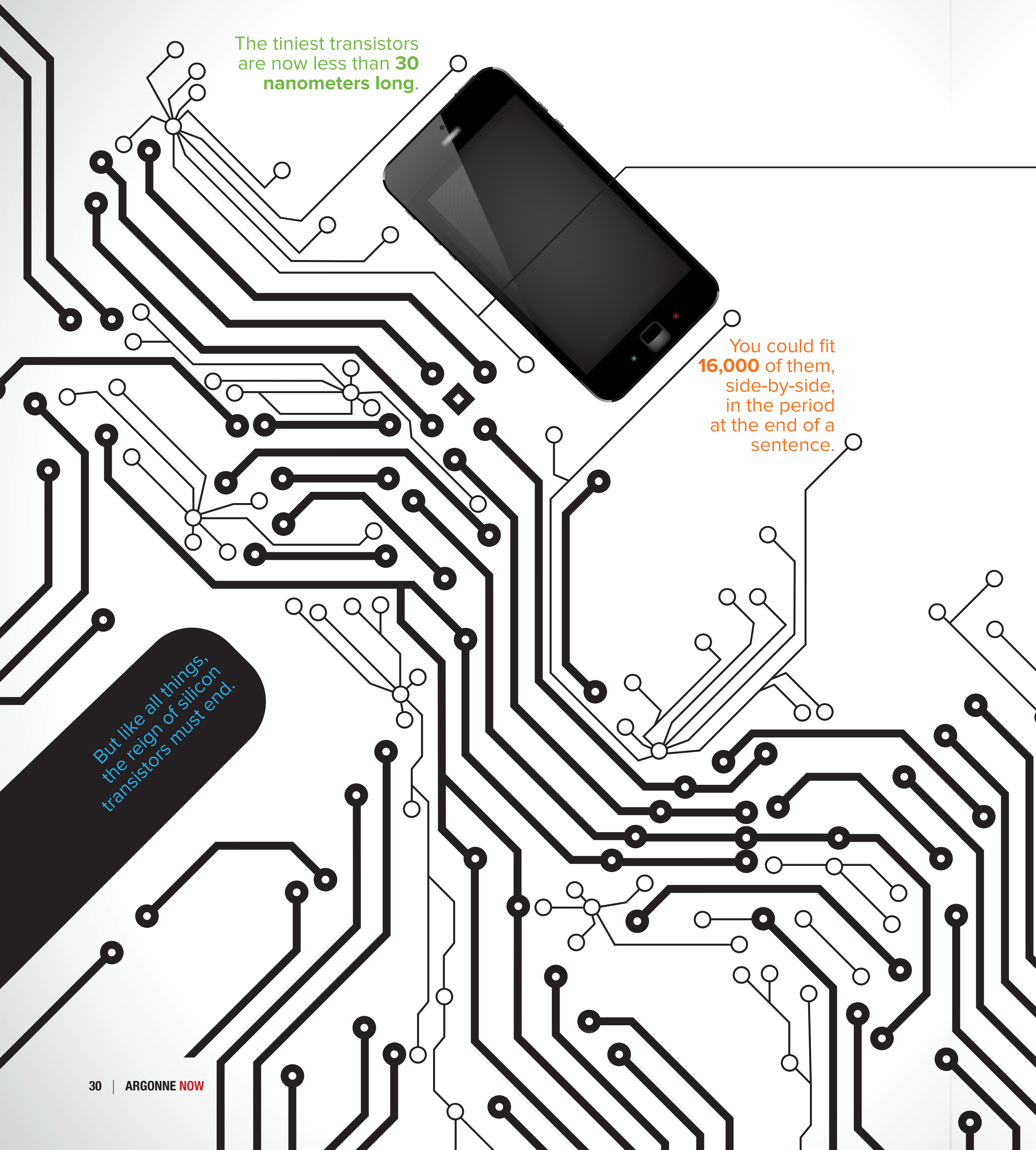
Research was supported by the U.S. Department of Energy, the Department of Homeland Security, and the Federal Emergency Management Agency.

MORE

More information on the Argonne Infrastructure Assurance Center: http://1.usa.gov/SNKJlq

More information on PROTECT: smithsdetection.com

FEATURES



The tiniest transistors are now less than **30 nanometers long**.

You could fit **16,000** of them, side-by-side, in the period at the end of a sentence.

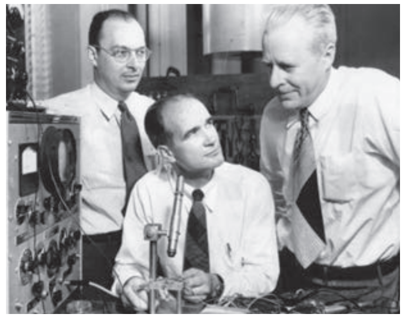
But like all things, the reign of silicon transistors must end.

how your smartphone got so smart

>> or how basic science today drives the electronic marvels of tomorrow

by Louise Lerner

In 1947, the Cold War, David Letterman, and the CIA were born; the future Queen Elizabeth got married; and a U.S. postage stamp cost three cents. That was also the year the seed that would eventually grow into smartphones first took root.



The seed didn't look that impressive, at least not next to the flashier rockets for outer space that other scientists and engineers were building at the same time.

Three scientists at AT&T's Bell Laboratories in New Jersey were tinkering with a device that would turn an electrical signal on and off. The dime-sized contraption, cobbled together out of germanium and gold, turned out to be the reason why you can get email from a person halfway around the world, look up restaurant reviews on your phone, and get driving directions from your car.

Today, we know this device as the transistor.

Transistors form the basis of modern electronics; we stamp out millions at a time, and they could all fit on the end of a pin.

It's not much of an exaggeration to say that the transistor changed the world.

Before the transistor, TVs and radios ran on vacuum tubes. These were hard to manufacture and hard to miniaturize (the world's first general-use digital computer weighed 30 tons), partly because they depend on maintaining a perfect vacuum.

Once transistors took off, though, electronics never looked back. Scientists quickly figured out that silicon was the perfect material for transistors—it made cheap, precise, and easily miniaturizable devices. In the latter half of the 20th century, the potential for better electronics seemed virtually limitless. In fact, in 1965 a scientist named Gordon Moore predicted that the number of transistors on a computer chip would double every two years, and Moore's Law has been remarkably accurate through the present day.

As transistors got smaller and smaller, computers performed more and more calculations per second. This let engineers pack unbelievable computing power into smaller platforms. Silicon transistors are why computers could shrink down from the monsters that occupied entire rooms in the 1940s into the sleek laptops of today.

The tiniest transistors are now less than 30 nanometers long. You could fit 16,000 of them, side-by-side, in the period at the end of this sentence.

But like all things, the reign of silicon transistors must end.

A transistor is really a glorified on/off switch. When it's "on," it allows current to flow through. When it's "off," the current stops. This is the language of computers: 1 (on) and 0 (off).

As they get smaller, silicon transistors get less efficient. The barriers separating "on" from "off" are so thin that the transistor never quite turns completely off, and it starts to leak power. It's like trying to dam a stream of water with your hand; most of the water stops, but a little still trickles through.

In electronics, power is lost as heat; leaky transistors are one reason why laptops run so hot. Much of the engineering in computers, from your phone to the largest supercomputers, revolves around cooling the chips. In fact, in terms of watts emitted per square inch, a transistor is comparable to a nuclear reactor.

"At some point, we'll hit the limit, and we won't be able to cool the transistors fast enough," said Anand Bhattacharya, a physicist at Argonne. "The answer almost certainly lies in a new class of materials to replace transistors."

Transistors, and everything else in your smartphone, are the domain of a field called "materials science."

Materials science is the field that takes discoveries in physics and >>

chemistry and uses them to arrange atoms to do what we want them to do. Blacksmiths, among the earliest materials scientists, melted iron and charcoal together to make steel. Egyptian materials scientists found that melting sand and something alkaline made glass.

New materials transform the world. We categorize our past according to what materials we could make: the Bronze Age, the Iron Age, the Atomic Age. The hunt for the next round of miracle materials will give us faster, cheaper, and smarter electronics, as well as everything from affordable solar panels to batteries that power cars for 300 miles.

But inventing a material today is a bit more complex than it used to be. Our electronics have gotten so sophisticated that in order to create a new material, we have to know what it looks like at incredibly fine detail—at the level of molecules and atoms. To do so, scientists have several ways of getting pictures of what's happening down there, even though it's far too small for human eyes to see.

One way is to shoot beams of incredibly powerful X-rays at a sample using a giant synchrotron like Argonne's Advanced Photon Source. When the beams hit and scatter in all directions, scientists piece together the information to recreate a "picture" of the material at nearly atomic detail.

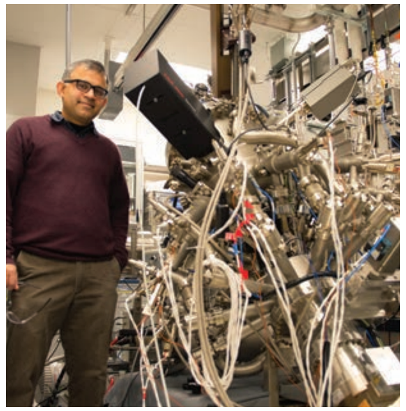
For more on X-rays, turn to page 38.

Sophisticated computer models can predict behaviors of unknown materials; running them on a supercomputer like Mira, Argonne's IBM Blue Gene/Q, lets scientists combine millions of data points for the most accurate models. They run thousands of simulations of different ways to combine chemicals. Once the computer spits out a few interesting answers, they can take those to the lab to confirm the results.

"Our ultimate goal would be the ability to custom-tailor a new material—building it atom by atom to suit our purposes," said Argonne senior chemist John Mitchell. "There's no one clear road to a successor to the transistor, but there are several bright prospects."

OXIDES

Scientists at Argonne are looking at interesting materials called Mott insulators, which could eventually knock silicon off its pedestal.



Argonne physicist Anand Bhattacharya uses the molecular beam epitaxy machine to build new materials for electronics.

Mott insulators are a curious class of materials. Conventional theory predicts that they should conduct electricity, but when scientists tested them, they found the materials were actually insulators. Many in the field believe that if we could find the right recipe, we could build Mott insulators that flip back and forth between conducting and insulating when a voltage is applied.

The problem is that we don't understand the basic physics behind Mott insulators nearly as well as we do silicon; we don't know enough about them to harness them. Until last year, no one had built a working Mott-based transistor. A team of Japanese scientists managed to build a prototype in 2012, which set the materials world buzzing, but it only worked partially, and the conditions they used aren't really practical for a working smartphone or computer. So the race is still on.

Mott insulators are made out of transition metal oxides: metals from a particular section of the periodic table (like copper, manganese, or iron) with oxygen added.

"What we have to do is learn to understand and control a material fairly well, and then we explore how they behave under different conditions," said Bhattacharya. "We look for new and exciting properties that pop up when we arrange atoms in different ways."

To study them, Bhattacharya designed a very useful device at Argonne called a molecular beam epitaxy machine. It looks a bit like a smaller Apollo lunar module: a large metal cylinder with a dozen smaller tubes feeding into it.

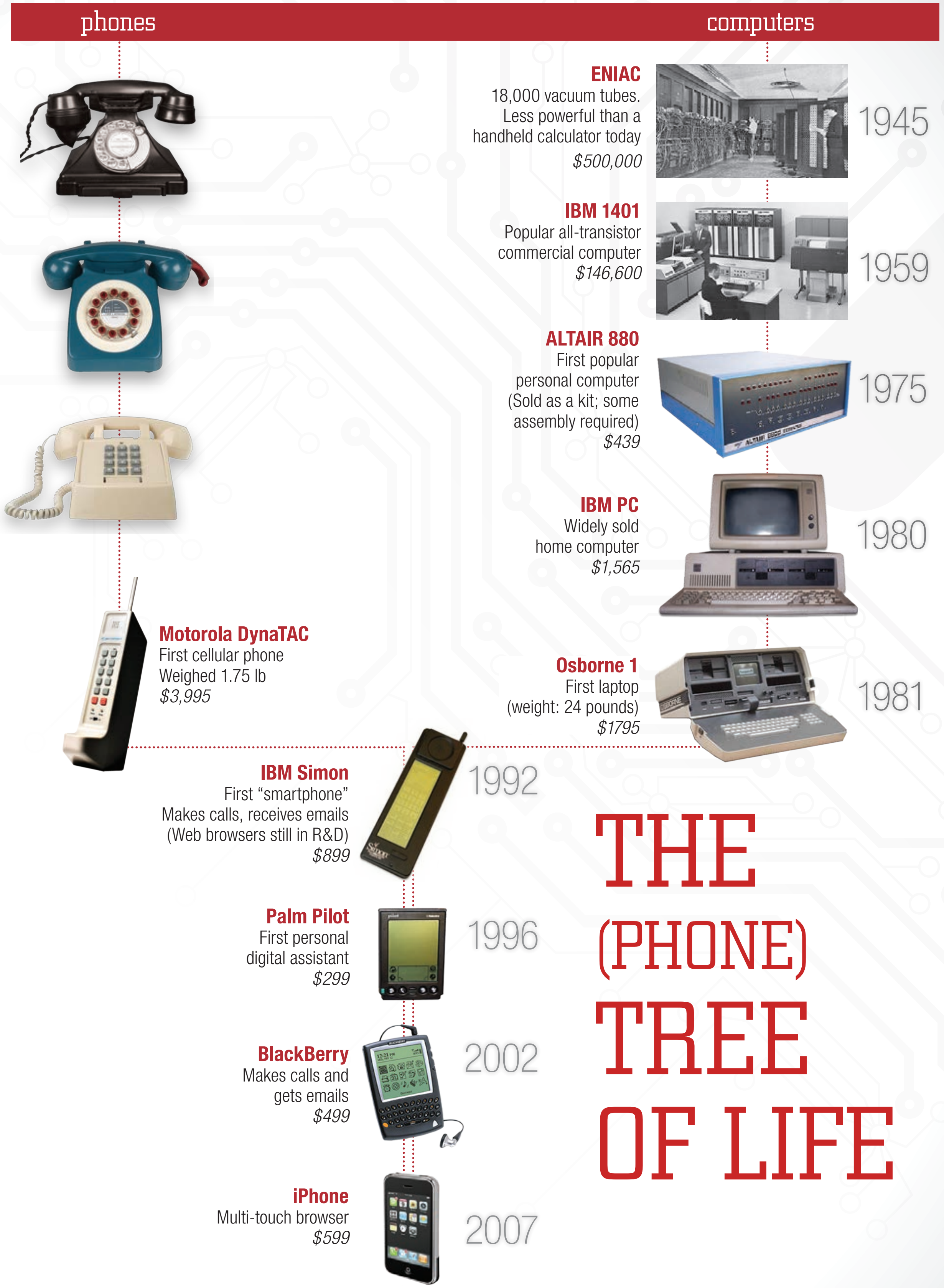
Each tube contains a different metal. The tubes have exceptionally accurate shutters that release just a few atoms of, say, strontium. The strontium reacts with oxygen atoms in the chamber and forms a crystal layer. Working this way, scientists can build very precise layered materials, like a birthday cake with layers just atoms thick, and then test them to see how they work.

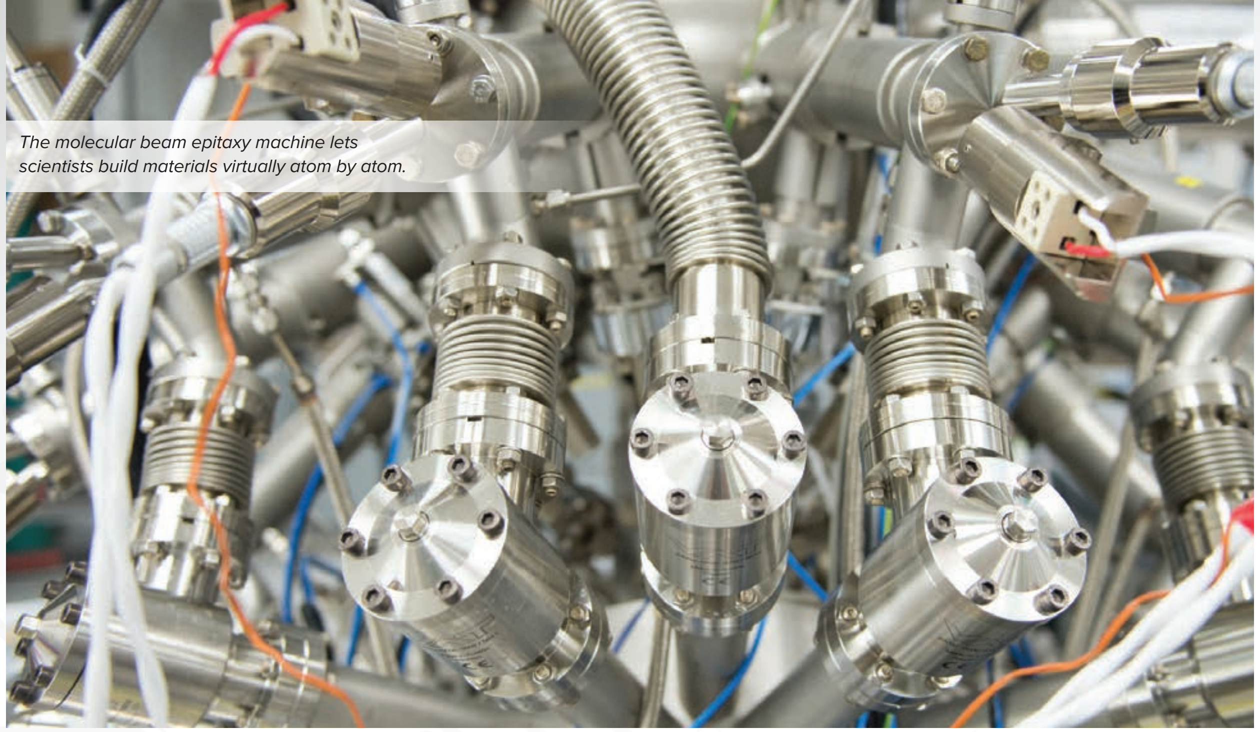
"Oxides can do things that silicon can't do," Bhattacharya said. "For example, they can change to be magnetic or not magnetic, or even to be superconductors."

Either of these properties could represent "on" and "off." In fact, other scientists at Argonne are looking at extending these ideas further. >>

"We look for new and exciting properties that pop up when we arrange atoms in different ways."

— Anand Bhattacharya, Argonne scientist





The molecular beam epitaxy machine lets scientists build materials virtually atom by atom.

MAGNETS

Magnets are already the magic behind loudspeakers, from the tiny ones inside earbuds to the big ones in amps at concerts. But if experiments pan out, they might become the backbone of electronic computing as well.

German scientist Peter Grünberg spent a year and a half as a visiting scientist at Argonne in the 1980s studying magnetism. He wanted to know what would happen if he alternated extremely thin layers of magnetic and non-magnetic materials. Argonne staff built him some prototypes using a process similar to molecular beam epitaxy.

Grünberg took the samples back with him to Germany and continued studying, discovering an effect called “giant magnetoresistance.” When he applied a magnetic field, the magnetic layers aligned themselves parallel to one another, accompanied by a dramatic change in the material’s electrical resistance. This switching, too, could be used to transmit on or off.

Giant magnetoresistance represented a breakthrough in materials science and permanently transformed the field. “Less than ten years later, IBM was selling the first hard disk drives based on the effect, and Grünberg went on to share the Nobel Prize,” said Sam Bader, a physicist and Argonne Distinguished Fellow who worked with Grünberg.

While giant magnetoresistance was only used to read stored information on computers (and the original iPods), some scientists are imagining entire logic systems based on magnetism instead of silicon transistors.

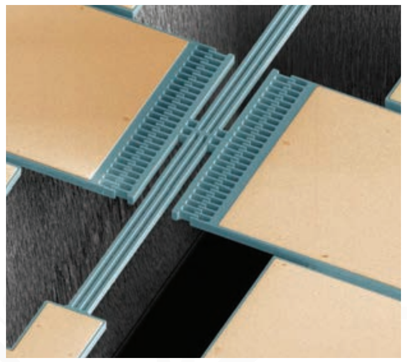
“Magnets have all sorts of interesting properties for electronics,” Bader said. “For example, they are non-volatile, meaning that they don’t use power to maintain stored information; the data remain even if you turn off the device. Computers built based on magnetic logic, therefore, could boot up instantaneously.”

Disk drives based on giant magnetoresistance, and other newly discovered magnetic effects, exploit a property of electrons called spin. Electrons are either “spin up” or “spin down.” Changing this property changes the material’s conductivity without altering the actual atomic structure of the material.

“If we could figure out how to make a reliable solid-state memory, which has no moving parts, we could see a future where hard drives would cost the same but store 100 times more memory and work at least 100 times faster,” Bader said.

TEENY MACHINES

When you tilt your phone sideways, the picture re-orients itself along with you. How does your phone know?



Technology like this tiny microelectromechanical system resonator, fashioned at Argonne’s Center for Nanoscale Materials, could soon make clocks more accurate.

Inside the case, microscopic machines sense the change in speed as you tilt the phone and relay the message to the phone’s brain. The phone’s compass, microphone, and clock all use these tiny machines, called microelectromechanical systems, or MEMS. Some are even small enough to be called nanoelectromechanical systems (NEMS).

MEMS are tiny mechanical machines, usually made out of silicon, that run in the neighborhood of 10 microns long—the diameter of a single red blood cell. NEMS are even smaller.

MEMS are interesting because they let electronics do all sorts of interesting things that transistors alone can’t do.

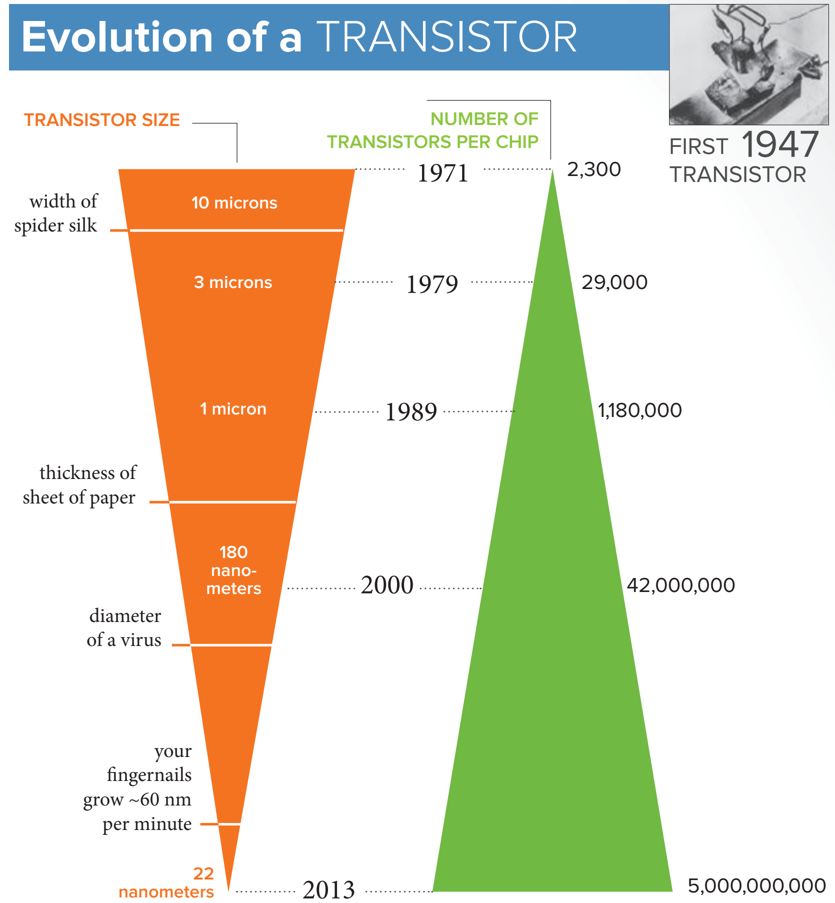
“Basically, what you are doing is taking a computer chip and giving it eyes, ears, arms, and legs."

— Daniel Lopez, Argonne scientist

“Putting MEMS and electronics together is a powerful combination,” said Daniel Lopez, a nanomaterials scientist at Argonne’s Center for Nanoscale Materials. “Basically, what you are doing is taking a computer chip and giving it eyes, ears, arms, and legs. MEMS allow transistors to interact with the real world.”

For example, the device that tells the phone it’s being tilted is called an accelerometer. The same accelerometer lets you play video games and even measure your car’s horsepower and speed with remarkable accuracy.

MEMS already appear in a variety of devices. Since the 1990s, they have been embedded in your car’s airbags to sense crashes the instant they happen. They also pick up data to activate anti-lock brakes. Many laptops have MEMS accelerometers that detect a sudden change in altitude (i.e., when the laptop is dropped) and adjust the hard drive in midair to prevent damage. Lopez and others at Argonne are developing MEMs that will eventually replace the quartz-based timekeeping system in clocks around the world.



Another bonus: “Because they are so small, they consume virtually no power,” Lopez said.

At Argonne, scientists study NEMS and MEMS to find out new ways to make them smaller and better. The Advanced Photon Source can take pictures of the devices at nearly atomic resolution, which helps scientists like Lopez study the basic structures of the machines.

“The newest NEMS are so sensitive that they can measure quantum forces,” Lopez said. “All of a sudden we can explore situations that we couldn’t even imagine a few years ago. It’s a very strange world down there. In theory, you could make devices that are virtually frictionless and thus almost 100% energy efficient.”

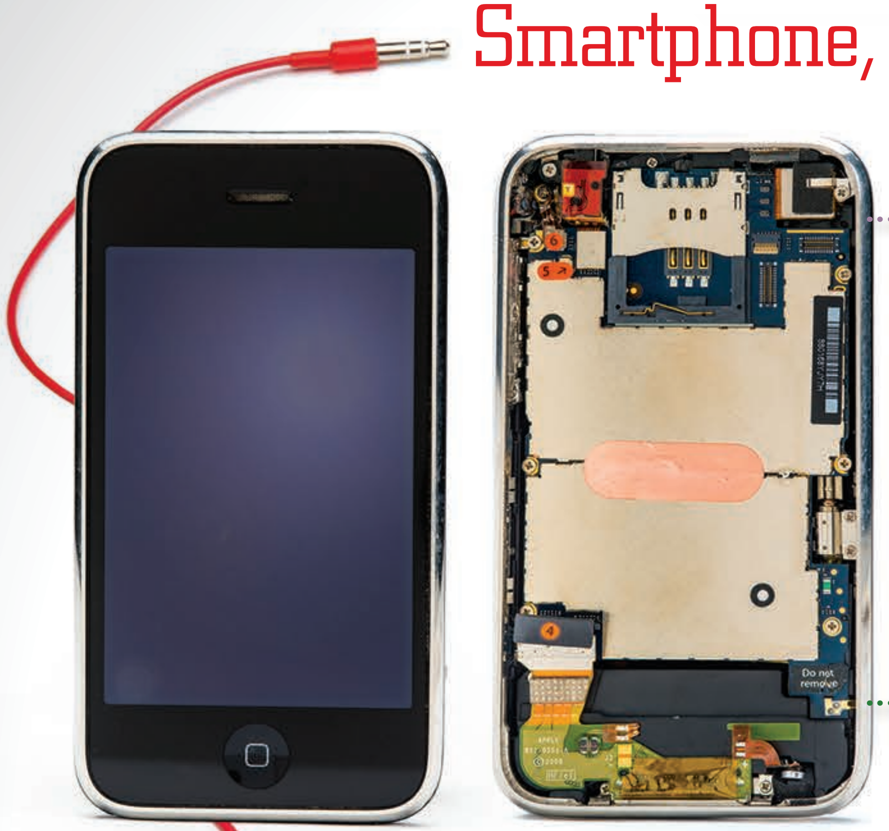
The “strange world” has many more surprises for us and the scientists who are delving into it. Our phones may be smarter today than 50 years ago, but like the three scientists at Bell Laboratories in 1947, we still stand gloriously unaware of what they’ll be able to do after another 50 years of research.

Research discussed in this article is supported by the U.S. Department of Energy. The Advanced Photon Source and Center for Nanoscale Materials are funded by the Department of Energy’s Office of Science.

MORE

For more information on Argonne materials science, visit: www.msd.anl.gov

Smartphone, Deconstructed



Touch Screen

Touchscreens grew out of research by E.A. Johnson at Britain's government-funded Royal Signals and Radar Establishment and Sam Hurst at Oak Ridge National Laboratory. Today's touchscreens use many layers of material, including one that senses changes in electrical current when you touch the surface with your finger.

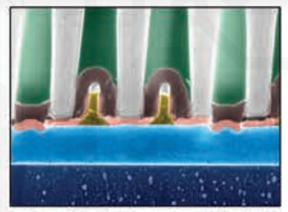
Headphones

Most of today's headphones use a kind of magnet called a neodymium magnet, partially grounded on basic magnetism research funded by the U.S. Air Force, General Motors, and the Chinese Academy of Sciences.

Today's smartphone is brought to you by a rainbow of discoveries in basic materials sciences over the years, many pioneered at national laboratories or government-funded research facilities. Here are a few.

The Brains

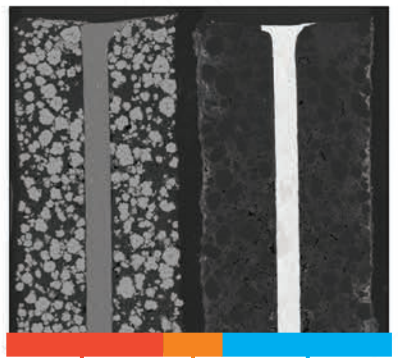
Most phones use two processors, made of circuits built out of silicon transistors. Modern computers are built on computing principles developed at public universities and national labs, including Argonne, in the 1980s and 90s.



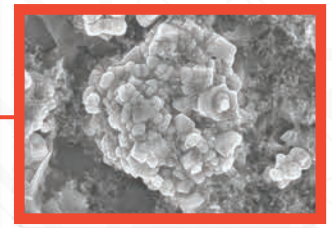
This cross-section of an IBM microprocessor shows two transistors, colored gold, out of the 790 million on this thumbnail-sized chip.

Image: IBM

The Battery

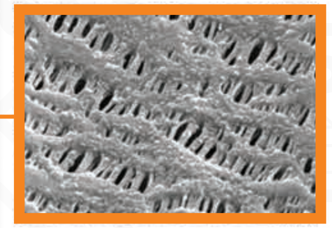


Cell phones run on lithium-ion batteries, which pack the most punch for their weight of all known battery types. They're based on many breakthroughs. Research at Argonne continues to help tweak these structures and elements to just the right proportions to make them more powerful, safer, and longer-lived.



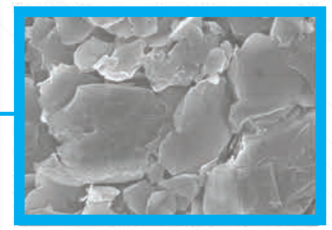
THE CATHODE

Zoom in even further and you can see the positive pole, or cathode, made of lithium mixed with various other elements.



THE SEPARATOR

A thin plastic film separates the two poles of the battery, with tiny holes to let lithium ions shuttle back and forth.



THE ANODE

The negative pole of a battery, called the anode, is usually made of graphite.

Images courtesy Argonne battery scientist Daniel Abraham.

ALL THESE PARTS:

$178

The Department of Energy's Office of Science is the single largest supporter of basic research in the physical sciences in the U.S.

DID YOU KNOW

This is a slice of copper foam captured by a process called X-ray tomography, which works a bit like a medical CAT scan—only on materials. Photo by Argonne scientists Fikile Brushett, Xianghui Xiao, and Lynn Trahey.

7 THINGS you may NOT KNOW about X-RAYS

by Jared Sagoff

1 X-rays are a type of light.

When atoms have been excited, they emit packages of energy called photons. These make up every kind of light. X-rays are particularly energetic photons emitted by the atoms.

2 X-rays are used to look at especially tiny structures because they have a shorter wavelength than visible light.

The shortest wavelengths of visible light—what we see as violet—measure somewhere around 400 nanometers. By comparison, soft X-rays have wavelengths around one nanometer and hard X-rays have wavelengths of just a fraction of a nanometer. (Your fingernails grow about one nanometer per second.) It's impossible to see structures smaller than the wavelength of whichever form of light is used, so scientists need to use short-wavelength pulses to analyze materials at the atomic scale.

3 There's a big difference between "soft" and "hard" X-rays.

Soft X-rays carry far less energy than hard X-rays, and are for this reason more easily absorbed by air and especially by other mediums. In water, the majority of soft X-ray photons will be absorbed before they have travelled even a millionth of a meter. Doctors and scientists use hard X-rays to look at broken bones or to investigate the atomic-level properties of solid materials.

4 X-rays were discovered by accident.

X-rays, originally named Röntgen rays, were discovered in 1895 by German physicist Wilhelm Röntgen. Röntgen had been doing experiments with cathode rays—streams of electrons in vacuum tubes. He had prepared a glass cathode ray tube covered with black cardboard, and noticed that even though the cardboard completely covered the tube, a glow still appeared on a fluorescent screen several feet away. After Röntgen prepared one of the earliest X-ray images of the bones in the hand of his wife, she remarked: "Now I have seen my death!"

5 X-rays were used to discover the double helical structure of DNA.

Although James Watson and Francis Crick are typically credited with the discovery of the structure of DNA, their breakthrough would not have been possible without the X-ray crystallography performed by chemist Rosalind Franklin. X-ray crystallography involves striking a crystal's surface with X-rays and then looking at the "scattering" pattern generated as a result. By working backwards mathematically, scientists can reconstruct the structure of small molecules from these intricate patterns.

6 Particularly powerful X-rays are produced by large particle accelerators that can stretch for miles.

The brightest X-rays that U.S. scientists use today for their experiments are produced at large "light sources" located at national laboratories. Argonne's Advanced Photon Source represents one example of a synchrotron light source—a large ring that uses magnets to keep electrons travelling at close to the speed of light around a kilometer-long ring. As the electrons travel around the ring, they emit energy in the form of brilliant, high-energy X-rays.

7 It's possible to combine X-rays with microscopes.

X-ray microscopy does not really look a lot like the optical microscopy most of us are familiar with from high school. Because X-rays are invisible to the human eye, scientists using an X-ray microscope expose film or use a sensor to detect X-rays that pass through samples. Then they analyze the results from these exposures to create an image.

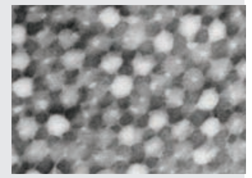
MORE

Visit the Advanced Photon Source website: www.aps.anl.gov

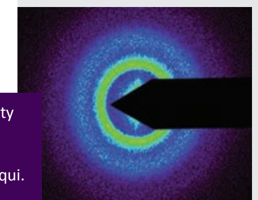
Scientists wanted to discover why some bird feathers look blue—without any blue pigments. X-rays at the Advanced Photon Source helped reveal that the birds use tiny nanoscale-level structures on the feathers that only reflect light in the blue wavelength.

WHAT WE SEE
A Plum-throated Cotinga.

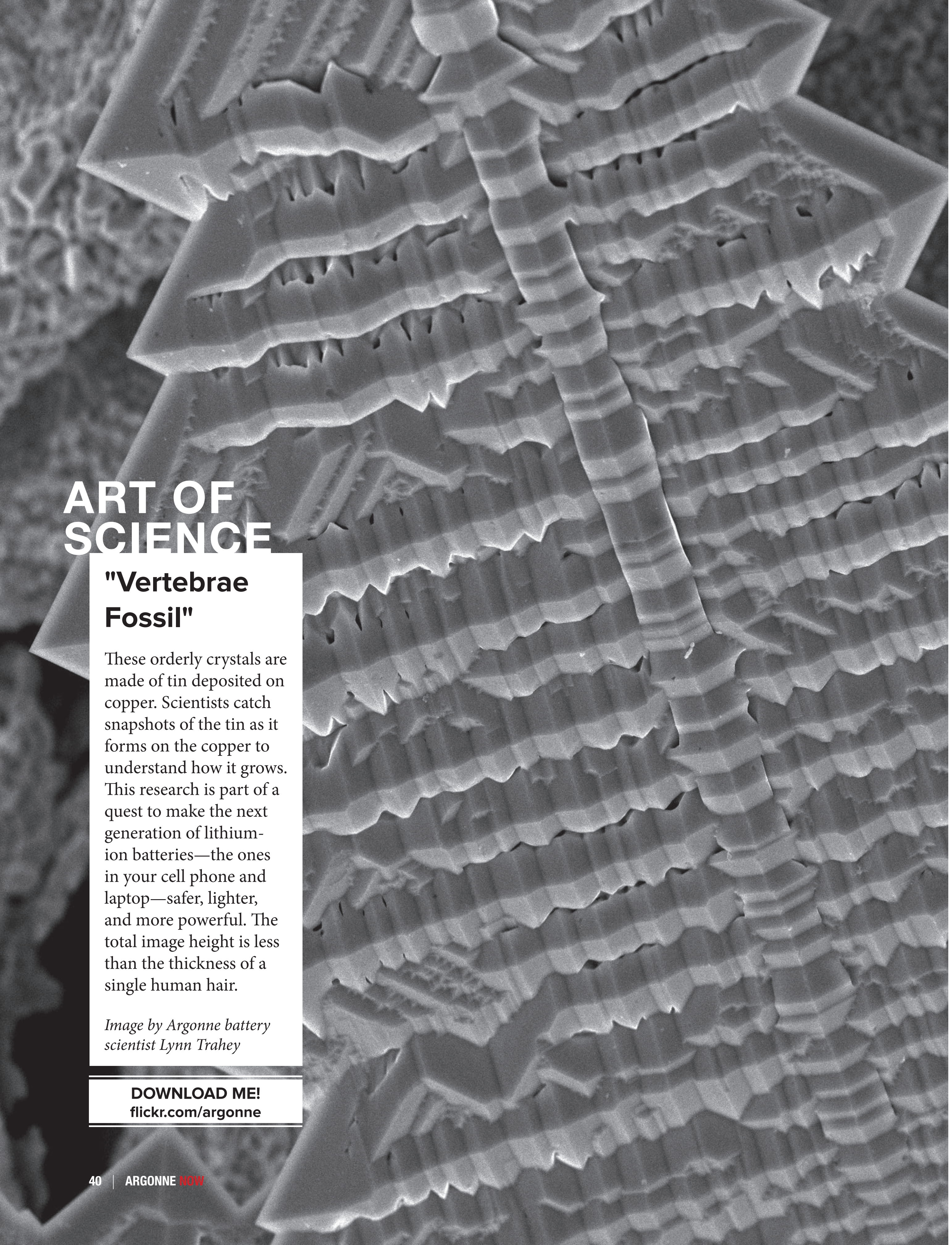
WHAT AN ELECTRON MICROSCOPE SEES
Electron microscopes shoot a beam of electrons at the feather and measure how they interact to get an image of the structure. But electron microscopes can only see down to the nanometer level. To go even further, to the atomic level, you need X-rays.



WHAT THE X-RAYS SEE
Scientists focus an X-ray beam on one tiny spot. When it hits, the photons scatter symmetrically around the beam (highlighted in different colors). Then the scientists can piece together the scattering information to reconstruct how the feather's atoms are arranged.



Collage by Vinod Saranathan (University of Oxford); X-ray scattering at the Advanced Photon Source; photo of Plum-throated Cotinga by Thomas Valqui. From V. Saranathan et al., *J. R. Soc. Interface*. ©2012 The Royal Society.



ART OF SCIENCE

"Vertebrae Fossil"

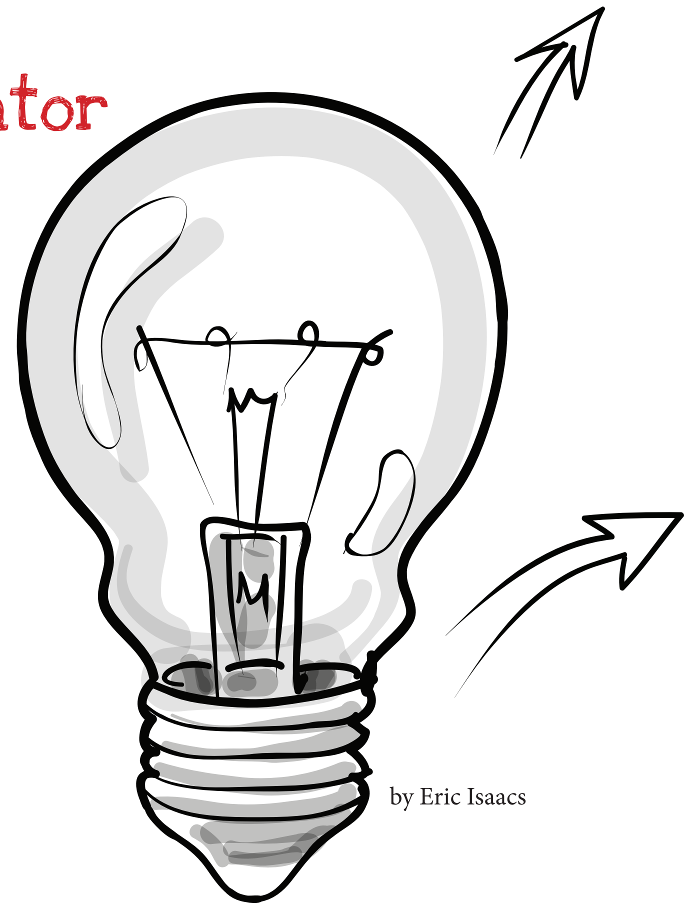
These orderly crystals are made of tin deposited on copper. Scientists catch snapshots of the tin as it forms on the copper to understand how it grows. This research is part of a quest to make the next generation of lithium-ion batteries—the ones in your cell phone and laptop—safer, lighter, and more powerful. The total image height is less than the thickness of a single human hair.

Image by Argonne battery scientist Lynn Trahey

DOWNLOAD ME!
flickr.com/argonne

Forget About the Mythical Lone Inventor in the Garage

Thomas Edison is often romanticized as a solitary genius scientist, but his many inventions actually sprang from a large, well-funded laboratory. (Photo: Library of Congress)



by Eric Isaacs

REAL INNOVATIONS HAPPEN IN **BIG, WELL-FUNDED LABS**

Eric Isaacs

Where are the best scientific ideas created and developed?

a) A garage.
b) A dorm room.
c) A full-scale laboratory equipped with the latest technology and staffed with highly trained professional researchers.

It might not be romantic, but the correct answer is c).

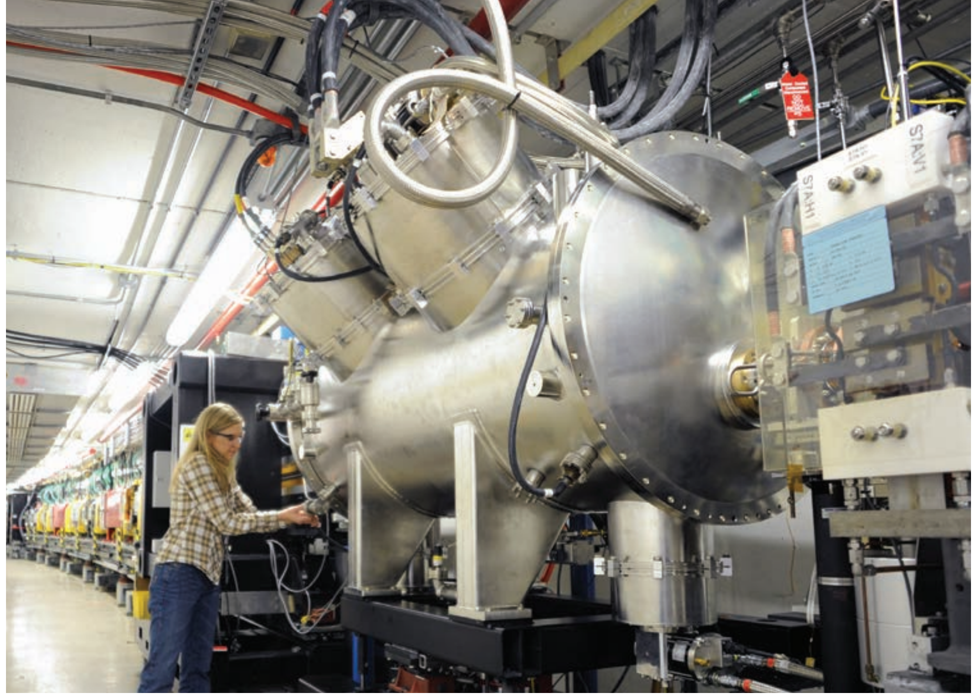
As Americans, we tend to embrace the notion that a brilliant inventor doesn't need much more than a garage, a sturdy workbench, and a dream. From Thomas Edison to Iron Man, our inventor-heroes have been popularly viewed as single-combat warriors working feverishly in a basement or some other threadbare den of solitude.

And that's unfortunate, because the myth that innovative genius burns brightest in dingy isolation has a real impact on the way this nation views the importance of the knowledge enterprise and the scientific infrastructure that supports it.

Consider Edison. In his 14-month quest to develop a commercially practical electric light bulb, he wrote, "I tested no fewer than 6,000 vegetable growths, and ransacked the world for the most suitable filament material."

It's awe-inspiring to think of Edison sitting alone at his workbench in Menlo Park, N.J., patiently testing fiber after fiber, hour after hour, day after day. It's also patently untrue. In fact, Edison was leading the world's first large-scale research and development laboratory, a highly organized, multipurpose facility staffed by a 40-person team of scientists and technicians.

After the light bulb proved successful, Edison went on to build an even larger "Invention Factory" in nearby West Orange, a complex that included sophisticated research facilities and manufacturing capabilities. At its peak, it employed more than 200 scientists, machinists, craftsmen, and other workers. >>



Argonne technician Sue Bettenhausen works on the Advanced Photon Source at Argonne National Laboratory, where big facilities like this synchrotron help scientists make the crucial breakthroughs.

Edison succeeded in burnishing his public image as a lonely genius. After his death in 1931, the New York Times mourned: "No figure so completely satisfied the popular conception of what an inventor should be. Here was a solitary genius revolutionizing the world—a genius that conquered conservatism, garlanded cities in light, and created wonders that transcended the predictions of Utopian poets. ...With him passes perhaps the last of the heroic inventors and the greatest of the line. The future probably belongs to the corporation research laboratory, with trained engineers directed by a scientific captain." But away from the reporters and the newsreel cameras, Edison was in fact that scientific captain, the executive director of a big, world-class laboratory.

These romanticized versions of technological history aren't just inaccurate. They threaten to undermine public support for the scientific infrastructure that is necessary to fuel American innovation and assure global economic competitiveness in the decades to come.

Today, American scientists and engineers are facing a number of perplexing questions that will have a lasting impact on our economy and our environment: How can we create a solar cell that costs five cents per kilowatt-hour? How can we reduce the cost of a car battery to one cent per mile? How can we cost-effectively capture the excess carbon in our atmosphere and store it permanently and safely?

At this point, we don't know the answers to those questions. But we do know the most promising way to find those answers—by putting world-class researchers in world-class labs, inspiring them with an urgent sense of mission, and organizing them into "dream teams" with the combined expertise necessary to look at these questions from multiple perspectives and come up with the smartest, most practical solutions.

In years past, these types of mission-focused teams of experts could be found in America's renowned corporate laboratories, such as IBM, Xerox PARC, and AT&T's Bell Laboratories—organizations designed to turn scientific discoveries into commercially viable inventions and technologies.

I began my own career at Bell Labs, back in 1988, drawn by its reputation as a place where fundamental research was prized as the basic building block of technological innovation in the service of information technology.

For decades, as Jon Gertner describes in his recent book *The Idea Factory*, Bell Labs had served as a magnet for some of the world's top researchers in science, computers, and mathematics. The results were tremendous, both scientifically and commercially—the invention of the charge-coupled device and the laser, as well as vital contributions to computing, satellite communications, semiconductors, and wireless technologies. By putting great scientists in great facilities, Bell Labs spurred whole new industries, created millions of new jobs, and changed the way we live.

But in 1995, in the wake of deregulation, AT&T spun off the labs, resulting in sharply decreased research budgets and a much narrower focus on technological research with a shorter-term likelihood of commercial marketability. Bell Labs' reign as the world's greatest industrial laboratory ended in 2008 when it pulled out of basic science, material physics, and semiconductor research—a decision that put an end to one of the last bastions of basic research within the corporate world.

BIG-LAB **BREAKTHROUGHS**

- The magnets in MRI scanners were developed by U.S. Department of Energy national lab researchers.
- SLAC National Accelerator Laboratory scientists, seeking to share particle physics information, were the first to install a web server in North America—kick-starting the development of the Internet as we know it.
- 16 elements on the periodic table were discovered at national labs.

In a financial world that is focused on quarterly results, it's understandable that corporations have become unwilling to invest in basic research that can take 10 or 15 years to result in new money-making products and technologies. But without basic research, we will not be able to create the new products that spawn new industries and create good new jobs. So, increasingly, the responsibility for funding basic scientific research has fallen on the federal government.

That's an enormous responsibility. But it also is an enormous opportunity for the national laboratories to demonstrate our unique ability to bring together partners from academia and industry to address the grand challenges of our time.

This effort isn't easy. It requires armies of highly intelligent, highly educated people with deep curiosity, strong work ethics, and unflagging persistence. It requires a new, open approach to collaboration and teamwork. It requires a critical mass of state-of-the-art laboratories and instruments. It requires adequate funding to keep those vital factors in place over years, and even decades.

Increasingly, the responsibility for funding basic scientific research has fallen on the federal government.

And perhaps most importantly, it requires a new, reality-based understanding that most breakthrough innovations are developed in laboratories, not garages or dorm rooms.

As a scientist, I know that every transformative idea is first born in the mind of an individual genius. But a lone inventor burning the midnight oil cannot match the impact of a team of brilliant experts working to develop that idea within a system designed to maximize discovery, with access to the best tools on earth—supercomputers, synchrotrons, accelerators, and all the other dazzling technologies that support science today.

We can't allow romantic myths about creative loners to overshadow the reality that America's knowledge enterprise depends on the work of robust teams of highly trained experts, enabled by a world-class scientific infrastructure and supported consistently by public funds.

The work we do in the national laboratories promises to dramatically accelerate the discovery and development of new materials, technologies, and processes—and ultimately, those efforts will power the expansion of the American economy. It may not be glamorous, but it's important and it's real—and personally, I think our real-world researchers are far more interesting and compelling than any mythical introverted genius working alone in a backyard shed.

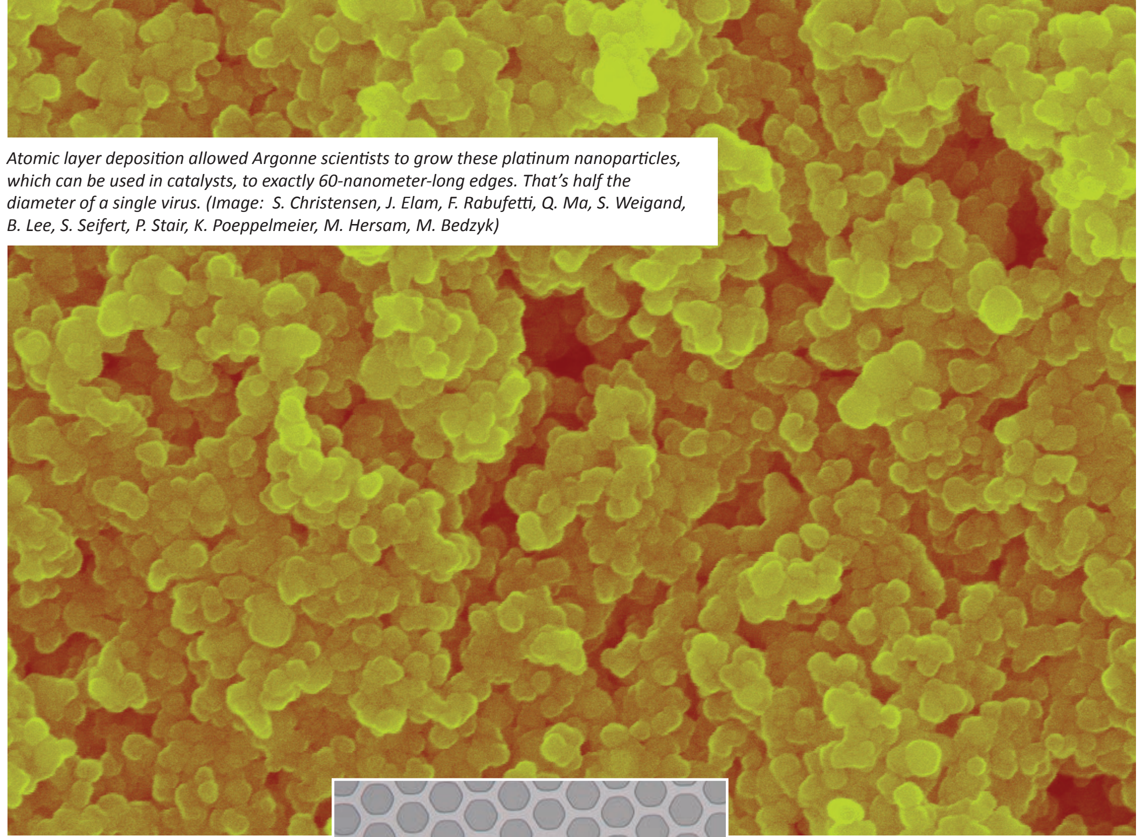
After all—these days, even Iron Man is working in a team.

This article arises from Future Tense, a collaboration of Slate, the New America Foundation, and Arizona State University, and was originally published at Slate.com.

In this split-screen image, Argonne's Henning Lohse-Busch evaluates an electric vehicle under extreme hot (left) and cold conditions (right). The chamber can evaluate vehicles from 20°F to 95°F.

DID YOU KNOW?

Another of Edison and team's inventions, wax cylinder phonographs, hold some of the world's first recorded sounds. Today, though, many are too fragile to play. National laboratory scientists engineered a high-tech way to digitally reconstruct aging sound recording, including Edison cylinders. Archivists estimate that many of the millions of recordings in the world's sound archives, including the U.S. Library of Congress, could benefit from the technology.



Atomic layer deposition allowed Argonne scientists to grow these platinum nanoparticles, which can be used in catalysts, to exactly 60-nanometer-long edges. That's half the diameter of a single virus. (Image: S. Christensen, J. Elam, F. Rabufetti, Q. Ma, S. Weigand, B. Lee, S. Seifert, P. Stair, K. Poeppelmeier, M. Hersam, M. Bedzyk)

by Vic Comello

ATOMIC LAYER DEPOSITION:

A VERSATILE TOOL FOR COATING COMPLEX SURFACES

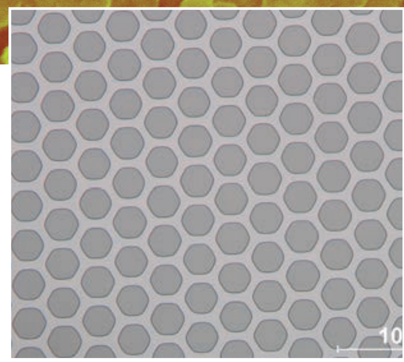
Think of an eight-inch square honeycomb structure made of glass whose pores are just a few tens of microns thick—the size of a single bacterium. In your mind's eye, you hold the beginnings of a breakthrough technology.

Such honeycombs, developed by Incom, Inc., form the backbone of microchannel plates, which are critical for numerous imaging and sensing applications. These include cheaper medical imaging cameras, high-energy particle detectors, vision enhancement devices, and national security detector arrays capable of scanning inside trucks and shipping containers for hidden nuclear materials.

A microchannel plate amplifies incoming signals so that images are both preserved and enhanced. Researchers apply about 1,000 volts across a microchannel plate from front to back, which makes incoming electrons traverse the open pores. As they do, they crash into the walls of the pores over and over, causing large numbers of new electrons to enter the stream with each impact. Through this avalanche effect, the spatial pattern of electrons at the front surface is amplified up to ten thousand times.

Each tiny pore must have a uniform coating along its length to give its walls the correct electrical conductivity and emission properties. To make this possible, Incom, Inc., turned to Argonne's expertise in a special technique called atomic layer deposition.

Argonne scientist Anil Mane inspects a microchannel plate developed by Argonne and Incom, Inc.



These honeycombs, manufactured with a technique from Argonne, form the backbone of microchannel plates used in many imaging and sensing technologies. Image by Incom, Inc.

Atomic layer deposition, or ALD, is a technique to grow very thin films on complex objects such as Incom's microscopic pores. Researchers feed in reactive chemical vapors to coat the pore walls with a layer of material. The chemical reactions are self-limiting, so each reaction sequence deposits a layer of material just one atom thick, allowing researchers to precisely control the film's composition and make each layer uniform.

To give microchannel plate pores the right electrical properties, Argonne developed ALD processes for blending insulating and conducting materials in exact proportions. The marriage of Incom Inc.'s honeycomb plates and Argonne's ALD films received an R&D 100 Award as one of the most innovative products to be commercialized in 2012.

It turns out that nearly the same conductive coatings promise to help another company, KLA-Tencor, remove a barrier to commercializing its reflective electron beam lithography nanowriter system. The system uses a digital pattern generator chip to independently control a million electron beams at the same time; the idea is to speed up electron beam lithography to make it suitable for high-volume semiconductor manufacturing.

Upon testing the system, however, KLA-Tencor found that the chip quickly becomes electrostatically charged, distorting the patterns being written by the electron beams. Working with KLA-Tencor, Argonne has developed an ALD coating for the chip that permits electrical charges to drain away without distorting the chip's complex nanoscale surface structures or creating an electrical short.

ALD can deposit a wide variety of materials, including oxides, nitrides, sulfides, and metals. Argonne's ALD research program is extending the list of ALD process chemistries to deposit new thin film materials for a broad range of applications. ❁

This research has been supported by the U.S. Department of Energy's Office of High Energy Physics. Work on ALD at Argonne has additionally been funded by the Office of Basic Energy Sciences and Office of Energy Efficiency and Renewable Energy.

MORE

Interested in licensing an Argonne technology? Visit www.anl.gov/technology

ARGONNE IN THE MARKETPLACE

$1.20-$1.67

The return on investment for every federal dollar spent on research and development, depending on the field.

DID YOU KNOW?

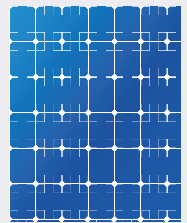
Science-driven technology has been responsible for more than 50% of the growth of the U.S. economy during the last half century.

AVAILABLE FOR LICENSING

An array of technologies based on atomic layer deposition techniques are available for licensing from Argonne. If you're interested in licensing, please contact **partners@anl.gov** or visit **www.anl.gov/technology**.

Microchannel Plates

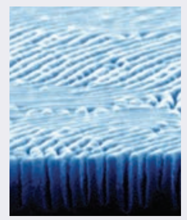
U.S. published patent application # 13/011,645



Transparent Conducting Oxides

ALD can be applied to make indium tin oxide, a transparent conducting oxide used in a variety of processes including photovoltaic cells, flat panel displays, and touch screens. The films produced by the new process are robust, cheaper to make, and can be deposited over large areas on a variety of materials.

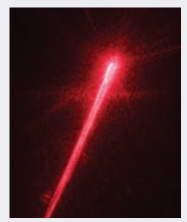
U.S. patent 7,709,056 and US published patent application # 12/895,305



Sequential Infiltration Synthesis for Advanced Lithography

Scientists at Argonne have developed a unique lithography resist transformation process that dramatically improves image quality while reducing cost by eliminating steps in the process. The process does not need an intermediate hard mask layer, reducing cost and complexity, and can be used on a wide variety of materials and chemistries.

U.S. published patent application # 13/427,619

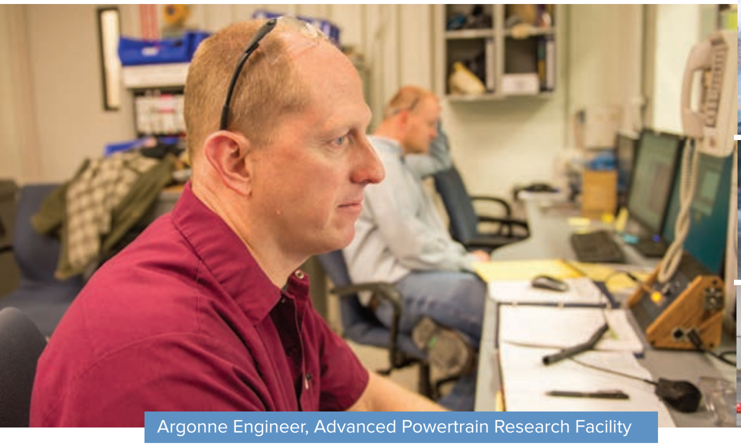


Doping Control by ALD Surface Functionalization

Slowing ALD down lets the researcher grow thinner and more even films, which have exhibited better performance. This method could benefit transparent conducting oxides for solar and photovoltaic cells, laser fibers, dye-sensitized solar cells, heterogeneous catalysts and supports, waveguides for optoelectronics, and large-area solid-state detectors.

U.S. published patent application # 13/370,602

THE *SECRET LIVES* OF SCIENTISTS & ENGINEERS



Argonne Engineer, Advanced Powertrain Research Facility

Top Fuel Dragster Crew Chief, National Hot Rod Association

Meet scientists and engineers from Argonne with unusual hobbies and interests — and how they bring science to bear on them.

MIKE KERN

Argonne Engineer, Advanced Powertrain Research Facility | Top Fuel Dragster Crew Chief, National Hot Rod Association

ARGONNE NOW: What's your day job?

KERN: I'm an engineering technical assistant at Argonne, and I work in the lab's Center for Transportation Research testing and tweaking cars and engines to make them more efficient.

AN: And your other job?

KERN: I'm also crew chief for a top fuel dragster team in the National Hot Rod Association, which is the premier drag racing organization in North America.

AN: How did you get into that?

KERN: I was kind of born into it. My dad owned his own transmission shop and also raced cars growing up, so I traveled all over the country with him—just minor drag racing around the country. These cars are the fastest accelerating vehicles on wheels. In raw numbers, they go from zero to 320 miles per hour in under four seconds.

AN: What's your schedule like?

KERN: Aside from my full-time job here, I work on the car two days a week: Tuesday night and all day Sunday. That's anywhere from 12 to 20 hours a week on the racecar. Plus racing weekends, which are all three-day events—last year we did 10 races—so basically every vacation day I have goes towards racing.

AN: What is the margin of victory in a drag race?

KERN: Thousandths to ten-thousandths of a second. We race to 1,000 feet, and in that distance the cars accelerate from a standing start, zero, to upwards of 320 miles an hour. The national record is 3.72 seconds; we've done a best of 3.83 seconds.

AN: So you miss it if you blink.

KERN: We call it forty hours of preparation for every three seconds down the track.

AN: What does a crew chief do?

KERN: I'm responsible for all the decisions regarding how the car runs on the racetrack. I manage the crew at the racetrack and all the jobs they have. I'm responsible for the whole car getting put together the right way. Between every round of racing, we completely disassemble the engine and put it back together in under an hour.

AN: Why?

KERN: Because the incredible amount of horsepower that the engine generates is stressful on all the components, so we check every component after every run and put the whole engine back together. Now that doesn't mean we take it apart and look at those same pieces right away; we have another set of parts that we put on the car in order to make the next run. But everything that comes off the car gets inspected before it goes back on the car again.

AN: How many times do you have to take the engine apart?

KERN: In a race, there are two days of qualifying, which is two runs per day. And then it's a single-elimination 16-car format on Sunday, so if you win all four runs, you win the race.

AN: What kind of tweaks are you making to the engine?

KERN: Depending on the weather and track conditions, I have to make all the tuning decisions. And within that everything is critical. These are the fastest accelerating cars in the world, so little changes make a big difference. The air temperature and the amount of sunlight affect the amount of traction you can get on the track. The humidity and the air pressure also affect how the engine runs because an engine is basically a giant air pump, in a sense. The more air you can move through the engine, the more fuel you can burn, and the more power you can make—and the quicker and faster the car can be.

AN: Tell us a little bit more about your day job.

KERN: My main job at Argonne is to run our climate-controlled test dynamometer, make sure all the tests get run properly, the instruments are working, and collect the data.

AN: What's a dynamometer?

KERN: A dynamometer is basically a treadmill for a vehicle. It simulates all the stresses of driving on a road you would see in the real world, only in a controlled environment. So we can control temperature, humidity, everything—it's always the same and repeatable. Then we can throw in different variables to see how the vehicle reacts in different situations.

AN: Is it similar to tuning engines for a race?

KERN: In races, the car is fully instrumented, and we collect data from every run and use it to make a decision for the next run, which is the same way you run a lab. The difference is that at Argonne we're more into learning how to conserve energy and not burn fuel, and my other job is burning as much fuel as you can to make as much power as you can. Although they are complete opposites, all the theory is identical. In a race we're trying to run the car at maximum power as efficiently as possible, and at Argonne we're finding what makes vehicles run most efficiently with the least amount of fuel. So, similar but different.

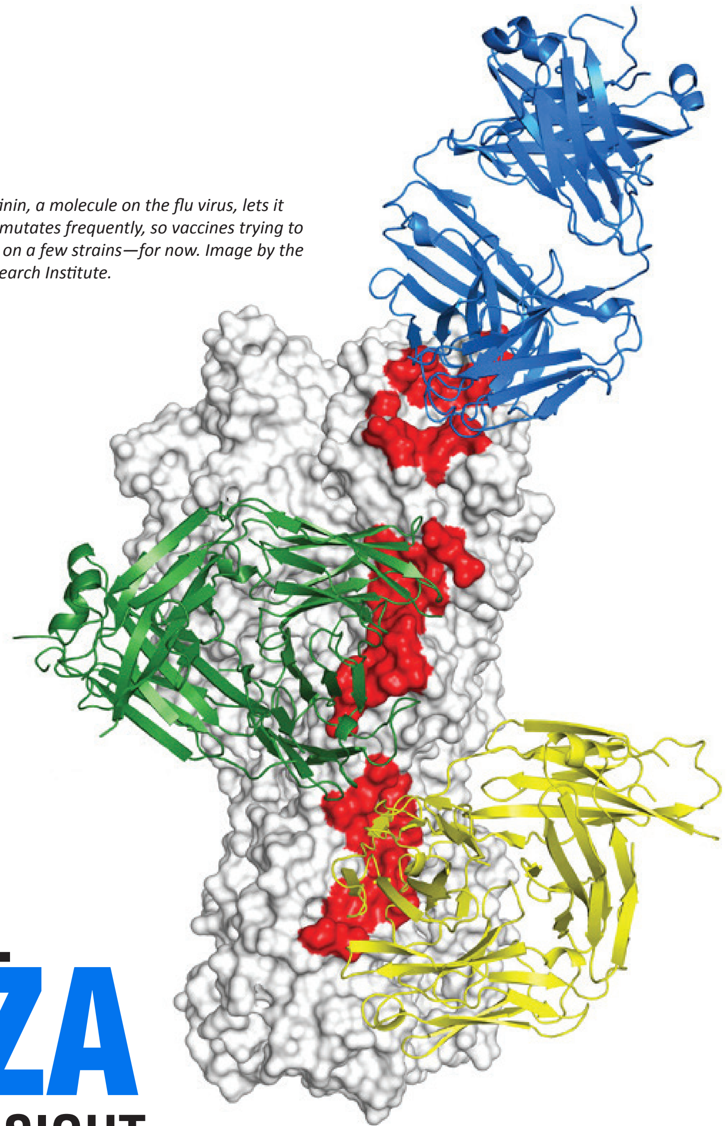
AN: Do you apply things from one job to the other?

KERN: Absolutely. Things I learn and see racing—how to think about a problem, different ways of collecting data and doing tests—I can bring to the lab and say "Hey, I saw this idea," or I can apply the same principles. And some ideas we work with at Argonne—what you see different scientists and engineers changing with an engine—I can take back and apply as different things to do for the racecar.

AN: Do your coworkers at Argonne come out to races?

KERN: They do. They think it's really cool.

Every issue, we take a look at Argonne research on a different human disease or condition.



The structure of hemagglutinin, a molecule on the flu virus, lets it invade your body's cells. It mutates frequently, so vaccines trying to block the protein only work on a few strains—for now. Image by the Wilson Lab/The Scripps Research Institute.

UNIVERSAL INFLUENZA

VACCINE POTENTIALLY IN SIGHT

by Tona Kunz

The fall ritual of getting an annual influenza shot could join castor oil on the list of bygone remedies within a decade, some scientists say. And as that tradition fades away, so too will our fears of the virus mutating into a global pandemic.

To many, the concept of a world free from the coughs and fevers brought on by influenza sounds improbable—impossible, even.

If you listen to media reports, influenza seems to be gaining strength. In 2009, swine flu reached pandemic levels in the human population, while avian flu killed millions of birds worldwide. In 2012, a new strain of swine flu sickened children attending a state fair. And early this year, the virus rose for two consecutive weeks to epidemic levels, with 7.3% of deaths attributed to influenza or pneumonia.

By anyone's scorekeeping, influenza is winning.

Yet technology and dogged determination have given scientists a fighting chance and renewed optimism. During research over the last several years at the Advanced Photon Source at Argonne, two teams of scientists closed on what they suspect is the virus's Achilles' heel.

"There is a lot of hope that a universal flu vaccine is not as far off as we used to think," said Damian Ekiert, a research scientist at the University of California, San Francisco.

1918 THE FLU COMES TO CHICAGO

St. Louis Red Cross Motor Corps on duty in October, 1918 during the influenza epidemic. (Photo: Library of Congress)

The 1918 flu pandemic spread during the height of World War I, probably hitching a ride into the center of the U.S. along with troops as they were stationed at new military bases. It arrived at the Great Lakes Naval Air Station on September 18, 1918. People in Evanston and Wilmette began to sicken two days later. The city ordered public places like dance halls and ice rinks to shut their doors. By November's end, the pandemic had killed at least 8,500 people in Chicago and sickened 51,000.

Insight into how the virus works—and where it is collectively weakest—came out of a mix of research that combines computer modeling of the virus and X-ray crystallography to unravel the structure of individual proteins in the virus. These proteins often contain thousands of atoms tightly interwoven in a seemingly random pattern, like the world's most challenging knot. To identify a protein that could serve as a target for new pharmaceuticals, scientists have to puzzle out how the atoms and their bonds fit together and identify vulnerable sites where the immune system could target.

"Tools developed here were crucial for the collection of high-quality diffraction data," Ekiert said. "Several of the structures would have been difficult or perhaps impossible to obtain at many other beamlines."

Our immune system fights viral infections by creating antibodies that attach to proteins on the surface of the virus and block its ability to enter a healthy cell. However, influenza has many subtypes, or strains, and the virus mutates quickly, so researchers have to predict which strains are most likely to spread that year and create a flu shot for those viruses.

Decades of research have revealed that the most effective antibodies target a protein called hemagglutinin. Hemagglutinins are the molecules on the flu virus that let it invade the cells of respiratory passages. These flower bouquet-shaped proteins are common targets for influenza vaccinations, which aim to block the hemagglutinin from latching onto healthy cells. Each strain of influenza has a slightly different hemagglutinin. Current vaccinations work on just a small subset of strains—so if the virus mutates, the vaccination fails.

In order to overcome this variability among influenza virus strains, a team of researchers at the Dutch biotechnology company Crucell set out to identify antibodies that worked against several strains.

Ekiert, then a graduate student in Ian Wilson's laboratory at The Scripps Research Institute, got the task of identifying which spot on hemagglutinin the antibodies were targeting.

Using the high-energy X-ray beam at the Advanced Photon Source, Ekiert determined the structure of several antibodies bound to the hemagglutinin protein. Remarkably, the structures revealed that while the head of the protein changed with each substrain of influenza, the antibodies bound to a region on the stem that remains essentially the same in all strains and subtypes.

It was a discovery that has changed the direction of influenza research. Now several teams of scientists are starting to find antibodies that neutralize an entire group—or even all the flu strains—instead of focusing on a single seasonal form.

The early results are good. The new attack strategies could very well shift the balance of power to humanity and away from a virus that, in its 1918 incarnation, killed millions of people around the world.

One of the tools that gave Ekiert the upper hand against this virus, which others have studied for decades, was the invention of techniques such as a micron-sized X-ray beam and automated computerized rastering at an Advanced Photon Source beamline called the General Medical Sciences and Cancer Institutes Structural Biology Facility. That unique tool allows scientists to quickly scan the landscape of a biological sample and hone in on a smaller area for scrutiny than ever before. It's as if on Ekiert's mission to scout out the best way that the immune system can attack the virus, he was given super binoculars. Ekiert admitted that this gave him an edge.

"Tools developed here were crucial for the collection of high-quality diffraction data," Ekiert said. "Several of the structures would have been difficult or perhaps impossible to obtain at many other beamlines."

The micro-X-ray beam allowed him to see how the antibodies bind to the hemagglutinin protein—and thus how >>

they are so effective at neutralizing the virus.

Three of the most promising advances stem from this APS research.

Industrial research partners at Crucell Vaccine Institute have been developing these antibodies into new therapies for influenza, including human clinical trials.

A research team led by Wilson has now found multiple human monoclonal antibodies that bind to the portions of the hemagglutinin that protect against infection from several influenza strains.

Another very promising area of research led by University of Washington professor David Baker uses computer modeling to design proteins from scratch that will bind to the virus to keep it from entering a healthy cell. Baker has successfully made proteins that bind to all types of a particular group of hemagglutinins, which includes the strains H1, or swine flu; H5, or avian flu; and H2, or Asian flu. Baker plans to create a database of proteins that would fight potential mutations of various influenza strains. This would save scientists valuable time by not having to grow protein samples, sort through hundreds of potential drug proteins, and then find a live virus to test them against. Instead, these designed proteins could be tested with advanced computer modeling and stored in a database accessible to drug manufacturers.

A universal vaccine would change the way influenza shots are manufactured. No longer would companies have to wait for the first wave of infection to start designing an antibody. People would be protected from childhood on, ideally with one shot and one or two boosters in adulthood. Influenza would become like polio or whooping cough or measles: a serial killer rendered powerless by the use of preventative medicine.

Just like ending any war, victory over influenza would send ripples through national economies. Each year in the United States, about 10% of the population gets sick from the influenza virus; 36,000 die. Hospitalization related to influenza costs the U.S. about $10 billion annually.

Ekiert thinks advances in high-energy X-ray technology might accelerate studies that could reveal similar commonalities in other stubborn viruses and potentially unlock new treatments.

"You could imagine trying to take this approach to target any pathogen that mutates or has been difficult to design a vaccine for, such as tuberculosis, malaria, or HIV," he says.

The Advanced Photon Source is supported by the U.S. Department of Energy's Office of Science. The General Medical Sciences and Cancer Institutes Structural Biology Facility is supported by the National Institute of Health's National Institute of General Medical Sciences and the National Cancer Institute. The research was also supported by university collaborators.

MORE
More on research at the Advanced Photon Source: aps.anl.gov

DID YOU KNOW?

In the last 10 years, the U.S. installed 46,000 megawatts of wind power capacity.

That's the equivalent of about 200 coal plants.

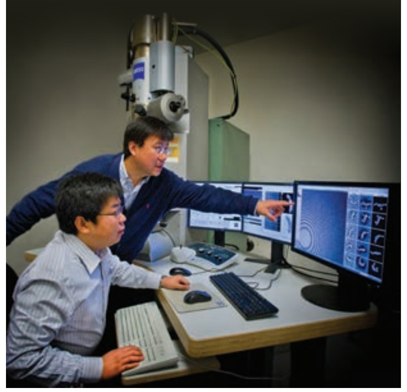
NATIONAL LAB
BREAKTHROUGHS

BAD Cholesterol, GOOD Cholesterol

Cholesterol is a molecule that can be carried in either high-density lipoproteins (HDLs, or "good" cholesterols) or low-density lipoproteins (LDLs, or "bad" cholesterols). Thanks to advanced nanoscale imaging and techniques, researchers at Lawrence Berkeley National Lab imaged a protein that acts as a tunnel between the two types, transferring cholesterol molecules over to LDLs. Scientists are exploring ways to keep cholesterol from transferring into LDLs, so this new information could be quite useful for drug treatments in the future.

In fact, U.S. national lab research was the first to identify the good and bad sides of cholesterol back in the 1960s. Today, diagnostic tests that detect both types of cholesterol save lives.

Gang Ren and Lei Zhang at Berkeley Lab's Molecular Foundry were part of a team that found new evidence to explain how cholesterol is moved from HDLs to LDLs.



SOMETHING NEW UNDER THE SUN

by Diana Anderson

Argonne grew a fine crop of solar panels last summer. The lab built a 95-kilowatt solar farm onsite, which powers the laboratory's emergency operations center and saves about $9,400 and 94 metric tons of greenhouse gas emissions annually. The solar array doubles as a test bed for scientific research.

Argonne nanoscientist Seth Darling is using the new solar array to study how various types of solar panels perform in the Midwest region. "There's an absence of good, objective comparative data on real-world solar panel performance, particularly in the Midwest," said Darling. "That sort of information is good for everyone to have—homeowners, business owners, and so on."

Argonne has already partnered with the Illinois Tollway for several renewable energy projects, including multiple solar panel technologies located at the Tollway's Downers Grove headquarters. They are testing how solar technologies perform in the Midwest region under various environmental conditions.

"We're using six different types of panel technologies in our research partnership with the Illinois Tollway," said Darling. "So we're getting some great data, but not very strong statistics because there's only a small number of panels of each type in the study."

To alleviate this problem, Darling worked with Argonne sustainability manager Devin Hodge to install an onsite array that is more than ten times larger than the array located at the Tollway's headquarters and uses three different types of panel technologies.

"Argonne's larger solar array will enable us to collect more reliable data," said Darling. "We've also set up lots of weather data-gathering technology stations as part of the solar array."

The study is also recording weather data, which helps scientists calculate important statistics, like how much of the available sunlight a panel is capturing. Each solar panel is equipped with a temperature sensor, and the site has dynamometers to measure wind and pyrometers to measure sunlight, or "insolation"—the measure of solar radiation energy received on a surface area.

"We'd like to determine which types of panels perform better in higher or lower levels of light, and, most importantly, the real cost is per unit of electricity generated from each one," said Darling.

Argonne is collaborating with the U.S. Air Force on this research.

MORE
Read more about Argonne's sustainability program at blogs.anl.gov/greenlab

ASK A SCIENTIST

FORREST JEHLIK, MECHANICAL ENGINEER

Does ethanol extend or decrease your gas mileage?

—Tommy Holly, via Facebook

JEHLIK: In a one-to-one comparison in a regular engine, ethanol will decrease your mileage. This is because the energy content of a gallon of ethanol is lower than the energy in a gallon of gasoline—it only has about 70% of the energy. The reason why is purely chemical: the chemical bonds in ethanol store less energy than those in gasoline.

However, ethanol does have some characteristics that we engineers can take advantage of to make more power, decrease the energy loss, and make ethanol a fine fuel for a number of applications. In fact, in low concentrations, it can actually increase efficiency. There's lots of research going on here and elsewhere to optimize engines to take advantage of that. However, if the ethanol concentration gets too high, you start to lose that advantage.

I actually worked on a renewable-fuel racecar that used ethanol, and it definitely improved the performance—while being largely sustainable.

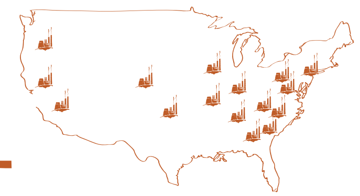
(WE DID NEED A BIGGER TANK, THOUGH.)

You might ask: what does "sustainable" mean? One of my colleagues, Michael Wang, is an expert on what we call "well-to-wheels" analysis—looking at the whole picture of a fuel, including land use, water use, energy to process the fuel, etc. In our racecar we used ethanol from waste biomatter (leftover wheat straw from a farm). We ran the numbers through Michael's model and found that using that fuel in our car reduced overall carbon dioxide emissions by 75%. Same with petroleum use. We were happy about that.

Do you have a question you've always wanted to ask a scientist? *Send it to* ***argonnenow@anl.gov*** *or join us for one of our occasional Ask a Scientist series on Facebook:* ***facebook.com/argonne.***

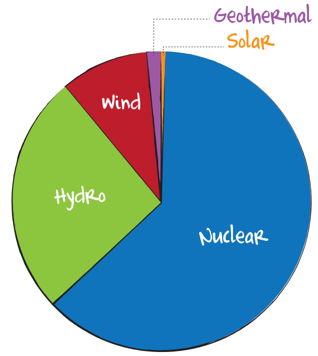
NUCLEAR ENERGY

1 pound of uranium provides the same amount of energy as 10 tons of coal.



104 reactors are operating in the U.S. today—more than any other nation. We get 20% of our energy from nuclear energy.

We've avoided releasing 3,000,000,000 tons of carbon dioxide in the U.S. since 1970 thanks to nuclear energy.



63% of the carbon-free energy produced in the U.S. is from nuclear power plants.

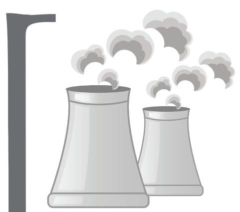
* Source: U.S. Energy Information Administration

48% of Illinois's electricity comes from nuclear energy. If you live in Chicago, it's closer to 80%.

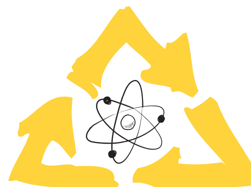
ENERGY USED

By recycling nuclear fuel and burning it again in advanced reactors, we could extract 100 times more energy from the same amount of uranium and reduce the volume of waste we have to store permanently by 95%.

VOLUME OF NUCLEAR WASTE



No new nuclear plants have been built in the U.S. in decades, but utilities have become much more efficient at operating them—the equivalent of adding 38 new reactors.



The equivalent of 14,000 nuclear warheads has been recycled into American nuclear reactors for energy. The dismantled Soviet warheads provide about 10% of America's electricity. The U.S.-Russian program has recycled 352 tons of highly enriched uranium since it began.

Science Behind the Fiction

by Louise Lerner

Science Behind the Fiction critiques the science portrayed in popular films and literature. In this issue, Argonne nuclear scientist Keith Bradley debunks the "fusion" bomb in *The Dark Knight Rises*, the final installment in Christopher Nolan's Batman trilogy.

"Theatricality and deception are powerful agents to the uninitiated," says the villain Bane, Batman's rather eloquent enemy in *The Dark Night Rises*. But ironically, Bane's most terrifying threat—a fusion reactor crafted by a captive scientist into a "four-megaton nuclear bomb"—is itself a deception. It wouldn't work.

Argonne physicist Keith Bradley knows a few things about fusion and bombs: He's worked both as a weapons designer and in fusion research at Lawrence Livermore National Laboratory. (He also knows a bit about Hollywood: he was born there.)

"That scenario could never happen," Bradley said. "Basically, The Dark Knight Rises confuses fission and fusion."

There are two ways to get enormous energy out of atomic nuclei. One is by splitting heavy atoms apart: a process called fission. That's what today's nuclear reactors do. But light nuclei also give off energy when you combine them. This is fusion, and we haven't mastered it.

Controlled fusion would be a huge breakthrough, if we could figure out how to produce more energy than we put into the reaction. It's cleaner than fission and doesn't require fossil fuels.

That's why it's a big deal when Bruce Wayne's company builds a working fusion reactor in the movie. When Bane gets ahold of the reactor, however, he orders a captured scientist to recraft it into a nuclear weapon.

But an additional attractive thing about fusion energy is that it's really, really hard to make into a weapon.

"It's impossible to reconfigure even today's fission reactors into atomic bombs," Bradley said. "But it's even more ridiculous to think that one could convert a fusion reactor into a bomb."

Fusion doesn't proceed from a nuclear chain reaction like fission. That makes it extremely difficult to weaponize.

It takes a tremendous amount of energy to combine atoms, even the light hydrogen atoms in fusion research. "If you turn off a fusion reactor and walk away, it will just quickly run out of fuel and stop," Bradley said.

"Think of it like this," Bradley said. "Say you put two matches down on a table next to each other. They're not going to spontaneously burst into flame, right? That's like fusion. The matches will just sit there. You have to put an enormous amount of energy into the equation first—that is, you have to strike one of the matches."

Even though Batman's reactor-turned-bomb is never detonated, Bane explains that the reactor is "decaying" and will go off by itself in five months because it's so unstable.

As we've already learned, fusion reactions are inherently stable. The fuel itself can't melt down, because it's in gas form. More importantly, it can't be reconfigured into an unstable situation.

"Decaying would make a fusion reactor harder to ignite, not easier," Bradley said. "As the tritium fuel sits around, it decays into helium, which is even more difficult to ignite."

Oh yeah, and the size of the reactor is a bit of a problem, too.

"Though we have yet to actually produce a fusion reactor here on Earth—our Sun is a fusion reactor—when we eventually do, it will be huge," Bradley said. "The most prominent attempt at a fusion reactor in the U.S., the National Ignition Facility, uses lasers which are more than two football fields long. That's because it takes more than 500 trillion watts to ignite the tiny pellet of fusion gas."

So much for Bruce Wayne's reactor, which is carted around in trucks during the movie.

"It is practically impossible to imagine a fusion reactor that size," Bradley said. "It needs way too much energy to get it started."

Today, Bradley is working in fission research—ways to make current reactors safer, cheaper, and more efficient. He manages programs in advanced modeling and simulation for the U.S. Department of Energy's Office of Nuclear Energy.

"It makes for a great story," Bradley said of the weaponized reactor, "but it does mislead the moviegoer. There are real risks and benefits to this type of technology, but not these. It's too bad it isn't more accurate."

MORE
Learn more about current reactor research at www.ne.anl.gov

RENEWING OUR GRID – POWER FOR THE 21ST CENTURY

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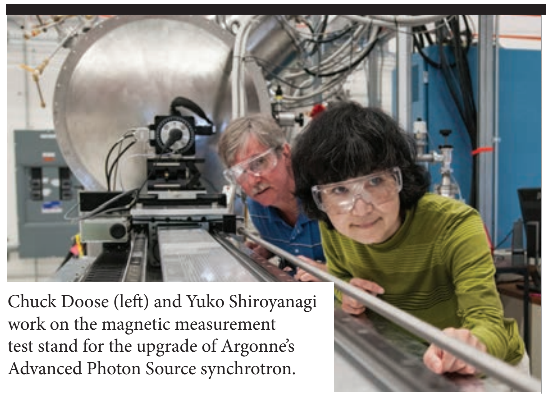
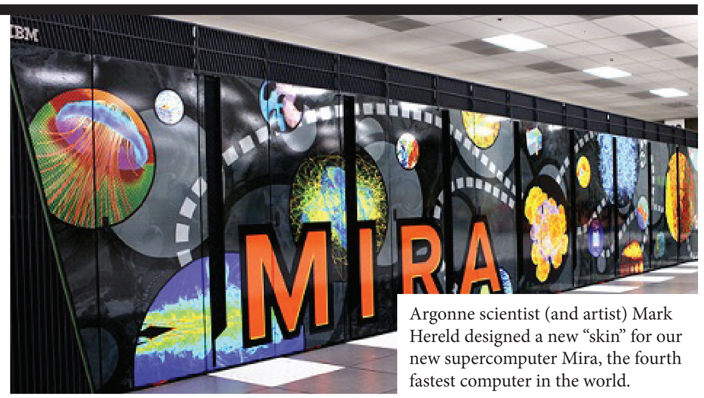
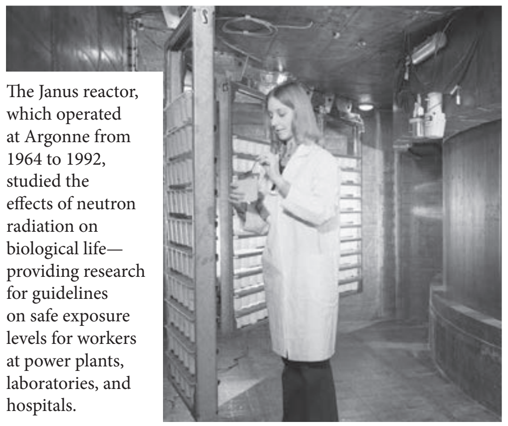


Chuck Doose (left) and Yuko Shiroyanagi work on the magnetic measurement test stand for the upgrade of Argonne's Advanced Photon Source synchrotron.



Argonne scientist (and artist) Mark Hereld designed a new "skin" for our new supercomputer Mira, the fourth fastest computer in the world.



The Janus reactor, which operated at Argonne from 1964 to 1992, studied the effects of neutron radiation on biological life—providing research for guidelines on safe exposure levels for workers at power plants, laboratories, and hospitals.

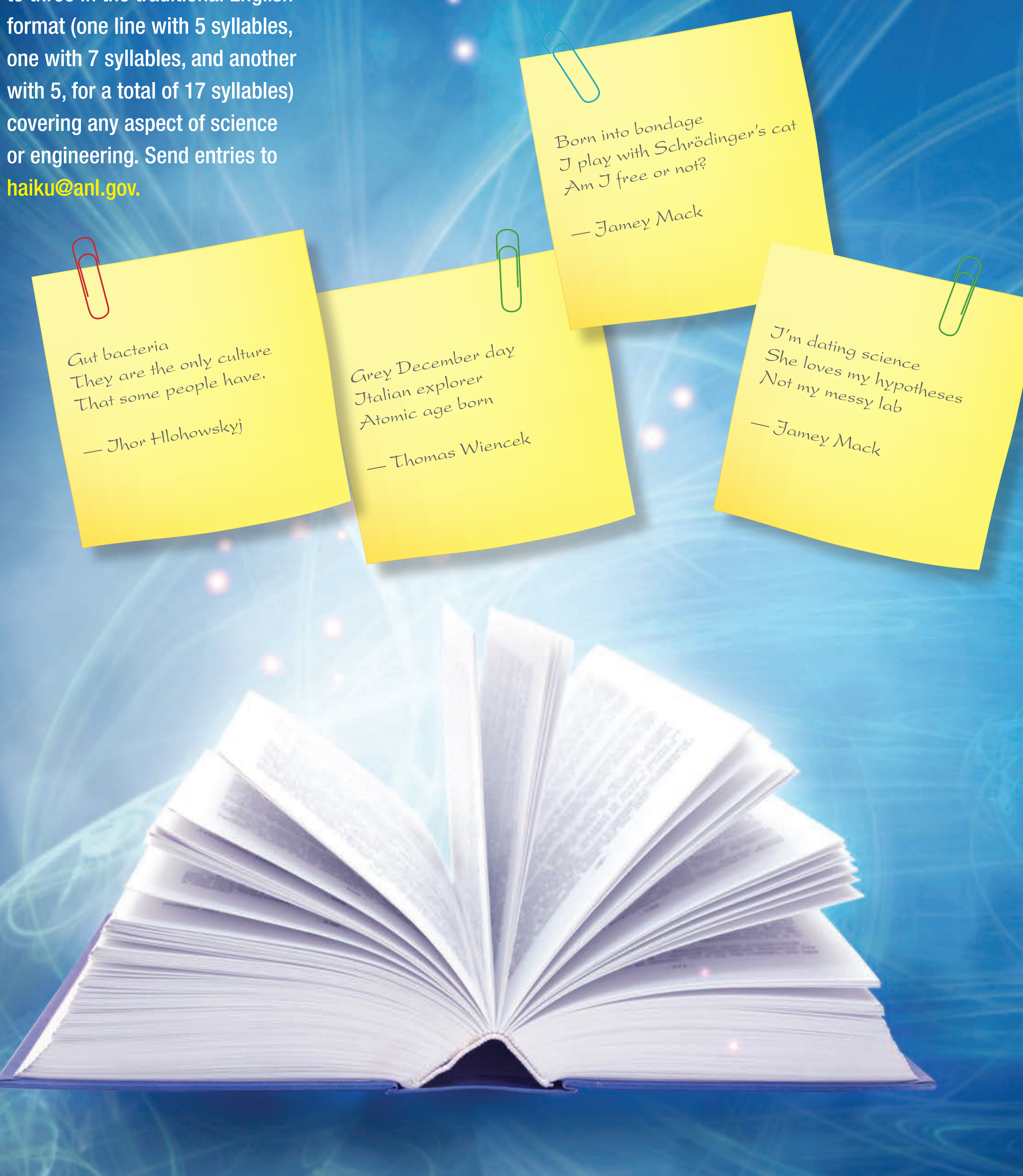
Argonne scientist Magda Tylka performs research on reprocessing nuclear waste inside a glovebox.

Instruments in Argonne's Terahertz Test Facility, such as the one Sami Gopalsami is using, can detect traces of chemicals at the part-per-billion level.

Contestants watch at the annual Rube Goldberg machine contest held for area high schools.

Science Haiku

SEE YOUR HAIKU IN THE NEXT MAGAZINE! The haiku contest is open to all. You may submit up to three in the traditional English format (one line with 5 syllables, one with 7 syllables, and another with 5, for a total of 17 syllables) covering any aspect of science or engineering. Send entries to haiku@anl.gov.



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U.S. DEPARTMENT OF ENERGY

Argonne NATIONAL LABORATORY

This field of cadmium selenide crystals is what scientists discovered when they looked at one of their experiments at the nanoscale level with a scanning electron microscope. The entire field of view is just 500 microns across—the size of a period at the end of a sentence. Studying formations at the nanoscale helps scientists discover new materials for technologies like computer memory and solar cells.

Image by Argonne nanoscientists Arnaud Demortiere and Elena Shevchenko