

OAK RIDGE NATIONAL LABORATORY

Review

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space missions

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your car (and vice versa)

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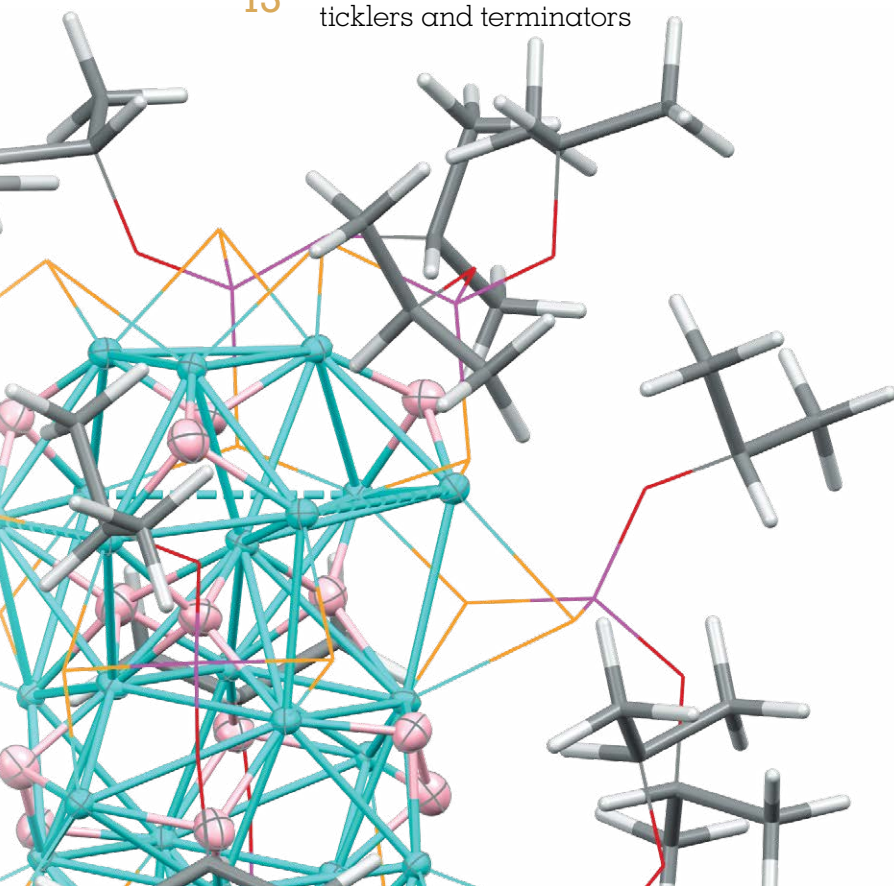
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On the Cover

Diamond anvils and ORNL's Spallation Neutron Source help explain the odd behavior of water inside some of our solar system's gas giants.





Boosting the economy with ORNL tech

As the Department of Energy's largest science and energy laboratory, ORNL has many responsibilities. We promote clean, dependable energy and national security. We build world-class user facilities and make them available to researchers from around the world. We hire talented scientists and nurture their work in materials science, neutron science, nuclear science, computational science, and scores of other critical fields.

We also promote high-tech industries and high-paying jobs. While researchers are understandably proud each time we contribute to fundamental advances in human knowledge, we are just as proud when our technologies create skilled employment and improve people's lives.

In this issue, we highlight ORNL's important role in the regional economy and our contributions to American industry. ORNL works with private businesses in a variety of ways, but two are especially important right now.

The first is a cluster strategy that promotes regional businesses specializing in carbon fiber technology and additive manufacturing. These are particular strengths here at ORNL, and we have collaborated with the state and the University of Tennessee to promote them within the region.

Our efforts have been noticed. The Oak Ridge Carbon Fiber Composites Consortium has grown to more than 50 members, including industry giants BASF, 3M and Dow Chemical. In addition, our combined efforts helped to draw the public-private Institute for Advanced Composites Manufacturing Innovation to East Tennessee, where it will be led by the University of Tennessee at Knoxville while involving partners around the U.S.

The second focus is a technology licensing effort that yields around 70 commercially viable patents each year. These are especially important because while the lab creates valuable technologies, we don't put them to commercial use. Fortunately, we reach licensing agreements with about 20 companies each year, with many licenses encompassing multiple patents.

These successes grow from strong research and development, and each new issue of the Review will update you on recent advances in our fundamental science. For example:

- By using diamonds to create a million atmospheres of pressure, researchers at ORNL's Spallation Neutron Source open the door to new manufacturing technologies and illuminate the workings of planets such as Neptune and Uranus.
- By focusing on responses to changing temperature and carbon dioxide levels, ORNL researchers working in a bog forest in Minnesota show how terrestrial ecosystems respond to varying climates.
- By developing the technology to restart production of plutonium-238, ORNL scientists will give NASA the means to continue exploring the solar system.

These are just a few of the achievements you'll learn about in this issue. In addition, some of our talented graduate students and postdoctoral researchers explain why they chose careers in science, and we talk to accomplished scientists who joined us in recent months to participate in the Eugene P. Wigner Distinguished Lecture Series in Science, Technology, and Policy.

Thanks for keeping up with ORNL and learning more about our impact on the nation and world.



Thomas Mason

Thomas Mason
Laboratory Director

Creating tunable shape-memory polymer

Not all plastics are created equal. Malleable thermoplastics can be easily melted and reused in products such as food containers. Other plastics, called thermosets, are essentially stuck in their final form because of cross-linking chemical bonds that give them their strength for applications such as golf balls and car tires.

"Nobody takes a thermoset and recycles it like you would a water bottle," said ORNL's Orlando Rios.

Rios and a team of researchers from Washington State University and the University of Idaho have developed a process to make a thermoset that can be reshaped and reused. The team's study, published in the journal *Macromolecules*, was featured on the cover of the May 12 issue.

The new plastic is a shape-memory polymer, so named because the material can "remember" its original shape and return to it after being deformed with heat or other forces. The materials exhibit triple-shape memory behavior, meaning that the polymers can transform from one temporary shape to another temporary shape at one temperature, and then back to a permanent shape at another temperature.

For more information: <http://go.usa.gov/3AH34>

'Spiky screws' promising for industrial coatings

It took marine sponges millions of years to perfect their spike-like structures, but research mimicking these formations may soon alter how industrial coatings and 3-D printed objects are produced.

A molecular process developed by ORNL researchers paves the way for improved silica structure design by introducing microscopic, segmented, screw-like spikes that can more effectively bond materials for commercial use.

The study, conducted by Jaswinder Sharma and his colleagues Panos Datskos and David Cullen, has been published in



A new plastic developed by ORNL and Washington State University transforms from its original shape (left) through a series of temporary shapes and returns to its initial form. The shape-shifting process is controlled through changes in temperature. Image credit: Washington State University

Angewandte Chemie International Edition.

Authors said other applications of the screw-like spikes could include coatings for eyeglasses, television screens, commercial transportation and even self-cleaning windows and roofs in rural and urban environments.

Created by emulsion droplets applied to a silica particle's surface, the new, segmented spikes offer an alternative tool for material scientists and engineers that can better maintain and fuse bonds within a variety of microstructures.

Combined with tetraethyl orthosilicate, an additive molecule, the emulsion droplets begin to produce rod-like spikes whose growth can be controlled for silica structures and configured into new materials.

The development of a segmented spike comes as an enhanced version of previous research conducted by the team. Sharma explained that the screw-like shape of these spikes was achieved when temperature control was incorporated with the spike growth on preformed particles.

For more information: <http://go.usa.gov/3AHsF>

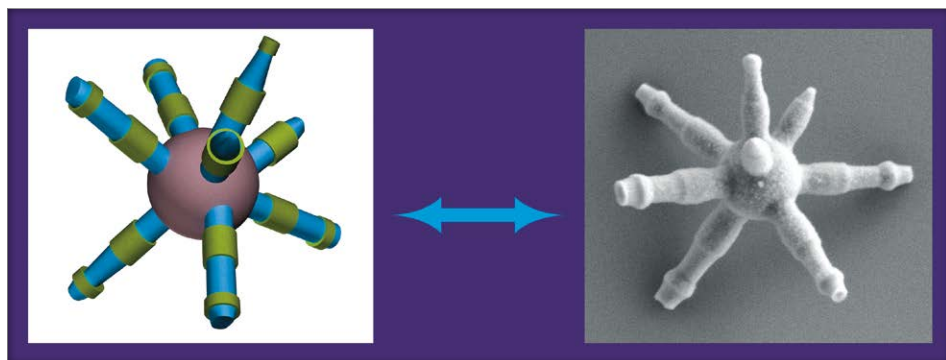
Tool quickly determines if tissue is cancerous

Surgeons could know if a tissue is cancerous while their patients are still on the operating table, according to researchers from ORNL and Brigham and Women's Hospital/Harvard Medical School.

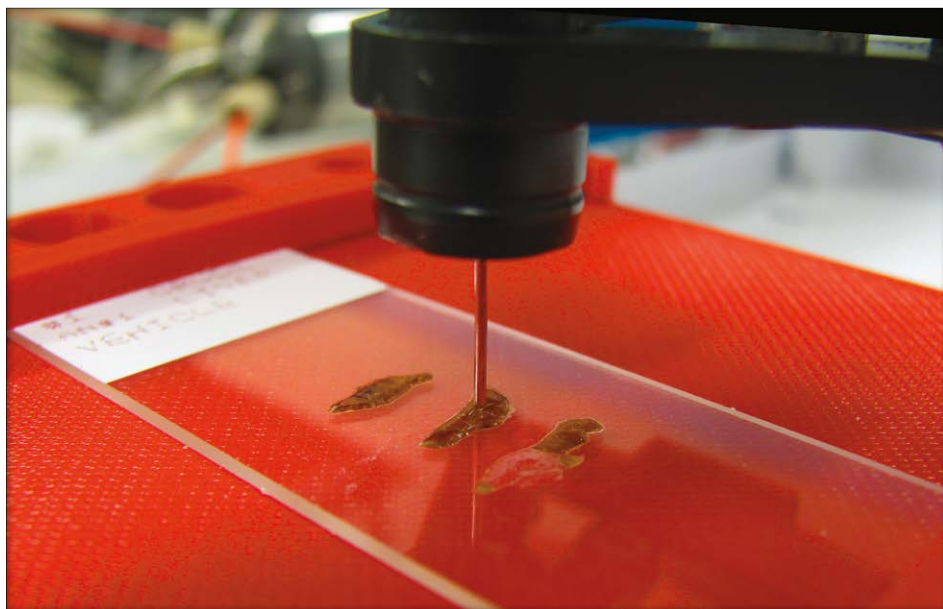
In the journal *Analytical and Bioanalytical Chemistry*, a team led by ORNL's Vilmos Kertesz describes an automated droplet-based surface sampling probe that accomplishes in about 10 minutes what now routinely takes 20 to 30 minutes. Kertesz expects that time to be cut to four or five minutes soon. For this proof-of-concept demonstration, researchers rapidly profiled two hormones from human pituitary tissue.

"Instead of having to cut and mount tissue and wait for a trained pathologist to review the sample under a microscope, a technician might soon perform an equally conclusive test in the operating environment," Kertesz said.

The new mass spectrometry-based technology provides an attractive alternative to the traditional method called immu-



The screw-like spikes grown from a spherical silica particle depicted above may alter the internal strength of materials used in industrial coatings, 3-D printing and other additively manufactured objects. Image credit: Jaswinder Sharma, ORNL



ORNL's new droplet-based surface sampling probe speeds the process of analyzing a liver biopsy sample. Image credit: ORNL

nohistochemistry, or IHC, which looks for specific protein biomarkers to make a diagnosis. Although the IHC approach provides a high degree of spatial recognition, it is time consuming and limited by the quality and specificity of the antibody used to detect the protein.

ORNL researchers trace this success to patents resulting from previously funded Department of Energy projects and note that this work advances the liquid microjunction surface sampling probe technology first patented by ORNL. Additionally, ORNL houses the only laboratories in the world that have this automated droplet-based surface sampling probe and the requisite software.

While yet other mass spectrometry-based techniques such as desorption electrospray ionization and rapid evaporative ionization mass spectrometry are being evaluated for classifying tumors and providing prognostic information, they are limited mainly to the analysis of lower molecular weight biomolecules. These include metabolites, fatty acids and lipids. The new droplet-based method developed at ORNL does not share this limitation.

For more information: <http://go.usa.gov/3AHZk>

New strain of yeast boosts biofuel production

Biofuels pioneer Mascoma LLC and the ORNL-based BioEnergy Science Center have developed a revolutionary strain of yeast that could help significantly accelerate the development of biofuels from nonfood plant matter.

C5 FUEL™ features fermentation and ethanol yields that set a new standard for conversion of biomass sugars from pretreated corn stover—the non-edible portion of corn crops such as the stalk—

converting up to 97 percent of the plant sugars into fuel.

Researchers announced that while conventional yeast leaves more than one-third of the biomass sugars unused in the form of xylose, Mascoma's C5 FUEL™ efficiently converts this xylose into ethanol, and it accomplishes this feat in less than 48 hours. The finding was presented at the 31st International Fuel Ethanol Workshop in Minneapolis in June.

"The ability to partner the combined expertise at Mascoma and BESC in engineering microbes to release and convert sugars from lignocellulosic biomass has greatly accelerated the translation of basic research outcomes to a commercial product," BESC Director Paul Gilna said.

Gilna noted that this success and continued efforts through BESC, one of three DOE BioEnergy Research Centers could go a long way toward reducing the cost of ethanol and growing the number of commercial-level ethanol production plants. A key focus of BESC is to use basic research capabilities and expertise to validate the consolidated bioprocessing approach to improve cost competitiveness.

For more information: <http://go.usa.gov/3AHYR>

Pilot gives businesses access to lab expertise

Small companies in the advanced manufacturing, transportation and



Small businesses can gain access to ORNL resources such as the Manufacturing Demonstration Facility through a new Department of Energy voucher pilot. Image credit: Brittany Piercy, ORNL

building sectors have a new opportunity to partner with ORNL.

ORNL was among five national laboratories selected to participate in a new DOE small business voucher pilot that aims to connect small clean-energy businesses with technical experts and world-class facilities at the national labs.

DOE's Office of Energy Efficiency and Renewable Energy is funding the \$20 million pilot as part of its National Laboratory Impact Initiative. ORNL will receive \$5.6 million to conduct outreach, merit review, and matchmaking efforts for small business projects.

"We're pleased to be given the opportunity to partner with smaller businesses who can take advantage of the world-class facilities at ORNL and other national laboratories across the country," said ORNL's Jhoney Green. "Through this pilot, we will help industry achieve their goals of developing innovative, energy-efficient products and being more competitive in the marketplace, particularly in manufacturing, building and vehicle technologies."

Industrial collaboration has long been a focus for ORNL, which has worked with hundreds of large and small companies in recent decades. The new pilot will expand the lab's ability to make an impact in the private sector by helping small businesses develop, validate and improve their technologies.

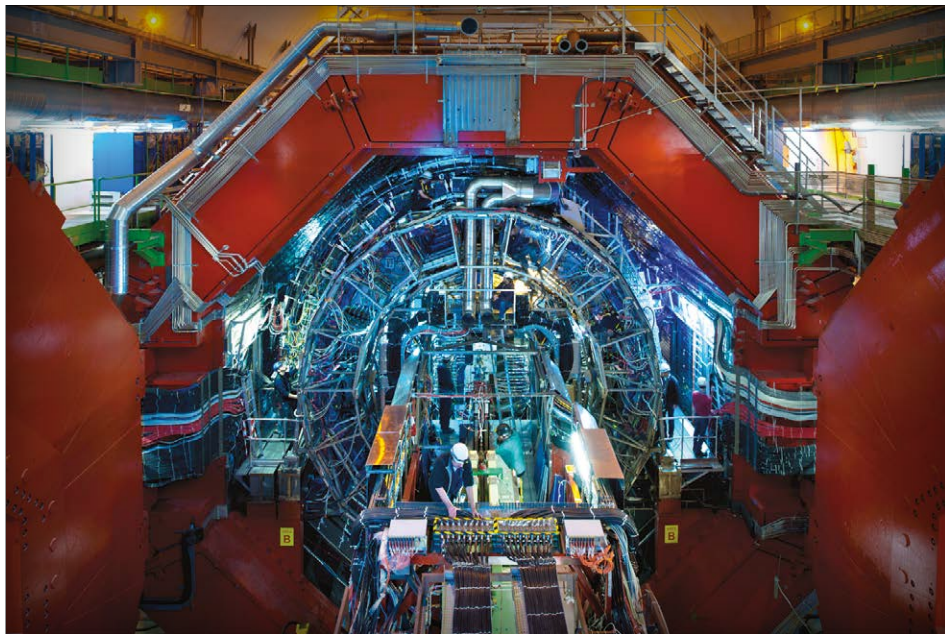
Companies will have access to unique equipment and expertise at ORNL facilities such as the Manufacturing Demonstration Facility, National Transportation Research Center, and Building Technologies Research and Integration Center as part of the pilot.

For more information: <http://go.usa.gov/3AHyF>

ORNL researcher leads LHC upgrade project

Run-2 for the world's most powerful particle collider began earlier this year, with the help of ORNL's Thomas Cormier.

Cormier led an upgrade of the electromagnetic calorimeter used for the Large Hadron Collider's ALICE—short for A Large Ion Collider Experiment—in prepa-



ORNL's Thomas Cormier led an upgrade of the electromagnetic calorimeter used in the LHC's ALICE experiment. Image credit: CERN

ration for the new run. The ALICE detector measures the energies of high-energy electrons and gamma rays emitted from the quark-gluon plasma.

LHC is located at the European Laboratory for Nuclear Research. In LHC, lead ions create tiny samples of matter at energy densities not seen in the universe since microseconds after the Big Bang.

At these densities, ordinary matter melts into its primordial constituents—quarks and gluons that shine brightly at a temperature more than 100,000 times hotter than the center of our sun. Studying the electromagnetic radiation emitted by this plasma as it expands and cools provides insights into the nature of primordial matter.

"When these particles interact with the material from which the calorimeter is built, they undergo what's known as an electromagnetic shower, depositing their full energy in a relatively short distance in the detector," said Cormier, who leads ORNL's LHC Heavy Ion Group. "An electromagnetic calorimeter is designed to measure the energy in these showers. By measuring the energy of these particles, we can determine the temperature of the quark-gluon plasma matter produced."

Detecting particles under the universe's most extreme conditions is a

grand challenge for scientists and engineers. To address that challenge, a team of researchers from U.S. universities and national labs, known as the ALICE-USA Collaboration, designed, deployed and tested 16 large electromagnetic calorimeter super-modules, each weighing 8 tons, for Run-1.

The instruments let scientists explore the theory of the strong interaction, called quantum chromodynamics, which describes how quarks and gluons produced at the Big Bang became confined inside neutrons and protons. At temperatures exceeding 2 trillion kelvins, created in nucleus-nucleus collisions at the LHC, quarks and gluons are freed to travel outside of neutrons and protons in a state analogous to how they existed during the very earliest universe.

For more information: <http://go.usa.gov/3sJjG>

ORNL, Hyundai sign new R&D agreement

ORNL and Hyundai Motor Company have signed an agreement intended to strengthen the automaker's U.S. research and development portfolio.

Hyundai and its affiliate Kia Motors Corp. will identify and provide R&D needs

of the automotive industry; provide feedback and evaluation technology concepts; consult with ORNL on R&D topics related to the industry; and develop potential Hyundai-sponsored projects to be carried out under separate agreements.

As the world's fifth largest automaker, Hyundai Motor Company employs more than 30,000 workers in the U.S., and more than 700,000 Hyundai and Kia vehicles are made in the U.S.

Through this agreement, Hyundai Motor and UT-Battelle, which manages ORNL for DOE, will also work to identify R&D funding opportunities of mutual interest and coordinate meetings to exchange information. Hyundai sees ORNL as providing significant expertise in diverse areas.

The first collaboration is scheduled for this fall with a workshop on materials development and multimaterial joining methods. Additional research areas will be explored as the partnership matures. ORNL will also provide coordination with other national laboratories to pursue best technology and technical expertise.

For more information: <http://go.usa.gov/3su95>

ORNL computing tackles BigNeuron challenge

Researchers will be using ORNL supercomputing to advance the digital reconstruction and analysis of individual neurons in the human brain.

Led by the Allen Institute for Brain Science in Seattle, the BigNeuron project aims to create a common platform for analyzing the three-dimensional structure of neurons.

Mapping the complex structures of individual neurons, which can contain thousands of branches, is a labor-intensive and time-consuming process when done by hand. BigNeuron's goal is to streamline this process of neuronal reconstruction—converting two-dimensional microscope images of neurons into 3-D digital models.

"Neuronal reconstruction is a huge challenge for this field," said ORNL's Arvind Ramanathan. "Unless you understand how these different nerve endings are connected to each other, you're not going to make any sense of how the brain is functioning."

Digital algorithms could help automate the process, but researchers worldwide use different approaches to collect images, manage data and create their models. The BigNeuron collaborators hope to standardize the process and identify which algorithms are best suited for different neuron types, which would accelerate scientists' attempts to map each of the nearly 100 billion neurons in the human brain.

ORNL's Titan, the second most powerful supercomputer in the world, will allow scientists to gauge which algorithms are most effective at reconstruction and tune the codes to take advantage of high-performance computers.

"By bench-testing, we'll get an idea of which ones tend to perform better than others," Ramanathan said. "If Titan were to help even one of these algorithms to run faster or better, then I think that would be a huge win."

For more information: <http://go.usa.gov/3sJrQ>

Institute licenses invention for recovering rare earths

A new technology developed by DOE's Critical Materials Institute that aids in the recycling, recovery and extraction of rare earth minerals has been licensed to U.S. Rare Earths Inc.

The membrane solvent extraction system, invented by CMI partners Oak Ridge and Idaho national laboratories, is the first commercially licensed technology developed through the institute.

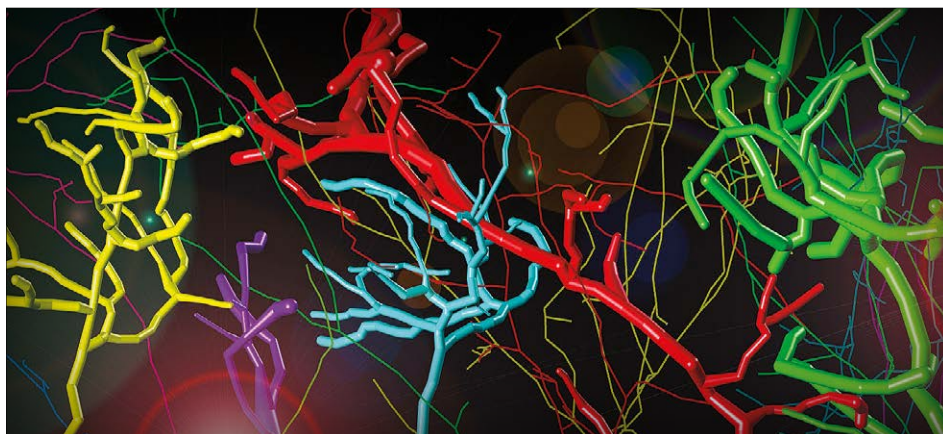
Established in 2013 as a DOE Energy Innovation Hub, CMI explores ways to assure supply chains of materials critical to clean energy technologies such as wind turbines, electric vehicles, efficient lighting and advanced batteries. CMI Director Alex King credits a close collaboration with industry as key to making technology transfer happen well ahead of traditional time frames.

"Going from an idea to a licensed technology in just two years is exactly what CMI is intended to do, and we've proven we can do it," King said.

The recycling of critical materials from electronic waste has been limited by processing technologies that are inefficient, costly and environmentally hazardous. ORNL's Ramesh Bhawe, who led the membrane solvent extraction research and development, says the team's new simplified process eliminates many of these barriers.

"Our single-step process to recover rare-earth elements from scrap magnets is more environmentally friendly and has the potential to be a more cost-effective approach compared to conventional routes such as precipitation," Bhawe said.

For more information: <http://go.usa.gov/3suSP>



BigNeuron, a new project led by the Allen Institute for Brain Science, aims to streamline scientists' ability to create 3-D digital models of neurons. Image credit: Allen Institute for Brain Science

ORNL shares its know-how

by Leo Williams
williamsjl2@ornl.gov

Local Motors CEO Jay Rogers became the first person to drive the first 3-D printed car on September 13, 2014.

Built on site at the International Manufacturing Technology Show in Chicago over the previous six days, the vehicle—known as a Strati—demonstrated the ability of a national laboratory to rapidly develop transformative new technology.

It also underscored the benefits of lab collaboration with private industry. Production of the Strati depended not only on the materials science and advanced manufacturing expertise at ORNL's Manufacturing Demonstration Facility; it also required Ohio manufacturer Cincinnati Inc.'s big-area advanced manufacturing know-how and Local Motors' design skills.

The collaboration did not end with the Strati. For all of ORNL's technology

pro prowess, the lab is not a commercial manufacturer; that job belongs to Local Motors, which is building a "microfactory" for 3-D printed vehicles just a few miles from the MDF.

The company plans to produce "neighborhood" vehicles by early 2016 and

There are a lot of people at the lab who can help make this happen."

ORNL's relationship with Local Motors is especially visible, but it is just one of many that the lab has developed with companies across the United States and even around the world.

"It's not about the money that we get in royalties; it's about the impact that we can have. Every decade there have been billion-dollar impacts, and there's no reason you wouldn't expect that to continue."

—Jim Roberto, ORNL associate lab director, Partnerships

highway-ready vehicles later in the year. Within five years it plans to have 50 such microfactories. These are ambitious goals made possible by the company's collaboration with ORNL.

"Local Motors is going to commercialize this technology," Rogers explained, "but it needs help so we can make it work.

ORNL has actively promoted commercial use of lab-created technology throughout its seven-decade history. The lab made its first shipment of medical isotopes—radioactive materials used to diagnose and treat diseases—in 1946.

These are especially good days for economic development and technology transfer, however. The lab, operated by

Local Motors' microfactory for 3-D printed vehicles is located just down the road from ORNL's Manufacturing Demonstration Facility. Plans call for the factory to be in production by early 2016.
Image credit: Brett Hopwood, ORNL



the University of Tennessee and Battelle Memorial Institute, enjoys strong support from state government and partner institutions as well as ORNL's parent agency—the U.S. Department of Energy. And lab staff actively seek partnerships to improve their research and broaden its reach.

Public funding, public responsibility

For ORNL, the explanation for this approach is simple: a lab created and operated with public funding has a responsibility to share the fruits of its work.

"When we're making the case for taxpayer funding, that's based on a return," explained ORNL Laboratory Director Thom Mason. "There's a promise to society that says, 'If you invest in this research there will be paybacks in terms of improvements to health, improvements to standard of living, improvements to quality of life, improvements to the environment, because of the results of that research.'

"And that promise only becomes real when the research makes its way out of the lab or the university and into the hands of the private sector. We don't make anything. We don't sell anything. We want our research to get into the hands of people who do."

The lab works with private businesses in many ways. At the local and regional level, ORNL collaborates with the state and UT to nurture technology-focused businesses, especially firms that produce or use carbon fiber and those that use additive manufacturing—another term for 3-D printing. Carbon fiber and additive manufacturing are particular strengths for ORNL, and the lab works hard to make life a little easier for companies in these industries doing business in Tennessee.

In the larger economy, ORNL works to get lab-created technologies into the private sector, where they can create and improve lives. Each year the lab receives about 70 patents and enters new licensing agreements with about 20 businesses. In addition, the lab makes its unique facilities available to researchers from private industry. These include the Oak Ridge Leadership Computing Facility, whose Titan system is the world's second-most-

September workshop looks for progress that lasts

When the Brookings Institution decided to explore how national laboratories should approach economic development, their conversations naturally included Thom Mason and his staff at ORNL.

"Clearly, Oak Ridge is a preeminent innovation and tech development source," said Mark Muro, senior fellow with Brookings' Metropolitan Policy Program. "There have been increasing efforts in the last five years to build better tech partnerships and links into the regional industry scene. I think Thom Mason has always had a strong focus on regional tech development."



Mark Muro

Brookings' conversations at ORNL and elsewhere informed its exploration of national laboratories as potential forces for promoting high-tech industry. "Going Local: Connecting the National Labs to their Regions for Innovation and Growth" was published in September 2014. It praises the labs for their potential as economic drivers but faults them for not doing more.

While ORNL took a hit for missed opportunities in the past, it also earned praise for recent efforts and collaborations. These include the RevV! voucher program (in which the state pays for businesses to work with experts at the lab) and the Oak Ridge Carbon Fiber Composites Consortium, whose membership includes industrial giants such as 3M and Dow Chemical.

Brookings' deep dive into economic development goes beyond the labs. The institution has also focused on the auto industry in Tennessee and the space industry in Colorado. It continues the conversation Sept. 15 at a one-day event at ORNL, "Making Innovation Sticky," with about three dozen leaders in business, government and academia, including ORNL's Mason.

"It begins with the idea that this country has a portfolio of strong, innovation-oriented institutions in a lot of regions," Muro noted, "but not always are they well-leveraged or connected to their regional economies. We believe East Tennessee is a great place to look at these issues."

Organizers hope that with the right mix of "thought leaders" in the room, the workshop will have concrete benefits.

"We're hoping for action to put some of the right models into place. Tennessee has already done that. It may be that attendees from other states will pick up ideas."

"We spent a lot of time developing a commercialization strategy for carbon fiber, so we really understand the whole value chain."

—Tom Rogers, ORNL's director of industrial partnerships and economic development

powerful supercomputer, and the Spallation Neutron Source, which provides the most intense pulsed neutron beams in the world to examine materials and biological systems.

Business clusters

In March, the state of Tennessee announced it would provide \$2.5 million

for a voucher program—dubbed RevV!—that allows businesses to collaborate with researchers at the lab.

According to Tom Rogers, ORNL's director of industrial partnerships and economic development, the program shows that Tennessee officials understand

Continued on page 10

ORNL national reach

1. Arcimoto

ORNL tech: AC-DC inverter, battery system charger and DC-DC inverter combine to make charging, storing and supplying electricity more efficient.

Product: Arcimoto 3-wheel electric vehicle (in development)

2. PerkinElmer

ORNL tech: Microfluidic Lab-on-a-chip

Product: LabChip Systems

3. KLA-Tencor

ORNL tech: Wireless Instrumented Silicon Wafer

Product: SensArray Process Probe Wafers

4. Oxford Instruments Asylum Research, Inc.

ORNL tech: Scanning Probe Microscopy

Product: SensArray Process Probe Wafers

5. FWD: Energy, Inc.

ORNL tech: Converts used tire rubber to high value graphite

Product: Conversion process (in development)

6. Da Vinci Emissions Services, LTD

ORNL tech: Determines the amount of fuel dilution in engine oil.

Product: Da Vinci Fuel-In-Oil (DAFIO™) measurement system

7. Dry Surface Technologies, LLC

ORNL tech: Superhydrophobic technology

Product: Barrian™ superhydrophobic additives

8. East View Geospatial

ORNL tech: LandScan Global Population Database

Product: LandScan Global Population Database

9. GE Reuter-Stokes, Inc.

ORNL tech: Radiation detection systems

Product: Scintillation-based neutron scattering detectors

10. SecureWaters

ORNL tech: Water supply monitoring system

Product: AquaSentinel

11. Lambda Technologies

ORNL tech: Microwave polymer curing technology

Product: Variable Frequency Microwave (VFM)

12. R&K Cyber Solutions

ORNL tech: Hyperion cyber security technology

Product: Malware detection technology (in development)

13. RJ Lee Group, Inc.

ORNL tech: Converts used tire rubber to high value graphite

Product: Conversion process (in development)

14. AMSC

ORNL tech: High temperature superconductive materials

Product: Amperium® high temperature superconductor wire

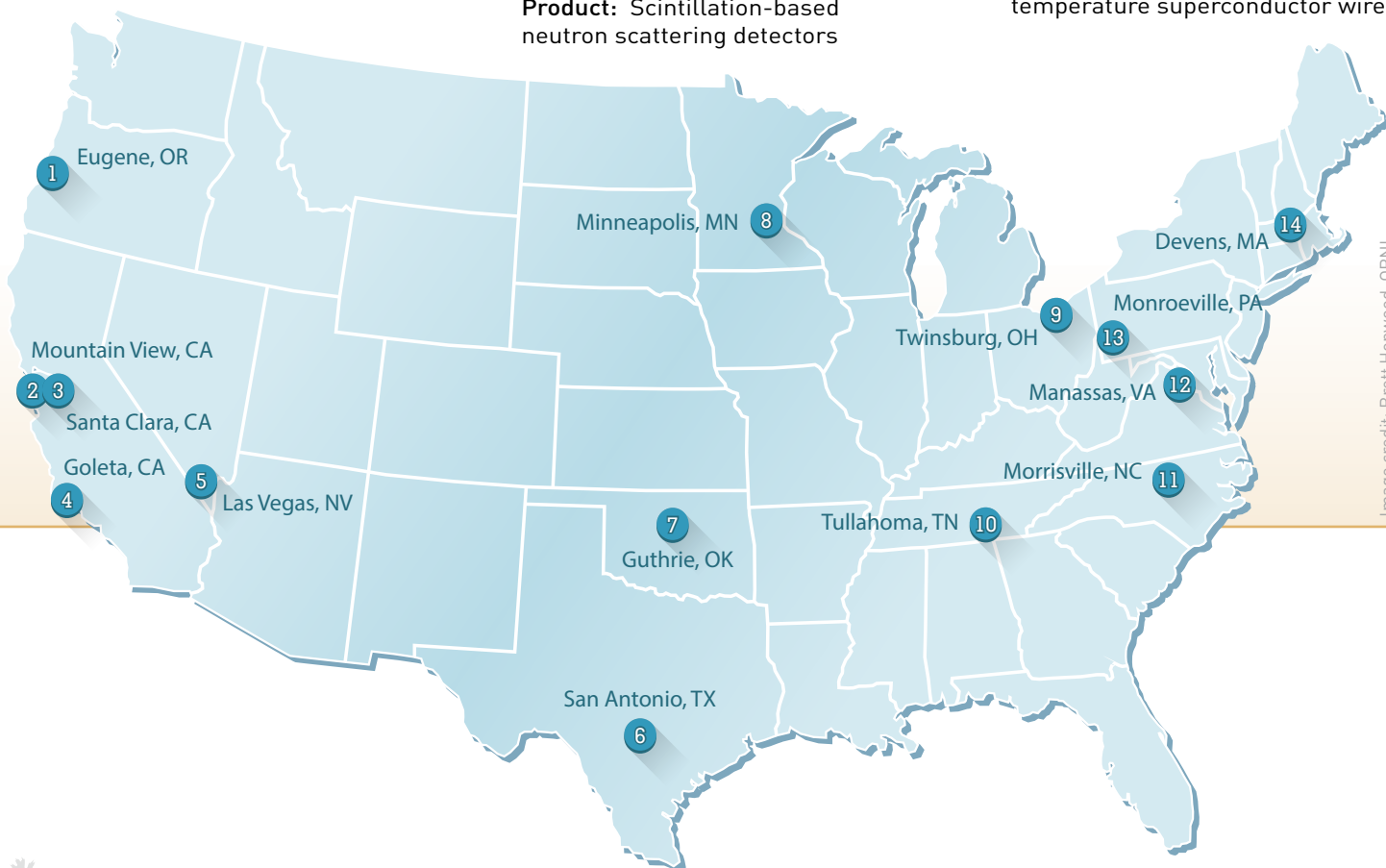


Image credit: Brett Hopwood, ORNL

Technology in the wider economy

Not all of ORNL's commercial partners are in East Tennessee, and not all work in carbon fiber or additive manufacturing. Each year, ORNL researchers identify around 200 inventions and discoveries they believe have commercial application—from sophisticated sensors to data analysis tools to advances in medical diagnostics. Of those, the lab submits about 80 patent applications, about 70 of which are successful.

Mike Paulus, the lab's technology transfer director, credits part of that success to ORNL's Technology Innovation Program, an in-house research and development effort to make technologies ready for prime time.

"I think we're pushing harder," Paulus said. "We're doing a better job of marketing. We're investing in technology maturation via our TIP program. We have a really sharp team of commercialization managers. And I think the lab across the board has emphasized commercial outputs as something they expect. As a result, the researchers are engaging more in the process."

Paulus said the lab reaches licensing deals with about 20 businesses a year, with each license potentially encompassing multiple technologies. While new licensing deals can be exciting, he said a relatively small number of older, established companies provide almost all of

the \$3 million in licensing revenue that come back to ORNL each year.

Companies have an uphill climb even with the most promising technologies. According to Paulus, only one in three new licenses will still be in effect after five years, and the lion's share of ORNL income will come from the top 2 percent.

"Our philosophy is to put as many technologies in play as possible," he explained, "because it is a very competitive world. If you put all your eggs in a few baskets, then it's likely statistics aren't going to work out in your favor."

ORNL tech successes



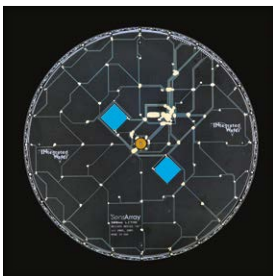
DNA analysis on a chip

Caliper Life Sciences saw the potential for ORNL's Microfluidic Lab-on-a-chip and licensed the technology in 2002. The success of the technology contributed to Waltham, Mass.-based PerkinElmer Inc.'s decision to buy Caliper in 2011 for \$600 million.

The company produces a variety of robust, easy-to-use, miniaturized chips that analyze samples of RNA, DNA, proteins and other compounds down to a few millionths of a liter.

Caliper founders include Mike Ramsey, who was on ORNL's staff

at the time and has since joined the faculty at the University of North Carolina.

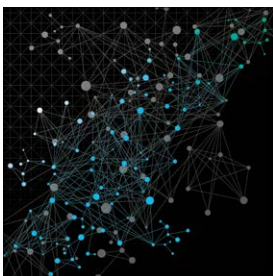


Wireless temperature sensors

SensArray long made tools for measuring temperature uniformity in heating silicon computer chips, but there was a problem: Wires from the sensors were getting in the way and potentially altering the measurements.

The solution came from ORNL's Bob Lauf and Don Bible, who developed technology to transmit the information wirelessly. SensArray licensed their ORNL patent in 2001, and in 2007 the company was purchased by Milpitis, Calif.-based KLA-Tencor.

The company's Process Probe 1730 allows precise measurements from minus-150 degrees to 300 degrees Celsius.



Where is everybody?

ORNL's LandScan is the community standard for global population distribution, producing data at 1 kilometer resolution averaged over 24 hours.

This information is especially valuable for Minneapolis-based East

View Geospatial, which licensed the technology in 2008. East View Geospatial uses LandScan data to provide geospatial information to clients ranging from the energy, avionics, telecommunications and defense

industries to humanitarian organizations and academic institutions.

ORNL shares its know-how

Continued from page 7

ORNL's potential as a magnet for high-tech business.

"We're becoming top-of-mind for our state and regional economic development leaders," he said. "Hardly a week goes by that we don't get a call saying, 'We're recruiting a company, and we think working with the laboratory might be a differentiator for them, and so will you get involved?'"

"When we're making the case for taxpayer funding, that's based on a return. There's a promise to society that says, 'If you invest in this research there will be paybacks in terms of improvements to health, improvements to standard of living, improvements to quality of life, improvements to the environment, because of the results of that research.'"

—ORNL Director Thom Mason

This realization has brought ORNL into some high-profile recruiting efforts, he said, including the siting of an \$800 million plant for South Korean tire maker Hankook Tire in Middle Tennessee that will employ 1,800 people, a new location for Beretta Firearms, also in Middle Tennessee, that will employ 300 people, and most recently a new facility for Cirrus Aircraft in East Tennessee that will create 170 new jobs.

But the focus of ORNL's regional efforts comes from something known as a cluster strategy, first proposed by Michael Porter of Harvard University. The cluster concept is to build a geographic concentration of interconnected businesses, suppliers, and research institutions to increase the capacity for companies to compete, and in so doing create a strong regional competitive advantage. Examples of successful clusters include California's Silicon Valley and North Carolina's Research Triangle.

Carbon fiber: strong, lightweight, good business

Materials based on carbon fiber are wonders: light as plastic and stronger than steel. ORNL's Rogers said they can help the American auto industry meet rigorous fuel economy standards that are

on the horizon. The challenge, he said, is that carbon fiber is expensive to produce, making it a prime candidate for manufacturing innovation.

The cornerstone of ORNL's carbon fiber cluster is the lab's 2-year-old Carbon Fiber Technology Facility, a 42,000-square-foot test manufacturing plant capable of producing 25 tons of carbon fiber each year—small enough to be flexible for R&D but large enough to demonstrate scaling to commercial productivity, typically 500 tons or more.

"What we're doing is leveraging ORNL's capabilities," Rogers explained. "We spent a lot of time developing a commercialization strategy for carbon fiber, so we really understand the whole value chain, from feedstocks, to fibers, to different composites, all the way to end-use applications."

Because of ORNL's expertise, the cluster has gotten the attention of some important players. The Oak Ridge Carbon Fiber Composites Consortium began in 2011 with 14 members and has grown to well over 50, including industry giants such as 3M, BASF, Dow Chemical, General Electric and Ford Motor Company.

ORNL also promotes the cluster by collaborating on workforce training efforts with nearby Roane State Community College.

More recently, President Obama announced in January 2015 that the University of Tennessee at Knoxville will lead the \$250 million Institute for Advanced Composites Manufacturing Innovation—or IACMI—a public-private partnership with substantial backing from DOE. Rogers noted that the carbon fiber consortium will be absorbed into IACMI

Additive manufacturing—progress in three dimensions

Additive manufacturing—once just the 3-D printing of prototypes and hobbyists—has also made it to the big time. To help prove the point, ORNL collaborated with Cincinnati Inc. to print a replica of the classic Shelby Cobra sports car and unveiled it at the 2015 North American International Auto Show in Detroit. Components containing carbon fiber made up more than a third of its 1,400 pounds.

The Shelby was produced at MDF, where ORNL provides tools for designing and evaluating new products, reducing the time taken up by prototyping. Besides additive manufacturing, the facility focuses on technologies such as carbon fiber and composites, lightweight metals processing and magnetic field processing, where strong magnetic fields and high heat are used to improve material properties such as strength and toughness.

ORNL partners with nearby Pellissippi State Community College to provide workforce training in advanced manufacturing, and the University of Tennessee has a Governor's Chair in the field—Sudarsanam Suresh Babu, a materials scientist who serves in the university's Department of Mechanical, Aerospace, and Biomedical Engineering and its Department of Materials Science and Engineering.

Mason pointed to the importance of collaboration among business and government leaders in promoting economic competitiveness.

"I think it makes us stronger as a national lab when we have an innovation ecosystem here," said Mason, long-time chairman of the Knoxville-Oak Ridge Innovation Valley, a regional partnership of economic development groups.

"We have a research university, we have a private sector that's interested in what we're doing and engaged in trying to take our ideas to market," Mason said, pointing out that such partnerships directly benefit ORNL, too. "It helps us serve our national missions." ❁

Who is ORNL's next big tech success story?

Looking forward, there's no reason to doubt ORNL will keep pushing valuable new technologies into the economy. The lab is committed to promoting high-tech industry, and its partners are equally committed.

"It's not about the money that we get in royalties; it's about the impact that we can have," explained Jim Roberto, ORNL's associate laboratory director for science and technology partnerships. "Every decade there have been billion-dollar impacts, and there's no reason you wouldn't expect that to continue."

Here are a few possible breakout companies:



Arena lighting from LED North America

Compact, lightweight arena lighting

Oak Ridge-based LED North America produces the SuperSport 2.0 arena light, which it bills as the smallest, lightest and most technologically advanced arena sport lighting in existence.

The company is able to get such a bright light into such a small package by using graphite foam technology from ORNL, freeing lights from bulky, traditional aluminum heat sinks.

LED North America has installed SuperSport lighting in the University of Tennessee's Thompson-Boling Arena.



Handheld mass spectrometer from 908 Devices

Handheld mass spectrometer

Boston-based 908 Devices has introduced the first genuinely handheld high-pressure mass spectrometer.

Conventional mass spectrometry is usually limited to centralized laboratories because of the size

and fragility of the equipment and the complexity of operating it. The company's M908 device allows first responders and others to immediately detect and identify trace levels of explosives and other chemicals.

The device uses breakthroughs developed by the company's science founder, Michael Ramsey, when he was at ORNL and, later, at the University of North Carolina-Chapel Hill.



The Piranha text-mining tool has a range of applications

Text mining to catch bad guys

The Piranha text-mining tool was developed by researchers at ORNL, who worked with Oak Ridge-based Pro2Serve to commercialize it and create a Pro2Serve subsidiary called Global Security Information Analysts.

The software can look at mountains of text documents and identify relationships between them. It has a wide range of applications, from protecting national security to uncovering health care fraud and identifying child predators.

Piranha, which won an R&D 100 Award, was developed through DOE's Work for Others program.



Patients can now get retinal scans outside the doctor's office

Retinal scans on the go

Hubble Telemedical—recently acquired by Skaneateles Falls, N.Y.-based Welch Allyn—uses technology developed at ORNL and the University of Tennessee to enable retinal screenings in a wide variety of locations.

With retinal imaging, a specialized camera photographs deep within a person's eye to detect conditions ranging from diabetes-related disease to some types of cancer. With the TRIAD Network, patients

and care providers no longer need to be in the same location.



Superhydrophobic coatings repel water using the same principles as this lotus leaf

Coatings reject water

Oklahoma-based Dry Surface Coatings uses an ORNL-developed waterproofing technology to create additives for use in paints, coatings and other materials

The company's founders adopted the superhydrophobic technology through experience with the effect of extreme environmental conditions on energy producers.

The additives protect equipment from water, ice and corrosion.

An isotope for space exploration

by Leo Williams
williamsjl2@ornl.gov

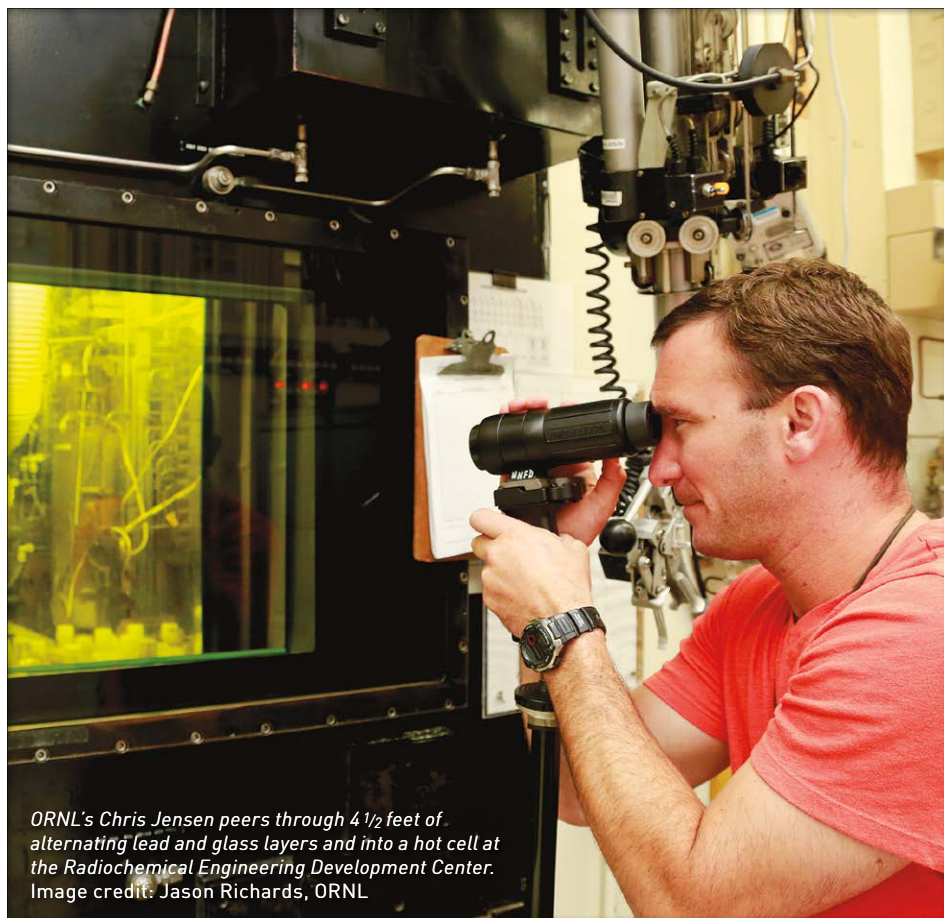
NASA's Voyager 1 spacecraft is impressive for at least two reasons: One, it's the first manmade object ever to leave the solar system, and two, it's still communicating with us 38 years after its 1977 launch.

For the longevity of Voyager and other NASA missions—such as the New Horizons probe that recently gave us a close-up of Pluto—we can thank plutonium-238.

Neither batteries nor solar generators can power decades-long missions to the edge of the solar system and beyond. For that, you need plutonium-238's decay heat, which lets NASA's thermoelectric generators produce electricity over the long haul.

But the United States is running out of plutonium-238. If NASA is to continue exploring the heavens, it will need more.

Plans for producing more rely on two ORNL facilities: the Radiochemical Engineering Development Center, known as REDC, and the High Flux Isotope Reactor, known as HFIR.



ORNL's Chris Jensen peers through 4½ feet of alternating lead and glass layers and into a hot cell at the Radiochemical Engineering Development Center. Image credit: Jason Richards, ORNL

HFIR and Idaho National Laboratory's Advanced Test Reactor will bombard targets containing neptunium-237 with neutrons, and some of those neptunium nuclei will become plutonium-238 nuclei through a process called beta decay.

The targets will be processed at REDC, which is uniquely qualified to perform sophisticated processing of extremely dangerous radioactive materials. According to ORNL's Bob Wham, REDC is the only facility in the country

that could do this work without requiring a major overhaul.

Once the program gets up to speed, it will produce about 1.5 kilograms of plutonium-238 each year, about enough to fill a 16-ounce soda can.

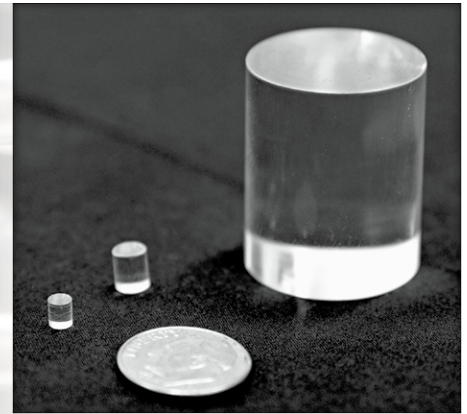
See pages 14 and 15 for a detailed explanation of how plutonium-238 is produced and prepared for NASA missions. 🌱

A manipulator holds up a target that has been bombarded with neutrons. The target will be dissolved, and neptunium and plutonium will be separated and recovered. Image credit: Jason Richards, ORNL

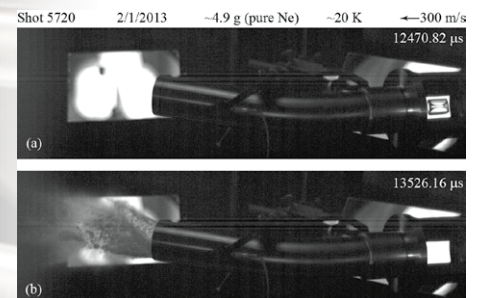




The inside of a pellet selector, which directs pellets to different outputs. Image credit: Jason Richards, ORNL



Models placed next to a dime show pellet sizes for (from left) the tickler, the fueler, and the terminator. Image credit: Carlos Jones, ORNL



High-speed photos show a shattered terminator pellet as it exits the system. Image credit: Stephen Combs, ORNL

Controlling ITER

with fuelers, ticklers and terminators

by Leo Williams
williamsjl2@ornl.gov

When it's up and running, the ITER fusion experimental reactor will be very big and very hot, with more than 800 cubic meters of hydrogen plasma reaching 170 million degrees Celsius. The systems that fuel and control it, on the other hand, will be small and very cold.

ORNL researchers are developing three systems that shoots pellets of frozen

gas into ITER's plasma to keep it fueled and under control. Larry Baylor of ORNL's Plasma Technology and Applications Group calls the systems "fuelers," "ticklers" and "terminators."

"The pellets are much more efficient at fueling the fusion plasma because they can penetrate fairly deep into the hot plasma before being ablated and ionized into additional plasma," Baylor explained.

One system will create the fuelers and ticklers. Fuel pellets will contain two hydrogen isotopes—deuterium and

tritium. About 15,000 will be shot into the lower outside of the donut-shaped plasma each hour.

The same system will produce smaller tickler pellets, which will prevent a fusion reactor's version of damaging solar flares—bits of plasma that peel off and hit the containment wall. They do this by creating a series of smaller flares to diffuse built-up energy.

The third type of pellet is used if the whole plasma becomes unstable and will quench the fusion plasma altogether.

Baylor said the pellet systems will go through final design review during the 2018 federal fiscal year. He expects delivery of the systems to the ITER site in southern France to begin in 2020. 🌱

From Oak Ridge to Pluto and beyond

ORNL helps produce plutonium-238 so that NASA can keep pushing into space.

1 Idaho National Laboratory

- Home to U.S. stockpile of Neptunium-237. Half-life: 2.14 million years.
- Np-237 is sent to ORNL to produce Plutonium-238.



4 Idaho National Laboratory

Final assembly

- The vent sets are loaded into a general purpose heat source that uses the plutonium to reach 600°C (about 1,000°F).
- The heat source is loaded into a Multi-Mission Radioisotope Thermoelectric Generator that uses the heat to create electricity.
- The generators are sent to Kennedy Space Center.



3 Los Alamos National Laboratory

Plutonium fabrication/stockpiling

- Powder is dissolved to remove uranium-234, a decay product of Pu-238.
- New plutonium is blended with stockpiled plutonium to increase the Pu-238 level to 83 percent.
- Powder is converted to an oxide.
- Plutonium is divided into two parts, with one heated to 1,200°C (about 2,200°F) and the other to 1,500°C (about 2,700°F).
- Plutonium is pressed into pellets.
- Pellets are placed in iridium-clad vent sets, which are sent back to INL.



2 Oak Ridge National Laboratory

Preparation

- Np-237 powder is dissolved into a liquid and purified, converted back into a solid, mixed with aluminum, pressed into eraser-sized pellets, and placed into aluminum rods.

Irradiation

- Rods are bombarded with neutrons—some in the beryllium reflector at ORNL's HFIR reactor and some at INEL's Advanced Test Reactor.

Transmutation

- Np-237 nuclei absorb a neutron and become Np-238, which morphs into Pu-238 through beta decay, in which a neutron becomes a proton by emitting an electron and an antineutrino.

Chemical processing

- Targets are cooled for several months to reduce fission products' radioactivity.
- The aluminum rods are dissolved, the targets are placed in nitric acid to dissolve the newly created plutonium and remaining neptunium, and fission products are discarded.
- The neptunium and plutonium are separated out.
- The neptunium stays at ORNL to be reused.
- The plutonium is sent as powder to Los Alamos National Laboratory.

Image credit: Brett Hopwood, ORNL

 **OAK RIDGE**
National Laboratory

2



5

5 Kennedy Space Center

Up, up and away

- The generators fuel NASA missions into space.

The pressure is on

by Leo Williams
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Question: What do you get when you take two surfaces roughly the size of a celery seed and crush them together with 15 tons of force?

Answer: You get pressures approaching those inside planets, allowing you to distort nearly any material beyond recognition.

Researchers with Oak Ridge National Laboratory's Spallation Neutron Source have developed technology to squeeze materials with a million times the pressure of the earth's atmosphere. When they bombard these materials with neutrons, the materials provide an unprecedented picture of the changing nature of matter under extreme pressure.

"The exciting thing about pressure is you can put in so much more energy than you can with temperature," said Bianca Haberl, a Weinberg Fellow at SNS. "That means you can change the atomic bonding so much more."

"The exciting thing about pressure is you can put in so much more energy than you can with temperature."

—ORNL physicist Bianca Haberl

The technology is known as diamond anvil cells. To date, it has helped researchers at SNS explore the odd behavior of water at extreme pressure and the effect of hydrogen on thin films.

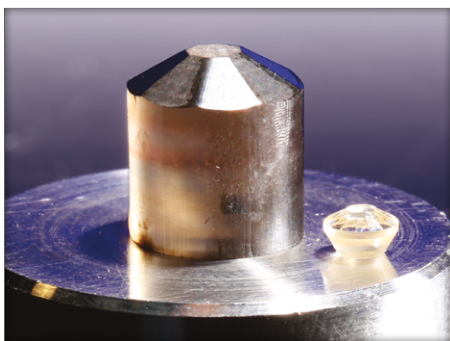
Reinhard Boehler of SNS and the Carnegie Institution of Washington in

Washington, D.C., has been squeezing ice, at least in part to replicate the interiors of planets such as Neptune and Uranus. Haberl, whose background is in materials science, has been using diamond anvils at SNS to study the effects of hydrogen contamination on deposited materials, such as the silicon used in electronics.

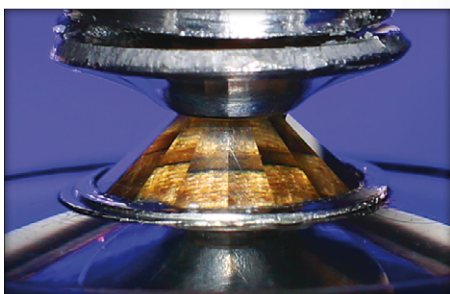
Looking forward, high-pressure research at SNS will expand both to new scientific areas and to other instruments in the facility. Research proposals include studies of pure carbon, hydrogen sulfide

(a promising superconductor), and even heavy elements such as actinides (a group that includes uranium and plutonium). ❄️

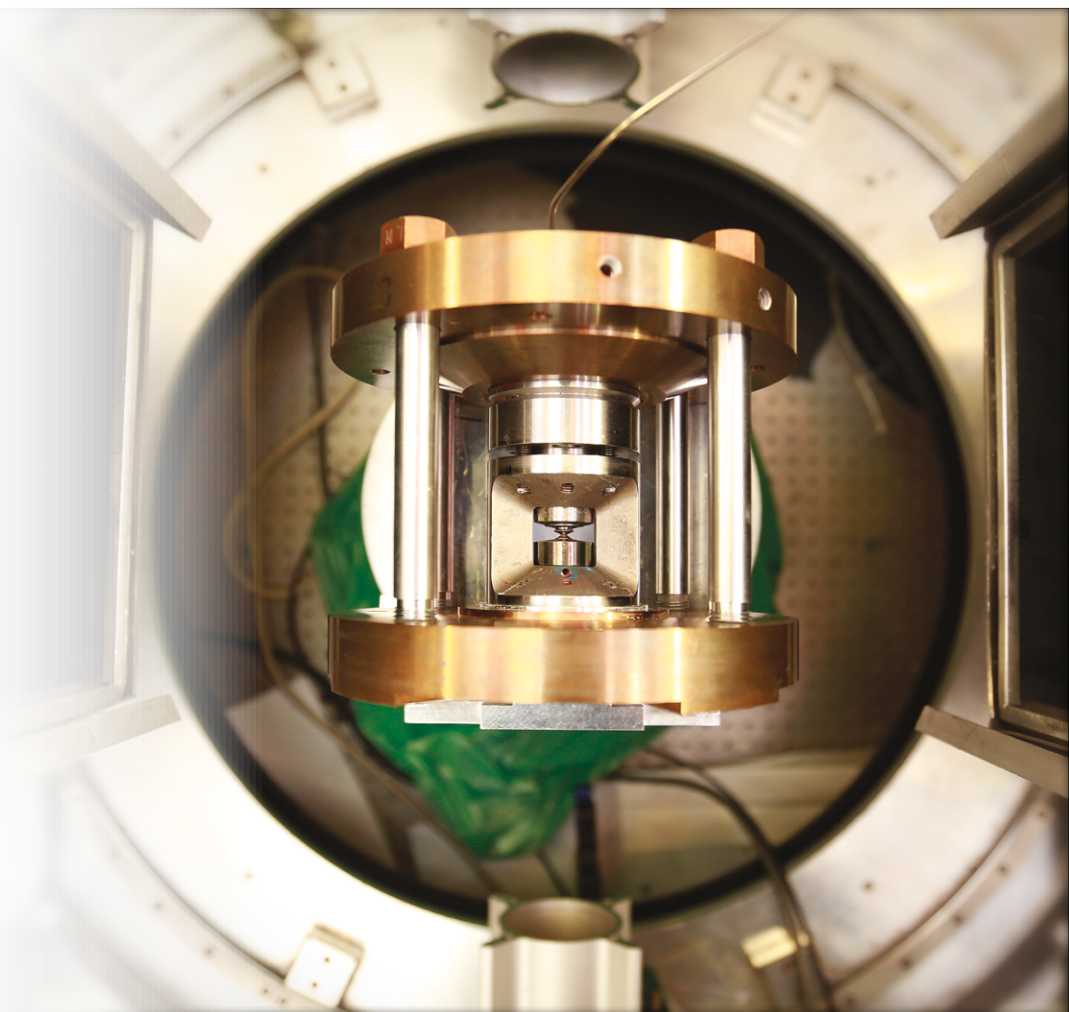
For more information:
<http://go.usa.gov/3HBdJ>

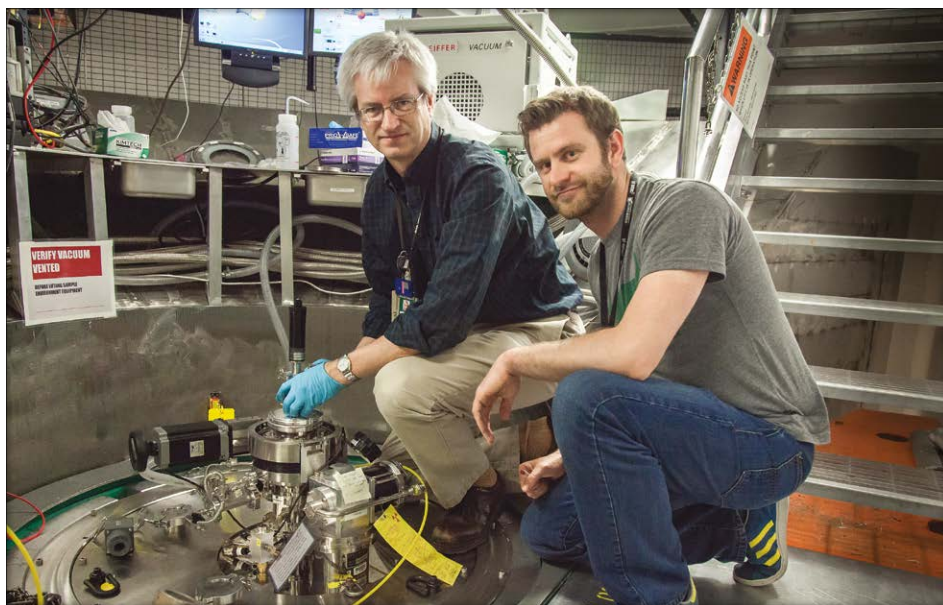


Two diamond anvils side by side. The smaller is 0.3 carats. The larger—11 carats—was cut out of an approximately 20 carat cube of diamond. Image credit: Jason Richards, ORNL



The metal housing of a large-volume neutron diamond anvil cell loaded with ice. The top anvil is covered with a "flapped over" metal disk that is filled with the sample. Image credit: Jason Richards, ORNL





Doug Abernathy, left, of ORNL and Marc Janoschek of Los Alamos National Laboratory prepare a sample for experiments at ORNL's Spallation Neutron Source. Image credit: Genevieve Martin, ORNL

Neutron scientists

explain the magnetism of plutonium

by Jeremy Rumsey
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Plutonium isn't unmagnetic; it's just complicated.

Neutron scattering at ORNL's Spallation Neutron Source enabled researchers from Los Alamos National Laboratory and ORNL to make the first direct measurements of plutonium's fluctuating magnetism. According to Marc Janoschek from Los Alamos, plutonium is not devoid of magnetism, but in fact its magnetism is just in a constant state of flux, making it nearly impossible to detect.

"Plutonium sort of exists between two extremes in its electronic configuration—in what we call a quantum mechanical superposition," Janoschek said.

"Think of the one extreme where the electrons are completely localized around the plutonium ion, which leads to a magnetic moment. But then the electrons

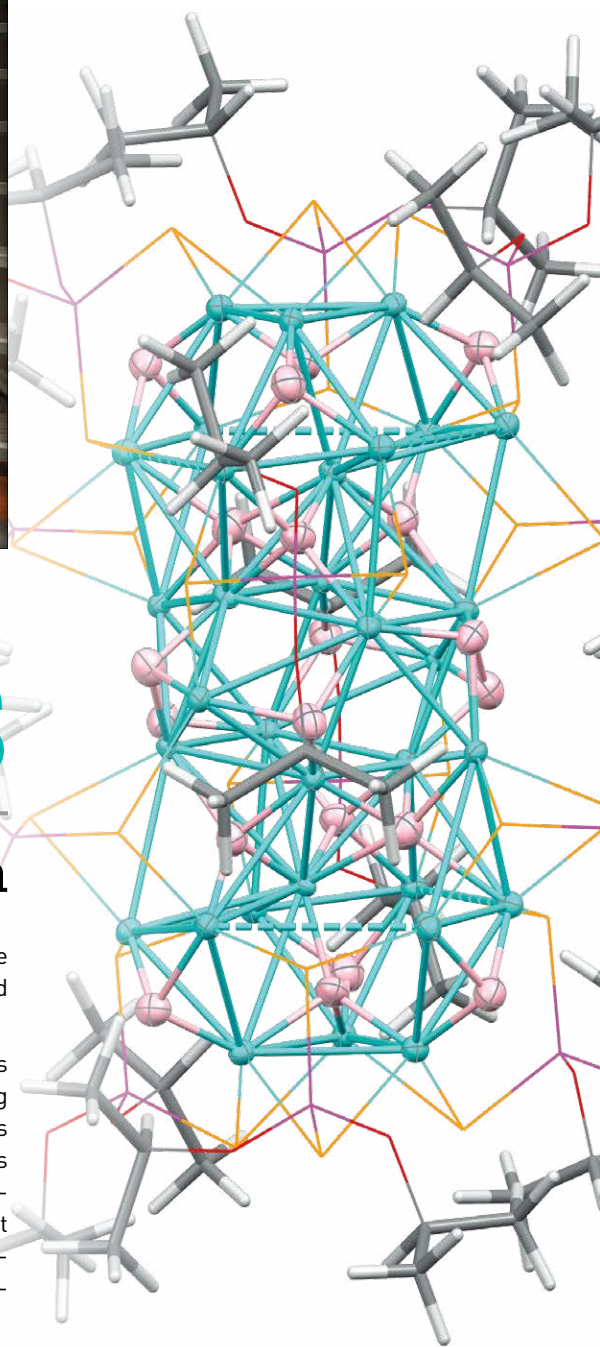
go to the other extreme where they become delocalized and are no longer associated with the same ion anymore."

Scientists have understood plutonium's unstable nucleus for some time, allowing them to use it for nuclear fuels as well as nuclear weapons. But they had a much less certain grasp on the atom's unstable electron cloud. In fact, plutonium is the most electronically complex element in the periodic table, with intriguingly intricate properties for a simple elemental metal.

Using the SNS ARCS instrument, Janoschek and his team determined that the fluctuations have different numbers of electrons in plutonium's outer valence shell—an observation that also explains abnormal changes in plutonium's volume in its different phases.

The researchers discuss their findings in the journal *Science Advances*. 🌱

For more information: <http://go.usa.gov/3GNWF>



Counting hydrogen

ORNL scientists and their collaborators recently used the Spallation Neutron Source to count the hydrogen atoms in a copper nanocluster (seen here). They revealed this synthetic structure has a record number of hydrides (shown in pink) for a discrete metal cluster. For more information: <http://onlinelibrary.wiley.com/enhanced/doi/10.1002/chem.201501122>

Helium ‘balloons’ harness complex materials

by Morgan McCorkle
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ORNL researchers recently discovered that adding a few helium ions into a complex oxide crystal yields an unprecedented level of control over its magnetic and electronic properties—a step toward bringing complex materials into commercial electronics applications.

“By putting a little helium into the material, we’re able to control strain along a single axis,” said ORNL’s Zac Ward, who led the team’s study, published in *Physical Review Letters*. “This type of control wasn’t possible before, and it allows you to tune

material properties with a finesse that we haven’t previously had access to.”

Complex oxide materials are known for their unusual properties such as superconductivity, but they are notoriously challenging to work with.

The intricate way in which electrons are bound inside complex oxides means that any strain—stretching, pulling or pushing of the structure—triggers changes in many

different electronic properties. This ripple effect complicates scientists’ ability to study or make use of the finicky materials.

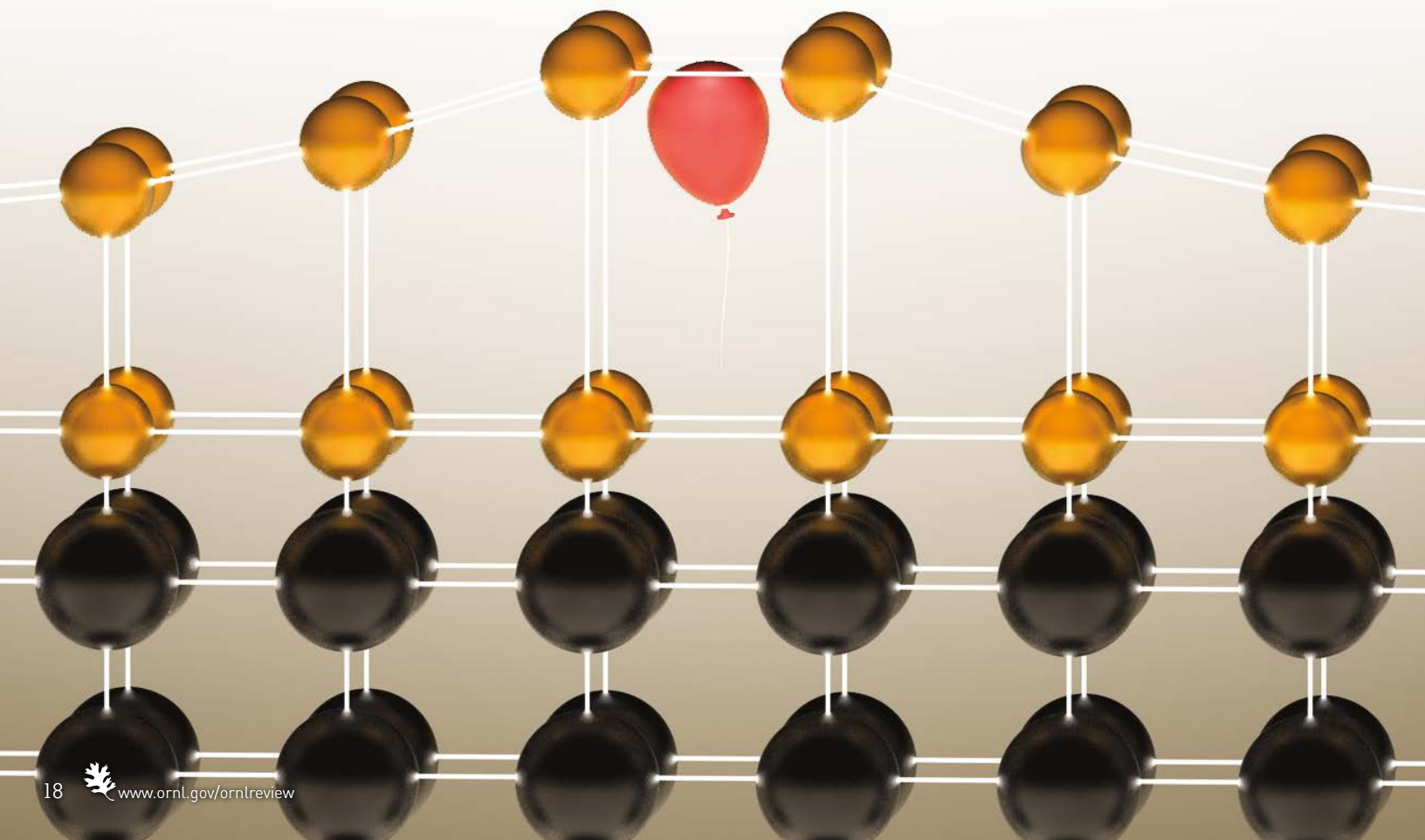
“Our strain doping technique demonstrates a path to achieving this need, as it can be implemented using established ion implantation infrastructure in the semiconductor industry,” Ward said. 🌱

For more information: <http://go.usa.gov/3GmzQ>

“This type of control wasn’t possible before, and it allows you to tune material properties with a finesse that we haven’t previously had access to.”

—ORNL physicist Zac Ward

Inserting helium atoms (visualized as a red balloon) into a crystalline film (gold) allowed ORNL researchers to control the material’s elongation in a single direction. Image credit: ORNL



Atomic shaking turns an insulator into a metal

by Dawn Levy
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What turns some oxide insulators, in which electrons barely move, into metals, in which they move freely? Using a novel combination of X-rays, neutron scattering and high-performance computing, an ORNL-led team proved that atomic vibrations drive this transition in at least one well-studied material: vanadium dioxide.

Vanadium dioxide is a classic transition-metal oxide, a compound in which oxygen chemically bonds with metal atoms to yield a wide variety of electronic properties. It is promising for use in "smart glass," nanoscale actuators, optical shutters, electronics and more.

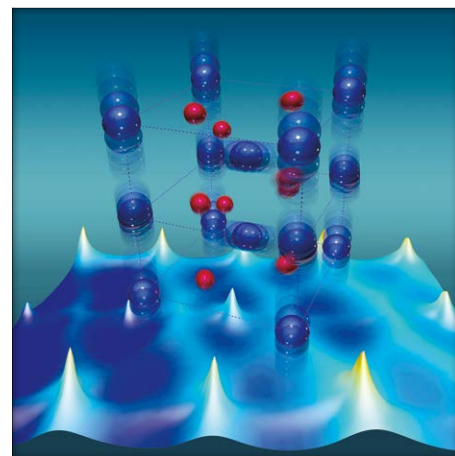
Below 152 degrees Fahrenheit, known as the material's transition temperature, leaning atomic rows in the material cause

its crystal lattice to slant, and it becomes an insulator. At higher temperatures, the lattice no longer leans, large atomic vibrations allow electrons to flow, and the material exhibits metallic behavior.

"This is the first complete description of thermodynamic forces controlling this archetypical metal-insulator transition," said John Budai, who co-led the study with Jiawang Hong, a colleague in ORNL's Materials Science and Technology Division.

Added Hong, "This insight into how lattice vibrations can control phase stability in transition-metal oxides is needed to improve the performance of many functional materials, including colossal magnetoresistors, superconductors and ferroelectrics."

Future studies of other transition metal oxides will investigate the impact of atomic vibrations on physical proper-



Vanadium atoms (blue) have unusually large thermal vibrations that stabilize the metallic state of a vanadium dioxide crystal. Red depicts oxygen atoms. Image credit: ORNL

ties such as electrical conductivity and thermal transport. ❄

For more information: <http://go.usa.gov/3AqUk>

Scientists develop promising oxygen 'sponge'

by Ron Walli
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ORNL scientists have developed a new oxygen "sponge" that can easily absorb or shed oxygen atoms at low temperatures. Materials with these novel characteristics would be useful in devices such as rechargeable batteries, sensors, gas converters and fuel cells.

Materials containing atoms that can switch back and forth between multiple oxidation states are technologically important but very rare in nature, says ORNL's Ho Nyung Lee, who led the international research team that published its findings in *Nature Materials*.

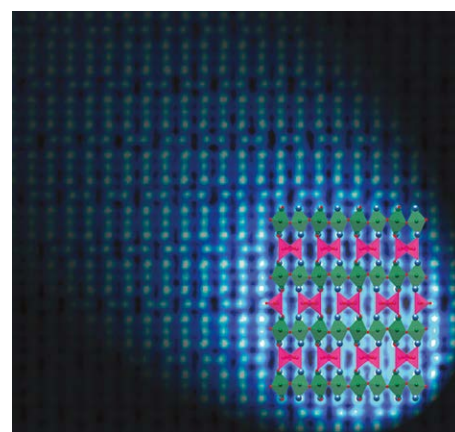
"Typically, most elements have a stable oxidation state, and they want to stay there," Lee said. "We've found a chem-

ical substance that can reversibly change between phases at rather low temperatures without deteriorating."

Many energy storage and sensor devices rely on this valence-switching trick, known as a reduction-oxidation or "redox" reaction. For instance, catalytic gas converters use platinum-based metals to transform harmful emissions such as carbon monoxide into nontoxic gases by adding oxygen.

Less expensive oxide-based alternatives to platinum usually require very high temperatures—at least 600 to 700 degrees Celsius—to trigger the redox reactions, making such materials impractical in conventional applications.

"We show that our multivalent oxygen sponges can undergo such a redox process at as low as 200 degrees Celsius, which is



This schematic depicts a new ORNL-developed material that can easily absorb or shed oxygen atoms. Image credit: ORNL

comparable to the working temperature of noble metal catalysts," Lee said. ❄

For more information: <http://go.usa.gov/3GNKh>

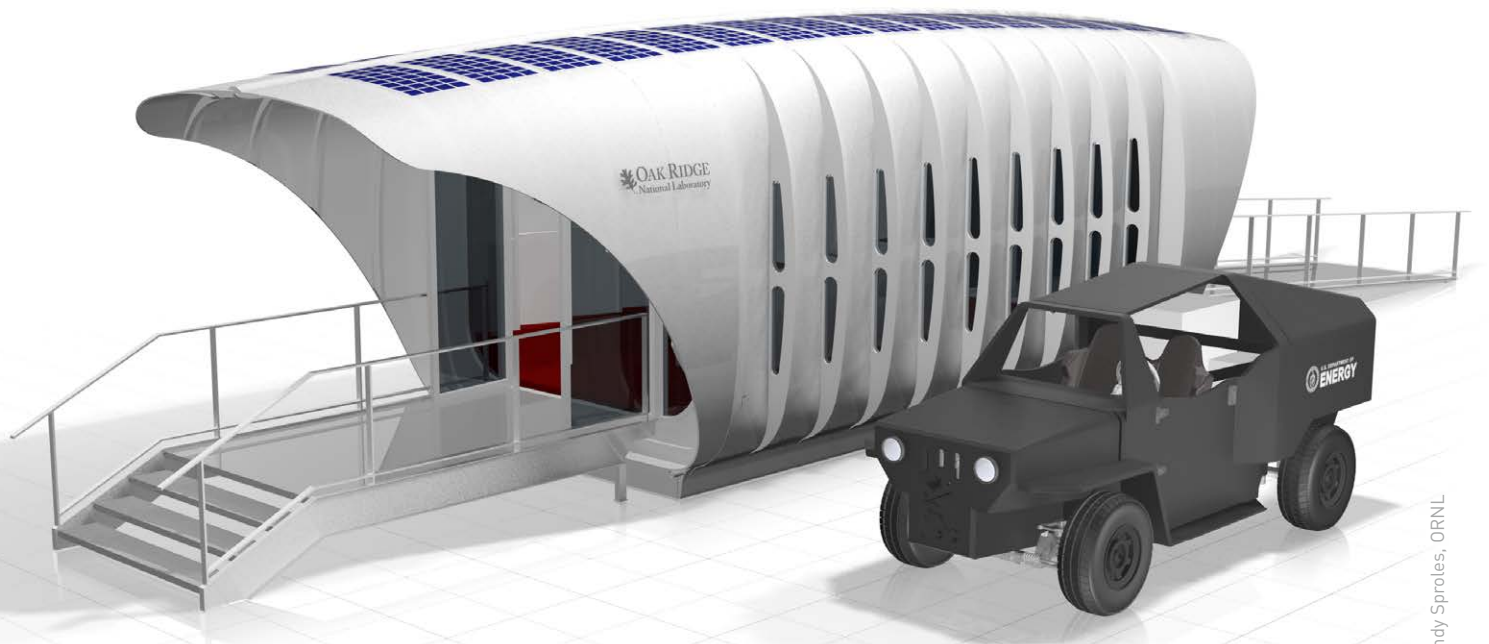


Image credit: Andy Sproles, ORNL

All together now

ORNL demonstration connects power of transportation, buildings and manufacturing

by Morgan McCorkle
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A new project at ORNL is examining the potential for consumers to generate, store and use electrical power via an energy system that includes their homes, their vehicles and the grid—all managed by a common “brain.” The Additive Manufacturing Integrated Energy (AMIE) demonstration may be a bellwether for the energy efficient home of the future.

Working with industrial partners, the ORNL team is connecting a natural-gas-powered hybrid electric vehicle with a small solar-powered building to create an integrated energy system.

Power can flow in either direction between the vehicle and building through a lab-developed wireless charging technology. This approach allows the car to provide supplemental power to the house when the sun is not shining.

Complementing this energy efficient concept, the team is exhibiting the rapid prototyping potential of additive manufacturing in architecture and vehicle design by using large-scale 3-D printers to construct both the car and building. The initial demonstration was unveiled during a September industrial outreach event at ORNL sponsored by the DOE Office of Energy Efficiency and Renewable Energy.

ORNL researchers hope their integrated approach to energy generation,

storage and consumption will introduce solutions for the modern electric grid, which faces challenges ranging from extreme weather events to growing renewable energy use, particularly as the transportation sector transitions away from fossil fuels.

“We’re looking at large community issues from the single-unit level,” said ORNL’s Martin Keller, associate laboratory director for Energy and Environmental Sciences. “Our research provides solutions on a small scale, which will translate to a significant reduction in energy use and an increase in cost savings when ramped up to a national, and even global, level.” 🌱

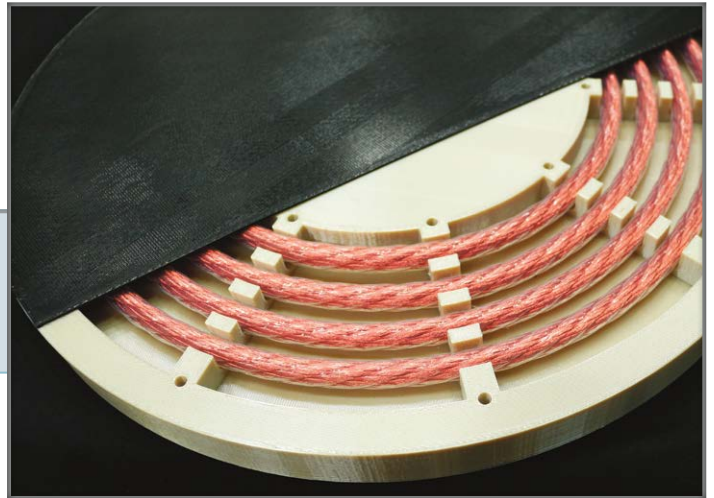


3-D printing

ORNL is pushing the boundaries of 3-D printing in terms of size, speed, strength and performance. The demonstration building, designed by Skidmore, Owings & Merrill LLP, features 3-D printed rings assembled into a shell by Clayton Homes, the nation's largest builder of manufactured housing. Most of the custom printed utility vehicle's components, including the chassis and body panels, were additively manufactured.

Wireless charging

When the vehicle is parked, magnetic coils on the car and in the ground enable power transfer between the vehicle and the building. The ORNL-developed wireless charging technology helps drivers avoid the hassle of plugging in their vehicle.

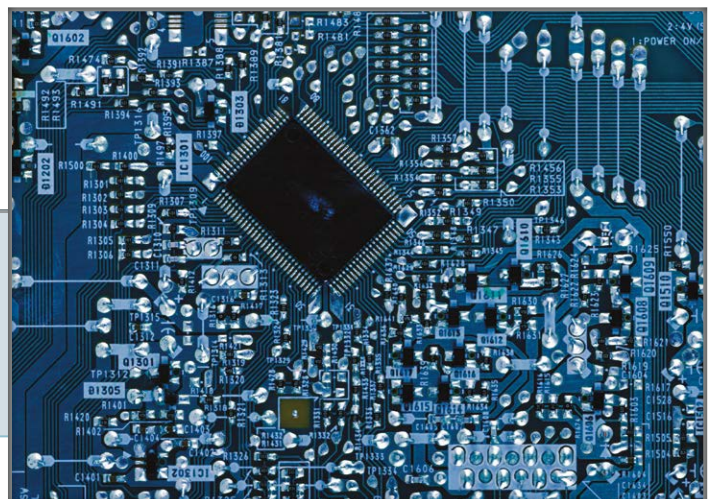


Innovative insulation

The demonstration showcases low-cost modified atmosphere insulation panels developed by ORNL and NanoPore. The panels offer the same energy savings as high-performance vacuum insulation panels at half the cost and thickness. Each panel slides into the building's 3-D printed shell, providing a drop-in energy efficiency solution.

Integrated energy controls

Advanced building control and power management strategies integrate the project's multiple components to maximize the system's efficiency. This brain-like control center manages the system's electrical demand and load by balancing the intermittent power from the building's 3.2 kilowatt solar array with supplemental power from the vehicle's engine.



Landmark SPRUCE experiment

expected to clarify ecosystem responses to climate change

by Ron Walli
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A natural spruce bog in northern Minnesota contains more than 10,000 years of carbon accumulated from peatlands and may answer questions about how Earth will respond to predicted warming and increases in atmospheric carbon dioxide.

About seven acres of the raised bog is home to SPRUCE, which stands for Spruce and Peatland Responses Under Climatic and Environmental Change, a new Department of Energy experiment that will allow researchers to adjust air and soil temperatures and levels of carbon dioxide.

Ten open-topped 12-meter wide, 8-meter tall transparent enclosures are the

laboratories for the experiments to assess ecological responses. The enclosures, superimposed on a belowground corral that isolates the peatland, will host measurements of microbial communities, moss populations, various higher plant types and some animal groups.

"The SPRUCE experiment continues ORNL's involvement in environmental change studies that are conducted in the real

world at scales relevant to an ecosystem's stature, biodiversity and biogeochemistry," said Paul Hanson, who leads the project and is a member of Oak Ridge National Laboratory's Environmental Sciences Division and Climate Change Science Institute.

With the ability to control heating of the air and soil within the chambers down to two meters, scientists hope to gain an understanding of the possible effects of

"Peatlands contain a disproportionate amount of carbon compared to other ecosystems, and understanding their sensitivity to climate change will be critical to predict what happens to the balance between carbon stored in peatlands and the amount of carbon dioxide and methane in the atmosphere."

—Randy Kolka, U.S. Forest Service research soil scientist

The SPRUCE research project is spread across seven acres in a natural spruce bog in northern Minnesota. Image credit: ORNL





ORNL's Jana Phillips measures surface CO_2 and CH_4 exchange in the back of a typical SPRUCE enclosure. Image credit: ORNL

projected higher temperatures on vegetation and ecosystems.

While peatlands cover about 3 percent of Earth's land surface, they contain up to 33 percent of the global soil carbon pool. Although that carbon dioxide has been trapped in the cold oxygen-poor environment for thousands of years, warming conditions threaten to see peatlands release large amounts of carbon dioxide and methane. This occurs through a combination of enhanced decomposition and aeration of surface peats.

"SPRUCE is the first experiment to test the combination of warming and elevated carbon dioxide on carbon-rich peatland ecosystems," said Randy Kolka, team leader and research soil scientist with the U.S. Department of Agriculture Forest Service, a partner in the project.

"Peatlands contain a disproportionate amount of carbon compared to other ecosystems, and understanding their sensitivity to climate change will be critical

to predict what happens to the balance between carbon stored in peatlands and the amount of carbon dioxide and methane in the atmosphere."

The location in the peatlands on the Chipewewa National Forest was carefully selected by a team led by Hanson, who worked with ORNL colleagues Stan Wullschleger and Rich Norby to formulate plans for SPRUCE. The group benefited from Norby's experience designing and running the 12-year Free-Air CO_2 Enrichment experiment, which examined the responses to elevated carbon dioxide levels in a stand of sweetgum trees a few miles from ORNL.

The SPRUCE project gives them a chance to expand on those findings as they conduct previously impossible experiments with other researchers from ORNL, the Forest Service, other DOE laboratories and universities.

The official launch of SPRUCE was celebrated with an August 2015 event attended by representatives from DOE, ORNL, the Forest Service and elected officials.

With design, construction and ceremony behind them, Hanson and colleagues are focusing on questions that cover ecosystem responses ranging from the microbe to landscape scale. Those questions include:

- Will deep belowground warming release 10,000 years of accumulated carbon from peatlands?
- Will these carbon releases be in the form of carbon dioxide or methane, which has 30 times the warming potential of carbon?

- Are peatland ecosystems and organisms vulnerable to atmospheric and climatic change? What changes are likely?
- Will ecosystem services such as regional water balance be compromised or enhanced by atmospheric climatic change?



Scott Bridgham of the University of Oregon (seated) and ORNL's Natalie Griffiths collect peat pore water samples to evaluate dissolved organic carbon losses from warming. Image credit: ORNL

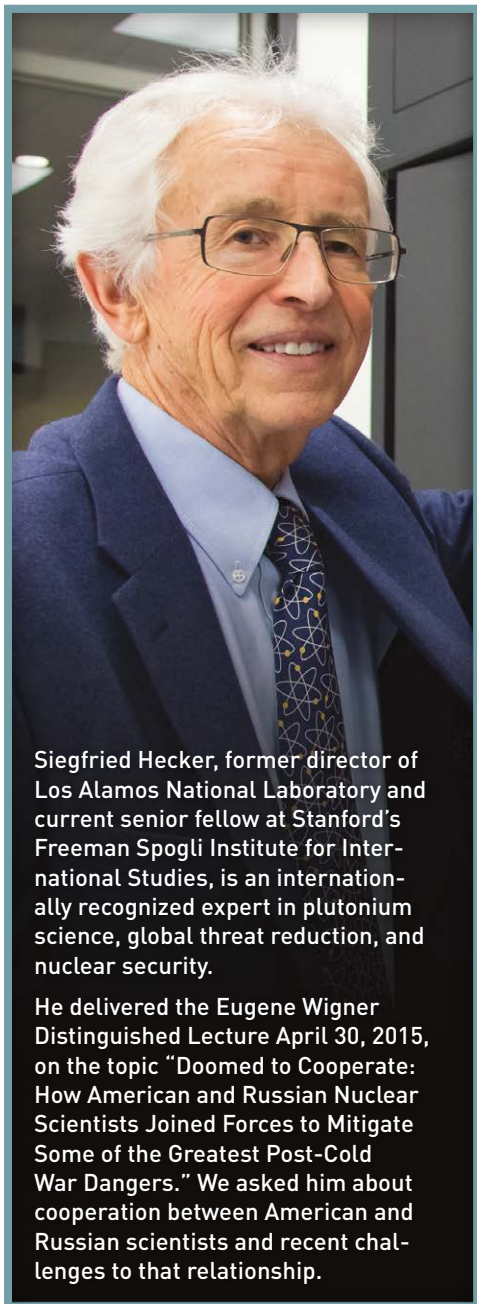


The open-topped enclosures—12 meters wide and 8 meters tall—sit over a corral bed that isolates the peatland. Image credit: ORNL

"Answers to these questions will provide insights not only for small-scale processes but also for landscape-relevant water, carbon and energy fluxes for similar peatlands," Hanson said. "Results will inform higher-order models of vegetation responses under various levels of climatic warming and associated end-of-the-century atmospheric change." 🌱

Distinguished

Siegfried Hecker



Siegfried Hecker, former director of Los Alamos National Laboratory and current senior fellow at Stanford's Freeman Spogli Institute for International Studies, is an internationally recognized expert in plutonium science, global threat reduction, and nuclear security.

He delivered the Eugene Wigner Distinguished Lecture April 30, 2015, on the topic "Doomed to Cooperate: How American and Russian Nuclear Scientists Joined Forces to Mitigate Some of the Greatest Post-Cold War Dangers." We asked him about cooperation between American and Russian scientists and recent challenges to that relationship.

1. What are some of the dangers U.S. and Russian scientists have been working to mitigate since the collapse of the Soviet Union?

The first is loose nukes—the safety and security of nuclear weapons. The second is loose nuclear materials, and the security of the enormous amount of fissile materials that the Soviet Union had at its dissolution. The third is loose people, and the concern that perhaps economically stressed Russian nuclear workers might sell their capabilities to others. And the fourth I call loose exports, with the Russian state itself actually exporting nuclear technologies that would be useful in building a nuclear program.

2. How is our deteriorating relationship with Russia harming this cooperation?

The current situation is quite unfortunate; for the time being it's pretty much stopped nuclear cooperation. What's happened in the last year is a combination of the Russians' actions in the Ukraine, which brought an American government response that included isolation on the scientific side. The U.S. government said, we'll continue to work with you on security-related issues, and the Russians said, "Thank you very much, but no science, and none of these other things."

3. What should we do about it?

That's very, very difficult. Whatever contacts individual American scientists have with their Russian colleagues, they should keep them up as much as possible. However, I think without some governmental change, it's not going to be possible to go back to useful collaboration. And what's not clear is which country's going to make the first move.

4. You are working to expand the use of nuclear energy. How can this technology be restricted to peaceful uses?

The technologies required to build the bomb or pursue nuclear energy are interdependent and interchangeable. We knew from 1946 on that if you develop one, you had the potential of the other.

For the most part you have to look back on that and say it's been reasonably successful. We know there are eight states that have nuclear weapons. (Israel doesn't admit or deny that they have nuclear weapons.) But compared to 192 or so states in the world today, it's a small number.

Next, is it safe? There have been three major accidents: Three Mile Island in the U.S., Chernobyl in the Soviet Union, and Fukushima in Japan. Can you do it safely? I think the answer to that is, yes, it can be done safely.

Then the third part is, can you do it without proliferation? There are four new reactors being built in the United Arab Emirates. The UAE has agreed they will not reprocess the fuel. If that model is used in other places, that will help.

5. Why was it important to visit ORNL meet with researchers here, and participate in the Wigner Lecture Series?

It's an enormous honor for me to give a lecture to honor Eugene Wigner. He was one of the great scientists of the 20th century, and he had so much to do with the nuclear enterprise. He was there with Enrico Fermi when Fermi started up the first reactor [at the University of Chicago].

Lecturers

Harold Kroto

1. We know that carbon is a unique element, being, among other things, the basis of biology. What makes carbon so special?

The major difference between carbon and all other elements is the subtle differences between the single, double and triple bonds. As an example, benzene, with double bonds, reacts in a different way from methylene, which also has carbon double bonds. It's those very great subtle differences depending on what's attached to it that changes the way in which it reacts.

2. In the mid-1980s, you and colleagues created a previously unknown form of carbon—a soccer ball-shaped molecule that you called buckminsterfullerene. What implications does buckminsterfullerene have?

The most important aspect of our discovery is that they self-assembled spontaneously. When we said that we had discovered it, half a dozen people in the cluster nanotechnology area said it couldn't be right. The fact that it self-assembled so easily was a very important breakthrough in our understanding of the factors involved in self-assembly.

3. Earlier, you and colleagues discovered that long carbon-chain molecules are surprisingly abundant in some regions of interstellar space. What are the implications for this discovery?

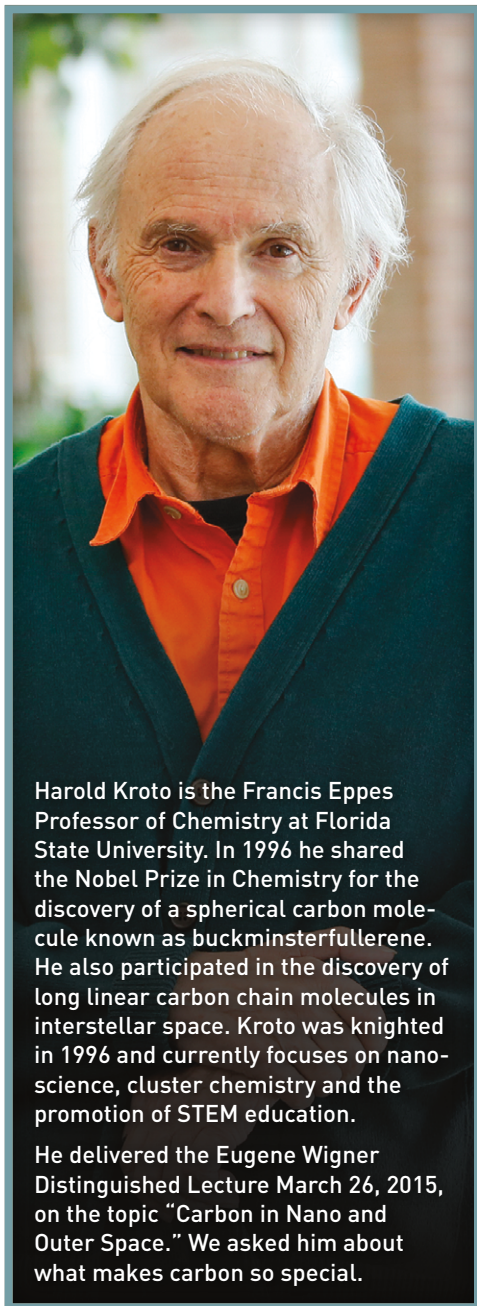
We discovered that some much larger molecules were in the interstellar medium than previously expected. We also came to the conclusion, or I did, anyway, that they were produced in stars. It was that discovery which opened up my eyes to the fact that carbon stars were very interesting places. We now know that the clouds of gas and dust out of which planets form already have large amounts of interesting molecules, molecules that can form a molecular soup out of which biological molecules can form.

4. Part of your current focus at Florida State is the promotion of STEM education. How can we best promote interest in technology and the sciences?

Research used to be 100 percent fundamental. Since the war, in particular, huge amounts of money have been put into research and development. I think we're very close to where there won't be a big enough environment for people like me. I didn't want to work on what other people were interested in; I wanted to work on what I was interested in. There are a large number of people like that, and it's there where the big surprises come.

5. Why was it important to visit ORNL, meet with researchers here and participate in the Wigner Lecture Series?

I give a lot of talks, particularly to young people, and there are young people here. I want them to hear what I think about research, especially in research organizations like this one where there's a lot of strategic research being carried out.



Harold Kroto is the Francis Eppes Professor of Chemistry at Florida State University. In 1996 he shared the Nobel Prize in Chemistry for the discovery of a spherical carbon molecule known as buckminsterfullerene. He also participated in the discovery of long linear carbon chain molecules in interstellar space. Kroto was knighted in 1996 and currently focuses on nanoscience, cluster chemistry and the promotion of STEM education.

He delivered the Eugene Wigner Distinguished Lecture March 26, 2015, on the topic "Carbon in Nano and Outer Space." We asked him about what makes carbon so special.



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

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

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



Christine Ajinjeru

Graduate student, Manufacturing Demonstration Facility
Ph.D. student, Energy Science and Engineering, University of Tennessee–Knoxville (Bredesen Center)

What are you working on at ORNL?

My role at MDF has been to understand and characterize the properties of the materials that are printed on the BAAM [big area additive manufacturing] blue gantry machine. Most 3-D printed materials have unique properties that are not yet completely understood, so my role is to understand the chemistry of what's actually going on. Understanding these properties means 3-D printed products can penetrate the market, saving both time and cost.

What would you like to do in your career?

I hope to continue being a researcher in advanced manufacturing on the industry or national lab level. I want to be a mentor to other young women and girls who have an interest in science. With my science background, I also want to return to Africa and work on the continent's energy infrastructure. I hope to leverage the contacts and knowledge I have gained here with the untapped resources in Sub-Saharan Africa.

Why did you choose a career in science?

I chose science as a career path because I've had great colleagues, friends, teachers and mentors who influenced my decision. I was good at the sciences, enjoyed the lab component of it, and had a lot of research experience, so when it came down to choosing a career path, it was easy to make that decision. The hardest part was choosing whether I wanted my work to focus on public health.



Johnbull Dickson

Postdoc, Environmental Sciences Division
Ph.D., Environmental Soil Chemistry, Washington State University

What are you working on at ORNL?

I work with DOE's Mercury Project in East Fork Poplar Creek, which is contaminated with leftover mercury from the Y-12 plant. The purpose of this project is to develop a remedial solution to clean up mercury from the creek. We are currently characterizing the system and trying to understand the mercury cycling. My task group samples the floodplain and soil sediments so we can understand biomagnification between the creek water and the fish.

What would you like to do in your career?

I'm sure it will take five to eight years to figure out a solution to this problem, so my hope is to stick around until then. I also want to do some teaching, so I'm looking for opportunities in a university setting. I'm still exploring different options, and until then, I'll keep doing research. There's not a lot of opportunity for this in Nigeria, and I've always wanted to teach in the United States.

Why did you choose a career in science?

In that experimental learning process, I figured out that I loved mathematics. I loved chemistry, biology—that makes sense to me. And I remember my dad, he actually liked doctors, and he spends a lot of time saying that the smartest people on Earth are doctors. So I wanted to live up to that, but I've always wanted to be in the sciences.



Lyndsey Earl

Postdoc, Chemical Sciences Division
Ph.D., Materials Chemistry, University of British Columbia

What are you working on at ORNL?

I'm investigating porous polymers for carbon capture. The project has two major aspects: the relationship between structure and function of the materials and the structural evolution of the monomers into a porous connected network. The application we envision will reduce the amount of CO₂ in the air, primarily through vehicles, and perhaps decrease our world's carbon footprint at least somewhat.

What would you like to do in your career?

I see myself continuing in materials research. I hope some part of my life will be devoted to promoting science literacy and critical thinking skills with the public. The idea is to either run my own science cafe or partner with a community-based eatery to promote scientific discussion and special topics within the establishment.

Why did you choose a career in science?

Simply put, I'm interested in how the world works. For me, staying in science is the bigger battle. Science isn't glorious, or people shouting "Eureka!" What keeps me going are the times in the lab where I am able to say, "Huh, that's odd," follow the scientific method, and, if I'm fortunate, say "Aha!" at the end of the experiments.



Hoi Chiu Hon

Graduate student, Materials Science Division

Ph.D. student, Energy Science & Engineering, University of Tennessee–Knoxville (Bredesen Center)

What are you working on at ORNL?

I am still trying to define my Ph.D. research direction. In general, my group works on carbon and composite materials. We want to make better, stronger, cheaper and “greener” materials. One of our projects is to produce recyclable and biodegradable plastics and rubbers from renewable materials. Plastics and rubbers are everywhere, and a lot of their use today is not very environmentally friendly. We are trying to change that.

What would you like to do in your career?

I want to do science—science that can become the next big commercial product, science that can better inform politicians, and science that can excite the public and attract more people to the scientific community. Scientists, politicians, industries and the public need to work together to solve many challenges that we are facing today, including producing reliable energy, clean water supplies, safe food and a healthy environment.

Why did you choose a career in science?

Science can let me discover new knowledge, invent new things, help people and make this a more sustainable world. Think about Thomas Edison, Alexander Graham Bell or Alfred Nobel. They invented a lot of things that revolutionized and transformed the way we work, the way we live, the way we communicate and the way we do construction. They invented the light bulb, telephone and explosives, among many great things.



Andrew King

Postdoc, Biosciences and Environmental Sciences divisions

Ph.D., Soil Microbial Ecology, University of Colorado–Boulder

What are you working on at ORNL?

I’m in two different projects. The Mercury Project is looking at mercury-contaminated stream systems because of isotope refinement activity from the past 60 years. The project I am most intimately involved in, ENIGMA, looks at the link between genes and ecosystems. We’re looking at how contaminant gradients in groundwater change microbial communities. From looking at their genomes, we can identify their potential functions and how they interact to result in a community that metabolizes carbon or nitrate.

What would you like to do in your career?

I would like to continue on in the national lab system, but it’s hard to transition from a postdoc to a staff scientist. I can also see myself going into landscape management, since I’ve been working with contaminated sites. I can transition into a job with the Forest Service in national parks and learn how to steward the health of the landscape by protecting it from contamination and providing a resource to the public.

Why did you choose a career in science?

I chose a career in science because it excited me from a young age. I like problem solving and working in a team, but most of all I like learning about the natural world. My favorite projects involve the interactions between communities of organisms and how they respond to and play a role in structuring the environment in which they live. I believe it’s important to understand these interactions and how human activity affects them.



Naresh Osti

Postdoc, Chemical & Engineering Materials Division

Ph.D., Chemistry, Clemson University

What are you working on at ORNL?

My job is to perform elastic, inelastic and quasi-elastic neutron scattering studies of complex fluids in various confinement environments to elucidate the structure and dynamics at the fluid–solid interface. The outcome of this research enables us to optimize the performance of energy storage devices as compared to conventional batteries that suffer from low power density and shorter life spans.

What would you like to do in your career?

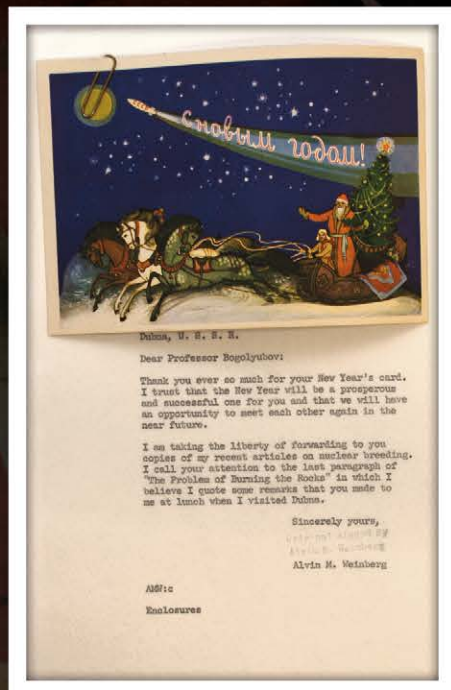
I did extensive studies on conjugated polymers and ionomers of energy applications in my graduate study using neutron scattering. My long-term goal is to establish independent research on composites of polymers and inorganic materials using neutron techniques that can help to meet the demand of current energy needs. I would like to expand my research interest in a national lab like ORNL as a staff scientist or in an academic institution as an assistant professor.

Why did you choose a career in science?

When I was in high school in Nepal, science was an optional subject. Only a limited number of students who were talented in the class could take the course. As a merit student in the class, the prospect of job opportunities grabbed my interest in science from the beginning. I love to explore new things. These never-ending learning activities that keep me busy and up to date made me choose my career in science.



In October 1959, ORNL Director Alvin M. Weinberg and other scientific advisers accompanied Atomic Energy Commission Chairman J. A. McCone on a 10-day visit to Russian atomic energy installations. Above, Weinberg speaks with Professor V. S. Emelyanov, director of Main Administration for the Peaceful Uses of Atomic Energy in the Soviet Union. At top right, he stands with Raymond Garthoff, who was sent on the trip as a translator. At right, Weinberg thanks one of his hosts for a New Year's card that shows a Soviet rocket headed to the moon.



Alvin Weinberg and scientific diplomacy in the Cold War

by Tim Gawne
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Former laboratory director and ORNL patriarch Alvin Weinberg had many gifts, including an innate ability to bridge gaps both political and scientific.

Those who knew him said he was approachable to a degree rare among the world's scientific elite. So it was only natural to include Weinberg in the first official exchange of scientific delegations between the United States and the Soviet Union.

To put Weinberg's geniality in context, the exchange followed a journey by American Admiral Hyman Rickover, who visited the nuclear-powered Ice Breaker Lenin with then-Vice President Nixon. Rickover, father of the nuclear navy, was a brilliant man, but he was also notoriously difficult to get along with.

"The Admiral had a difficult character," Vasily Emelyanov, a high-ranking Soviet nuclear

official, told his American counterpart, Atomic Energy Commission Chairman John A. McCone.

"This was the view of some people here, too," McCone replied.

The exchange of delegations took place at a time—October 1959—when the Soviets were America's only nuclear rival. Weinberg would later discuss the rationale for the visits:

"The Soviet Union realizes that the existence of nuclear weapons makes a large-scale shooting war a difficult thing to conceive, but for whatever reason, it appears that the Soviet Union has entered into a period—or we hope it has entered into a period—in which it would like to explore with the United States whether it is, indeed, possible to work through some grave difficulties which separate our countries."

The American delegation consisted of top AEC brass, a couple of other nuclear physicists and Weinberg, who was clearly amused by the pomp of the occasion.

"This was an official visit, extremely official and—well, as a Tennessean who lives out in the

hills of Tennessee, I just was not used to the lavishness to which we were subjected."

On his return, Weinberg shared his thoughts with ORNL staff.

"I believe that we can get it through our heads that these are a very earnest, dedicated people, quite apart from the question of whether they will some day drop H-bombs on us, and take for granted for the time being, at least, that the evidence of the apartment buildings [with no bomb shelters], if you like, suggests that they do not expect to drop H-bombs on us but that they clearly expect to be in competition with us. If we take this to heart and work at it, meet them at their own game and, if you like, beat them at their own game, then I think we have nothing to fear for the future—for our life."

By the way, the exchange of delegations was followed by an exchange of gifts. Weinberg sent the complete Toscanini recordings of Beethoven's nine symphonies. In turn, he received a case of fine Russian vodka. 🍷



next issue

Science protecting the environment

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